p-ISSN: 2225-6733; e-ISSN: 2519-271X

271 РІЧКОВИЙ ТА МОРСЬКИЙ ТРАНСПОРТ

UDC 531.43+681.5 doi: 10.31498/2225-6733.47.2023.300113

© Khudyakov I.V.[1], Gritsuk I.V.[2], Pohorletskyi D.S.[3], Bulgakov M.P.[4], Chernenko V.V.[5], Litvinov M.E.[6]

PECULIARITIES OF SHIP POWER PLANT DIAGNOSTICS USING THE ERS-500 TECHSIM TRANSAS MIP LTD SIMULATOR COMPLEX IN THE PROCESS OF SHIP ENGINEERS' TRAINING

This paper presents an analysis of the results obtained using the ERS 5000 TechSim Engine Room Simulator software. The software simulates remote control from the ship's central control station using virtual equipment panels, which are dedicated hardware combined into a separate console. The simulator covers the main areas of training in accordance with the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers with the Manila Amendments of 2010 and meets the requirements of IMO Conventions and Resolutions and IEC standards. The simulator is certified by the Norwegian classification society DNV/GL. Main engine diagnostics are performed using the Cylinder Combustion Quality diagnostic panel and the Indicator Diagram Comparison panel. Analysis of changes in gas turbine engine parameters and the indicator diagrams themselves at different levels of piston ring wear showed a decrease in compression pressure, mean indicated pressure and maximum combustion pressure, as well as an increase in the return oil temperature of the piston cooling system and the consumption of lubricating oil in the cylinder. The advantages of using simulators in the training process include the ability to perform laboratory work in a frontal method, which significantly improves the learning experience.
Key words: *training equipment, ERS 5000 TechSim, diagnostics, engine.*

І.В. Худяков, І.В. Грицук, Д.С. Погорлецький, М.П. Булгаков, В.В. Черненко, М.Є. Літвінов. Особливості діагностування судової енергетичної установки з використанням тренажерного комплексу ERS-500 TechSim TRANSAS MIP LTD у процесі підготовки суднових механіків. *Тренажерні системи займають один із пріоритетних напрямів у навчанні безаварійної експлуатації судової енергетичної установки (СЕУ). Імітаційно-тренажерні комплекси, максимально наближені до реального суднового машинного відділення, дозволяють курсантам набувати правильних та стійких навичок. Враховуючи важливість тренажерної підготовки у формуванні професійно важливих якостей, внесок у безпеку експлуатації при обслуговуванні машинного відділення суден – її забезпечення потребує комплексного та системного підходу. Розвиток і конструктивне ускладнення спеціальної техніки, що спостерігається в даний час, а також збільшення кількості реалізованих в ній*

[1] *PhD (Engineering), associate professor, Kherson State Maritime Academy, Kherson, ORCID: 0000-0002-8900-7879, khudiakov.ihor@ksma.ks.ua*
[2] *Dsc (Engineering), professor, Kherson State Maritime Academy, Kherson, ORCID: 0000-0001-7065-6820, gritsuk_iv@ukr.net*
[3] *PhD (Engineering), associate professor, Kherson State Maritime Academy, Kherson, ORCID: 0000-0002-1256-8053, pohorletskyi.dmytro@ksma.ks.ua*
[4] *PhD (Engineering), associate professor, Odesa National Maritime University, Odesa, ORCID: 0000-0002-7172-8678, npbulgakov2@gmail.com*
[5] *senior clerk, Kherson State Maritime Academy, Kherson, ORCID: 0000-0001-6639-1102, v.chernenko18@gmail.com*
[6] *postgraduate student, Kherson State Maritime Academy, Kherson*

