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Towards improving energy efficiency regulations of bulk carriers

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ABSTRACT

The introduction of the Energy Efficiency Design Index (EEDI) by the International Maritime Organization (IMO) caused an upsurge in activities for increasing the energy efficiency and reducing CO_2 emissions of new vessel designs. However, application of the EEDI is not expected to further advance future design improvements partly owing to the fact the majority of the new buildings already comply with EEDI requirements and particularly since EEDI only considers a single operating point. In addition, the EEDI does not effectively assess a realistic improvement of measures for increasing the ship operating energy efficiency as they can be quite effective in the considered operating point for the EEDI but their performance greatly varies in the real operating conditions. In this study, a more realistic definition of the EEDI is proposed, which is based on a number of representative vessel operating points. The application of the proposed approach for the case of bulk carriers is investigated and the results are discussed in order to reveal its advantages against the currently used approach. The proposed approach can be employed by IMO for improving the energy efficiency regulatory framework.

1. Introduction

The International Maritime Organization (IMO) has adopted new regulation on energy efficiency for ships (MEPC, 2011a) according to which, the International Energy Efficiency (IEE) Certificate should be issued for every ship. In order to obtain it, the ship has to comply with the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) requirements. The EEDI is a technical measure and requires that for every new ship of 400 GT and above, the Attained EEDI has to be calculated (MEPC, 2014) and not exceed the Required EEDI, which is defined by the EEDI reference line value and an appropriate reduction factor. The EEDI reference line value is a function of the ship type and its capacity (MEPC, 2013). The reduction factor is defined in a set of time intervals, roughly 10% reduction every 5 years (MEPC, 2011a,b). The EEDI reference line values should represent the average ship energy efficiency of current fleet, whilst the reduction factor should represent a requirement for new ships to improve their energy efficiency compared to the status of the current fleet. SEEMP is an operational measure to increase ship energy efficiency and is also compulsory to every ship of 400 GT and above.

The introduction of the EEDI and the SEEMP has the noteworthy aim, as recognized in the preamble of MEPC (2011a), to improve the energy efficiency for ships through a set of technical performance standards, which would result in reduction of emissions of any substances that originate from fuel and its combustion process, including those already controlled by Annex VI. These policies as well as policies aiming to improve the implementation of energy efficiency in shipping need to be carefully considered in order to ensure energy efficiency improvements whilst avoiding unnecessary burden on the shipping industry with ineffective regulation through technical, operational or market-based measures, as pointed out by Rehmatulla and Smith (2015). This is particularly pronounced in the definition of the reduction factor, as thoroughly investigated by Ancic and Sestan (2015). They concluded that the reduction factor seems to be rigidly set and is likely to be either too lenient or too strict for the new ships, and proposed an alternative requirement that would allow for a feedback from the market and that is more likely to stimulate the improvements in energy efficiency and the CO_2 emission reduction. Feedback from the market is particularly important as many parameters could influence the energy efficiency of new ships. For example, sailing at lower speeds proved to have a significant impact on the fuel consumption and directly on the CO_2 emission (Lindstad et al., 2011), so it seems reasonable to include ship speed in the

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Required EEDI definition. Similar remarks were given by Simic (2014) who analysed the energy efficiency of inland waterway ships and identified a strong influence of the ship speed on the EEDI value. In addition, some externalities could indirectly lead to the GHG emission reduction. For example, Lindstad et al. (2013) assessed the impact of the Panama Canal expansion on the new bulk carriers design and concluded that the fuel consumption saving by up to 15–25% could be possible at negative abatement cost. The current approach set by the EEDI is insensitive to such occurrences.

Special consideration should be given to innovative energy efficient technologies. The abatement cost and cost effectiveness of these technologies are analysed in detail by MEPC (2011b). It is concluded that these technologies have a potential to significantly reduce the CO_2 emission from ships, but there are many barriers in their implementation, even though many of them seem to be cost effective. It has to be pointed out that these technologies have the potential to further reduce not only GHG emission, but also other harmful substances emission. Dedes et al. (2012) investigated possibilities of implementing energy storage devices on-board bulk carriers. They found that a Power Take-Off/Power Take-In (PTO/PTI) system with batteries could save fuel and reduce harmful substances emissions, especially for Panamax and Handysize bulk carriers. It is even proved to be economically feasible, although for a relatively high fuel price (520 USD/tonne). Mäkiharju et al. (2012) analysed the cost effectiveness of an air lubrication system, whilst Butterworth et al. (2015) performed the experimental analysis of implementing air cavity concept on a container ship model. Both technologies lead to the drag reduction, even though their influence is less pronounced at higher speeds. The implementation of a twisted rudder on a container ship provided greater performance driven by increased hull efficiency due to lesser thrust deduction fraction and more effective wake fraction as well as the decreased propeller rotating speed (Kim et al., 2014). Other technologies, referred as Carbon dioxide Reduction Technologies (CRT) have also been considered by Calleya et al. (2015) and found to have potential to reduce the CO_2 emissions.

