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DEVELOPMENT OF SOCIAL AND ENGINEERING INNOVATION IN MARITIME EDUCATION AND TRAINING TO ENSURE SHIPPING

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Tarptautinė mokslinė konferencija skirta skatinti technologijos mokslų srities mokslinius tyrimus. Mokslinėse publikacijose vyrauja laivybos saugumo, jūrų uosto technologijų, jurų aplinkosaugos, jūrų inžinerijos ir technologijų bei kita tematika. Konferencijos leidinyje publikuojami Ukrainos aukštojo mokslo mokslininkų, dalyvavusių tarptautinėje stažuotėje „Development of social and engineering innovation in higher maritime education in European higher education area“, kuri vyko 2022 m. gruodžio 12 d. - 2023 m. vasario 28 d., moksliniai straipsniai.

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CONTENTS

UAB „NTG LITHUANIA“ KONTEINERIŲ PRISTATYMO PROCESO OPTIMIZAVIMAS: DIRBTINIO INTELEKTO PRIEMONIŲ PANAUDOJIMO ATVEJIS

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Abstraktas. Šiame straipsnyje aptariamas UAB „NTG Lithuania“ konteinerių pristatymo proceso optimizavimas naudojant dirbtinio intelekto priemones. Didėjant konteinerių gabenimo jūra paklausai, būtina nuolat tobulinti konteinerių pristatymo technologijas. Dirbtinis intelektas yra viena iš tokių priemonių, kuri gali padėti transporto įmonėms realiuoju laiku rinkti informaciją iš įvairių šaltinių ir priimti geresnius sprendimus. Dėl šių priežasčių *tyrimo objektu* pasirinktas UAB „NTG Lithuania“ konteinerių pristatymo procesas, naudojant dirbtinio intelekto priemones, o tyrimo metu *siekiama įvertinti* UAB „NTG Lithuania“ konteinerių pristatymo proceso optimizavimo galimybės naudojant dirbtinio intelekto priemones. Taip pat šiame straipsnyje nagrinėjama dirbtinio intelekto sąvoka, jo istorija, apibrėžtis, skirtingi tipai ir grupės. *Tyrimo rezultatais* siekiama teoriškai ištirti konteinerių pristatymo proceso optimizavimo galimybės, naudojant dirbtinio intelekto priemones ir nustatyti UAB „NTG Lithuania“ dirbtinio intelekto priemonių panaudojimo poveikį konteinerių pristatymo proceso optimizavimui. Dirbtinio intelekto naudojimas logistikoje gali padėti optimizuoti maršrutus, valdyti atsargas, užtikrinti stebėjimą realiuoju laiku, automatizuotą planavimą ir prognozuojamąją techninę priežiūrą – visa tai pristatymo procesą padaro efektyvesnį ir patikimesnį. Straipsnyje daroma išvada, kad logistikos įmonės turi investuoti į dirbtinį intelektą, norėdamos išlikti pranašesnės už konkurentus šiuolaikinėje verslo aplinkoje.

Raktiniai žodžiai: dirbtinis intelektas, dirbtinio intelekto priemonės, konteinerių pristatymo procesas, ekspedijavimas, logistikos technologijos.

Įvadas

Tyrimo problemos aktualumas. Šiuolaikinės technologijos atlieka svarbų vaidmenį konteinerių gabenimo srityje. Kasmet poreikis konteinerių transportavimo jūra didėja, 2016-2021 m. konteinerių srautas išaugo 18,25 proc. Toks pokytis reikalauja nuolatinio konteinerių pristatymo technologijų tobulinimo. Vienas iš būdų yra dirbtinio intelekto priemonių įdiegimas. Dirbtinis intelektas – tai yra kompiuterio pagalba sukurtas specialus algoritmas, kuris sprendžia jam priskirtas ekonomines, technologines ir kitas užduotis. Dirbtinis intelektas leidžia transporto įmonėms realiuoju laiku rinkti informaciją iš skirtingų šaltinių ir parengti sprendimą: apskaičiuoti galimą konteinerio gabenimo kainą, stebėti visą jo kelionę realiuoju laiku, pan.

UAB „NTG Lithuania“ įmonė įkurta 2011 m., teikia importo, eksporto bei sandėliavimo paslaugas dirbtinio intelekto priemonių pagalba. Pagal pajamų dydžius įmonėje per analizuojama laikotarpį 2017-2021 m., konteineriu apyvarta padidėjo 51,53 proc. Be to, įmonė teikia savo paslaugas visame pasaulyje, tuo metu, kai filialai yra tokiuose regionuose kaip Europa, Azija ir Amerika.

Tyrimo tikslas – įvertinti UAB „NTG Lithuania“ konteinerių pristatymo proceso optimizavimo galimybės naudojant dirbtinio intelekto priemones.

Tyrimo objektas – UAB „NTG Lithuania“ konteinerių pristatymo procesas, naudojant dirbtinio intelekto priemones.

Tyrimo uždaviniai:

1. Teoriškai ištirti konteinerių pristatymo proceso optimizavimo galimybės, naudojant dirbtinio intelekto priemones.
2. Nustatyti UAB „NTG Lithuania“ dirbtinio intelekto priemonių panaudojimo poveikį konteinerių pristatymo proceso optimizavimui.

Tyrimo metodai. Tyrimo metu taikyta mokslinės literatūros analizė ir buvo nagrinėjami tokie pagrindiniai autoriai kaip: Chereau, P., Meschi, P. (2018), Proctor, T. (2018), Sakalas, A., Savanevičienė, A. & Girdauskienė, L. (2016) ir Song, D. P. (2021). UAB „NTG Lithuania“ duomenų

analizė statistiniais metodais (pokyčiai, vidurkiai, kt.) ir rodiklių ryšių modeliavimas (koreliacija), kurių reikia siekiant nustatyti tendencijas ir modeliuoti įmonės pokyčius.

1. Dirbtinio intelekto samprata

XX a. viduryje, atsiradus pirmiesiems elektroniniams kompiuteriams, pastebėta, kad mašinos skaičiavimo galimybės gali prilygti žmogaus skaičiavimo galimybėms. Mokslininkai susidomėjo kompiuterių galimybių ribomis ir pradėjo svarstyti, ar jie gali pasiekti žmogaus mąstymo lygį.

Analizuojant dirbtiniu technologijų raida istoriniame aspekte, galima išskirti tokios pagrindinės DI teorijos vystymo kryptis. Išsamesne informacija pateikta 1 lentelėje.

1 lentelė. Dirbtinio intelekto teorinis pagrindimas istoriniame aspekte

Metai	Autorius (-iai)	Tyrimo kryptis
1943 m.	Warreno McCullough & Walter Pitts	Žmogaus smegenų modelį imituojančio termino „neuroniniai tinklai“ pasiūlymas publikuojant mokslinį darbą „Idėjų loginis skaičiavimas, neatsižvelgiant į nervinę veiklą“.
1950 m.	Alan Turing	Turingo testo pasiūlymas moksliniame straipsnyje garsiu pavadinimu „Skaičiavimo mašinos ir intelektas“.
1956 m.	John McCarthy Dartmut	Termino „dirbtinis intelektas“ formulavimas pristatant pranešimą dirbtinio intelekto konferencijoje.
1958 m.	Frank Rosenblatt	Perceptrono schemos sukūrimas – dabartinių neuroninių tinklų prototipas.

Šaltinis: Turing, 1950; Rosenblatt, 1958, Душкин, 2019 & Schroer, 2022.

Pirmieji dirbtinio intelekto moksliniai tyrimai buvo pradėti 1943 m., bet jau 1958 m. Frank Rosenblatt sukūrė perceptrono schemą – dabartinių neuroninių tinklų prototipą. Visų pirma, dirbtinis intelektas vystėsi politinėje, karinėje, inžinerijos ir medicinos srityse, vėliau buvo plėtojama transporto logistikoje.

Dirbtinis intelektas (DI) – tai sistema, galinti imituoti žmogaus intelektinę ir kūrybinę veiklą, o tai ne tik matematiniai skaičiavimai. Šia veikla siekiama kurti nematerialius dalykus moksle, meno ir literatūros srityje, taip pat mokytis, priimti sprendimus, nustatyti išvadas ir daug kitų dalykų.

Psichologai žmogaus intelektą dažniausiai apibūdina ne vienu bruožu, o kaip daugelio skirtingų gebėjimų derinį. Atliekant dirbtinio intelekto tyrimus daugiausia dėmesio skiriama tokiems komponentams kaip mokymuisi, samprotavimui, problemų sprendimui, suvokimui ir kalbos vartojimui (Encyclopedia Britannica, 2023).

Dirbtinis intelektas leidžia mašinoms mokytis iš patirties, prisitaikyti prie naujų įvesties ir atlikti žmogaus užduotis. Naudojant šias technologijas, kompiuteriai gali būti išmokyti atlikti konkrečias užduotis apdorojant didelius duomenų kiekius ir atpažįstant duomenų šablonus (SAS Institute, 2023). Dirbtinis intelektas turi daugybę įsikūnijimų, tai nėra formatas ar funkcija – tai procesas, gebėjimas mąstyti ir analizuoti duomenis. Jo paskirtis – tobulinti žmogaus įgūdžius, gebėjimus ir galimybes, kas daro jį vertingu verslo šaltiniu (Oracle, 2023).

Atsižvelgiant į pateiktus 2 lentelėje apibrėžimus galima daryti šias išvadas:

- *pirma,* dirbtinis intelektas savarankiškai dirba su informacija, o ne tiesiog ją apdoroja, automatizuodama protingus veiksmus, kuriuos paprastai atlieka žmogus;
- *antra,* dirbtinis intelektas yra orientuotas į užduotį arba rezultatą, todėl pritaiko savo elgesį, siekiant savo tikslų;
- *trečia,* dirbtinis intelektas gali perprogramuoti save, remdamasis tuo, ką išmoksta. Kitaip tariant, AI yra aktyvus, agentinis, automatinis ir prisitaikantis.

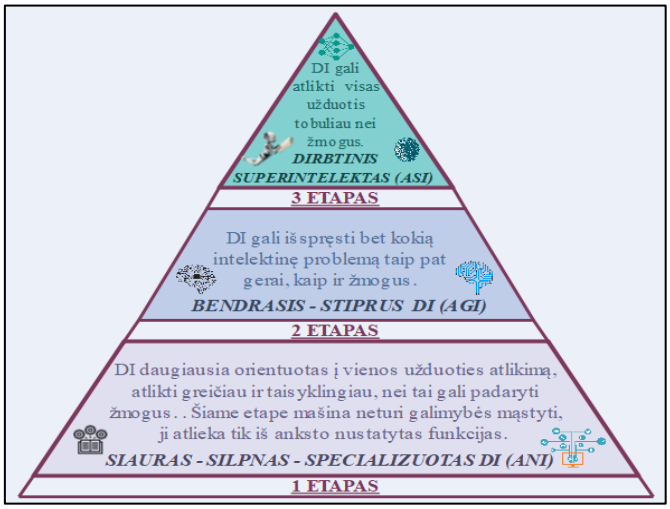
2 lentelė. Žymių asmenybių dirbtinio intelekto apibrėžimai

Autorius		DI apibrėžimai
John McCarthy		Protingų mašinų kūrimo mokslas ir inžinerija ... kur intelektas yra kompiuterinė dalis, padedanti siekti tikslų pasaulyje.
Marvin Lee Minsky		Mokslas apie tai, kaip priversti mašinas daryti dalykus, kuriems atlikti reikėtų intelekto, jei tai darytų žmonės.
Kompanijos	IBM	Viskas, kas priverčia mašinas veikti protingiau.
	Accenture	Technologijų, suteikiančių žmonėms galimybę suvokti, suprasti, veikti ir mokytis, visuma, leidžianti žmonėms padaryti daug daugiau.
	Salesforce	Kompiuterių mokslo sritis, kurioje pagrindinis dėmesys skiriamas mašinų, galinčių mokytis, atpažinti, numatyti, planuoti ir rekomenduoti, suprasti vaizdus ir kalbą bei reaguoti į juos, kūrimas.
	Amazon	Informatikos mokslo šaka, kurioje sprendžiamos kognityvines užduotys, paprastai skirtos žmogaus intelektui, pavyzdžiui, mokymasis, problemų sprendimas ir modelių atpažinimas. Šiandien dirbtinis intelektas yra pažangių kompiuterinių technologijų dalis.
Stanfordo universitetas		Mokslas ir technologija, skirta pažangiems įrenginiams, ypač pažangioms kompiuterių programoms, kurti. Tai susiję su panašiu iššūkiu – kompiuterių naudojimu siekiant suprasti žmogaus intelektą, tačiau dirbtinis intelektas neturėtų apsiriboti tik biologiškai stebimais metodais.
Lietuvos vyriausybė		Sistemos, kurios demonstruoja protingą ir sumanų elgesį, analizuodamos savo aplinką ir darydamos gana savarankiškus sprendimus tikslui pasiekti.

Šaltinis: Marsden, 2017.

Žmonėms toks informacijos apdorojimo gebėjimas reikalauja intelekto ir intuicijos, kurie yra kognityvinių procesų dalis, įskaitant dėmesį, suvokimą, samprotavimą, problemų sprendimą, mokymąsi ir atmintį (Marsden, 2017). Išnagrinėjant mokslinius šaltinius, galima pabrėžti, jog intelektas yra sudėtingas objektas.

Analizuojant dirbtinio intelekto ekspertų duomenis, galima teigti, kad pagrįsta gabumais ir įgūdžiai dirbtinio intelekto sistema skirstoma į 3 pagrindines kategorijas: 1 – **silpnas** arba **siauras** dirbtinis intelektas; 2 – **bendrasis** dirbtinis intelektas ir 3 – **superintelektas** dirbtinis intelektas (1 pav.).



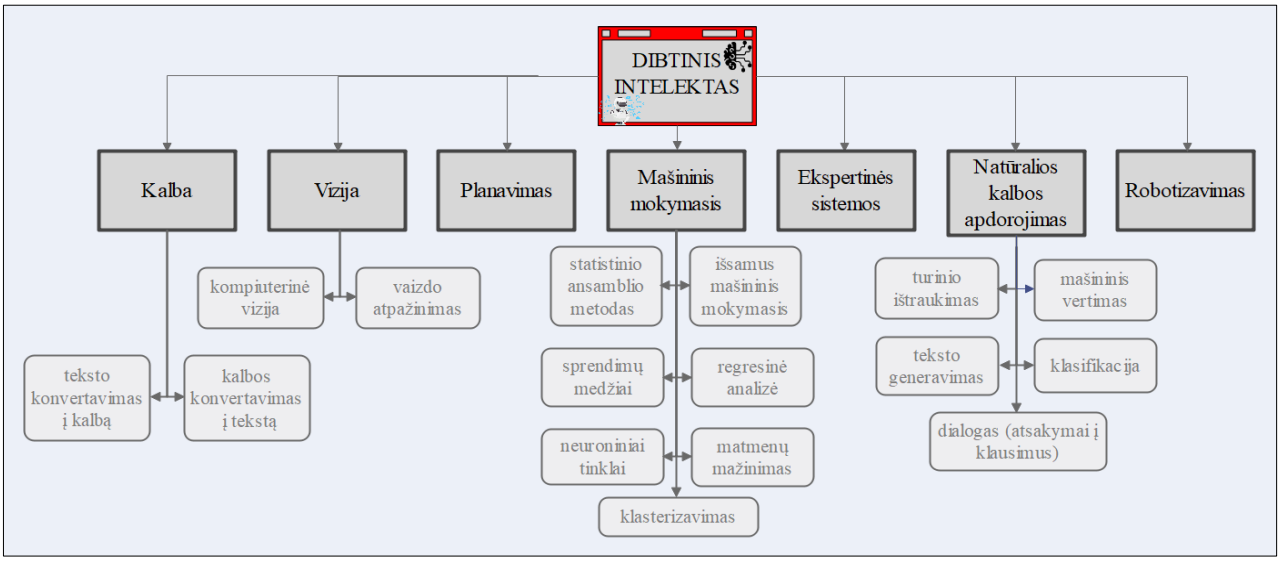
1 pav. Trys dirbtinio intelekto vystymo stadijos

Siauras arba silpnas intelektas (ANI) – dirbtinis intelektas taikomas tik tam tikroms užduotims arba užduočių rinkiniams, taip pat specifinėms problemoms spręsti. Specializuota DI sistema gali būti išmokyta atpažinti objektus vaizduose, versti tekstą iš vienos kalbos į kitą (Datascientest, 2023). Specializuotos DI sistemos šiuo metu yra labiau paplitusios nei bendrosios DI sistemos, nes jas galima išmokyti atlikti konkrečias užduotis labai tiksliai.

Dirbtinis bendrasis arba stiprus intelektas (AGI) – mašinos su žmogaus lygio intelektu, kurią būtų galima pritaikyti bet kokiai užduočiai, turinčią visą kognityvinių gebėjimų rinkinį ir tokį pat platų naudojimo atvejų spektrą, galinti išspręsti problemas, su kuriomis ji niekada nebuvo išmokyta dirbti – panašiai kaip žmogus, tik imituoti jo mąstymą ir nieko daugiau (Schroer, 2022).

Dirbtinis superintelektas (ASI) – mašinos, dėl itin aukšto lygio duomenų apdorojimo, atminties ir sprendimų priėmimo galimybių, galės atlikti absoliučiai visas intelektinio ir kūrybinio pobūdžio užduotis geriau nei žmogus (Narain at al., 2019).

AI yra bendras terminas, apimantis visas sąvokas, neatsiejama mašininio ir gilaus mokymosi dalis. Gilųjį mokymąsi galima vadinti mašininio mokymosi forma, o mašininis mokymasis yra dirbtinio intelekto pogrupis, viskas tarpusavyje susiję.



2 pav. Dirbtinio intelekto vystymosi krypčių atsišakojimai

Dirbtinis intelektas yra labai plati sritis, turinti daugybę krypčių, su kuriomis susiduriame kasdien ir kasdieniame gyvenime (2 pav.). Viena iš jų – neuroniniai tinklai, analizuojantys *žmogaus kalbą*, neatsižvelgiant į kalbos pobūdį, aukštį, toną, kalbą ir akcentą, taip pat neuroniniai tinklai, leidžiantys kompiuteriams atskirti ir *atpažinti vaizdus* taip, kaip tai daro žmonės. Su tuo glaudžiai susijęs gebėjimas apdoroti natūralų, žmogaus sukurtą tekstą. Neuroniniai tinklai padeda kompiuteriams iš tekstinių duomenų ir dokumentų išgauti informaciją ir prasmę. Be to, labi svarbi DI sritis, kurią įmonės dažnai naudoja savo darbe – tai *planavimas*. Užduotis rasti procedūrinę veiksmų kryptį, kad deklaratyviai aprašyta sistema pasiektų savo tikslus, optimizuojant bendrus veiklos rodiklius. Nors dirbtinis intelektas yra tarpdisciplininis mokslas, kuriam taikomi įvairūs metodai, mašininio mokymosi ir gilaus mokymosi pažanga sukuria paradigmos pokytį beveik kiekviename technologijų pramonės sektoriuje.

2. Dirbtinio intelekto priemonės konteinerio pristatymo procese

Transporto ir logistikos sektoriuose didėjant susidomėjimu verslo procesų automatizavimo IT sprendimais, krovinių pervežimas ir jų rinka patiria vis svarbesnius pokyčius. Didėjantis transporto ir logistikos sektoriaus skaitmenizavimui siūlomų sprendimų kiekis bei jų įvairovė iškelia naują problemą – kaip transporto ir logistikos įmonėms išsirinkti tinkamiausią ir optimaliausią sprendimą jų procesų skaitmenizavimui.

Visų pirma, pagrindinis DI taikymo logistikoje pranašumas visada bus duomenų kokybė, kuriuos jis padeda nustatyti. DI pajėgumai, tokie kaip natūralios kalbos apdorojimas (*angl*. NLP) ir mašininis mokymasis (*angl*. ML), padeda tiksliai gauti ir tvarkyti informaciją, kuri kasdien patenka į logistikos įmones neįveikiamais kiekiais. NLP gali suprasti dažnai kartojamus terminus, frazes ir net žargoną, o ML gali užmegzti ryšius tarp šių pagrindinių punktų – sukurti kontekstą ir mokytis, kai šie žodžiai vystosi (Transmetrics, 2021).

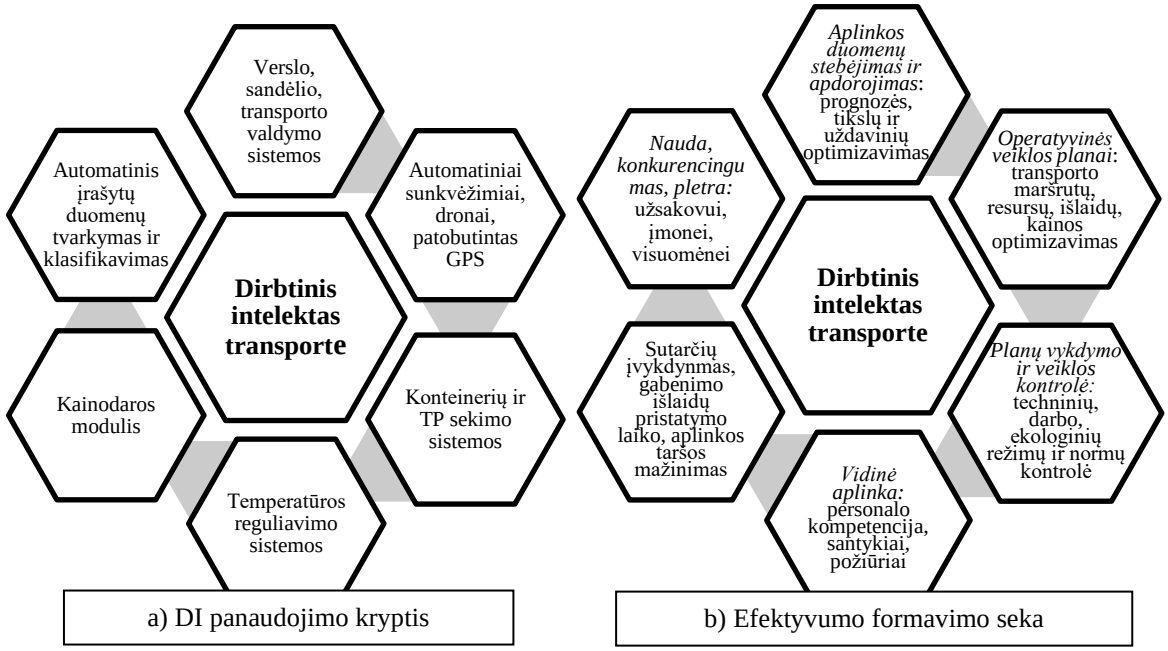
Logistikos pramonei teikiama technologijų nauda ir toliau auga – tai rodo naujausi išradimai ir bandymai, grafiškai pavaizduoti 3 paveiksle. Norint išlikti konkurencingiems ir užtikrinti atliekamų darbų efektyvumą, būtina pritaikyti naujausias technologijas tiekimo grandinės valdyme. Tai ne tik

padeda sumažinti transportavimo išlaidas, bet taip pat užtikrina efektyvų konteinerių pervežimą tiek vietiniu tiek tarptautiniu lygiu. Dirbtinio intelekto pagalba automatiškai analizuojami įvairūs duomenys, gaunami iš specialių sunkvežimio programų, konteinerio siekimo programų ir globalios padėties nustatymo sistemos (*angl*. GPS). DI apdoroja visą gautą informaciją, savarankiškai mokosi kurti algoritmus, kurie optimizuoja užduoties atlikimą ir saugumą, numatyti potencialias problemas ir sukurti jiems alternatyvius sprendimus.

DI technologinės priemonės, didinančios konteinerių pervežimo efektyvumą:

- **Konteinerių išdėstymo organizavimas.** Dirbtiniu intelektu varomi mechanizmai gali optimizuoti konteinerio padėtį, kad būtų kuo geriau išnaudota turima erdvė. Mašinos išdėsto konteinerius, naudodamos kompiuterinį matymą, priimdamos savarankiškus sprendimus, mokydamosi neprižiūrimais metodais. Stebėjimo įrenginys perduoda vaizdą į interpretavimo įrenginį, kuris klasifikuoja konteinerį, atpažindamas tokius kintamuosius kaip dydis ir forma. Tada jis įvertina esamą saugyklos konfigūraciją, kad nustatytų tinkamiausią vietą naujam konteineriui.
- **Konteinerių gabenimo planavimas – nuspėjamasis planavimas.** Šis procesas gali būti sudėtingas, nes reikia atsižvelgti į tokius veiksnius kaip konteinerių prieinamumas, gabenimo maršrutai ir transporto rūšys. Nuspėjamoji analizė naudojant DI apima dirbtinio intelekto algoritmų naudojimą su konteinerių gabenimu susijusiems duomenims, pavyzdžiui, istoriniams gabenimo modeliams, orų prognozėms ir eismo duomenims analizuoti, siekiant numatyti efektyviausius ir ekonomiškiausius gabenimo maršrutus ir transporto rūšis. Ši technologija gali padėti padidinti konteinerių gabenimo planavimo tikslumą ir greitį, todėl tiekimo grandinė valdoma veiksmingiau, o gabenimo išlaidos sumažėja.
- **Efektyvus tiekimo grandinės ir gamybos planavimas.** Dirbtinio intelekto įrankiai ir sprendimai padeda realiuoju laiku analizuoti didžiulius duomenų rinkinius, subalansuoti pasiūlos ir paklausos spragas, veiksmingai planuoti gamybos veiklą ir kurti be klaidų parengtus planus ir strategijas.
- **Verslo valdymo sistemų diegimas.** Kompiuterinė programa, skirta verslo procesų kontrolei ir valdymui, padedanti valdyti ir pagerinti tokius procesus kaip pardavimai, aptarnavimas, santykiai su klientais (*angl*. CRM), projektų valdymas, žmogiškųjų resursų paskirstymas, gamyba, tiekimas, prekių ir paslaugų judėjimas ir finansai.
- **Veiklos procesų skaitmenizavimas** – tai analoginių technologijų ir fizinių objektų konvertavimo į skaitmeninius formatus procesas. Jis padeda automatizuoti įprastus procesus, sumažinti išlaidas ir pagerinti klientų aptarnavimą. Logistikoje skaitmeninimas atlieka ypatingą vaidmenį, nes leidžia optimizuoti visus tiekimo grandinės etapus.
- **Krovinio sekimo sistemos.** Sistemos, padedančios realiu laiku stebėti krovinio transportavimo procesą, padeda efektyviau valdyti tiekimo grandinę bei užtikrinti, kad vilkikų vairuotojai neatsiliktų nuo numatyto grafiko.
- **Temperatūros reguliavimo sistemos.** Greitai gendančioms prekėms reikalinga stabili, žemesnė arba aukštesnė temperatūra. Tam, kad prekės neprarastų savo prekinės išvaizdos ir kokybės, krovinių pervežimo paslaugas siūlančios įmonės transporto priemonėse pritaikė specialią, temperatūros reguliavimo sistemą, kuri užtikrina šviežiu gaminiu transportavimo procesą. Paprastai, krovininėse transporto priemonėse palaikoma nuo -18 iki +20 laipsnių temperatūra.
- **Patobulintas GPS sistema.** Leidžia išvengti kliūčių kelyje, nepatekti į automobilių spūstis ir žinoma, nenuklysti nuo teisingo kelio, pristatymas efektyviau, greičiau ir ekologiškiau.
- **Automatiniai sunkvežimiai ir dronai.** Bepiločiai orlaiviai (dronai), kuriais gali būti pristatomi užsakymai. Automatiniam krovininiam automobiliui dar reikalingas vairuotojas, kuris turi sėdėti keleivio vietoje ir stebėti kompiuterio duomenis.
- **Transporto valdymo sistemos** (*angl*. TMS). Programinės įrangos moduliai padeda parinkti optimaliausią maršrutą ir tinkamiausią transporto priemonę kroviniams pervežti, leidžia visus vykdomus procesus stebėti realiu laiku.
- **Automatinis įrašytų duomenų tvarkymas ir klasifikavimas.** Gaunamų sąskaitų faktūrų, tiekėjų dokumentų ir gaminių etikečių tvarkymas reikalauja rankų darbo ir užduočių, susijusių su informacijos išgavimu iš šių dokumentų ir teisingu jos įvedimu į serverio sistemas, supratimo.

- **Kainodaros modulis.** Dirbtinio intelekto įrankiai padeda ekspeditoriams prisitaikyti prie dinamiškai besikeičiančių rinkos sąlygų.
- **Reiso planavimas ir maršruto prognozavimas.** Leidžia įmonėms optimizuoti savo maršrutus atsižvelgiant į kintamuosius, pvz. orą, ir reaguoti į netikėtus įvykius.
- **Logistikos maršrutų optimizavimas.** Dirbtinio intelekto ir ML pagrindu veikiantys duomenų apdorojimo įrankiai padeda realiuoju laiku fiksuoti su prekių judėjimu susijusią informaciją ir teisingai apskaičiuoti pristatymo laiką, sumažinant bendras išlaidas.
- **Tikslus prognozavimas.** Leidžia organizacijoms rinkti informaciją iš kelių skirtingų rangovų, klientų ir įmonės grandžių (įskaitant tiekėjus, atsargas ir produktus) ir naudoti ją tikslioms prognozėms rengti, taip didinant efektyvumą.
- **Automatizuotas prekių rūšiavimas** – šios sistemos naudoja kameras ir jutiklius, reikalingus gaminiams rūšiuoti ir nukreipti ant skirtingu konvejerio juostu.

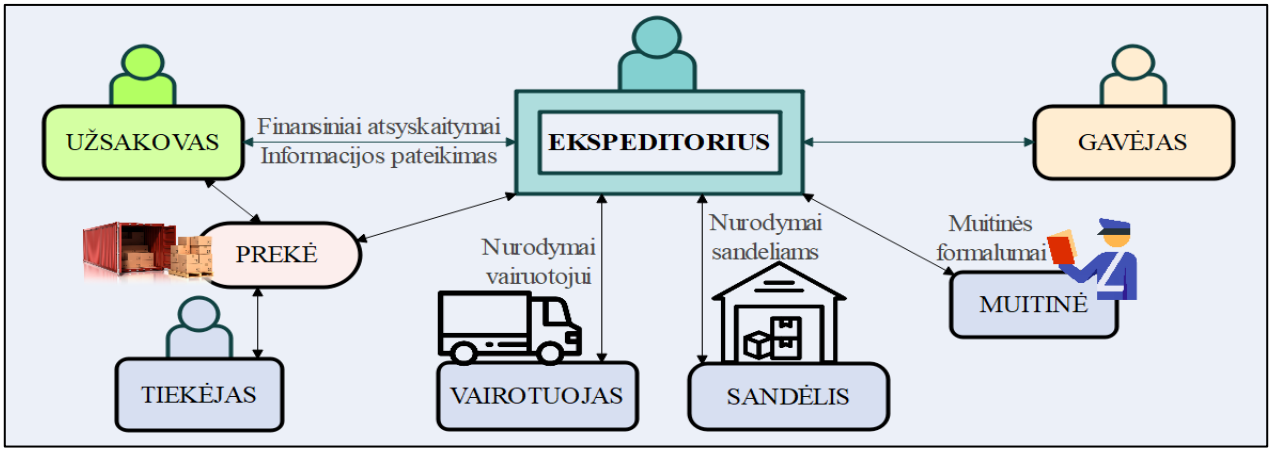


3 pav. DI panaudojimas logistikos transporto sektoriuje

- **Sandėlio valdymo sistema** (*angl*. WMS). Naudojant dirbtinio intelekto sprendimus galima sumažinti tiek perteklinių, tiek nepakankamų atsargų kiekį. Kasdienių užduočių, tokių kaip krautuvų valdymas, rūšiavimas ir atsargų valdymas, automatizavimas, naudojant dronus ar autonomines antžemines transporto priemones, keičiant sandėlių valdymą.
- **Anomalijų aptikimas.** Objektų, įvykių ir duomenų, kurie skiriasi nuo laukiamų rezultatų arba stipriai išsiskiria savo objektų kategorija, identifikavimas.
- **Sukčiavimo aptikimas.** Prognozavimo modelių sukūrimas, kad aptikti galimai apgaulingus sandorius ir nesąžiningus ar neteisingus prašymus.
- **Klientų srauto nutrūkimas.** Nustatyti klientus, kurie gali atsisakyti paslaugų. Taip galima iš anksto sudominti šiuos klientus pasiūlymais ar asmeninėmis paslaugomis.
- **Individualus turinio pritaikymas.** Analizės modeliai su prognozavimo analitika, siekiant rekomenduoti produktus ir rodyti svetainėje pritaikytą turinį, pagrįstą ankstesniais klientų veiksmais.

Ekspeditorius – juridinis asmuo (verslininkas), sudaręs krovinių ekspedijavimo sutartį su užsakovu ir įsipareigojęs užsakovo (užsakovo kliento) lėšomis, jo ar savo vardu gabenti jam priklausantį krovinį ir atlikti kitus su tuo susijusius veiksmus. Krovinių ekspedicijos sutartimi, ekspeditorius, įsipareigoja kliento lėšomis teikti arba organizuoti sutartyje numatytas paslaugas, susijusias su krovinių vežimu (Lietuvos respublikos civilinio kodekso patvirtinimo, įsigaliojimo ir įgyvendinimo įstatymas Nr. VIII-1864, 2000).

Pagrindinės ekspeditoriaus funkcijos, kurios parodytos 4 paveiksle – yra informacijos valdymas ir pateikimas, organizavimas-vykdymas duomenų ir dokumentų pateikimas, proceso kontrolė (Valionienė, 2019).



4 pav. Pagrindines ekspeditoriui deleguotos užduotys

Ekspeditoriaus sutartyje nurodomi visi jo įsipareigojimai, visų procesų reikalavimai ir sąlygos bei atsakomybė. Šie darbuotojai turi suprasti sudėtingus klientų reikalavimus, verslo taisykles ir išimtis, spręsti duomenų kokybės klausimus bei kt. Jų darbe neretai tenka vadovautis sveiku protu, kuris dar nėra stipriausia dirbtinio intelekto savybė. Atsakomybės srities klaidos atveju dar nenustatytos. Atsižvelgiant į dabartinę dirbtinio intelekto technologijų būklę, negalima visai optimizuoti ir užimti ekspeditorių vietą, geriausia sutelkti dėmesį į DI priemonių pagalbą ekspeditoriaus darbe.

Daugelį ekspedicijos operacijų dirbtinis intelektas atlieka per kelias sekundės, be to, jis gali nuolat realiuoju laiku stebėti visus pervežimus tuo pačiu metu, o tokį darbą žmogui atlikti sudėtinga. Ekspeditoriaus darbui įtakos turi jo fizinė ir psichinė būsena, priešingai nei naudojant kompiuterines technologijas DI pagrindu. Problemas, su kuriomis susiduria tradiciniai ekspeditoriai, tokias kaip žmogiškosios klaidos vykdant veiklą, pajamų nutekėjimas, grynųjų pinigų trūkumas, nepakankamas krovinių stebėjimas, pasiūlos ir paklausos neatitikimas ir sumažėjusi pelno marža, galima išspręsti įdiegus dirbtinį intelektą (Еремина at al., 2019). Per pastaruosius kelerius metus skaitmeninių technologijų atsiradimas pakeitė pasaulinės konteinerių vežimo ir transporto pramonės scenarijus, tuo metu kai dirbtinis intelektas gali atlikti tokius dalykus, apie kuriuos dar niekas net negalvojo.

3. Dirbtinio intelekto priemonių panaudojimo galimybės UAB „NTG Lithuania“ veikloje

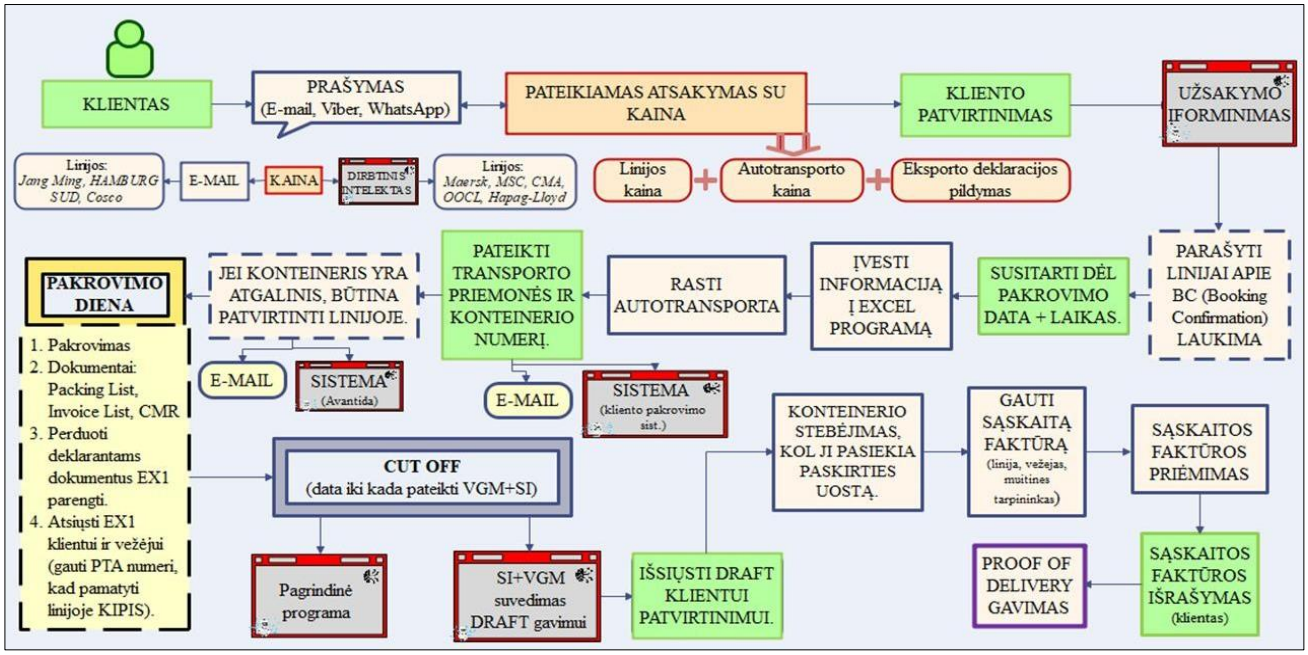
UAB „NTG Lithuania“ – transporto ir logistikos paslaugų kompanija, kuri priklauso *Nordic Transport Group* įmonių grupei, dabar turinčiai savo biurus pagrindiniuose pasaulio uostuose: Roterdame, Hamburge, Šanchajuje, Šendžene ir Honkonge. *Nordic Transport Group A/S* ir *NTG Nordic A/S* įsteigtos 2011 m. balandžio mėn. ir jau 2012 m. buvo įsigyta *ATS Cargo UAB* Lietuvoje ir pervadinta į UAB „NTG Lithuania“. Dabar Lietuvoje įmonė turi trys padalinius: generalinis Vilniuje, Kaune bei Klaipėdoje – 12 darbuotojų. Viso įmonė turi 50 darbuotojų, iš kurių 12 Klaipėdos padalinio, tai jūrų-oro transporto vadybininkai, kelių transporto vadybininkai, pardavimo vadybininkai, apskaitos skyrių darbuotojai bei kt. (NTG Lithuania, 2023).

„NTG Lithuania“ individualiai pritaikanti sprendimus įmonė, kuri specializuojasi teikiant krovinių vežimo sprendimus. Turėdama ilgametę patirtį šioje srityje, įmonė turi sukaupusi didelį transporto priemonių parką, specialiai pritaikytą kroviniams vežti visoje Europoje. „NTG“ siūlo visą spektrą krovinių gabenimo jūrų (*angl.* FCL ir LCL, nuo durų iki durų) ir oro transportu paslaugų su visais formalumais. Atidus dėmesys detalėms yra gyvybiškai svarbus krovinio eigai. Net ir globalizuotame pasaulyje muitinės klausimai ir su jais susiję komerciniai dokumentai, leidimai, licencijos bei importo ir (arba) eksporto draudimai visada išlieka labai svarbus. Krovinių gabenimas

importo ir eksporto kryptimi, tarptautiniais maršrutais pastoviai organizuojamas į tokias šalys: Švedija, Suomija, Norvegija, Danija, Vokietija, Olandija, Belgija. Kaune yra sandėliavimui skirtas patalpas, kuriose galima sandėliuoti plataus asortimento prekes. Teikiamos sandėliavimo paslaugos įvairių dydžių prekėms, nuo smulkios pakuotės iki negabaritinių, įvairių dydžių krovinių.

„NTG Lithuania“ veiklą vykdo pagal Lietuvos ekspeditorių asociacijos bendrąsias sąlygas (LINEKA). Sąlygos riboja atsakomybę dėl prekių praradimo, jų kokybės pablogėjimo ar pažeidimo. Vykdant tarptautinę prekybą, yra naudojamos INCOTERMS sąlygos, kurias parengė Tarptautiniai prekybos rūmai (*angl.* ICC). Jose yra aprašoma pirkėjų ir pardavėjų rizika, atsakomybė ir pareigos, vykdant tarptautinę prekybą (NTG Lithuania, 2023). Kaip ir daugelis logistikos įmonių, „NTG Lithuania“ naudoja dirbtinio intelekto priemones krovinių ekspedijavimo paslaugoms palengvinti ir pagerinti darbo kokybė.

DI priemonių naudojimas vykdant konteinerio eksporto procesą. Eksporto konteinerio vykdymo proceso aprašymas prasideda nuo kliento prašymo su kainos apskaičiavimu (*INCOTERMS* nustatymas). Dirbtinio intelekto panaudojimo konteinerio pristatymo proceso, eksporto atvejo nuosekli schemą parodyta 5 paveiksle.



5 pav. Dirbtinio intelekto panaudojimas konteinerio pristatymo procese (eksporto atvejis)

Kainos apskaičiavimo būdas priklauso nuo laivybos linijos, tokios linijos kaip *Jang Ming, HAMBURG SUD, Cosco* naudoja pirmąjį metodą. Tai reiškia, kad linijai siunčiamas elektroninis laiškas, kuriame nurodoma užsakymo informacija: išvykimo uostas – paskirties uostas ir užklausiama apie frachto kainą.

Antrąjį krovinių vežimo paslaugų apskaičiavimo metodą taiko tokios linijos kaip *Maersk, MSC, CMA, OOCL, Hapag-Lloyd*. Šiame etape naudojama dirbtinio intelekto programinė įranga; tinklalapyje įvedus visą reikiamą užsakymo informaciją, dirbtinis intelektas pagal gautus duomenis apskaičiuoja ir pateikia kainą.

Šiame etape klientas turi pateikti ekspeditoriui informaciją apie pageidaujamą užsakymą (iš kokios ir į kokią vietą, transporto rūšį, krovinio tipą, pageidaujamą tranzitinį laiką ir t. t.).

Kai iš kliento gaunamas kainos patvirtinimas, galima įforminti užsakymą, kurį taip pat formuoja dirbtinis intelektas; įvedus informaciją, užsakymas parengiamas automatiškai.

Suderinus su autotransportu vežėju, būtina informuoti klientą apie transporto priemonės ir konteinerio numerį elektroniniu paštu arba jo pakrovimo sistema.

Verta atsižvelgti į tai, kad jeigu grąžinamas konteineris yra atgalinis (*angl.* Backload – tai konteineris, naudojamas atgaliniam pakrovimui), o ne iš terminalo, kas taupo pinigus, tai turi būti

patvirtinta linijoje naudojant *Avantida* DI pagrindu veikiančią programą arba siunčiant el. laišką į laivybos liniją.

Toliau reikia nurodyti datą (*angl*. Cut Off), iki kurios būtina pateikti VGM (krovinio svoris + konteinerio svoris) ir OBL pildymo instrukcijas (*angl*. SI – Shipping Instructions) laivybos linijai interneto svetainėje.

Visi šie duomenys automatiškai patvirtinami dirbtiniu intelektu ir DRAFT (juodraštinis BL) siunčiamas el. paštų, tada galima jį siųsti kliento patvirtinimui.

Nustatyta dokumentų skenavimo DI priemonė perkelia gautas sąskaitas faktūras iš standartinės formos į elektroninę ir automatiškai užpildo visą reikalingą lydimąją informaciją.

Konteinerio eksporto proceso tobulinimas naudojant dirbtinio intelekto priemones, atsižvelgiant į dabartinius iššūkius:

1. Optimizuoti prašymų teikimą;
2. Optimizuoti autotransportą parinkimas;
3. Optimizuoti pagrindinį programą pritaikius jį jūrinėms pervežimams;
4. Problemų su duomenų apsauga (nutekėjimu) sprendimas;
5. Automatizuoti sąskaitų priėmimą ir išrašymą.

Išvados

1. Apibendrinant galima teigti, kad konteinerių pristatymo proceso optimizavimo galimybes naudojant dirbtinio intelekto priemones gali iš esmės pakeisti logistikos įmonių veiklą. Pasitelkusios dirbtinį intelektą, įmonės gali padidinti pristatymo procesų efektyvumą, sumažinti išlaidas ir padidinti klientų pasitenkinimą. Dirbtinis intelektas gali padėti optimizuoti maršrutus, valdyti atsargas, sekti realiuoju laiku (konteinerius, transporto priemones ir kt.), automatizuotai sudaryti tvarkaraščius ir atlikti prognozuojamąją techninę priežiūrą, o visa tai padeda racionalizuoti ir užtikrinti patikimesnį pristatymo procesą. Technologijoms toliau tobulėjant, dirbtinio intelekto naudojimas logistikoje tik plėsesi, o įmones, kurie pritaikę DI priemones anksčiau, turės didesni konkurencinį pranašumą. Todėl logistikos bendrovėms būtina ištirti ir investuoti į dirbtinį intelektą, kad optimizuoti konteinerių pristatymo procesą ir išlikti konkurentų priekyje šiuolaikinėje nuolat besikeičiančioje verslo aplinkoje.

2. Išanalizavus UAB „NTG Lithuania“ dirbtinio intelekto priemonių panaudojimo poveikį konteinerių pristatymo proceso optimizavimui, buvo nustatyta, jog atsižvelgiant į dabartinius iššūkius, naudojant dirbtinio intelekto priemones įmanomas konteinerių eksporto proceso tobulinimas optimizuojant prašymų teikimą, autotransporto parinkimą, pagrindinį programą pritaikius jį jūrinėms pervežimams. Taip pat sprendžiant duomenų apsaugos bei nutekėjimų problemas ir automatizuojant dokumentu tvarkymo formalumus. Reikia atkreipti dėmėsi, kad modernių technologijų, susijusių su elektroninių dokumentų tvarkymu, naudojimas numato, kad pati aplinka turi įteisinti elektroninius dokumentus teisiniu aspektu.

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LITHUANIAN MARITIME ACADEMY

HIGHLY EFFICIENT 2 STROKE MARINE ENGINE ANALYSIS COUPLED WITH A COLD ENERGY RECOVERY SYSTEM

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Abstract. Climate change due to global warming is a proved fact. In the maritime sector, the International Maritime Organization issued several regulations to limit greenhouse gases emissions. Nowadays, the use of fuels that have a lower impact on air pollution is of great importance among decarbonization strategies. In merchant ships, primary energy source are fossil fuels and the use of natural gas is the most extended solution to limit pollution. In this study, a two stroke marine engine from the manufacturer MAN Diesel ES is analysed. This type of engine is widely used on board ships due to its high power and efficiency. First, an energy analysis was conducted, followed by an exergy analysis. Once the exergy available to recover is known, a waste heat recovery system is implemented. Due to the high efficiency of the engine, a cold energy recovery application was chosen as best way to recover energy and satisfy refrigeration needs on board. The implementation of this energy recovery system increases engine's thermal performance leading to a specific fuel consumption reduction, which at the same time reduces the amount of air pollution.

Keywords: Slow speed marine engine; Waste heat recovery; Exergy; Cold energy; Combined heat and power.

Introduction

Maritime transport is currently responsible of 2.89% of total anthropogenic CO_2 emissions (International Maritime Organization (IMO), 2021a). Focusing on decarbonization, the International Maritime Organization implemented MARPOL Annex VI along with technical and operational efficiency indicators. The goal is to reduce emissions at least 50% by 2030, compared to 2008; and to achieve a 70% reduction by 2050 (International Maritime Organization (IMO), 2018).

New build vessels can be equipped with state of the art technology, which is highly efficient. But according to the United Nations Conference on Trade and Development, average age of world fleet is 21.9 years (United Nations Conference on Trade and Development, 2022). This means that, in order to accomplish decarbonization, already in-service vessels have to take action as well. Main engine replacement in already sailing vessels may not be feasible in all cases, depending on the age of the vessel and the cost of the refit. For this reason, waste heat recovery technologies can be the strategy to follow in order to increase the efficiency of the vessel and consequently reduce pollutant emissions (Díaz-Secades et al., 2022; Singh & Pedersen, 2016). Options to recover energy suggested by IMO can be found in MEPC.1/Circ.896 (International Maritime Organization (IMO), 2021b).

Nowadays, dual-fuel engines are the standard in liquefied natural gas (LNG) tankers. In this type of vessels, LNG is stored at -162 ºC but needs to be fed to the engine at room temperature. In order to do this, the gas needs to be previously heated. Taking advantage of this condition, the recovery of cold energy can be implemented as an energy efficiency measure that satisfies crew needs on board (Ouyang et al., 2020). By using the cold energy contained in the LNG fuel lines, less electric power needs to be used to maintain temperatures in the cold storerooms. This energy recovery reduces the fuel consumption and pollutant emissions.

In this study, a case study LNG tanker has been used to analyse engine thermal and exergy efficiency, implementing a cold energy recovery system that produces cooling power enough to satisfy daily needs on board.

The object of the research is the cold energy recovery from liquefied natural gas (LNG).

The aim of the research is to evaluate the thermo-economic feasibility of an energy recovery system on board ships.

The objectives of the research are the following:

1. Increase awareness about the potential uses of cold energy in the maritime industry.
2. Increase knowledge about exergy and its role in engineering projects.
3. Highlight the future role of energy-saving devices in the shipping industry to comply with the Sustainable Development Goals.