завдань, вимагають від суднових інженер-механіків технічного професіоналізму, дотримання встановлених правил і порядку дій. З цієї причини підготовка операторів немислима без використання тренажерних засобів, які дозволяють заощаджувати ресурси навчального закладу, скоротити вартість навчання, зменшити аварійність дорогого обладнання у процесі його освоєння, відпрацьовувати дії у разі виникнення нестандартних ситуацій. Будь-який тренажер є фізичною моделлю, подібною до реального об'єкта із заданим ступенем точності. Особливістю тренажера є те, що при впливі навколишніх пристроїв та блоків на органи почуттів оператор отримує візуальну, тактильну, звукову та іншу інформацію, яка і створює ілюзію управління СЕУ. Тренажер охоплює найважливіші напрями навчання у повній відповідності до вимог Міжнародної конвенції про підготовку та дипломування моряків та несення вахти STCW з манільськими поправками від 2010 року. Практична підготовка суднових інженер-механіків на тренажерах є завершальною стадією теоретичного навчання. При роботі на тренажері ERS 5000 TechSim, інженер-механік (курсант), застосовуючи наявні знання, отримує досвід, дуже близький до роботи в реальних умовах, і одночасно йде процес уточнення та закріплення його теоретичних знань.

Ключові слова: *тренажерне обладнання, ERS 5000 TechSim, діагностика, двигун.*

Description of the problem. Despite the installation of the latest energy systems and equipment on ships, improvements in shore services and crew training, the number of ship accidents remains high. The main cause of this situation is the «human factor».

This mainly concerns the appropriate actions of ship engineers during emergency and abnormal conditions of ship power systems. In order to prevent such situations, special attention is paid to improving the safety of ship operation through regular diagnosis of the ship's technical equipment.

Simulator systems are one of the priority directions in training for safe operation of marine power plants. Simulation and training complexes that are as close as possible to the real ship machinery department allow cadets to acquire correct and stable skills.

Given the significance of simulator training in cultivating crucial professional skills and ensuring safe operation while servicing the engine room of ships, its provision demands a comprehensive and systematic approach. The present-day development and construction complexity of specialized equipment, coupled with an increase in the number of tasks performed on it, necessitate technical expertise, adherence to established protocols and procedures from ship engineers. Consequently, operator training without the use of simulators is unfeasible. Simulators allow educational institutions to conserve resources, minimize training expenses, reduce equipment damage, and practice actions in emergency situations such as fire, water ingress, and power plant control system failure.

Analysis of recent research and publications. Simulators can be linked together in a network to practise interaction skills between several people. In this case, a common simulator computer with multiple operator interfaces or separate simulator computers with a matching device between them can be used. Separately, there is a class of simulators that do not use a specific hardware interface. These are pure computer simulators (hereafter referred to as «computer simulators»). The role of the interface in these simulators is performed by standard computer input/output devices: keyboard, mouse, monitor. The use of such simulators is advisable in cases where there is no need to use special equipment in the simulated objects and situations. An example would be simulators for decision making and developing behavioural skills that are not directly related to the control of equipment. The following review provides examples of existing training systems developed around the world. The selection of systems for review has been made in order to cover the most diverse methods of implementation and areas of application, as well as to identify the best examples of training systems.

The simulator can be as simple as a personal computer or as complex as a state-of-the-art multiprocessor minicomputer. The simulation computer is connected to the operator interface via an input/output system. The operator interface may consist of control and monitoring panels, video terminals and a distributed control system serving the video terminals. In most cases, the physical characteristics of the HMI correspond exactly, or as closely as possible, to the specific process being simulated.

The software models used in the simulation computer realistically represent the interaction of the components and systems of the simulated process. This is the most important part of the training system;

the quality of the skills acquired depends on how close the simulation model is to a real object or situation.

The operator interface allows the learner to manipulate controls in a manner similar or identical to that used in the actual process. The dynamic response of the simulator should be as close as possible to the response of the systems and components of the real object.

The instructor interface allows you to control the operation of the simulator, select a training scenario and the initial state of the simulated process, introduce failures of the simulated process or its components, or change external factors. Some of the instructor's functions can be performed automatically by the simulation model itself.

Peripherals include printers, alarm panels and any other equipment needed to enhance the realism of the simulated environment or to document the training process.

Simulators are physical models that resemble real objects to a certain degree of accuracy. What sets simulators apart is that external devices and blocks stimulate the operator's sensory organs, providing visual, tactile, and auditory cues, creating an impression of managing the ship's power plant [1, 2].

