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REDUCING POLLUTING EMISSIONS BY IMPROVING NAUTICAL FEATURES OF EXISTING COMMERCIAL SHIPS

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Abstract: *The paper treats a range of solutions for retrofitting commercial vessels to increase energy efficiency as a imposed necessity by new pollution regulations for the marine environment. Based on research made in this study area by major international shipping companies, the paper summarizes the main results obtained through various methods in order to improve nautical qualities of the ship.*
Key words: *retrofit, bulbous bow, new propellers, air-lubrication system*

1. Introduction

In terms of energy, the most efficient way of transporting goods over long distances is by sea. However shipping, although provides 90% of total goods transport, has a negative impact on our planet through the pollution generated.

More exactly, 2% of total anthropogenic CO_2 emissions caused by humans and 5-10% of the total SO_2 emissions worldwide are made by shipping [8].

Also, research based on satellite observations suggests that shipping produce between 15 and 30% of global emissions of NOx (figure 1).

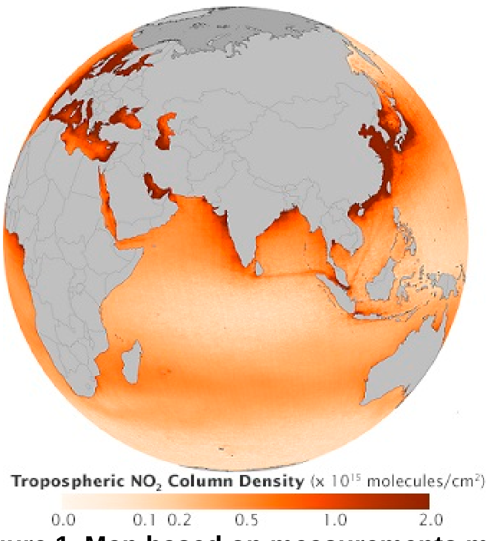

Figure 1. Map based on measurements made by the Ozone Monitoring Instrument (OMI) between 2005 and 2012 [8]

Large shipping companies have still managed to orient development strategies and profit growth in order to reduce environmental impact by reducing emissions. These results were possible through several implemented strategies, such as: optimizing the operating procedures of vessels, monitoring the performance, building of new ships that follow new standards of energy efficiency, investments in the use of alternative sources of energy and modernization of existing fleet by installing new systems and by constructive modifications made on ship's hull to reduce drag or increase transport capacity. Reduction by 40% of CO_2 emissions per container have been recorded from 2007 to 2014, according to the graphics delivered by Maersk shipping company (figure 2).

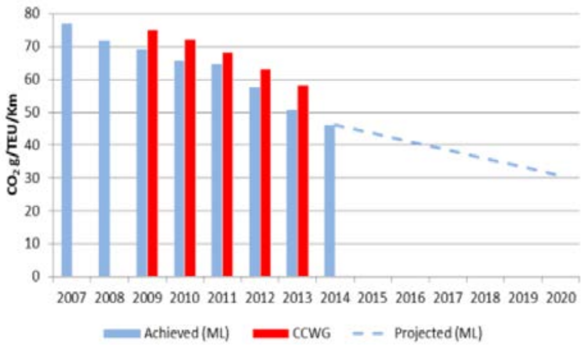

Figure 2. Average CO2 emissions per TEU per km [4, p.6]

According to IMO forecasts, CO_2 emissions from shipping worldwide could double by 2050 and even be multiplied three times. In order to counter these developments, IMO has introduced regulations (named Tier regulations) to gradually reduce emissions caused by ships including nitrogen oxides (NOx), sulfur oxides (SOx) and carbon dioxide (CO_2) – figure 3[4].

The impact of sulfur emission requirements introduced in 2015 on global trade flows were negligible, the result of increasing total costs for a container ship on Asia - North Europe trade lane varying between 1.2% and 3.6%. However, the total increase in container shipping costs due to the 2015 requirements amounts to 500 millionUSD [1, p.9].

