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3. Пугач І. І., Харченко В. В. Сучасні підходи до реконструкції аварій у гірничотехнічній експертизі: методологія, моделювання, перспективи // Proceedings of the 1st International Scientific and Practical Conference "Scientific Research: Emerging Theories and Practical Breakthroughs" (Edinburgh, Scotland, July 28–30, 2025). Edinburgh, 2025. P. 135–147.
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RELIABILITY INDICATORS OF SHIP POWER PLANTS: COMPARATIVE ASSESSMENT AND DEVELOPMENT PROSPECTS

Doshchenko Halyna
Ph.D., Associate Professor
Department of Operation vessel electrical equipment and Automation
Kherson State Maritime Academy, Ukraine

Abstract. A comparative analysis of the reliability indicators of various marine power plants shows that there is a significant diversity in their characteristics, due to both technical and operational factors. This diversity highlights the need for an individual approach to the design and operation of marine power plants (MPP), taking into account the specifics of each specific vessel and its purpose. Modern standards and regulations require shipbuilders and ship operators to take into account not only economic but also environmental aspects, which in turn affects the choice of technologies and materials used in MPP. This creates additional challenges, but also opens up new opportunities for innovative solutions that can improve the reliability and efficiency of ships.

Keywords: shipbuilding, diesel, system, modernization, load, reliability indicator, marine transport, optimization, environmental safety, operational levels.

Introduction

Modern marine propulsion systems (MPS) are complex, high-tech systems that play a key role in ensuring the efficient and safe operation of maritime transport. In the context of globalization and increasing maritime transport volumes, requirements for the reliability and efficiency of MPS are becoming increasingly important. The reliability of MPS not only influences the safety of the vessel and its crew but also determines the economic efficiency of vessel operation, which in turn influences the competitiveness of shipping companies [1, 2].

Research tasks

Conduct a thorough analysis of the main indicators of the reliability of various types of ship power plants (SPU) and identify the reasons for their variability.

Comparative analysis of reliability indicators

The reliability of marine propulsion systems (MPS) is a multifactorial characteristic determined not only by the technical characteristics of the equipment but also by operating conditions, operating modes, and a number of external factors. This paper provides a comparative analysis of the reliability indicators of various marine propulsion systems, highlighting the strengths and weaknesses of existing solutions. Reliability indicators include parameters such as the probability of failure, mean time between failures (MTBF), mean time to repair (MTTR), as well as availability and operational readiness factors.

To assess the reliability of various systems, it is necessary to consider the latest advances in technologies used in design and control systems. Modern marine propulsion systems often integrate automated control functions and diagnostic systems, which significantly influences their reliability indicators. For example, systems equipped with condition monitoring systems enable diagnostics, which reduces the incidence of unexpected failures and downtime [3].

A comparison of traditional and modern power plants shows that the latter generally have higher reliability rates due to the use of advanced materials, control systems, and data processing algorithms. In particular, the use of composite materials and improved design solutions reduces the impact of mechanical stress and fatigue, which in turn reduces the likelihood of failure. In practice, organizational aspects such as crew training and adherence to maintenance and operating procedures significantly influence system reliability. Reliability rates may vary depending on the level of professionalism of the maintenance personnel and the skills of the crew, which is also important to consider in the comparative analysis.

Recent studies have focused on the use of mathematical statistics methods for reliability analysis. The use of appropriate models and equations allows for more accurate predictions of the failure probability of specific power plant components. Thus, a statistical approach, taking into account operational data from various types of installations, reveals varying levels of reliability, which helps in selecting the optimal configuration and design solution for new projects.

A comparative analysis shows that achieving high reliability requires a systematic approach that combines high-quality design, advanced equipment, and regular technical refresher training for the crew. Effective operation of a power plant requires the operator to be able to analyze and resolve any issues that arise, which directly influences reliability. Some power plants that utilize autonomous monitoring and data collection technologies for all systems demonstrate the most impressive results. These systems integrate mechanisms that allow engineers to monitor system status in real time and promptly respond to changes, avoiding serious consequences.

Given the heterogeneity of approaches to the design and operation of marine power plants, several categories should be distinguished: legacy systems with insufficient automation, modern plants with intelligent control elements, and experimental models developed as part of scientific research. Each category has its own unique reliability indicators, reflecting both technological advances and the shortcomings of previous stages.

An important stage of the analysis is identifying the strengths and weaknesses of each of the technologies under consideration in terms of reliability. Comparative analysis highlights the benefits of using new technologies, such as artificial intelligence-based control units, which can optimize plant operation based on changing conditions. Upon completion of the analysis, it becomes clear that the reliability of marine propulsion systems varies depending on the technologies used, design approaches, and organizational processes. Comparative data demonstrates that the implementation of integrated solutions, such as automated diagnostics and monitoring processes, significantly improves system reliability, which, in turn, leads to safer and more efficient ship operation.

