

## SHIP HANDLING AS AN INFLUENTIAL FACTOR IN PROCESSES WITHIN FUNCTIONAL SHIP TECHNICAL SYSTEMS

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***Abstract.** The thesis examines the impact of ship handling methods on the operation of its technical systems, especially in complex maneuvering conditions. It highlights the human factor in decision-making processes, particularly during complex maneuvers in unpredictable situations, and their influence on ship energy systems, specifically engines. The research emphasizes the need for the development and implementation of automated and intelligent control systems to enhance efficiency and safety in navigation, as well as to reduce the impact of human factors on the risks of accidents.*

***Keywords:** ship handling, technical systems of ships, human factor, energy systems, automated control systems, intelligent systems, maritime safety.*

## УПРАВЛІННЯ СУДНОМ ЯК ФАКТОР ВПЛИВУ НА ПРОЦЕСИ У ФУНКЦІОНАЛЬНИХ СУДНОВИХ ТЕХНІЧНИХ СИСТЕМАХ

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***Анотація.** Теза розглядає вплив методів управління судном на роботу його технічних систем, особливо у складних умовах маневрування. Вона акцентує увагу на людському факторі в процесі прийняття рішень, особливо під час виконання складних маневрів у непередбачуваних ситуаціях, та їх вплив на суднові енергетичні системи, зокрема двигуни. Дослідження підкреслює необхідність розробки та впровадження автоматизованих та інтелектуальних систем керування для підвищення ефективності та безпеки мореплавства, а також для зменшення впливу людського фактора на ризики аварійності.*

***Ключові слова:** управління судном, технічні системи суден, людський фактор, енергетичні системи, автоматизовані системи керування, інтелектуальні системи, безпека мореплавства*

**Introduction.** The modern development of maritime transport faces challenges and tasks, among which the issue of rational ship handling occupies a special place. The relevance of this research lies in identifying and analyzing the role of the human factor in decision-making processes on ships, especially during the execution of complex maneuvers in unpredictable situations.

Considering global challenges such as ensuring environmental safety and increasing the energy efficiency of maritime transport, research with both theoretical significance and practical value for the maritime transportation industry is required. This research aims to improve maritime safety, reduce the risks of accidents, and contribute to the efficient operation of ship technical systems.

**Main research material.** During the execution of complex maneuvers in unpredictable situations, such as quick actions during ship divergence [1–3], storms, search and rescue, etc., emergency situations arise that negatively impact ship energy systems, particularly the technical systems of ship engines. Considering the state of

navigational risk, the human factor of the navigator directly influences decision-making processes [4–6], which are reflected in the methods and approaches to ship movement control [7–9], and thus the operating modes of the engine and its energy systems.

This dependency is examined in several scientific studies, particularly in the article [10], where four engine operating modes were investigated: 25 %, 50 %, 75 %, and 100 % load, within the analysis of combustion characteristics and exhaust emissions in ship diesel engines. It was determined that the maximum methanol substitution rate (MMSR) varies depending on the engine load level. The MMSR increased from 5 % to 43 % with an increase in load from 25 % to 75 %, and then decreased to 20 % at 100 % load, indicating unacceptable operating modes. Considering that complex situations often involve maneuvers that require high engine load or frequent load changes, they can affect combustion stability, emissions, and fuel consumption efficiency. Such maneuvers may include rapid speed changes, movement at low speeds with frequent engine revolutions changes, or prolonged maneuvers in confined spaces.

It should be noted that in the diesel/methanol mode, the maximum pressure and temperature in the cylinder are significantly higher than in the normal mode, which can increase the mechanical and thermal loads on the engine. In general, higher pressures and average temperatures indicate increased mechanical loads, which can limit the engine's operating range and increase the risks of ship management.

In the article [11], a model was created specifically to detect these negative phenomena, capable of accounting for different engine operating modes and loads based on the use of Wiebe parameters, which are considered linear functions, to adapt to variable engine operating modes. The model's effectiveness was verified using experimental data in dual-fuel engines, particularly in the context of different operating modes and loads.

From the article's materials, it can be noted that extreme ship handling modes, such as rapid acceleration, stopping, maneuvering in port, or navigating in complex weather conditions, may require changes in engine operating modes. Frequent changes in load and operating modes can cause additional wear and increase the risks of engine failure. This is especially important in the context of dual-fuel engines, where different types of fuel can have different combustion properties and impacts on engine components. Moreover, ship handling requiring frequent changes in speed or direction can increase fuel consumption, as the engine operates in less optimal conditions. This is particularly important in the context of reducing CO<sub>2</sub> emissions and maintaining fuel efficiency.

Indeed, in such circumstances, several studies, particularly [12], focus on improving the ship's power plant automatic control system, which entails significantly reducing the human factor. This reduction in accidents is expected to be achieved through the use of a decision support system oriented towards modeling, especially during transitional and dynamic engine operating modes. Indeed, modern control systems can affect the efficiency and safety of power plants on ships, especially in the context of transitional and dynamic operating modes.

Unfortunately, there is no concept yet that allows for the complete replacement of human control. Therefore, there must be an appropriate concept of human interaction with optimization tools using automated and intelligent approaches. On the one hand, there is the importance of modeling transitional operating modes for accurate determination of process parameters with sufficient accuracy for dynamic assessment. On the other hand, there is a need to assess the risks of equipment failure and wear due to incorrect actions by personnel, which lead to unstable operating modes. Unfortunately, modern control systems often do not take into account the impact of operator errors, and none of the existing systems contain elements or algorithms to reduce the impact of the human factor and decrease the number of accidents. Increasingly, methods are being proposed to reduce the impact of the human factor on accidents through the use of artificial intelligence algorithms.