The research methods include the following: analysis of scientific literature, synthesis and interpretation.

The structure: The first part of this study presents the case study engine along with its particulars, the thermodynamic analysis and the proposed energy recovery system. The second part of the research includes the results of the analysis displayed in the first part and performance improvement when the system includes an energy recovery device.

1. System configuration and working fluid

In this study, a MAN 5G70ME-C9.5-GI engine from a recently build LNG tanker was studied. Main characteristics were retrieved from MAN CEAS calculation tool (MAN Energy Solutions, 2022). Reference conditions are taken from ISO 15550. Contrary to previous literature, the engine data used for the study corresponds to 70% MCR as it matches regular operation of the vessel. In Table 1, particulars of the engine are shown.

Table 1 - Case study engine particulars

Parameter	Value
Engine load	70%
Shaft power at studied load	10870 kW
LNG consumption	135.1 g/kWh
MDO pilot oil consumption	3.18 g/kWh
Exhaust gas mass flow	25.9 kg/s
Scavenging air mass flow	25.5 kg/s
Exhaust gas temperature	212 ºC
HT water temperature (outlet)	85 ºC
Engine block temperature (average)	70 ºC
Heat dissipated by cooling water	1620 kW
Heat dissipated by oil exchanger	890 kW

In order to design an efficient waste heat recovery system, First and Second Law of Thermodynamics analyses were conducted. In Figure 1, a diagram of the engine used for the energy and exergy analyses is shown.

First, energy balance was calculated. Intake energy of the system is obtained from LNG and pilot oil supplies:

$$Q_{fuel} = W_{shaft} \cdot \dot{m} \cdot LHV \quad (1)$$

Where W_{shaft} is the shaft power, $\dot{m}$ represents fuel mass flow and LHV is the lower heating value which are 49529 kJ/kg for the LNG and 42700 kJ/kg for the MDO.

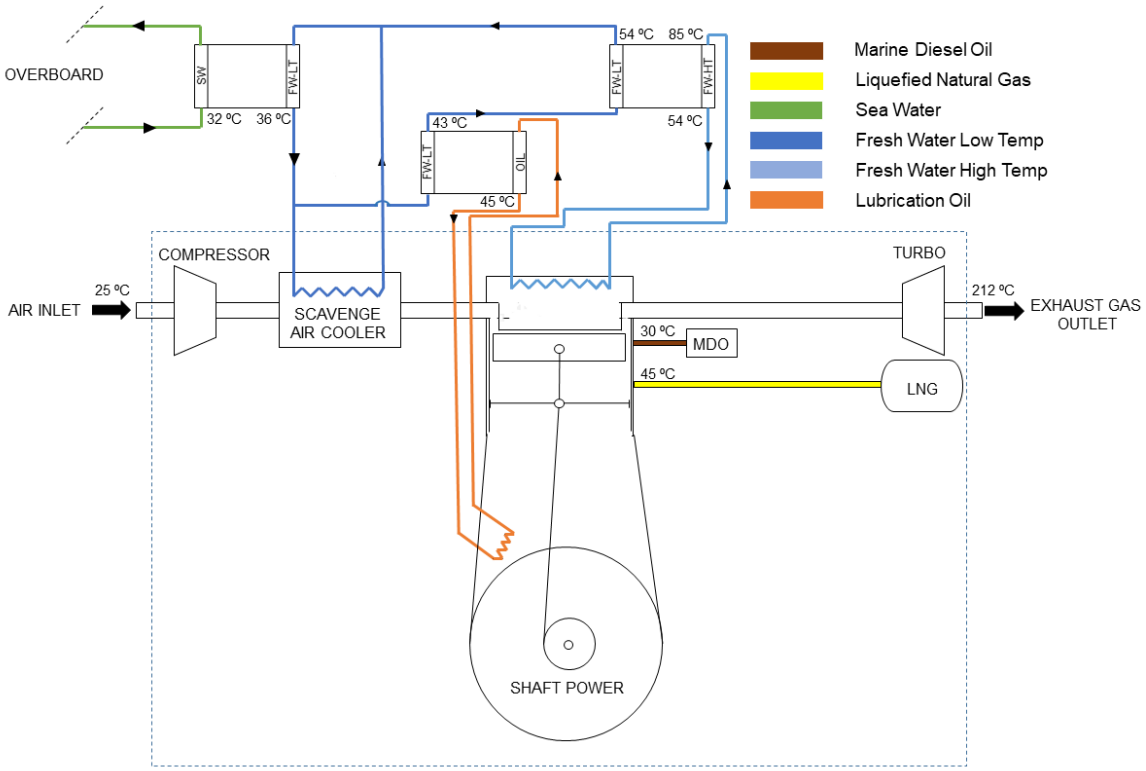

Figure 1 - Diagram of the diesel engine studied.

At the outlet, exhaust gas and heat dissipated into the cooling water were studied. Both scavenging air and lubricating oil heat are supposed to be fully transferred to the cooling water system. Heat dissipated into the abovementioned currents is obtained by:

$$Q = \dot{m} \cdot C_p \cdot \Delta T \qquad (2)$$

Where heat of each current is obtained with the mass flow, $\dot{m}$; constant pressure specific heat, C_p and the temperature gradient, ΔT. In the case of specific heat, values for exhaust gas and lubricating oil are 2.11 and 1.185 kJ/kg·K, respectively (Koshy, 2015).

In addition, heat dissipated by the engine block and its accessories is quantified:

$$Q_{block} = Q_{fuel} - Q_{exhaust} - W_{shaft} - Q_{water} \qquad (3)$$

Thermal efficiency of the engine is obtained in order to assess the amount of fuel used for propulsion versus losses:

$$\eta = \frac{W_{shaft}}{Q_{fuel}} \cdot 100 \qquad (4)$$

In order to visualize the amount of energy lost on heat dissipation through the engine block against the power delivered by the shaft, ratio is calculated:

$$\eta_{block} = \frac{Q_{block}}{W_{shaft}} \cdot 100 \qquad (5)$$

Following the energy analysis, an exergy study was conducted. Exergy is defined as the useful quantity of energy that produces work, based on its quality and specific reference state.

Intake exergy of the engine comes from charge air and fuel. Since charge air is at environment temperature and pressure and in chemical equilibrium, it does not contain any exergy. Chemical exergy of the fuel is calculated by:

$$Ex_{fuel} = \varphi \cdot Q_{fuel} \quad (6)$$

The term φ is taken from the experimental ratios defined by Stepanov (Stepanov, 1995). As in other studies, shaft work is considered to be reversible energy (Dincer & Rosen, 2021).

Exergy at the outlet of the engine will be defined by the power on the shaft and the exergy available on the heat dissipated into exhaust gas and cooling water currents along with the heat dissipated by the engine block. Since all of them correspond to a heat transfer, exergy is obtained by:

$$Ex = \left(1 - \frac{T_0}{T}\right) \cdot Q \quad (7)$$

Where T_0 is the ambient temperature, defined by ISO 15550; T is the temperature of the heat source and Q corresponds to the amount of heat, calculated on the energy analysis.

Finally, exergy performance is calculated. According to Kotas (Kotas, 1985), this can be obtained by:

$$\varepsilon = \frac{W_{shaft}}{Ex_{fuel}} \quad (8)$$

Once engine performance was assessed, a waste heat recovery solution was implemented. In the case of a modern two stroke marine engine operating with LNG, thermal and exergy efficiencies are relatively high to the point that the cost – benefit ratio of improving performance of the engine itself is very high. For this reason, waste heat recovery is a practical tool that reduces both specific consumption and pollution emissions. In this case, cold energy extraction was chosen as LNG stored on board needs to be heated before entering the engine. This cold energy satisfies the daily needs of cooling power of the vessel and her crew. In Figure 2, a schematic of the proposal is shown.

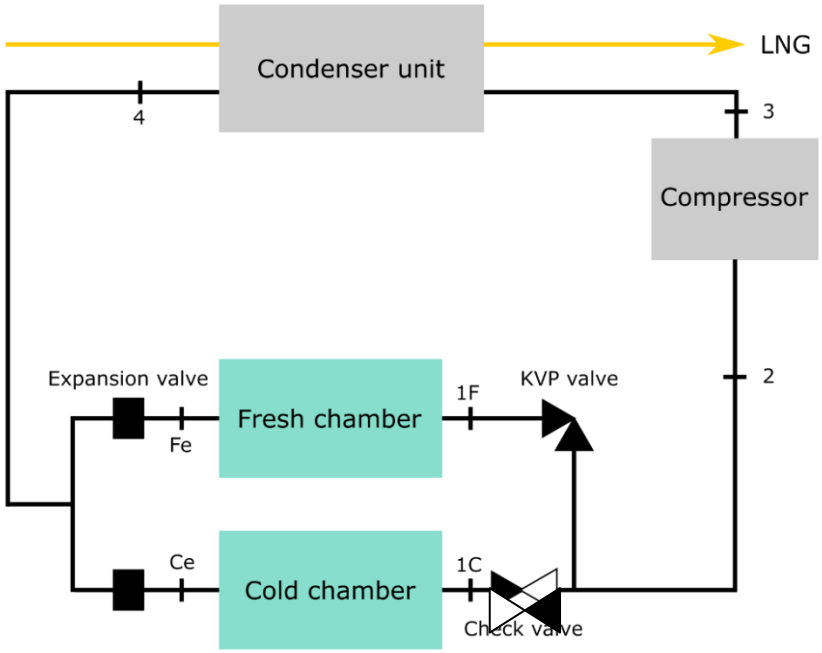

Figure 2 - Cold energy recovery proposal

Cold energy recovery system proposed in Figure 2 feeds two cold stores: the fresh chamber is dedicated to hold vegetables while cold chamber holds frozen foods. The refrigeration cycle uses ammonia (R717) as working fluid since it is a very environmentally friendly fluid (Ozone Depletion Potential = 0 and Global Warming Potential = 0) (Wu et al., 2021). Also, it is a working fluid economical, highly available and already proven in the maritime industry.

The proposed system is designed with one main circuit that splits into two evaporators at different temperature. This is achieved by maintaining different pressures on each branch by means of a pressure regulator of the KVP type. For the system to work and avoid pressure equalization between branches, each one has its own expansion valve and cold chamber is equipped with a check valve that avoids high pressure ammonia from the fresh chamber to enter on the lower pressure cold chamber circuit. Ammonia exit both evaporators and circulates to the compressor, which releases the working fluid at higher temperature and pressure. The condenser of the system is a heat exchanger that uses cold energy from the LNG supply line to the engine to return the ammonia into liquid state. Particulars of the designed system were taken from a real vessel and are shown in Table 2.

Table 2 - Cold storerooms features

Parameter	Fresh store	Cold store
Dimensions (m)	8x8x3	4x8x3
Inlet temperature (ºC)	12	-5
Storeroom temperature (ºC)	6	-22
Outer temperature (ºC)	25	6
Temperature gradient between heat sources (ºC)	5	5
Heating of working fluid at evaporator (ºC)	8	8
Heating of LNG at condenser (ºC)	8	

Also, thermal load inside chambers were calculated. Air infiltrations through walls, floor and ceiling of chambers were calculated:

$$Q_{infiltration} = S_i \cdot K \cdot \Delta T \cdot H \cdot 3600 \quad (9)$$

Where S_i corresponds to the area of the chamber; K is the polyurethane heat transfer coefficient, 0.045 kW/m^2·K; ΔT the temperature difference between the environment and the storeroom and H represents the amount of working time.

For the air entering into the chamber when doors are opened, thermal loads are calculated by:

$$Q_{doors} = V \cdot \frac{50}{\sqrt{V}} \cdot \rho \cdot \Delta h \quad (10)$$

Where V is the volume of the storeroom, ρ is the air density at the storeroom temperature and Δh the difference between enthalpies of the air outside and inside of each storeroom.

In LNG tankers, food provisions are usually received once a month. As an average, 400 kg of vegetables and 300 kg of meat are delivered to a vessel with 27 crew. Thermal load of lowering food temperature is obtained:

$$Q_g = G \cdot C_{non-frozen} \cdot (T_E - T_C) + G \cdot C_L + G \cdot C_{frozen} \cdot (T_C - T_F) \quad (11)$$

Where G is the amount of food stored per day, $C_{non-frozen}, C_L$ and C_{frozen} are the specific heat of the food when it is not frozen, latent and frozen, respectively. Also, T_E, T_C and T_F are the temperatures of the food before entering the storeroom, at freezing point and final, respectively. Once the total thermal load of each storeroom was totalized, the necessary mass of ammonia along with the power needed on the compressor were calculated:

$$\Sigma Q_{store} = \left(h_{out_{evap}} - h_{in_{evap}}\right) \cdot \dot{m} \quad (12)$$

$$\eta = \frac{(h_{3s}-h_2)}{(h_3-h_2)} \quad (13)$$

$$P_{compressor} = (h_3 - h_2) \cdot \dot{m} \quad (14)$$

In this study, compressor performance was assumed to be 75%. Enthalpies for the calculation were obtained from the CoolProp v.6.4.1 database and the R717 P-h diagram. Subindex numbers represent the point of the system represented in Figure 2.

Power extracted from the LNG supply line to the engine as cold energy was also calculated:

$$P_{condenser} = (h_3 - h_4) \cdot \dot{m} \quad (15)$$

Finally, engine performance improvement when implementing the proposal is calculated:

$$\eta_{LNG} = \frac{W_{shaft}+(P_{condenser}-P_{compressor})}{Q_{fuel}} \cdot 100 \quad (16)$$

2. Results and discussion

In this section, relevant results from the designed system are listed and explained in depth. In first place, results of the energy analysis are shown in Table 3.

Table 3 - Results of energy analysis

Parameter	Value
Inlet	
LNG main fuel	20204.2136 kW
MDO pilot oil	412.5769 kW
Outlet	
Shaft power	10870 kW
Exhaust gas	5739.3105 kW
Cooling water	2510 kW
Engine block heat	1497.48 kW
Engine thermal performance at 70% load	
52.724%	

From obtained results shown in Table 3, it can be observed that on dual-fuel engines pilot oil represents a small fraction, a 2% in this case, of the total consumption but cannot be neglected. On top of the energy use, MDO is the responsible of SO_X emissions so minimizing the use of pilot oil should be a priority.

Also, the amount of waste heat dissipated by the engine block while running at 70% load represents a 7.26% of the fuel used by the engine and a 13.776% if compared with shaft power. For this reason, heat dissipated from engine block should be considered in waste heat recovery systems.

Following the energy analysis, the results of the exergy analysis are presented in Table 4.

Table 4 - Results of exergy analysis

Parameter	Value
Inlet	
LNG main fuel	21012.3014 kW
MDO pilot oil	441.4160 kW
Outlet	
Shaft power	10870 kW
Exhaust gas	2212.8887 kW
Cooling water	420.6703 kW
Engine block heat	196.461 kW
Engine exergy performance at 70% load	
50.667%	

Exergy analysis becomes key to identify which losses are more suitable to recover as not all the energy will be available to produce work. In a machine like a large marine engine different heat sources with different quality coexist. High temperature heat sources like exhaust gas are more attractive for recovery as its level of exergy is higher. On the contrary, other heat sources like cooling water and engine block heat are of a lower quality as entropy generated is much higher and thus more exergy is destroyed. In the case studied, exhaust gas exergy represents 38.56% of its total energy while cooling water exergy and engine block exergy represent 16.76 and 13.12% of their energy, respectively.

Modern marine engines use LNG as fuel so an extra source for waste heat recovery technologies is in place, in this case in the form of cold energy recovery. The system proposed in this work recovers cold energy and satisfies the needs of cooling power on board. In Table 5, results of cooling power needs for a modern LNG are presented.

Table 5 - Cooling power needs on board

Load	Fresh store	Cold store
Air infiltrations (kW)	127.68	225.60
Doors opening (kW)	0.194	0.225
Food load (kW)	0.0077	0.0042
Total load (kW)	127.882	225.830

Results of the analysis of the proposed cycle are shown in Table 6. Nomenclature used in the table corresponds to Figure 2.

Table 6 - Cold energy system results

Control point	Results
1F – Fresh store outlet	Temperature: 1 ºC Enthalpy: 1608.516 kJ/kg Pressure: 4.453 bar
1C – Cold store outlet	Temperature: -27 ºC Enthalpy: 1573.339 kJ/kg Pressure: 1.379 bar
2 – Compressor inlet	Temperature: -27 ºC Enthalpy: 1573.339 kJ/kg Pressure: 1.379 bar
3 – Compressor outlet	Temperature: 40 ºC Enthalpy: 1601.765 kJ/kg Pressure: 2.758 bar
4 – Condenser outlet	Temperature: -40 ºC Enthalpy: 164.617 kJ/kg Pressure: 0.7163 bar
Fe – Fresh store inlet	Temperature: -7 ºC Enthalpy: 313.464 kJ/kg Pressure: 3.235 bar
Ce – Fresh store outlet	Temperature: -35 ºC Enthalpy: 186.882 kJ/kg Pressure: 0.9305 bar

Once the cold energy process is calculated, power required for the compressor and obtained from the LNG at the condenser were calculated. Table 7 shows the energy balance of the system.

Table 7 - Energy balance of cold energy application

Device	Load
Compressor (kW)	7.437
Condenser (kW)	376.015

So, in order to provide a total of 353.712 kW of cooling power to the evaporators onboard, a total of 376.015 kW of cold energy have to be extracted at the condenser. Also, the compressor needs 7.437 kW of energy in the form of electricity.

After calculation of the energy retrieved from the LNG line, an engine performance calculation was conducted, including the cold energy recovery system. Comparison with original performance is presented in Table 8.

Table 8 - Comparison of engine performance with and without cold energy recovery system

	Thermal efficiency
Engine, original system	52.724%
Engine with cold energy recovery system	54.512%

As it can be seen in Table 8, the application of the proposed system increases thermal efficiency in 1.788%. Since the cold energy from LNG line needs to be removed before entering the engine and can be used on board in order to satisfy cooling power needs, a feasible combined heat and power system can be achieved with this design.

Conclusions

A two stroke large marine engine, which uses natural gas as fuel, is the subject of thermodynamic analysis and study. Due to its high performance and the cost-benefit ratio of improving performance by modifications in its internal operation, a waste heat recovery system is proposed. In this case, and due to the fact that dual-fuel engines are becoming a standard, a cold energy recovery system working with ammonia as working fluid is proposed. From this work, the following conclusions are extracted:

1. Energy balance shows that after exhaust gas and cooling water, heat dissipated by the engine block is a heat source that should be considered as it represents 13.776% of shaft power.

2. Heat available for recovery in the engine comes from different sources. While the exhaust gas current is of medium quality, 38.56% of its energy, other sources like cooling water and engine block heat are of low quality. Low temperatures on the latter two heat sources lead to a higher entropy generation and thus higher irreversibilities.

3. Since the case study engine uses liquefied natural gas to work and this has to be heated before entering the combustion chamber, a cold energy recovery system was proposed. Ammonia was chosen as working fluid due to its high availability, price and low environmental impact.

4. Cold energy recovery system proposed in this study is capable of recover 368.578 kW of cooling power that can be used to satisfy cooling needs of the storerooms on board. If implemented, the recovery system increases engine performance from 52.724 to 54.512%.

5. The use of energy saving devices is recommended by the International Maritime Organization under MEPC.1/Circ.896. In order to reduce pollution emissions and lower CII rating this proposal could contribute satisfactorily.

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FUNCTIONAL STATES IN THE SEAFARER'S PROFESSIONAL ACTIVITY

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Abstract. The objective of the research is to analyze the key functionstates, which influence the professional activities of the maritime and river transport. The indicators of physical, emotional and mental fatigue are specified. The recommendations of the experts to minimize the fatigue on boards are studied. The main reasons of the stressand pressure of the seafarers are considered. The effective methods tocope with stress of the crew members have been identified. The psychological pressure factors were studied. The essential role of recreation to save the psychological health of seafarers is pointed out. The attention to the importance of the training of the maritime sphere professionals to mitigate the possible functional states on the board have been highlighted.

Keywords*:* Seafarers specialists, fatigue, stress, monotony, hypokinesia.

Introduction

Professional activities of the sea sphere professional have been performed in the specific conditions, related to the limited space of the ship, multicultural team, deficit of time for decision making, high level of stress pressure etc. The problem of regulation of functional states is relevant for protection of the psychological and physical health of specialists of maritime and river transports. The functional state of the seafarer is the factor which identifies his behavior and efficiency.

Last years the problem of the functional state impact on the efficiany of the professionals attracts more attention of the researchers in different spheres: military, law enforcement officers, doctors, managers etc. Specific aspects of this problem were studies by B.Ananjev, O.Bondaruk, O. Ganushkin, X.Keller, T.Kodlubovska, O.Kokun, O.Leontjev, Z.Freid and others. Physiological aspects of professional activities of seafarers were in focus of research ofA. Antropov, A.Ananjev, T.Kodlubovsk, K. Kosenko, G. Kryvorodko, P. Kryvoruchko, T. Nazavitin, A. Pobidash, E. Sosnov, O. Soroka, L. Shafran, M. Sherman, T. Robert, B. Iversen, Vsevolod Rozanov, Douglas B. Stevenson, Lawrence Jacobson, Alex Mellbye, Tim Carter, Neil Greenberg and others.

The aim of the research to analyse the importance f the functional states and their impact on the seafarer efficiency.

The methods of the research. Inductive, deductive, modeling and data synthesis, its comparison and systematization.

1. Theoretical Analysis of the Prevention of the Fatigue Marine Specialists

Occupational activity of marine specialists requires them a certain degree of activity and comes with the emergence of adverse functional states. Depending on the peculiarities of work and the working environment, as well as personal factors, such mental conditions as deprivation, fatigue, stress, frustration, monotony, etc. arise.

Fatigue is a functional state of the organism that manifests itself in a temporary decline in performance, in non-specific changes in physiological functions, in a number of subjective sensations combined by a sense of fatigue as a result of performing intense or prolonged work.

The STCW-78/95 unequivocally requires:

- that all persons keeping bridge navigational watch have a minimum of 10 hours rest during a 24-hour period;
- in the event of an accident and other emergencies, such rules may be not complied with;
- ten-hour daily rest may be reduced to 6 hours, but only for 2 days with subsequent compensation;

- all personnel keeping the bridge watch should be able to fully focus only on their duties, delegating and entrusting duties to persons keeping bridge watch is unacceptable.

Concerns about the problems of fatigue of seafarers entailed the preparation and adoption of a Special Resolution of the International Maritime Organization of 4 November 1993, A.772 (18) „Fatigue factors in manning and safety“. According to this Resolution, fatigue is characterized as degradation in human performance, reduced physical and mental abilities and/or the impairment of the ability to make rational judgments. It is also indicated that fatigue may be caused by such factors as a long period of mental and physical activity, inadequate rest, adverse effects of the environment, physiological factors and/or stress, or other physiological factors. The classification of factors of fatigue is given [7].

In November 1999, the IMO adopted Special Resolution A.772 (18) – “Fatigue factors in manning and safety”. The purpose of this document was to raise awareness and understanding of the complexity of the term “fatigue” and its influence on the physical and mental abilities of a person [7].

In 2001, IMO published the “Guidelines on Fatigue Mitigation and Management” (MSC/Circ.1014). In 2006, Cardiff University investigated the problem of seafarers' fatigue. Based on the investigation findings, in 2012, Guidelines entitled „Adequate Crewing and Seafarer Fatigue: The International Perspective” were issued. Fatigue, as a threat to safety of navigation, became the main theme of the “Maritime Safety Awareness Bulletin”, issued in 2017 by the Australian Maritime Safety Authority (AMSA) [6].

Fatigue is dangerous both for a seafarer himself and for all crew members, ship and the human environment.

The International Transport Workers’ Federation believes that fatigue cannot be considered in isolation from such factors as the number of crew members (crewing level), the duration of the working day, the duration and frequency of rest, the quality of rest (whether the noise of diesel engines, weather etc. disturbs), the situation on board, the duration of the voyage and the duration of isolation from normal social life.

IMO Recommendation on Mitigating and Fighting Fatigue (MSC/Circ.1014) names the following causes of fatigue on a ship:

- poor sleep;
- poor quality of sleep;
- lack of time to rest;
- poor quality of rest;
- stress;
- monotonous work;
- noise, vibrations;
- food;
- ship movement;
- medical care and illnesses;
- ingestion of chemicals;
- violation of the daily rhythm of the organism;
- excessive workload [6].

In this very IMO Recommendation, it has been proposed to distinguish physical, mental and emotional fatigue of marine specialists, and their signs were defined.

Signs of physical fatigue:

- inability to control sleep;
- visual coordination difficulties;
- speech difficulties;
- feelings of heaviness in upper and lower extremities or slowness of movement;
- non-site specific physical discomfort;
- headache;
- dizziness;
- rapid heartbeat;

- rapid breathing;
- loss of appetite;
- insomnia;
- pain and cramps in the lower extremities.

Signs of emotional fatigue:
- risky actions;
- intolerance and anti-social actions;
- incomprehensible anxiety;
- lack of motivation for qualitative performance of work;
- abrupt changes in mood.

Signs of mental fatigue:
- inability to estimate distance, speed, time;
- misunderstanding of the situation, for example, reluctance to consider danger;
- delayed response or lack of response to normal, extreme or emergency situations;
- decrease in the attention span;
- decrease in ability to pay attention to anything [2].

2. Ways to Fight the Problem of Accumulation of Fatigue of Seafarers

To help the seafarers, in 1998, the International Transport Workers' Federation issued a booklet „Seafarer fatigue: wake up to the danger", which provides practical advices on fighting fatigue in the fleet [8].

In turn, the AMSA indicates that the following measures can help the seafarers to cope with the overfatigue:
- monitoring and assessment of sleep;
- monitoring of the concentration of attention during the watch;
- possibility to make short breaks during work;
- rotation of works to avoid monotony;
- regular exercises and regular balanced nutrition;
- periodic reviewing of hours of work and rest;
- arrangement of conditions for open communication between seafarers and managers on issues related to fatigue, as well as for reporting on incidents caused by fatigue.

For the seafarers who feel fatigued, experts recommend the following:
- to make the most of your opportunities for sleep and rest;
- to inform your supervisor, if you feel that overfatigue can reduce your ability to work;
- if possible, to change the procedure for fulfilling your duties, to alternate heavy and simple duties;
- to train every day;
- to eat healthy food as much as possible, to restrict smoking, drinking coffee, to avoid alcohol [4].

One of the effective ways to fight the problem of accumulation of fatigue of seafarers should be the method of determining the degree of fatigue of crew members before the ship leaves the port. But the most suitable for this is the definition of the minimum number of crew members, depending on the purpose and size of the ship. IMO calls for taking the necessary measures to ensure that each seagoing ship, to which the STCW Convention applies, always has a document issued by the administration, specifying the minimum safe manning for such a ship.

It should be noted that one of the leading factors that reduces the performance of the work of the crew on board the ship and results in physiological and psychological disorders of the individual is stress.

Stress is a state of mental strain that occurs in the process of activity in the roughest and the most difficult conditions.

According to experts, these are the officers, who are mostly stressed on board the ship: master, chief officer, chief engineer, etc. The smallest mistake during work on the complex automated ships can lead to an ecological catastrophe, shipwreck or injuries to seafarers. Undoubtedly, it affects the emotional state, first of all, of the ship's officers and the crew in general.

The Australian Safety Agency has made a list of the main causes of seafarers' stress:

- separation with friends and loneliness on board;
- lack of good quality sleep;
- bad nutrition;
- frequent inspections and monitoring at ports;
- changes in crew composition every few months;
- extreme temperatures;
- bad weather conditions for a long time;
- claustrophobia;
- monotony of work;
- deprivation (sensory, informational, emotional, sexual, etc.);
- family-friendly stressors;
- economic and commercial stressors (how not to get unemployed, payment of wages);
- hypo-and hyperthermia, etc [4].

Accidents and the threat of piracy can also injure the psyche, increasing the level of anxiety and fear.

There are the following signs of stress the navigators may have:

- inability to concentrate;
- „radar hypnosis“;
- mistakes in the work;
- decrease in memory;
- feeling fatigued
- fast language.
- pain (in head, back, stomach area);
- increased excitement;
- loss of sense of humor;
- sharp increase in the number of the cigarettes smoked up;
- addiction to alcoholic beverages;
- permanent feeling of malnutrition;
- loss of appetite (appetite for food is totally lost);
- inability to finish work in time, etc.

In recent years, the mental health of crew members has become one of the priorities for many shipping companies, charity organizations and insurance clubs.

So, some maritime organizations have launched special projects designed to provide assistance to seafarers, wherever they are. For example, the International Seafarer’s Welfare Organization (ISWAN) offers crew members to make use of round-the-clock telephone line SeafarerHelp, which is also available in the WhatsApp and Viber mobile applications. Specialists involved in the project speak English, Filipino, Chinese, Turkish, and Arabic and try to help seafarers in difficult and stressful situations, regardless of their nationality and religion or race. In addition, ISWAN has released brochures „Psychological Well Being at Sea“, „Steps to Positive Mental Health“, „Managing Stress and Sleeping Well at Sea“, which contain simple and clear recommendations for coping with stress at sea. Among the recommendations, there are physical exercises, communication with relatives via the Internet, communication with other crew members. These brochures and many others are free to read at ISWAN’s site [9].

The “Traumatic stress management guidance“, prepared by Professor of Defense Mental Health at the Royal College (London) Neil Greenberg, will also help the seafarers to cope with depression. The publication provides scientifically based methods for managing stress, designed specifically for the marine industry [10].

In turn, the International Transport Workers' Federation and the World Maritime University announced the launch of a new crew training program for key welfare skills on board. Professional Development Program in Maritime Welfare (MARI-WEL) is provided remotely, allowing participants to go through it anywhere in the world.

The UK Chamber of Shipping and the Association of Navigators of the Kingdom of the Netherlands have opened a web page where the contact details of charitable organizations, chapel services, and other funds that can provide support to crew members, are collected.

The international charity "Sailors' Society" has launched an online version of its "Wellness at Sea" program, which focuses on five aspects of the health and well-being of seafarers that can affect safety of navigation. In addition, answering simple questions by using the mobile application, it is possible to track how the physical and emotional state changes during the voyage [3].

The International Maritime Safety Committee has developed recommendations for crews of seagoing ships that will help to stay in shape and deal with stress. Most exercises can be performed simply in the cabin: walking, running on the spot, arms circling and body rotations, squatting. Experts advise to find twice a week 20 minutes for weightlifting exercises; three times a week half an hour for suppling exercises, push-ups, abs exercises, pull-ups; 20 minutes for aerobic activity (exercises on a treadmill, exercise bike or jumping rope exercises).

However, it should be noted that the negative impact on the safety of navigation is not only low stress tolerance of the seafarer, but, on the contrary, his hyper-endurance.

Special conditions of the activity of marine specialists are always related to the influence of extreme factors or the occurrence of emergency situations. Depending on the frequency of their occurrence and duration, there are:

1) special conditions of the activity related to the occasional effects of extreme factors;

2) extreme conditions of activity, constantly associated with the effects of extreme factors.

Work even in occasional extreme conditions leads to mental tension. Mental tension may be operational and emotional. Operational tension occurs under the influence of factors of activity.

These factors include: monotony; hypokinesia; performance of combined and continuous activity; isolation, etc.

The mental state of experiencing monotony is determined by the homogeneity of the work of the seafarers. It can be kinetic (characterized by monotonous repetition of movements) and sensory (conditioned by monotonous repetition of signals and stimuli of the environment). Monotony is characterized by a decrease in mental activity, a decrease in the switching of attention, a deterioration of adaptive abilities, sleepiness, boredom, coordination dysfunction, etc. In the work, it primarily affects the reduction of motivation to work. Under the influence of monotony, a person, who does not know how to restrain this mental condition, becomes sluggish, reluctant to work. In addition, the state of monotony adversely affects the work of the employees and results in their untimely fatigue [1].

Hypokinesia is a state of reduced motor performance of a person, characterized by a lack of movements. Hypokinesia is conditioned by insufficient general motor performance, as well as intense monotonous work of individual muscle groups. Prolonged hypokinesia reduces physical and mental capacity, leads to organism detraining, deteriorates the state of health. Many mental processes, especially attention, thinking, memory, are suffering. Therefore, it is necessary to diversify the motor performance of the personnel, to change the production tasks, to create conditions for doing sports, etc. All these factors contribute to the emergence of work-related stress.

Therefore, the work and rest schedule plays an important role, allowing a rational combination of loads and recovery measures. To perform recovery measures, special conditions are required. The ship should provide a rest room (room for psychological relief).

Conclusion

So, mental health for navigators is no less important than physical. Marine specialist should prepare themselves in advance for possible manifestations of functional states on board to help themselves and their colleagues to withstand stress, fatigue, deprivation, frustration, etc., thereby

reducing the level of accidents. When the seafarer is psychologically stable, he will be able to make carefully weighed decisions in any situation, to adapt to different working conditions, to work productively in a multicultural team.

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THE RELEVANCE OF THE DEVELOPMENT OF THE "MARINE ASTRONOMY" TRAINING COMPLEX FOR IMPROVING THE QUALITY OF THE MARINE EDUCATION

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Abstract. The article analyzes the directions of development of astronavigation, as well as the search for ways to improve the professional training of future navigators in navigational astronomy and presents the development of appropriate laboratory and training support for the process of teaching students and cadets, improving their workplaces and installing simulators, that simulate being at sea and will allow to comprehensively implement the acquisition of the necessary competencies and fully obtain the relevant skills and learning outcomes. The creation of an interactive laboratory in combination with scientific developments will assist to practice practical skills using the existing laboratory facilities, instruments, and computer programs, such as “Stellarium”, which acts as a virtual planetarium and helps to solve a range of tasks and creates a virtual representation of being at sea, a moving star map (as star finder), which allows solving many tasks, such as selecting stars for observations, as well as determining the time of navigational twilight, a cellular sky, the Summer Triangle simulator, which allows determining the location of a ship using the most common method, determining the location using three navigational stars in the northern hemisphere, and others. The article discusses ways to improve the professional training of future navigators in navigational astronomy by implementing a comprehensive interactive laboratory in the educational process, which will be a handy way to solve all the necessary tasks in navigational astronomy and will be a convenient and interesting way to better understand the material, as it allows you to complexly carry out all the required tasks and models of various astronomical situations that arise in the conditions of working on the ship. It is believed that after the commissioning of the integrated interactive laboratory, the quality of training will be maintained at a high level, i.e. an integrated approach will be implemented to simultaneously solve all the tasks of navigational astronomy required for future navigators. All these measures are very relevant and realize the main goal of the modern demand in training requirements, convenience and interest, and will promote greater interest of students and cadets in studying "Nautical Astronomy", maintain and increase motivation in learning, thereby improving the quality of training of future mariners.

Keywords: marine astronomy, marine navigation, task methods.

Introduction

Scientific problem of research. Over a long period of time, nautical astronomy developed without fundamental changes, by improving the tools, manuals and methods used. However, in recent times, there have been proposals for certain innovative solutions in this area. Analyzing modern research in the field of astronavigation, several directions and trends can be identified.

Representatives of marine education have widely studied the issues of innovation in the professional training of navigation officers (**object of research**). Directly the problem of applying innovative teaching technologies during the teaching of "Nautical Astronomy"(task of to future ship officers was considered by Sokolov I. V., Cheroi L. I. [10]. Where the author analyzed the content and features of the discipline "Nautical Astronomy". Based on this analysis, several pedagogical

innovative **research methods** were proposed for application, in particular, the task-based and case method. The author claims that the task-based method is one of the most appropriate in the study of nautical astronomy, the peculiarities of its application are in the development of practical tasks by research and teaching staff which are peculiar models of future professional situations. The essence of the task-based method is to transform the content of a particular academic discipline into a set of professional learning tasks [10].

The main conditions for using the task-based method are:

- approximation of the content of the discipline "Nautical Astronomy" to professional activity;
- development of not one task, but a complex of educational and professional tasks;
- the content of the developed tasks should be aimed at the acquisition of certain professional knowledge and skills by future seafarers (determining the serviceability/operability of navigation equipment; determining the coordinates of the ship's location by celestial bodies; analyzing the timekeeping system on board the ship, etc;
- in the development of educational and professional tasks, the methods of activity that future seafarers, must be positioned as a direct educational product.

As a modern innovation, the task-based method is multifunctional, as it allows for differentiation of the developed tasks and their multilevel nature. At the same time, depending on the content of the tasks, they are divided into informational, analytical, communicative, and reflective.

As for the case method, the author notes that it consists in developing professional tasks in the form of blocks or cases. The author emphasizes the development of real or fictional situations in the professional training of future seafarers. An important condition for the development of cases is not to provide an ordinary description of the situation, but to formulate a certain contradiction in it [3]. We agree with the author on the advantages of the case method compared to other innovations in the study of "Nautical Astronomy" are as follows:

- practical orientation of the method, as future seafarers can use theoretical knowledge to solve a practical problem;
- high level of interactivity of the method, since the use of cases creates a high emotional and active interaction between the subjects of the educational process;
- improvement of competencies, which are further used mainly in professional activities;
- joint analysis of practical tasks is a universal method of learning today;
- development of skills of systematization, generalization and analysis of information necessary to find the best solution in the case.

Similar to the task method, the case method has several types: by format (thematic, Harvard, and executive), by level of complexity (small essays, large unstructured, structured). Our practical experience of using the case method in the course of studying Nautical Astronomy has shown that its value lies not only in finding an optimal and effective solution, but also in formulating questions for future navigators, expressing certain hypotheses, and identifying gaps in knowledge. Thus, after analyzing the innovations that can be applied in the study of the discipline "Navigational Astronomy", we chose those that have a pragmatic orientation, that is, bring future navigators as close as possible to the world of real professional activity.

The aim of the research is to actualize the use of astronomical methods in maritime navigation and to find ways to improve the professional training of future navigators, in particular in maritime astronomy.

The objectives (tasks) of the research are the following:

1. To provide a theoretical basis for the relevance of astronomical definitions in modern navigationю
2. To prepare the appropriate set of training modules and develop the relevant technical components for the laboratories or simulators.

The structure of the research. The first part of the research compares the accuracy and reliability of positioning observations using Global Navigation Satellite Systems (GNSS) and Astronavigation System (ANS). The second part of the research considers the preparation and implementation of innovative technologies to improve the teaching of Maritime Astronomy.

1. Methodological Approach of Astronomical Methods in Marine Navigation

Primarily, the safety of navigation of a ship depends on the frequency and accuracy of location determination, as a result of which the determination of the ship's location is considered, as one of the main operational tasks of navigation. On the route at the open sea, when there are no visual landmarks, in recent years, ship's navigators often solve this problem by using the global navigation satellite systems (GNSS), primarily such as GPS.

The GPS receiver, measuring the difference between the time of receipt of the signal from the satellite and the time of generation of this signal, determines the distance to this satellite. From any point on the surface of the Earth, where at least 4 satellites are observed. Since the coordinates of the satellites at a given time are known with high accuracy, the GPS receiver can calculate its own coordinates with an accuracy of 5-10 m. Obtaining observed coordinates to determine the location of the vessel using GNSS under any circumstances of navigation takes a short period of time, it is enough to read them from the monitor screen.

The GPS receiver of civilian vessels does not provide for authentication of navigation information, that is, the GPS receiver works with information received from the antenna and accepts this information as reliable. Thus, the received navigation information from GNSS in the GPS receivers of civilian vessels remains unprotected and prone to cyberattacks. The GPS receiver does not distinguish false signals from true ones. For the first time, an experiment to substitute a signal from GNSS on a ship at sea was conducted in 2013 by researchers at the University of Austin. Signal substitution of navigation systems is called spoofing. As a result of this experiment, the receiver began to display false information. To organize spoofing, a special transmitter device is used, which is located on any moving object (ship, aircraft, drone, etc.) and simulates a signal from the GNSS satellite, provided that the level of the simulation signal slightly exceeds the signal level of real satellites. The GPS receiver installed on the ship will receive a fake signal and calculate its location based on the data received, provided that reception is possible at a weak signal level, that is, below the noise. GPS signal – periodic, respectively, even "static" spoofing requires dynamic transmission of the same in the actual content of navigation connections. The obstacle can be made such that it will simulate the movement of the receiver along a spoofer‘s given path. In the course of these studies, the real possibility of disabling existing models of receivers of the navigation signal by manipulating the transmitted information was shown.

In addition to signal spoofing, the suppression of GPS signal reception by more powerful signals is actively used. This process is called jamming (suppression). Suppression is both easier and more common than spoofing. In order to drown out the signals of the GNSS satellite, it is enough to emit unmodulated frequencies of 1577 MHz (civilian channel) and 1230 MHz (military channel) from the Earth. At the same time, the transmitter's radiation power of 20 watts in each frequency range reaches a range of 150 km with a mass of 10 kg [1].

It is clear that spoofing and jamming can only occur forcibly, but the possibility of such cyberattacks cannot be rejected. Cyberattacks distort information about the state of the vessel by penetrating through the ship's equipment. Therefore, the methods of constant monitoring of the work of GNSS in independent ways are remain relevant.

In addition to the considered artificial obstacles, the reliability and stability of the GNSS can be influenced by some natural phenomenon. Since the results of the experiments and the study of the navigation situation during transitions in the open sea, in certain areas, breaks in the use of satellite navigation systems can be from two and a half to ten hours a day, and the total time of absence of navigation on satellite systems – up to 25-27% of the total transition time [2].

Given the above factors, the widespread use of GNSS in modern navigation practice does not remove the relevance of other traditional navigation methods. First of all, it concerns research related to the improvement of astronomical methods, because nautical astronomy is able to fully provide autonomous orientation of the vessel at the open seas, as in cases of loss of integrity of the satellite

navigation system and emergency situations on board and in natural disasters leading to the failure of satellite navigation equipment [3].

Thus, author of scientific article [5], analyzing possible ways to optimize the methods of nautical astronomy, found out that to this day there have been contradictions between the variety of previously developed methods of nautical astronomy and the lack of their implementation on modern computing technology, between the unlimited possibilities of computing technology and traditional manual methods of nautical astronomy, between the role of nautical astronomy, which has changed, and a large amount of material studied [5]. One of the ways to solve these contradictions was the development of optimal methods for the synthesis of a single set of software for a personal computer, a methodology for planning astronavigation observations using a personal computer, drawing up planning algorithms and their organic inclusion in a single set of software for astronomical navigation methods, as well as the development, taking into account the universal algorithm of control and training programs for nautical astronomy.

The problems of practical use of analytical methods for processing astronavigation observations, as well as determining their real accuracy, were investigated by author of scientific article [2], who developed an optimal algorithm for automated processing of astronavigation observations, based on the method of iterations. The effectiveness of this method was proved during the comparative analysis of the results of processing materials of a full-scale experiment according to the traditional graphical analytic method and according to the method of iterations developed within the framework of the study. In addition, methods for processing a series of measurements of a navigation parameter with a small number of observations, taking into account the criterion of internal convergence, as well as technical solutions and organizational measures to improve the accuracy of measurement results and processing of astronomical observations, were developed and proposed. For the first time, a special training system and a method of teaching how to measure the heights of celestial bodies in laboratory conditions were developed.

A separate innovative direction in nautical astronomy can determine the attempts of scientists, designers of astronomical navigation equipment to automate the process of observing natural astronomical landmarks. In this context, the astronavigation system (ANS) proposed by a scientific article [6] for sea vessels deserves attention. According to the authors, this system will automate the process of measuring astronavigation parameters and solve the following tasks:.

1) automatic formation of the plane of the artificial true horizon;

2) calculation of the equatorial and horizon coordinates of the celestial body in order to direct the measuring device on it;

3) direct to the celestial body the measuring device and measuring the astronavigation parameters both in the optical range and by radio emission;

4) processing of all measured astronavigation information in real time, displaying the results of this processing and their translation into automatic calculation systems;

5) determination of the ship's location, direction of the geographical meridian, corrections of heading indicators;

6) determination and preservation of the exact time;

7) assessment of natural light [6].

To solve these problems, the following composition of the ship's ANS is proposed:

1) stabilization system in the plane of the true horizon;

2) a measuring device consisting of an optical circuit with a tv camera and a radio sextant on a platform stabilized in the plane of the true horizon;

3) computing device for processing astronavigation information [6].

Practical interest in the direction of automating the process of observing natural astronomical objects and obtaining on the relevant navigation information in particular is described at scientific article [7]. Scientists have proposed:

- Modernization of the sextant by automatic reading of the measured height and time of observations;

- Automatic data processing by transferring them to a computer by a wireless channel of communication;

- Automatic calculation of the observed coordinates of the vessel's location using astronomical programs. Instant obtaining of the alternative GNSS observation;

- Control of GNSS coordinates on the ECDIS electronic map [7].

In accordance with Chapter II of Chapters A-II/1, A-II/2 of the International Convention on the Training and Certification of Seafarers and Watchkeeping (STCW) of 1978 (with the Manila Amendments of 2010), the mandatory minimum requirements for the certification of junior officers, chief officers and captains of vessels with a gross capacity of 500 units or more include the ability to use celestial bodies to determine the location of the vessel. The criteria for assessing the competence of this skill is the observation obtained using astronomical methods, which is within the permissible levels of accuracy. This proficiency requires stable skills, which under modern conditions of training is quite difficult to achieve [8], [9]. Therefore, another relevant direction in the development of astronavigation can determine the research the ways to improve the professional training of future navigators, in particular in the issue of nautical astronomy and the development of appropriate training complex for this process [3].

2. Practical Implementation of the Training complex

The innovative methods we have discussed cannot be implemented without appropriate technical and laboratory support. In addition, further research on the spread of the use of astronomical methods in maritime navigation should also be carried out in laboratory conditions..

In our opinion, the solution to these problems will be facilitated by the laboratory and training complex for "Marine Astronomy", which allows for training and research regardless of weather conditions and geographical location. That is, there is no need to be in the sea or on the seashore and only in clear weather, so it becomes possible to train specialists not only in educational institutions located near the sea. The course of studies using this complex is intended to instill in higher education cadet’s professional skills, the use of which is aimed at ensuring the safety of navigation, including the preparation of astronomical instruments and instruments during the preparation for the voyage and use during the voyage, as well as solving problems of determining the chronometer correction, determining the correction of the direction indicator and the position of the ship using astronomical methods. The knowledge, skills and abilities acquired during the training should be sufficient to solve these tasks during the watch without additional training.

Let's take a closer look at the composition of the laboratory and training complex components and a description of each of them.

1. Astronomical simulator " Stellar Sky" (Fig. 1) - is a ceiling in the form of a model of a map of the starry sky (plastic or stretch fabric) for studying the main navigational stars and constellations of the northern hemisphere and their imaginary location.

Fig. 1. The appearance of the astronomical simulator "Star Sky"

2. Astronomical simulator "Summer Triangle" (Fig. 2) is a non-transparent screen with a photo print of the stars of the "summer triangle", whose direct function is to determine the angular distances between the observer, the horizon and the celestial body.

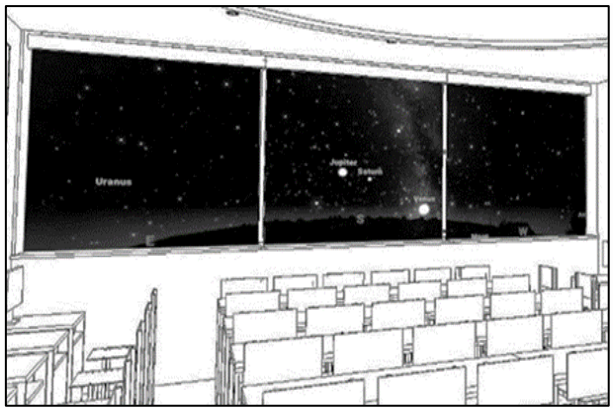

Fig. 2. Variant of the appearance of the astronomical simulator "Summer Triangle"

3. Information stands on nautical astronomy.

4. A multifunctional wall (Fig. 3) with built-in interactive whiteboard, clocks of different time zones, a specialized cabinet for storing and demonstrating special astronomical equipment and literature used for practical classes in marine astronomy.

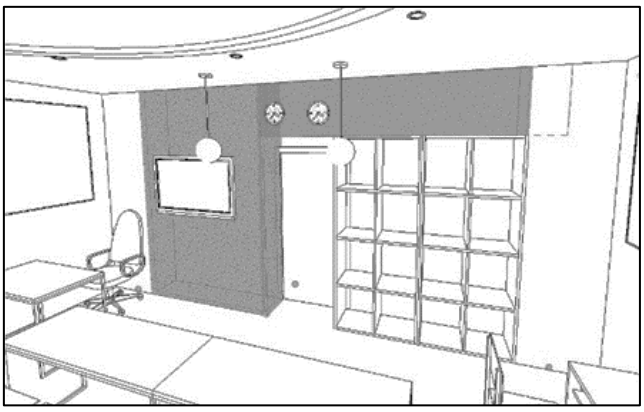

Fig.3 Implementation option for a multifunctional wall

5. The workstation of cadets (researchers) is equipped with a personal computer, appropriate software “Stellarium”, which serves as a virtual planetarium, and a moving map of the celestial sky (star finder), which is intended for practicing practical skills:

- determination of the sextant index correction by horizon, star and Sun;
- definition of chronometer correction;
- measuring the height of the celestial objects with a sextant;
- correction of the heights of the celestial bodies measured by the sextant;
- reduction of heights measured by the sextant to the same zenith;
- selection of a celestial body for astronomical observations using a star globe;
- calculating the time of the meridional height of the Sun;
- determination of latitude by the height of the North Star or the meridional height of the Sun;
- determining the time of sunrise (sunset) and moonrise
- determining the start and end times of navigational twilight;
- preparation for astronomical observations with the help of a star globe and a moving map of the stellar sky (star finder) and the virtual planetarium "Stellarium";
- obtaining the observed coordinates of the vessel by elevation lines of position;
- determining the compass correction by the azimuth of sunrise (sunset).