Scientists from California State University conducted research to investigate how different methods of information delivery impact the quality of information retention. The findings revealed that learners retain approximately 10% of what they hear, about 20% of what they read, and roughly 90% of what they see, hear, and do [3].

The aim of the article is to describe the use of simulators in training for the safe operation of marine power plants.

Objective is to emphasize the importance of simulator training in cultivating critical job skills and ensuring safe operation in ship engine room maintenance.

Methods of the study:

1. Conducting a literature review to gather relevant research and papers on the use of simulators for training in the safe operation of marine power plants.
2. Performing a comprehensive analysis of the Transas ERS 5000 TechSim engine room simulator, including its functionalities and features.
3. Utilizing diagrams and tables to visually present the technical and operational aspects of the LCC tanker and its propulsion system.
4. Providing a detailed account of the simulator training conducted with the Transas ERS 5000 TechSim engine room simulator, including its methodology and outcomes.

The structure of the study consists of an introduction, research problem statement, analysis of the obtained results, and conclusions.

Problem Statement: To conduct technical diagnostics of the ship's power plant using training equipment and software produced by TRANSAS - ERS 5000 TechSim. This version of the simulator is designed to provide comprehensive and advanced training in normal and emergency situations [4-5].

Presentation of the main material.

Analysis of the obtained results. The software of the ERS 5000 TechSim engine room simulator simulates remote control from the ship's central control station (CCS) using so-called «virtual equipment panels» – Dedicated Hardware (DHW panels) combined into a separate DHW console. These panels simulate equipment and can represent individual touch screens or pages on a monitor screen, such as the «Propulsion» console or the virtual «Hardware» console, containing all displays for controlling and monitoring ship systems, units, and mechanisms. The lower part of the simulator screen contains buttons with page names. The list of items on the selected page will open as a pop-up menu [6].

The simulator covers the most important areas of training in full compliance with the requirements of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) with the Manila Amendments of 2010. It meets the requirements of IMO conventions and resolutions and IEC standards, and is certified by the Norwegian classification society DNV/GL (in accordance with Standard for Certification of Maritime Simulators No. 214, October 2007) [4-6].

The Transas ERS 5000 TechSim engine room simulator includes 15-20 prototype ship models, and diagnostics are performed on the LCC tanker model, the short technical and operational characteristics of which are presented in Table 1.

Table 1

Technical and operational characteristics of the LCC tanker

Tanker LCC (Large Crude Oil Carrier) (Aframax):	
Maximum length	248.92 m
Overall width	43.8 m
Draft by summer load line:	14.925 m
Deadweight	115 000 t

The propulsion system is a six-cylinder, two-stroke, single-acting, low-speed, crosshead-type, with gas-turbine supercharging, reversible main engine of MAN B&W brand, model 6S60MC-C with direct drive to the fixed pitch propeller (refer to Table 2).

Table 2

Technical characteristics of the propulsion system of the LCC tanker

Maximum continuous rating, MCR	13736 kW (at n = 105 min^{-1})
Nominal continuous rating, NCR (85% MCR)	12364 kW (at n = 101 min^{-1})
Operational speed of the vessel	15,5 kn

Fig. 1 – General view of LCC tanker (Aframax)

Main engine (ME) diagnostics are performed using a Cylinder Combustion Quality diagnostic panel (Cylinder Combustion Process tab) (Fig. 2) and an Indicator Diagram Comparison panel (Comparison tab) (Fig. 3).

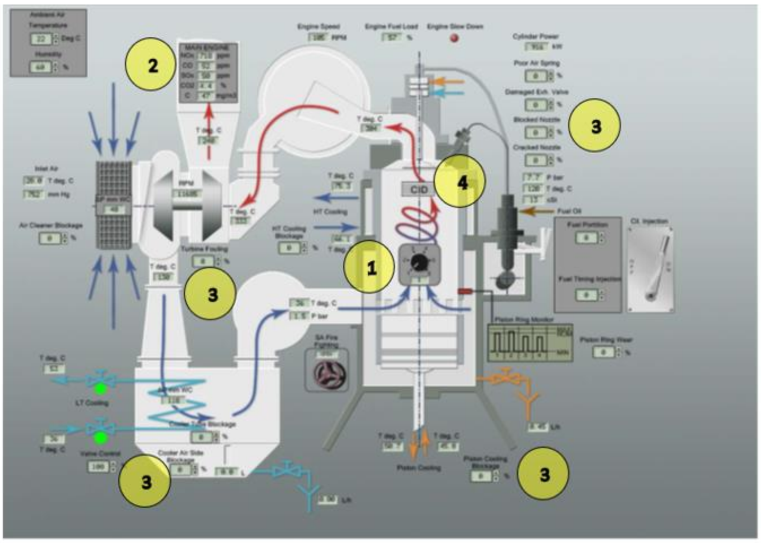

Fig. 2 – Diagnostic panel for fuel combustion process quality in engine cylinder

Clicking on the Diag\Cylinder Combustion Process menu item opens an interactive ME diagram that allows the effects of different fuel combustion qualities in the cylinders to be observed. It is also possible to manipulate the combustion process by making online adjustments or entering disturbances in real time.

The diagram includes:

• 1 selector switch – to select the required cylinder;
• 2 MAIN ENGINE – ME exhaust gas indicator;
• 3 rotation controllers (sliders) – to set the specified parameter values for introducing faults;
• Digital indicators for displaying the actual response of the ME system parameters;
• 4 CID button – to open the indicator diagram panel in a pop-up window [6].