Not only alternative technologies, but also alternative fuels and renewable power sources could lead to the reduction of the CO_2 emissions. Bengston et al. (2012) performed an analysis of two pathways: first leading from heavy fuel oil (HFO) to marine diesel oil (MDO) and then to biodiesel, and the other leading from HFO to liquefied natural gas (LNG) and then to biogas. Both pathways lead to the reduction of the CO_2 emission, but a detailed life cycle analysis of a ro-ro passenger ship engaged in short-sea shipping revealed that the use of biofuels can increase the eutrophication potential (EP). This emphasizes the importance of a detailed analysis in order to accurately estimate the environmental impact of a ship, which is especially important for ships employed in short-sea shipping. The pollution originated from these ships is especially pernicious for public health, since it occurs mostly in and near ports and highly populated areas, as highlighted by Runko Luttenberger et al. (2013). In that sense, the use of LNG offers significant advantages as it reduces the emission of local pollutants substantially below all current and proposed emissions standards for marine diesel engines and does not increase NO_X emissions (Livanos et al., 2014; Thomson et al., 2015). A study on the implementation of renewable power sources on ro-ro passenger vessels revealed that they have significant impact on the CO_2 emissions, but rather negligible impact on the EEDI (Ancic et al., 2014).

Apart from technical and operational measures, there has been a discussion about market-based measures (MBM). A feasibility study and impact assessment of introducing MBMs on a global scale has been performed by MEPC (2010). A similar study by Miola et al. (2011) was focused on the EU region. Both studies concluded that the MBMs have a significant abatement potential, even though there are also significant barriers and challenges, which are more pronounced in cases they are implemented on a regional basis.

Ekanem Attah and Bucknall (2015) investigated the impact of the EEDI on LNG carriers and concluded that the current EEDI reference baseline is insufficient to stimulate improvements in their energy efficiency, as the recently proposed ship designs with dual fuel (DF) engines already satisfy the EEDI regulations requirements. However, when considering the methane slip, they concluded that the GHG emissions could potentially increase by up to 115%. Hence, a modification of the EEDI formulation is required, which was partly recognized by MEPC (MEPC, 2011a,b).

With the introduction of the EEDI requirements, the review of the status of technological developments was also planned aiming to assess the influence of new technologies on the EEDI. If proven necessary, the EEDI regulation requirements including the time periods, the EEDI reference line parameters for relevant ship types and the reduction rates will be amended by the MEPC. The review was planned in two stages, the first at the beginning of phase 1 (1 January 2015), whereas the second at the midpoint of phase 2 (1 July 2022). The results of the first review process were presented at a recent MEPC session (MEPC, 2016). The majority of bulk carriers (57%) built during Phase 0 already meet phase 2 requirements. However, bulk carriers smaller than 40,000 DWT and larger than 75,000 DWT do not on average meet phase 2 requirements. This report does not provide explanation on why some ships meet the requirements whereas others do not. Although suggestions to increase the phase 2 reduction rate to 25% for bulk carriers were discussed, this was not implemented, partly due to political pressure reasons, and partly due to the lack of the sufficient data.

The aim of this work is to propose an innovative approach in the EEDI definition for bulk carriers, with particular objective to provide a fair basis for the comparison of the energy efficiency of different bulk carriers and encourage the application of innovative energy efficient technologies.

There are three main challenges in the EEDI definition: the first one is to evaluate the ship energy efficiency, the second is to compare different ships in order to rate their energy efficiency (performance) and the third is to set the benchmark that every new ship has to comply with.

The first challenge is addressed in Section 2.1 through the analysis of the current approach for assessing the ship energy efficiency performance by using the Attained EEDI. Based on the conclusions from this analysis, a new methodology for the Attained EEDI calculation is proposed that ensures a corrected and more realistic assessment of the ship energy efficiency.

The second challenge is addressed in Section 2.2 through analysing the current approach used to define the Required EEDI. This approach also tackles with special emphasis the consequences of defining the EEDI reference line value solely by using the ship capacity. A new approach that defines the EEDI reference surface based on the ship capacity and design speed is proposed. The methodology that employs the coefficient of determination used to determine how well the proposed function describes a defined set of data is also outlined.

The third challenge requires the analysis of the EEDI reduction factor definition. This was addressed in detail in Ancic and Sestan (2015) and thus, it will not be discussed herein.

The results of the proposed methodology along with their comparison with the current approach are presented in section 3. A thorough discussion follows in section 4 pointing out the pros and cons of the two approaches. Finally, the concluding remarks along with guidelines for further research and policy implications are reported.

2. Methods

2.1. Attained EEDI calculation

According to MEPC (2014), the attained EEDI is calculated according to the following equation: