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ENERGY EFFICIENCY ON SHIPS. STRATEGIC APPROACH

Ye.V. Kalinichenko[1], G.G. Tomchakovsky[2]
[1]Candidate of Technical Science, Docent, Master Mariner,
Head of Navigation and Control of the Ship Department,
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0003-2898-7313
[2]Master Mariner, Senior Lecturer,
Navigation and Control of the Ship Department,
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0002-9799-4368

Summary

Introduction. *The shipping industry is a critical component of the global economy, with around 90% of the world's trade being transported by ships. However, the industry also has a significant environmental impact, contributing to around 2.5% of global greenhouse gas emissions. As such, there is a growing need to improve the energy efficiency of ships to reduce their environmental impact and comply with increasingly stringent regulations.* ***Purpose.*** *This article will explore the various technologies and strategies available to improve energy efficiency on ships and provide a scientific analysis of their effectiveness.* ***Results.*** *Wind propulsion technologies, such as rotor sails or kite sails, can be used to reduce fuel consumption and emissions in the shipping industry. These technologies harness the power of wind to propel the ship, reducing the need for fossil fuels. While wind propulsion technologies are still relatively new, they have shown promising results in terms of reducing fuel consumption and emissions. Energy management systems can also be used to optimize the operation of a ship's engines and equipment and improve energy efficiency. Energy management systems can also help reduce maintenance costs and extend the lifespan of the ship's equipment. Hybrid propulsion systems, which combine two or more power sources, can also help improve the energy efficiency of ships. This can reduce fuel consumption and emissions, especially during low-load conditions. Hybrid propulsion systems can also help improve the overall performance and reliability of the ship's power system.* ***Conclusions.*** *improving the energy efficiency of ships is an important step in reducing the shipping industry's impact on the environment. There are various strategies and technologies that can be employed to achieve this goal, including hull coatings, waste heat recovery, energy management systems, hybrid propulsion systems, and wind propulsion. While each strategy has its advantages and limitations, their combined use can help improve the overall energy efficiency of ships and reduce their impact on the environment.*

Key words: *energy efficiency of ships, vessels fuel consumption, wind propulsion technologies.*

ЕНЕРГОЕФЕКТИВНІСТЬ НА МОРСЬКИХ СУДНАХ. СТРАТЕГІЧНИЙ ПІДХІД

Є.В. Калініченко[1], Г.Г. Томчаковський[2]
[1]к.т.н., доцент, КДП, завідувач кафедри навігації і керування судном,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0003-2898-7313
[2]КДП, старший викладач кафедри навігації і керування судном,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0002-9799-4368

Анотація

Вступ. *Індустрія судноплавства є критично важливою складовою світової економіки, оскільки близько 90% світової торгівлі транспортується суднами. Однак галузь також має значний вплив на навколишнє середовище, спричиняючи приблизно 2,5% глобальних викидів парникових газів. Таким чином, зростає потреба покращити енергоефективність суден, щоб зменшити їхній вплив на навколишнє середовище та відповідати дедалі суворішим нормам.* ***Призначення.*** *У цій статті розглядатимуться різноманітні технології та стратегії, доступні для підвищення енергоефективності на суднах, і буде проведено науковий аналіз їхньої ефективності.* ***Результати.*** *Технології вітрової тяги, такі як роторні вітрила або повітряні змії, можна використовувати для зменшення споживання палива та викидів у судноплавній галузі. Ці технології використовують силу вітру для руху судна, зменшуючи потребу у викопному паливі. Хоча вітряні рушійні технології все ще є відносно новими, вони продемонстрували багатообіцяючі результати щодо зменшення споживання палива та викидів. Системи енергоменеджменту також можна використовувати для оптимізації роботи суднових двигунів і обладнання та підвищення енергоефективності. Системи керування енергією також можуть допомогти зменшити витрати на технічне обслуговування та подовжити термін служби суднового обладнання. Гібридні силові установки, які поєднують два або більше джерел енергії, також можуть допомогти підвищити енергоефективність суден. Це може зменшити споживання палива та викиди, особливо в умовах низького навантаження. Гібридні силові установки також можуть допомогти підвищити загальну продуктивність і надійність енергетичної системи судна.* ***Висновки.*** *підвищення енергоефективності суден є важливим кроком у зменшенні впливу судноплавної галузі на навколишнє середовище. Існують різні стратегії та технології, які можна застосувати для досягнення цієї мети, включаючи покриття корпусу, рекуперацію відпрацьованого тепла, системи управління енергією, гібридні системи силової установки та вітрову тягу. Хоча кожна стратегія має свої переваги та обмеження, їх спільне використання може допомогти підвищити загальну енергоефективність суден і зменшити їхній вплив на навколишнє середовище.*