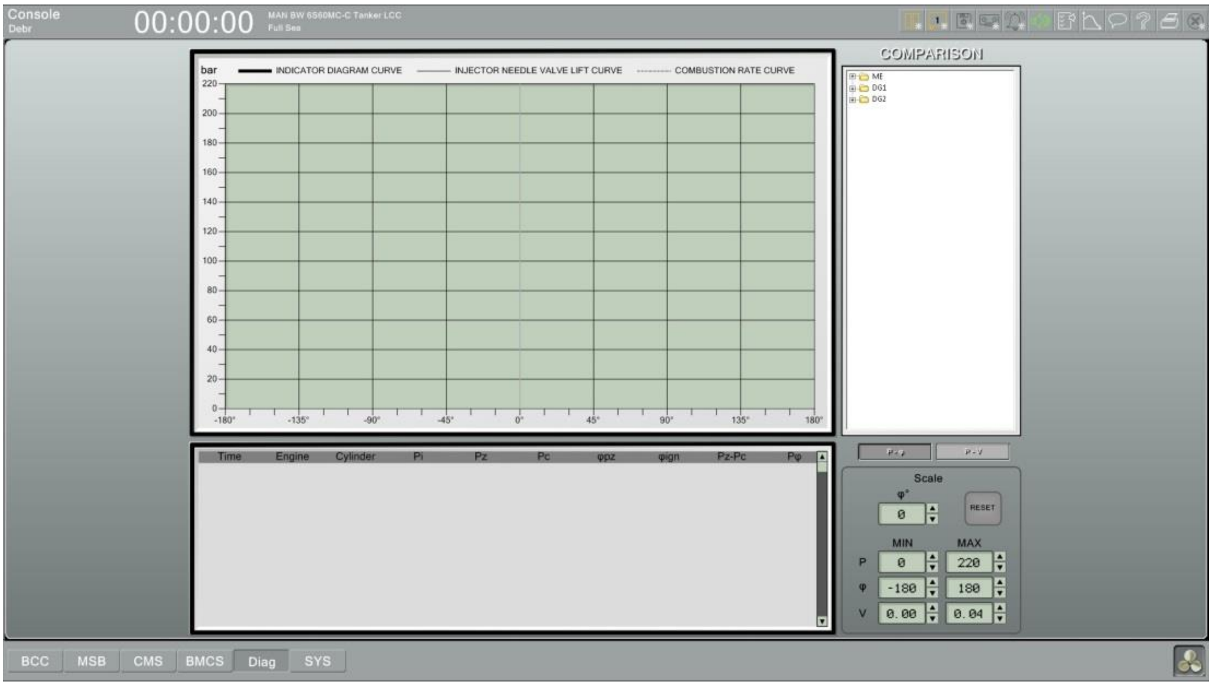

Fig. 3 – Indicator diagram panel

On the cylinder combustion process diagnostic panel for the main engine (ME), we have the ability to simulate faults such as: • contamination of the air filter for the turbocharger air inlet; contamination of the gas component of the turbocharger air inlet; • contamination of the air cooler after the turbocharger air inlet; • contamination from the cooling system; • temperature difference of the high temperature (HT) cooling circuit; temperature difference of piston cooling; exhaust valve air spring density; damage (burning) of the exhaust valve; contamination or cracks in the fuel injector nozzle; changes in fuel supply; changes in fuel injection timing angle; wear of piston rings.

Considering that damaged or worn piston rings in 2-stroke engines are difficult to diagnose based on indirect parameters, the damage may not be apparent until it becomes serious. This article describes the diagnosis of this particular fault.

The diagnosis is made using the following algorithm:

Take an indicator diagram of cylinder 1 without wear on the main engine piston rings (Fig. 4) and store it in the diagnostic panel memory (Fig. 3). Record the engine parameters in the CMS, M/E Overview tab (Fig. 5).

Using the Piston Ring Wear Simulator on the Cylinder Combustion Diagnostic Panel (Fig. 2), set the wear value of the main engine piston rings sequentially to 20%, 40% and 60%. At each piston ring wear value, take a graph of Cylinder #1 and record the engine parameters in the CMS, M/E Overview tab and the exhaust gas quality parameters in the Diag / Emission tab.

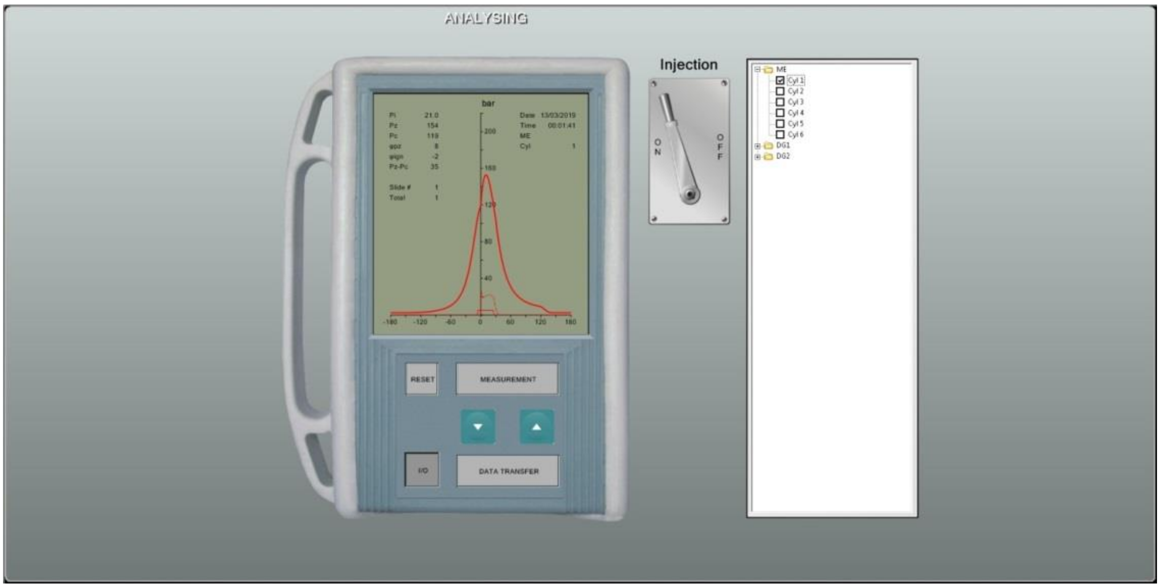

Fig. 4 – Taking the indicator diagram in cylinder #1 with no wear on the piston rings in the main engine

Fig. 5 – Parameters of the main engine without worn piston rings in cylinder #1

Following the same methodology as described in Fig. 2, the piston ring wear level of the gas turbine engine is set to 40% and 60%. Subsequently, an indicator diagram is taken at each position, and the engine parameters are recorded. These indicator diagrams are saved in the diagnostic panel memory for future reference.

