UNDERSTANDING APPROACHES TO VESSEL ENERGY EFFICIENCY SYSTEMS

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ABSTRACT

Concerns and policies regarding emissions in the shipping sector have been discussed a great deal over the past two decades, to improve the pace of energy efficiency management. The increased effort in tackling this issue resulted in standards and guideline for improving energy efficiency on board vessels. Documents such as the Ship Energy Efficiency Management Plan (SEEMP), Energy Efficiency Operation Index (EEOI) and Energy Efficiency Design Index (EEDI) are designed to help users to achieve the goals of reducing CO_2 emissions globally. Some research and products are readily available in the market to help users improve the energy efficiencies within the safety boundaries. A healthy competition between different products will help push forward the frontiers of achieving a cleaner shipping world. Despite achieving these global environmental goals, companies developing energy efficiency systems may financially benefit from selling different energy efficiency systems while individual ship owners can benefit from lower fuel consumption cost and overflow to a better usage of machinery leading to savings in maintenance costs. A clear breakdown and understanding of how different products and research can feed into this common goal will enable end users to customise the best solution to their individual needs. This research will allow users to understand the impact of various operational practices, and provide a clearer outline of what technology and service are available that could help with the current situation. A clear overview of this approach will also contribute to identify the gaps where additional research and efforts can be focus on.

Keywords: energy efficiency system, vessel energy systems

1. INTRODUCTION

The world energy consumption can be categorised into usage by three main sectors, namely, the building sector, the industry sector and the transport sector, with a consumption of 21%, 54% and 25% respectively (IEA, 2016). For each sectors, policy makers have started to increase awareness by setting boundaries and goals to achieve. The forecast of energy saving breakdown in 2040 can be seen as efficiency in end-users, efficiency in energy supply, fuel and technology switching, reduced energy service demand with respective proportion of 62%, 7%, 11% and 21% (WEM, 2012). There is also a large window of unrealised energy efficiency potential under the new policies scenario, where industry, transport, power generation and buildings have approximately 58%, 62%, 79%, 82% room of improvement. Strictly regulated policies regarding emissions within the shipping industry such as the need to comply with the Energy Efficiency Operation Index (EEOI) (IMO, 2009) and Ship Energy Efficiency Management Plan (SEEMP) (IMO, 2009) reflects on the increase in awareness to address global warming (IMO, 2009; IMO, 2015). One of the key goals of the European strategies on transportation introduced the White Paper on transport 2011 is to reduce at least 40% of shipping emissions (European Commission, 2011). The EU Commission also initiated a debate on the 2030 framework for climate and energy policies through the Green Paper 2013 (European Commission, 2013), which as a response fosters competitiveness in terms of energy efficient technologies and emphasis on intelligent networks (CEER, 2013).

The increased awareness and stringent regulations of shipping in changing climate contribute to the increasing market competition for reliable energy monitoring and management systems on-board vessels as well as providing a positive boost for research from both the industry and academic partners to enhance and improve the energy usage. This movement also addresses the challenge and movement of the market towards digitalisation (DNV GL, 2016). The Contribution of academic research to the industrial commercialisation is relevant in the marine industry, however, there is a time lag of the social rate of return from academic. Traditionally, academic research carried out in 1975-1985 takes about 7 years to see a significant impact in industrial innovation (Mansfield, 1998). From 1986-1994, the average time fell to 6 years. At present time (2017), academic research and industrial innovation go side by side to develop effective systems for the industry. With the tough competition in the industry, sales and market pitch are sometimes released whilst research is still on-going or before the research is fully mature.

Improvements are implemented on both new and older vessels. Introduction of new innovative designs may require a high level of retrofitting or only applicable to new design vessels. Some of the examples are such as the air lubrication technology that was first patented in the year 1929 by Mitsubishi Heavy Industry, a series of experiments (Mizokami, 2010) and computational fluid dynamic studies (Kawabuchi, 2011) have been conducted following this. The first application is carried out on a cruise vessel, Quantum of the Seas and Anthem of the Seas built by Meyer Werft, contributing to 20% efficiency gain (Mizokami, 2013). Despite changes made on new vessels that make huge contributions, much effort should focus on the current vessels to improve energy efficiency. Many monitoring platforms and products claim to address all these issues, but a clear understanding of chosen methodology and literature review is crucial to guarantee the system integrity.

There are many sources of information that can be gathered when targeting certain aspect to improve. The source of information could be using the documents from technical specification, from model testing such as in a controlled experimental environment, from sea trials when vessels are tested in calm water or from data during real time monitoring. In this paper, a proposed methodology to investigate available approaches to address the energy efficiency matter is discussed. This framework will consolidate and explain the pros and cons of each approach and the extra benefit when combined methodology is utilised. This methodology will help endusers with product selection and provide the knowledge to choose the products that best suit their needs.

2. PROBLEM STATEMENT

MEPC.213 (63) and MEPC.282 (70), guidance to using SEEMP proposed certain main categories that are dedicated to improve energy efficiency on vessels (IMO, 2012; IMO, 2016). Figure 1 shows the main resolution proposed in 2012 to assist vessels to develop individual SEEMP. Each of this development and the variables associated can be further categorised as influence from external factors, internal factors or operational factors.