In general, the equipment and software modules of the laboratory and training complex provide:

- a comprehensive overview of all operations to determine the location of the vessel and calculate corrections;
- real-time playback of operations;
- measurements anywhere on the Earth's surface;
- quick creation of tasks for calculations and evaluation of their results;
- the ability to choose the type of astronomical task: identifying a celestial body, determining the location of a ship by celestial bodies, determining the correction of a directional indicator by astronomical methods;
- possibility of installation on the local network of the educational institution;
- work on a PC of standard configuration;
- studying the stellar sky in any hemisphere;
- measuring the height of a celestial object using a navigation sextant simulator (day and night tube) in real time;
- real-time bearing measurement to the object in real time;
- modeling the movement of the observation point at a given speed and a given course.

Also improve the quality of training functionality of the simulator such as:

- keeping a progress log;
- automatic evaluation of computing results.

Conclusions and prospects for further research

Thus, the use of astronomical methods in maritime navigation remains relevant today. The main ways to improve these methods include the development of planning algorithms and their organic inclusion in a single software package of astronomical navigation methods, as well as the development of control and training programs in navigational astronomy based on a universal algorithm, the development of an algorithm for automated processing of astronomical observations based on the iteration method, automation of the process of observing natural astronomical landmarks.

Another relevant area of astronavigation development is the search for ways to improve the professional training of future navigators, in particular in navigational astronomy and the development of appropriate laboratory and training support for this process. The advantage of using such equipment is obvious. Students have the opportunity to practice the procedure for measurements and calculations in real time and in a situation close to real ship conditions, obtaining the ship's location by astronomical means, as well as conducting various studies in the field of astronavigation.

In the future, research will be conducted using the above-mentioned training complex to determine the effectiveness and quality of cadets' training and the impact of the latest teaching methods on their level of training.

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KEY ASPECTS OF SIMULATOR TRAINING SPECIALISTS FOR INLAND WATERWAYS NAVIGATION

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Abstract. The article reviews the problem of simulator training in the field of navigation. A special role is given to simulator training the future specialists for inland waterways navigation and ships handling. In order to organize this analysis, the main criteria were formed and on the basis of which an assessment of simulators was made that provide the formation of skills and competencies of trainees for navigation on inland waterways. Based on the list of proposed criteria formulated for the assessment of simulators, the key aspects of training specialists for inland waterways navigation are identified.

Keywords: simulators, training apparatus, simulator training, inland waterways, maritime transport.

Introduction

The modern world dictates new requirements for specialists in all areas without exception. Modern training simulators and equipment based on new information technologies play a special role.

These devices allow us to artificially simulate virtual reality, completely or partially repeating the professional activities of students. By means of simulator training the formation of professional skills in an artificially simulated environment is ensured. Replacing real technological processes, production and life situations, they can significantly form and supplement the practical skills and competencies of students.

The results of a group of American scientists' studies [1-4] showed that in order to develop an adaptive experience associated with adaptation to a complexly changing environment students must be active participants in the learning process, and the learning must take place in a meaningful or appropriate context of the subject area to which adaptation is to be achieved.

Simulator training has recently played a special role in future seafarers training. First of all, we are talking about specialists related to the maritime and inland waterways navigation and ships handling and ship's power plants and complexes operation.

The indicated areas of marine specialists training have a wide range of tasks, each of which can be implemented using a simulator. The following article focuses its study on the simulator training the crews for the inland waterways navigation.

Thus, the purpose of this study is to determine the key aspects of the simulator training specialists for inland waterways transport.

1. The main criteria

Modern simulators for training specialists in navigation and ship handling to a greater extent meet the requirements for training operators to navigate at sea. In a number of cases, the same simulators provide for situations that simulate the navigation of ships in narrow spaces. It can also be noted that a number of educational institutions and training centers operate various types of simulators adapted for training specialists in ships handling for navigation on inland waterways.

As a detailed analysis showed these training simulators for the most part do not meet the real conditions of navigation on inland waterways and, in general, of the organization of navigation in such conditions.

In order to organize this analysis, the main criteria were formed and on the basis of which an assessment of simulators was made that provide the formation of skills and competencies for navigation on inland waterways among trainees:

- the level of ensuring the functional characteristics of the simulator;
- the scale of coverage of the simulator by virtualization of inland waterways in Europe and Asia;
- the possibility of using the simulator at various educational levels of training;
- pedagogical potential of the simulator;
- the level of technological solutions that increase the realism of the simulated processes.

2. The key aspects

Being based on the list of criteria formulated for the assessment of simulators we shall determine the key aspects of training specialists for inland waterways navigation.

It is known that simulators as learning systems are most effective in cases when the performer is required to perform error-free actions according to a clear algorithm while the number of outcomes of the simulated situation is quite large. In other words, training involves working out emergency and emergency situations when handling complex technical objects and systems. Thus, the level of ensuring the functional characteristics of the simulator is the base point of its assessment as an object capable to provide the learners with the appropriate skills.

The studies [5-8] present a systematic review and qualitative analysis of the use of simulators in training specialists for maritime transport. The main emphasis was placed on the functional characteristics of the simulator associated with operations on the bridge during training and assessment of the navigational situation. In the course of the study the authors identified three main areas in which it is possible to assess the level of functionality of each simulator, those are: the level of provision of the subject area in terms of visualization and its connection with physical controls; the level of influence of the human factor on the outcome of simulated events; the level of opportunities for the implementation of pedagogical techniques.

The authors have made an important conclusion that the potential use of simulators in teaching and assessment of their training is obvious, but it is still difficult to answer the question of which teaching methods will provide valid and reliable learning outcomes based on simulators.

Thus, according to the authors' conclusions, there is a global need for empirical research, which will have to lay the foundation for educational practice based on data obtained by practical means.

As a basis for analysis in accordance with the above criteria, let we take the Wärtsilä company's solution, the so-called "Inland Functionality" for training inland waterways specialists, based on the NTPRO (Navi Trainer Professional) 5000 software package, which is currently one of the leading systems in the training specialists for maritime transport and provides its multifunctional tool for learning inland navigation. This simulator is integrated with real types of river ECDIS and radar systems, Alphatron is offered by default. The configuration of this simulator is available in three types (Fig. 1): desktop solution; full tug mission bridge; full mission ship handling bridge.

The functionality of this simulator is represented by an extensive library of models of ships, tugs and barges. The simulator also provides full control of environmental conditions, it also allows

to change weather conditions, seasons and other parameters that affect the level of interaction with the environment.

The next aspect is no less important, this is how large-scale the coverage of the inland waterways of Europe and Asia by the simulator is. Today, the coverage is not systemic and, unfortunately, does not provide a complete virtual environment for the waterways of Europe and Asia. All this is associated with several significant problems. First, in contrast to the maritime simulator where only port water areas are actually subject to virtualization, for the inland waterways simulator it is necessary to virtualize the entire route of the vessel. This entails a significant increase in the cost of additional modules for the functioning of the simulator.

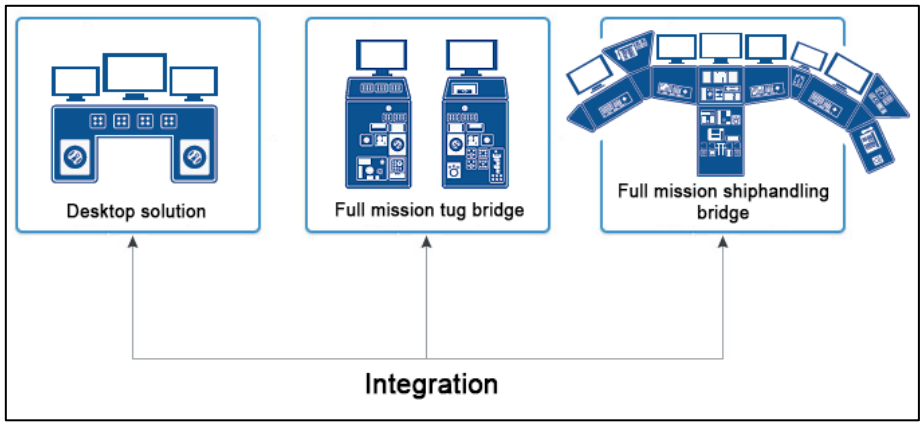

Fig. 1. Types of simulator configurations for training inland waterways navigators

At the moment, the simulator contains a number of ready-made models that comply with the requirements of the European Committee for the Development of Standards in the Field of Inland Navigation, including some sections of the Danube and the Rhine. A number of developed models are of particular interest, such as: Rotterdam, Dortmund, Ruse (Bulgaria), Detroit, St. Clair, St. Mary, the Seine (France), the Amazon, the Pau, the Amur, the Forth, the Brazos, the Tombigbee and others.

Wärtsilä company has a loyal policy towards educational institutions that train maritime transport specialists, and therefore is ready to develop any additional model of a vessel, river or navigation area on an individual request. In 2022, a major project is planned, as a result of which models of the entire navigable part of such large European rivers as the Danube and the Rhine will be developed. This project was initiated by the Romanian side and will be funded by the European Union.

From the point of view of using the simulator at various educational levels of training it is possible to be stated that this simulator can be used both at the level of vocational education and at the levels of higher education. In addition, the simulator can be widely used in the system of postgraduate education, in advanced training courses, retraining. Such versatility is dictated by the technologically and functionally adapted interface of the simulator which is highly close to the real conditions for the trainee to perform the functional duties.

The special role in the capabilities of any simulator, and, in particular, the one we are considering, is occupied by its pedagogical potential. For example, in the works [9-12], various technologies were proposed to increase the learning rate. Each of these technologies, as the study showed, enjoys some success, but the authors opened the question of the impact of each of these technologies on pedagogical factors associated with learning outcomes.

The simulator in question also allows to create one's own ship motion model or select any model from the existing collection which includes more than 400 models, and make changes to it. After that, this model can become the base for creating new models. One of the unique features that significantly expands the pedagogical potential of the simulator is the ability for trainees, under the supervision of a teacher, to change ship models in real time or fast simulation (Fig. 2).

As a rule, we are talking about the training of specialists at the level of higher education, the teacher shows the trainees the process of modeling the performance of the vessel in different operating conditions. Based on the requirements put forward the trainee models the parameters of the vessel achieving the desired result. This gives trainees the opportunity to delve deeper into the system of interrelated processes that ensure the efficient operation of the vessel. One example is the effect of changes in the properties and configuration of the ship's hull and propulsion system on fuel consumption.

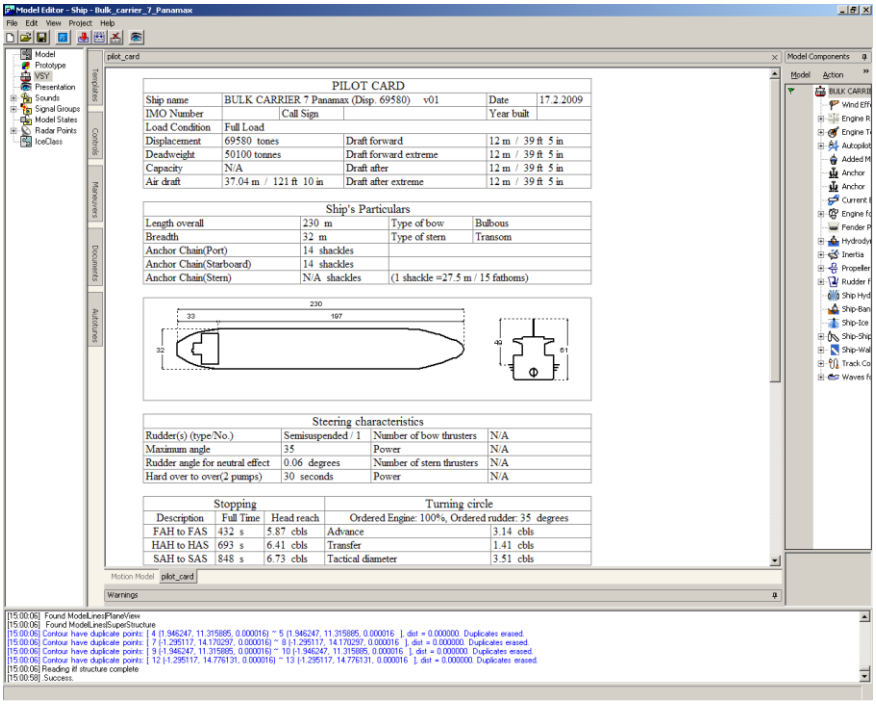

Fig. 2. Interface of the software environment for changing the model and parameters of the ship

The last of the aspects under consideration is the level of technological solutions that increase the realism of the simulated processes. This aspect, within the framework of the development of approaches to the creation of simulators, has a high degree of dynamism. Along with the rapid development of information technology, computer technology and programming methods, simulators become more realistic (Fig. 3.). Without any doubt, one of the decisive roles in achieving maximum realism is the created mathematical models of the vessel's performance in various conditions. Scientists from different countries pay great attention to this issue. For example, in the studies [13-16], the authors consider an improved simulator of a commercial container ship in a virtual environment. The motion of the ship in this simulator is based on a 6 DOF (degrees of freedom) model, which includes a model for simulating surge, sway and yaw, as well as a closed form expression for pitch, roll and heave. The simulator considered by the authors is part of a research project related to the traffic optimization system in the port, in connection with which it recreates the maneuvering of a real vessel with high accuracy. As part of the same project a software tool was created by means of which an analytical model of the vessel's movement was tested.

Fig. 3. High degree of realism of visual objects on the simulator

Accordingly, it can be noted that with the modification of the concept of training specialists for inland waterways transport with the use of simulators, the functional, theoretical, pedagogical and other requirements for such devices also change. A professional simulator, within the framework of the practical training of specialists, is considered as a tool that provides the trainee with a high degree of freedom, allowing trial and error and creating opportunities for professional identification on this basis. At the same time, the idea of a simulator as a device ready to ensure the achievement of learning outcomes and the acquisition of the necessary skills is changing. Thus, the main thing is not the degree of realism, although this indicator is important, but the reproduction of the material environment in which the student will be in the performance of his professional duties.

Conclusions

As the analysis shows, based on the proposed criteria, in order to widely integrate simulators into the system of training specialists for inland waterways transport and make their use productive and efficient, it will be necessary to solve a whole range of related psychological, didactic, pedagogical, organizational and technical tasks. The theoretical description and solution of these problems are in the field of close interaction between educational institutions, software companies and international and state bodies for the management and control of safety in maritime and inland waterways navigation.

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INNOVATIVE USE OF LASER POSITIONING SYSTEMS FOR MOORING OPERATIONS IN PORTS UNDER THE HELP OF VESSELS AND COAST MARINE DEVICES OF THE INTERNATIONAL AUTOMATIC IDENTIFICATION SYSTEM

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Abstract. The main target of the research is to rich a minimization of errors due the mooring operations to a berth into any port and at open sea. These errors take place by the objective and subjective faults of classical navigation practice, specially by the wrong data of satellite systems and lack of communication between bridge and ship's mooring stations. The article describes a new concept about using the well-known navigational systems of positioning for safe mooring without data of GNSS and any problem of the ship's internal communication to the crew members, engaged in these operations.

Keywords: ship, laser positioning, mooring, AIS

Introduction

More than 55 years have passed since the invention of the first laser. During this time, laser sources of various types have been created: gas, solid-state, semiconductor, diode, fiber, chemical, etc. (Herashchenko, 2022). Today, the laser industry is one of the fastest growing sectors of the global economy. Its growth from 1970 to 2015 was about 12.5% (Ignatov, 2015). The volume of the world market of laser sources in 2015 was estimated at about 10 billion US dollars, with the market share of industrial lasers being about 4 billion dollars (Overton et al., 2016). At the current time, we can conclude that by 2023 this industry has increased by at least twice. Real data is not available due to the use of this technology for the military purposes.

Considering all these trends, in the late 90s of the previous century, the offshore fleet industry began to actively use the laser devices for dynamic positioning (DP) of vessels (Mehrzadi et al., 2020). The principle of their work is simple and cost-effective.

The object of the research is the interface between the port facilities and vessels on the port's own water areas during the mooring operations.

The aim of the research is to define the benefits of new method of approaching and leaving any berth of a Port.

The tasks of the research are the following:

1. To compare the classical style of mooring and useful benefits of the new proposition.
2. To distinguish the perspective impact of the innovation to the economic effectiveness of ports operations.
3. To make the feasibility assessment of using these devices into the coastal infrastructure of port facilities.

The methods of the research include the following: systematic review, meta-analysis, analysis of scientific literature, statistical analysis, synthesis, interpretation, generalization.

1. The base of innovative proposition

Nowadays, the classical Laser positioning systems work on the next principle. The scanning beam of the laser installation in a sector determined by the settings is looking for the most strongly reflective surfaces. For these purposes use the cylinders covered with reflective material. The strongest reflection of the laser beams is remembered and, relative to its stable repetitions, the distance

to the target is calculated with an error (less than by GNSS) relatively to the location of the laser radiation source (Wärtsilä, 2020a; American Bureau of Shipping, 2021).

The base of use this equipment is changing, on the contrary. That is, the Laser positioning de vices will be located at clearly founded position and geographically defined points of each berth. Additionally, uniquely fixed coordinates of the geographical location of the Automatic Identification System (AIS) devices are attached to them (without dynamic operation of satellite positioning, i.e. hardly fixed by installers service). Such combined stations will use their already legally allocated VHF communication channels with the AIS stations of ships under mooring operations and the AIS devices of the Vehicle Traffic Center (VTC) or Port State Control (PSC).

Each vessel, when entering or before leaving the port, will be obliged to hang on the mooring board hollow reflective cylinders-tubes. Their length has to be at least 1.5 m at a height and hang at height not lower than its main deck. Minimum 2 cylinders-tubes have to be visible from the quay wall. Information exchange of positions occurs by identifying the mooring place and is displayed on the interface of the vessel's AIS device. Over there, a unique name and navigation information of the approach of the vessel under mooring operation relative to the location of the onshore AIS device are displayed. The navigational information is associated with the location of the laser installation device for positioning of the appropriate berth.

The joint use of two associated systems (Laser Positioning and AIS) will increase the safety of approaching or moving away from any berth. In addition, the port VTC and PSC will have GNSS independent control of the actions of any vessel in the port water area according to its mooring place (“point”).

2. The philosophy (base) of functioning and elements of the "CyScan" and "AIS" systems

The CyScan system is the standard laser sensor preferred by all major users of DP installations. It is a local reference position sensor for maritime dynamic positioning applications that measures the range and bearing of retroreflective targets, which in turn provides the installation's DP system with position and heading information relative to the target structure of another vessel or object.

Currently, the CyScan Mk4 sensor is the latest in DP laser technology. It can be used as the main standard or additional equipment for the DGPS satellite positioning system. The CyScan with an optional -40ºC operating temperature is also available in an extreme low temperature (XT) variant for operation in ice and arctic conditions. The CyScan Mk4 has proven to be an excellent reference sensor for the Gulfmark fleet and is the standard laser reference for all new offshore vessels. Vessels equipped with the older CyScan Mk3 system are in the process of being upgraded to the Mk4 system to take advantage of the latest design features and the new Dashboard interface. Therefore, the use of these systems in the port industry will facilitate the work of both the port authorities and the port industry safety (Seatrade Maritime News, 2015; Wärtsilä, 2020b).

The revolution in navigation and information technology has created the basis for the emergence of a new generation system for the safety of navigation: Universal Automatic Identification System (UAIS).

The main functional requirements for a universal AIS are fixed in the fundamental IMO Resolution (MSC. 74 (69)) in May 1998. In November of the same year, the International Telecommunication Union adopted Recommendation ITU-R M.1371, which standardized SOTDMA for radio traffic in the mobile maritime service.

Universal AIS is a system that provides information exchange in lines between ships and between ships and shore, installed at offshore facilities and operating in the VHF range of the maritime mobile service. (In accordance with the radio regulations: AIS1 - 161.975 MHz, AIS2 - 162.025 MHz).

They are capable of sending ship information to other ships and to shore with high frequency and high reliability using Self Organizing Time Division Multiple Access (SOTDMA) technology.

The prospect of the AIS development is planned to expand its capabilities and, consequently, its will be renamed into "Automatic Information System".

The main advantages of this navigation system include the following:

- mutual exchange of coordinates determined with high accuracy (using DGNSS: accuracy 2 m – 1 m), information about other navigational parameters of the environment, increase the accuracy of determining the characteristics of the movement of ships, and hence the efficiency of their divergence at sea;

- transmission by each transponder of unique call signs and the name of the vessel provides the possibility of a targeted call to any participant in the situation within a radius of 30 nautical miles via VHF channels, especially in dangerous situations, which is very important with reduced visibility in darkness and adverse weather;

- mutual exchange of data on the gyrocompass heading in almost real time, provides information about the direction of the diametrical plane of the target ships and their angle, which contributes to making the right decision when diverging or mooring. The maneuver of the target ship or the position of coastal AIS buoys is easily detected both by changing the gyro compass heading value and by transmitting the value of ROT (Rate Of Tern).

- correction of the target maneuver detection delay on the Automatic Radar Plotting Aides (ARPA), which sometimes reaches 3 minutes;

- no influence on the operation of AIS transponders of precipitation and sea waves, which are observed on the radar, which ensures the observation of a small target vessel in conditions of strong sea waves or dense illumination of the radar screen from a rain cloud;

- the operation of transponders makes it possible to exclude the influence of illiterate use of the radar controls, when the operator, trying to suppress interference from waves, also suppresses all useful targets;

- operation of transponders is provided in the shadow sectors of radars (beyond the island, around the bend of the river, breakwater, etc.);

- transponder transmission of ship dimensions and GNSS antenna location allows displaying the contours of ships on an electronic chart or radar scale around the antenna location, which can help when maneuvering in narrow areas, especially when visibility is limited or at night;

- thanks to the mutual exchange between ships of information about the type of vessel, its draft, dimensions and navigational parameters, as well as planned maneuvers, collision prevention is provided.

- information automatically transmitted in digital format makes it easy to register, store, reproduce, including with the help of its databases. Thus, the effective monitoring up to 4499 objects, equipped with AIS devices into a radius of 30 and more nautical miles can be ensured by port authorities.

The listed advantages of the AIS contributed to the IMO (MSC) in 1999 to prepare and adopt proposals for the inclusion in chapter V of SOLAS of a provision on the installation of an AIS on ships. According to this document, starting from July 1, 2002 and ending on July 1, 2008, all ships must have the appropriate AIS on board.

Along with the obvious advantages, the AIS has some disadvantages compared to the same radar possibilities, for example, it allows you to observe only objects equipped with a transponder, while the radar allows you to observe any objects that reflect radio waves. Therefore, to eliminate the shortcomings of both devices, there is a possibility to use an addition the Laser positioning system. This will help the interaction of both port traffic control facilities in their water areas, and for the interaction of ships on the high seas during emergency rescue operations. Reflective tubes aboard of each cargo vessel will make it easier for a rescue fleet, equipped with a laser positioning system to use their equipment for ensure operations in different weather conditions.

Conclusions

1. The perspective results of the combined use of the Laser positioning and the Universal Automatic Identification System (UAIS) devices will have the real economic feasibility, specially, during the emergency situations.

2. Their combined applying as a part of technological complexes for mooring operations into the ports and during emergency rescue operations at the high sea will be more save for seafarers.

3. The price of this technology implementation is low-cost.

4. The final result of this innovation will be the minimization of port's and rescue accidents in the sphere of water transport industry.

5. The innovative use of the well-known navigational systems will save a lot of money and many lives of maritime workers.

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LITHUANIAN MARITIME ACADEMY

CAN SOUTH AFRICA BECOME A TRANSSHIPMENT AND LOGISTICS HUB FOR SUB-SAHARAN AFRICA?

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Abstract. Ports play an important role in the transport sector in the world so as their location because the form part of entry to many countries for business activities. The location qualities demand characteristics and strategies of the role players define the potential of a set of locations to develop port functions such as transhipment activities, warehousing and distribution, industrial activities, trade and value-added logistics.
This paper looks at the possibility of developing a transhipment and logistics hub in South African port system for the Sub-Saharan Region. It also looks at providing the insight in the port system concept in South Africa from the current system to a single transhipment hub with a set of feeder ports.
It also looks or examine on whether the demand for the transhipments of containers exists and the establishment of such a hub in a South Africa port system. It is also important to describe the requirements and prospects for a successful transhipment hub in South Africa in this paper which will include the recommendation.
The Southern African container port system features a diverse range of different port types and sizes. Collectively, ports in this region constituted a significant 40% market share of all container traffic through the African continent. One of the busiest container ports on the continent, the Port of Durban is located within the Southern African region. One of the prospective ports earmarked for transhipment hub by the South African government (Transnet National Port Authority and Port Terminals) is the new port of Ngqura and port of Durban which will be discussed in the contents of this paper.

Keywords: ports; terminal; transhipment; logistics;

Introduction

Ports play an important role in the transport sector in the world so as their location because the form part of entry to many countries for business activities. The location qualities demand characteristics and strategies of the role players define the potential of a set of locations to develop port functions such as transhipment activities, warehousing and distribution, industrial activities, trade and value added logistics, (Notteboom, 2010)

Transhipment hubs are not created or occurring in all port systems but on separate regions which are ideally suited for maritime hub-and-spoke distribution patterns as a result of geographical, nautical and market related factors. We look into the South African need for the transhipment considering the factors highlighted above. Unlike the central Mediterranean and Caribbean with many opportunities for transhipments, other regions or port systems do not have the capacity to develop transhipment hubs (Notteboom, 2010)

There has been a proposal of the development of a hub at a South African port for the transhipment of large numbers of containers shipped on intercontinental routes because of the geographical location and physical attributes of the country's container ports which is believed to be favouring such development. This is supported and motivated by the fact that the Port of Durban already handles a substantial number of transhipments between ocean-going liners. (Notteboom, 2010)

According to NDoT SA Maritime Transport Sector Study (2011), the lack of success in building transhipment are not only as a result of the geography of intercontinental trade and ocean transport, but the technology and economics of liner shipping, supply concentration in markets, logistics of container services, repositioning of empty containers, finance, ownership and operation of terminals

and supply chain integration. It is also the political stability and maritime policies of the host countries, and the legal implications of transhipment for the finance and insurance of the cargo.

The South Africa government wants to position South Africa as a regional transshipment hub for Sub-Saharan Africa and deliver on NEPAD's regional integration agenda. This is after they have invested billions of rands in the infrastructural development and marketing in the South African port, in particular port of Durban and Ngqura.

This initiative includes various improvements to the Durban-Gauteng Rail corridor and the phased development of a new 16 million tons per annum manganese export channel through the Port of Ngqura. The South African government has also announced the decrease in port charges (equal to about R1bn in total) as agreed by the Port Regulator and Transnet to the exporters of manufactured goods and as part of reducing the costs of doing business. (BuaNews, 2012)

1. The Sub-Saharan Africa

There is an increasing trend towards the development of trade towards Africa especially towards Sub-Saharan Africa. Increasing technology, productivity in shipping business, new and improved innovative systems are common place in the developed as well as the developing countries. This new technology and the tendency towards globalization have brought about attention to the Southern African countries as a centre to reshape the entire transportation sector in Southern Africa and Africa as a whole. (NDoT SA Maritime Transport Sector Study, 2011)
This article examines whether South Africa can become a transhipment and logistics hub for the Sub-Saharan Africa. This will be addressed deeply in the discussion to follow in this paper.

2. Main body

2.1 Infrastructure Requirements for Transhipment Hubs

A depth of 16 metres is probably sufficient for all ships up to the size of so-called Suezmax, which is a ship of a maximum length of 400 metres and beam of 50 metres. As the Suez Canal has been deepened to accept ships drawing 17 metres and Suezmax container ships have been designed with draughts of 15 metres when fully laden, it seems that 16 metres of depth at berths will be adequate for any transhipment port in Southern Africa for some time. (NDoT SA Maritime Transport Sector Study, 2011)

Figure 1: PS class ship, Emma Maersk
Source: Picture Adopted from Google

The Suezmax container ships are some of the largest container ships in current use, namely the PS class of Maersk Line, comprising seven ships similar to Emma Maersk (see figure 1), which has a length of 397metres, beam of 56 metres, draught of 14,5 metres and a capacity in use of 11 000 containers. Ships of that size could be accommodated at the Port of Ngqura (although their lengths exceed the berth dimensions and their beams exceed the reach of the cranes), but it is unlikely that the traffic will be sufficient to require their employment on any of the routes to South Africa in the near future. (NDoT SA Maritime Transport Sector Study, 2011)

The depth of water at berths and in the channels is probably the most critical limitation on the infrastructural development of ports as transhipment hubs, apart from the availability of space for the stacking of containers. With the shift in trade to the Far East and the logistics of liner operation now being based on increasingly larger ships, South African ports without sufficient depth to berth ships requiring depths of at least 15 metres will be relegated to feeder ports. Sufficient space for stacking containers is another requirement of hub ports, although it can be argued that the idea behind transhipment is to move the containers quickly between ships and that space should be limited in order to preclude storage. However, plenty of space is needed to provide slots for the sorting and stacking of containers rapidly offloaded from a ship carrying 7 000 to 9 000 containers or accumulated for loading. The simultaneous offloading and loading between ships is a prospect that requires logistical planning not feasible yet in trade with South Africa, although it does occur in the Far East. With the exception of the Port of Ngqura, South Africa's container ports are all located near the Central Business Districts of cities and the lack of space has given rise to the so-called "off-dock" concept for the stacking of containers. As that concept cannot be adopted at transhipment hubs, lack of space imposes a limitation on the development of any of the existing South African container ports as a large transhipment hub, except at the Port of Ngqura. (NDoT SA Maritime Transport Sector Study, 2011)

The South African ports are not able to carry so large ships but it is able to receive ships with the carrying capacity below the 11 000 TEUs. The previous largest ship to call at Durban was the 11,660-TEU MSC Luciana in the past few years. MSC Fabiola with the carrying capacity of 12,562-TEU was received in Durban early last year. It was able to get through but this is because the ship was not fully laden otherwise the port would not have been able to accommodate the ship. The deepest berths at the Durban Container Terminal are 12.8m and those at Pier 1 are about the same. (SAPorts, 2013)

MSC Fabiola is a charter vessel and is currently deployed on MSC's pendulum service between Northern Europe and Singapore via Durban, Cape Town and Ngqura. The rotation is Northern Europe ports, Cape Town, Ngqura, Durban, Singapore, Durban, Ngqura, and Northern Europe. (SAPorts, 2013)

South Africa is aiming to have the 14,000-TEU box ships deployed on the South African service, defying all previous projections, as indeed has been the case with the 12,500-TEU MSC Fabiola.

It has been noted that the main obstacle in having these post panamax ships calling at Durban is that the country's main container port lacks a deep-water berth. This is despite the entrance channel having been dredged and widened several years ago to -19m decreasing to – 16.5m in the harbour inside entrance. (SAPorts, 2013)

2.2. Factors Influencing the Location of Transhipment

The importance of where liner companies will locate transhipment is evident to a large extent from an examination of the geography of existing hubs and the locational advantages which have induced rivalry. Algeciras (Spain), Gioia Tauro (Italy) and Malta Freeport in the Mediterranean are all located on the major Asia - Europe trade route and in proximity to feeder origins and destinations in Southern Europe and North Africa. Those hubs face competition from Port Said East (Egypt), Tangier (Morocco) and Damietta (Egypt) also in the Mediterranean and located near the main shipping route. Colombo (Sri Lanka) and Dubai (United Arab Emirates) and regional hubs for the

Arabian Gulf and Indian sub-continent face competition from Salalah (Oman) and Aden (Yemen) which have more recently come into the market. Singapore which is still the largest transhipment hub for the East - West trade route and the intra-Asia trade is confronted with serious competition from Port Klang and Tanjung Pelepas in Malaysia. The main East-West trade route and several of the important transhipment hubs are illustrated in Figure 3. (NDoT SA Maritime Transport Sector Study, 2011) Although these competing ports all have the advantage of being located on or near the major East - West trade routes, their future as transhipment hubs depends largely upon the decisions of the liner companies that take account of the total logistical costs of including transhipment in their networks of services. (Aurecon, 2011)

In order to avoid that happening, liner companies need to be locked into the investment in a transhipment hub, which is usually a satisfactory reciprocal arrangement enabling a high rate of throughput and productivity to be achieved in view of the mutual interest in the financial outcome, e.g. the container hub in Salalah, Maersk Line is a major investor together with the Government of Oman. As mentioned above the liner companies take into account the total costs of their logistical decisions, which imply that a favourable location of a transhipment hub is not necessarily the overriding factor in its use. Where ports have a substantial gateway function on a major route, it might be worthwhile to divert liners to serve those ports and use their transhipment facilities at the same time. An example is the deviation of 1300 nautical miles from the East - West route to serve Jebel Ali in the United Arab Emirates, as against the deviation of 163 nautical miles to Salalah (Oman) for transhipments only. (Aurecon, 2011)

Figure 2: Main East-West Route and several transhipment hubs mentioned in text
Source: Aurecon, 2011

Another reason why transhipments take place at locations seemingly irrational if only geography is taken into account concerns the network costs. Although the transhipment hubs mentioned in this section might be remote from South Africa and seemingly of no relevance, their influence on the volumes of traffic moving on the networks serving South Africa should not be discounted.

Gateway ports become more engaged in transshipment, and pure transshipment hubs have emerged. More than 20 of the 100 largest ports worldwide are transshipment hubs, in the sense that at least half of traffic is ship-to-quay-to-ship (Baird, 2007). This evolution is related to increasing vessel size and fewer port calls per service discussed before, and is taking place in many regions. Major gateway ports are increasingly profiling themselves as transshipment terminals, because the fragmentation of production tends to pull production out of (relatively expensive) gateway cities. (Joint Transport research Centre, 2008)

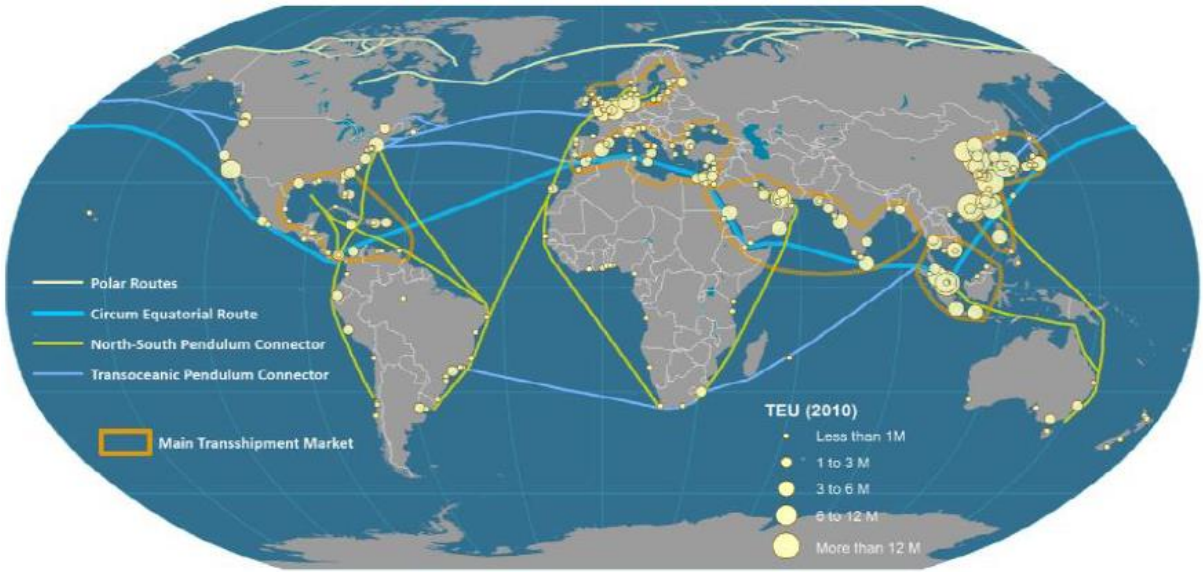

Figure 3: Structure of the future interconnectivity
Source: Rodrigue (1998-2012), Hofstra University (Department of Global studies)

According to Rodrigue (2012), a global maritime freight transport system has been established since the late 19th century and expanded with containerization. It includes east-west and north-south routes and location enabling interconnectivity between these systems of circulation. The above map illustrates the structure this system is likely to take in the coming years. The main components are:

- **Circum Equatorial Route** - With the expansion of the Panama Canal expected to come online in 2014, a relative parity will exist for the first time between the Panama and Suez canals. In such a setting, maritime shipping companies may elect to establish circum-equatorial routes in both directions with the usage of high capacity (8,000 to 12,000 TEU) containerships. This high frequency "conveyor belt" could support a significant share of global east-west freight movements in a cost effective way.
- **North-South Pendulum Connectors-** These connectors reflect existing commercial relations, namely for raw materials (oil, minerals, agricultural goods), such as South America / North America, Africa / Europe or Australia / Asia. For container shipping, they are mostly based on the rationale that there is not enough volume to support transoceanic services, so cargo is collected / delivered along a latitudinal sequence of ports. This conventional network will be expanded with transshipment opportunities with the circum equatorial route.
- **Transoceanic Pendulum Connectors** - Connect through pendulum services selected ports of the facades of large oceanic masses. The three main transoceanic connectors are transpacific, Asia-Europe (through the Indian Ocean) and transatlantic. The industrialization of Asia (China in particular) has made the Asia - Europe and the transpacific connectors particularly important. Growth within the "BRICS" countries (Brazil, Russia, India, China and South Africa) favours the emergence of a new connector in the Southern Hemisphere between the east coast of South America, the Cape of Good Hope and to Southeast Asia.
- **Polar Routes** - Consider the usage of circum-polar routes as shortcuts to link East Asia, Western Europe and North America (both east and west coasts). Even if the distance advantages of these polar routes appear significant, they are subject to the uncertainties of climate change.
- **Transshipment Markets**- They connect regional port systems to transoceanic and circum equatorial routes, mainly through hub-and-spoke services. The relay function between long distance shipping services performed by those markets is also significant. The most important are Southeast Asia, the Mediterranean and the Caribbean. They are referred as markets because the transshipment function can be substituted to another port. Therefore, a group of ports in a transshipment market are "bidding" for port calls as this type of traffic is difficult to anchor. The

development of circum equatorial routes is thus likely to expand the opportunities of transshipment, including interlining between these routes. (Rodrigue, 2012)

According to Notteboom (2011), the terminal location decision process encompasses identification, analysis, evaluation and selection of alternative locations. For the prospective South African transhipment and logistics hub, three locations have been identified which are; the new port of Ngqura, the existing but non-containerised port of Richards Bay and the large gateway port of Durban.

2.3 SWOT Analysis of Southern Africa Ports

In this section of SWOT Analysis we try to look at the potential of the South African ports (Durban and Ngqura) which are on the prospects of becoming transhipment hub in the Sub-Saharan African region. We are benchmarking them with other competing Southern African ports (Walvis and Maputo). This will help to see if South Africa is positioned to offer the transshipment and logistical hub in the Sub-Saharan Africa. Given the size of the African maritime market we are benchmarking based on the Southern African region as some of these ports in the region are considering building the transhipment hub. The SWOT is not looking at the global level but competing ports in the Southern African region.

Table 1. Swot analysis of port of Durban

STRENGTHS	WEAKNESSES
❖ Largest port in South Africa; ❖ Total Land area 1854 hectares, distance around the port is 21 km; ❖ The ports offer the fullest range of ship services ❖ Dedicated feeder services operating to Mozambique, East Africa, Indian Ocean Islands and South African Coastal ports; ❖ 57 effective berths, 19 cranes and 1.68 million TEUs per annum; ❖ Offers a full range of ship services, e.g.; Bunker, ship repair facilities; ❖ Strongly developed road and rail corridors to the Gauteng area, its position as an established gateway port in Sub-Saharan Africa;	❖ Night restrictions are for ships length of 200 m and a beam of 26m and maximum draught of 11.6m; ❖ Congestion in ports due to growth of Maritime Traffic; ❖ Pressure on infrastructure as well as operational performance; ❖ Queues of up to 20 ships caused by slowing working practices including strikes and bad weather(ports & ships,2007);
OPPORTUNITIES	**THREATS**
❖ Maputo is one of the main corridors for the South Africa Hinterland; ❖ Establishment of the regional transshipment hub will require special efforts;	❖ Faces growing tensions between the port and the city; ❖ Congestion and delays in the urban area and on the corridors to Gauteng; ❖ DP World has invested $32 million in the south-eastern African port of Maputo in Mozambique; ❖ High level of Absenteeism and lack of skills, culture of the people needs to be changed;

Table 2. SWOT analysis of Wallis Bay

STRENGTHS	WEAKNESSES
❖ Transhipment hub for MSC to West Africa; ❖ A five-day saving in transit on containers; ❖ Annual throughput;	❖ The container stacking capacity is expected to be increased; ❖ Need to build a new permanent reefer stacking area with 1000 reefer points;
OPPORTUNITIES	**THREATS**
❖ Establishment of the regional transshipment hub will require special efforts;	❖ High level of Absenteeism and lack of skills, culture of the people needs to be changed

Table 3. SWOT analysis of port of Mozambique

STRENGTHS	WEAKNESSES
❖ DP World has invested $32 million in the south-eastern African port of Maputo in Mozambique; ❖ Maputo is one of the main corridors for the South Africa Hinterland	❖ Two additional berths will be needed; ❖ Few gantry cranes and straddle carriers; ❖ Very small in terms of performance
OPPORTUNITIES	**THREATS**
❖ The R16-million investment in reefer plugs plant will attract more reefer cargo through an improved service level;	❖ The port will need to generate substantial new throughput volumes; ❖ It is situated away from the east/west arterial trade routes; ❖ Minor player amongst the South African Ports;

Table 4. SWOT analysis of port of Ngqura

STRENGTHS	WEAKNESSES
❖ A total of 32 berths have been identified in the port's master plan; ❖ The main breakwater is the longest in South Africa; ❖ Situated at the mouth of river Coega and good for international trade; ❖ It is in a position to serve both important economic centres;	❖ Long inland distance to main markets in Gauteng; ❖ Need to develop short sea, deep sea and inland connectivity; ❖ Long inland distances to main markets in Gauteng and the poor rail connectivity;
OPPORTUNITIES	**THREATS**
❖ 12,000-hectares piece providing serviced industrial sites with a purpose-built infrastructure; ❖ Bunkering services to develop in due time; ❖ Likely to face the least opposition to green field development;	❖ A major threat is its geographic location. The major carriers are increasing concentrating their services between East/West arterial trades and North/South routes. The port Is unfortunately not situated along the main trade routes

The SWOT analysis provides a lot of valuable insights on the attractiveness of the three South African terminals including the neighbouring countries, Namibia (Port of Walvis Bay) and Mozambique (Port of Maputo). In this SWOT we are benchmarking the South African ports with those of the neighbouring countries. However the qualitative information does not allow selecting the best alternative for the larger-scale terminal development in South Africa port system. Transnet has identified and chosen port of Ngqura as the future hub, and the port of Durban also is considered to have potential should the proposed expansions take place in the old airport site. We will look at the ability of whether South Africa can become a transshipment and logistics hub in the Sub-Saharan African region with the port of Ngqura or Durban to facilitate such decision or selection.

The SWOT analysis was to see on the potential of the ports in South Africa but not as the determining factor towards which port could be chosen.

Each port/ terminal site may have an appealing advantage in this favour, but the final selection will be the result of compromise other than an optimal decision (Notteboom, 2011)

Summary of the SWOT analysis

The SWOT analysis of South African ports has revealed that the potential for any of the Southern African ports to develop into a large transshipment hub is limited but there is an opportunity to explore much. The reasons are explained below:

a. Geographic location - The location of Southern African ports are away from the main navigation routes which can make it difficult to develop a transhipment but given the challenges experienced at Suez Canal high rates, congestion, etc., South Africa can be positioned to address that. Generally, the so-called Equatorial East-West route is the busiest loop around the world. It meanders across the Pacific Ocean, Atlantic Ocean and Indian Ocean and through the Panama Canal, the Suez Canal, the Gibraltar Straits and the Malacca Straits. The deviation to main navigation routes is a crucial point when carriers consider which port to select as a hub transshipment centre.

b. Container Transhipment Volumes- For ports to be considered as a transshipment hub it should be able to handle at least 60% of cargo. Currently the biggest port handles about 17 %. This mainly because of few feeder networks to support large transshipment activities.

c. Labour Issues: Southern African ports have received criticism in the past relating to slow container moves in comparison with other ports internationally. Another reason for the low productivity is the departure of skilled operational personnel, through HIV Aids, and staff turnover.

d. Southern Africa ports are situated in urban or semi-urban locations (e.g. Durban) and do not offer an optimal position for transshipment services and also does not have a strong or large shipping industry compared to Asia or Europe.

e. The possibility of any of the Southern African ports to develop into a transshipment hub is significantly undermined by high freight costs and customs delays. Example High freight costs and delays in South Africa ports reduce Africa's trade competitiveness.

It is acknowledged that the current low transshipment volume does not imply that a port is unable to develop its transshipment functions

2.4 Opportunities for Increasing Transhipments in South Africa

The prospects for port of Ngqura and Durban to attract transhipments will depend upon the provision of the port features described in the earliest section as well as the marketing ability of the port authority and the economics of the logistical networks of the liner companies trading with Africa, especially with South, East and West Africa, and between the Far East and the East Coast of South America. It will also depend on whether Transnet involves other role players such as terminal operators and shipping lines to the transhipment development. This paper suggests that because shipping lines wants to be involved in ports where their service is being operated.

According to NDoT SA Maritime Transport Sector Study (2011), at present there seem to be several targets, as follows:

Asia-ECSA

The trade to the East Coast of South America from Asia grew. Further rapid growth is expected, but draught limitations restrict the use of fully laden ships.

Most of the services are direct, but several are routed via South Africa. The return trade is small. As the forward trade is likely to continue to increase quite rapidly for a while, the opportunity exists for transhipments in South Africa (Ngqura and Durban) enabling liners of any size currently on order to be used on the first segment of the route and the cargo to be relayed in smaller ships to the ports of destination.

Asia to West Africa

Traffic from the Far East to West Africa moved via the Cape at one time, but is now transhipped from the main East-West route through the Suez Canal at hub ports in the Mediterranean for services round the bulge in Africa. The volumes are substantial and it is feasible that some of the traffic could be routed via South Africa for transhipment at Ngqura or Durban.

CSAV already has a service between Asia and West Africa transhipped at its Durban hub.

Maersk line has also very recently launched a new service from the hub ports of Tangier and Algeciras in the Mediterranean to West Africa, which will link with an existing service with Asia to Walvis Bay, where cargo is transhipped to West Africa. Those services via two very different routes, which enhance the lines overall capacity to West Africa, provide an example of the transhipments for which Ngqura could compete, especially as the unit costs on the voyage to that port could be minimised by enabling the employment of very large ships.

Asia-East Africa

Asian traffic to East Africa is currently being transhipped at hubs in the Middle East on the main East - West trade route or carried direct by small container ships with capacities of 1500 TEUs. Some 2400 TEUs per week are currently carried inbound on the latter services.

Routing that traffic by large liners for transhipment at Ngqura and Durban feedering to East Africa might be worthwhile if spare capacity on the trunk route is available (which it is at present). At least 200 000 transhipments annually would be created at Ngqura.

Figure 4 Main prospects for Port of Ngqura and Durban as transhipment hubs

Source: NDoT SA Maritime Transport Sector Study / Part 3/27

Port of Ngqura and Durban as hubs for South Africa

The development of Ngqura or Durban as the hub for the feedering of containers to and from other South African ports is something to be taken into account. With the transhipments currently undertaken at the port and the transhipment work that could be acquired, Ngqura could then attain sufficient status to be included in the list of the world's important transhipment ports and to attract foreign capital for development and management experienced in competitive hub exploitation. However, the combination of a gateway and hub port might not enable the requisite high efficiency to be attained if the experience at Durban is taken into account. (NDoT SA Maritime Transport Sector Study, 2011)

In order to establish a transhipment hub in South Africa for the relay of the container traffic between India and the East Coast of Latin America and West Africa, at least 360 000 containers would need to be consolidated annually at the port of origin and carried in 6 000 TEU ships to the hub for transhipment and onward carriage in smaller ships. Some traffic for South Africa could be included in the first leg, but the logistical purpose would not be to construct a hub-and-spoke system, but rather to join intercontinental services in a manner that enables the full utilisation of the capacities of ships on each segment of routes that otherwise would require multi-porting.

The port of Durban comprises the potential to be the hub, as with port of Nqgura. The space where the International airport used to be situated in the south of the city can also be contributing to a transhipment hub in South Africa. But there are some challenges that need to be taken into account. But it this paper we do not see that as a block for the port of Durban to become one of the transhipment hub same as Nqgura. Among those challenges the following have been identified:

- Space constraints within the port
- Forecasting demand and designing capacity in response
- Adjacent rail and road network constraints
- User perceptions of the port
- Integration into the Provincial Development Strategy

3. Conclusion and recommendations

The discussion of this paper is to see if South Africa is able to become a transhipment and logistics hub for the Sub-Saharan African region. This topic has been in the discussion by the South African government in particular Transnet Port Terminals and National Port Authority. Transnet has

opted to use the port of Ngqura is the proposed transshipment hub with Durban coming second (NDoT SA Maritime Transport Sector Study, 2011).

The recommendation that we can make in this paper is that transhipment is needed in the Sub-Saharan African region given the opportunities and the location of the region. It has been said in the discussion that the Suez Canal is experiencing some challenges (e.g. congestions, high charges) and this gives the Southern region an opportunity to establish one. Africa is become a global player in the economy and that should also be part of grabbing the opportunities. It is therefore important that South African port management (Transnet), develop the port of Ngqura or Durban further to realise this proposal and to serve the Sub-Saharan African region. There is the need for South Africa to consider the Public Private Partnership Model in establishing a hub especially with the terminal operators and liner shipping companies. South African ports can benefit from the following advantages of public private partnership; the public authority may enjoy greater freedom from public sector constraints, there would be more opportunities for terminal operators to diversify their operations, the port authority will easily define its strategy and competitive advantage.

The large transshipment hub should be able to incorporate many activities such as distribution centre, warehouses, insurance and many more. As mentioned in the discussions, liner companies need to be involved in the establishment of a transhipment hub. Therefore, it is important for Transnet to review the policies in the operations and management of ports to allow room for the private sector. There must be cooperation and policies tailored to the needs of the operators like the terminal operators, logistics providers.

