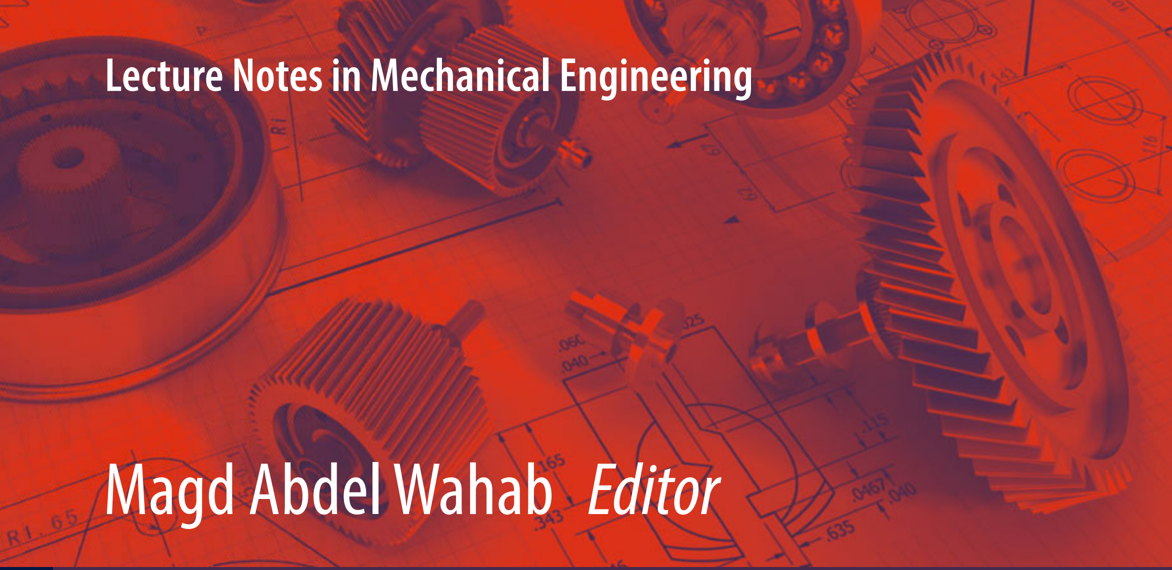

Lecture Notes in Mechanical Engineering

Magd Abdel Wahab *Editor*

Proceedings of the 5th International Conference on Numerical Modelling in Engineering

Volume 2: Numerical Modelling in Mechanical and Materials Engineering, NME 2022, 23–24 August, Ghent University, Belgium

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Editor
Magd Abdel Wahab
Faculty of Engineering and Architecture
Ghent University
Ghent, Belgium

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Preface

This volume contains the Proceedings of the 5th International Conference on Numerical Modelling in Engineering—Volume 2: Numerical Modelling in Mechanical and Materials Engineering. Numerical Modelling in Engineering NME 2022 is the 5th NME conference and was held online via MS Teams, during the period 23–24 August 2022. Previous NME conferences were celebrated in Ghent, Belgium (2018), Beijing, China (2019), and Ghent, Belgium (2020–2021).

The overall objective of the conference is to bring together international scientists and engineers in academia and industry in fields related to advanced numerical techniques, such as FEM, BEM, and IGA, and their applications to a wide range of engineering disciplines. The conference covers industrial engineering applications of numerical simulations to Civil Engineering, Aerospace Engineering, Materials Engineering, Mechanical Engineering, Biomedical Engineering, etc. The presentations of NME 2022 are divided into two main sessions, namely (1) Civil Engineering and (2) Mechanical and Materials Engineering. This volume is concerned with the applications of Mechanical and Materials Engineering.

The organising committee is grateful to keynote speaker, Prof. Timon Rabczuk, Bauhaus Universität Weimar, Chair of Computational Mechanics, Germany, for his very interesting keynote speech entitled 'Machine Learning-based solutions of Partial Differential Equations'.

Special thanks go to members of the Scientific Committee of NME 2022 for reviewing the articles published in this volume and for judging their scientific merits. Based on the comments of reviewers and the scientific merits of the submitted manuscripts, the articles were accepted for publication in the conference proceedings and for presentation at the conference venue. The accepted papers are of very high scientific quality and contribute to the advancement of knowledge in all research topics relevant to the NME conference.

Finally, the organising committee would like to thank all the authors, who have contributed to this volume, and those who have presented their research work at the conference in MS Teams.

Ghent, Belgium

Prof. Magd Abdel Wahab
Chairman of NME 2022

Contents

Chapter 1
Optimization of Ship Energy Efficiency Considering Navigational Environment and Safety

Min Hyok Jon and Chung Il Yu

Abstract The attention to ship energy efficiency and CO_2 emission is significantly increasing. Both are related to fuel consumption and can be assessed by ship energy efficiency operational indicator (EEOI). The aim of this research is to develop a formula for estimation of operational carbon intensity indicator (CII) and an optimal model of ship's route and operational speed to minimize the EEOI considering navigational environment and ship's safety. The formula for CII is given assuming to be a function of a ship's main particular, i.e. block coefficient, and ratio of operating speed to design speed of the ship. For navigational environment, wave and wind, which influence the ship's performance especially including resistance and seakeeping, are considered. For ship's safety, motion sickness incidence (MSI) which is one of seakeeping indices is considered. Particle Swarm Optimization (PSO) algorithm is adopted to solve the model. The proposed method is illustrated with a numerical example, comparing with full-scale data. The comparing results show the proposed method can effectively reduce the CO_2 emission and improve the ship energy efficiency.