In certain cases [13], the situation can be complicated by the fact that in strong weather conditions, the engine control system may fail to stabilize the speed and power of the engine, which can lead to its shutdown. This mostly leads to the development of robust, adaptive, and fault-tolerant engine control systems to ensure safety and efficiency in challenging maritime conditions. For instance, with a wind force of 10, a force of up to 2.5 MN affects the ship, which is significantly higher than the force of waves in calm weather (1 MN). In such conditions, full speed and full engine load do not ensure safe navigation. If the engine speed is reduced to half the maximum, navigation is possible with permissible fluctuations in engine and ship speed. The engine control system in such conditions must be very reliable, self-adaptive, and fault-tolerant.

This multifactorial nature indicates the importance of digital data processing for accurate monitoring and analysis of ship engine conditions. In work [14], methods were defined related to converting traditional mechanical indicator diagram data into digital formats for detailed analysis. This is important for identifying efficiency losses in engines that may arise due to incorrect maneuvering or other operational factors. This information allows ship operators to timely detect and correct potential problems, ensuring efficient and safe engine operation. For example, the use of digital profiles allows for the generation of a calculated indicator diagram for comparison with the one actually obtained during engine indication in any mode of operation. This allows assessing the technical condition of the engine and determining the necessary preventive maintenance and repair measures, which affects the efficiency of engines and the safety of navigation as a whole.

The complexity in determining the correlative connections between maneuver execution on the navigation bridge and the multifactorial processes of ship engines necessitates a more thorough examination of the hidden structure within the chosen operating area of the engine [15]. This involves several steps, including classifying data according to engine operating points, defining three engine operating areas, and a data clustering approach using Gaussian Mixture Models (GMM) with the Expectation Maximization (EM) algorithm. Thus, the ship's movement, in terms of its performance and navigation, is discussed within the chosen operating area of the ship's engine. The work also notes that the chosen engine operating area can be further subdivided, taking into account the average conditions of the ship's draft and thrust.

Large volumes of discrete information about the state and dynamics of the ship's movement and its energy systems must be processed with appropriate mathematical and informational tools, such as Data Mining, etc. In work [16], a generalized concept is proposed for using digital models to support the data processing framework of the shipping industry. These models can be derived from datasets on ship performance and navigation, considering a large-dimensional parameter space. They consist of several data clusters, each with a unique data structure, to account for the corresponding operating modes of the main engine, define data clusters in the engine-propeller diagram, and anomalies related to sensors and data collection errors, system failures.

Therefore, the human factor, both as a navigator and an engineer, creates a multi-level and multifactorial system for managing the ship as a complex of technical and information control systems. This fact necessitates corresponding developments from automated and intelligent systems with the ability to process a wide range of heterogeneous data. This task involves creating a complex of automatic [17, 18], automated, and intelligent control systems for the ship's technical systems and complexes, as well as supporting operators' decision-making.

Thus, the main focus should be on improving ship handling methods [19], which directly affect the operation of engines and other ship technical systems:

- developing algorithms to optimize ship control methods: Algorithms that consider different engine operating modes and maneuvering conditions;
- integrating automatic control and decision support systems: Developing systems that can analyze various scenarios and provide recommendations to the crew to optimize control methods;
- adapting to dynamic maneuvering conditions: Creating systems capable of quickly adapting to changing operating conditions, especially during complex maneuvers;
- applying machine learning and artificial intelligence technologies: For analyzing large volumes of data on engine operation and maneuvering conditions, to improve control methods;
- developing comprehensive ship control systems: Integrating various technical and information control systems for effective maneuvering and supporting the captain's decisions.

Also, based on the analysis of existing methods and technologies for ship control affecting the operation of engines and other ship technical systems, the following main approaches can be identified:

- modeling and optimizing engine operating modes: Using digital models for precise monitoring and analysis of the condition of ship engines, particularly for assessing the technical state of the engine and determining necessary preventive maintenance and repair measures;
- automation and intelligent control systems: Developing complex automated and intelligent control systems for ship technical systems, which include automatic control and operator decision support;
- integration of artificial intelligence and machine learning: Using AI algorithms to analyze large volumes of data and adapt to changes in operating conditions and operator behavior in complex maneuvering situations;

– decision support systems: Developing systems focused on modeling, especially during transitional and dynamic engine operating modes, to reduce the impact of human factors on accidents;

– digital data processing for engine status control: Using Data Mining technologies and other information tools to process large volumes of discrete information about the state and dynamics of the ship's movement and its energy systems.

The combination of these approaches and tools can be integrated to create more reliable and efficient ship control systems capable of adapting to variable maneuvering conditions and reducing risks associated with human factors.

**Conclusion.** Therefore, the considered approaches to rationalization in the management of ship technical systems focus on developing new and improving existing ship handling systems, particularly automation and integration of intelligent systems, which can reduce risks associated with the human factor. This implies the development of complex systems that include automatic control of ship technical systems and support for operators' decision-making.

A deep understanding of the interaction between the navigator, engineer, and technical systems of the ship is key to the development of new automation systems and intelligent data analysis capable of reducing risks associated with the human factor.

In turn, the application of automation and advanced artificial intelligence technologies, machine learning algorithms, will allow for the creation of more reliable and efficient control systems that can adapt to changes in operating conditions and operator behavior in complex maneuvering conditions.

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