There is a need for synergy between different modes in a multimodal approach which will enable the South African ports (Port of Ngqura and Durban) to serve its own extensive hinterland, which includes Gauteng and many Sub-Saharan Countries.

That the geographic location of South African ports do have potential for the establishment of a hub providing for the transhipment of containers between intercontinental trunk routes and spokes serving ports in Sub-Saharan Africa, nor for a relay hub for traffic between the Far East and the East Coast of South America but such needs commitment.

Both the port of Durban (that is if the proposed development is taken into account) and port of Ngqura can compete for transhipment traffic for East Africa from the Far East presently shipped on direct services via Salalah or other hubs on the main East - West routes and feasibly for container traffic for West Africa from the Far East presently transhipped at hubs in the Mediterranean and at Walvis Bay.

The South African ports need to work on their ship and container handling efficiency, infrastructure and superstructure and the pricing of services.

In order to achieve the establishment of a transhipment hub for South Africa's containerised imports and exports, the inland transport and coastal shipping feeder services should be in place. This will enable economies of scale to be achieved as well as savings in the investment and operating costs at other ports.

Because of the public ownership of the port systems in South Africa, the have been political ties within the port operations which according to some hindered the development of the ports system. This should be eliminated because in other instances they have been delaying the success of the development in the South African ports.

South Africa should develop a short sea shipping and rail/ road network that are able to link the port with the hinterland and the main business hub of South Africa and nearby countries. This should be achieved through the involvement of the nearby countries, (Ng and Pallis, 2010; Notteboom et al. 2012) as these factors have to some extent been undervalued by existing models.

Transnet needs to consider that the involvement of the private sector does not bring capital in investment but also the skills issue that has been lacking from their disposal. The situation is further worsening by huge, bureaucratic administration and custom delays which need to be looked upon to achieve establishing of a transshipment and logistical port.

Notteboom (2010) noted that the success of South Africa (e.g. Ngqura or Durban) will depend on them becoming efficient, cost effective and well serviced hubs and to be able to compete with

globally. This is because the port of Maputo in Mozambique and Walvis Bay of Namibia are well situated to offer the better services if they are well improved.

It will be up to the South African port system to act as soon as possible in order to grab the opportunities of creating a large hub and benefit from the first mover advantages compared to the potential competing hub that might emerge in the region (Notteboom (2010). The transhipment and logistics hub that South Africa should develop will not serve South Africa but to serve the broader hub function for the entire region of Sub-Saharan region.

Given the unavailability of the large transhipment in Sub-Saharan African region, South Africa (Ngqura) stands a chance to be the transhipment hub in the region.

Ngqura being the chosen hub (by Transnet) is able to make the model a success if it becomes efficient, cost effective and well serviced hub, so that vessels can rely on a low turnaround time. It must also be that cargo moves in and out of the hinterland at competitive rates in an efficient and congestion free inland transport system (Notteboom, 2010). This includes port of Durban as well.

From the discussion, we can conclude that South Africa is in a position to offer and become the transhipment and logistics hub in the Sub-Saharan African region. This can be facilitated by the port of Ngqura given the investment in the port and Durban should the proposed expansion at the old airport site continue.

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LEGAL REGULATION OF RELATIONS FOR IMPLEMENTATION OF INFRASTRUCTURE PROJECTS IN RURAL TERRITORIAL COMMUNITIES

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Abstract. The article examines the legal basis of the organizational and administrative doctrine for the implementation of infrastructure projects within the framework of the state policy for the development of rural territorial communities. The theoretical and categorical apparatus of the considered relations is characterized, and the authors' definition of the category "infrastructure project" as formed for satisfaction of needs of the whole society or its part of the task and certain means of realization of such tasks by application of specific methods and processes that ensure achievement of the desired economic, technological or organizational result, as well as contribute to normal functioning and development of economic, social or ecological spheres of life of the whole state or a separate territorial community is given. Reference is made to a number of general legal and administrative regulations that regulate the basic principles of entrepreneurial activity and cooperation between state authorities, local authorities and private partners. A more detailed analysis of the Regulations on the State Agency for Infrastructure Projects of Ukraine and the Laws of Ukraine "On Local Self-Government in Ukraine" and "On Public-Private Partnership", which regulate legal relations between the implementation of infrastructure projects, as well as state authorities, local self-government bodies and subjects of private power, especially agricultural producers. An attempt has been made to generalize how to solve the problem of implementation of infrastructure projects for rural territorial communities, ensuring coordination and consideration of mutual interests of state and entrepreneurial structures through the implementation of joint innovation and investment projects.

Keywords: infrastructure project, legal acts, local government, legal framework, rural territorial communities.

Introduction

The high potential of material and resource supply of rural areas in the largest part of Ukraine, created by the unique combination of natural and climatic conditions and geostrategic location, the presence of a considerable amount of land suitable for commercial agricultural production, traditions in the field of agriculture, animal husbandry and arable farming, is a key factor in ensuring successful socio-economic development of rural territorial communities. However, the actual state of affairs in the field of this development is not characterised by high indicators of cultural and living conditions of rural residents and the development of industrial and social infrastructure of rural areas. At present, in the rural areas of Ukraine, most of the representatives of the territorial authorities are engaged in the production or processing of agricultural products. These activities provide the rural population with material means for their subsistence and form a certain (low) level of their abundance.

The scientific relevance of the research arises from the fact that the described evidences arose in such conditions that the transition of the agricultural sector of the Ukrainian economy to market relations, which was accompanied by a radical transformation of agricultural production and its concentration in the private sector of the administration, was not sufficiently connected with the changes in social processes in the countryside. The state social policy of the last three decades did not provide with systemic infrastructure projects for rural local authorities, which gradually led to a deep crisis in rural areas, a decline in the rural population, unemployment, poverty, labour migration, population aging, the deterioration of the existing social infrastructure and the like. Now, in the

conditions of the war, the consequences of which are, in particular, the destruction of the infrastructure of settlements in urban and rural areas as a result of direct military operations in some areas of Ukraine, the temporary occupation of certain territories, a paradigm of post-war restoration of the infrastructure of the country should be formed in modern Ukrainian society, including through the implementation of infrastructure projects in rural areas. Consequently, **the scientific problem of the research** is critical and a fundamental analysis will play an important role in addressing the issue from the point of view of legal norms and their implementation of infrastructure projects for rural communities.

Our position on the significant role of the implementation of infrastructure projects related to agricultural activities is justified by the following point of view: The first such national and at the same time still existing international infrastructure project related to the proclamation of martial law regime is a project related to the results of agricultural producers activities – "grain initiative" and growth export of grain. The implementation of this infrastructure project began at the end of July 2022, when Ukraine, the United Nations and Turkey signed a trilateral agreement on lifting the blockade of the ports of the Odessa region - "Chernomorsk", "Odessa", "Yuzhny". On August 1, the first ship loaded with grain left Odessa. In the first month of the agreement, a total of 1.7 million tons of agricultural products were exported to 20 countries through 3 ports.

The "Grains Initiative" has had a positive impact on international markets and global food security – the cost of food in the world has fallen. A total of 5 million tons of agricultural products were exported in August by all modes of transport [1].

This fact indicates that Ukraine can further increase the export of agricultural products from the very beginning and in the conditions of full-scale invasion, provided that the infrastructure project "Grain Initiative" continues to be successfully implemented and other projects are prepared and implemented with the participation of the state, international partners, rural local authorities, national private partners, etc. However, in our opinion, there is no clear legal mechanism in the national legislation to regulate the relations in the implementation of infrastructure projects with direct participation of local self-governments.

The object of research is to study and analyse the theoretical and methodological approach, to mark the limitations of previous studies on the evaluation of the problem of legal regulations for the implementation of infrastructure projects in rural communities, as well as to consider the urgent issues of legal regulation of the implementation of infrastructure projects for rural territorial communities, which can contribute to the improvement of the legal regulatory systems of the studied relations in Ukraine.

The aim of the study is to address the issues and general problems in the definition of conceptual approaches to the legal regulation of relations for the implementation of infrastructure projects for rural communities, as well as in the formation of proposals for the operational improvement of the current legal regulation of relations, as well as to ensure the restoration and development of infrastructure in rural areas.

The objectives of the research include:

1) Analysis of legal norms and scientific approaches to the implementation of national legislation related to infrastructure projects for rural territorial communities.

2) Evaluation of the existing complex legal regulatory systems and implementation of infrastructure projects for rural territorial communities in Ukraine.

The research methods include: systematic review of legal norms and regulatory systems for infrastructure project implementation, analysis of scientific literature, synthesis, interpretation, and generalization.

The structure of the research. The first part of the study describes the literature review and the boundaries of the field, the next part deals with the main existing legal norms that apply to rural local authorities. The second part of the study examines the possibility of improving the legal norms for the implementation of infrastructure projects in rural communities. The conclusion summarises the results of the research analysis.

1. Background and overview

The analysis of the scientific positions carried out by the authors on the study of the peculiarities of the domestic legal regulation of relations in the implementation of infrastructure projects for rural territorial communities, gives rise to the conclusion that specialists in the field of law, public administration, economics, etc., such as Aristova I.V., Borodina A.N., Zachko A.B., Zhurakovskaya L.A., Kovaleva A.V., Kropivko M.F., Kurilo V.I., Kurilo I.V., Kurilo L. I., Lupenko Yu. A., Mushenok V. V., Prokopa I. V., Ryzhenko A. S., Rusan V. M., Shershneva S. E., Yunin I. O. et al. so far have studied only specific elements of the problem.

Borodina A. N. and Prokop I. V., in particular, studied the theoretical and methodological bases, main features and institutional foundations of rural development in Ukraine as a whole, indicating the main directions for strengthening the economic potential of rural development and determining the role of infrastructure projects in this establishment [2]. Kurilo V. I., Mushenok V. V., Ryzhenko A. S. in collective and individual works presented a legal mechanism for managing the risks of organizational and fiscal development of subjects of the agricultural sector, which should be taken into account in the implementation of infrastructure projects by these subjects independently or jointly with state authorities. In addition, the conceptual, theoretical and practical bases of financial regulation of various types of relations, including the implementation of projects to improve the infrastructure of rural local authorities in the framework of the transformation of local self-government relations, were studied [4-5]. Kurilo I. V. studied the issues of agro-innovative activity and the problems of protection of Ukrainian flora, directly related to the implementation of infrastructure projects in rural areas. Kurilo L. I. studied the problems of intellectual capital development of the agricultural sector of Ukraine. Zachko A. B. reviewed the conceptual and categorical tools of the research questions, conducted a comparative analysis of the largest infrastructure projects in the world, characterized their main elements, and also proposed the results of a study of systemic approaches to improving the process of management of infrastructure projects based on methods of system analysis and strategic control [6], etc.

However, in our opinion, there is no sound study on issues of complex legal regulation of relationships in the implementation of infrastructure projects for rural territorial communities in Ukraine, which remains relevant and requires further research.

Accordingly, **the main goal** of this research is to study the issues and general problems of defining conceptual approaches to the legal regulation of relations for the implementation of infrastructure projects for rural communities, as well as in the formation of proposals for the operational improvement of the current legal regulation of relations, as well as to ensure the restoration and development of infrastructure in rural areas.

2. Elaboration of the problem and research findings

Ensuring indicators of economic development of rural territorial communities and the social sphere of the village is possible through the preparation and implementation of state, sectorial and regional programs and infrastructure projects for socio-economic development. Therefore, attention should be drawn to a certain freshness of the problems of administrative and legal support of management relations in Ukraine in relation to the possibilities of implementation of infrastructure projects, and at the same time, the lack of clear legal regulation of this type of socio-economic relations.

As Zachko A. B. rightly notes, "the implementation of Euro-2012 showed the first peculiarities in the implementation of infrastructure projects in Ukraine. In general, the implementation of infrastructure projects was successful, despite some shortcomings related to the underestimation of project budgets at the design stage and inefficient use of the infrastructure project product at the operational stage" [6, p. 60].

Based on the above assumptions of management and economic research, it can be concluded that the implementation of infrastructure projects will be successful only if there is a clear legal framework in Ukraine, which will also help to strengthen the indicators of the functioning of the

market in the Ukrainian economy and provide strategic directions for the further development of rural regions. In order to develop the legal basis of organizational and management theory for the implementation of infrastructure projects within the concept of state policy for the development of rural areas, we will first consider the theoretical categorical apparatus of the studied relations.

Thus, infrastructure is a set of specific forms, methods and processes, as well as various structures and means of communication that ensure the general conditions and normal functioning of economic, social, environmental and other spheres of society, its reproduction and development [7, p. 12]. A project is an idea (task, problem) and the necessary means for its implementation to achieve the desired economic, technical, technological or organizational result [7, p. 27].

The combination of the above categories in a single sentence gives rise to the formulation of a semantic definition of the category "infrastructure project" as formed to meet the needs of the whole society or part of the task and certain means of implementation of such a task through the use of specific forms, methods and processes that ensure the achievement of the desired economic, technical, technological or organizational result, and will also contribute to the normal functioning, reproduction and development of economic, social, environmental and other sectors of life of the whole state or a separate territorial community. When studying the relationship between the legal regulations of the implementation of infrastructure projects for rural territorial communities, it is necessary to take into account the interpretation of the category of "social infrastructure" as a set of general conditions for the reproduction of the labour force and ensuring the normal life of people [8, p. 173]. Given this definition, we define the social infrastructure of rural areas as a derivative that depends directly on the development of agricultural production in a particular area and the functioning of other economic sectors. The specific tasks of implementation of social policy of the state in rural areas are realized as a degree of ensuring socio-economic human rights. An important guideline for the development of rural local communities is the socially oriented market economy. This is because in the social sphere the conditions for the social and legal protection of the population, the development of democracy, new norms and patterns of behaviour, the possibility of free choice of employment and professional development, the development of private property and entrepreneurial relations are created. Considering the individual definitions of the conceptual and categorical apparatus of the studied problems in the implementation of infrastructure projects in rural areas, we note that in the national socio-economic environment the issue of legal regulation of relations in the implementation of infrastructure projects has not been adequately consolidated.

The basic principles for the implementation of entrepreneurial activity as the main factor for the development of the national economy, as well as for the cooperation between the authorities, local self-governments and private partners are determined by "a number of basic legal and administrative acts, including the Economic and Tax Code of Ukraine, the Laws of Ukraine "On State-Private Partnership", "On Local Self-Government in Ukraine", "On Concessions", the National Strategy of Development Assistance to Civil Society in Ukraine for the period 2021-2026, the Strategy for the Development of the Agricultural Sector of the Economy for the period until 2020, the Concept for the Development of Public-Private Partnerships in Ukraine for 2013-2018, the State Target Program for the Development of the Ukrainian Village for the period until 2015. etc. "[5, p. 221]. Since, in our opinion, the abovementioned legal acts are general regulatory acts related to the implementation of infrastructure projects, it is advisable to delve deeper into the analysis of a specific law – Regulations on the State Agency for Infrastructure Projects of Ukraine (approved by the Resolution of the Cabinet of Ministers of Ukraine dated September 22, 2016 No. 714) [9].

This legal act establishes that the State Agency for Infrastructure Projects of Ukraine (hereinafter "Ukrinfraproekt) is the central executive body implementing state policy in the field of development, construction, reconstruction and modernization of air, sea and inland waterway transport infrastructure, as well as financial support for transport safety measures or state programs.

By analysing the influences of Ukrinfraproekt we come to conclusions about priority areas in the activity of this state institution

- development of urban and interurban (interstate) infrastructure.

In paragraph 3 of section 12 of the Regulations, its main tasks are the development of air, sea and river transport infrastructure through the construction and commissioning of such infrastructure facilities, as well as checkpoints at the state border for vehicle pairing and financial support for measures to ensure transport safety in accordance with government programs.

Among the impacts defined above, but not entirely related to rural areas, it is advisable to pay attention to the authorities related to the "implementation of infrastructure projects as a contractor and / or executor of state targeted programs", which include programs to promote the development of civil society in Ukraine, the development of the agricultural sector economy and the Ukrainian village, etc. It should also be noted that under paragraphs 6 and 7 of the Regulations, Ukrinfraproekt has the right to perform the tasks assigned to it:

1) to involve in the prescribed manner specialists, professionals, employees of local self-government, enterprises, institutions and organizations (in agreement with their authorities) in the performance of certain works and in the study of certain issues;

2) to obtain free of charge from local self-government bodies, enterprises, institutions and organizations, as well as from citizens and their associations, information, documents and materials necessary for the performance of the tasks assigned to it;

3) to cooperate with local self-government bodies, citizens' associations and public associations in accordance with the established procedure [9].

Thus, the analysis of the individual paragraphs of the Regulation on the State Agency for Infrastructure Projects of Ukraine allows us to conclude that in this normative legal act there are provisions on the possible cooperation with local self-governments and local enterprises, institutions, organizations, rural residents in the implementation of infrastructure projects for rural territorial communities. In addition to the Regulations, the issue of proper formation and modernization of territorial community infrastructure was also considered in the Law of Ukraine "On Local Self-Government in Ukraine" dated 21.05.1997 No. 280/97- VR. In particular, paragraphs 1-3, Article 18 of the Law determine the relations of local governments with legal and natural persons not directly subordinated to them, located within the boundaries of each territorial relations, in matters related to the jurisdiction of local governments, occur on the basis of control, accountability and provision of necessary information, the initiation of the organization and implementation of controls in the framework of fiscal regulation and in resolving other issues [10].

Considering the main powers of local governments (village and settlement councils), we have tried to describe their own (self-government) powers and the delegated powers to interact with other agencies, including the implementation of infrastructure projects in the sectors concerned.

1. In the field of budget, finance and prices: on a contractual basis, the raising of funds from enterprises, institutions and organizations, regardless of the form in which they are located in the territory concerned, and of funds from the population, as well as budgetary funds for the construction, expansion, repair and maintenance of social and industrial infrastructure facilities and for environmental protection measures on a joint basis (paragraph 5, article 28).

2. In the field of construction: organizing the development of the infrastructure of construction sites, public transport for the placement of technical means of electronic communication to meet the needs of the population for electronic communication services (paragraph 1, Article 31).

3. In the field of education, health, culture, youth policy, physical culture and sports: support for the development of public youth and children's associations, youth centres, youth councils, youth infrastructure (paragraph 10, Article 32)

4. In the field of foreign trade: support for the establishment of joint ventures with foreign partners for industrial and social infrastructure and other facilities on the basis of legislation; attracting foreign investment to create jobs (paragraph 3, Article 35).

5. Ensuring the rule of law, public order, protection of rights, freedoms and legitimate interests of citizens: taking the necessary measures to protect critical infrastructure, restore the

functioning of key state institutions of the national economy, critical infrastructure and facilities that ensure the livelihood of the population (paragraph 2-1, Article 38) [10].

Within the framework of this study, we have also attempted to discuss separately the transfer of powers of district and regional councils to the competent local state administrations for the maintenance of local infrastructure made by the Law of Ukraine "On Local Self-Government in Ukraine":

1) pooling on a contractual basis the funds of enterprises, institutions and organizations located on the respective territory and the population, as well as budgetary funds for the construction, reconstruction, repair and maintenance on a joint basis of social and industrial infrastructure facilities, local roads, for the rehabilitation and ongoing repairs of roads and streets in settlements and other roads that are part of state roads (as co-financing on a contractual basis), as well as for labour and environmental protection measures (Section 6, Article 44);

2) assistance in the development of youth infrastructure, youth centres and other objects of youth work (Section 19, Article 44) [10].

According to the Law of Ukraine "On Public-Private Partnership" dated 01.07.2010 No. 2404-VI [11], the spheres of application of public-private partnership for the development of rural local authorities can be, independently or in clear combination with the production activities of the subjects of the agricultural sector, the implementation of infrastructure projects for:

1) Ensuring the functioning of irrigation and drainage systems that are central to the development of agriculture and rural areas in certain regions of Ukraine where, due to unfavourable natural and climatic conditions, well-functioning reclamation systems contribute to stable production of crop products;

2) Construction and operation of sea and river ports and their infrastructure will expand the capacity of domestic ports to handle agricultural products, which will increase the supply of domestic products to the global agricultural market in the context of the global food crisis;

3) Building networks for the management and maintenance of markets for fruits, vegetables, root crops, etc., refrigeration and storage facilities for the preservation of agricultural products, processing of their waste, which will contribute to reducing the gross costs of the agricultural sector, the development of infrastructure for the sale of food products, as well as expand the scope of entrepreneurial activity of representatives of rural local authorities.

In summary, the mechanism of cooperation between the state, local authorities and enterprises in the form of public-private partnership allows for coordination and consideration of mutual interests of the state, business structures and citizens in the implementation of joint innovation and investment projects, targeted industrial programs and the like. However, the current legislation rather regulates relations for modernization of urban infrastructure, therefore, in our opinion, for implementation of infrastructure projects for post-war reconstruction of Ukraine, it is advisable to improve the current legislation and develop a separate legal act for implementation of infrastructure projects in rural areas.

Conclusions

In Ukraine, before the start of a full-scale enemy invasion, dozens of major infrastructure projects were carried out. The need to develop innovations in the content and implementation of such projects in the post-war period with the broad involvement of foreign partners confirms the relevance of the problem of studying the legal regulation of these relations and developing ways to improve the basic management mechanisms. Implementation of infrastructure projects in rural areas has specific legal and economic features, and their successful implementation depends on the instruments of legal regulation, the needs of society in certain specific types of it, the formation of legal thinking, etc. The functions of infrastructure projects in rural spatial development are manifested as the influence of infrastructure on various subjects and objects of rural areas and the relationship between them in terms of:

- accommodation of population and objects of agriculture;

- nature management, culture and life;
- organization of agricultural production, labour performance, provision of services, etc.

Proclamation of martial law has negatively affected the possibility of implementation of rural infrastructure modernization projects and requires the implementation of military infrastructure projects.

These include:

1) The restoration of roads in expropriated areas;

2) The restoration of export routes important to the economy;

3) Preparation for the full restoration of the country.

In the perspective of post-war reconstruction, the main forms of interaction between local self-government bodies of rural local authorities and other participants in the implementation of infrastructure projects are mainly:

- public-private partnership;
- cooperation in the development of agricultural clusters and technology parks;
- interaction between state and local governments with self-regulatory organizations;
- partnership at the local level to support rural community initiatives in the development of village social infrastructure.

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LITHUANIAN MARITIME ACADEMY

SECURITY OF MODERN INFORMATION TECHNOLOGIES IN MARITIME TRANSPORT UNDER SIGNIFICANT INCREASE CONDITIONS IN CYBER THREATSRISK

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Abstract. In this work on the theme "Security of modern information technologies in maritime transport under significant increase conditions in cyber threats risk", presence, degree of risks and threats of cyberattacks on maritime transport were considered and analysed in detail. The development of modern information technologies as a means of protection and combating the growing trend of cyber threats, as well as the degree of damage caused in the maritime industry as a whole, is determined. The joint interaction analysis of international maritime organizations and leading transport associations to develop a general strategy for combating cyber threats was carried out.The degree of vessels protection against possible cyber threats and development of information technologies for their prevention are considered.A comparative analysis of cyberattacks development chronology in the world and tendency towards their growth was chosen as the method of scientific research and, as a conclusion, the need to unite leading maritime organizations efforts in countering cyberthreats. The conducted research can be useful in creating an effective information security system and combating cyber threats.

Keywords: cyber security in maritime industry, vulnerable vessel systems, cyberattacks, terrorism and transport security, IT technologies in modern maritime industry.

Introduction

The presence, degree of risks and threats of cyberattacks on maritime transport, development of modern IT technologies as a means of protection and combating the growing trend of cyberattacks, as well as the degree of damage caused in the maritime industry as a whole are considered and analysed in detail. The joint interaction analysis of international maritime organizations and leading transport associations to develop a general strategy for countering cyber threats is being carried out. For the ship's electronic on-board systems interconnection, electronic maps and software updating and for the ship's crewmembers needs, the need for Internet active use has emerged. All this significantly increased the degree of planned cyberattacks on the entire system of the ship's electronic equipment. However, predicting the cyber security future is difficult because a lot of data remains secret, and no one is completely sure of the methods used by attackers to penetrate systems, and companies themselves do not want to disclose the security measures they have adopted.

The object of the research is cybersecurity in maritime industry. The goal is to analyse the factors of cyber security in maritime industry. The main tasks are the following:

1) to describe to cyber security and cyber security prevention in maritime industry;
2) to analyse applications of information technologies in maritime industry;
3) to highlight the human factor as a problem in cyber security.

The methods of the research based on the analysis of scientific literature and practical cases of maritime industry.

The global spending on cyber security be close to 70 billion USA dollars, the USA is growing at a rate of 10-15% per year and annually, many key employees of information security services believe that hackers are ahead of them in equipment and development by 2-5 years, requiring the

development and implementation continuous cycle of stronger and more innovative protection mechanisms.

1. Cyber security in maritime industry

Currently, a global trend that fully affects maritime transport is economy progressive digitization. Electronic navigation is actively developing in maritime transport. Vessels are increasing in size and crews are decreasing in number due to the increasing vessel operation processes automation. Onboard systems receive updates during sailing, crews have access to the Internet (Meland et al., 2021; Gavalas et al., 2022).

To vulnerable vessel systems International Maritime Organization (IMO) belongs to:

- integrated systems of the ship's running bridge;
- cargo handling and management systems;
- engine, machine and power management systems;
- access control systems;
- passenger service and management systems;
- shippublic internet networks, which are intended for passengers use;
- administrative systems and networks;
- internal and external communication systems.

Based on this, it can be concluded that the vessel is extremely vulnerable to a planned cyberattack.

In June 2017, the IMO Maritime Safety Committee adopted Resolution MSC.428 (98) - maritime cyber risk management in safety management systems. The resolution calls on administrations to ensure that cyber risks are adequately addressed in existing security management systems no later than the first annual review of a company's compliance document after January 1, 2021.

International Maritime Organization (IMO) has already prepared the 3rd version of "Guidelines on Maritime Cyber Risk Management" and recommended "Cyber Security Onboard Ships Guidelines" developed by leading maritime transport associations. In 2019, the International Chamber of Shipping together with BIMCO prepared "Cyber Security Workbook for Onboard Ship Use".

International Organization for Standardization and International Electrotechnical Commission developed and published the 27001 standard for information technology.

In the United States of America, „US National Institute of Standards and Technology Framework for improving critical infrastructure cybersecurity" has been adopted.

The first forecast confirmations about possible sanctions in foreign ports have become available. On October 27, 2020, the USA Coast Guard published Work Instruction CVC-WI-027, "Vessel Cyber Risk Management", which provides guidance for inspectors and officials to assess cyber hygiene on board both US-flagged and foreign-to-US vessels as well as complying requirements options when deficiencies are identified. On page 5, actions of inspectors in case of deficiencies detection are defined. In particular, for foreign vessels in relation to the USA, in case of detection any of 2 deficiencies (a total of 3 deficiencies), the vessel detention is provided for.

Despite years of attention from the IMO, the maritime cyber security field remains partially latent. Business owners often hide information about successful cyberattacks against them, fearing such consequences as loss of image, claims from customers and insurance companies, investigations by third-party organizations and government agencies.

Nevertheless, the mass media analysis allows us to concisely describe the current state of maritime cyber security and cite a number of interesting examples.

Thus, May 9, 2020 the Port of Shahid Rajaee, Iran was subjected to a cyberattack. Experts agree that the cyberattack was carried out by Israel.

In 2020, the Australian logistics group TollGroup was subjected to cyberattacks twice within three months.

MediterraneanShippingCo was hit by a cyberattack in April. Due to a network outage in one of the company's data centers in Geneva, the msc.com website was down for more than 10 hours, its social networks were unavailable, and postal services were down.

In the middle of May this year as a result of the cyberattack, approximately 370 (20%) workstations and 20 (10%) servers of the Anglo-Eastern company were encrypted.

Israeli company NavalDome, specializing in the field of maritime cyber security, has conducted a series of successful demonstration cyberattacks on naval vessels. As a result of „hacker“attacks, information about the ship's location was changed, radar display was misled, ship's equipment was turned on and off, and fuel management system, steering control and ballast system were taken under control. A video about the cyberattack results is available on the company's website.

NavalDome estimates a 400% increase in hacking attempts since February 2020. This growth is largely related to the employees transition of remoting work mode.

64% of those surveyed in 2020 by SafetyatSea magazine and the BIMCO (Baltic and International Maritime Council) maritime cyber security survey said that their companies have a business continuity plan in the event of a cyber incident. The percentage obtained during the survey seems significant. However, this share is only among those who agreed to participate in the survey!

According to estimates by Lloyd's of London, the damage from cyberattacks in maritime industry is estimated at $200 billion. With a low level of insurance, approximately only 10% of losses from cyberattacks will be covered by insurance.

The main trend of recent times is that cyberattacks are increasingly becoming a part and tool of a general crime, rather than a self-sufficient crime.

Attackers are less interested only in stealing data from corporate IT systems. Now they are actively trying to understand how to take control of vessel operational networks and systems, denoted by the term operational technology.

According to the experts of Maritime Executive magazine, the sea piracy evolution lead to the fact that pirates will be able to capture the vessel command and control systems (Международный морской журнал “Судоходство”, 2020).

International Ports and Harbours Association's cyber security white paper emphasizes that a vessel itself can also pose a threat to a port facility (IMO, 2004).

Cyberattacks pose serious risks to the unmanned shipping development. Guidance and consultation documents on maritime cyber security have been developed by the authorities of the USA, Great Britain, the European Union, Denmark and Norway. Of course, the list is not exhaustive. These are only those documents that came into view. Looking at the published documents on maritime cyber security, it can be stated that the International Maritime Organization, other international organizations and foreign governmental organizations use a sector approach to regulation.

Information received from shipping companies indicates that from January 1, 2021, maritime administrations of a number of IMO member countries will begin checking vessels entering their ports for compliance with IMO cybersecurity recommendations.

The reason for special attention to this theme was:

1. Organization practical implementation of Chapter XI-2 requirements of the International Convention for the Safety of Life at Sea of 1974 and International Ship and Port Facility Security ISPS Code.

2. Abroad, there is a consensus on cyber security assessment relationship and cyber security plan to other documents.

Currently, preparations have begun for the joint pilot project implementation with shipping companies to conduct a cyber security assessment, develop a cyber security plan, as well as policies, processes and procedures for both the companies' ships and the companies themselves.

Thus, it is appropriate to consider maritime cyber security as a relevant issue for the industry as a whole (United States Court, 2018; Chang et al., 2019; IMO, 2021).

In this direction, all segments of port economy should be immersed in the digital environment. Fully automatic container terminals are already being successfully operated, such as Dutch Maasvlakte II or Chinese Qingdao New Qianwan Container Terminal.

The most famous incident related to port cyber security occurred in the port of Antwerp in 2012. For about two years, the port's systems were subjected to targeted cyberattacks organized by a drug cartel. Presumably back in June 2011, hackers took control of the terminal's systems and operated loading and unloading operations without port knowledge.

In 2017, as a result of the large-scale NotPetya virus epidemic, 17 out of 76 cargo terminals of the Maersk company stopped, and in 2018, the ports of Barcelona and San Diego suffered a cyberattack.

According to Israeli Internet security company ThetaRay, there was a case where a hacker managed to tilt a floating oil rig to the side, forcing it to shut down.

And in 2010, on a drilling rig on route from South Korea to Brazil, malware caused the ship's systems to shut down. As it turned out, computer and control systems were full of viruses.

Unfortunately, this situation is typical for many ships.

In June 2017, the IMO Maritime Safety Committee adopted Resolution MSC.428 (98) - maritime cyber risk management in safety management systems. The resolution calls on administrations to ensure that cyber risks are adequately addressed in existing security management systems no later than the first annual review of the company's compliance document after January 1, 2021.

IMO recommends the “Cyber Security Onboard Ships Guidelines“ developed by leading maritime transport associations and the “US National Institute of Standards and Technology Framework for Improving Critical Infrastructure Cybersecurity“.

The draft resolution of XVIII International Conference “Terrorism and Safety on Transport“ (item 16) calls on the federal executive authorities, when considering the committing acts threats of illegal interference in transport infrastructure objects activities, when conducting a vulnerability assessment and developing plans to ensure transport security, to take into account the committing acts ways of illegal intervention using cyberattacks, make appropriate changes to the threats description.

An important industry feature of maritime transport is that information security issues are also regulated by legislation and norms of international industry associations.

IMO recommends that cyber risk management be carried out through the existing maritime natural extension and vessel security management methods. The IMO considers cyber security as part of maritime security.

In view of the aforesaid, it is possible to predict collisions in law enforcement. Formation of a unified industry policy in the information security field is not a task or obligation of federal authorities in the field of transport. Their competence in this area is limited to subordinate organizations and institutions

Let's look at the same question from the transport safety point of view. The data bank threats to information security contains as of June 14 this year, information on 213 threats and 21,617 software and hardware vulnerabilities. However, the transport security legislation does not consider cyber-attacks as acts of illegal interference, but their implementation threats as threats of illegal interference acts. That is, information security separately, and transport security separately.

2. Ways to solve cybersecurity problems in shipping industry

The maritime industry, as well as the ports and terminals that support it, are important to the global economy, as well as to national and international security.

Today, the maritime industry is highly vulnerable to the integration of previously autonomous operational technology (OT) systems that physically control multiple systems on vessel’s board with information technology (IT) systems that are deployed on board and ashore. As the maritime industry continues to adopt cloud computing, the Internet of Things (IoT) and autonomous technologies,

relationship between OT and IT will grow rapidly, leading to even higher risks. In fact, cyberattacks on OT systems in maritime industry have already increased by 90 percent over the past three years (Meland et al., 2021; Gavalas et al., 2022; Akpan at al., 2022).

A cybersecurity incident or successful cyberattack on maritime IT and OT interconnected systems can have serious consequences both regionally and globally. These include, but are not limited to: health and safety impacts, environmental incidents, supply chain disruptions, reputational/brand damage and financial losses.

To make matters worse, cybersecurity is a relatively new field in maritime industry, with rapidly evolving technologies and emerging threats. Many maritime organizations may lack the specialized expertise and knowledge to identify, assess, manage and respond to cyber threats.

Cybercriminals can use attack techniques such as navigation spoofing and satellite hacking to manipulate vessel's GPS and set it up for collision or physical attack. Other methods are aimed at stealing confidential information for ransom.

In the last few years, there has been a steady increase in cyberattacks on terminals and shipping companies. In fact, as shown in Table 1, all four of top shipping companies have been tested by cyberattacks. In September 2020, French container shipping line CMA CGM SA reported a malware attack at two of its Asia-Pacific subsidiaries. The company said some of its data may have been stolen in the attack, which caused its online booking platform to go down, cargo delays and electronic communication with customs authorities to be disrupted.

Table 1. Recent cyberattacks on maritime objectives

Date	Victim	Location	Incident Type	Malware
May 2017	Clarksons LLS	UK	Unidentified Hacker(s)	Unknown
June 2017	Maersk	130 countries	Ransomware	Not Petya
July 2018	China Ocean Shipping Company (COSCO) Terminal	Long Beach Port, CA, USA	Ransomware	Unknown
Sept 2018	Port of Barcelona	Spain	Attack	Unknown
Sept 2018	Port of San Diego	USA	Ransomware	Sam Sam
July 2019	Deep Draft Vessel Round for thePort of New York	New York. USA	Malware	Emotet
April 2020	Mediterranean Shipping Company (MSC)	Geneva, Switzerland	Malware	Unknown
May 2020	ShahidRajaee	Port Terminal	UnidentifiedHacker(s)	Unknown
Sept 2020	CMA CGM SA	Asia-Pacific	Ransomware	Ragnar Locker
Sept 2020	US Tugboat	Louisiana	Phishing Email	Unknown
Oct 2020	The International Maritime Organization (IMO)	International	Malware	Unknown

Source: Международный морской журнал “Судоходство” (2020). Осторожно, злой… хакер! Как решить проблему кибербезопасности в судоходной отрасли? https://bit.ly/3YCxBS5

Around the world, regulatory bodies, industry associations, and standards bodies recognize the urgency of addressing cybersecurity challenges. Regulatory rules with which maritime operators should be familiar: International Maritime Organization (IMO) Resolution MSC.428 (98) „Maritime Cyber Risk Management in Security Management Systems“ and MSC-FAL.1 / Circ.3 „Guidelines on Maritime Cyber Risk Management“ call on organizations to ensure that cyber risks are adequately addressed in existing security management systems no later than the first annual review of a company's Compliance Document after 1 January 2021.

The guidelines provide high-level instructions on maritime cyber risk management to protect against current and emerging cyber threats and vulnerabilities. Owners risk having their vessels detained if they do not incorporate cyber security into their security management systems by the deadline (Mission Secure, 2021).

In order to improve information protection on vessels, information on new requirements for information protection (Cybersecurity) is offered: the Circular MSC-FAL.1 / Circ.3 “Guidelines on

Maritime Cyber Risk Management“ and the International Code for Vessels and Port Facilities Security (Mission Secure, 2021, IMO, 2004) (Table 2).

Table 2. Implementation plan of the information (cyber) security management system (ISMS)

No.	Measures	Functional element
1	*2*	*3*
1.	Update the policy in the security fieldand contamination prevention to include the cyber risks analysis, development and approval of the Policy in cyber security field and company's personnel familiarization (clause 2.2, ISMC)	Identification
2.	Update the information on responsibility and authority specified in the SMS to establish the responsibility and authority for managing cyber risks and cybersecurity for the SMS, including the organizational chart development of the Company's SMCS (clause 3.2, ISMC)	
3.	Determine the need for personnel training, which may be necessary for cyber risk management in SMCS in accordance with current company procedures (clause 6.5, ISMC)	
4.	Determine the (critical) equipment and technical systems (OT and IT), sudden failure of which can lead to dangerous situations in accordance with the company's current procedures (clause 10.3, ISMC)	Protection
5.	Assess all identified risks for vessels, personnel and the environment and establish appropriate safety measures (clause 1.2.2.2, ISMC)	
6.	Update procedures, plans and instructions for key vessel operations related to the personnel safety, vessel and environmental protection, which are related to OT (clause 7, ISMC)	
7.	Update emergency plans regarding response measures to cyber incidents (clause 8.1, ISMC)	
8.	Update the informing procedures about non-conformities, accidents and dangerous situations, including the reports preparation on cyber incidents (clause 9.1, ISMC)	Detection
9.	Ensure the appropriate resources availability and shore units support to the Designated person to respond in case of critical systems failure (clause 3.3, ISMC)	Response
10.	Update the implementation procedures of corrective actions reflecting cyber incidents and measures to prevent their recurrence (clause 9.2, ISMC)	
11.	Update the specific measures aimed at increasing the reliability of equipments or technical systems (clause 10.3, ISMC)	
12.	Develop procedures for creating a backup copy and recovery and include them in the planned and preventive maintenance system (clause 10.4, ISMC)	Restoration

Source: Mission Secure (2021). A Comprehensive Guide to Maritime Cybersecurity. https://bit.ly/4079fkB; IMO (2004). International Code for Vessels and Port Facilities security. imo.org.

The main functional elements contributing to the cyber risks effective management are the following (Table 2):

1. Identification: defining the tasks and responsibilities of cyber risk management personnel and identifying systems, resources, data and functionality that, in the event of failures, may pose a threat to the vessel’s operation.

2. Protection: implementation of risk control procedures and measures; planning actions in the event of an emergency in order to prevent cyber incidents and ensure vessel’suninterrupted operation.

3. Detection: development and use of measures necessary for timely cyber incidents detection.

4. Response: development and implementation of measures and plans to ensure fault tolerance and restoration of systems necessary for the operation of the vessel or functions disrupted as a result of a cyber incident.

5. Restoration: measures identification for backup duplication and necessary cyber systems restoration for the vessel’s operation, which were affected as a cyber incident result.

3. General application of information technologies in maritime industry

In modern maritime industry, IT technologies play a very important role, and their role and importance are constantly increasing. All these processes are closely interrelated. More precisely, we can say that they represent a single innovation stream in maritime industry. At the same time,

introduction of these technologies creates relevant problems that cannot be solved exclusively by technical and technological means. Adequate political and legal solutions are needed, the shortage of which is already felt. Therefore, security issues, especially cybersecurity, the Internet development, in particular, the Internet of Things, as well as blockchain technology application and the furthervessel automation implementation, up to fully automatic vessels, will be in the center of our attention (IMO, 2004).

In 2017, cyber attacks revealed vulnerabilities in navigation and other information systems on vessels and in ports. For example: there was interference with automatic identification systems and electronic maps, jamming of global positioning systems and manipulation of cargo and ship management systems, including by introducing malicious programs, ransomware and viruses (Interlegal, 2018; Akpan et al., 2022; Gavalas et al., 2022)

To date, international cyber security rules in maritime industry have not yet been adopted. At the same time, the IMO guidelines for managing cyber security risks in seaports contain high-level recommendations for international shipping protection from existing and potential threats in cybersecurity field. These recommendations help reduce the vulnerability associated with them. The IMO Principles contain five functional elements for effective risk management in maritime industry, namely: identify, protect, detect, respond and restore. To be effective, these elements must be incorporated into all aspects of shipping company's operations and personnel management. Currently, issues of safety culture are being developed within the framework of the International Safety Management Code (ISM Code).

The main purpose of the Code is to create an international standard for safe management and operation of vessels and the prevention of environmental pollution. It sets out safety management objectives and mandates that the shipowner or any other authorized person (for example: an operator or bareboat charterer who has assumed responsibility for vesseloperation) create a safety management system and establish appropriate policies to achieve security purposes. In accordance with IMO Maritime Safety Committee Resolution No. 428 (98) on cyber risk management issuein safety management systems, the administration undertakes to ensure that cyber risks are accounted for in information systems defined in the Code no later than the first annual review after January 1, 2021.

The Internet of Things technology is a connected devices network with unique identifiers in the form of Internet Protocol addresses that have embedded technologies or are equipped with technologies that allow them to perceive, collect data and report on the environment in which they are located and / or themselves.

Shipping industry is increasingly using data obtained from satellites and sensors linking equipment, systems and mechanisms to support informed decision-making on route optimization, object tracking and mechanism maintenance. Applications that can be used in this area include, for example, a program that uses data obtained by satellites to determine the most efficient route and estimate the arrival times of vessels in real time, as well as the latest smart containers that use sensors and telemechanic for tracking temperature, vibration, humidity and air quality indicators during sea transportation. For example, Maersk and MSC use these technologies to track the refrigerated containers movement.

Also, the Internet of Things is increasingly used in the industry to improve communication between the vessel and the shore, for intelligent traffic management. A closer interface between vessels and ports includes, for example, the analysis of large databases to reduce transit time and the time spent by vessels entering ports and other high-traffic areas, thereby helping to reduce port congestion. For example, digitization cooperation initiative between the Port of Rotterdam and IBM is helping to prepare the port to further accept vessels up to 42 km away to improve the safety and efficiency of the port.

A similar joint initiative was also shown by the Maritime and Port Administration of Singapore, academic institutes of Singapore and the Fujitsu company, to implement the Internet of Things and Artificial Intelligence technology to provide long-term traffic forecasting, calculation of access points and formation of intelligent coordination models.

The Internet of Things is also used to develop systems that support navigation in difficult environments, for example, in adverse weather conditions or on congested waterways. Thus, in March 2018, the Rolls-Royce company launched an intelligent information system, which includes several sensors with intelligent software to create a three-dimensional model near vessels and dangerous areas, in order to improve safety.

Other application areas of the Internet of Things are remote control of vessels departure without human intervention, remote transition control and automatic docking.

As soon as it becomes possible to record vessels departure in real time, it will be possible to optimize operations using blockchain technology, for example, to track reserve capacities, improve communication between different stages of the transportation route, and improve port capacity.

Among the achievements in cyber systems field and digitization in maritime industry, autonomous sea surface ships attract special attention. Like autonomous technologies in other industries, automated ships can provide increased safety and cost savings by removing the human factor from certain operations. However, the concepts of “autonomous ship“ and “unmanned ship“ are not identical, since the former can act autonomously to varying degrees, including as partially autonomous, that is, with person participation, and fully autonomous, that is, without any human intervention. However, these terms are not yet fully defined either at the national or international levels, and there are many different formulations of autonomy levels.

4. Human factor as a problem in cyber security

It is impossible to ensure one hundred percent cyber security. Even at the highest level, when government organizations are the objectives, neither huge budgets nor thousands of employees with connections around the world will help prevent an attack completely. Among large corporations, which deduct serious funds for protection organization and compliance with procedures, the situation does not stand out much. Take, for example, the attack on the British Airways flight check-in system: it paralyzed the company's work, which reverberated throughout the airline industry.

Shipping is at a lower level. Budgets are smaller there, although management companies and on board ships have employees responsible for cybersecurity (Chang et. Al., 2019; Meland et al., 2021). The example of the Maersk attack shows that even a large business can be forced to stop work for almost a day by disrupting logistics chains timing. Losses from such attacks can be calculated in billions of dollars.

The most underestimated risk in relation to cybersecurity is related to people (Kadena & Gupi, 2021). We all know very well that there is turnover in crews, that crew members bring personal smartphones, tablets, laptops and connect to wireless networks. Sometimes they connect where they shouldn't and do something online that they shouldn't.

Main mistake is psychological properties, when people sincerely believe that they can break anyone, but not them. For those who think so, it is important to understand: cyber adventures happen every day, and one day they will become victims. Whenever you see a phishing email in your inbox, someone is targeting you, hoping to get money, information, resources, or something else. Therefore, you need to monitor your own cybersecurity in the same way that you monitor the safety of money in your accounts.

Although there are a number of IT advantages, there are still problems in their implementation. In addition, the question remains as to whether insurers and mutual insurance clubs will offer insurance coverage for commercial fully automated vessels. Also of particular concern is the potential loss of maritime professions in developing countries. In general, it is impossible to predict the social effects of IT development in all details. Of course, in short term, there can be very painful processes in economic and social, for example, labour relations. This is especially relevant for countries that lag behind in economic and technical terms.

However, in long term, IT beneficial impact on all spheres of social life is absolutely obvious. Moreover, it is impossible to stop progress in the field of automation and informatization of the industry in general and maritime industry in particular. Thus, it can only be a matter of finding such

solutions and ways of development that would mitigate the diseases of growth, in no way hindering high rates of development achievement of IT. The Internet stable growth is introduction condition of technologies such as Artificial Intelligence and the Internet of Things. Of course, the risks associated with information technologies development require special management. However, there is no doubt that progress in this area opens up new opportunities to ensure safety and compensate for possible negative consequences in short and medium term.

Thus, we see that effective information security system creation is a complex and time-consuming process that requires substantial financial costs, organizational and training measures.

Conclusions

1. The International Maritime Organization considers cyber security as part of maritime security. IMO recommends that cyber risk management be carried out through the existing maritime natural extension and vessel security management methods. In view of the aforesaid, it is possible to predict collisions in law enforcement. Formation of a unified industry policy in the information security field is not a task or obligation of federal authorities in the field of transport. Their competence in this area is limited to subordinate organizations and institutions. From the transport safety point of view the transport security legislation does not consider cyber attacks as acts of illegal interference, but their implementation threats as threats of illegal interference acts. The information and transport security are treated separately.

2. In modern maritime industry, IT technologies play a very important role, and their role and importance are constantly increasing. Four most significant trends stand out, in particular, the Internet of Things, as well as blockchain technology application and the furthervessel automation implementation, up to fully automatic vessels, will be in the centre of our attention. At the same time, introduction of these technologies creates relevant problems that cannot be solved exclusively by technical and technological means. Adequate political and legal solutions are needed, the shortage of which is already felt.

3. In accordance that ships crew members bring onboard personal smartphones, tablets, laptops and during the voyages connect it to the shore wireless networks. These connections not always are secure and the personal IT equipment can be “open gates” for cyber attacks. Thus, human factor is primary, so every ships should have clear rules that define what can and cannot be done.

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"SANDPITS" AS AN INNOVATIVE METHOD OF TRANSDISCIPLINARY RESEARCH IN HIGHER MARITIME EDUCATION

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Abstract. The "Sandpits" is analyzed as a transdisciplinary research method in higher maritime education, which requires a paradigmatic transformation of the educational process, the development of students' exploratory competences, deductive and inductive skills and other. The article analyses the peculiarities of this approach, during which participants go through an intensive path of innovative, out-of-the-box thinking and brainstorming. The researchers find that the key ideas are not those that have been prepared before, but those that are developed from scratch at the event itself, created in a few days by participants who have just made contact. The results of the implementation show that participants are challenged in an interactive process with researchers from disciplines with which they do not normally collaborate. The authors determine that the implementation of collaborative activities can be effective if there is mutual involvement in key activities, such as defining research questions and problem solving, cooperation aimed at achieving an agreed common goal, and regular contacts between group members, during which they try to collectively influence the development of an unconscious common scientific identity. The publication emphasises that the implementation of the "Sandpits" opens up new avenues for scientific research, allowing it to be viewed in a new, interdisciplinary dimension.

Keywords: Sandpits, method, synergy, transdisciplinary approach.

Introduction

Nowadays, in the modern educational environment, in particular in higher maritime education, there is a need to innovate approaches to encourage and develop research competence for students. Modern scientific research is polyphonic in its essence, so many approaches and ideas could be considered. The most interesting of the approaches is synergetic (Haken H. 2006), which focuses on the enormous possibilities of transdisciplinary research. Nowadays there is a demand to explore innovative approaches to encourage different groups of researchers towards cooperation in addressing technical and humanitarian issues in higher maritime education. To effectively achieve a succession of tasks, it is advisable to implement joint interdisciplinary initiatives. The central place of interdisciplinary research in addressing the challenges of the XXI century is evidenced by a number of developments in theory and practice. Scientists perceive the task of interdisciplinary cooperation in effective integration, which takes into account the relevant norms and values of different communities sufficiently to enable collective action around specific research tasks. This can be accomplished through participatory research processes in which researchers address specific issues that arise around value contradictions. Studying this process as a collective scientific inquiry provides insight into the dynamics through which meaningful interdisciplinarity is formed in practice (Maxwell, Benneworth, 2018).