For easier analysis, the ERS 5000 TechSim engine room simulator software provides the feature of overlaying previously saved diagrams on the indicator diagram panel, as shown in Fig. 6. The numerical values of the engine parameters are also displayed on the same screen and highlighted in the same color as the graphs, enabling a comprehensive analysis of the engine's performance at different wear levels of the piston rings.

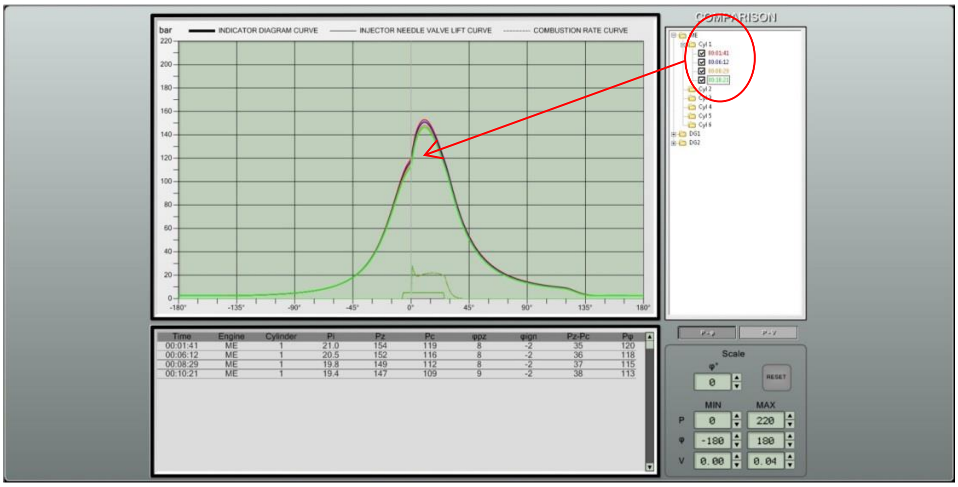

Fig. 6 – Indicator diagrams of different states of the main engine

As a result of the analysis of the changes in the gas turbine engine parameters and the indicator diagrams themselves at different levels of piston ring wear, the following changes were identified, indicating a change in the engine condition:

- A decrease in compression pressure Pc from 119 to 109 bar, CID;
- A decrease in mean indicated pressure Pi from 21.0 to 19.4 bar
- A decrease in maximum combustion pressure Pz from 154 to 147 bar
- An increase in the return oil temperature of the piston cooling system;
- An increase in the consumption of lubricating oil in the cylinder.

The graphs were made with a constant fuel supply.

Conclusions

The main advantages of using simulators in the training process are:

- The possibility of conducting laboratory work in a frontal method (all students perform a task at the same time), which significantly increases the efficiency of this type of learning;
- The ability to model and safely investigate extreme and emergency modes of equipment operation;
- Ability to change experimental conditions extensively;
- Intensification of learning without losing the quality of material assimilation.

Practical training of marine engineers on simulators is the final stage of theoretical training. While working on the ERS 5000 TechSim simulator, mechanical engineers (trainees) apply the acquired knowledge, gain experience very close to working in real conditions, and at the same time the process of refining and consolidating their theoretical knowledge is underway.

References:

1. I.V. Gritsuk, V. Volkov, V. Mateichyk, Y. Grytsuk, Y. Nikitchenko, D. Klets, M. Smieszek, Y. Volkov, R. Symonenko, and A. Grytsuk, «Information Model of V2I System of the Vehicle Technical Condition Remote Monitoring and Control in Operation Conditions», *SAE Technical Paper*, 2018-01-0024, pp. 1-14, 2018. **doi: 10.4271/2018-01-0024**.
2. N.Ia. Hovorushchenko, *Systemotekhnyka avtomobylnoho transporta (raschetnыe metodы yssledovanyi): monohrafyia* [System engineering of motor transport (calculation methods of research): monograph]. Kharkov, Ukraine: KhNAHU Publ., 2011. (Rus.)
3. T. Metcalf, «Listening to your clients», *Life Association News*, vol. 92(7), pp. 16-18, 1997.
4. *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers*, July 1978; *International Code on Standards of Training, Certification and Watchkeeping for Seafarers*, 1995, with amendments adopted in 2010 (Manila Amendments).
5. *IMO Model Course 2.07 «Engine-room simulator»*. 2017.
6. *TechSim 5000 simulator. ERS 5000 TechSim. MAN B&W 6S60MC-C Diesel Engine – Tanker LCC (Aframax)*. 2014.

