DECARBONIZATION OF MARITIME INDUSTRY

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Abstract: *Maritime transport plays a crucial role in global trade, accounting for the transportation of approximately 80% of goods by volume. However, the industry's reliance on fossil fuels has led to significant environmental concerns, including carbon emissions, air pollution and the impact on marine ecosystems. To address these challenges the maritime sector is actively pursuing strategies to decarbonise and transition towards a more sustainable future.*

Keywords: *Maritime transport, sustainable shipping, greenhouse gases, decarbonisation, environmental protection*

ДЕКАРБОНИЗИРАНЕ НА МОРСКАТА ИНДУСТРИЯ

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Резюме: *Морският транспорт играе решаваща роля в глобалната търговия, като представлява транспортирането на приблизително 80% от обема на стоките. Разчитането на индустрията на изкопаеми горива обаче доведе до значителни опасения за състоянието на околната среда, включително въглеродните емисии, замърсяването на въздуха и въздействието върху морските екосистеми. За да се справи с тези предизвикателства, морският сектор активно следва стратегии за декарбонизация и преход към по-устойчиво бъдеще.*

Ключови думи: *Морски транспорт, устойчиво корабоплаване, парникови газове, декарбонизация, опазване на околната среда*

1. Introduction

The maritime industry is a major contributor to greenhouse gas emissions, primarily through the burning of heavy fuel oil and diesel. Carbon dioxide (CO2), sulfur oxides (SOx), nitrogen oxides (NOx) and particulate matter are among the pollutants released into the atmosphere (Fig.1).

Fig.1 Air pollution by ships

Recognizing the urgent need for action international bodies as the International Maritime Organization (IMO) have set ambitious targets to reduce emissions. In 2018 the IMO set a first-ever target to reduce the total annual green-house gases (GHG) emissions by at least 50% by 2050 compared to 2008 levels and in 2023 adopted the “2023 IMO Strategy on Reduction of GHG Emissions from Ships” [1] which updated the initial strategy, incorporating a net-zero GHG emission goal to be achieved by or around 2050.

2. Decarbonisation of ports

As global trade continues to thrive, the environmental impact of maritime activities has come under scrutiny. Energy consumption in shipping is almost exclusively fossil fuel based with heavy fuel oil (HFO) and marine diesel oil/marine gas oil (MDO/MGO) responsible for the largest shares of GHG emissions. Ports, serving as crucial hubs in the supply chain, have a pivotal role to play. The need to reduce emissions in ports has become increasingly apparent, driven by concerns over air quality, public health and the broader commitment to combat climate change.

In general, vessels need to use engines in port in order to keep the necessary systems running. In Germany and the UK emissions in port add up to 20% of total emissions from the sector while in Greece the share is a staggering 37%. The average emissions in port for the four countries combined being 26%, equal to 440,000 tons of CO_2. [2]

Mooring a ship in the traditional conventional way takes normally between 30 and 90 minutes depending on the circumstances and the meteorological situation. During this time ship's main engine(s) and at least two auxiliary engines are running on diesel fuel, emitting harmful gases. Additionally, gasses emitted from the running engines of port tugboats assisting berthing of big vessels should be taken into consideration, increasing the negative impact on the environment. There are innovative methods for mooring introduced in many ports worldwide such as vacuum and magnetic systems (Fig. 2).

Fig. 2 a) Vacuum mooring system b) magnetic mooring system

In these systems the traditional mooring lines are substituted by suction pads mounted on the pier. When ship is brought close to the berth forces created by vacuum or electromagnets are bringing her alongside and holding her position during port stay. Usually, such systems are equipped with sophisticated electronic hydraulic controls which minimise vessel movement (surge, sway and yaw) in order to maintain ship's position with millimetre accuracy without the need for using her engine(s) or the help of tugs. It is possible to finely adjust ship's position after her berthing. This might, for instance, be important for ferries that need to line up accurately in order to use land mounted gangways or equipment. System's performance can be monitored in real-time and mooring processes and forces can be controlled from the ship's bridge or from a shore station by means of a tactile screen. [3, 4]

While moored at port, ships require power to maintain their lights, heating, cooling, and other essential vessel functions. Usually, this power is provided by running vessels' auxiliary engines (generators) on diesel fuel. Normally, ships use more than one generator during cargo operations. The result is deterioration of air quality, especially in big and busy ports with concentration of many vessels. Emissions in port are a relatively large part of the total emissions. The experience with the use of shore power transmission systems showed a reduction of port emissions from 20% up to 37% which is a considerable success in emissions reduction. [2]

Enabling ships to shut down their engines while docked and to connect to shore-based electrical power, known as *cold ironing* or shore power, helps to eliminate emissions from ships during port stays. Ports are increasingly investing in shore power infrastructure to encourage vessel operators to make the switch. On European level the EU Recommendation 2006/339/EU promotes the implementation of shore-side electrical facilities while EU Recommendation 2003/96/EC proposes the subsidisation of shore-side power supply for ships through the cancellation of electricity taxes.