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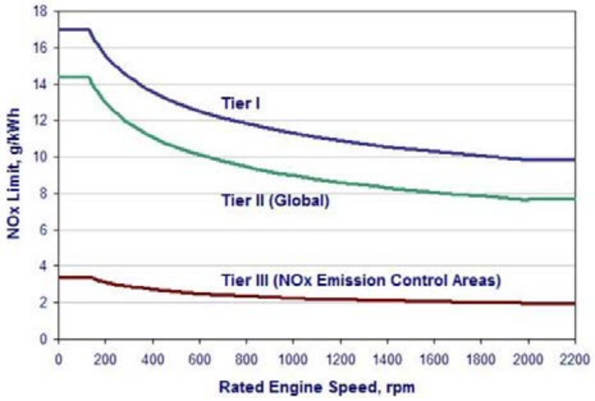

Figure 3. Tier regulations for NOx emissions (Tier I – from 2000, Tier II – from 2011, Tier III – from 2016) [7, p.5]

The sulphur upper limit of 0.50% planned for 2020 will have a more significant effect on transport costs and estimates show that they could increase between 20% and 85%, depending on the assumptions regarding the speed, fuel price and size of the vessel [1, p.9].

Also, in order to control the marine greenhouse gas emissions IMO has developed a number of technical and operational measures that include [5, p.1]:Energy Efficiency Design Index (EEDI), Energy Efficiency Operational Index (EEOI) and Ship Energy Efficiency Management Plan (SEEMP).

The SEEMP is a management tool offered by Lloyd’s Register helping shipownersto manage the energy efficiency of their ships. The IMO introduced the SEEMP as a mandatory tool under MARPOL Annex VI, from January 1, 2013 [5, p.1].

A study made by HSH Nordbank, at the end of 2013, shows the responses at the question "What measures are you taking with the aim of meeting the new IMO emission requirements and the associated sharp rise in fuel costs (multiple choices allowed)?" from around 60 shipping companies according to Figure 4[6].

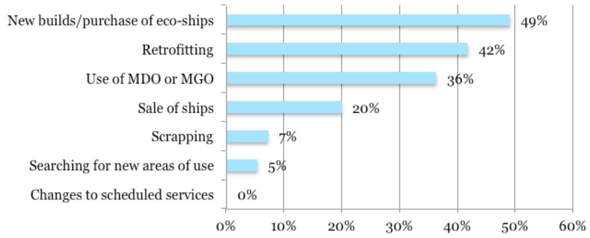

Figure 4. Results of the HSH Nordbank study, answering: “What measures are you taking with the aim of meeting the new IMO emission requirements and the associated sharp rise in fuel costs (multiple choices allowed)?” [6, p.10]

According to results presented in Figure 5, a large percentage of companies are planning to retrofit its fleet, and the present paper will further cover this subject.

2. Radical Retrofit of ships

Because of low freight rates and high marine fuel costs, shipping companies are searching ways to improve ship efficiency.

The current tendency towards new large vessels (up to 20,000 TEU) will put additional pressure on the fleet in service [2, p.22].

Retrofitting of ship can be done either by installing or replacing systems on board, either by constructive modifications. When we refer to a radical retrofit then we must take into account both methods. According to strategies already adopted by shipping companies reducing fuel consumption and thus pollutant emissions, this goal can be achieved by simply de-rating of main engine and operating at a low speed (the average cruising speed was lowered to 16 or 18 knots) or by:

- improving propeller performance;
- retrofitting the bulb shape for optimal performance at low speed;
- reducing friction between the hull and water through modern technology;

2.1 Propeller optimization

In many retrofitting operations, in addition of changing bow, the ships’ propellers will be replaced. “When considering the propulsion layout, there are no significant differences between a new vessel with contemporary specifications and a retrofit candidate” [2, p.22].

The Hapag-Lloyd shipping company changed its ships’ propellers with slightly larger ones (from 9,00m to 9,20m) but about 11 tonnes ligher. Also the number of blades attached to the hub was raised from 4 to 5 (figures below).

Experts at Hapag-Lloyd expect the optimisation measures to lead to fuel savings of roughly 10% for a 13,200-TEU vessel [2, p.21].

The main task regarding ship propellers design is to improve overall efficiency by identifying the optimum propeller geometry for each vessel.

Highly developed modern softwares are capable nowadays of giving detailed insight of the fluid dynamics around the propeller (figures 7 and 8) [2, p.22].