Modern pedagogical research devotes a lot of attention to the transdisciplinary approach in the educational process. Research indicates that the integration of academic disciplines, continuous scientific research and finding effective ways for future specialists to acquire theoretical knowledge and practical skills will provide a new consolidated basis for the implementation of vocational higher education requirements (Daneshpour, Kwegyir-Afful, 2022). This issue is very relevant in contemporary studies of pedagogy, philosophy and other social sciences and humanities, as it is

considered by such Ukrainian researchers as Ganaba, S., Dolska, O., Zabolotna, O., Zelinskiy, S., Lebid, A.

In foreign studies the issues of transdisciplinary, synergy stimulation and knowledge integration were studied by Osborn, T. Nicolescu, B., Klein, J. Th, Jantsch, E., Galvani, P. and others (UNESCO 2020). Thus, successful and coherent participation in interdisciplinary research, and now it is possible to speak about transdisciplinary research, requires participants to make assumptions in accordance with the standards established in at least two different research communities.

Actual issues of higher maritime education are actively pointing to the challenges and relevance of finding new transdisciplinary approaches to activities, in particular to the study of technical and humanitarian issues. Thus, O. Barylnyk-Kurakova argues that interdisciplinary links in the system of professional training of future maritime specialists are an integral part of the development of a modern maritime specialist, as it contributes to the training of highly qualified personnel competitive in the labour market (Korobova, Barylnyk-Kurakova, 2020).

The **object** of the study is "Sandpits" as an innovative methodology for researching technical and humanitarian issues.

The **aim** is to analyze the use of "Sandpits" to actualize changes in research practice in higher maritime education.

The **tasks** of the research are the following:

1. Identify the features of Sandpits as an innovative methodology for researching technical and humanitarian issues.
2. Analyze the experience of implementing "Sandpits".
3. Discuss the results of the implementation of "Sandpits" as an innovative methodology for researching technical and humanitarian issues in higher maritime education.

The research **methods** include: analysis of scientific literature (as a decomposition of the whole complex phenomenon into its components, simpler elementary parts and the allocation of individual sides, properties, connections), synthesis (as a combination of components of a complex phenomenon, that is, knowledge that expands previous experience, constructs something new), interpretation (interpretation of features and results), generalization (fixing common features and properties of objects, making the transition from the individual to the general, from less general to more general).

1. Sandpits methodology

"Sandpits" claim to be innovative determinants of generating ideas for solving vital technical, humanitarian, philological and other issues. "Sandpits" research, where an interdisciplinary group of researchers and practitioners come together for a limited time to generate new ideas on a specific topic, is becoming increasingly common as a way to encourage innovation and creativity in research. This intensive event aims to encourage the transition from individual researchers interested in a particular problem to the formation of teams that present more or less well-founded ideas to research councils. Typical "Sandpits": participants spend the first few days actively thinking without the usual institutional constraints to imagine how research could develop with a group of participants. All the following days are devoted to selecting and combining these creative ideas, turning them into ideas for concrete proposals that will be decided in a more traditional form afterwards.

The feature of such events is that:

- participants of "Sandpits" go through an intensive way of innovative, non-standard thinking and brainstorming;
- the key ideas are not those that were prepared earlier, but those that were developed from scratch at the event itself, created in a few days by specialists who have just made contact;
- participants are challenged in an interactive process with researchers from disciplines with which they do not normally collaborate;
- establish regular contacts between members of the group, during which they try to collectively influence the development of an unconscious common scientific identity.

Implementation of joint activities can be effective provided that mutual involvement in core activities such as defining research questions and problem solving; collaboration aimed at achieving an agreed common goal.

Through this "Sandpits" format, however, it was hoped to bring together different disciplines and stakeholders to generate new ideas, learn more about opportunities, and provide participants with the opportunity to make connections that can continue into the future. A constant feature of the discussion with the participants and a frequent point of reference for personal reflection (as "Sandpits" coordinators) concerned the question of how, and if so, to what extent, disciplines can interact.

Thus, "Sandpits" open new ways for scientific research allowing us to consider them in a new, interdisciplinary dimension.

2. Empowering Sandpits in practice

The event was attended by 10 first-year cadets of the Faculty of Navigation. The language of the event was English. They were faced with a number of challenges: the search for effective sea routes. The cadets had to work out on their own the peculiarities of the geographical location of territories and ports, to know the requirements for the technical condition of the vessel to pass this zone and to take into account all the factors that may affect the passage. Two teams were organized, each team had to develop the most dangerous ways of the vessel and prove the effectiveness of the implementation of such a way, taking into account the technical features of the vessel, the specifics of geographical zones, etc. The experimental work took place during several days: the first day was the acquaintance of students with each other, communication in order to understand each other's preparedness, exchange of thoughts and ideas (2 hours). The second day: the direct solution of the task (3 hours).

In order to determine the effectiveness of this event and the personal impression of the participants, we conducted a survey.

The followings questions were suggested:

A. Was the format of the training convenient/not convenient / undecided?

B. Did you feel comfortable/not comfortable / undecided?

C. Was the learning process using the scientific research method "Sandpit" interesting/not interesting/undecided?

D. When working in a team, was I heard/not heard/not included in the process?

3. Outcomes of the event

Most participants assessed the event as effective, which was determined by a number of indicators, which included:

a) convenient format of engaging participants in cooperation (allowed ensuring the balance of interests between researchers and creative and active practitioners). Thus, 5 (50%) of higher education applicants noted the convenience of the format of work, 4 (40%) of higher education applicants did not feel comfortable in the process of work. 1 (10%) student has not decided on the specifics of working with this methodological tool;

b) each participant felt comfortable, and each participant's opinion was of equal value to the opinion of other participants. Thus, 9 (90%) of higher education applicants confirmed the feeling of comfort while working in the Sandpit. 1 (10%) applicant could not say for sure whether he or she felt comfortable while working or, on the contrary, it was uncomfortable;

c) all participants acknowledged that the learning process using the Sandbox method is interesting, all 10 (100%) of higher education students noted that this method makes it easier to perceive and remember information, because during the work, attention, memory, motivation to find the answer as quickly as possible, even a certain degree of competition are maximally involved.

d) as a result, the event was quite inclusive and the opinions of the participants were properly reflected. 8 (80 %) of higher education students confirmed that their opinions and ideas were taken into account in the process of work and created conditions for a comprehensive analysis and critical evaluation of the proposed solutions to educational problems. 2 students (20%) could not decide on

a specific answer or whether they were able to get involved in the work process. Perhaps, the main role here was not played by the ability to work in a team, but this is the task of another study, which has significant prospects not only for studying the specifics of the scientific sandbox method, but also issues related to the formation of teamwork skills.

The participants suggested launching a series of "Sandpits" following the main series of events, using the following methodology:

- the initial stage is to identify the dominant problem and secondary issues that objectively arise in the process of deduction;
- the second stage - determination of effective ways of further epistemological search using the inductive method;
- the third stage is the organisation of management and implementation of the identified ways through the explication of the results obtained on all key components of the educational problem to be solved;
- the final stage is the discussion of the results, their verification, validation and extrapolation of the developed solutions.

Conclusions

The analysis of the study on the implementation of the "Sandpits" as an innovative methodology for researching technical and humanitarian issues and for actualising changes in the scientific practice of higher maritime education has made it possible to draw certain conclusions.

1. The study revealed certain features of the "Sandpits" as an innovative methodology for researching technical and humanitarian issues. In more details, using research "Sandpits" as a teaching method in higher maritime education, it is possible to actively develop basic general scientific competences, such as fundamental knowledge of the peculiarities of the scientific process of cognition, understanding of the cause and effect relationships of the development of the process of scientific cognition and the ability to use them in professional and social activities. To develop and improve social and personal competences, especially teamwork and interpersonal communication skills: the ability to interact with other members and work in a team, the ability to form interpersonal relationships in a team, to defend one's own position during a discussion; a positive attitude to the "dissimilarity" of thinking and research and, at the same time, sociability, responsibility, dedication, ability to self-development and self-improvement. Thus, sandbox research creates an opportunity to deepen the knowledge of higher education students, as they have to master a number of issues, prepare for the event, and form their own vision of the situation.

2. Having reviewed the experience of conducting "Sandpits", it was concluded that these competences can be actively developed through the use of a transdisciplinary approach, which creates a number of challenges for students in terms of the level of development of communication skills, the availability of a certain theoretical level of training in a number of disciplines, etc. Thus, the proposed methodology can be reasonably used as an active tool for the formation of the creative personality of a higher education student.

3. The results of the implementation of the "Sandpits" as an innovative methodology for researching technical and humanitarian issues in higher maritime education as presented in the study are the first tentative effort to explore the specifics of the proposed methodology and give reason to assume that the use of research "Sandpits" in the educational process in higher maritime education will have significant prospects for the development of the educational process.

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LITHUANIAN MARITIME ACADEMY

IMPROVING BRIDGE RESOURCE MANAGEMENT THROUGH ECDIS ENHANCEMENT

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Abstract. The widespread use of Electronic Charts Display Systems (ECDIS) in recent years has not always resulted in improved Situational Awareness of navigators, partly due to the way navigation has been conceptualized on the screens. This paper briefly analyzes the causes and looks at ongoing and future developments that may improve this undesirable situation. Particularly relevant are the problems derived from the human-screen interaction, so different from the traditional ones with paper charts, the inherited conceptualization of the maritime space, which seems not to have reached an optimal behavior yet, and the maintenance of awareness via warnings and alarms, a very relevant issue that however has been little addressed in the academic field. Almost as a conclusion, it is discussed how training methodologies could help to overcome most of these problems, provided that they are treated with a prism closer to the BRM than to pure computer training. It also opens the door to MiniECDIS systems, a scaled down and optimized version of ECDIS, as an efficient means of transmitting traditional maritime knowledge to small vessels that will soon be orphaned from paper charts.

Keywords: Nautical charts, BRM, MiniECDIS

Background

The navigational charts represent a technological milestone in the history of mankind, not only for the quality and reliability of the charts themselves, but also for the whole process from the manual survey, their updating and distribution to the most remote places on the Planet.

Navigation charts represent a technological milestone in the history of mankind, not only for the quality and reliability of the charts themselves, but also for the whole process from the manual survey, their updating to their distribution to the most remote places on the planet. All this implied a perfection and optimization of resources difficult to imitate. The navigation charts, unlike the usual more or less thematic land maps, offered all the necessary information for navigation in open format, including some in "real time", such as magnetic declination or tidal diamonds.

Indeed, only the development of computers, and more specifically, the spectacular improvement in graphic outputs that came around 1990, was able to provide an alternative solution to paper charts. In fact, this made possible the development of GIS and within these, of ENC, as a logical and peremptory application (Kerbiriou 2021).

It is worth remembering here some important initial efforts, such as that of Cardiff University around 1999 (CEM 2000), which already designed a system to send Notices to Mariners, text with chart updates, to fishing vessels operating in oil exploitation areas of the North Sea. At that time the constant changes to the platforms and their services caused many accidents, and updating was particularly important.

Things have changed a lot since then and ECDIS is now mandatory for large vessels, although for the time being, they can only use ENC, i.e. official, charts. And yet, although there is no doubt that its use revolutionized the way of navigating, there is no doubt that the system was born with some serious flaws in origin, which have been only partially debugged over the years.

It seems that the main problem is the predominance of legal and technical aspects, in that order, over "purely nautical" ones. This led to an excessively rigid formulation of how the devices should be and, logically, as happens with everything in the computer world, this rigidity quickly translated into obsolescence. The issue of the use of mouse and integrated keyboard was one of the most noticeable.

But the issue was very different for smaller vessels, at least in the case of Spain, although this is most likely also the case for most of the Mediterranean. Paper charts on these vessels continues to be mandatory, even though their use has practically disappeared on boats below 30 m length.

The process began with the use of "privately produced" charts, usually plastic-coated of increasingly smaller size, designed for sailboats. In fact, to comply with the law, it is sufficient to keep an up-to-date chart on board, even if it is not used. Or even if it cannot be used, due to the lack of a routing table. This represents a misrepresentation of the principles of coastal navigation. The main issue is that they usually do not have an acceptable cartography, nor updatable, nor are the input sensors those that they should be. Thus, many of them do not have an efficient gyroscope and log on board, even though reliable equipment of very small size is available today. For convenience, they prefer to input basic variables from satellite data, which is, from a nautical point of view, aberrant. In the immediate future, the MiniECDIS would incorporate these technologies and, in addition, should educate about the need for autonomy of each vessel in obtaining the data that matter to it.

We must remember that ECDIS simply shows a model of reality, not a sensorial view, and that for navigation only the information obtained by sensors as sight or radar is actually reliable. The radar image is a sensory image that implies a way of interpreting reality at a precise moment in time. This is why we must insist on the absolute imperative to superimpose a radar image in confined or conflicting waters, as this image can really be considered a “primary navigation” system, because it is an extension of our senses, regardless of the size of our craft. Confusing model with sensor is at the basis of many accidents and above all, it is an absolutely unacceptable perversion of the seafaring tradition.

The situational awareness on paper charts

In traditional navigation with paper charts, the process for locating the vessel was very well defined as it was to locate a series of bearings from the vessel to known points of land, as quickly as possible (usually running!) go to the chart-room, and there draw the lines based only in our memory. Wherever the lines are cut, there our ship will be on the chart.. This technique obviously implied a high level of Situational Awareness, in which any doubt about the veracity of the lines meant, immediately, a check and if necessary, a correction. Compare this with the current attitude of many navigators, staring absent-mindedly at the screen, interacting at a minimum with the data displayed...

From the point of view of the conceptualization of space, the method is practically perfect: a series of straight lines subject to few errors in their tracing, define a point. With two lines, it is enough. With three, it is absolute perfection. The main problem was that the location of the point on land, from which the reverse bearing was traced, was really the right one. But it should be noted that this mechanism was very demanding on the observer's interpretation of the coastal locations. On a slightly known coastline, errors are practically non-existent.

Traditionally, coastal reconnaissance was done on the basis of panoramic drawings, sailing directions readings and, above all, the constant comparison between what appeared on the chart and what could be seen from the bridge. These practices, together with the improvement of the charts, formed a strong theoretical corpus of maritime knowledge. But above and beyond that knowledge, there was the way in which all these practices maintained the navigator's awareness during coastal navigation watches. A person making constant mental calculations from observations of a changing environment can hardly be in a better state of situational awareness.

However, IMO made several proposals to try to improve the situational awareness of mariners, no doubt to alleviate the increasing flow of people from outside the seafaring tradition arriving at bridges around the world. In particular resolution “a.893” (IMO 1999), which tried to homogenize cartographic practices in the layout of passage plans, a problem that hardly had ever been considered as such on board. Basically, the aim was to increase the crew member's awareness and concentration while plotting the routes, by marking with prominent colours those lines that could imply some hazard that would be considered as less radar-sensitive. In fact, the original electronic chart courses, when simulators were not yet available, were based on these practices, which reinforce the idea that they were designed with the idea of transferring those techniques to ECDIS.

Conceptualizing the maritime space

Kandinsky (Kandinsky,1926) taught us that any structure could be reduced, on the plane, to combinations of points, lines, and polygons. The tremendous simplicity of his postulates allowed, in fact, the development of the so called Geographic Information Systems (GIS), which in turn are nothing more than the graphical expression of geo-referenced databases.

GIS, already at the beginning of its development, was applied to nautical charts. From the first raster charts, which were no more than faithful images of paper charts, this "simple" conceptualization made it possible to move on to vector charts. The historical conceptualization of the maritime space had a great weight in this transition, but it was neither respected nor preserved in its entirety. On the contrary, the new ENC charts exhibited some peculiar versions of what had been the traditional interpretation of space. An example of this is the way in which the seabed has been depicted so far. Their quality has only been taken into account in terms of depth, the only variable that has really been reflected, and even then not exactly as a continuous variable.

Thus, the areas considered as shallow depths have always had a leading role, since the use of colour with a combination of blues began to be used. But it was a generic consideration, usually in the -5 and -10m, "valid" for any kind of vessel. However on the "navigable" waters, always represented in white, depths were only indicated at specific points where a sounding was available. Thus, what should be a continuous variable became a discrete one.

Was this a mistake of the paper charts? Could it be considered a bug? Not really, since until very recently the degree of accuracy of the charts was limited, as was the positioning from the bridge. In this way, indicating potentially dangerous soundings depending on the ship was enough to maintain situational awareness at a sufficiently high level. In reality, as a practice, it was a very perfect system, because it must be taken into account that the same chart was used by everyone, from a motorboat to a large ship, and there were no differentiated charts depending on the size of the ships. This is a point that electronic cartography tried to solve, on the basis that in reality the charts would be, so to speak, customized. And not only adapted to each ship but to each moment of navigation, and even for each crew member. Some of this even happens with pilots who board and request to have the ECDIS display as they like.

In fact, one of the main failures of the whole system refers to the inability to correctly reflect the safety contour for a given condition of a ship. This is due to the fact that when composing the charts, the safety contours are included as separate layers, and are very scarce, being available only every 5 m on the European charts. It is the ECDIS itself that selects the first one it finds below the one indicated by the captain. This situation can make the validation of certain routes unfeasible.

This issue is one of those solved by the new s-100 charts, which will be able to display the seabed as a continuous surface. In this way, the ECDIS will be able to interpret at any time a depth that will closely resemble the real one, as is already the case with navigation simulators that triangulate the seabed.

There is even the possibility of distinguishing the qualities of the bottom, with several variables, from those that may have special environmental value, such as *posidonia* meadows, to bottoms suitable for anchoring. In fact, when these charts are available on MiniECDIS equipment, new opportunities for safe navigation of small vessels in shallow waters will open up.

The very legal expression of how hazards are to be depicted is flawed by parameters beyond the control of the mariner: “indication of isolated underwater dangers at depths of less than the safety contour which lie within the safe waters defined by the safety contour” (IMO 1995)

It is also very interesting to think about the way our own vessel is represented on electronic charts. Until now, it was only a point defined by the intersection of two lines after a manual process. With the introduction of electronic positioning systems, it became possible to conceptualize the ship in other ways. Currently, there are several, the most frequent being a double circle that rather than a specific point, defines a small space. This introduction of a doubt is of interest to improve performance in the human-machine relationship. It generates something like a "reasonable doubt"

about the most important question, where are we. It is a doubt that contributes to focus the attention and therefore, to improve situational awareness.

The representation in the form of a line or vector is also common, to which attributes are usually added to avoid excess certainty. It is also possible to display our vessel with a silhouette as close as possible to our real dimensions. But this solution, as it has been exposed in many forums, will hardly reflect the actual situation of the vessel, since it will depend on several factors, such as the actual location of the antenna, the quality of the signal and others that may negatively influence the quality of the location. It should be noted that these vessel silhouettes are tuned to distances in meters, and this level of quality in the geo-referenced graphical representation is too demanding to have blind confidence in it. Anyone can do the test by consulting a ship tracking page on, for example, the Panama Canal, and see how many of them are located above the lock piers and not in the water.

Georeferenced alarms

Among the "buts" that have been put to the ECDIS, the most relevant has undoubtedly been the safety contour that has aroused the most criticism. Since it is based on a design flaw, because safety contours are only available every 5 m, it is easy to blame it. If I have a safety contour of 11 m, ECDIS will automatically assign me a functional one of 15 m, and from then on, when trying to validate the route, a large number of alarms for lack of draft will be triggered, which do not correspond to the actual state of the vessel. For example, in ECDIS we could not "enter" a port with a draft of 13 m, although in reality, it would be possible.

But the truth is that this is not the only serious problem. There are also the alarms, five of which are listed as "mandatory" in the IMO guidelines, plus optional or only warning alarms. If we analyse them, we will see that not all of them make real sense for safe navigation.

Of the five mandatory warnings, some even lack cartographic logic, such as the "Diferent geodetic datum". It is difficult to find charts with datum different from the usual ones, and in any case, in navigation it is not the time to worry about such an abstruse cause. Of the others, the positioning system failure is hardly informative, as positioning should not depend on an external awareness system, but on the skills of the operator. Something similar can be said about the "approach to critical point". Being alert in the most complex places, even without any previous warning, should be the main concern for the navigator.

In fact, the alarm system associated with ECDIS is a typical case of safety understood from a "terrestrial" point of view, which is more based on insurance statistics than on seafaring practice. Alarms are associated with secondary issues for navigation. It is apparent that there is a certain lack of confidence in sailors. It would even seem that from the very beginning manufacturers and regulators have devised a system of artificial maintenance of personal awareness, based on many alarms. It must be recognized that this attitude has even reached the instructors, who have come to teach that "the use of satellite positioning allows greater precision and to obtain situations every few seconds, thus freeing the crew members from the heavy task of navigating". How did this come to be written? Navigating a ship is not a "heavy task", not a punishment, but just an activity that requires good training, commitment and a high level of concentration.

In the in the "Muros" (MAIB 2017) grounding analysis, a lot of ideas related to ECDIS misuse appear. But among them we are going to highlight the contribution of a Danish researcher who among other issues, such as "ECDIS safeguards were ignored, overlooked or disabled" or "The OOW's performance was probably adversely affected by a low state of alertness", simply pointed out:

"Alarm functions were disturbing."

By way of conclusion we can say that if the alarms are geo-referenced, i.e. they are directly linked to fixed obstacles at sea such as shallows or current zones that can be located on the land surface then, they are superfluous because the main function of the navigator is to maintain awareness wherever a fixed danger is in the vicinity. In addition of course, to maintain awareness of moving hazards, i.e. other vessels.

If in the merchant navy, transition from paper to electronic charts are proving complex, on smaller vessels, where electronic charts were not mandatory, the situation may drift towards a collective loss of situational awareness applied to space, which we may call "spatial awareness".

In fact, the current situation in the field of cartography use on small vessels can be described as rather unfortunate. To a large extent, traditional techniques and knowledge of the coastal environment have been replaced by low-cost graphic information, deficient in terms of its expression, without rigor or updating and fed by inadequate sensors or even by external electronic signals subjects to all kinds of dysfunctions. It is also unsatisfactory in terms of the sensors that the ECDIS display brings together, as radar is often not included. In fact the limited use of radar on these vessels is the most worrying, and is at the root of some recent accidents involving professional vessels (CIAM, 2022).

At the root of the problem lies the lack of seafaring knowledge of the skippers, point in what refers to the sports yachts, the issue is even more serious. And we must think that at the moment yachts of 80 m length and displacing more than 300 tons and more are considered pleasure crafts. In spite of the fact that their captains and officers must have Merchant Marine qualifications, the truth is that in practice, there are many factors involving leisure economy which often imply cutbacks in the safety parameters.

However, in the face of these obvious problems, we must consider the important challenge that represents the end of paper charts, not as a disaster, not as a song of nostalgia for a lost past, but as a great opportunity to rethink the kind of navigation training we are offering. And also, about the attitude that future navigators should have towards the maritime space. The combination of S-100 charts with BRM and MiniECDIS offers great potential in these fields.

The keys to success will undoubtedly lie in the way in which the equipment will be simplified so that, without reducing its efficiency, it will facilitate the maintenance of Situational Awareness, instead of creating problems in the management of the screen, the scale with respect to the size of the display, the diversity of inputs, the limitation to the minimum of the number of alarms and the rest of the issues we have been seeing.

On the other hand, the new S-100 charts will bring cartographic quality and reliability. And they will probably offer new possibilities to turn recreational navigation into an educational activity for a better management of our seas and coasts.

Conclusions

There is an underlying problem in maritime training worldwide, which is the lack of transmission of traditional seafaring culture to recent generations. In this context, the figure of the navigator, as the person who should be in control of navigation, has been greatly weakened. In fact, perhaps the main problem with electronic charts is the never explicitly stated desire to replace the entire navigator's knowledge with automated computer processes. However, in any case, we must take advantage of the arrival of the s-100 charts, the Mini-ECDIS and other advances to regain lost ground in this field. Regardless of the developments that may arise in automated navigation, the role of the navigator should not be blurred, but rather take on a more prominent role, since with today's technology his or her personal capabilities may be greatly enhanced.

Even more vigorous action must be taken on smaller vessels, for which the use of Mini-ECDIS equipment may be the last chance to ensure that nautical knowledge is not lost in a sea of radio signals and remote controls. The most important thing will be to reduce and rationalize the controls and the number of layers, to provide them with good gyroscopes and navigational sliders, to improve the relationship with the radar and to define a minimum screen size that allows a sufficiently wide view of the scene.

One of the virtues of ECDIS is that it raises uncertainty about the exact positioning, which is to be welcomed because it promotes an optimal state of situational awareness. There is no greater danger for a navigator than overconfidence in means outside his own perception. Aids to navigation are fine

and increasingly efficient, but navigational decisions depend and will continue to depend on the officer of the watch. The question of ECDIS as the "primary navigation system" needs to be revisited.

Training must be the other factor that can make us take advantage of this great opportunity. To this end, it will be necessary to design new, more ambitious courses that will combine mapping with BRM and virtual environments in simulators.

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IŠMETAMŲJŲ DUJŲ PLOVIMO PROCESO LAIVUOSE POVEIKIO EKOLOGIJAI TYRIMAS

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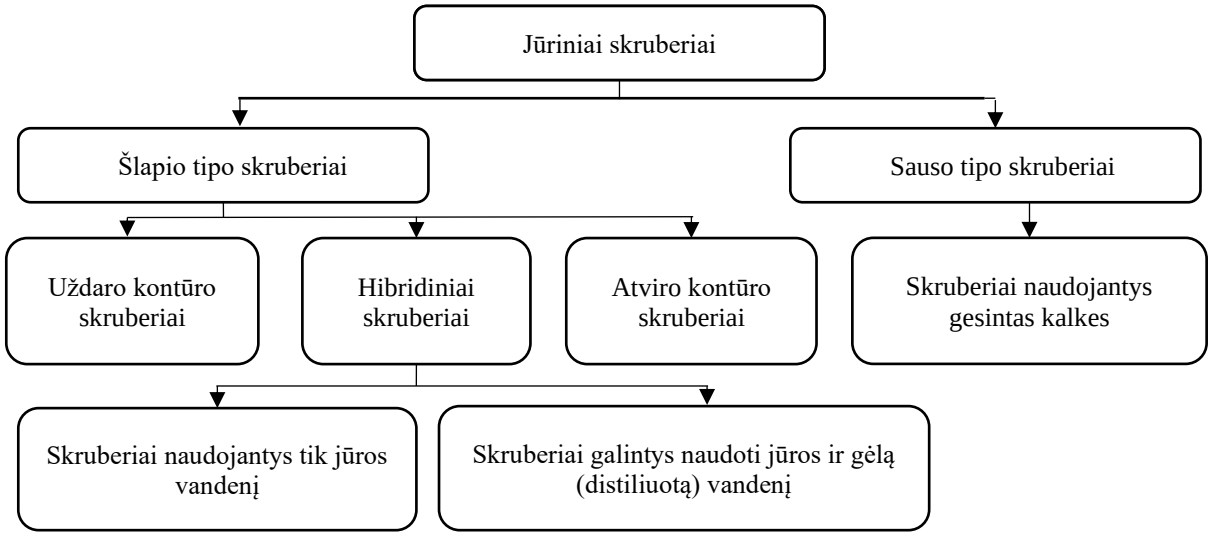
Abstraktas. Tarptautinė jūrų organizacija (IMO) yra nustačiusi sieros kiekio ribas jūrų transporto degaluose, tačiau laivai ir toliau naudoja šiuos likutinius didelio sieros kiekio degalus kartu su išmetamųjų dujų valymo sistemomis (skruberiais). Deginant šiuos degalus išmetama ne tik daug sieros, bet ir daugiau teršalų, įskaitant metalus tokius, kaip chromas, varis, nikelis, cinkas ir policiklinius aromatinius angliavandenilius (PAH) (Johannes Teuchies, 2020). Laivų, kuriuose įrengti skruberiai, skaičius sparčiai auga, tačiau žinių apie jų plovimo vandens kokybę ir poveikį aplinkai ir jūros ekosistemai yra nedaug. Tyrimo duomenys parodė plovimo išmestame vandenyje esamas medžiagas ir jų poveikį jūros ekosistemai.

Raktiniai žodžiai: jūriniai skuberiai, SOx šalinimas, DPM šalinimas, ekologija.

Įvadas

Kad laivai atitiktų jiems keliamus gamtosauginius reikalavimus, jie gali naudoti tik reikalavimus atitinkantį mažai sieros turintį mazutą arba alternatyvius degalus, kuriuose yra mažai sieros, pavyzdžiui, suskystintas gamtines dujas (SGD) arba metanolį (Wenjun Li, 2022). IMO nustatyti sieros kiekio apribojimai taikomi tik į atmosferą išmetamiems teršalams, todėl leidžiama ir toliau naudoti daug sieros turinčius degalus kartu su išmetamųjų dujų valymo sistema (EGCS arba skruberiu). Skruberiuose laivų išmetamosios dujos apipurškiamos skysčiu, kad būtų pašalintas SOx prieš išmetant jį į orą. Skruberiai gali pašalinti iki 95 % išmetamosiose dujose esančių SOx ir atitikti IMO nustatytas sieros išmetimo ribas. Dauguma laivuose įrengtų skruberių yra šlapieji skruberiai ir juose naudojamos atviro ir uždaro kontūro sistemos arba hibridiniai galintys veikti tiek uždaru, tiek atviru kontūru (Tran TA, 2017).



Pav. 1. Jūrinių skruberių tipai

Rinkoje dominuoja atvirojo kontūro sistemos. Šiose sistemose išmetamosios dujos dideliu našumu purškiamos jūros vandeniu, o išmetamosiose dujose esantys SOx sulaikomi ir paverčiami sieros rūgštimi (SO_3^{2-}) ir sieros rūgštimi (SO_4^{2-}) (Tran TA, 2017).

Tyrimo tikslas: ištirti išmetamųjų dujų plovimo proceso poveikį jūros ekologijai

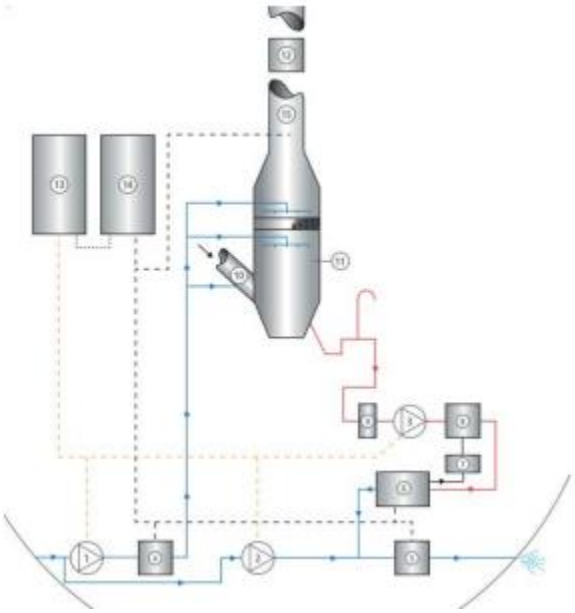
Tyrimo uždaviniai:

1. Išanalizuoti skruberio veikimo principą.
2. Išnagrinėti skruberio išleidžiamo vandens poveikį uždariems vandenims ir ekosistemai.
3. Ištirti elektrostatinio vandens purškimo skruberio kietųjų dyzelino dalelių pašalinimo efektyvumą.

Tyrimo objektas: jūriniai skruberiai ir jų plovimo vanduo.
Tyrimo metodai: mokslinės ir technologinės literatūros analizė

1. Skruberio veikimo principo analizė

Išmetamųjų dujų valymo sistema (skruberis) - tai įrenginys, kuris montuojamas variklio ir katilo išmetamųjų dujų sistemoje. Plačiausiai yra naudojamas atviro kontūro skruberis (pav. 2) (Tran TA, 2017).



Pav. 2. Atviro kontūro skruberio sistema. 1 - užbortinio vandens siurblys, 2 – nuotekų skiedimo siurblys, 3 – nuotekų išleidimo siurblys, 4 – užbortinio vandens stebėjimo monitorius, 5 – nuotekų stebėjimo monitories, 6 – alyvos ir suodžių separatorius, 7- EGC likučių tankas, 8 – šlamo separatorius, 9 – atkūrimo įrenginys, 10 – išmetimo dujų iėjimas, 11 – skruberis, 12 - išmetimo dujų iėjimas, 13 – ventiliatorius, 14 – stebėjimo ir aliarmų įrenginys, 15 - išmetimo dujų išėjimas.
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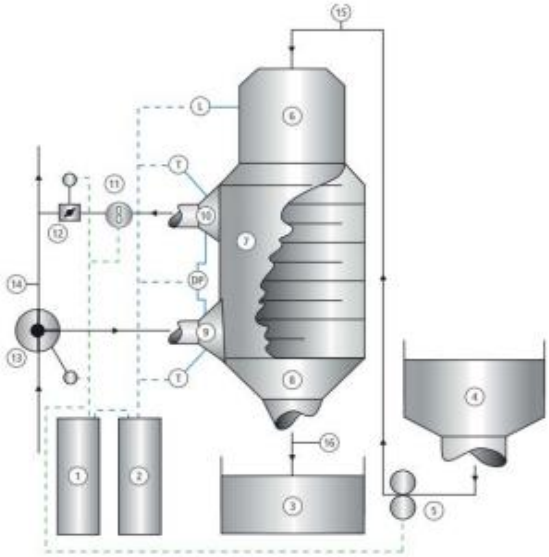
Apdoroti išmetamąsias dujas, naudojamos įvairios medžiagos, įskaitant jūros vandenį, chemiškai apdorotą gėlą vandenį arba sausas medžiagas, kad iš išmetamųjų dujų būtų pašalinta didžioji dalis SOx ir šiek tiek sumažintas kietųjų dalelių kiekis. Išvalytos išmetamosios dujos išmetamos į atmosferą. Taikant šias plovimo technologijas susidaro atliekų srautas, kuriame yra valymo procesui naudotos medžiagos, SOx ir kietosios dalelės, pašalintos iš variklių išmetamųjų dujų ir katilų (Tran TA, 2017). SOx (SO2 ir SO3) dujos tirpsta vandenyje. Ištirpusios šios dujos iš stiprių rūgščių reaguoja su natūraliu jūros vandens šarmingumu arba šarmingumu, gautu iš pridėtų medžiagų (paprastai natrio hidroksido), sudarydamos tirpią natrio sulfato druską, kuri yra natūrali jūros druska. Be to, išmetamosiose dujose esančios kietosios dalelės patenka į plovimo vandenį ir prisideda prie plovimo įrenginyje susidarančio dumblo. Skruberyje susidaręs plovimo vanduo išleidžiamas į aplinkinius paviršinius vandenis.

Sausuose skruberiuose (pav. 3) kalcio hidroksidas (CaOH2), arba dažniau vadinamos hidratuotos kalkės, reaguoja su SOx, o reakcijos produktas yra kietasis kalcio sulfatas (CaSO4), arba dažniau vadinamas gipsas. Atliekų srautas ir susidaręs dumblas prieš išleidžiant už borto, jei

leidžiama, turi būti apdoroti pagal IMO nurodymus arba saugomi ir išleidžiami į krantą kaip atliekos. (Tien Ahn, 2017).



Pav. 3. Sauso skruberio sistema. 1 – valdymo skydas, 2 – skydinė, 3 – reakcijos produktas, 4 – granulių laikymo vieta, 5 – granules konvejeris, 6 – granulių laikymo vieta, 7- skruberio reakcijos vieta, 8 – reakcijos produktas, 9 – išmetimo iėjimas, 10 – išmetimo dujų išėjimas, 11 – išmetimo dujų ištraukimo ventiliatorius, 12 – izoliacinis vožtuvas, 13 – 3 kelių įėjimo/apėjimo vožtuvas, 14 – išmetimo dujų apėjimo kolektorius, 15 – granulių sorbcijos įėjimas, 16 – reakcijos produkto išėjimas
Šaltinis: Tran TA, Research of the Scrubber Systems to Clean Marine Diesel Engine Exhaust Gases on Ships(2017). J Marine Sci Res Dev 7:243

Uždaro ciklo sistemose (pav. 4) kaip plovimo terpė naudojamas gėlas vanduo, kuris iš anksto apdorojamas natrio hidroksidu (NaOH).

Šis plovimo vanduo cirkuliuoja plovimo sistemoje. Plovimo pajėgumas palaikomas dozuojant papildomą NaOH kiekį ir periodiškai išleidžiant mažesnius kiekius paprastai vidutiniškai 0,5-3 l s^{-1} , jei laivas veikia 15 MW galia. Taip pat egzistuoja "hibridinės sistemos", kai laivai gali perjungti plovimo įrenginio veikimą iš atvirojo ciklo į uždarojo ciklo režimą (Johannes Teuchies, 2020).

2. Skruberio išleidžiamo vandens poveikis uždariems vandenims ir ekosistemai

Naudojant skruberius, sieros poveikis aplinkai perkeliamas nuo išmetimo į atmosferą prie tiesioginio išleidimo į vandens sistemas. Be to, laivuose su skruberiais naudojamas daug sieros turintis sunkusis kuras - mazutas (HFO), kuris yra likutinis kuras, susidaręs distiliuojant žalią naftą (Johannes Teuchies, 2020). Yra žinoma, kad kartu su dideliu sieros kiekiu į aplinką išmetama daugiau kitų pavojingų medžiagų, įskaitant metalus ir policiklinius aromatinius angliavandenilius, palyginti su mažai sieros turinčiais distiliatais, pavyzdžiui, jūriniu gazoliu (MGO). Šie teršalai atsiranda dėl didesnės metalų tokių, kaip chromas, varis, nikelis, cinkas ir PAH (policiklinių aromatinių agliavandenilių) koncentracijos degaluose ir didesnio išmetamų teršalų kiekio deginant šį likutinį kurą (Johannes Teuchies, 2020). Keliuose tyrimuose nurodoma, kad skruberiai sumažina į atmosferą išmetamų SOx arba KD (kietųjų dalelių) kiekį iki tokio lygio, kuris yra panašus į išmetamų teršalų

Pav. 4. Uždaro kontūro skruberio sistema. 1 – skruberio aušintuvo jūros vandens siurblys, 2 – skruberio plovimo vandens tiekimo siurblys, 3 – nuotekų vandens recirkuliacinis siurblys, 4 – alyvos ir suodžių separatorius, 5 – NaOH laikymo vieta, 6- EGC likučių tankas, 7- šlamo separatorius, 8 – reakcijos vieta, 9 – vandens aušintuvas, 10 – išmetimo dujų įėjimas, 11 – skruberis, 12 – išmetimo dujų ištraukimo ventiliatorius, 13 – valdymo skydas, 14 – stebėjimo ir aliarmų skydas, 15 – išmetimo dujų išėjimas. 16 – nuleidimo valdymo įrenginys, 17 – laikymo tankas 18 – nuotekų vandens stebėjimo vieta, 19 – skruberio vandens aušinimo stebėjimo vieta.
Šaltinis: Tran TA, Research of the Scrubber Systems to Clean Marine Diesel Engine Exhaust Gases on Ships(2017). J Marine Sci Res Dev 7:243

kiekį naudojant MGO (Tom J. S. Cox, 2020). Tačiau KD šalinimas skruberiais priklauso nuo daugelio veiksnių, ir buvo pranešta apie mažesnį skruberių šalinimo efektyvumą, dėl kurio išmetama daugiau kietųjų dalelių, įskaitant juodąją anglį ir policiklinius aromatinius angliavandenilius, palyginti su laivais, kuriuose naudojamas MGO.

Didelė dalis išmetamų junginių patenka į skruberio plovimo vandenį ir yra išleidžiami į aplinkinius paviršinius vandenis, o tai gali turėti įtakos vandens ekosistemoms. Šia tema atliktų tyrimų yra nedaug, jie daugiausia skirti atviroms jūrų sistemoms ir juose daroma išvada, kad bendras skruberių naudojimo poveikis pH pokyčiams ir teršalų koncentracijai daugeliu atvejų turėtų būti nedidelis. Tačiau ilgalaikis teršalų kaupimasis dėl skruberių išleidimo gali kelti susirūpinimą mažesniuose vandens telkiniuose, kuriuose yra daug laivų, pavyzdžiui, upių žiotyse ar uostuose (Filip J. R. Meysman, 2020).

Tyrimas buvo atliktas „Flemish" aplinkosaugos agentūros 2019m Antverpeno uoste. Laivų skruberių plovimo vandens mėginiai buvo paimti iš dviejų atskirų jūrinių laivų, naudojančių plovyklą.

	Units	Conc. docks (1)	WQS (2)	CLOSED loop—scenario HIGH			OPEN loop—scenario HIGH		
				Discharge conc. (90th perc.)	Flux kg year^{-1} (20% scrubbers)	Conc. increase docks	Discharge conc. (90th perc.)	Flux kg year^{-1} (20% scrubbers)	Conc. increase docks
Cr	µg L^{-1}	3.34	5	10,120	448	0.122	45.0	342	0.093
Cu		8.38	7	1780	78	0.021	130	998	0.273
Ni		5.86	4*	6060	268	0.073	127	994	0.272
Zn		32.9	20	1524	66	0.018	260	1863	0.509
V		3.94	4	25,000	1107	0.303	500	4069	1.112
Ace	ng L^{-1}	4.92	60	745	3.28E−02	8.96E−03	648	5.27	1.44
Acy		7.20	4000	185	7.87E−03	2.15E−03	536	4.34	1.19
Ant		2.67	100*	446	1.96E−02	5.37E−03	308	2.50	0.685
Fluoran		9.51	6.3*	661	2.88E−02	7.89E−03	478	3.84	1.05
Flu		3.72	2000	2370	1.05E−01	2.86E−02	1200	9.81	2.68
Naph		8.24	2000*	6370	2.82E−01	7.70E−02	6960	57.0	15.6
Phe		7.95	100	6970	3.08E−01	8.43E−02	3700	30.3	8.28
Pyr		13.0	40	554	2.40E−02	6.55E−03	1220	9.90	2.71
Total PAH		58.1		22,200	9.80E−01	2.68E−01	13,620	111	30.4

(1) Average values for total concentrations in the harbour docks

(2) Water quality standards (WQS) from the EU WFD (*) or Flanders (dissolved concentrations for metals, total concentrations for PAHs)

Pav. 5. Skruberio vandens koncentracijos, srautas ir poveikis vandeniui

Šaltinis: Johannes Teuchies, Tom J. S. Cox, Katrien Van Itterbeeck, Filip J. R. Meysman and Ronny Blust., The impact of scrubber discharge on the water quality in estuaries and ports (2020)., Enviromental Sciences Europe, 32:103.

Pirmajame laive buvo įrengtas hibridinis skruberis, kurio mėginiai 2019 m. spalio mėn. du kartus buvo imti Belgijoje: kai jis stovėjo Antverpeno uoste ir veikė uždaro ciklo režimu, ir kai plaukė Šeldos žiotimis atviro ciklo režimu. Antrajame laive buvo įrengtas atvirojo ciklo plovimo įrenginys, kurio mėginiai 2019 m. spalio mėn. buvo imti du kartus: plaukiant Šiaurės jūroje ir manevruojant Antverpeno uoste. Išsamią informaciją apie ploviklio tipą, degalus ir eksploatavimo sąlygos pateikiamos duomenų lape (pav 5).

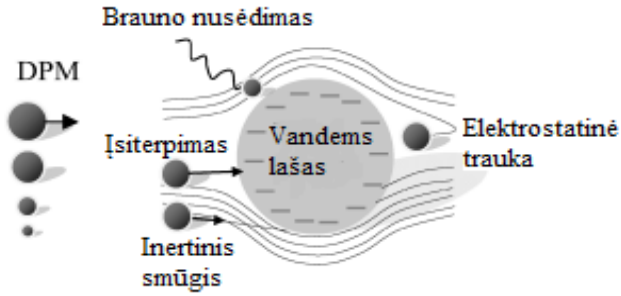
Daugumos PAH ir visų metalų koncentracijos uždaro ciklo sistemose gerokai viršijo jiems nustatytus standartus (WQS) ir, kaip manoma, yra ūmiai toksiškos daugumai vandens organizmų. Pranešama apie ūmų toksinį skruberio plovimo vandens poveikį fitoplanktonui ir zooplanktonui, net kai metalų ir PAH koncentracijos yra daug mažesnės nei šiame darbe nurodytos koncentracijos. Papildomas nitratų kiekis, atsirandantis dėl laivybos, gali turėti didelį poveikį pelaginio mikroplanktono augimui, ypač eutrofikuotose aplinkoje, pavyzdžiui, Baltijos jūroje, uostuose (Erik Ytreberga, Ida-Maja Hassellöva, (2019). Taip pat pastebėta padidėjęs zooplanktono mirtingumas, kai metalų koncentracija viršija nustatytas normas (M. Koski, 2017). Metalų ir PAH mišinio sinergetinis poveikis, kartu su žemu pH skruberio plovimo vandenyje lemia didesnį toksiškumą, nei apskaičiuotas pagal atskirų junginių poveikio ribines vertes (M. Stedmon, 2017).

Laivų su plovimo įrenginiais skaičius sparčiai auga. Apskritai laivų su skruberiais, naudojančių HFO, bendras rūgščių išmetimo potencialas ir išmetamų pavojingų medžiagų kiekis yra didesnis nei laivų, naudojančių mažai sieros turinčius degalus MGO. Didelė dalis šių išmetamų teršalų tiesiogiai su plovimo vandeniu patenka į vandens ekosistemas. Nustatyta, kad šis plovimo vanduo yra labai toksiškas vandens organizmams (Katrien Van Itterbeeck, 2022).

Šių junginių standartų (WQS) viršijimas rodo, kad daugelis Europos vandens sistemų jau patiria spaudimą, todėl daugiausia pakrantėse ir žiotyse, turinčiose didelę ekologinę vertę, reikėtų riboti plovimo įrenginių panaudoto vandens išleidimą.

3. Elektrostatinio skruberio poveikis kietosioms dyzelino dalelėms tyrimas

Skruberio eksploatavimo sąnaudos paprastai yra didelės, visų pirma dėl energijos sąnaudų ir mažo submikroninių DPM (dyzelino kietosios dalelės) surinkimo efektyvumo. Jau daugelį metų siūloma naudoti elektrostatinius skruberius mažųjų DPM šalinimo problemai spręsti. Tačiau šia tema mažai duomenų ir tyrimų, o pagrindinė šių sistemų didelio vandens suvartojimo problema vis dar neišspręsta (Tran Hong Ha, 2009). NOx šalinimui yra keletas šlapio plovimo procesų. Kai kuriose sistemose buvo atlikti tyrimai su metalų chelatais , skirtais NOx dujoms valyti. Daug cheminių medžiagų buvo kaip absorbentai arba oksidatoriai, siekiant pašalinti arba NO, NO_2, NOx ir SO_2 naikinimui vandens terpėje, įvairiose drėgnojo plovimo sistemose (Tran Hong Ha, 2009). Šiame darbe analizuojamas elektrostatinis vandens purškimo skruberis, kuriame susidaro įkrauti lašeliai, įkrautiems DPM surinkti (pav. 6).



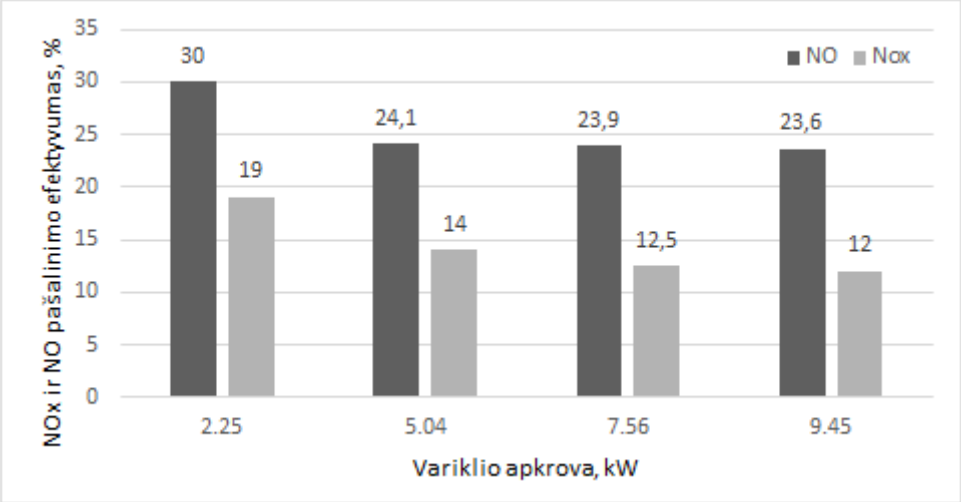
Pav. 6. DPM surinkimas naudojant įkrautą vandens lašą

Jūros vandens elektrolizės elementas generuoja Cl_2 dujas, Cl_2 ir NO reakcija pašalina NO iš išmetamųjų dujų.

Tiriamas eksploatacinių parametrų, tokių kaip variklio apkrova, poveikis vandens plovimo našumui. ir variklio galios poveikiui, DPM ir NOx šalinimo efektyvumas ištirtas tik laboratorinėmis sąlygomis. (Tran Hong Ha, 2009).

Įkrautas neutralus DPM lašelis. Įkrova ant DPM sukelia priešingo ženklo krūvį ant kolektoriaus krūvio, kuris sukelia traukos jėgą tarp DPM ir lašelių.

Atliktas eksperimentinis dyzelinio variklio išmetamų kenksmingų DPM ir kitų teršalų šalinimo tyrimas naudojant elektrostatinį vandens purškimo skruberį. Nustatyta, kad elektrostatinis vandens purškimo skruberis veiksmingai šalina smulkiuosius DPM. Šiame tyrime buvo apžvelgta keletas eksperimentų su skruberiais, kuriais vienu metu buvo šalinami DPM, NO ir NOx. Faktinis dyzelinių variklių išmetamųjų teršalų kiekis išmatuotas prieš ir po apdorojimo skruberiu pateikti 7 pav.