Keywords Energy efficiency operational indicator (EEOI) · Carbon intensity indicator (CII) · Navigational environment · Marine safety · Seakeeping

1.1 Introduction

The excessive greenhouse gas (GHG) emission from shipping, which results in the speed-up in global warming, caused the pressing concern around the world. Anderson and Bows [1] showed that shipping should reduce its CO_2 emissions by more than 80% by 2050 compared to 2010 levels for achieving the 2 °C climate goal. International Maritime Organization (IMO) established the Initial IMO Strategy on

M. H. Jon (✉) · Chung Il Yu
Faculty of Naval Architecture and Ocean Engineering, Kim Chaek University of Technology, Pyongyang, Democratic People's Republic of Korea
e-mail: jmh82117@star-co.net.kp

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Reduction of GHG Emissions from Ships in 2018. In accordance with the strategy, CO_2 emissions per transport work as an average across international shipping are to be reduced by at least 40% by 2030, pursuing towards 70% by 2050, compared to 2008 [2].

Under the circumstances, useful indices such as Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ship Index (EEXI) and Energy Efficiency Operational Indicator (EEOI) were introduced to indicate CO_2 emissions of ships. All of them reflects the effective energy usage on ships, especially EEOI being an operational carbon intensity indicator related to CO_2 emission from ship operation activities. That is, energy efficiency management and improvement are fundamental issues to account for fuel costs savings and CO_2 emissions reduction.

In order to reduce the GHG emission from ships and improve the energy efficiency of ships, many researches were carried out proposing some technical and operational measures during a few decades [3–5].

Regarding technical measures, some researches focused on improvement of ship's performance, which is closely related to many design parameters of ships' hull and propeller. From the point of view of hull form optimization, Hou [6] proposed a uncertainty ship hull design method to achieve a minimum EEOI with a focus on the influence of speed perturbation. Hou et al. [7] introduced a mixed aleatory/epistemic uncertainty analysis and optimization method based on probability and evidence theory and demonstrated excellent adaptability and reliability in minimum EEDI ship hull lines' designs. Niese et al. [8] proposed a novel ship design evaluation framework rooted in Markov decision analysis and derived metrics, examining scenarios subject to carbon emission regulations and uncertainty surrounding enforcement of the EEDI.

Other technologies including energy-saving, use of renewable energy (e.g. wind engine, solar panels) and use of alternative fuels (e.g. LNG, hydrogen, ammonia) are also developed and costs and GHG emission reduction potential of the technologies were discussed [9–13]. For instance, Bøckmann et al. [14] performed route simulations on a general cargo ship equipped with retractable bow-mounted foils for resistance reduction and motion damping in waves, showing the result of the average fuel saving, while Zhao et al. [15] investigated propulsion system optimization design.

Some researchers focused on seakeeping to optimize the ship's performance considering ship's safety and human comfort [16, 17]. Scamardella and Piscopo [18] presented a method to achieve the best seakeeping performances for passenger vessels by only varying several hull form parameters.

Regarding operational measures, there are researches on navigation speed and route optimization for in-service ships in order to improve energy efficiency [19–25]. Wang et al. [26] proposed a dynamic optimization method adopting the model predictive control (MPC) strategy to optimize ship energy efficiency accounting for time-varying environmental factors such as weather. Hou et al. [27] introduced uncertainty analysis and optimization theory when considering ice loads and other important stochastic factors, taking the main engine speed of ships as the design variable to solve the minimum EEOI optimization model. Tran [28] addressed a numerical method to decrease the fuel consumption of diesel engine and restrict the exhaust gases emission from the ship operational activities focusing on EEOI. Aiming at optimal path and speed profile for a ship voyage on the basis of weather forecast maps, ship motions and human comfort was also taken into account to minimize fuel consumption [29]. Wang et al. [30] established ship energy efficiency real-time optimization model to determine the best engine speed under different working conditions which were predicted by the method of wavelet neural network in short distance ahead of the ship.

Different studies were conducted regarding the vessel's power management. Kanellos [31] pointed out a three stages method based on the operational cost minimization to find out an optimal power management solution under the limitation of the greenhouse gas emissions without changing the technical and operational constraints. Baldi et al. [32] proposed a method to model the power plant of an isolated system with mechanical, electric and thermal power demands and to optimize the load allocation of the different components. Anconaa et al. [33] proposed an optimization framework based on genetic algorithms in order to maximize the energy efficiency and minimize both the fuel consumption and the thermal energy dissipation, by optimizing the load allocation of the ship energy systems.

There are various papers about shipping emissions where some tried to develop emission factors and estimate current and future emissions and some focused on single emission type and its impacts on human health and environment [34–36]. Shipping emission estimations are realized by using two basic methods: Top-down and bottom-up approaches. Bilgili and Celebi [37] developed some equations in order to estimate the potential airborne emissions of a bulk carrier based on two main characteristics (DWT and CB) during pre-design, by applying a regression analysis to the three-year operation data of nine bulk carriers. In the calculation of the EEDI for ships, the ship speed/power curves is of great significance. Tu et al. [38] suggested a more accurate estimation method of speed/power curves for container ships based on investigation of the influence of three important factors (i.e. the main engine power, the deadweight and the reference speed) on the EEDI value.

In light of the above, there is lack of researches on calculation of the operational carbon intensity indictor for individual ships and on optimization of ship energy efficiency.

This paper aims at developing a formula in order to estimate the operational carbon intensity ahead of navigation and a method to optimize the ship energy efficiency during navigation considering navigational environment and safety.

The rest of paper is organized as follows. In Sect. 1.2, a simple formula to estimate CII is developed and a method is proposed to optimize the ship energy efficiency during navigation considering navigational environment and safety. Section 1.3 shows the case study results to demonstrate the feasibility and efficiency of the proposed formula and method. Finally, Sect. 1.4 contains conclusions and potential contributions of the paper.