The onshore power supply system is equipment which can supply onshore electric power to ships moored in port, both High and Low Voltage (Fig. 3) Except for shore installations it also requires ship-side installations in order to accept shore power. On both sides the installations consist of different devices as switchgear and protections, transformers, frequency convertors (if necessary), plugs, power cables, automation, cable monitoring system etc. Shore power can be supplied to all types of vessels and has been used for years for smaller vessels and for some larger passenger vessels too. [5]

Fig.3 Shore power supply systems

Transitioning from diesel-powered to electric cargo-handling equipment, such as cranes and forklifts, can significantly reduce emissions within ports. Implementing charging infrastructure and utilizing renewable energy sources for electricity further enhance the environmental benefits.

3. Decarbonization of shipping

There are three types of possible measures to achieve decarbonisation of shipping: technological, operational and measures related to alternative fuels and energy [6].

Technological measures: Improving energy efficiency via technological measures is the aim of the global regulation on the energy efficiency of ships. This regulation requires ships built after 1 January 2013 to comply with a minimum energy efficiency level: the Energy Efficiency Design Index (EEDI). The EEDI measures the CO2 emitted (g/tonne-mile) based on ship design and engine performance data. The EEDI level is tightened incrementally every five years with an initial CO_2 reduction level of 10% for the first phase (2015-2020), 20% for the second phase (2020-2025) and a 30% reduction mandated from 2025 to 2030. This regulation is part of Annex VI of the International Convention for the Prevention of Pollution from Ships, often abbreviated as MARPOL Convention.

Technological measures cover technologies applied to ships that help to increase the energy efficiency of a ship: related to the weight of ships (lighter materials), the design of ships (slender hull designs and bulbous bow), ways to reduce hull resistance of ships (such as hull coatings and air lubrication) and ways to recover energy, such as propeller upgrades and heat recovery.

Operational measures: Operational measures are related to the way vessels and, more broadly, the maritime transport systems are being operated: speed, ship size, ship-port interface and onshore power. Both slower speeds ("slow steaming") and larger ship sizes have over the last years contributed to a decrease in shipping emissions. Lower speeds reduce fuel consumption and emissions. A rule of thumb used in the scientific literature states that the engine power output of a ship is a third power function of speed. This means that a speed reduction of 10% translates into engine power reduction of 27%. As it takes longer to sail a given distance at a lower speed, a 10% speed reduction results in a reduction of the energy required for a voyage by 19%. Largest vessels of all ship types emit less CO_2 per tonne-kilometre as long as the larger capacity is similarly utilized. This implies that increasing average vessel sizes can help to lower emissions – CO_2 emissions could be reduced by as much as 30% at a negative abatement cost by replacing the existing fleet with larger vessels. The smoother and shorter ship-port interface as well as onshore power supply was described in part 3 of the article.

Alternative fuels and energy: Alternative fuels and energy usually have lower or zero ship emissions when used for ship propulsion:

- *Hydrogen-Powered Ships:* Hydrogen, a clean and abundant energy carrier, is gaining traction as a fuel for propulsion systems in maritime transport. Hydrogen, when used as a fuel, emits only water vapour and heat, making it a zero-emission energy source. In the context of maritime transportation, hydrogen can be harnessed to power fuel cells that drive electric propulsion systems on ships.

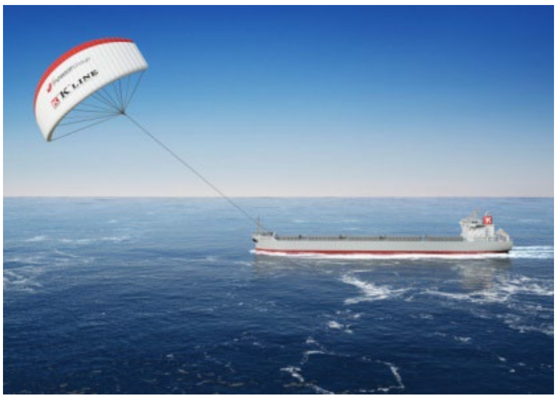
- *Ammonia as a marine fuel*: Ammonia, a compound composed of nitrogen and hydrogen, has gained attention as a clean and efficient alternative fuel for maritime propulsion. When burned, ammonia produces only nitrogen and water vapor, emitting no carbon dioxide or sulphur oxides. This makes it a zero-emission fuel, aligning with global efforts to combat climate change and reduce the environmental impact of shipping.

- *Bio fuels:* Bio fuels, derived from organic materials such as plant-based feedstocks, agricultural residues or waste, offer a renewable and cleaner alternative to traditional fossil fuels. Bio fuels for ships are typically produced through processes like biodiesel or bio ethanol production. They can be used as direct replacements or blended with conventional marine fuels to reduce the carbon footprint of vessel operations.