Pav. 7. NO ir NOx pašalinimo efektyvumas esat skirtingoms variklio apkrovoms

Atlikus matavimus paaiškėjo, kad varikliui dirbant 2.25 kW apkrova NO pašalinimas siekė 30%, o dirbant 5-9.45 kW apkrova siekė 23,6-24,1% šalinimo efektyvumą. NOx pašalinimas siekė iki 19% efektyvumą dirbant 2.25 kW apkrova ir 14-12% efektyvumą dirbant 5-9.45 kW apkrova (pav. 7). Dar labiau padidinti mažų dyzelino kietųjų dalelių pašalinimo efektyvumą galima įkraunant purkštukus naudojant elektros jėgą. (Tran Hong Ha, 2009)

Išvados

1. Išanalizavus skruberių veikimo principą ir ypatumus, buvo nustatyta, kad plačiausia praktikoje naudojami šlapio tipo atviro kontūro skruberiai, nes jų plovimo vandeniui nereikia laikymo vietos, vanduo yra išmetamas už borto ir jie yra pigesni instaliuoti ir eksploatuoti palyginus su kitų tipų skruberiais .
2. Išnagrinėjus atviro kontūro skruberio po veikimo proceso likusio išleidžiamo vandens poveikį uždariems vandenims ir ekosistemai, buvo pastebėtos padidėjusios metalų tokių, kaip chromas, varis, nikelis, cinkas ir PAH (policiklinių aromatinių agliavandenilių) koncentracijos, dėl kurių gali sutrikti pelaginio mikroplanktono augimas ir buvo pastebėtas zooplanktono mirtingumas, kai metalų koncentracija viršija nustatytas normas. Todėl rekomenduojama atlikti daugiau ekotoksikologinių tyrimų, susijusių su skruberio plovimo vandenimis ir neleisti skruberio panaudoto vandens uždaruose vandenyse tokiuose, kaip uostai ir upių žiotys.
3. Ištirtyrus elektrostatinio vandens purškimo skruberio kietųjų dyzelino dalelių pašalinimo efektyvumą, buvo nustatyta, kad elektrostatinis skruberis efektyviau valo išmetamąsias dujas, daug geriau surinkdamas DPM (kietąsias dyzelino daleles), nei paprastas atviro kontūro skruberis. Optimaliausių rezultatų buvo pasiekta varikliui dirbant 2.25 kW apkrova, kai NO pašalinimas siekė 30%, NOx pašalinimas iki 19%.

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ENGINEERING OF VIRTUAL TRAINING SIMULATORS USING CODESYS AUTOMATION PLATFORM

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Abstract. The study devoted to the relevant scientific problem – the development of an effective software model of a virtual simulator for mastering the fundamentals of theoretical courses in the design and operation of modern technical means of automation, as well as for usual study and practical training in the learning process. Problem solving were performed in next steps: creation of a model of a typical equipment control system, implementation of a model set of controlled objects in the form of functional blocks using available CODESYS Automation Platform programming languages, developing the virtual stimulator interface in the form of human-machine interface using visualization tools. The virtual simulator developed in the study will contribute to the formation of competences and the achievement of learning outcomes for students of technical specialties in disciplines related to PLC programming, simulation modeling and simulation of the interaction of structural components of software-technical means of measuring and control-executive channels. A further development of research may be the expansion of the set of models of typical objects corresponding to certain devices, mechanical units of the machine, where each object includes software implementation and visual representation, establishment of communication between territorially distributed devices using industrial networks for construction of a unified information and control environment.

Keywords: simulator, training, model, interface, visualization.

Introduction

Virtual learning simulations are increasingly being used in diverse educational and training contexts as a supplement to traditional educational methods and previous research has shown that they provide important educational benefits [1]. For instance, virtual learning simulations provide cost-effective access to state of the art training equipment and learning tools, beyond what many teaching institutions would be able to provide physically, due to financial or practical constraints. Virtual learning simulations let students observe otherwise unobservable phenomena, reduce time demand of experiments that would be very time consuming if done physically, and provide online, adaptive guidance. Simulators provide the formation of professional skills in an artificially simulated environment.

Simulation modeling of dynamic systems is **the scientific relevant** direction and an effective toolkit of software modeling of dynamics using both universal and specialized software products. CODESYS software [2] is a tool for programming the equipment and application processes in the field of automation, mechanical engineering and system integration. This software product allows you to solve applied tasks related to the programming of powerful PLCs or operator panels, and the creation of communication with devices in any industrial networks, i.e. it is ideal for modeling the structural components interaction of software and technical measurement and control means with execution channels. Joint use of modern software and technical tools and computer modeling systems will allow to create own set of objects corresponding to certain devices, mechanical components of the machine, etc., where each object includes a software implementation and a visual representation.

The scientific problem of the research is the development of an effective software model of a virtual simulator for mastering the fundamentals of theoretical courses in the design and operation of modern technical means of automation, as well as for usual study and practical training in the learning process.

The object of the research is the Virtual Training Simulators for use in courses of professional disciplines of engineering specialties of higher educational institutions.

The aim of the research is to define the methodological approach of the virtual training simulator engineering on the base of "Main Engine Control System Virtual Simulator".

The objectives of the research are the following:

1. Create a model of a typical equipment control system in CODESYS.
2. Implement a set of models of controlled objects in the form of functional blocks (FB) using available CODESYS programming languages;
3. Develop the virtual stimulator interface in the form of human-machine interface (HMI) using CODESYS visualization tools.

The research methods include the following: methods of computer modeling of objects and systems; methods of modern theory of automatic control; methods of visualization of operational control systems; methods of programming algorithms for the functioning of technical means.

The structure of the research. In the first part of the study, the need to develop software for a virtual simulator for working with the technical means of automation of basic technological units and aggregates using CODESYS was substantiated. In the second part of the study, the implementation of the mathematical model and the control system in the languages of the IEC 61131-3 standard and the HMI of the virtual simulator were developed.

1. The theoretical basis for the development of virtual simulators

Computer simulators are complex software and hardware systems containing modeling, analysis, simulation and visualization tools. The main tasks that are solved with the help of computer simulators are the theoretical training of students and the development of their practical skills.

To ensure the functioning of the simulator, it will be necessary to develop the following software components: the control system scheme implemented in the form of a continuous functional scheme CFC (Continuous Function Chart), the main mnemonic diagram of the process, including the representation of technological parameters, events and alarms, and control tools at the operational level.

When developing the virtual simulator, a typical scheme of automatic control with feedback (Fig. 1) was used, which consists of a controller, an actuator, a controlled object and a measurement system [3].

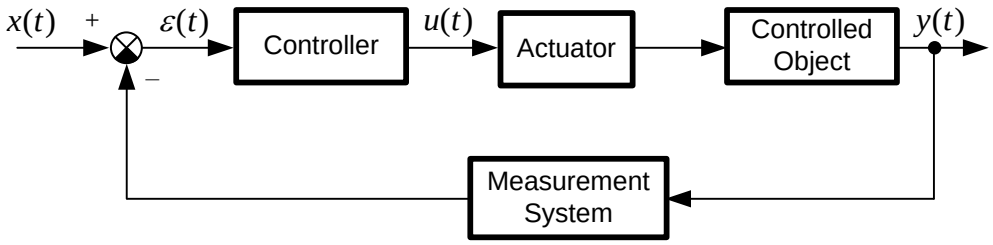

Fig. 1. Typical scheme of the control system with feedback

According to statistics, more than 90% of all industrial controllers are precisely PID-controllers. The use of a PID controller in automatic control systems makes it possible to ensure the fulfillment of all requirements for the quality of the control process, namely, high speed, the absence of static error (that is, the constant disturbance is fully compensated), the smoothness of the transient process.

When developing the simulator, the following requirements were taken into account: simulation models should be adequate to real physical processes, control of the technological process should be carried out on a real-time scale, model parameters should be able to be adjusted for a specific type of equipment, the simulator interface should correspond as closely as possible to the interface of a real control system.

2. Practical implementation of the virtual simulator in CODESYS

As a result of the research, a computer-integrated subsystem for simulation of the ship's main engine control was developed. For this, the control system scheme was implemented in the form of a continuous functional scheme CFC (Continuous Function Chart) in the CODESYS Automation Platform (Fig. 2).

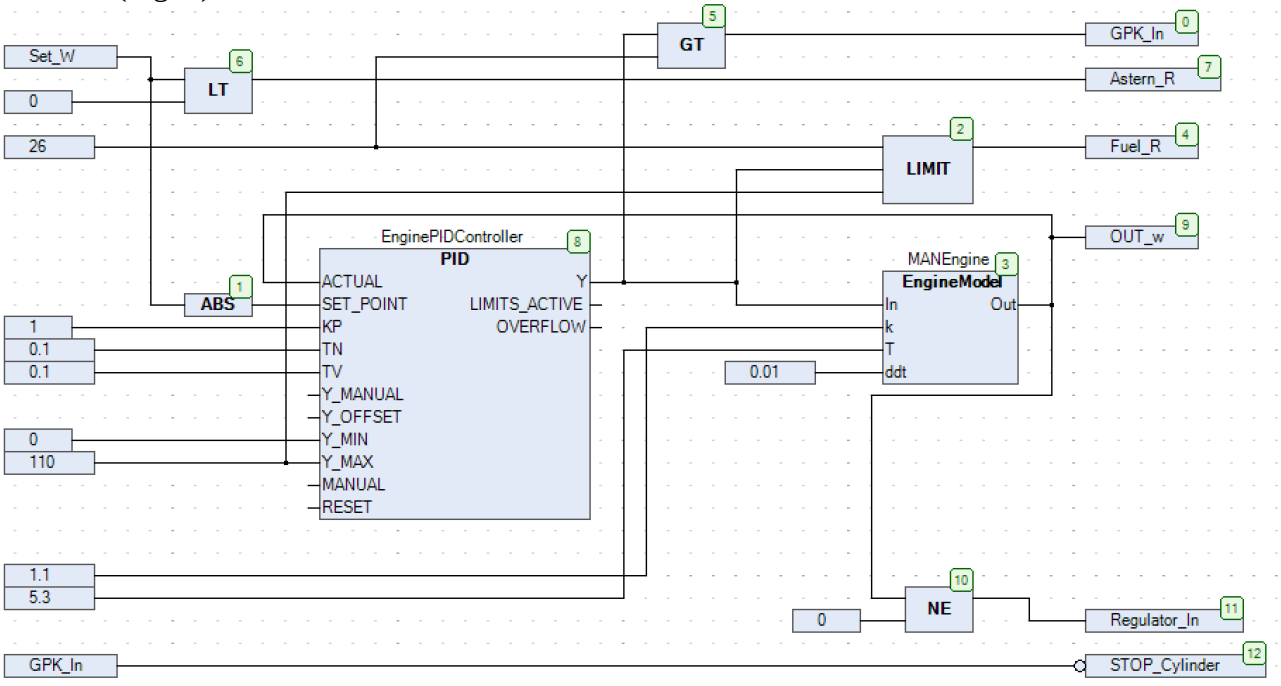

Fig. 2. Diagram of the control system in the form of a CFC in the CODESYS Automation Platform

The functions of the control device are performed by the EnginePIDController block, implemented on the basis of the PID block from the "Util" standard library. A PID controller continuously calculates an error value $\varepsilon(t)$ as the difference between a desired set point (SET_POINT) and a measured process variable (ACTUAL). The PID controller applies a correction based on proportional, integral, and derivative terms (KP, TN, and TV respectively) which give their name to the controller type. Y_OFFSET, Y_MIN and Y_MAX serve for transformation of the manipulated variable within a prescribed range. MANUAL can be used to switch to manual operation; RESET can be used to re-initialize the controller. The controller performs the functions of collecting information in digital and analog form from sensors and outputs control signals to the drives of actuators.

The controlled object (main engine) specified by the inertial link unit (aperiodic link of the 1st order) with a transfer function:

$$W(s) = \frac{y(s)}{x(s)} = \frac{k}{1 + T \cdot s}, \tag{1}$$

where k is the amplification factor, T is the time constant.

The transformation of the continuous model of the object into a digital form was performed using the method of difference equations. The corresponding equation (1) in finite differences has the form:

$$kx(t) = y(t) + T \cdot \frac{y(t + \Delta t) - y(t)}{\Delta t}. \tag{2}$$

Equation (2) made it possible to obtain an expression for calculating the output signal of the controlled object:

$$y(t+\Delta t) = y(t) + \frac{(kx(t) - y(t)) \cdot \Delta t}{T}. \quad (3)$$

The model of the controlled object in a discrete form is implemented in the form of a function block (FB). The ST (Structured Text) programming language was used to implement the model (3) (Fig. 3).

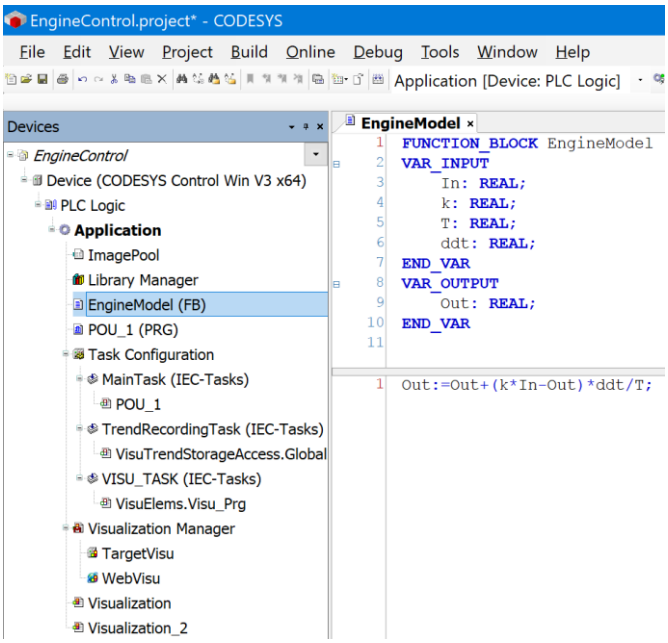

Fig. 3. Implementation of the controlled object model in the ST programming language

When building the control system, standard blocks are also used: ABS – finding the absolute value (module), LT/GT/NE – logical functions “Greater Then”/“Less Then”/“Not Equal to”, LIMIT – limits the input value in a given range: if the input value is within the specified limits, then we have it at the output of the block, otherwise it is limited by the lower or upper limit. All parameter variables have default values calculated from installed hardware data, but the values can be changed.

In the next step of the development, it was necessary to develop the user interface of the automated control system using the visualization tools of the IDE CODESYS integrated development environment. An example of the final rendering in operation mode is shown below (Fig. 4). Visualization was performed using the CODESYS Visualization Toolbox, which includes a wide range of standard graphical elements with the possibility of customization. The following elements were used to create the HMI: Label, Slider, Meter 180°, Lamp, Image, Line, Text Field, Trace. Additional graphics that are not in the standard feature set have been added to the simulator using the ImagePool component.

The implemented human-machine interface shows the possibility of improving the visualization of the interaction of the functional elements of the control system, which significantly facilitates the control of its functioning.

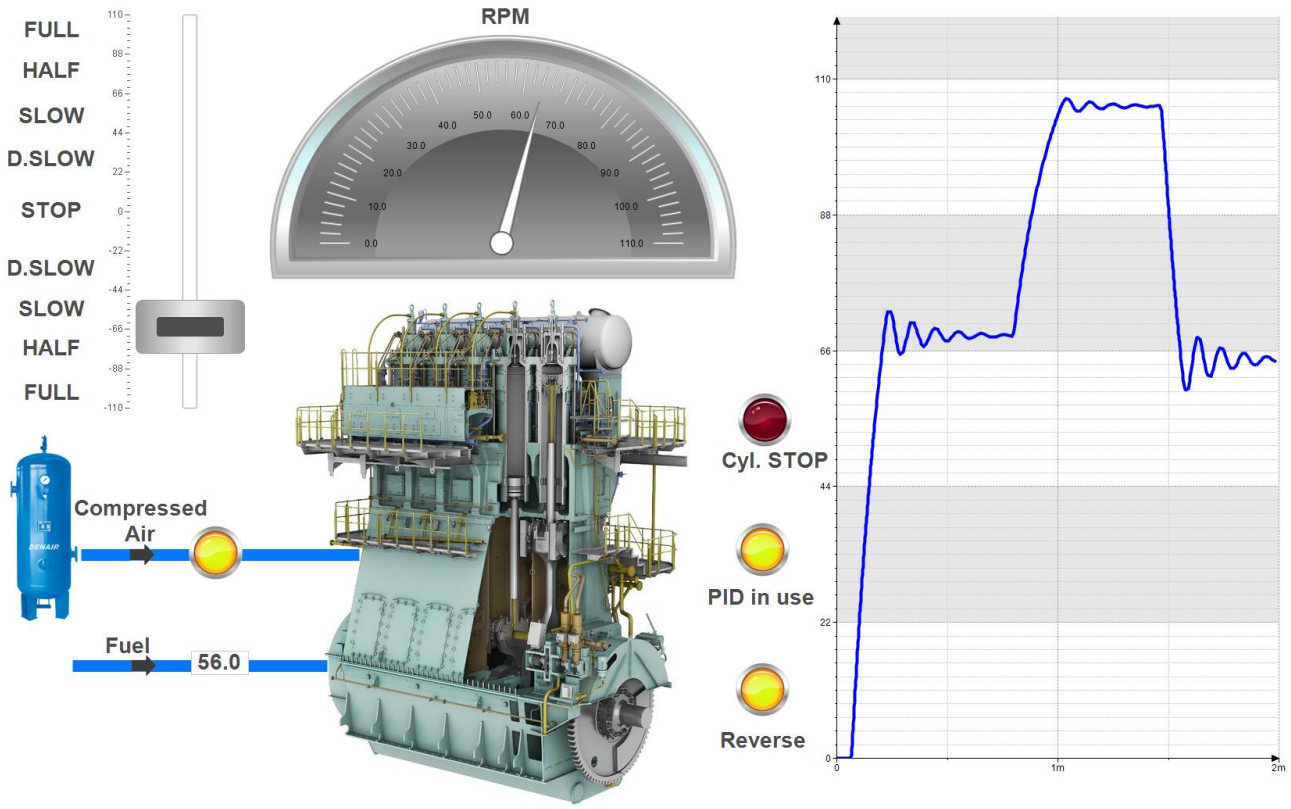

Fig. 4. Virtual stimulator interface in the form of HMI

Conclusions

1. The virtual simulator developed in the study will contribute to the formation of competences and the achievement of learning outcomes for students of technical specialties in disciplines related to PLC programming, simulation modelling and simulation of the interaction of structural components of software-technical means of measuring and control-executive channels.

2. A further development of research may be the expansion of the set of models of typical objects corresponding to certain devices, mechanical units of the machine, where each object includes software implementation and visual representation, establishment of communication between territorially distributed devices using industrial networks for construction of a unified information and control environment.

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ACCIDENTS AS A RESULT OF VESSELS' SIZE INCREASING

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Abstract. The accident rate of vessels is one of the most important and urgent problems of the modern merchant fleet. Marine accidents can lead to loss of vessels, loss of life, material and environmental damage, and serious social and economic consequences. Therefore, leading international organizations (UN, IMO, ILO) pay constant attention to this problem and have developed such fundamental documents as SOLAS, COLREGs, STCW and others to prevent accidents. However, any accident is also a lesson that allows navigators to analyse the current situation and, if it happens again, be able to prevent its development and take adequate correct actions. The study of the accidents and incidents causes, ways to prevent them for students and cadets is a method of minimizing risks in their further practical activities on marine vessels. At present, despite the technical progress in creating means and methods for ensuring navigation safety, the human factor continues to occupy a leading place in the list of accidents causes and loss of vessels: according to various authors, 75-80% of accidents occur due to the vessels' crews fault. Therefore, study and analysis of marine vessels' accidents causes, ways to prevent them in the professional training process of cadets and students at the institute is one of the promising and effective methods for reducing accidents in the fleet.

Introduction

Formulation of the problem. Despite challenges related to COVID-19 and global supply chain disruption, overall vessel losses in the shipping industry continue to decrease steadily. The Global Shipping and Safety Review 2022 shows a decrease in the total number of vessel losses from 65 in 2020 to 54 in 2021 (Safety and shipping review, 2022).

In the early 1990s, the world fleet was losing more than 200 vessels a year, and in the last four years this figure has fallen from 75 to 50 a year. Total losses over the last decade decreased by 57% from 2012 (127) to 2021 (54) and is a significant improvement on the 10-year average annual loss rate (89), indicating that the industry remains focused on regulation, improvements in vessel design and technology, as well as advances in risk management reinforce general safety trends. This is even more impressive given the fact that there are almost 130,000 vessels (over 100GT) in the global fleet, up from around 80,000 30 years ago (Safety and shipping review, 2022).

While total vessel losses have decreased over the past year, the number of reported vessel accidents or incidents has increased. The British Isles had the highest number of cases (668 out of 3,000). Equipment damage accounts for more than one-third of all incidents worldwide (1,311), followed by collisions (222) and fires (178), with fires increasing by nearly 10%. In the last ten years worldwide, the majority of incidents were caused by equipment damage or malfunction (9,968), followed by collisions (3,134), contact (2,029), piracy (1,995), and fire/explosion (1,747) (Safety and shipping review, 2022).

Purpose of the article. Analysis of materials published in the open press on marine vessels emergency situations for recommendations development to improve the navigation safety.

Main **tasks** of the research are the following:

1) to analyse the risk factor of maritime acidents;
2) to base maritime accidents prevention actions;
3) To analyse the human factor importance.

Methods of the research: analysis of scientific literature, case study, analysis of the documents etc.

1. Anglysis of Maritime Accidents Cases

While the number of serious maritime accidents worldwide has declined in the long term, incidents involving large vessels, namely container carriers, vehicle carriers and ro-ro vessels, result in disproportionately high losses. Large vessels continue to be exposed to increasing risks: fires, loss of containers, undeclared or mis-declared dangerous goods, more expensive salvage operations, problems with refuge ports leading to excessive losses and general accidents are becoming more frequent.

Fires are the main cause of huge losses on large vessels. The container carriers carrying capacity has increased by approximately 1,500% since 1968 and has almost doubled in the past decade. And safety analysis and shipping shows that over 70 fires have been registered on board container carriers in the last five years alone.

In the last decade, the focus has been on vehicle carriers, whose fires lead to one of the most expensive marine insurance losses in recent times. The largest fires list in recent years is presented below.

On 02.06.2015 aboard the US-flagged ro-ro / vehicle carrier ***Courage***, on route from Bremerhaven to Southampton, a fire occurred due to a short circuit in the vehicle's automatic braking system module on board. As an accident result, significant damage was caused, the cargo was destroyed, and vessel's owners sent it for As a result of the accident, significant damage was caused, the cargo was destroyed, and the owners of the vessel sent it for scrap (Fire aboard (A)...).

On 24.02.2017, a fire broke out aboard the US-flagged vehicle carrier ***Honor*** after leaving the port of Southampton in the English Channel, apparently caused by a faulty starter in one of the cars. As an accident result, the vessel was damaged in the amount of 700,000 dollars. The vehicles damage amount on the vessel has not been disclosed (Fire on board (B)…).

On 21.05.2018, a fire occurred on the cargo deck of ***Auto Banner*** vehicle carrier at Incheon Port, Korea. An overheated engine of one of the 2,000 loaded used cars bound for Libya caught fire, and the flames spread to other cars. About 40 units of equipment, including helicopters and tugboats, and a total of 150 firefighters were involved in extinguishing the fire. After 67 hours of large-scale extinguishing, the fire was extinguished. All cars burned, the vessel was sent for scrap (Car carrier major fire…).

On 31.12.2018, a fire broke out aboard the Panamanian-flagged vehicle carrier ***Sincerity Ace*** on New Year's Eve while in the Pacific Ocean, 1,800 nautical miles west of the Hawaiian Islands. Two crew members died, three are missing. The cars on board were not subject to recovery, the insurance compensation exceeded 100 million dollars. The vessel was scrapped in Japan (Fire-damaged Sincerity …).

On 10.03.2019, one of the trucks caught fire on the roller-container ***Grande America***, which was transporting 2,184 new and used cars, 365 containers, including dangerous goods, from Hamburg to Casablanca, 250 miles northwest of Cape Finisterre, then the fire spread to containers with dangerous cargo on the upper deck, the crew left the burning ship in a lifeboat, and on 12.03.2019 the ship sank in the Bay of Biscay at a depth of 4,600 m. An oil slick 6 miles long and 0.6 miles wide formed at the site of its demise (M/V Grande America…).

On 15.05.2019, a fire occurred on the roller-container ***Grande Europa*** approximately 25 miles south of Palma de Mallorca in the Mediterranean Sea. Fifteen crew members were evacuated from the ship by helicopter, while three crew members remained on board and helped fight the fire with three fire ships that came to the rescue. As a result, the fire was contained and the ship was towed to the port. This is the second fire involving Grimaldi Lines vessels in 2019 (the first on Grande America) (Two fire break …).

On 04.06.2020, a fire broke out on the ***Hoegh Xiamen*** vehicle carrier at the port of Jacksonville, Florida, after the end of loading. The fire was caused by an electrical component failure in one of the used vehicles being transported from the US to West Africa. The fire lasted for eight days. City firefighters and their port colleagues failed to extinguish it. The fire destroyed all cargo decks and all living quarters of the ship. During the fire, several powerful explosions occurred, as a result of which

9 firefighters received burns and injuries. The entire cargo was declared unusable and lost. The vessel was towed to Turkey, where it was disposed of (Fire aboard Roll-on/Roll-off …).

20.05.2021 on the Singapore-flagged container carrier ***X-Press Pearl***, a fire broke out at the port of Colombo (Sri Lanka). On board the ship were 81 containers with dangerous goods, including 25 tons of nitric acid. For two weeks, the efforts of the Sri Lankan military aviation and military sailors to extinguish the fire were in vain, on May 25 an explosion occurred on board the container , and on 02.06.2021, the container ship sank while trying to tow the ship away from the shore. After the shipwreck, oil products (residues of fuel), dangerous chemicals and a huge amount of small plastic pellets from containers with dangerous goods got into the sea. The entry of a large amount of harmful substances into the waters of the Indian Ocean led to a large number of turtles death, dolphins, and rare coral fish that lived in this region (X-Press Pearl…).

On 16.02.2022, a fire broke out on the car carrier ***Felicity Ace*** 90 nautical miles southwest of the Azores. The fire spread quickly and forced all 22 crew members to abandon ship. The fire was contained. However, on March 1, while towing the vessel to the port, it tilted to starboard and sank. Damages from the loss of cargo amount to more than 400 million US dollars. The probable fire cause is the lithium-ion batteries of electric vehicles transported on the ship (Felicity Ace car carrier sank …).

2. The Main Causes of Vessel Accidents

All fires and vessel losses occur due to cargo fires, and the main fires causes reflect the problem areas of large vessels.

The size and construction of large vessels make fire detection and fighting a more difficult task than on medium and small ships. Fires need to be contained quickly, but it can take several hours to reach a fire on a container carrier with 20,000 containers on board.

The number of fires due to incorrect declaration of goods, including dangerous ones, is increasing. The audits revealed that out of 500 inspected containers, 55% have one or more violations of regulatory requirements, including structural damage, weak fastenings, incorrect labelling or loading documents (Safety and shipping review, 2022).

The situation is complicated by the presence on vessels' board of electric vehicles with lithium-ion batteries that cannot be extinguished with water. Substances released during the burning of lithium-ion batteries are toxic and potentially explosive, which, together with the risk of exploding fuel tanks, precludes the possibility of firefighters climbing aboard a burning vessel to more effectively contain the fire.

If it is impossible to localize and extinguish the fire, the crew has to leave the distressed vessel. Once the crew is forced to abandon vessel, emergency response and rescue operations become more difficult and expensive, and the risk of major or total loss increases. Fires that lead to vessel capsizing and sinking leave gaps in knowledge in terms of determining the root incident cause, which can help prevent similar events in the future. Once a vessel has capsized or sunk, a forensic examination of the fire cannot be conducted and valuable information is lost forever.

The steady increase in shipping intensity, increase in vessel size and speed, level of automation, constant commercial pressures, increased safety requirements, resulting increased workload, together with the Covid-19 pandemic have resulted in many skilled and experienced seafarers leaving the industry. Such a working situation is fraught with errors, therefore 75% of events on the vessels are related to the human factor (Safety and shipping review, 2022). The most resonant events of recent years due to the human factor are listed below.

On 03.01.2015, the vehicle carrier ***Hoegh Osaka*** lost its stability while leaving the port of Southampton, fell to the starboard side and ran aground. As a result of the accident, 1,400 damaged high-class cars with a total value of 52.7 million US dollars were sent to the scrapyard (Report on the investigation into the listing…).

The investigation results show that the ship left the port of Southampton effectively unseaworthy, with insufficient stability due to the following factors:

– in the fatal voyage, the port visits order and cargo placement was changed, however, during the actual loading, the cargo placement scheme was not revised, as a result of which heavy equipment was loaded on the higher decks, and passenger cars were loaded on the lower decks;

– in addition, there were significant discrepancies between the declared and actual cargo weight, by 265 tons more;

– due to the malfunction of most ballast system water meters, the amount of water in the tanks was determined "by eye", therefore the amount and placement of ballast water provided by the senior assistant did not correspond to reality at all;

– despite the fact that the ship has an on-board computer for calculating seaworthiness, an executive cargo plan, mandatory stability calculations were not carried out;

– due to these reasons, the metacentric height real value did not coincide with the one declared before the ship's departure;

–in addition, during the investigation, it was found that some fasteners for cars did not meet the standard, which required double their strength, because of this, apparently, the cargo in the ship's hold shifted as a result of the maneuver when the ship passed the buoy.

The most alarming fact in the investigation report is this: it appears to be a normal practice for wheeled cargo carriers not to check the cargo placement and the vessel's stability before going to sea. They just silently hope for "maybe" that they will safely reach the port of destination. A similar false practice exists on almost all modern vehicle carriers. Which is confirmed by the following very resonant and very expensive example.

On 08.09.2019, the vehicle carrier ***Golden Ray***, leaving the port of Brunswick with a cargo of 4,200 cars, lost stability and fell to the port side in shallow water. Due to the difficulty and cost involved in raising and transporting the vessel and cargo, it was declared a total loss and a decision was made to saw the vehicle carrier directly in the water along with the cars into eight parts weighing from 2,700 to 4,100 tons. Then take the scrap to the shore for disposal. The rescue operation to dismantle and remove the ship took almost two years and cost more than 800 million dollars (Marine Accident Report, 2021).

The investigation showed that, as in the previous case, the vessel's lose cause was insufficient stability caused by improper cargo placement.

On 23.03.2021, in the Suez Canal at a distance of 6 nautical miles from the southern entrance, the 400-meter container carrier ***Ever Given*** turned around across the canal and rested against its walls. Only on 29.03.2021, with the tide arrival, the vessel managed to be lifted from the shallow water. From March 23 to 29, 437 vessels, including 77 container carriers with a total capacity of 876 thousand TEU plus 20 thousand TEU on the *Ever Given* itself, accumulated on both ends of the channel. According to expert estimates of logistics companies and cargo owners, the closure of the Suez Canal for just one week, as the main shipping artery connecting Asia and Europe, cost world trade more than 10 billion dollars. The accident cause is human error, about which the report on the investigation results states the following: "*...the question of professional negligence or prosecution in accordance with national legislation must be decided individually on the basis of departmental investigations... parallel and simultaneously with the determination of financial responsibility of the master or pilot may be found personally guilty of professional negligence and thus liable to their respective employers, as for the pilot, to the port administration and licensing authority, as for the captain, to the shipowner, the flag state and the authorized body"* (Report on grounding…).

On 13.03.2023, the container carrier ***Ever Forward*** ran aground in the Chesapeake Bay, USA. The ship was on its way from the port of Baltimore to Norfolk. 500 of the 5,000 containers it was carrying were unloaded from the ship to remove it from the beach, but only five weeks later, on 17.04.2023, with the arrival of a powerful spring tide, the ship managed to be pulled into the navigable channel by the efforts of two barges and five tugboats. *Ever Forward*, like the container carrier *Ever Given*, is owned by Evergreen Marine Corporation. The grounding was caused by "the pilot's inability to maintain situational awareness and attention during navigation and inadequate bridge resources management." The US Coast Guard supports the civil case initiation against a pilot for negligent commercial vessel operation (Marine Accident Report, 2021).

On 17.03.2022, the ***Al Salmy 6*** vehicle carrier sank 30 miles from the Iranian port of Eseluiye during a strong storm in the Persian Gulf. All 30 crew members left the ship on a life raft and using life jackets. 28 people were rescued, 2 are missing.

Conclusions

1. For large vessels, a port infrastructure with special rescue equipment, trained specialists is needed, capable of reducing the time and costs of emergency response in case of problems. A case in point is the experience of the container carrier *X-Press Pearl*, which eventually sank after two ports refused it asylum when a damaged container of dangerous cargo was discovered. All too often, what should have been a manageable incident on a large vessel ends in total loss.
2. Real-time cargo temperature monitoring systems, effective water curtain systems, and robotic fire suppression systems are needed because the current shipbuilding regulations are not keeping up with the increase in their size.
3. As vessels became larger, the importance of risks increased and the environmental bar was raised. At the same time, regulation of the safety management system and rescue capabilities have not always kept up with the pace of growth in vessels sizes and growing risks. The International Union of Marine Insurance (IUMI), shipowners' associations, and interested flag states co-authored a submission to the Maritime Safety Committee and the Sub-Committee on Carriage of Cargoes and Containers with a proposal to conduct a comprehensive review of the International Maritime Dangerous Goods Code (IMDG Code) in order to expand the list of dangerous goods, as well as to amend SOLAS in order to expand the possibilities of fire detection and fighting them on new container carriers. The amendments are expected to enter into force on January 1, 2028.
4. Assessing that the vessel has sufficient stability for the intended voyage after cargo operations completion and before going to sea is a fundamental principle of maritime business that cannot be neglected. An accurate stability calculation before leaving port is essential for safety.
5. A cargo seaworthiness computer is an effective and useful tool for safe vessel navigation, but its output can only be as accurate as the information entered into it.
6. It is extremely important that the shipowners working methods, shippers, and port administration allow for the provision of correct information and that there is sufficient time before departure to perform an accurate calculation of the vessel stability.
7. The understanding that the human factor is the main component of most emergency situations at sea causes an urgent need to educate the cadets of maritime educational institutions of high professional competence, striving to form future maritime officers responsibility for the vessel safety, their comrades, responsibility for the environment safety. And this will be a reliable way to improve the quality of navigation safety and reduce the influence of the human factor on the sea vessels accidents.

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SELEKTYVINIO KATALITINIS NOX MAŽINIMO TECHNOLOGIJOS LAIVŲ PRAMONĖJE SCR SISTEMOS ĮTAKOS NO_X MAŽINIMUI TYRIMAS

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Abstraktas. Ši tema yra svarbi dėl kelių priežasčių. Pirmiausia, laivų pramonė yra viena iš pagrindinių teršėjų, prisidedančių prie oro taršos ir klimato kaitos. Todėl yra svarbu ieškoti būdų, kaip mažinti laivų pramonės poveikį aplinkai ir padaryti ją tvarią. Antra, azoto oksidų (NOx) emisijos yra viena iš pagrindinių laivų pramonės oro taršos rūšių. Trečia, selektyvinio katalitinio NOx mažinimo technologijos (SCR) yra viena iš labiausiai perspektyvių būdų, kaip sumažinti laivų pramonės azoto oksidų emisijas. Pagrindinis tikslas yra išnagrinėti, kaip selektyvinio katalitinio NOx mažinimo technologijos, ypač SCR sistemos, gali būti veiksmingai taikomos laivų pramonėje. Straipsnyje bus nagrinėjamą SCR sistemos veikimo principus ir chemines reakcijas, kurios leidžia mažinti NOx emisijas laivų varikliuose, SCR sistemos naudojimo iššūkius laivuose, Palyginti SCR sistemą su kitomis laivų variklių emisijų mažinimo technologijomis jų privalumus ir trūkumus.

Raktiniai žodžiai: SCR- Selektyvinis katalinis redukavimas, NOx- azoto oksidai, SNCR- selektyvinis ne katalinis redukavimas.

Įvadas

Šiuolaikinės laivų pramonės vystymasis yra susijęs su didelių laivų variklių naudojimu, kurie yra išskirtinai efektyvūs, tačiau labai taršūs. Didelis taršos lygis, kurį šie laivų varikliai gamina, yra ypač susijęs su azoto oksidų (NOx) emisijomis, kurios gali turėti neigiamą poveikį tiek aplinkai, tiek ir žmonių sveikatai. Todėl pastaraisiais metais laivų pramonėje yra daug dėmesio skiriama naujų technologijų kūrimui, kurios galėtų sumažinti šias žalingas emisijas.. Šios technologijos pagrindas yra selektyvus katalitinis redukavimas (SCR) - cheminė reakcija, kurioje azoto oksidai yra konvertuojami į azotą ir vandenilį per katalizatorių, veikiančių esant aukštai temperatūrai. SCR sistemos susideda iš kelių pagrindinių komponentų, įskaitant: katalizatorių, amoniako įterpimo sistemą ir valdymo sistemą.

Temos objektas: SCR sistema, naudojama laivų pramonėje, ir jos įtaka azoto oksidų mažinimui.

Temos tikslas: Išnagrinėti selektyvinio NOx mažinimo technologijos taikymo laivuose ypatumus ir iššūkius.

Temos uždaviniai:

1. Išnagrinėti SCR sistemos veikimo principus ir chemines reakcijas leidžiančias mažinti NOx emisijas laivų varikliuose.
2. Išanalizuoti SCR sistemos naudojimo iššūkius laivuose.
3. Palyginti SCR sistemą su kitomis laivų variklių emisijų mažinimo technologijomis jų privalumus ir trūkumus prieš SNCR sistema.

Metodai - mokslinės literatūros ir techninės dokumentacijos analizė.

1. SCR sistemos veikimo principų ir jos ypatumų analizė

SCR (Selective Catalytic Reduction) sistema – įrenginys, kuris naudojamas mažinant deginimo kuro išmetamųjų dujų, ypač azoto oksidų (NO_X), kiekį. Ši sistema veikia pagal cheminę reakciją, kuri vyksta tarp reaktyvaus katalizatoriaus ir išmetamųjų dujų. SCR procesas pagrįstas NO_X (NO ir NO_2 mišinio) mažinimu, paprastai naudojant NH_3 kaip reduktorių, kad susidarytų nekenksmingas vanduo ir azotas. Vienas iš komercinėje praktikoje labiausiai paplitęs katalizatorius yra titanu paremtas vanadis oksidas, kuris yra selektyvus ta prasme, kad NH_3 pirmiausia redukuoja NO į N_2, o ne oksiduojasi iki NO esant O_2 (Lee et al., 2002).

Šis procesas vadinamas selektyviąja katalize. SCR sistema veikia taip, kad prieš išmetimą iš variklio, išmetamųjų dujų srautui yra pridedamas katalizatorius, kuris yra užpildytas reagentu. Kai išmetamųjų dujų srautas patenka per katalizatorių, reagentas susiduria su NOx ir virsta į nekenksmingas dujas. Cheminė reakcijos, kuriai naudojamas bevandenis vandeninis amoniakas, lygtis yra tokia:

$$4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 = 3N_2 + 6H_2O$$

$$NO + NO_2 + 2NH_3 = 2N_2 + 3H_2O$$

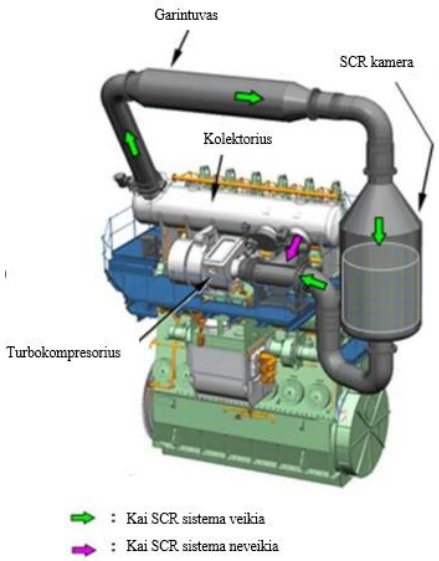
Karbamido vietoj bevandenio arba vandeninio amoniako reakcija, esant katalizatoriui, yra tokia:

$$4NO + 2(NH_2)2CO + O_2 = 4N_2 + 4H_2O + 2CO_2$$

Į išmetamųjų dujų srautą įpilamas reduktorius Bevandenis amoniakas (NH_3), vandeninis amoniako (amonio hidroksido) arba karbamido (karbamido) tirpalas, kuris absorbuojamas ant katalizatoriaus. Anglies dioksidas (CO_2) yra reakcijos produktas, kai karbamidas naudojamas kaip reduktorius (A. Mathur, 2020).

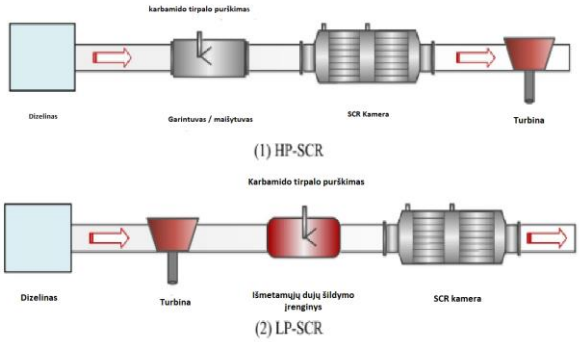
Ši išmetamųjų dujų papildomo apdorojimo technologija leidžia sumažinti NOx daugiau kaip 95 %. SCR koncepcija apima karbamido ir vandens tirpalo įpurškimą į išmetamųjų dujų srautą kartu su specialiu katalizatoriumi. SCR laikoma papildoma ir nepriklausoma išmetamųjų dujų apdorojimo sistema, todėl ji netrukdo pagrindinei variklio konstrukcijai ar degimo procesui. Toliau pateikta proceso schema padeda geriau suprasti SCR sistemą, kurioje karbamidas sąveikauja su azoto oksidais, esančiais į išmetamąsias dujas patenkančiose dujose, ir, esant katalizatoriui, paverčia juos laisvu azotu ir vandens garais. „The Maritime Environmental Protection Committee (MEPC)“ paskelbė selektyvaus katalitinio redukavimo (SCR) sistemų sertifikavimo gaires, vadinamas „SCR gairėmis“ (IMO rezoliucija MEPC.198[62]).

Laivų dyzeliniams varikliams būdinga žemesnė temperatūra ir didesnis sieros kiekis išmetamosiose dujose, o tai labai riboja SCR sistemos NOx konversijos efektyvumą. Siekiant didesnio NOx konversijos efektyvumo, SCR sistema dvitakčiame mažo greičio jūriniame dyzeliniame variklyje naudojama didinant išmetamųjų dujų temperatūrą ir taip tenkinant jūrinio dyzelinio variklio išmetamųjų teršalų kontrolės reikalavimus. Atsižvelgiant į jūrinio dyzelinio variklio išdėstymo formas, SCR sistemą galima suskirstyti į du tipus: žemo slėgio SCR sistemą po turbinos (LP-SCR) ir aukšto slėgio SCR sistemą prieš turbiną (HP - SCR).



1 pav. SCR sistemos aukšto slėgio veikimo principas.
Šaltinis: (A. Mathur, 2020).

Palyginus, HP-SCR (aukšto slėgio) sistema turi daugiau kompaktiškesnė ir geriau išnaudoja išmetamųjų dujų šilumą, tačiau ji gali turėti didelės įtakos dyzelinių variklių ir su jais susijusių turbinų darbo charakteristikoms, todėl daugiausia taikoma dvitakčiuose žemo sūkių dažnio laivų dyzeliniuose varikliuose, kurie varomi didelio sieros kiekio likutiniu kuru. SCR aukšto ir žemo slėgio sistemų schemos pateikto 2 pav.

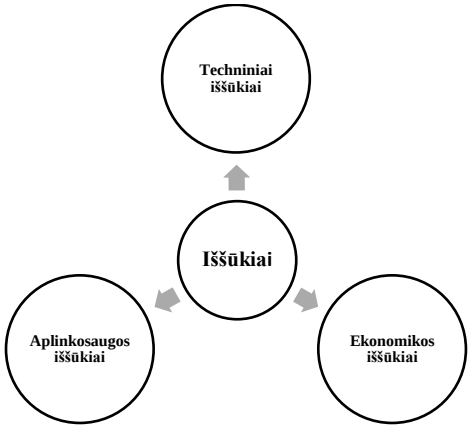


2 pav. SCR aukšto ir žemo slėgio sistemų schemos.
Šaltinis: (Y. Zhu, ir kt., 2019).

Tačiau LP-SCR sistema pasižymi didesniu pritaikomumu ir mažesne įtaka dyzeliniams varikliams ir su jais suderintoms turbinoms, todėl ją galima plačiai taikyti ir vidutinio, ir didelio sūkių dažnio dyzeliniuose varikliuose. (Y. Zhu, ir kt., 2019).

2. SCR sistemos panaudojimo iššūkių laivuose analizė

Remiantis „SCR On Ships: Challenges and Solutions“ ir Wärtsilä duomenimis, taikant SCR sistemą, laivybos pramonė susiduria su daugybe iššūkių, aktualiausi iš jų pateikti 3 pav.



3 pav. SCR sistemos panaudojimo iššūkiai

1. Techniniai iššūkiai: SCR sistemos įrengimas laive gali reikalauti didelių inžinerinių darbų, tokių kaip, pritaikymo prie laivo specifikacijų. Be to, turi būti užtikrintas sistemos patikimumas ir tinkama priežiūra.
2. Ekonominiai iššūkiai: SCR sistemos dažnai yra gana brangios, todėl reikia numatyti papildomas išlaidas, tokias kaip, sistemos priežiūros ir pakeitimo išlaidas. Be to, tokioms sistemoms gali prireikti papildomos vietos laive, o tai gali turėti įtakos laivo konstrukcijai ir krovinių talpai.
3. Aplinkosaugos iššūkiai: nors SCR sistemos sumažina oro taršą, jų naudojimas taip pat kelia tam tikrų aplinkosaugos iššūkių. Turi būti užtikrinta, kad sistema būtų įrengta ir prižiūrima nesukeliant kitų aplinkos problemų, tokių kaip triukšmas ar vandens tarša. Taip pat reikia pasirūpinti, kad sistemos naudojimas nesukeltų kitų neigiamų pasekmių, pavyzdžiui, didesnių CO_2 emisijų, dėl kurių sumažėtų išmetamųjų teršalų mažinimo nauda.

3. SCR NOx mažinimo sistemos pranašumų prieš SNCR sistemos naudojimą analizė

SCR (Selective Catalytic Reduction) ir SNCR (Selective Non-Catalytic Reduction) sistemos yra du skirtingi metodai, išmetamųjų duju emisijoms mažinti. SCR sistemos naudoja katalizatorių, kad chemiškai paverstų NOx į nekenksmingus dujas, naudojant amoniaką arba karbamidą kaip redukavimo agentą. Šios sistemos yra labai efektyvios mažinant NOx išmetimą ir taip pat leidžia pasiekti aukštesnę efektyvumo normą nei SNCR sistemos

SNCR sistemose naudojami redukciniai agentai tokie kaip amoniakas ar karbamidas, kuris įpurškiamas tiesiai į degimo zoną, siekiant sumažinti NOx emisiją. Šių sistemų pranašumas yra tas, kad jos yra pigesnės ir paprastesnės nei SCR sistemos, todėl jas lengviau įdiegti ir prižiūrėti. Tačiau jie yra mažiau efektyvūs nei SCR sistemos ir yra jautresni kintamos degalų kokybei todėl tinka tik tam tikroms degalų rūšims.

Todėl SCR sistemos turi keletą pranašumų, palyginti su SNCR sistemomis, įskaitant didesnį efektyvumą, didesnį degalų lankstumą. Tačiau SNCR sistemos tinka, jei reikia paprastos, mažos ir pigios sistemos, kurios gali būti pritaikytos specifiniam kuro tipui. Remiantis vienu iš oro taršos kontrolės lyderių, kompanijos Redecam Group SpA, straipsnio „Denitrification " duomenimis galima palyginti SCR ir SNCR sistemų privalumus ir trūkumus.

SCR sistemos pranašumai:

- Puikiai tinka didelio našumo varikliams;
- Efektyviai sumažina azoto oksido (NOx) emisijas, kurias galima sumažinti iki 90 - 95 %;
- Galima naudoti tiek su jūriniais, tiek su mažos galios varikliais.

SCR sistemos trūkumai:

- Brangi;
- Reikalingi specialūs reagentai, tokie kaip amoniako vanduo arba karbamido tirpalas;
- Reikalingas atsargumas transportuojant ir saugojant reagentus;

- Atliekų tvarkymas po reakcijos taip pat gali būti brangus.

SNCR sistemos privalumai:

- Gali būti įrengta greitai ir pigiau nei SCR sistema;
- Galima naudoti dideliems ir mažiems laivų varikliams;
- Gali būti naudojama esant didelės ir mažos variklio apkrovos režimams.

SNCR sistemos trūkumai:

- Mažiau efektyvus nei SCR sistemos;
- Gali būti reikalingi dažnesni remontai ir priežiūra.

Kaip matome iš pateiktų duomenų, nors SCR sistema efektyviau šalina NO_X (iki 95 %), taip pat gali būti taikoma didesnio galingumo laivams, bet dėl didesnių jos įdiegimo kaštų yra mažiau patraukli laivų gamintojams. Todėl, dėl ekonominio faktoriaus, šiandien vis dar plačiai naudojama, nors ir mažiau draugiška aplinkai, SNCR sistema.

Išvados

1. Išanalizavus SCR sistemos veikimo principus ir chemines reakcijas, kurios leidžia mažinti NOx emisijas laivų varikliuose, nustatyta, kad tai yra labai efektyvi ir patikima technologija, leidžianti iki 95 % sumažinti azoto oksido išmetimą iš laivų. Ši technologija taip pat yra nekenksminga aplinkai, nes neišskiria jokių kenksmingų teršalų
2. Išanalizavus SCR sistemos naudojimo iššūkius laivuose, buvo pastebėta, kad nepaisant visos teikiamos ekologinės naudos, dėl papildomų iššūkių, tokių kaip: inžineriniai darbai, sistemos priežiūros išlaidos, papildomos vietos poreikis, taip pat poreikis užtikrinti, kad sistema būtų įrengta ir prižiūrima nesukeliant kitų aplinkos problemų, tokių kaip triukšmas ar vandens tarša, šios sistemos naudojimas tampa mažiau patrauklus.
3. Palyginus SCR sistemą su kitomis laivų variklių emisijų mažinimo technologijomis jų privalumais bei trūkumais prieš SNCR sistemą, pastebėta, kad dėl didesnių finansinių sistemos įdiegimo kaštų, plačiausiai laivuose naudojama, mažiau draugiška aplinkai, SNCR sistema.