Ключові слова: *енергоефективність суден, споживання палива суднами, вітрові рушійні технології.*

Introduction. The shipping industry is a critical component of the global economy, with around 90% of the world's trade being transported by ships. However, the industry also has a significant environmental impact, contributing to around 2.5% of global greenhouse gas emissions. As such, there is a growing need to improve the energy efficiency of ships to reduce their environmental impact and comply with increasingly stringent regulations.

Improving energy efficiency on ships can also have significant economic benefits by reducing fuel consumption and operating costs. For example, a 2018 report by the International Maritime Organization (IMO) found that implementing energy efficiency measures could result in fuel savings of up to 75%, with corresponding reductions in emissions and operating costs.

Statement of the problem. Given the growing interest in improving energy efficiency on ships, there have been significant developments in technologies and strategies to achieve this goal. These range from advanced propulsion systems to hull coatings, waste heat recovery, and energy management systems. However, there is a need for further scientific analysis to assess the effectiveness of these technologies and strategies in different ship types and operating conditions, as well as to identify new solutions for improving energy efficiency in the shipping industry.

Therefore, this article will explore the various technologies and strategies available to improve energy efficiency on ships, and provide a scientific analysis of their effectiveness.

Background (Analysis of recent research and publications). The shipping industry is a significant contributor to global greenhouse gas emissions, accounting for around 2% of global emissions (around 4% in EU) in 2019. The primary source of emissions from ships is the burning of fossil fuels, which power the large diesel engines that propel the vessel through water (the shipping emission output varies on ships' types and their routes).

However, not all of the energy produced by the engine is used to move the ship. A significant amount of energy is lost through inefficiencies in the engine and transmission systems, as well as through drag caused by the ship's hull and propellers. Therefore, improving energy efficiency on ships can lead to significant reductions in fuel consumption and emissions.

The need to improve energy efficiency on ships is becoming increasingly urgent due to global efforts to address climate change. The International Maritime Organization (IMO), a United Nations agency responsible for regulating shipping, has set targets to reduce greenhouse gas emissions from the shipping industry. These include a target to reduce the carbon intensity of international shipping by at least 40% by 2030, compared to 2008 levels, and to reduce total greenhouse gas emissions from international shipping by at least 50% by 2050, compared to 2008 levels.

Improving energy efficiency on ships can also have significant economic benefits. Fuel costs can account for up to 60% of a ship's operating costs, and reducing fuel consumption can result in substantial savings, plus as per post-pandemic and war/post-war circumstances fossil fuel price will continue to grow (despite fuel spread and availability).

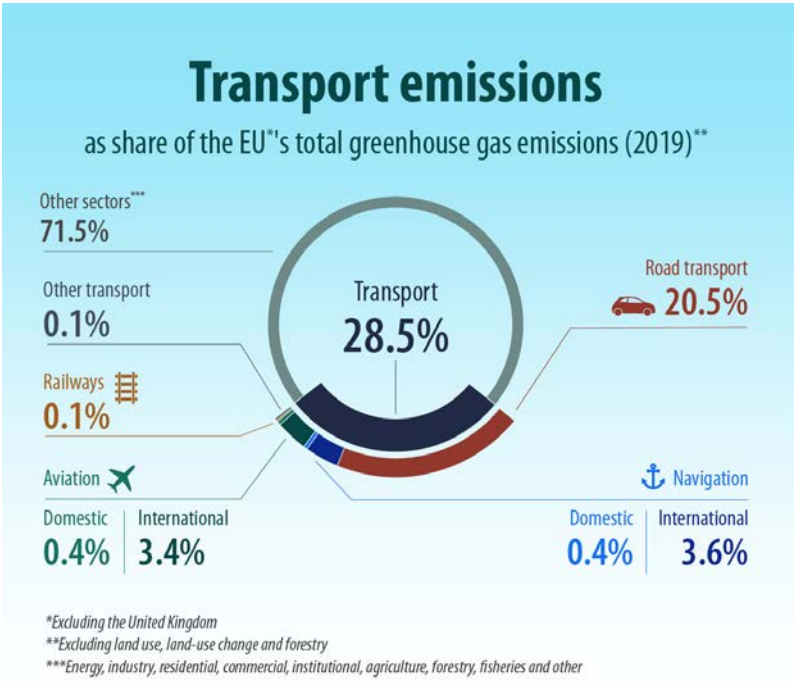

Fig. 1. Greenhouse gas emissions in EU, 2019 (info by EU Parliament) [1]