- *Electric ships:* These vessels, powered by electricity rather than traditional fossil fuels, are emerging as a promising solution to reduce emissions and mitigate the environmental impact of maritime transport. They utilize various electric propulsion systems, ranging from battery-electric to hybrid-electric setups.

- *Wind-assisted propulsion:* Wind-assisted ship's propulsion (WAPS) is an innovative, hi-tech and sustainable solution that can contribute to ships energy efficiency [7]. These technologies are not substituting the internal combustion ships engines, but definitely are limiting the negative impact of maritime transport to climate change by significantly reducing fuel consumption. Such technologies are Fletner rotors (using Magnus Effect), hard and soft sails, suction wings or "Ventifoils" (using Bernoulli Effect), kites [8]. (Fig. 4)

Fig.4 a) Fletner rotors b) Hard sails



c) Suction wing (Ventifoil) d) Kite

- *Hybrid ships:* In the quest for more sustainable and efficient maritime transportation, hybrid ships have emerged as a dynamic solution, blending traditional power sources with cutting-edge technologies. These vessels seamlessly integrate conventional engines with electric propulsion systems, harnessing the strengths of both to optimize efficiency and reduce environmental impact. Other more innovative hybrid ships combine alternative fuels with WASP, aiming to gain zero-emissions ships. The first vessel to combine the LNG fuel with wind assistance is a 210000 dwt bulk carrier and has been ordered by the Japanese company Kawasaki Kisen Kaisha ("K" Line) – in addition to LNG power to reduce GHG on the ship will be installed a "Seawing" automated kite for wind propulsion (Fig. 5).

Fig. 5 LNG and kite powered ship

A Norwegian project developed the world's first zero-emission cargo ship, powered by two large rotor sails in addition to a hydrogen-fuelled internal combustion engine (Fig. 6a); FutureShip has designed a zero-emission ferry for Scandlines (Fig. 6b), which have 8.3 MW fuel cells and 140 m3 hydrogen tanks, sufficient for a passage of 48 hours, as well as storage batteries with 2.4 MWh capacity. The ferry travels at 17 knots but can accelerate up to 18 knots by drawing additional power from the batteries. Flettner rotors harvest wind energy.

Fig. 6 a) **b)**

The example for combining the two of the most widely available sources of energy known to man, the wind and the sun, is the "Solar Sailor" ferry (Fig. 7), operating in Sydney Harbor, carrying 100 passengers.

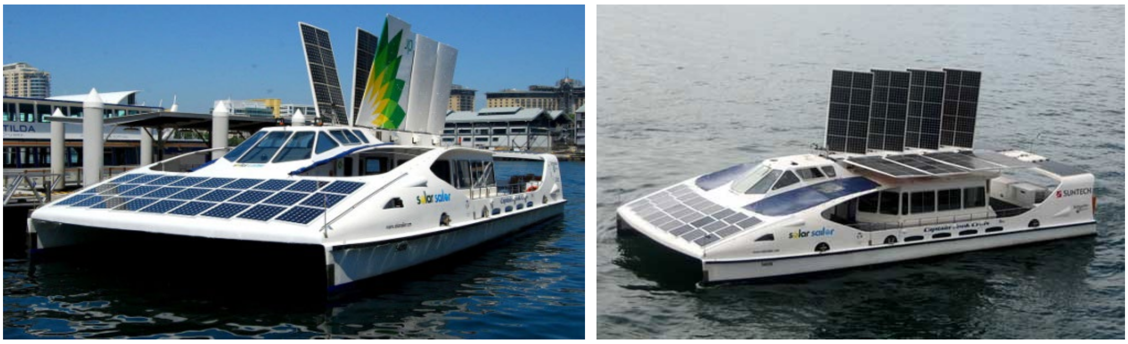


Fig. 7 Ferry "Solar Sailor"

"Energy Observer" is the name of a research vessel using only renewable energy, fuelled by only solar, wind and hydrogen (Fig. 8). The ship is self-sufficient in energy, with zero emissions, zero fine particles, zero noise, on a mission to prove that a future where ships sail the ocean without burning fossil fuels is a viable possibility. For collecting solar energy she has 141 square metre of solar panels. Wind is utilized by a revolutionary OceanWings rigid sail system that optimizes the energy input of the wind (by up to 42%) and the ship's motor acts as an electricity generating turbine when she is under wind propulsion.

Fig. 8 Sailing with a) hard sails b) VAWT

4. Conclusions

While significant progress is being made in decarbonising maritime transport, several challenges remain. The high upfront costs of adopting new technologies, the lack of infrastructure for alternative fuels and the need for global regulatory alignment are among the hurdles facing the industry.

The future of decarbonising maritime transport lies in continued collaboration between governments, industry stakeholders and the research and development sector. As technology advances and regulatory frameworks evolve, the maritime industry has the potential to navigate towards a more sustainable and environmentally friendly future ensuring that the vital global trade network is both efficient and ecologically responsible.

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