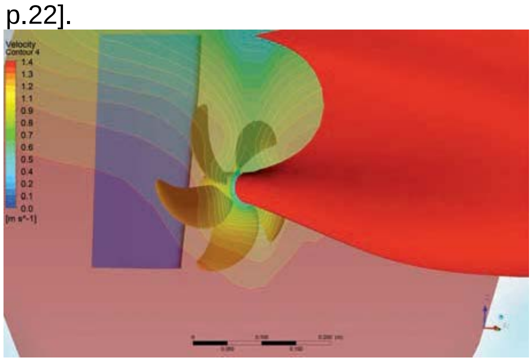

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Figure 8. Computational fluid dynamics tools calculate the flow around a propulsion device [2, p.23]

2.2 Addopting a new bulbous bow

The research done by the company Hamburg-based shipping company Hapag-Lloyd shows that the bulbous bows (figure 6) "displace water in a manner that minimises or even completely eliminates a bow wave, which noted that the lower the water resistance on the hull, the less fuel a ship needs to travel at the same speed" [2, p.21].

Other retrofit solutions already adopted in order to optimize the propeller were:

- install propeller boss cap fin (PBCF) - (figure 9 b. and 10);
- install a Mevis duct (figure 9.c);
- both installing a PBCF and Mewis duct (figure 9.d).

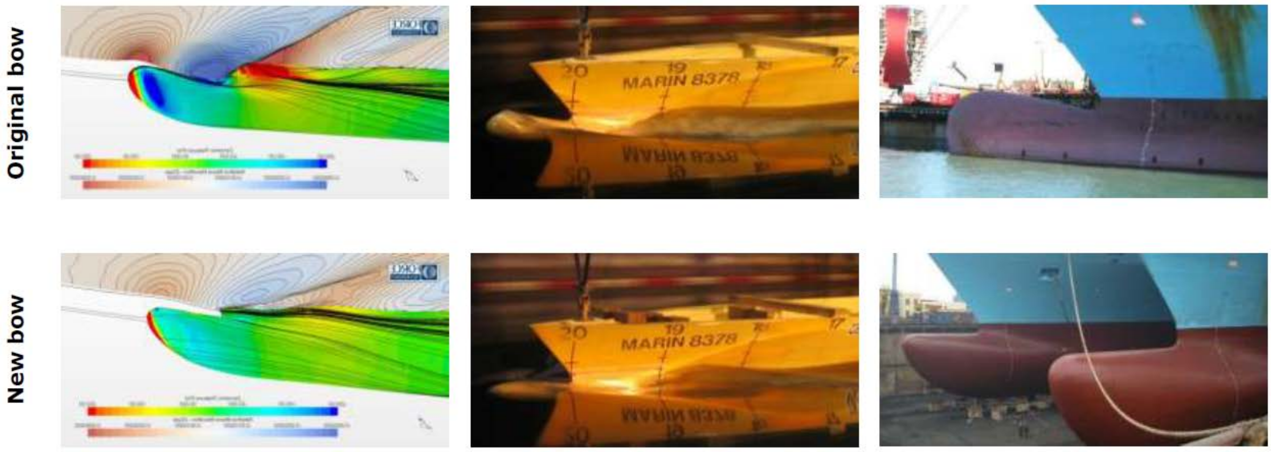

Figure 6. New bulbous bow design [4, p.18]

