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Review

Emission control based energy efficiency measures in ship operations

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ABSTRACT

This study presents an overview of emission control based energy efficiency measures in the ship operation phase with respect to possible energy conservation situations. The first part of the study discusses energy efficiency measures under the respective emission control regulations in the shipping industry. That illustrates the emission control concepts of Emission Control Areas (ECAs), CO_2 reductions, SOx limits, and NOx Technical Codes and the energy efficiency concepts of Energy Efficiency Design Index (EEDI), Energy Efficiency Operational Indicator (EEOI), and Ship Energy Efficiency Management Plan (SEEMP). The second part consists of identifying the possible situations of energy conservation at the ship operation phase with respect to the proposed energy flow path. Initial data analyses of performance and navigation parameters are for a selected vessel presented to support the above situations along the energy flow path. High power consumption regions identified and potential energy conservation situations with respect to the EEOI presented are an important part of the SEEMP. Finally, under these results the possibilities of using appropriate navigation strategies (i.e. voyage planning, and draft and trim optimization) especially in the designated ECAs to reduce exhaust emissions (i.e. CO_2, SOx and NOx) are also discussed.

Contents

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1. Introduction

The shipping industry is associated with approximately 90% of the world trade [1]. Due to the present economic downturn, the current shipping fleets should satisfy this global trade demand as a cost effective industry even under fuel price variations [2]. In addition, the International Maritime Organization (IMO) and other respective maritime authorities have introduced various emission control regulations in the recent years, where the sustainability of the shipping industry is further challenged. A major portion of the ship operating cost relates to its fuel consumption and can approximately be 35%–70% of the overall vessel operating cost [3]. Therefore, an appropriate fuel consumption reduction can reduce a significant portion of the operating cost and that eventually improves energy efficiency of the vessel and reduces the respective marine pollution.

IMO established the Marine Environmental Protection Committee (MEPC) in 1973 to address these marine pollution related issues due to the shipping industry. Similarly, the International Convention for the Prevention of Pollution from Ship (MARPOL) was in 1973 adopted by IMO with the same purpose. The MARPOL convention addresses several marine pollution issues due to the shipping industry i.e. marine pollution due to oil spill, noxious liquid substances and other harmful substances transporting, sewage, garbage, and ship air pollution. Therefore, that influences on controlling shipping related marine pollution, significantly and covers 99% of the world merchant tonnage [4,5].

MARPOL Annex VI was in 1997 introduced to prevent air pollution due to the shipping industry and that limits ships exhaust gas emissions (i.e. sulphur oxides (SOx) and nitrous oxides (NOx)) and other ozone depleting substances. A new chapter was adopted in MARPOL Annex VI in 2011 to prevent greenhouse gas (GHG) emissions (i.e. carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O), and ozone (O_3)) [6]. Therefore, these steps enforce to reduce marine pollution due to the shipping industry and improve ship energy efficiency by adopting technology advancements for both existing and future vessels.

The international shipping industry excluded in the Montreal Protocol was included under the Kyoto Protocol [7] so that IMO handles the responsibility for bunker emissions [8]. The Kyoto protocol that consists of a trading scheme for emissions (i.e. the carbon market) and includes domestic shipping emissions, is among the respective member countries implemented to reduce GHG emissions. Therefore, a joint development and implementation mechanism is under this step initiated that can be a realistic emission control platform for both developing and industrial countries [9].

The main contributor in anthropogenic GHG emissions is CO_2. A majority of energy efficiency measures initiated in shipping are to reduce CO_2 emissions [10]. The transportation sector contributed 23% of the world CO_2 emissions in 2009 [11] and the fuel demand in the same sector will grow approximately 40% from the current condition by 2035 [12]. Therefore, various emission control initiatives in other transport sectors are also proposed to reduce CO_2 emissions by improving fuel efficiency in the recent years Hickman and Banister [13], Chen and Cheng [14], Ferreira [15], Morris et al. [16] and ATAG [17]. CO_2 emissions are categorized as trading commodities by the emission control community under "the carbon market" in such situations. If the carbon market is properly managed "the carbon price" can play an important role by reducing fuel emissions in these transportation sectors.

Several mandatory regulations to reduce CO_2 emissions are from the shipping industry introduced under MARPOL Annex VI. That consist of two important factors to improve energy efficiency in shipping: Energy Efficiency Design Index (EEDI) (i.e. for new ships) and Ship Energy Efficiency Management Plan (SEEMP) (i.e. for all ships). The EEDI applies to all new ships over 400 gross tonnage and above, which may waive for new ships up to maximum 4 years by the respective ship administration [18]. However, each ship should accompany an International Energy Efficiency Certificate (IEEC) for normal inspections and audits as a part of the SEEMP in some situations. Furthermore, the Energy Efficiency Operational Indicator (EEOI) is introduced to measure and compare CO_2 emissions from the current shipping fleets as a voluntary condition under MARPOL Annex VI. One should note that a large number of such emission control regulations were on or after January 2013 enforced to develop low carbon shipping conditions [19,20].

Other contributors to air pollution due to the shipping industry are sulphur oxides (SOx) and nitrous oxides (NOx) that relate to bunker fuel types and engine operating conditions. The SOx emission limits restrict the sulfur content of the fuel and the NOx emission limits restricts the operating conditions (i.e. operating temperature) of marine diesel engines. Even though general SOx and NOx emission limits are introduced globally, tighter SOx and NOx emission limits are introduced in the designated Emission Control Areas (ECAs) (see Fig. 1). There is an expectation that IMO and other environmental authorities in the designated ECAs will further tighten these emission limits to restrict emission related pollution [21].

Hence, the main objective in this study is to present an overview of emission control based energy efficiency measures with respect to the possible situations of energy conservation in the ship operation phase. The important topics of emission control regulations and energy efficiency measures in shipping studied in combination is a novel approach. Further development of this approach can lead to appropriate ship navigation strategies especially in the designated ECAs, where tighter CO_2, SOx and NOx emission limits are enforced. In general, CO_2, NOx and SOx emissions relate to the vessel fuel consumption, therefore a considerable reduction in the respective fuel consumption on each voyage can improve vessel energy efficiency. This study also consists of identifying such possible situations of energy conservation with respect to the energy flow path in a vessel supporting those situations by initial data analysis with vessel performance and navigation parameters along several ship routes.

2. Emission control regulations

2.1. Emission control areas

IMO has adopted several guidelines (i.e. outside MARPOL) to preserve and protect Particularly Sensitive Sea Areas (PSSAs) with special ecological and socio-economic significance/scientific significances. These guidelines are adopted as a resolution of MARPOL for tighter emission control regulations (i.e. sulphur oxides (SOx), nitrous oxides (NOx) and particulate matter) in the designated