Thus, analyzing the reliability indicators of various propulsion systems makes it possible to identify trends and areas for further improvement, which is an important step towards creating more reliable and safer marine propulsion systems. It is important to continue studying the influence of various factors on reliability, which will allow for a deeper understanding of the processes occurring within propulsion systems and, based on these studies, develop recommendations for improving the design and operation of modern marine propulsion systems.

Results and discussion

The future development of marine propulsion plant (MPP) reliability indicators is drive by several significant trends, including the integration of numerical technologies, the use of artificial intelligence, and increasing process automation. These factors will influence the architecture and functional characteristics of MPPs.

Numerical technologies include modeling and simulation of system operation, which enables more accurate predictions of their behavior in various operating modes. High-quality models that identify critical failure points enable proactive measures to improve reliability. Thus, virtual prototyping capabilities provide a preventive approach to identifying and eliminating vulnerabilities, which is the key to safe operation.

Artificial intelligence and machine learning help analyze large volumes of data collected from sensors onboard ships. Predictive analytics systems can be used to assess equipment condition in real time, allowing operators to predict when a failure may occur. This not only helps reduce downtime but also optimizes maintenance, which in turn influences economic aspects. The installation of AI-based monitoring systems requires minimizing interdependencies between components, which again highlights the importance of reliability [4].

Automation of control and diagnostic processes will also play a significant role in improving reliability. Modern marine power plants are increasingly equipped with automated control systems that enable immediate response to operational deviations, reducing the time required to make adjustments. Importantly, such systems can independently analyze deviations from standards, minimizing human error and reducing the likelihood of errors caused by carelessness or insufficient personnel qualifications. The process of standardization and certification of reliability indicators is also closely linked to modernization.

Standards are constantly updated to reflect the introduction of new technologies and assessment methods. An important aspect is the inclusion of environmental standards and requirements in standard procedures for the design and operation of marine power plants, which further underscores the modern trend toward sustainable development.

The introduction of electrification and new energy sources, such as hydrogen and solar panels, also brings with it changes in reliability indicators. The transition to cleaner and more efficient energy sources necessitates the development of new control and monitoring systems, which in turn requires a revision of reliability assessment criteria. The performance indicators associated with traditional installations may not reflect the actual reliability of new solutions.

Changes in the regulatory framework regarding international safety and environmental standards will directly influence the design and operation of marine propulsion systems. Stricter requirements may necessitate the development of additional control and safety systems, which will ultimately contribute to the overall reliability of the design. However, despite technological advances, it is important to consider the potential for human error. The application of advanced training and personnel education methods remains critical to achieving high reliability. Organizations must focus not only on technical aspects but also on training operators who can effectively utilize new technologies and respond to non-standard situations.

The future of marine propulsion systems also requires adaptation to changing conditions in the international fishing, transport, and passenger markets. This includes commitments to reduce emissions and improve cost efficiency. The adoption of technologies that facilitate adaptation to these challenges will become essential, which will entail changing reliability requirements.

Conclusion

Based on the above, it can be predicted that in the future, reliability indicators will be integrated with environmental and economic requirements and adapted to new technological solutions. The ability to adapt to new conditions and trends will be crucial in creating efficient and reliable marine propulsion systems. A key aspect will be the continuous updating of indicators based on practical experience and current technological advances. Thus, one can expect the emergence of new approaches, methods, and criteria, which will be based on the progressive development of all elements of the ship's power system [5].

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ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ПРОЦЕСУ ВЗАЄМОДІЇ З ПОЛУМ'ЯМ АЕРОЗОЛЕВИХ ВОГНЕГАСНИХ РЕЧОВИН

Словінський Віталій
к.т.н.
Черкаський науково-дослідний експертно-криміналістичний центр МВС України

Для пошуку ефективності застосованих рецептур аерозольутворюючих сполук (далі-АУС), виконувалися експериментальні дослідження зарядів АУС з різними співвідношеннями окисників і з різними за хімічною природою горючими речовинами. Досліджувалась залежність ефективності аерозолю від співвідношення окисник : горюче, а також досліджувався вплив різноманітних добавок на вогнегасну ефективність аерозолів.

Як відомо мінімальна вогнегасна концентрація – це найменша концентрація вогнегасної речовини в об'ємі при якій досягається ефект гасіння за мінімальний час. Але методики різних авторів передбачають різні значення часу при яких концентрацію вважають за мінімальну. Способи подачі вогнегасного засобу також є різними. В методиках для визначення мінімальної вогнегасної концентрації (далі-МВК) газових засобів гасіння передбачено подачу аерозолю разом з супутнім потоком горючої газопароповітряної суміші в пальник, з швидкістю, яка також є різною. Зважаючи на те, що вогнегасний аерозоль утворюється при згорянні АУС, в методиках передбачено засоби запалювання АУС в об'ємах камер чи циліндрів. Приймаючи до уваги те, що методик для визначення мінімальної вогнегасної концентрації вогнегасного аерозолю на даний час немає, а існуючі призначені, як правило, для визначення МВК порошкових та газових засобів пожежогасіння, механізм гасіння яких відмінний