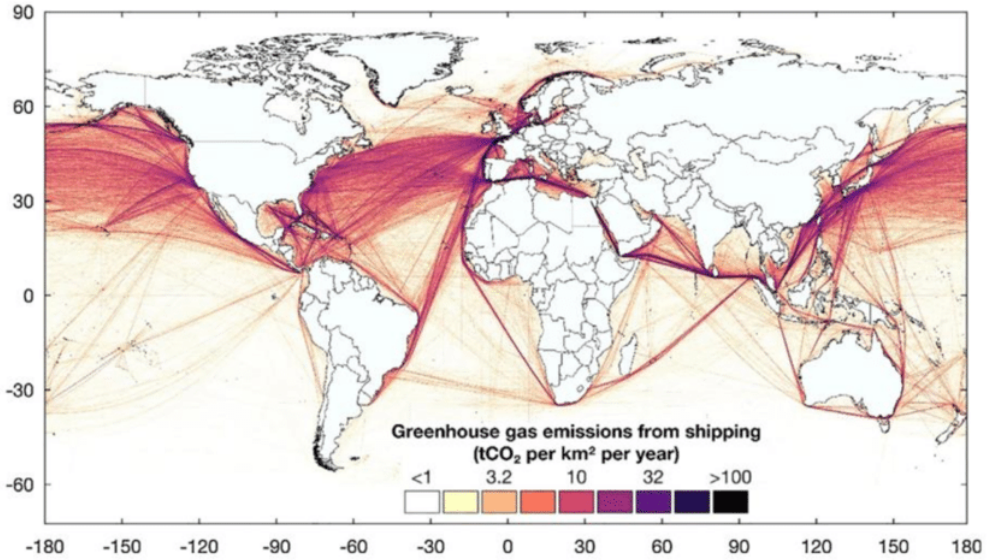

Fig. 2. Global distribution of gas emissions from shipping (as per routes/traffic density, AIS) [2]

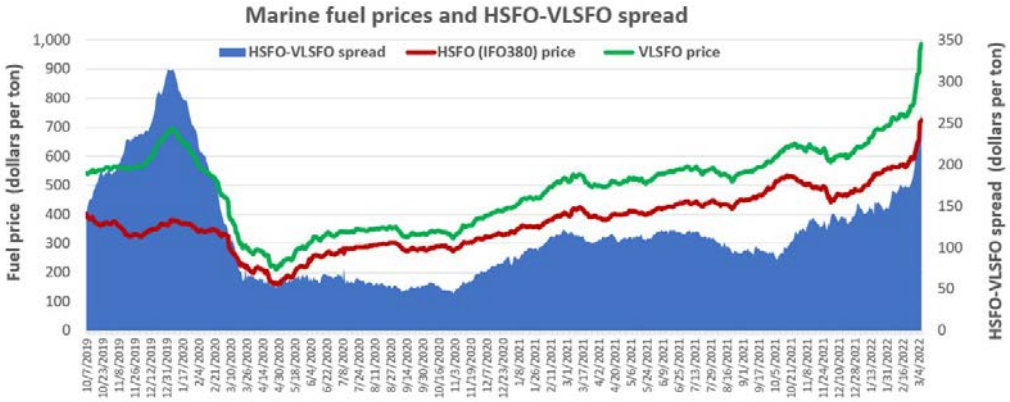

Fig. 3. HSFO/VLSFO prices worldwide, 2019-2022 (chart by "American Shipper" based on data from Ship & Bunker) [3]

In addition, improving energy efficiency can help shipping companies to comply with regulations and enhance their reputation as environmentally responsible organizations.

Purpose. Therefore, there is a growing need to identify and implement technologies and strategies to improve energy efficiency on ships. These can range from simple measures such as optimizing vessel speed and route planning to more advanced solutions such as hybrid or electric propulsion, hull coatings, waste heat recovery, and energy management systems. However, the effectiveness of these technologies and strategies can vary depending on a range of factors, including the ship's size and design, operating conditions, and maintenance practices. Therefore, it is important to carefully evaluate the potential benefits and costs of each technology or strategy on a case-by-case basis.

Technologies and strategies. There are several technologies and strategies that can be used to improve energy efficiency on ships, including but not limited to:

1. Hull coatings [4]:

Hull coatings can be used to reduce drag and improve the flow of water around the ship's hull, thereby reducing fuel consumption. For example, a silicone-based coating can reduce frictional resistance by up to 20%, while a super-hydrophobic coating can reduce drag by up to 30% [10].

Efficiency Calculation: A study conducted by the IMO estimated that a silicone-based hull coating could result in fuel savings of up to 5%, depending on the ship's size and operating conditions.

2. Waste heat recovery [5]:

Waste heat recovery systems can capture and reuse heat generated by the ship's engine, reducing the amount of fuel needed to generate the same amount of power. For example, a waste heat recovery system can recover up to 40% of the energy from the engine's exhaust gas [11].

Efficiency Calculation: A study conducted by the European Commission estimated that a waste heat recovery system could result in fuel savings of up to 10%, depending on the ship's size and operating conditions.

3. Energy management systems [6]:

Energy management systems can be used to optimize the operation of the ship's engines and equipment, reducing energy waste and improving efficiency. These systems

can monitor and control fuel consumption, adjust engine speed and power, and optimize equipment performance.

Efficiency Calculation: A study conducted by the IMO estimated that an energy management system could result in fuel savings of up to 15%, depending on the ship's size and operating conditions.

ISO 50001 is a voluntary international standard. It applies to organisations of any size, and provides requirements for establishing, managing and improving their energy consumption and efficiency.

ISO 50001 is designed to be compatible and harmonised with other system standards, such as ISO 14001 for environmental management systems and ISO 9001 for quality management systems. It is therefore ideal for integrating into existing management systems and processes such as environmental, and health and safety.

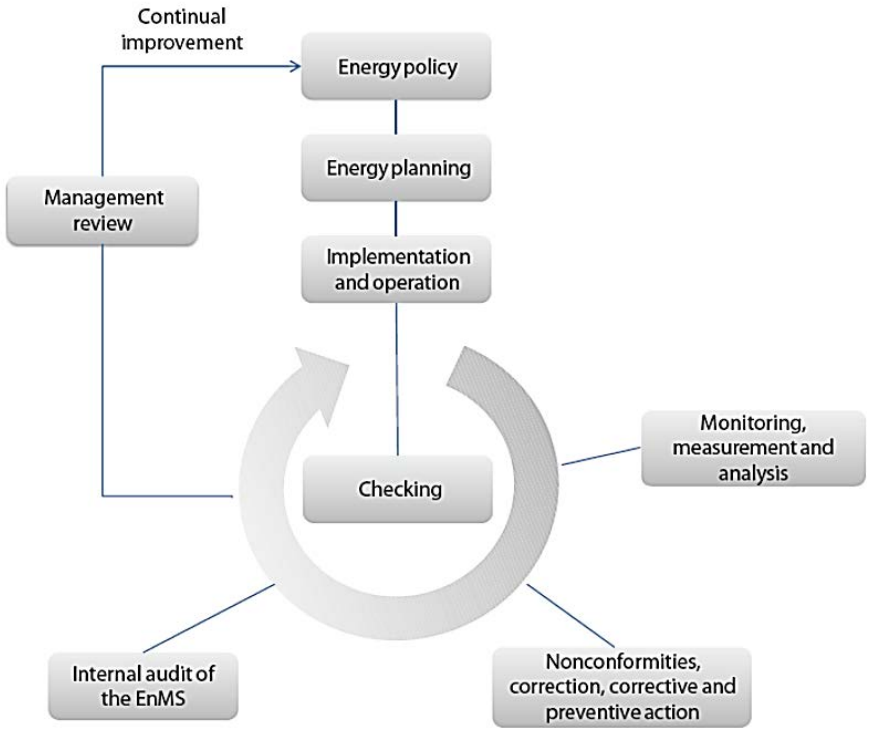

Fig. 4. ISO 50001 standard's principles for energy management systems on ships, IMO [6]

ISO 50001 assists facilities in evaluating and prioritizing the implementation of new energy-efficient technologies and in improving energy efficiency, energy use and consumption. It also creates transparency and facilitates communication on the management of energy resources. It promotes energy management best practices and behaviors, and provides a framework for promoting energy efficiency throughout the supply chain and facilitates energy management improvements for greenhouse gas emission reduction projects.