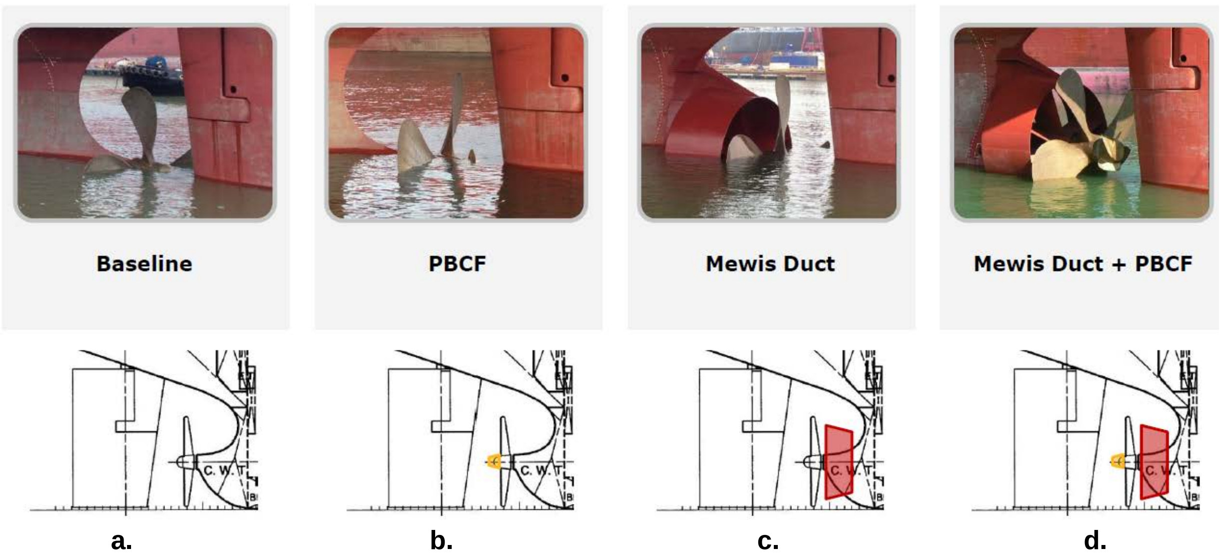

Figure 9. Propeller optimization solutions [3, p.13]

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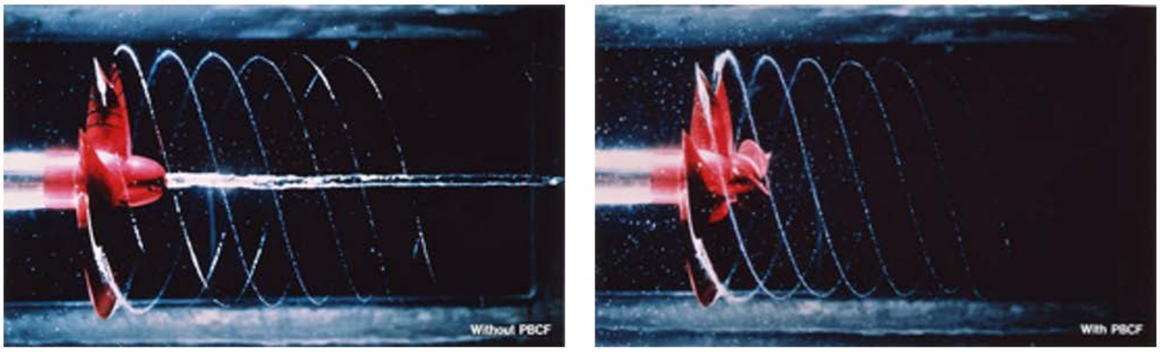

a. b.

Figure 10. Results before (a) and after (b) propeller boss cap fin (PBCF) installation [9]

2.3 Reducing friction

A recent innovation on reducing friction between water and hull, thus cutting fuel consumption and associated emissions, is already applied on ships in service, being based on an air-lubrication system that produce a rigid "carpet" of microbubbles (figure 11).

Figure 11. Close-up of microbubbles [2, p.57]

The system was developed by Silverstream® System, a London-based company previously known as DK Group and their first commercial installation was on a Norwegian Cruise Line vessel ("Norwegian Bliss" – scheduled for delivery in spring 2017). "Silverstream Technologies has pioneered, and invested significantly in the development of air lubrication technology for over ten years now" [2, p.56].

The research was made on a 40.000 dwt tanker - "MT Amaliengborg" - and the results showed mean average net power savings of 4.3% in ballast conditions and respectively 3.8% in laden conditions.

"The Silverstream® System works on all vessels. In particular, it is applicable on fullbodied or flat-bottomed vessels over 150m in length. However, the system will also work very well on any vessel operating at high speeds and consuming large quantities of fuel oil, such as container ships or cruise liners The Silverstream® System is applicable on both newbuild and existing vessels, and can be retrofitted in 14 days" [2, p.57].

Conclusions

As the results already proved it, retrofitting the ship can be made with positive results in order to reduce fuel consumption and associated emissions. Many shipping companies have already implemented strategies in retrofitting its fleet, and are looking forward for new solutions to further meet the increasingly resctrictive IMO regulations, while maintaining desired turnover.

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