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EVALUATION FOR THE INTERFACE BETWEEN FAULTS AND RELIABILITY OF THE VESSELS ELECTRICAL DISTRIBUTION NETWORK

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Abstract. The most important factor in the efficient functioning of the vessel is the system's reliability and stability. Faults and their frequency, overvoltages, mechanical load, temperature, short circuits, etc. have a significant impact on reliability. Automation and the reliance on energy for all equipment are transforming ships. As a result, if an electrical component of the vessel doesn't work, its functionality may be disrupted, which could result in losses of money. A high quality, cost-effective and reliable electricity network requires regular monitoring of the network, its performance, its lifetime and, at the same time, an assessment of potential faults in order to avoid them. In this research paper, we will discuss the main and most common reasons for electrical power faults. By eliminating the causes of the faults, or by referring to the experience of other ships, many failures, malfunctions and losses due to equipment inactivity and malfunctions could be avoided or incurred.

Keywords: reliability, vessel distribution network, faults

Introduction

Constantly advancing technologies are increasing the dependence of electricity consumption [1]. Not only is there a huge number of requirements [3], but the aim is to ensure that the supply and distribution of electricity is of high quality [11], the system itself is modern and the electricity grid is reliable. Electricity reliability and security is one of the most topical topics of analysis and research in the scientific field [2] [9]. Reliability is and will be very important in electric distribution network to supply electric energy of good quality, sufficient quantity, secure, reliable and safety without interruptions with continuity of the availability of power in a specific area for considered time of period [9] to the last point – customer. Electric network reliability also defined as a device suitability, functionality, continuous working capacity, meeting all operating characteristics within the specified frame of time.

A vessel's electrical system comprises: all electrical equipment, elements, components, without the absence of any one of which the operation of the electrical system would be impossible. In other words, all devices are considered to be an integral part of the system. Therefore, it is necessary to study the quality of the entire network as a set of characteristics when designing, repairing and operating electrical systems. In order to assess the frequency of power loss to the vessel's equipment or users, it is necessary to use index values to determine the availability of power supply during the expected period [13]. Reliability of both the power system and the electrical equipment is defined as the cumulative characteristics of all interruptions and failures over a long period of time and is assessed in terms of probability but calculated as the frequency of failures over a given period. A comparative analysis of the reliability status is possible when outage and reliability indexes should be collected, sorted, systematised on the same or similar principles. However, today not all historical data on interruptions are available and interruption data are not reliable and representative.

Knowing the most sensitive and vulnerable areas of the network, which environmental or other conditions and faults affect network outages, requires a detailed and methodical ongoing analysis of the network. In order to meet the needs of electricity users, to ensure that electricity of a specific quality is supplied to the ship's equipment, both the electricity network itself and its elements must be designed, installed and replaced, upgraded and maintained in order to ensure the operability of the system [6].

Factors affecting electric network reliability

Failure – an event that results in the partial or total loss of an object's serviceability. Faults and interruptions in the electrical system, network, equipment is inseparable from the reliability of the electrical network. The reliability of the electrical network is defined as the adequacy, functionality, uninterrupted operation, stability of the system or installation, meeting all specified performance specifications over the manufacturer's expected lifetime. Failures are classified into *planned* and *unplanned* failures. Unplanned equipment failures are the most damaging to electrical systems. Unplanned interruption [10] is defined as accidental, caused by short-term or permanent faults in the electrical network.

The electrical systems of the vessel contain a variety of equipment of diverse designs, structures, etc. According to data, the medium voltage (MV - 440 V and 690 V) electric distribution network on vessels is its weak point. MV network issues on the vessels are to blame for more than 90% of the unexpected outages. There are many factors which are affect the power grid of ship (See Fig. 1: lightning, salinity, temperature changes, overvoltage's, vibration, temperatures, human failures, etc. Those disconnection phenomena's is strongly influence outages, disconnections of the network parts, equipment on the vessels power system. Most of the outages are unexpected disturbances or other interruptions which can lead to the blackout of the whole distribution network, it can damage line connected equipment.

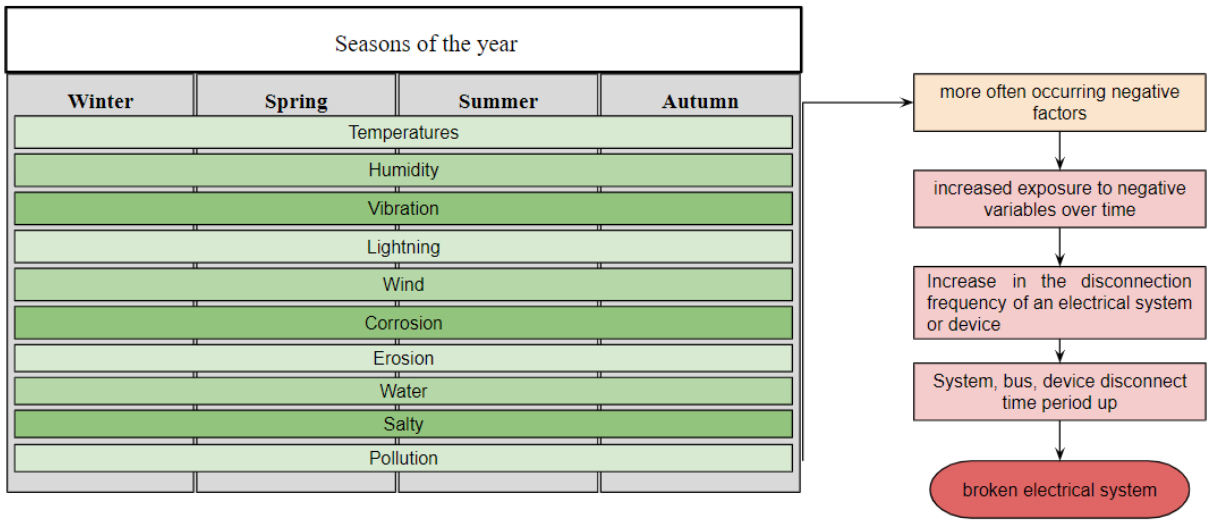


Fig. 1. Factors affecting failures

For different fault flow parameters (working time, normal operating period, period of intense depreciation), distribution rules are utilized to model reliability calculations.

Models for the analysis

There are two main methods used in research to assess the reliability of electricity supply: analytical [4] [5] [12] and modelling [7] (also known as strategic) approach. The choice of computational methods is based on the following main criteria: computational time, complexity of the network system to be developed, expression of computational results, analysis of the evaluation of results.

Modelling should be as simple as possible, but at the same time powerful and accurate in capturing and assessing all potential risks. Only when the model and its limitations are understood can the results be interpreted correctly without fetching them. The choice of the appropriate method depends on the topology of the network, the lifetime of the equipment, the calculations to be performed and the data required.

The accuracy of the calculation of the reliability characteristics of the devices depends on the number of objects monitored - on the sample of objects. To strain after an effect electricity grid of

good quality, economic and reliable work requires to monitoring the network, its operation, lifetime at the same time to evaluation of potential failures to avoid them. Electric energy reliability concern with appropriate equipment isolation, rapid response fault removal and reaching avoid all of this.

Randomness is known to be a feature of electrical systems. Faults in electrical systems are also characterised by randomness. Electric network's reliability also depends on if network topology, component's information. All networks can be shown as nodes The components at the same zone connect other switches. One of the most popular is the topological matrix, which is based on the Monte Carlo method [7]. Monte Carlo simulation methods evaluate the simulated real process and random states of the system. The suitability of the evaluation technique and model, the number of indicators to be evaluated, the appropriateness and quality of their inputs for the system under consideration, are the main and most important aspects in selecting the most appropriate solutions and the number of models. The Monte Carlo method uses congruent generation to generate random numbers, which produces a continuous distribution of random numbers (0,1). For modelling, the state modelling approach is commonly used, and the states of the systems are determined from the states of the system elements, which are obtained from a numerical experiment. The states of the system elements are assumed to be uniformly distributed random variables between 0 and 1. The random variable X is then given a specific value - a random realisation. The function of the random variable can then be expressed as:

$$X: \Omega \to S$$
$$X(\omega) = x \epsilon S$$

Here: Ω – sampling space;
S – the state space of the random variable *x*;
$X(\omega)$ – implementation;
ω – sample element.

Habitat spaces $S = \{available, busy, faulty, inactive\}$ is expressed in vectors:

$$S = (S_1, S_2, \dots S_i, \dots, S_n).$$

Here: S_i – *i* is the state of that element of the system.
The status of a system element shall be described by:

$$S_i = \begin{Bmatrix} 0\ (Available\ at) \\ 1\ (Not\ working) \end{Bmatrix} \quad (1)$$

If the uniformly distributed magnitude is less than the element's immaturity factor, the element is in a state of failure:

$$S_S = \begin{Bmatrix} 0, (S_1 = 0) \cup (S_2 = 0) \\ 1, (S_2 = 1) \cap (S_2 = 1) \end{Bmatrix} \quad (2)$$

The system state estimation is calculated:

$$R = \frac{n_0}{n} \quad (3)$$

$$n_0 + n_1 = n \quad (4)$$

here: n_0 – number of experiments where the system n_0 times is operational;
n_1 – the system is not working.

For comparative reliability state analysis of the situation is possible when interruption and reliability indexes should be collecting, sorting, systematizing in the same or similar principles. In these days there are no accumulate all historical data interruptions and interruptions are not reliable and representative in the data.

Calculation Results

The vessel's electrical network is of the radial type (see Fig. 2), which consists of many individual elements, and their efficiency affects not only special-purpose users (electric motors, ventilation system, etc.), but also general-purpose users.

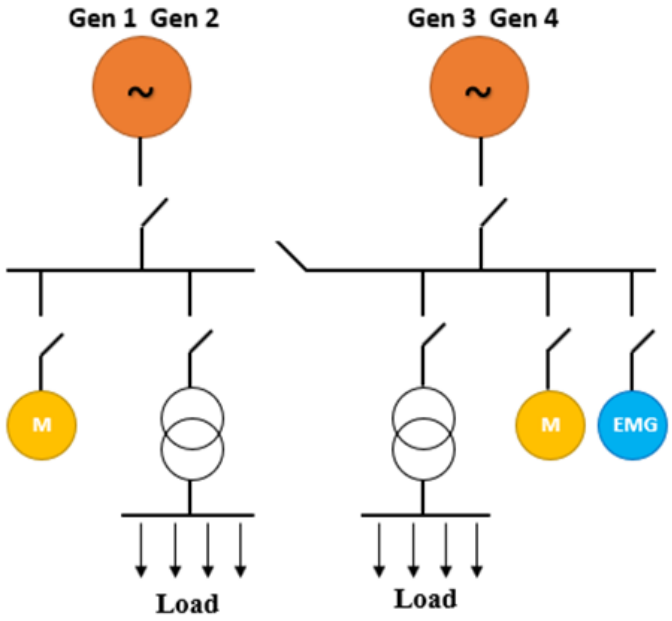


Fig. 2 Vessel's Electrical Diagram

Based on statistics obtained by different companies and different types of vessels, it is estimated that 80 % and more disconnections in the electricity network occur from 690 V, 440 V, 220 V network. Above 1000 V in the network, faults occur in about 5 %. Based on the data, a time frame of one year, all faults are rated in 100 %, the percentage size is distributed according to the event. The data of failures are converted to percentages and shown in Table 1.

Table 1: Faults distribution – based on vessel company real data case

Fault name	All failures
Environmental factors (nature conditions etc.)	12 %
The same parameters having devices but created of different companies (internal characteristics are different).	27 %
The Crew made mistakes	33 %
Installation time, load capacity, and lifetime	8 %
Load	17 %
Force majeure	3 %
Total:	100 %

From a reliability point of view, the assessment of the state of the electricity network requires information on the whole network, and also on individual installations as a result of the calculations and estimations made in the system modelling. Plant modelling is an important factor affecting the reliability of the whole system. The modelling should be as simple as possible and be able to cover and assess all possible risks. Therefore, a reliability flowchart has been developed (see Fig. 3).

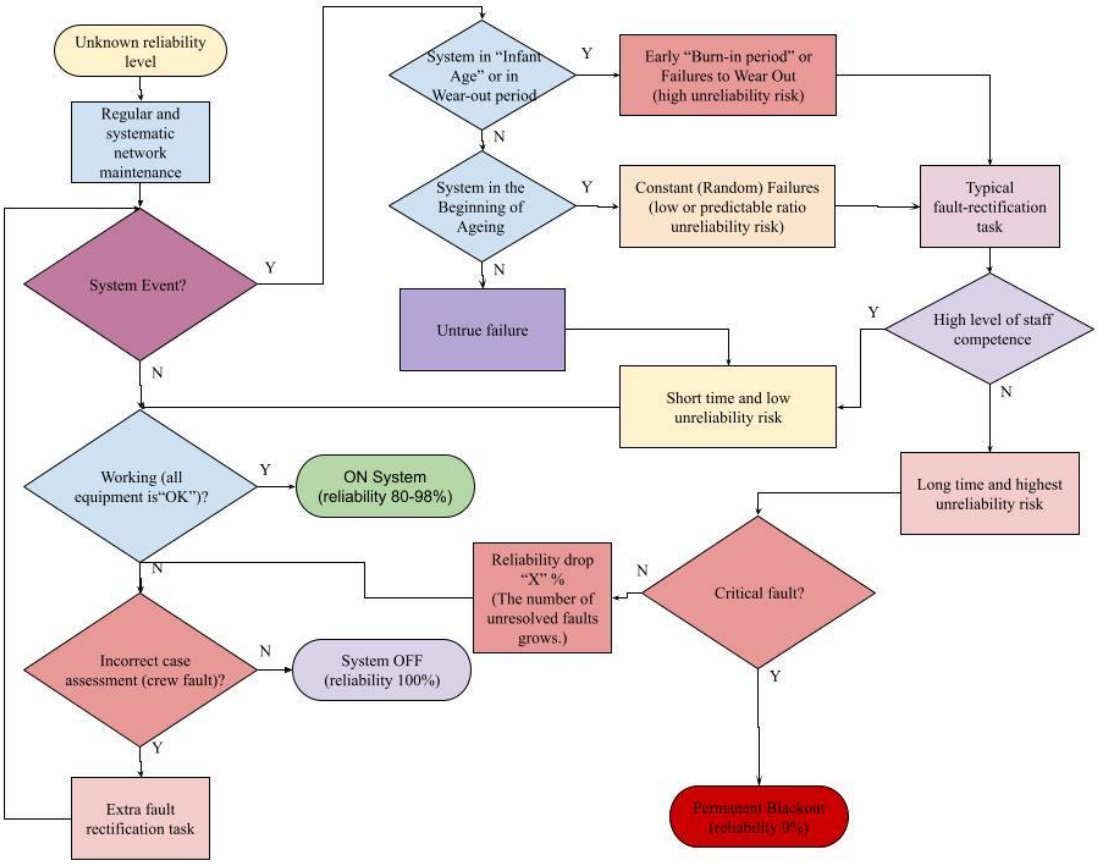
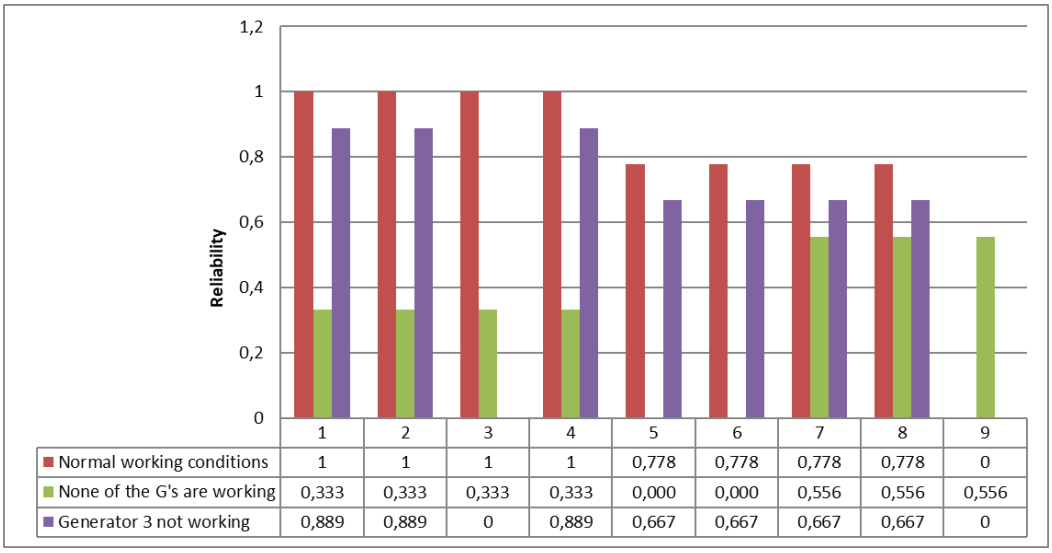


Fig. 3. Electrical system reliability flow chart

Under normal operating conditions, there are two or more generators on board. The rest are on standby. However, in various scenarios, the ship's system may not work reliably. The results are shown in the graph (see Fig. 4).



	1	2	3	4	5	6	7	8	9
Normal working conditions	1	1	1	1	0,778	0,778	0,778	0,778	0
None of the G's are working	0,333	0,333	0,333	0,333	0,000	0,000	0,556	0,556	0,556
Generator 3 not working	0,889	0,889	0	0,889	0,667	0,667	0,667	0,667	0

Fig. 4. Reliability assessment of how generators operate in full or under different operating conditions

Conclusions

Each outage event shall be recorded in the system as a separate element, referring to those primitives (planned and unplanned outages): location of the outage on the system; date and time; cause of the outage and its grouping (unplanned interference only); nature of the outage; number of

users affected by the outage; number of transmission and distribution system links interrupted; and the environmental impact. However, reliability is highly dependent on both the employee and the company, as well as on data input, tracking and proper maintenance of electrical equipment. It is now well known that companies often do not keep such data, resulting in constant disconnections and system failures. Therefore, in order to understand the reliability of the system with or without the operation of certain equipment, a calculation methodology is needed which shows the relationship between the operation of the electrical equipment, and which can be used to assess the reliability of the electrical system or equipment.

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TURBOKOMPRESORIAUS SKIRTINGŲ GEDIMŲ ĮTAKOS VARIKLIO PRAMETRAMS TYRIMAS

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Abstraktas. Šiais laikais jūriniai laivai yra varomi didelės galios dyzeliniais varikliais, kurie laivuose vadinami pagrindiniais varikliais. Didelių jūrinių dyzelinių variklių neatsėjama įrenginių dalis yra turbokompresorinė pripūtimo sistema. Šios sistemos padeda užtikrinti degimo proceso efektyvumą, didesnę variklio galią ir mažesnę kenksmingų nevisiškos oksidacijos junginių emisiją. Dėl netinkamos turbokompresoriaus pripūtimo sistemos eksploatacijos laive gali atsirasti tam tikrų gedimų, gali padidėti degalų sąnaudos, pagrindinis variklis gali veikti netolygiai ir sukelti nepageidaujamų vibracijų, o pačiu blogiausiu atveju nustoti veikti atviroje jūroje taip sukeliant pavojų kroviniui ir įgulos nuostolius laivų savininkams. Netinkamas turbokompresorinės pripūtimo sistemos naudojimas taip pat gali stipriai sugadinti patį turbokompresorių ir sukelti nepageidaujamą variklio avariją jūroje. Siekiant garantuoti tinkamą ir sklandų pagrindinio variklio veikimą ir išvengti tokių nepageidaujamų avarijų, būtina spręsti gedimų atsiradimų priežastis ir iškilusias problemas. Šio tyrimo tikslas – remiantis mokslinių šaltinių analize, ištirti dažniausia sutinkamų laivų turbokompresorių gedimų įtaką pagrindinio laivo varikliui, jo darbo parametrams, modeliuojant situacijas „Kongsberg“ variklio simuliatoriuje. Išnagrinėjus įvairius turbokompresorių gedimus, surinkti ir išanalizuoti atitinkamus duomenis. Tyrime siekiama nustatyti pagrindinį turbokompresoriaus gedimą ar gedimus iššaukiančius įvairių įvykių grandinę, pasibaigiančią visišku variklio sustabdymu. Atlikus tyrimą pateikiami siūlymai kaip išvengti turbokompresorinės pripūtimo sistemos ir kitų susijusių su laivo pagrindiniu varikliu, gedimų.

Raktiniai žodžiai: turbokompresorius, simuliatorius, pagrindinis laivo variklis, gedimai.

Įvadas

Laivo pagrindinio variklio, suteikiančio laivui eigą, saugi eksploatacija priklauso nuo jo sistemų, kurios susideda iš: degalų tiekimo sistemos, tepimo alyvos sistemos, aušinamo vandens sistemos ir aprūpinimo oru sistemos patikimumo. Turbokompresorinę sistemą sudaro keletas kitų posistemių, kurias sudaro turbokompresoriai ir oro aušintuvai, kurie, siekiant efektyvaus sistemos panaudojimo, yra neatskiriami nuo turbokompresoriaus veikimo. Šiame tyrime bus nagrinėjami turbokompresoriaus veikimo proceso principai ir gedimai, kurių nepriežiūra ir netinkamas naudojimas gali sukelti pagrindinio variklio gedimą.

Nuolat naudojant iškastinę energiją, energetikos ir aplinkosaugos problemos tampa vis rimtesnės. Vienu iš pagrindinių jūrų taršos šaltiniu tapo jūrinių dyzelinių variklių išmetami teršalai, kurie atkreipė atitinkamų tarptautinių organizacijų dėmesį, tokių kaip „Tarptautinė jūrinė organizacija“ (IMO). Norint pagerinti dyzelinių jūrinių variklių ekonomiškumą ir šiluminį efektyvumą, buvo sukurta turbokompresorinio priputimo sistema, kuri suspaudžia orą, kad būtų padidintas oro slėgis ir tankis, tam, kad pagerinti variklio efektyvumą. Dauguma kompresorių yra išcentriniai, su radialiniu mentračiu (rotoriumi) ir bepakopiai difuzoriai. Jie sukuria didelį į cilindrus paduodamo oro slėgį tuo gerindami degimo procesą cilindruose. Tai leidžia užtikrinti santykinai didelę specifinę galią, padidinti efektyvumą ir sumažinti anglies monoksidų ir suodžių emisiją lyginant su varikliais be turbokompresorinės sistemos (Roman Varbanets 2021).

Šiame straipsnyje buvo pasitelkti Australijos Tasmanijos universiteto atlikto tyrimo rezultatai. Norint nustatyti įvairių turbokompresoriaus gedimų įtaką laivo variklio darbo parametrams, Australijos Tasmanijos universitetas, Australijos jūrų koledže atlikto tyrimą, kurio metu situacijos

buvo modeliuojamos ,,Kongsberg“ variklių skyriaus simuliatoriumi. Minėtas simuliatorius naudojamas įvairiems turbokompresorių sistemos gedimams tirti.

Darbo objektas: laivo pagrindinio variklio turbokompresorius.

Darbo tikslas: naudojant Australijos Tasmanijos universiteto, Australijos jūrų koledžo ,,Kongsberg“ mašinų skyriaus simuliatoriaus atlikto su MAN B&W 5L90MC varikliu tyrimo rezultatais, nustatyti variklio parametrų pasikeitimus ir įtaką parametrams sugedus turbokompresoriui ar vienai iš jo sistemų.

Darbo uždaviniai:

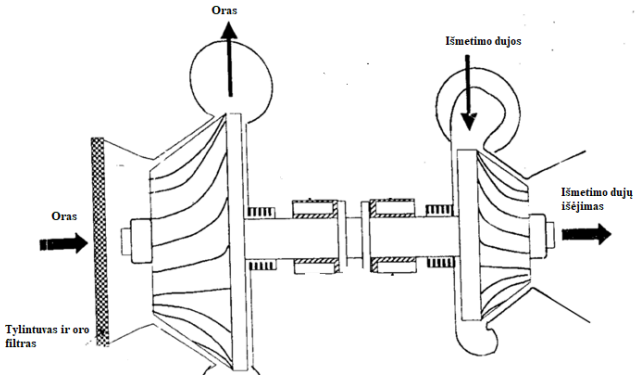
1. Išanalizuoti turbokompresoriaus veikimo principą;
2. Išanalizuoti turbokompresoriaus dažniausiai kylančius gedimus ir jų priežastis;
3. Nustatyti dažniausiai sutinkamų turbokompresorių gedimų poveikį ir įtaką laivo variklio darbo parametrams;
4. Sudaryti laivo turbokompresorių gedimų prevencijos planą.

Darbo metodai: Mokslinės ir technologinės literatūros bei duomenų analizė, lyginamoji duomenų analizė.

1. Turbokompresoriaus veikimo principo analizė

Šiuolaikiniai didelių dyzelinių variklių turbokompresoriai pasižymi dideliu slėgio padidinimo koeficientu kompresoriuje - iki 5 ir daugiau. Jie sukuria didelį įkraunamo oro slėgį, taip užtikrindami didelę specifinę galią ir didelio efektyvumo didelio variklio darbą su mažą anglies oksidų ir suodžių emisija. Jei turbokompresorius praranda našumą, dyzelinio variklio galia ir naudingumo koeficientas greitai sumažėja, o anglies oksidų ir suodžių emisijos lygis padidėja. Eksploatuojamų laivų dyzelinių variklių leistinas pavojingų išmetamųjų teršalų lygis yra ribojamas pagal galiojančius Tarptautinės jūrų organizacijos (TJO) reikalavimus. Kadangi didžioji dauguma įvairių jūrų transporto laivų naudoja dyzelinius variklius, jų efektyvaus ir saugaus eksploatavimo klausimas neabejotinai yra aktualus.

Turbokompresorius yra siurbimo posistemio dalis ir labai svarbi atliekant gyvybiškai svarbų darbą mašinų skyriuje veikiant pagrindiniam varikliui. Vienas iš turbokompresoriaus pavyzdžių pateikiamas 1 paveiksle.



1 pav. Turbokompresorius veikimo schema

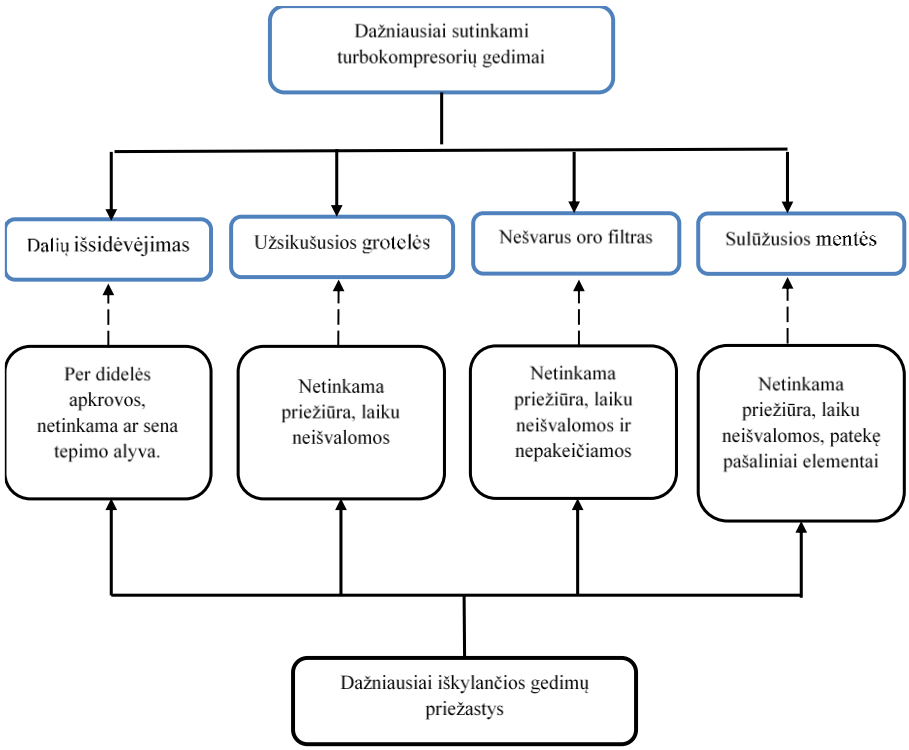
Šaltinis: prieiga internetu*:* *https://dieselship.com/marine-technical-articles/motor-engineering-knowledge/turbocharger-bearing-lubrication-system/*

Turbokompresoriaus gedimas gali sukelti neišvengiamų ir net pražūtingų varikliui pasekmių. Kompresorius paprastai vadinamas turbokompresoriaus oro įsiurbimo puse, o turbina – turbokompresoriaus išmetimo puse. Didelis pagrindinio variklio turbokompresorius paprastai yra sudarytas iš vienos pakopos ašinio srauto turbinos, sujungtas su vienos pakopos rotaciniu kompresoriumi, varomu bendro rotoriaus velenu (Sarah Simons, 2019 m.). Iš pagrindinio variklio išmetamosios dujos yra nukreiptos į turbiną, kuri varoma išmetamųjų dujų srauto varo kompresorių. Iš mašinų skyriaus oras yra siurbiamas kompresoriaus, kuris yra suspaudžiamas iki aukštesnio slėgio

bei temperatūros, kuri gali siekti 200 °C, po to yra nukreipiamas į oro aušintuvą ir ataušinamas, po to keliauja pro kolektorių iš kurio oras paskirstomas po cilindrus.

2. Turbokompresoriaus dažniausiai kylančių gedimų ir jų priežasčių analizė

Turbokompresoriaus darbo efektyvumas, saugumas ir patikimumas priklauso nuo dviejų skirtingų sistemų, tai yra nuo turbinos ir kompresoriaus atskirų sistemų dalių patikimumo. 2 paveiksle pateikta dažniausiai sutinkamų turbokompresoriaus gedimų schema. Įvertinant turbokompresoriaus efektyvumą, būtinai reikia įvertinti turbinos ir kompresoriaus efektyvumą, tyrimo atveju buvo įvertintas MAN B&W eksploatacijos vadovas.



2. pav. Dažniausiai sutinkami turbokompresorių gedimų schema

Labai svarbu yra tiek kompresoriaus tiek turbinos dalių veiksmingumas, kad būtų pasiektas aukštas turbokompresoriaus efektyvumas kaip parodyta lygtyje:

$$\boldsymbol{\eta_{total} = \eta_{compresor} + \eta_{turbine}} \quad (1)$$

kur:

η_{total} – turbokompresoriaus bendras naudingumo koeficientas

$\eta_{compresor}$ – kompresoriaus naudingumo koeficientas

$\eta_{turbine}$ – turbinos naudingumo koeficientas

„Kongsberg Simuliator‘‘ yra naudojamas turbokompresorinių sistemų gedimams analizuoti ir įvertinti. Turbokompresoriaus kompresorius ir turbina yra labai svarbus du pagrindinio variklio darbui ir veikimui užtikrinti komponentai, atsakingi už turbokompresoriaus bendrą efektyvumą, kaip matyti iš lygties.

Bet koks gedimas tiek oro išmetimo pusėje ar oro įsiurbimo gali sukelti nenormalų turbokompresoriaus veikimą, o tai turės didelės įtakos jo efektyvumui bei turbokompresoriaus sistemos patikimumui, o tai gali turėti labai neigiamos įtakos pagrindinio variklio patikimumui. Yra daugybė gedimų susijusių su turbokompresoriaus sistema, bet šiame tyrime bus analizuojami ir nagrinėjami du pagrindiniai gedimai, po vieną oro ir išmetimo pusėje, ir ištirtas jų poveikis pagrindiniam laivo varikliui bei pačiam turbokompresoriui.

Užsiteršęs oro filtras. Oras per oro įleidimo filtrus yra ištraukiamas iš mašinų skyriaus. Oro įleidimo angos yra supaprastintos, o viduje sumontuota izoliacija tam, kad būtų galima kiek įmanomą sumažinti triukšmą. Filtrai yra padaryti taip, kad juos būtų galima išimti ir išvalyti. Sumontuota filtro vaizdas pateiktas 3 paveiksle.

3 pav. Turbokompresoriaus oro filtras
Šaltinis: asmeninis archyvas

Turbokompresoriaus įsiurbiama oro kokybė ir kiekis yra labai svarbus ir priklauso nuo oro filtrų kokybės. Labai svarbu, kad filtrai būtų reguliariai valomi, pageidautina kas 500 darbo valandų. Tuo pačiu metu būtina, kad jie būtų gerai apsaugoti, kai pagrindinis variklis yra sustojęs. Įprasta filtro korpusą uždengti drobiniu dangteliu, kuris apsaugotų nuo dulkių patekimo iš uostų, ypač birių krovinių terminaluose, kuriuose kraunama anglis, geležies rūda ar grūdai. Taip galima išvengti krovinio dulkių patekimo iš uosto (M. Anantharaman, 2021).

Taip pat turbokompresoriaus linijoje gali būti izoliuota magistralė į ventiliatorių, kuri tiekia orą į kompresorių. Variklio valdymo patalpoje atskyrus orapūte, gerai matomoje vietoje, turėtų būti aiškiai matomas pranešimas apie tai. Laivui paliekant uostą orapūtę galima atidengti o filtrą atidengti, kad veiktų pagrindinis variklis.

Nešvarios įleidimo grotelės. Iš pagrindinio variklio išmetamosios dujos pro išmetimo kolektorių patenka į turbokompresoriaus dujų įleidimo angą per apsaugines išmetimo groteles. Išmetimo grotelių funkcija yra sulaikyti nesudegusias anglies ir kokso daleles, kurios nepatektų į turbiną. Užsikišusios grotelės pateiktos 4 paveiksle.

4 pav. Nešvarios grotelės
Šaltinis: https://www.gard.no/web/updates/content/53346/prevention-of-turbocharger-breakdown

Išmetimo grotelės taip pat sulaiko visus sulūžusius stūmoklių žiedus, sugedusius vožtuvo komponentus, kad nepatektų į turbokompresoriaus dujų įleidimo angą, o tai ne tik paveiks turbokompresoriaus rotoriaus pusiausvyrą, bet ir sukels didelę žalą turbokompresoriui ir pagrindinio variklio sustojimą, dėl kurio gali įvykti didelė laivo avarija (M. Anantharaman, 2021). Taip pat labai svarbu periodiškai patikrinti išmetimo kolektorių ir išmetimo įleidimo tinklelį. Būtina įsitikinti, kad nėra pašalinių dalelių pavyzdžiui kaip sulūžusių stūmoklio žiedų ar panašių komponentų.

3. Dažniausiai sutinkami turbokompresorių gedimų poveikiai pagrindiniam laivo varikliui

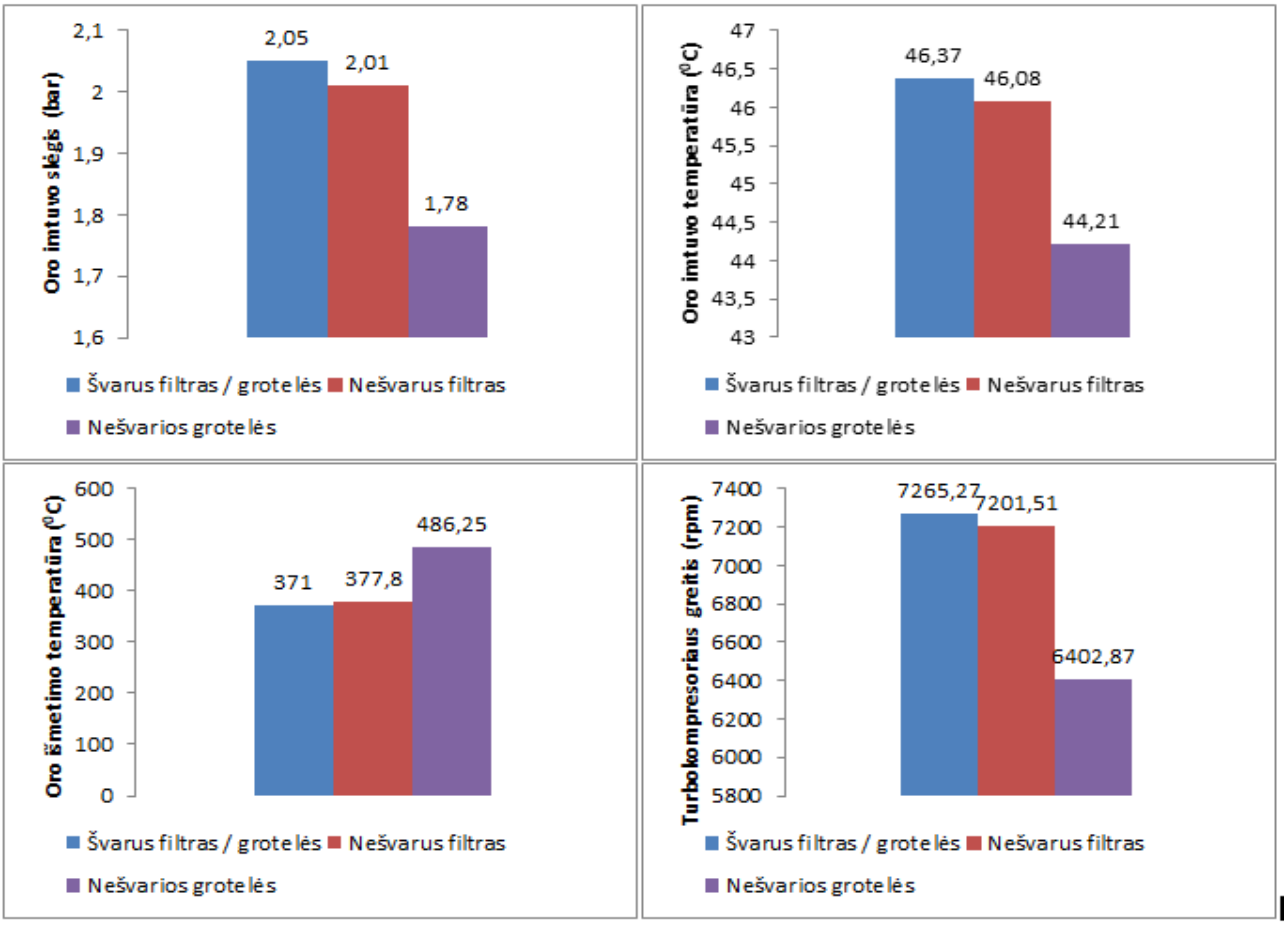
Universitetas kaupia atitinkamus duomenis iš kurių galima daryti naudingas išvadas jūrinių variklių gedimų mažinimui ir jų šalinimui. Vienas iš pagrindinių tyrimo modeliavimo variklių yra MAN B&W 5L90MC, kurio cilindro skersmuo yra 90 cm, stūmoklio eiga – 290 cm, sudaryta iš 5 cilindrų, 2 oro aušintuvų ir 2 turbokompresorių. Didžiausia nuolatinė variklio galia yra 17 400 kW, atitinkami variklio sūkiai yra 76 aps./min. Vidutinis kiekvieno cilindro slėgis yra 13,0 barų, o prapūtimo oro slėgis yra 2,1 baro. Turbokompresoriaus sūkių dažnis yra 8000 aps./min. Variklis suka prie 5 menčių sraigto, sraigto žingsnis yra 1,2. Variklis naudoja DO/HFO degalus, specifinės degalų sąnaudos 168 g/kWh.

Simuliatoriaus pagalba buvo suaktyvintas turbokompresoriaus oro filtro užsiteršimo gedimas. Pagrindinis variklis veikė visu greičiu 10 minučių. 1 lentelėje matyti, kad oro slėgio kritimas per šį filtrą padidėjo 22 %. Išskyrus slėgio kritimą filtre, kitų turbokompresoriaus sistemos parametrų pokyčių nebuvo. Turbokompresoriaus išmetamųjų dujų išleidimo angos temperatūra pakilo 2,4 % iki 245,49 °C. Turbokompresoriaus oro išleidimo temperatūra šiek tiek skyrėsi. Turbokompresoriaus oro išleidimo angos temperatūra padidėjo 2,6 %, o oro išleidimo angos temperatūra sumažėjo 1,2 %. Taigi, išskyrus padidėjusį oro slėgio kritimą filtre, pagrindinis variklio veikimas neturėjo didelės įtakos. Tačiau oro filtro elementus patartina keisti kuo anksčiau, kad sumažinti tikimybę susidurti su tolimesniu filtro elemento gedimu.

Lentelė 3 Pagrindinio variklio parametrai veikimo momentu

Pagrindinio variklio parametrai	**Vertės veikimo momentu**					
	Vienetai	Švarus oro filtras ir grotelės	Nešvarus oro filtras	Reikšmių pokytis %	Nešvarios grotelės	Reikšmių pokytis %
ME oro imtuvo slėgis	bar	2,05	2,01	2	1,78	13,2
ME išmetimo imtuvo slėgis	bar	1,69	1,66	1,8	1,52	10,1
ME oro imtuvo temperatūra	°C	46,37	46,08	0,6	44,21	4,7
ME oro išmetimo temperatūra	°C	371,00	377,80	-1,8	486,25	-31
ME TBCH 1 greitis	rpm	7265,27	7201,51	0,9	6402,87	11,9
ME TBCH 1 oro srautas	ton/h	78,39	74,38	5,1	35,68	54,5
ME TBCH 1 išmetimo srautas	ton/h	79,87	77,57	2,9	54,55	31,7
ME TBCH 1 išmetimo angos temperatūra	°C	239,82	245,49	-2,4	360,12	-50,2
ME TBCH 1 oro išėjimo temperatūra	°C	171,22	175,68	-2,6	231,78	-35,4
ME TBCH 1 oro filtro slėgio kritimas	mm WC	115,00	140,22	-21,9	23,83	79,3

Išnagrinėjus pateiktą lentelę apie groteles matyti, kad oro imtuvo slėgis sumažėjo 13,2 %. Atitinkamas procentinis išmetimo imtuvo slėgio sumažėjimas yra 10,1 %. Oro paėmimo imtuvo temperatūra sumažėjo nežymiai – 4,7 %. Priešingai, išmetimo imtuvo pakilo 31 %. Kadangi pagrindinio variklio turbokompresoriaus išmetimo grotelės buvo imituotas kaip nešvarios, galima pastebėti, kad tai turėjo įtakos turbokompresoriaus sūkių dažnis sumažėjo 11,9 %, bei turbokompresoriaus sūkių dažnis sumažėjo daug mažiau – 2,8 %. Išmetamųjų dujų srautas sumažėjo iš esmės 31,7 %, todėl oro srautas labai sumažėjo 54,5 %. Pagrindinio variklio turbokompresoriaus išmetimo temperatūra pakilo 50,2 %, todėl oro išleidimo angos temperatūra atitinkamai padidėjo 35,4 %. Kitas svarbus momentas buvo slėgio kritimas turbokompresoriaus oro filtre – 79,3 %. Pasak simuliatoriaus buvo matyti, kad automatiškai sulėtėjo variklis praėjus 11 minučių po gedimo įvedimo. Tyrimų duomenys pateikiami 1 lentelėje, o nešvarių grotelių ir užsikišusio filtro įtaka įvairiems variklio darbiniams parametrams pateikti 5 paveiksle.



5 pav. Nešvarių grotelių ir užsikišusio filtro įtaka įvairiems variklio darbiniams parametrams.

5 paveiksle pateikti grafikai parodo pagrindinių laivo variklių parametrus prie nešvarių grotelių ir užsikišusio filtro. Galima teigti kad būtina periodiškai tikrinti išmetimo sistemą, kolektorius uoste, imantis visų saugos priemonių. Būtina patikrinkite, ar nėra sulūžusių stūmoklių žiedų, vožtuvų ar per daug anglies sankaupų turbokompresoriaus įleidimo tinklelyje.

4. Laivų turbokompresorių gedimų prevencijos planas

Pagrindinio variklio ir turbokompresorių gamintojai nurodo įvairių pagrindinio variklio ir turbokompresorių sudedamųjų dalių kapitalinio remonto ir techninės priežiūros intervalus. Vienas iš svarbių veiksnių, būtinų apskaičiuojant bet kurio sistemos komponento patikimumą, yra laikas tarp konkretaus elemento gedimų. Laikas tarp kapitalinių remontų gali būti laikomas naudingu orientyru patikimumui apskaičiuoti pateiktas 2 lentelėje.

Lentelė 4 Valymo intervalai

Veikla	Valymo intervalas pateiktas valandomis
Turbinos sausas valymas	250
Turbinos šlapias valymas	250
Oro filtro valymas	250
Kompresoriaus patikrinimas ir valymas kartu su įdėklu ir ratu	12000
Kapitalinis remontas	24000–30000

Nepaisant gamintojų techninės priežiūros reikalavimų, yra gana sunku, kitais atvejais visai neįmanoma, užtikrinti įrenginių tinkamą darbą ar gedimų nepasikartojamumą.

5. Išvados

1. Išanalizavus laivinio turbokompresoriaus veikimo principą, mokslinės literatūros šaltinius buvo nustatytos dažniausiai sutinkami kompresorių gedimai ir jų atsiradimo priežastys, pavyzdžiui kaip dalų išsidėvėjimas, užsikišusios grotelės, nešvarus arba užsikišęs oro filtras, sulūžusios mentės, kurie kyla dėl per didelės sistemos apkrovos, netinkamo tepimo ar senos alyvos, netinkamos priežiūros, laiku neišvalomų detalių ar į sistemą patekusių pašalinių elementų.

2. Išanalizavus mokslinės literatūros šaltinius, atliktų tyrimų duomenis galime teigti, kad didžiausią neigiamą poveikį variklio darbui turi nešvarios kompresoriaus grotelės ir užsikišęs oro filtras.

3. Atlikus tyrimą buvo nustatyta, kad norint išvengti variklio gedimų, įtakotų nešvaraus oro filtro arba turbokompresoriaus nešvarių grotelių, patartina krovos metu užtikrinti sąlygas neleidžiančias smulkioms abrazyvinėms dalelėms patekti į mašinų skyrių, to galima pasiekti uždengiant oro paėmimo takus ir įsiurbimo landas, atlikti techninę įrenginių priežiūrą griežtai pagal gamintojo reglamentą.

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IŠMETAMŲJŲ DUJŲ RECIRKULIACIJOS PROCESO ĮTAKOS NOX MAŽINIMUI LAIVUOSE EFEKTYVUMO TYRIMAS

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Santrauka. Yra daug būdų siekiant sumažinti išmetamą azoto oksidų (toliau NOx) kiekį iš laivų jėgainių. Šiame straipsnyje yra analizuojamas išmetamųjų dujų recirkuliacijos sistemų panaudojimas laivų varikliuose, kaip efektyvi NOx mažinimo priemonė. Laivų varikliai šiuo metu stipriai prisideda prie pasaulinio oro teršimo. Išanalizuoti išmetamųjų dujų recirkuliacijos proceso įtaką NOx susidarymui laivų variklių išmetamosiose dujose buvo pagrindinis šio tyrimo tikslas. Iškeltam tikslui pasiekti išanalizuotos laivų jėgainėse naudojamų išmetamųjų dujų recirkuliacinių sistemų rūšys, jų ypatumai ir veikimas. Analizuotas skirtingų išmetamųjų dujų recirkuliacinių sistemų poveikis variklio darbo parametrams ir NOx emisijai. Kadangi NOx patekę į atmosferą sukelia šiltnamio efektą (rūgštų lietų taip pat sukelia), todėl išmetamųjų dujų recirkuliacijos sistemos yra naudojamos norint sumažinti žalingą NOx poveikį aplinkai. Šiai problemai spręsti buvo pasitelkta MARPOL konvencija, kurios VI priede nurodytos trys pakopos, pagal kurias laivuose naudojamuose varikliuose negali susidaryti per didelis NOx kiekis. Išmetamųjų dujų recirkuliacinės sistemos yra vienas iš būdų siekiant, kad laivų eksploatacijos rodikliai atitiktų šeštame konvencijos priede nurodytiems taršos iš laivų reikalavimams ir leistų laivams patekti į azoto emisijos kontrolės zonas (NOx Emission Control Area) teritorijas: Šiaurės Amerikos pakrantes, Karibų jūrą, Šiaurės jūrą ir Baltijos jūrą. Todėl, norint pasiekti tokius rezultatus yra naudojamos išmetamųjų dujų recirkuliacijos sistemos. Atliktų tyrimų rezultatai parodo, kad varikliai, kurie naudoja išmetamųjų dujų recirkuliacijos sistemą, iki 50% sumažina NOx išmetimą į aplinką. NOx koncentracijos kiekis, išmetamas iš variklio degimo kameros, didinant recirkuliacijos sistemos dujas praleidžiančios sklendės kampą mažėja. Didinant išmetamųjų dujų recirkuliacijos kampą yra matoma, kad tik 1 % pamažėja variklio galia ir degalų specifinis suvartojimas, kuris nedaro didelės įtakos laivo varikliui ir eigai.

Raktiniai žodžiai: laivų jėgainės, išmetamųjų dujų recirkuliacija, dyzelinis variklis, NOx emisijos.

Įvadas

Šiais laikais viena iš problemų yra laivų jėgainių išmetamųjų dujų poveikis aplinkai. Dyzelinio variklio sudegintus degalus ir kenksmingas dujas galima skirstyti į dvi grupes. Pirmoje grupėje, tai nevisiško degimo produktai, tokie kaip anglies monoksidas, angliavandeniliai, aldehidai, suodžiai. Antroje grupėje kenksmingi komponentai susidaro dėl degaluose ir ore esančių cheminių elementų oksidacijos, pavyzdžiui azoto oksidai (NOx) ir sieros oksidai (SOx) (Kuropyatnyk, Sagin., 2018).