Certification to the standard can contribute to:

– Improvement of energy performance, including energy efficiency, use and energy consumption.

– Reducing environmental impact, including greenhouse gas emissions without affecting operations and simultaneously increasing profitability.

– Continual improvement of the energy management systems.

– Ensuring measurement, documentation, reporting and benchmarking of energy consumption.

– Credible market communication about energy performance efforts.

Therefore, abovementioned principles can be applied in developing various strategies for energy efficiency on ships directly, as these are something that navigators can control and maintain on the operational level.

4. Hybrid propulsion:

Hybrid propulsion systems use a combination of conventional and electric power to reduce fuel consumption and emissions. For example, a ship equipped with a hybrid propulsion system can switch between diesel and electric power depending on the operating conditions, such as when entering and leaving ports.

Efficiency Calculation: A study conducted by the European Commission estimated that a hybrid propulsion system could result in fuel savings of up to 30%, depending on the ship's size and operating conditions [7].

5. Wind propulsion [8]:

Wind propulsion systems can be used to harness the power of wind to reduce fuel consumption. These systems can range from simple sails to more advanced solutions such as rotor sails or kites [9].

Efficiency Calculation: A study conducted by the University of Delaware estimated that a rotor sail system could result in fuel savings of up to 10%, depending on the ship's size and operating conditions.

Scientific analysis. Several studies have been conducted to assess the effectiveness of these technologies and strategies in improving energy efficiency on ships. For example, a study published in the Journal of Marine Science and Engineering found that using advanced propulsion systems and hull coatings could reduce fuel consumption by up to 35% and 12%, respectively. Similarly, a study published in the Journal of Cleaner Production found that waste heat recovery systems could improve energy efficiency by up to 20%.

Hull coatings can help reduce the drag on a ship's hull, thereby reducing fuel consumption and emissions. The use of silicone-based fouling release coatings has been found to be particularly effective in reducing drag and improving energy efficiency. However, the effectiveness of hull coatings depends on the specific design and operating conditions of the ship, and some hull coatings may not be effective in all situations.

Waste heat recovery is another strategy that can improve the energy efficiency of ships. Heat recovery systems can be used to recover waste heat from the ship's engine and other equipment, and convert it into useful energy. This energy can then be used to power the ship's systems, thereby reducing the need for fossil fuels. There are various waste heat recovery technologies available, including steam turbines, organic Rankine cycles, and thermoelectric generators.

Energy management systems can also be used to optimize the operation of a ship's engines and equipment, and improve energy efficiency. These systems can monitor and control the ship's energy consumption, and provide real-time data to the crew to help

them make more informed decisions about energy use. Energy management systems can also help reduce maintenance costs and extend the lifespan of the ship's equipment.

Hybrid propulsion systems, which combine two or more power sources, can also help improve the energy efficiency of ships. For example, a hybrid propulsion system may combine a diesel engine with an electric motor, allowing the ship to operate on either power source as needed. This can reduce fuel consumption and emissions, especially during low-load conditions. Hybrid propulsion systems can also help improve the overall performance and reliability of the ship's power system.

Finally, wind propulsion technologies, such as rotor sails or kite sails, can be used to reduce fuel consumption and emissions in the shipping industry. These technologies harness the power of wind to propel the ship, reducing the need for fossil fuels. While wind propulsion technologies are still relatively new, they have shown promising results in terms of reducing fuel consumption and emissions.

Conclusion. In conclusion, improving the energy efficiency of ships is an important step in reducing the shipping industry's impact on the environment. There are various strategies and technologies that can be employed to achieve this goal, including hull coatings, waste heat recovery, energy management systems, hybrid propulsion systems, and wind propulsion. While each strategy has its advantages and limitations, their combined use can help improve the overall energy efficiency of ships and reduce their impact on the environment.

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