Перелік використаних джерел:

1. Information Model of V2I System of the Vehicle Technical Condition Remote Monitoring and Control in Operation Conditions / I.V. Gritsuk, V. Volkov, V. Mateichyk, Y. Grytsuk, Y. Nikitchenko, D. Klets, M. Smieszek, Y. Volkov, R. Symonenko, A. Grytsuk. *SAE Technical Paper*. 2018-01-0024. 2018. Pp. 1-14. DOI: https://doi.org/10.4271/2018-01-0024.
2. Говорущенко Н.Я. Системотехника автомобильного транспорта (расчетные методы исследований). Харьков : ХНАДУ, 2011. 292 с.
3. Metcalf T. (1997). Listening to your clients. *Life Association News*. 1997. Vol. 92(7). Pp. 16-18.
4. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, July 1978; International Code on Standards of Training, Certification and Watchkeeping for Seafarers, 1995, with amendments adopted in 2010 (Manila Amendments).
5. IMO Model Course 2.07 «Engine-room simulator». 2017.
6. TechSim 5000 simulator. ERS 5000 TechSim. MAN B&W 6S60MC-C Diesel Engine – Tanker LCC (Aframax). 2014. 279 p.

Reviewer: E.V. Bilousov
Dsc (Engineering), prof., KSMA

The article was received on 21.08.2023
The article was admitted on 17.09.2023

УДК 656.616.2 **doi: 10.31498/2225-6733.47.2023.300114**

© Гусак І.Л.*

ДОСЛІДЖЕННЯ ФАКТОРІВ РИЗИКУ ПЛАВАННЯ СУДНА В АКВАТОРІЇ МОРСЬКОГО ПОРТУ

Метою статті є визначення, систематизація та аналіз факторів ризиків для підвищення безпеки плавання танкера в акваторії морського порту. У статті розглянуто методи оцінки ризиків та управління ризиками при плануванні плавання танкерів в акваторії порту. Запропонована класифікація факторів ризику плавання танкера в акваторії морського порту за п'ятьма класами: клас ризиків щодо структури порту та його акваторії; клас ризиків щодо гідрометеорологічних чинників; клас ризиків щодо керованості судна; клас ризиків щодо технічних засобів та методів судноплавства; клас ризиків щодо системи управління судноплавством в акваторії порту. Запропоновано проводити кількісну оцінка ризиків, що описуються, за допомогою коефіцієнтів безпеки. Ці коефіцієнти безпеки отримуються на основі експертних оцінок, які відображають складність виконання аналізованих операцій, що відповідає прийнятим підходам у морському судноплавстві. З урахуванням вже розроблених практикою методів інтуїтивної оцінки небезпек, коефіцієнти безпеки (для кожного фактору ризику) визначаються через ступінчасту функцію. Найбільш суттєвим науковим результатом є створення єдиного підходу щодо кількісної оцінки для всіх врахованих факторів ризику та побудова дерева факторів ризику плавання танкера в акваторії морського порту. Це є основою для наступного етапу оцінки коефіцієнта навігаційної безпеки плавання в акваторії порту та розробки комплексної моделі аналізу ризиків. Таким чином, проведений аналіз можливих ризиків, пов'язаних зі впливом різних факторів на безпеку навігації танкерів в акваторії морського порту. Ці ризики охоплюють широке коло впливів, включаючи структуру порту та акваторію порту, вплив гідрометеорологічних факторів, характеристики судна та його керованість, а також організацію контролю та управління рухом суден у

* *здобувачка ступеня доктора філософії, Державний університет інфраструктури та технологій, м. Київ, ORCID: 0000-0002-1546-5914*