Kadangi laivyba plačiai paplitusi pasaulyje, krovinių ir keleivių pervežimai kasmet auga, tai jos išskiriamų teršalų kiekiai vis didėja darydami žalą aplinkai. Dėl šios priežasties Jūrų aplinkos apsaugos komitetas (International Maritime Organization) susitarė dėl taikomų griežtesnių apribojimų NOx emisijos iš laivų. Tarptautinės konvencijos dėl prevencijos VI priedas dėl taršos iš laivų (MARPOL 73/78). Tai konvencija, kuri reguliuoja oro taršą iš laivų ir skiria daug dėmesio NOx emisijoms. Šiuo metu emisijos limitai yra suskirstyti į tris pakopas. Pirma pakopa yra skirta varikliams, kurie buvo gaminti ne ankščiau kaip 2000m. sausio 1d. arba varikliams pagamintiems iki 2010 m., bet po kapitalinio remonto. Antra pakopa taikoma laivuose, kuriuose įrengti dyzeliniai varikliai nuo 2011 m. Trečia pakopa taikoma dyzeliniams varikliams, įrengtiems 2016 m. arba vėliau. Ši pakopa yra taikoma laivams, kurie plaukioja emisijų kontroliuojamose zonose (IMO).

Lentelė 1. MARPOL Priedo VI NOx emisijų limitai.

Pakopa	Data	NOx limitai (g/kWh)		
		n<130	130≤n2000	n≥2000
Pirma pakopa	2000	17	$45\times n^{-0,2}$	9,8
Antra pakopa	2011	14,4	$44\times n^{-0,2}$	7,7
Trečia pakopa	2016	3,4	$9\times n^{-0,2}$	1,96

Siekiant sumažinti NOx susidarymą deginant dyzeliną reikia kontroliuoti didžiausią degimo temperatūrą, nes NOx pradeda susidaryti degimo kameroje siekiant 2000K. (Ariana et al. 2014). Siekiant sumažinti NOx kiekį, buvo tiriamas degimo procesas, degalų įpurškimas, Milerio ciklas ir drėkinimas vandeniu degimo kameroje. (Lu., et al. 2022). Degalų įpurškimo optimizavimo strategijos būdo nepakanka pasiekti trečiosios pakopos (Liu., et al. 2016). Pagal Milerio ciklą, reguliuojant išmetimo arba įsiurbimo vožtuvų laiką yra sumažinamas variklio suspaudimo laipsnis, tokiu būdu yra sumažinama degimo temperatūra ir įmanoma sumažinti 30% NOx kiekį (Cui., et al. 2014). Drėkinimas vandeniu degimo kameroje, taip pat gali sumažinti nuo 25 % iki 50 % NOx kiekį (Ithnin., 2014). Išmetamųjų dujų recirkuliacijos sistemos (IDRS) iš pradžių buvo naudojamos automobiliams. Pastebėjus, kad jie pasiteisino, pradėti naudoti ir laivo varikliuose. (Sagin., et al. 2022). Pagal atliktą Shirai 2014m. tyrimą buvo nustatyta, kad IDRS su degalų padavimo reguliavimu pasiekė 80 % NOx kiekio sumažinimą. Šioje analizėje yra nustatomas poveikis darbo parametrams ir NOx kiekiui, laivų varikliuose.

Tyrimo objektas – laivuose naudojamos išmetamųjų dujų recirkuliacijos sistemos, skirtos NOx kiekio mažinimui.

Tyrimo tikslas – išanalizuoti išmetamųjų dujų recirkuliacijos proceso įtaką NOx mažinimui laivuose.

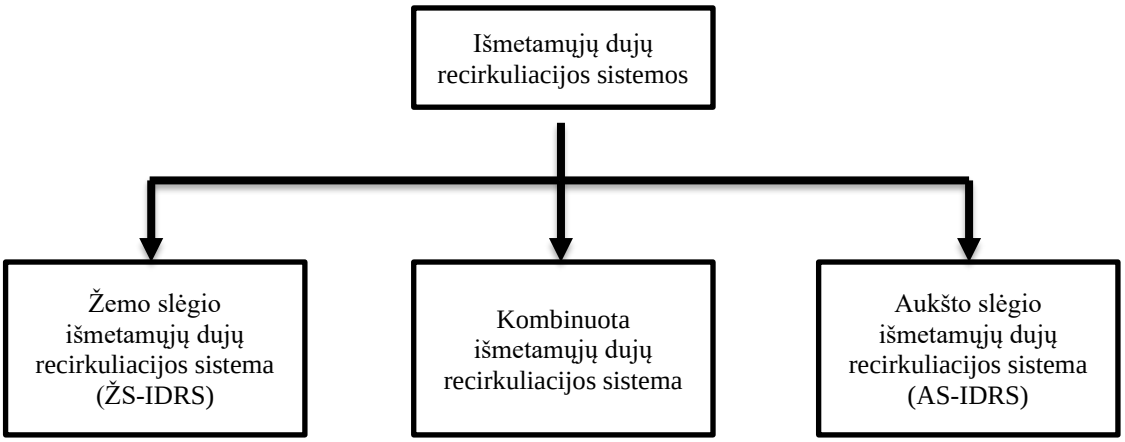
Straipsnyje nagrinėjami uždaviniai:

1. Išanalizuoti laivuose naudojamas išmetamųjų dujų recirkuliacinių sistemų rūšis, jų veikimo principus.
2. Ištirti skirtingų išmetamųjų dujų recirkuliacinių sistemų poveikį variklio darbo parametrams bei degalų suvartojimui.
3. Nustatyti skirtingų išmetamųjų dujų recirkuliacinių sistemų įtaką NOx emisijai.

Tyrimo struktūra. Pirmoje tyrimo dalyje nagrinėjamas laivuose naudojamų skirtingų išmetamųjų dujų recirkuliacijos sistemų veikimo principas. Antra tyrimo dalis apima išmetamųjų dujų recirkuliacijos įtaka laivo variklio darbo parametrams. Trečioje tyrimo dalyje nustatomas skirtingų išmetamųjų dujų recirkuliacijos sistemos įtaką NOx išmetamam kiekiui.

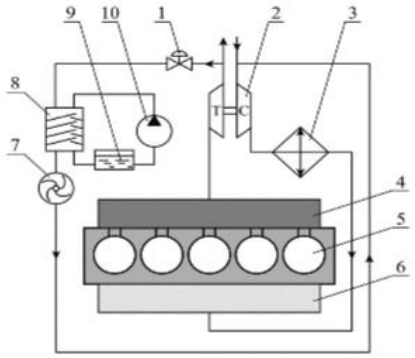
1. Išmetamųjų dujų recirkuliacinių sistemų rūšys, veikimo principai

IDRS yra vis dažniau naudojamos laivuose, norint sumažinti NOx koncentraciją išmetamosiose dujose (Kuropyantyk , Sagin 2018). Taigi, atsižvelgus į dyzelinio variklio charakteristikas yra naudojamos įvairios schemos, kurios užtikrina IDRS procesą, tai yra aukšto slėgio (AS – IDRS), žemo slėgio (ŽS – IDRS) ir kombinuotas – aukšto ir žemo slėgio IDRS (Sagin et. al 2022). Remiantis šiuolaikinių technologinių sprendimų analize, IDRS sudaro: recirkuliacijos vožtuvas, kuriuo yra valdomas į recurkuliaciją patenkančių dujų srautas; Skruberis, kuris reikalingas tam, kad išvalytų išmetamųjų dujų kietąsias nesudegusias daleles; Išmetamųjų dujų pripūtimo kompresorius, kuris recirkuliuoja dujas į prapūtimo liniją arba į turbokompresoriaus kompresorinę dalį.



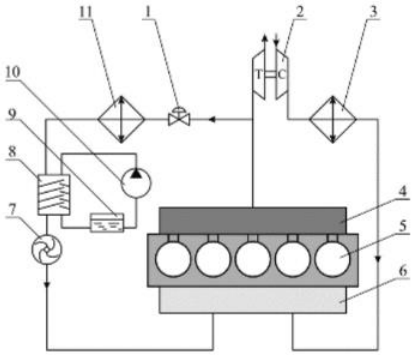
Pav. 1. Išmetamųjų dujų recirkuliacinės sistemos.

Šiame tyrime plačiau išnagrinėsime dvi dažniausiai laivuose sutinkamas sistemas. Žemo slėgio recirkuliacijos sistemoje (2 pav.), išmetamosios dujos iš degimo kameros 5 patenka į išmetimo kolektorių 4, po išmetimo kolektoriaus keliauja į turbokompresorių 2. Po turbokompresoriaus, kažkoks kiekis dujų grįžta recirkuliacijos būdu. Kiekis reguliuojamas vožtuvu 1, kuris gali būti reguliuojamas. Išmetamosios dujos po turbokompresoriaus yra labai aukštos temperatūros ir su kietosiomis dalelėmis, kurios gadina turbokompresoriaus mentes. Dėl šios priežasties išmetamųjų dujų linijoje 8 yra įdiegiamas skruberis, kuriame dujos yra išvalomos bei ataušinamos. Skruberyje yra naudojamas gėlas vanduo 9 ir cirkuliacinis siurblys 10. Išmetamosios dujos praėjusios skruberį 8 patenka į kompresoriaus dalį K turbokompresoriuje 2 ir naudojant dujų pūstuvą 7. Taigi, dujų ir oro mišinys patenka į oro aušintuvus 3 ir pasiekia įsiurbimo kolektorių 6.



Pav. 2. Žemo slėgio išmetamųjų dujų recirkuliacijos sistema. 1 – IDRS reguliavimo vožtuvas; 2 – turbokompresorius; 3 – oro aušintuvas; 4 – išmetamųjų dujų kolektorius; 5 – degimo kamera; 6 – įsiurbimo kolektorius; 7 – išmetamųjų dujų pūstuvas; 8 – skruberis; 9 – gėlo vandens talpa; 10 – gėlo vandens siurblys; T,C – turbinos ir kompresoriaus dalys turbokompresoriuje.
Šaltinis: Sagin et al. 2022.

Aukšto slėgio išmetamųjų dujų recirkuliacijos sistemoje (3 Pav.), iš degimo kameros 5, išmetimo dujos patenka į išmetimo kolektorių 4 ir patenka į dujų turbinos T dalį turbokompresoriuje 2. Kaip ir žemo slėgio sistemoje, patekęs išmetamųjų dujų kiekis yra aukštos temperatūros, bet šioje dalyje jis keliauja į papildomą oro aušintuvą 11. Toliau, įeina į skruberį 8 (kaip ir mažo slėgio sistemoje, dujos yra išvalomos ir dar kartą ataušinamos) ir dujų pūstuvo pagalba patenka į įsiurbimo kolektorių 6.



Pav. 3. Aukšto slėgio išmetamųjų dujų recirkuliacijos sistema. 1 – IDRS reguliavimo vožtuvas; 2 – turbokompresorius; 3 – oro aušintuvas; 4 – išmetamųjų dujų kolektorius; 5 – degimo kamera; 6 – įsiurbimo kolektorius; 7 – dujų pūstuvas; 8 – skruberis; 9 – gėlo vandens talpa; 10 – gėlo vandens siurblys; 11 – oro aušintuvas; T, C – turbinos ir kompresoriaus dalys turbokompresoriuje.
Šaltinis: Sagin et al. 2022.

Išanalizavus Sagin, 2022 atliktus mokslinių tyrimų rezultatus, galime išskirti sekančius ŽS – IDRS privalumus, tai:

- paprasta sistemos ir skruberio konstrukciją, dėl žemo slėgio ir mažesnės išmetamųjų dujų temperatūros sistemoje, lyginant su AS-IDRS.
- mažo pajėgumo dujų pūstuvas, kuris varinėja recirkuliuotas išmetamąsias dujas į turbokompresorių, nes žemo slėgio sistemoje išmetamosios dujos nėra nukreipiamos į įsiurbimo kolektorių lyginant AS-IDRS, o jos yra nukreipiamos į turbokompresoriaus kompresorinę dalį, kurioje yra sudaromas oro įpūtimo aukštas slėgis prieš patenkant orui ir recirkuliuotam išmetamųjų dujų kiekiui į įsiurbimo kolektorių (Sagin et al. 2022).
- AS – IDRS palyginti su ŽS – IDRS yra labiau kompaktiška, nes aukštas slėgis lemia mažesnį savitąjį išmetamųjų dujų tūrį.

Tačiau kiekviena sistema turi ir savo trūkumų:

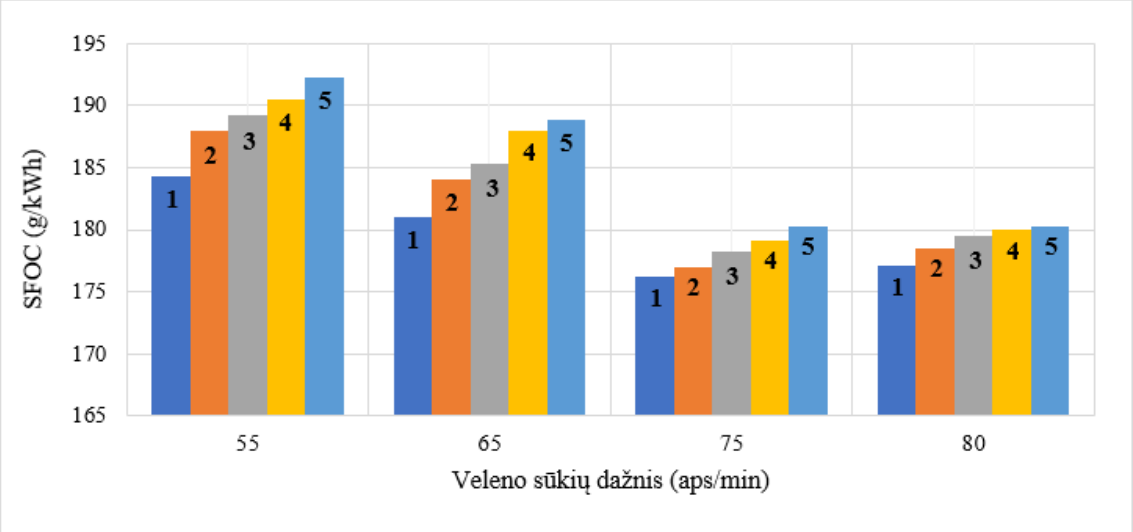
- dėl aukšto slėgio ir aukštos išmetamųjų dujų temperatūros, skruberis, kuris valo išmetamąsias dujas patiria didesnes šilumines apkrovas, todėl AS-IDRS konstrukcija pasidaro sudėtingesnė.
- AS – IDRS sistemoje išvalytos dujos į įsiurbimo kolektorių patenka pro oro pūstuvą, kuris turi sudarytį tokį slėgį, kokį sudaro turbokompresorius. Dėl naudojamo papildomo oro aušintuvo, kaip parodyta 2 pav., sistemos konstrukcija tampa sudėtingesnė, (kas mažina jos patrauklumą).

Išmetamųjų dujų recirkuliacinių sistemų poveikis variklio darbo parametrams

Siekiant nustatyti IDRS poveikį variklio galios parametrams ir degalų sunaudojimo kiekiui Kuropyatnyk ir Sagin, 2018 m. buvo atliktas tyrimas, kuriame buvo tirti žemo sūkių dažnio dvitaktis „Mitsubishi 7UEC60LS“ variklio sumontuoto kartu su ŽM – IDRS darbo parametrai. Variklio degalų suvartojimas pateiktas 2 lentelėje ir grafiškai pavaizduotas 4 pav.. Buvo matuojamas ties variklio 55–80 aps./min, keičiant IDRS kampą (0–18,8 %).

Lentelė 2. Variklio „Mitsubishi 7UEC60LS“ specifinis degalų suvartojimas (g/kWh).

Aps./min	IDRS kampas, %				
	0	4,7	9,8	14,6	18,8
55	184,3	188,0	189,2	190,5	192,3
65	181,0	184,1	185,3	188,0	188,8
75	176,2	177,0	178,2	179,1	180,2
80	177,1	178,5	179,5	180,0	180,3



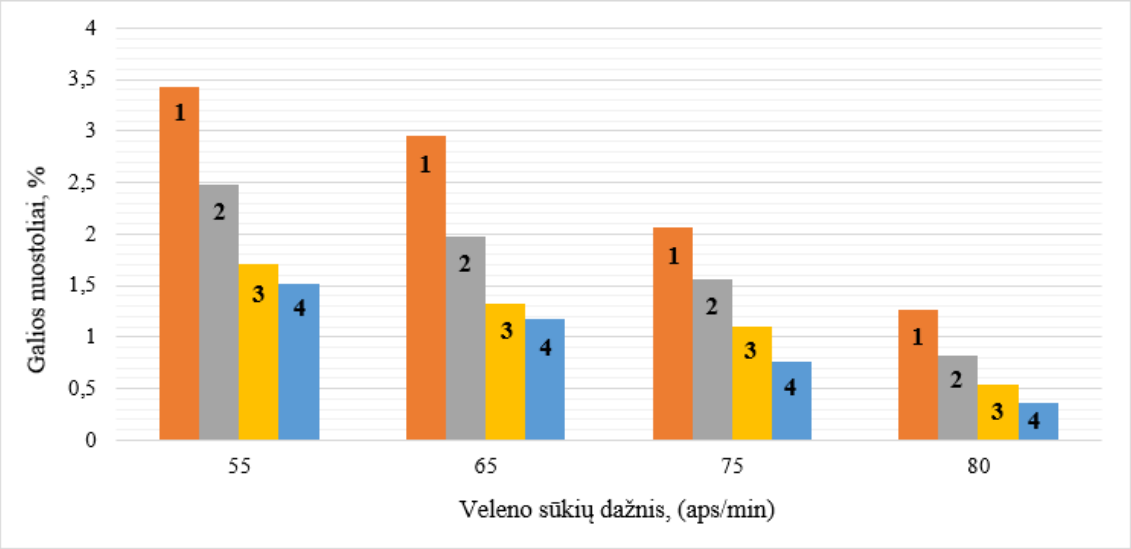
Pav. 4. Laivo dyzelinio variklio „Mitsubishi 7UEC60LS“ specifinio degalų suvartojimo (g/kWh) pokytis, priklausomai nuo veleno sūkių dažnio (aps/min) ir IDRS kampo (%): 1–0 % IDRS; 2–4,7 % IDRS; 3–9,8 % IDRS; 4–4,6 % IDRS; 5–18,8 % IDRS.

Iš 4 pav. matome, kad didinant IDRS kampą ir variklio aps/min. greitį kyla variklio specifinis degalų suvartojimas. Prie variklio 55 aps/min. matome didžiausia skirtumą. Lyginant prie 55 aps./min. be IDRS ir didžiausia IDRS kampą 18,8 %, galime sakyti, kad specifinis degalų suvartojimas padidėja 8 g/kWh. Ir lyginant prie 80 aps./min. be IDRS ir didžiausiu 18,8 % kampu, gauname 3,2 g/kWh deglų suvartojimo skirtumą. Norint, kad variklis atitiktų MARPOL konvencijos VI priedo trečiąją pakopą, panaudojus IDRS variklyje automatiškai pakyla specifinis degalų suvartojimas (Lu, et al. 2022). Taip vyksta dėl pamažėjusio išmetamųjų dujų kiekio, todėl degimo procesas pasikeičia (Zu, et al. 2019). IDRS panaudojimas šiek tiek padidina laivo eksploatacijos kainą, dėl didesnio degalų suvartojimo.

Pažiūrėjus (lentelė 3), matome „Mitsubishi 7UEC60LS“ variklio galios praradimus, kurie buvo matuojami laivo diagnostikos sistema „Doctor“. Naudojant IDRS, santykinė variklio galia sumažėja, bet didinant IDRS kampą matome galios padidėjimą lyginant ties 55 aps./min. ir 80 aps./min. (Kuropyatnyk, Sagin, 2018). Pažvelgus į 5 pav., didžiausi galios praradimai matomi prie 55 aps./min., o mažiausi prie 80 aps./min. Didinant variklio apkrovą ir IDRS kampą, mes sumažiname NOx emisijų kiekį ir pasiekiame trečiąją pakopą, bet tuo pačiu ir sumažiname variklio galią, dėl variklyje įvykstančio lėtesnio užsidegimo greičio (oro ir kuro santykio sumažėjimas) (Lu, et al. 2022).

Lentelė 3. Variklio „Mitsubishi 7UEC60LS“ galios nuostoliai

Aps./min.	IDRS kampas, %			
	4,7	9,8	14,6	18,8
55	3,43	2,48	1,71	1,52
65	2,95	1,97	1,33	1,17
75	2,06	1,56	1,11	0,76
80	1,26	0,82	0,54	0,36

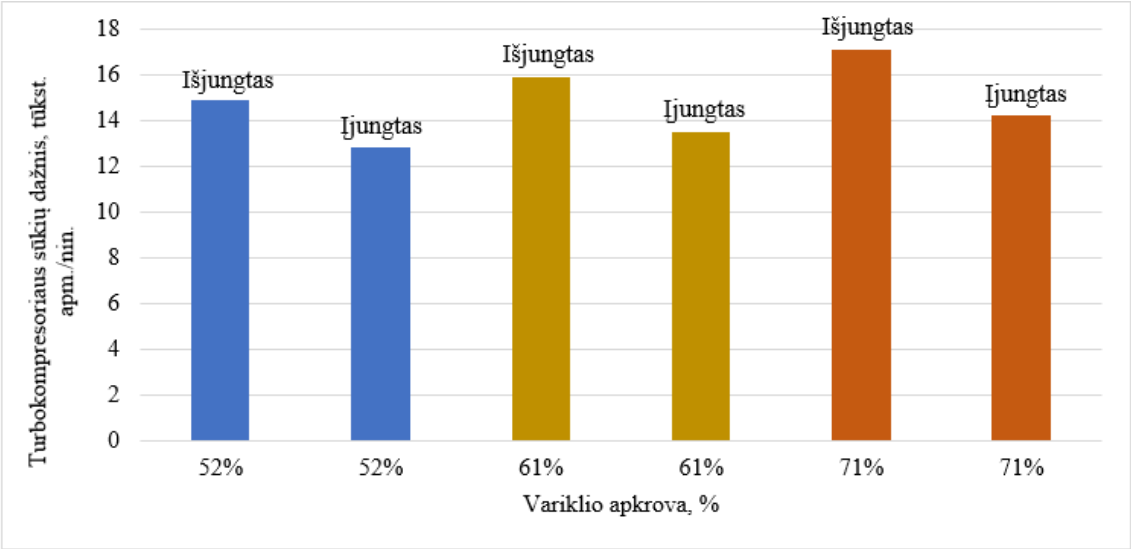


Pav. 5. Variklio „Mitsubishi 7UEC60LS“ galio nuostolių (%) pokytis, priklausomai nuo veleno sūkių dažnio (aps/min.) ir IDRS kampo (%): 1–4,7 % IDRS; 2–9,8 % IDRS; 3–14,6 % IDRS; 4–18,8 % IDRS.

Atliktame Hristov tyrime, kuriame buvo matuojamas išjungto ir įjungto AS - IDRS poveikis turbokompresoriaus sūkių dažniui. Tyrimui buvo naudojamas „MAN 6S70ME-C“ dvitaktis dyzelinis variklis su AS - IDRS.

Lentelė 4. Variklio „MAN 6S70ME-C“ turbokompresoriaus greičio sūkių dažnio pokyčiai naudojant AS – IDRS.

IDRS veikimas	Variklio apkrova, %	Turbokompresoriaus greitis, aps./min.
Išjungtas	52	148828
Įjungtas	52	128242
Išjungtas	61	159025
Įjungtas	61	134581
Išjungtas	71	170587
Įjungtas	71	142383



Pav. 6. Laivo dyzelinio variklio “MAN 6S70ME-C” su AS-IDRS turbokompresoriaus sūkių dažnio (tūkst. aps./min.) pokytis, priklausomai nuo variklio apkrovos (%) ir IDRS įjungimo/išjungimo pozicijos.

Apibendrinus, galime teigti, kad IDRS panaudojimas nėra labai blogas variklio darbo parametrams. Panaudojus IDRS minimaliai padidėja variklio degalų suvartojimas ir tik 1 % sumažėja variklio galia, dėl sumažėjusio įpučiamo oro kiekio. Turbokompresoriaus pokyčius matome 6 pav.

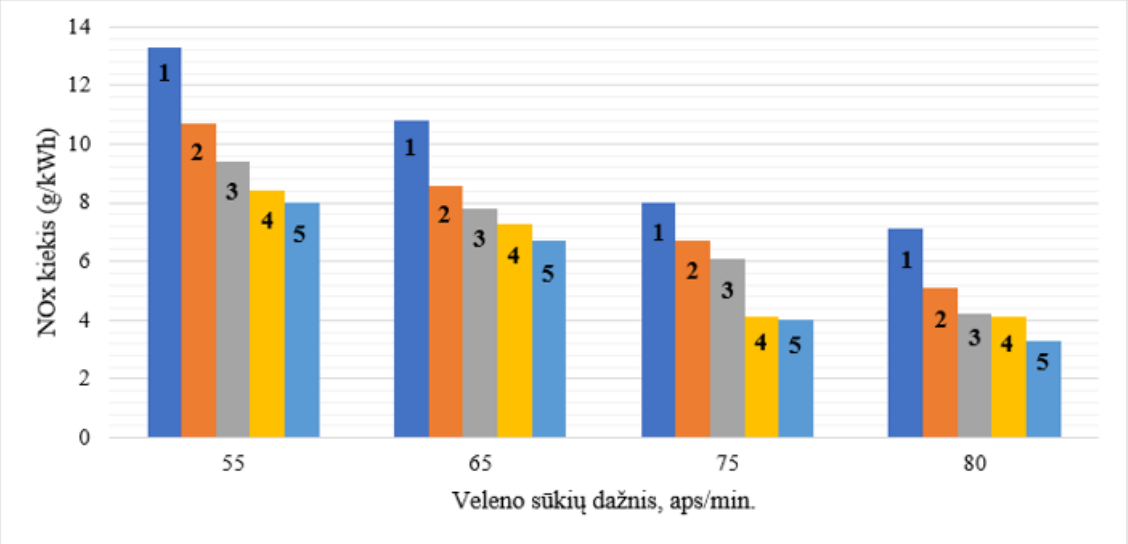
Didžiausias turbokompresoriaus greičio praradimas yra prie 71 % variklio apkrovos, tai nukenčia dėl to, nes yra išmetamųjų dujų trūkumas, dėl AS - IDRS ypatumo išmetamąsias dujas nukreipti ne į turbokompresoriaus kompresorinę dalį, o iškarto panaudojus recirkuliuotų išmetamųjų dujų pūstuvą, kuris recirkuliuotas išmetamąsias dujas nukreipia tiesiai į įsiurbimo kolektorių. Todėl, turbokompresorius veikia mažiau efektyviu režimu ir tokiu būdu oro įpučiamo kiekis mažėja, ko pasakoje gauname pablogėjusį degimo procesą, taip pat CO2 emisijų padidėjimą. Mažiausias prarandamas turbokompresoriaus greitis matomas ties 52 % variklio apkrovos. Lyginant variklį su įjungtu IDRS ir išjungtu, aktyvuotas IDRS sumažina turbokompresoriaus greitį apytiksliai 3000 aps./min., todėl sumažėja įpučiamo oro kiekis (Hristov, et al. 2021).

Išmetamųjų dujų recirkuliacinių sistemų įtaka NOx kiekiui

Kaip teigia Desphande, IDRS yra veiksmingas variklio išmetamų NOx kiekio mažinimo būdas. Kaip parodė Alfa Laval 2020m. atliktų tyrimų duomenys, IDRS padidina šiluminę talpą ir sumažina deguonies kiekį degimo metu, o tai sumažina didžiausią degimo temperatūrą ir taip sumažėja NOx. Remdamasis Kuropyatnyk 2019 m. tyrimu, kuriame buvo naudojamas „Mitsubishi 7UEC60LS“ dyzelinis variklis su įmontuotu MS-IDRS ir apskaičiuotas NOx kiekis, keičiant IDRS atsidarymo kampą, prie skirtingų alkūninio veleno apsisukimų. Šiame tyrime buvo gauti tokie NOx kiekio duomenys, prie skirtingų variklio aps./min. ir IDRS kampų (lentelė 5).

Lentelė 5. NOx emisija dyzelinio „Mitsubishi 7UEC60LS“ variklio su ŽS-IDRS prie skirtingų variklio apkrovų.

Aps/min.	IDRS kampas, %				
	0	4,7	9,8	14,6	18,8
55	13,3	10,7	9,4	8,4	8,0
65	10,8	8,6	7,8	7,3	6,7
75	8,0	6,7	6,1	4,1	4,0
80	7,1	5,1	4,2	4,1	3,3



Pav. 7. Laivo dyzelinio variklio „Mitsubishi 7UEC60LS“ su ŽS-IDRS NOx kiekio pokytis, priklausomai nuo veleno sūkių dažnio (aps./min.) ir IDRS kampo (%): 1–0 % IDRS; 2–4,7 % IDRS; 3–9,8 % IDRS; 4–14,6 % IDRS; 5–18,8 % IDRS.

Pažiūrėjus į 7 pav., matome aiškų IDRS efektyvumą, NOx kiekio mažinimui. Lyginant NOx kiekio sumažėjimą, prie variklio 55 aps./min., 0 % ir 18,8 % IDRS kampo skirtumas yra 6,2 g/kWh NOx. O prie variklio 88 aps./min., 0% ir 18,8 % IDRS kampo, sumažėja 4,7 % NOx kiekio. Remiantis duomenimis, galime sakyti, kad laivas, kuris naudoja IDRS, dirbs ties 80 aps./min. ir bus atidarytas

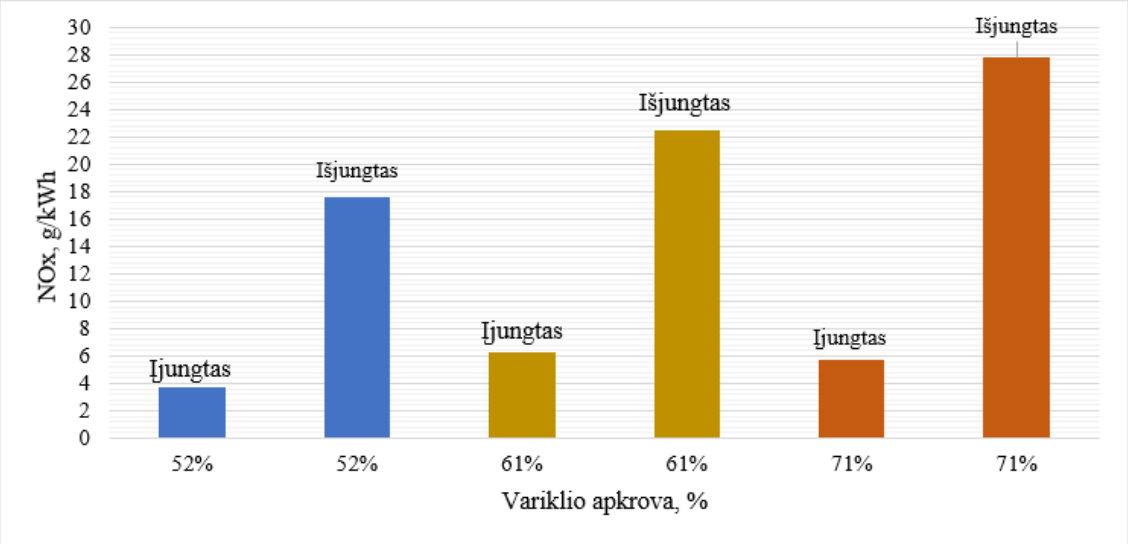
18,8 % IDRS vožtuvo kampas, pasieks 3,3 g/kWh NOx kiekį, kas reiškia, kad šis variklis patenka į MARPOL VI priedo nustatytas trečiosios pakopos normas.

Taip pat, tyrimo rezultatai rodo, kad kuo daugiau didinsime IDRS kampą, tuo mažesnis NOx kiekis bus išmetamas į atmosferą ir taip sumažinsime neigiamą poveikį ekosistemai. Pagrindinė priežastis, kodėl dyzelinis variklis prie mažų variklio apkrovų išmeta daugiau NOx yra todėl, kad išmetamosios dujos grįžusios iš recirkuliacijos į cilindrą sumažins deguonies kiekį ir tai atitinkamai pakels degimo kameros temperatūrą (Zu, et al. 2019). Taigi, IDRS geriausiai veikia prie didesnių variklio apkrovų.

Atliktame Hristov 2021 m. tyrime buvo tiriamas NOx mažinimas IDRS pagalba. Tyrime buvo laivuose naudojamas „MAN 6S70ME-C“ dyzelinis variklis su AS-IDRS. Šiame tyrime gauti rezultatai prie skirtingų variklio apkrovų matomi 6 lentelėje.

Lentelė 6. NOx emisijos variklio „MAN 6S70ME-C“ su AS-IDRS prie skirtingų variklio apkrovų.

IDRS veikimas	Variklio apkrova, %	NOx, g/kWh
Išjungtas	52	17,6
Įjungtas	52	3,7
Išjungtas	61	22,5
Įjungtas	61	6,3
Išjungtas	71	27,8
Įjungtas	71	5,7



Pav. 8. Laivo dyzelinio variklio „MAN 6S70ME-C“ su AS-IDRS NOx kiekio pokytis, priklausomai nuo variklio apkrovos (%) ir IDRS įjungimo/išjungimo pozicijos.

Iš 6 pav. matome, kad gauti rezultatai rodo ryškų NOx kiekio sumažėjimą lyginant su įjungta IDRS ir išjungta. Matomas aiškus NOx kiekio sumažėjimas, tiek prie 51 % variklio apkrovos, tiek prie 71 %. Pagal šiuos tyrimo rezultatus, laivas, kuris būtu pagamintas 2016 m., nepatektu į MARPOL trečiąją pakopą. Taip pat, laivo variklis, kuris yra sumontuotas su IDRS, ne tik sumažins NOx kiekį, bet ir padidins kitų ekosistemai nepriimtinų kenksmingų išmetamųjų dujų susidarymą. IDRS mažina NOx kiekį, bet tuo pačiu ir padidina angliavandenilių ir anglies monoksido susidarymą, nes sumažėja išmetamųjų dujų temperatūra, dėl lėtesnio vykstančio degimo, cilindro degimo kameroje (Lamas, et al. 2013).

Išvados

1. Išanalizavus laivuose naudojamų išmetamųjų dujų recirkuliacinių sistemų rūšis, jų veikimo principus, buvo nustatyta, kad naudojant IDRS kinta variklio darbo parametrai. Renkantis ŽS-IDRS

laivuose, nereikalingas daug galios turintis išmetamųjų dujų pūstuvas, nes šioje sistemoje išmetamąsias dujas reikia perduoti į turbokompresoriaus kompresorinę dalį. Lyginant kai naudojama AS-IDRS, tada reikalingas didesnio galingumo pūstuvas, kuris tūrėtų sukelti tokį slėgį, kokį sukelia turbokompresorius, ko pasėkoje didėja energijos suvartojimo kaštai.

2. Išanalizavus moksliniuose šaltiniuose aprašomų bandymų rezultatus, ištyrus skirtingų išmetamųjų dujų recirkuliacinių sistemų poveikį daromą variklio darbo parametrams bei degalų suvartojimui, buvo nustatyta, kad IDRS sklendės atidarymo kampas turi tiesioginę įtaką degalų suvartojimui ir variklio galios nuostoliams. Remdamiesi atliktų tyrimų rezultatais, galima teigti, kad esant IDRS kampo atidarymui 4,7 % gauname 0,85–2,01 % degalų suvartojimo padidėjimą, arba 2,16–4,34 % degalų suvartojimo padidėjimą padidinus IDRS kampo atidarymą iki 18,8%, o apkrovai esant 55–80 aps./min. Kuo didesnis IDRS kampas, tuo daugiau bus suvartotų degalų. Optimaliausi variklio galios nuostoliai pasiekiami kai variklis dirba 80 aps./min. ir IDRS atidarymo kampas yra 4,7–18,8 % . Prie šių veleno sūkių dažnio variklis patiria mažiausiai galios nuostolių.

3. Kaip rodo atliktų tyrimų rezultatai, IDRS efektyviai leidžia sumažinti degalų sunaudojimą, galios nuostolius ir NOx kiekį. Optimaliausių rezultatų pasiekiama, kai IDRS kampas 14,6–18,8 %, o variklio apkrova 75–80 aps./min. Galios nuostolių, degalų suvartojimo ir NOx išmetimo rodikliai pateikti 4, 5, 7 paveiksluose.

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LITHUANIAN MARITIME ACADEMY

ORGANIZATIONAL AND PEDAGOGICAL CONDITIONS FOR THE DEVELOPMENT OF THE SPEECH CULTURE OF FUTURE MARITIME INDUSTRY SPECIALISTS

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Abstract. The article presents an interpretation of the concept "pedagogical conditions for the formation of speech culture of future maritime industry specialists in the context of a competent approach that enables the success of interaction in a changing contemporary socio-economic, linguistic space, and determines the formation of a creative person capable of self-deciphering. A dedicated competence approach forms the basis for the training of specialists in the maritime industry and is aimed at forming their speech culture. It has been determined that in system education there is a competent approach in vocational education, the implementation of which requires changes in the content of professional training, in particular for the marine industry, the use of various modern technologies for their preparation, including innovative technologies for the formation of the language culture of cadets in educational institutions of the marine profile. Professions related to work at sea belong to such types of labor, where speech culture, knowledge of a foreign language is a professionally important component of the professionalism of ship crewmembers, and professional language communication – the leading form of professional activity realization, whose productivity is determined by the goals, content and values of communication with both local and foreign crew members, companies, etc. It is substantiated that vocational training of marine industry future specialists acquires a speech orientation on the basis of a competent approach.

Keywords: speech culture, future specialists in the maritime industry, professionally oriented learning, competence approach.

Introduction

The dynamic process of our country's entry into the European educational space necessitates proper mastery of a foreign language competency in various fields of human activity, maritime sphere in particular.

Hence, it has quite a significant impact on the establishment of mutual relations in the labor market, and accordingly on the quality of training of specialists who will be characterized with the ability to adapt to dynamic social conditions and a high level of intelligence, general culture, including speech culture. Having a perfect competency of the language itself and speech technique as well, the specialist can effectively form relationships with representatives of various spheres of activity, solving industrial, social, interpersonal and other issues. Therefore, the formation of the speech culture of the future specialist will ensure his success in personal development and professional growth.

Substantial elucidation of speech culture and culture of speaking in represented in the works of V. Aleksandrov, N. Babych, O. Bilyaev, N. Holub, O. Goroshkina, T. Donchenko, S. Doroshenko, V. Yehorov, M. Zhovtobryukh, S. Karaman, L. Kravets, N. Kryvets, L. Matsko, V. Melnychaiko, V. Pasynok, M. Pentylyuk, O. Tkachenko, T. Symonenko, M. Stepanenko and others.

Scientific researches of L. Baranovska, G. Berehova, T. Gorokhovska, I. Dovzhenko, M. Kryskiv, M. Marun, L. Romanova, T. Rukas, N. Totska and others reveal certain aspects and conditions (pedagogical, organizational and pedagogical ones) of the speech competence formation, development of its components including language culture, speech culture, professional functional speech, Ukrainian business speech, etc., among students studying in non-philological specialities.

The scientific problem of the research is that organizational and pedagogical conditions of speech culture formation among the future maritime industry specialists are not sufficiently covered.

The object of the research is the interface between the these conditions that will create opportunities for the successful formation of the speech culture of future maritime industry specialists in the process of professional training

The aim of the research is to define the methodological approach to the assessment of the formation of speech culture of future specialists in the process of professional training, structured with the leading role of language education, in the structure of which one of the leading places is occupied by language education.

The objectives of the research are the following

The objectives of the research are the following is to define organizational and pedagogical conditions that will create opportunities for the successful formation of the speech culture of future maritime industry specialists in the process of professional training, structured with the leading role of language education, in the structure of which one of the leading places is occupied by language education.

The objectives of the research are the following:

4. To analyze the scientific sources which form approaches to the interpretation of the essence of the concept of "pedagogical conditions".
5. To distinguish the aspects of the formation of professional foreign language competence of future specialists
6. To assess the factors of formation of speech culture in the conditions of integration of technical and linguistic education in the process of professional training of future specialists of the maritime industry.

The methods of the research include the following: systematic review, meta-analysis, analysis of scientific literature, statistical analysis, synthesis, interpretation, generalization

The structure of the research**.** The first part of the research analyzes the scientific sources which form approaches to the interpretation of the essence of the concept of "pedagogical conditions". The second part of the research includes the distribution of the indicators of the aspects of the formation of professional foreign language competence of future specialists. The need the factors of formation of speech culture in the conditions of integration of technical and linguistic education in the process of professional training of future specialists of the maritime industry.

1. The Analysis of the pedagogical conditions interpretation

The analysis of scientific and reference sources revealed that the most thorough definition of the concept of "condition" is interpreted in the philosophical aspect as "the diversity of the objective world which is relatively external to the subject. On the contrary to a cause, a condition directly gives rise to a particular phenomenon or process. The condition creates the exact environment and circumstances in which processes or phenomena arise, exist and develop". Based on this, "condition" is external phenomena that affect the emergence, functioning and development of a certain circumstance.

Modern pedagogical science offers several approaches to the interpretation of the essence of the concept of "pedagogical conditions". The study and analysis of the works of scientists and researchers proved that pedagogical conditions mean an external circumstance, a factor that exerts a significant influence on the course of the pedagogical process, to one degree or another consciously constructed by a teacher, in a way for it to cause, but not guarantee, a certain result of the process (Marykivska, H); a complex of interdependent and interconditioned measures of the pedagogical process, which ensure the achievement of a specific goal (O. Sokolenko); circumstances that depend on and in which the integral pedagogical process of professional training of specialists takes place, which is mediated by the activity of an individual, a group of people (O. Karas); determined circumstances of the educational and educational environment created by the teacher-researcher, under which one or another effective influence on the researched process and result is possible (Krutii) etc.

Therefore, single definition of "pedagogical conditions" doesn’t exist, but the common feature of any interpretations and definitions of the "pedagogical conditions" category is the focus of the

environment on improving the interaction of the subjects of the educational process, solving the set didactic or educational tasks.

It is crucial to draw attention to the fact that in today's scientific studies on the professional training of specialists in various fields in higher educational institutions, researchers define the concept of "organizational and pedagogical conditions" as components of the educational process of a higher education.

Having based on the mentioned above and having taken into consideration that the efficiency of the professional training of future maritime industry specialists is enhanced in the process of studying professional disciplines and disciplines of the selective part, which ensure the success of studying the achievements of shipbuilding, vessel operation and maintenance, international cooperation, which is implemented in a common language environment, we consider it appropriate to allocate organizational and pedagogical conditions for the formation of speech culture of future maritime industry specialists. Simultaneously, we emphasize that one of the requirements for the training of future maritime industry specialists is the study of professional disciplines in a foreign language. After all, according to the educational and qualification characteristics of a specialist in the maritime industry, a graduate of a higher maritime educational institution must be proficient in one of the foreign languages at the level of professional and everyday communication, which implies the ability for written and oral communication (speech), the development of professional (maritime) documents in a foreign language, etc.

The problem of foreign language education, especially the formation of professional foreign language competence of future specialists, including the maritime industry, which we consider one of the components of the speech culture of future maritime industry specialists, is studied from various aspects by scientists, modern researchers, in particular, the formation of foreign language professional competence of future specialists in natural sciences, technical and economic specialties. In the context of the training of future maritime industry specialists, the outlined problem was highlighted in the studies of N. Bobrysheva, M. Soter, O. Tyron, etc. The researchers, basing on the results of scientific investigations, proved that efficient learning of a foreign language has huge impact on the formation of professional competence, and this ensures the specialist in the future successful interaction (speech) with colleagues, employers, etc. in the conditions of a foreign language environment determined by the production needs of business relations with representatives of crewing companies, representatives of foreign seaports, etc.

One of the ways to solve the outlined issues is the consistent, systematic introduction of new methods, forms and technologies to the organization of the educational process in higher educational institutions, giving the top priority to the involvement of students into various educational, research and professionally oriented activities while implementing anything new into the educational process. Such approach will make possible preparation of competitive, competent maritime industry specialists, who will possess a high level of professional knowledge and skills, able to effectively use modern technologies in the field during changing production situations, possess foreign language communication skills, etc.

Successful solution of the given tasks seems reasonable to be conducted on the basis of competency and person-oriented approaches.

Retrospective analysis of works of scientists, practitioners and researchers on professional training of future specialists prove that competence and personal-participation approaches are decisive in the preparation of a specialist who is capable of solving working and domestic tasks expediently, consciously, creatively and independently.

Taking the above mentioned into consideration it must be admitted that a personality and interpersonal relationship gain great importance. Hence, we come to the conclusion that one of the conditions is a personal approach in developing the speech culture of future specialists. After all, revealing the essence and significance of the personal approach in the professional training of future specialists, in particular in the formation of their professional competence, modern researchers point out that "the personal approach assumes not the formation of a personality with given properties, but the creation of conditions for the full expression and appropriate development of personal functions

of the subjects of the educational process" Such a point of view is supported by I. Zimnya according to the provisions regarding the final result of the educational process. In her opinion, a personal approach to learning (a personal-participation approach) can be characterized from the perspective of those who study, as the presence of an expedient situation of integration of new forms, rules, methods and means of social-professional-communicative activity. And thus the leading educational task will be resolved by the development of a socially active personality via activating its internal reserves, a professionally competent specialist who develops himself it is worth noting that, justifying the peculiarities of the personal approach, scientists connect it with the competence approach. According to them, it is the acquisition of vital competences that contributes to the formation of a person's ability to navigate in the social and informational space, to effectively and creatively apply knowledge and skills in interpersonal relationships - situations involving interaction with other people in a social context as well as in professional situations.

And in such interpersonal relations, one of the leading roles is played by developed speech. According to T. Donchenko, an indicator of linguistic development of an individual is communicativeness, i.e. the ability to communicate, which leads to the active usage of means of speech, the ability to perceive and reproduce the content of someone else's speech and to produce one's own, namely, the ability to perceive and produce oral and written texts meaningfully and consciously, as systems of speech knowledge and skills.

Therefore, the issue of language education, which is aimed at the formation of language knowledge, speaking abilities and skills, and speech etiquette, is gaining relevance. It is possible to ensure the efficiency of language education in the presence of educational and methodological support - textbooks, manuals, which provide properly structured material that meets the requirements of general speech training and speech-specialized training.

The structuring of the content of the educational material in the integrative textbook on foreign languages, as I. Klyuchkovska notes, assumes that a student can strengthen and deepen his knowledge, abilities and skills during his studies.

In her opinion, it is created on the basis of substantiation of objectively existing relations between learned facts; solving tasks that require the application of acquired knowledge in new conditions for solving problems of theoretical, theoretical-practical or practical content, etc. Taking into account the point of view of I. Klyuchkovska and the specifics of our research, the formation of the speech culture of future maritime industry specialists in the process of professional training, it is necessary to take into consideration its professional orientation while structuring the educational material.

2 The impact of factors of formation of speech culture in the conditions of integration of technical and linguistic education

Taking into account that the practical training of the cadets occurs on board the vessels of different ship-owners around the world a cadet can meet a problem of communication with the crewmembers within of a mixed team. During the being aboard the vessel cadets should keep communication on professional and everyday topics and make the atmosphere appropriate to the situations very easily. They should realize the requirements to use English orally and in written form.

All duties require the ability to communicate in English with engine room personnel members and be able to analyze, discuss possible causes and methods of elimination. The safety of the engine room depends strictly on the order of cooperation within the engine room staff, knowledge and the desire to make their work successful.

The first step in the preparation of a young specialist exam is an interview with the crewing company, and the passing of the electronic tests for professional training. All these procedures are conducted exclusively in a foreign language.

But to be able to pass such an interview and electronic tests cadet should get definite amount of appropriate knowledge in a proper way. For this purpose cadets use English books that are written by their teaching staff and these books contain all the material that is required by conventions to

obtain such knowledge and to be capable of ensuring of all the requirements which are prescribed in these conventions.

A good example would be a cadet's book which is called Full ahead. This book comprises of 5 modules and can help a cadet to get theoretical knowledge about construction, maintenance, operation, technologies of repair procedures. Also this book not only gives knowledge about construction and operation of machinery, but also provides information about keeping watch in the engine room, how to take watch, what to do in case of machinery failure, and what can help to eliminate such failure and certainly how to avoid any malfunctions, what records to make during watch and so on. In a word, cadets gain all that can help them pass all the interviews with crewing company and ship-owners, electronic tests in English language and show them from their best side. Thus cadets have all the important communication skills at the end of learning the material that is given by their teaching staff.

Meanwhile we consider rather a complex of methods, forms, means, and learning technologies that ensure the creation of a subject-subjectivity in learning and a speech environment to be of great importance in language learning and the formation of speech culture. After all, as O. Dubasenyuk notes, the function of the learning technology is to focus on obtaining an integrative result with high quality and maximum amount of assimilation of educational information, dynamics, tension, variability, as well as universalization of knowledge, skills and methods of activity The analysis of scientific sources and results of modern research shows that the usage of active and dialogue-discussion methods (brainstorming, microphone, openwork saw, circle of ideas, aquarium, case method, etc.); project technologies; business, role-playing games, etc. contribute to the development of speech, enrich speech experience in future professional activities, enable modeling of typical communicative and production situations, stimulate speech behavior, etc.

The on-board training and practical practices are revealed as one of the factors of formation of speech culture in the conditions of integration of technical and linguistic education in the process of professional training of future specialists of the maritime industry. It has been established that practical trainings provide the consolidation of theoretical knowledge gained by cadets in the study of special disciplines, the formation of professional skills and skills in accordance with qualifications and acquired occupations, practical development of modern equipment and obtaining the necessary experience in using the foreign language in the specialty.

Consequently, they contribute to the improvement of the skills and abilities of dialogical foreign language communication, the discovery of tolerance in industrial situations and everyday life, which determines the formation of the language culture of future sailors.

Conclusion

1 All aspects mentioned above allow us to note that the formation of the speech culture of future specialists in higher educational institutions depends on the expediency and innovativeness of the methods and techniques of organizing educational and cognitive activities that correspond to the didactic purpose, nature and content of the educational material.

2 Such a process is based on the creative cooperation of the subjects of the educational process, during which both teachers and cadets are involved in solving the issue of professional language development, namely the formation of the speech culture of future specialists in the maritime industry, whose characteristic is positive motivation for professional speech activity, communication (of another language), speech behavior, tolerance.

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