	External factors	Internal factors	Operational
Variables	Wind Wave Current Density and temperature Fouling	Efficiency of machinery System connections	Safety factor Company policies
Improvements	Just in time Weather routing Improved voyage planning Optimised shaft power Hull maintenance	Waste heat recovery Energy management Alternative fuel type Speed optimisation	Optimised trim Optimum ballast Optimum propeller inflow Optimum rudder and heading control system
	Fleet management		

Figure 1: Factors that influence implementation of SEEMP.

The contribution of variables from external factors include mainly the environmental conditions such as wind, wave, current, water depth, density and temperature, and hull condition; whilst the variables within the internal factors accounts mainly for all machinery and systems within the vessel. Variables that affect the operational factors are compliance with the safety factors and also company policies. The impact of external factors has to be understood in order to make improvements in vessel's operation by applying techniques such as just in time arrival, weather routing, improved voyage planning, optimised shaft power or hull maintenance. The understanding of impact of the internal factors reflects on the improvements that can be carried out on waste heat recovery, energy management, alternative fuel type and speed optimisation. Lastly, changes of method of operation of vessel has to be understood to better plan and improve on optimum trim, ballast, propeller inflow, and the use of rudder and heading control systems.

3. METHODOLOGY DEVELOPMENT

Many commercialised products claim to be tackling the issues regarding energy efficiency and emissions relating to vessels, however, methodologies selected might differ. On-going research from both academic and industrial partners often collaborate to overcome these challenges, working within the boundaries of available technology and costs. The relevance of this methodology is to ensure that the industry and the academics are working alongside to achieve a common goal and contributing to sustainable shipping. This comparison will highlight the factors that the industry deems important and the contribution from the academic research that is able to bridge the gap. Figure 2 shows the proposed methodology to review the different approaches available to improve the energy efficiency of vessels.

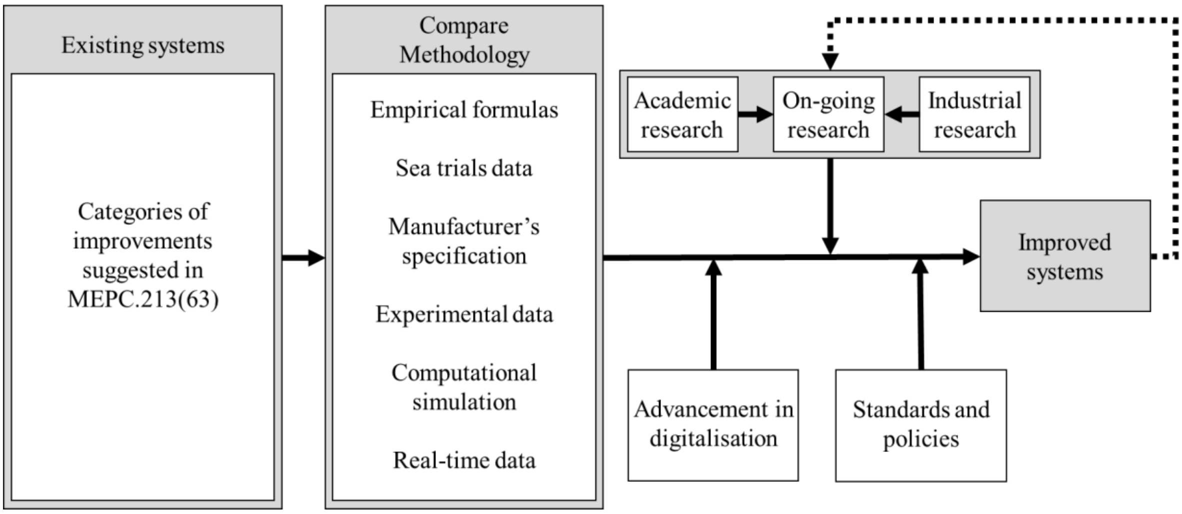

Figure 2: Methodology to review energy efficiency systems.

The effects of each variable presented in Figure 1 and the influence on vessel energy efficiency can be predicted through different methods. Some of the typical methods of analysis are through theoretical and empirical formulas, utilising data from initial sea trials, using data from manufacturer's technical specification, carrying out model experiments, advanced computational simulation and through real-time data monitoring. Theoretical development in hydrodynamics contributes to predicting the response vessel at sea. However, it is not yet sufficient due to the nonlinear properties of waves in real-time. Utilising initial sea trials are important to gain the ballpark value, but several iterations are needed to take into account degradation of machinery, hull and also changes made to the vessel over time. Manufacturer's technical specification is useful as a guideline, however, changes in loading conditions and system arrangements might cause values to differ from factory tests. Carrying out model experiments are suitable methods to capture values that might not be able to calculate, however, the cost, time taken and facilities available might be a constrain. Computational simulations are often used to carry out analysis, but improper use and unrealistic inputs might provide output that is not reliable. Real-time data monitoring has come a long way with the advancement of digitalisation, but care has to be taken to ensure the reliability of data recorded. Each of these methods contributes to quantifying and determining ways of managing energy on-board vessels. A clear breakdown and understanding of variables influencing energy efficient ships will help in the selection process of methodology that is used to quantify each variable. This breakdown will allow a more systematic approach for further diagnostics to be carried out.

The advancement of this digital age contributes to the culture of real-time data monitoring (Lohr, 2012). Furthermore, the digitalisation of these systems will contribute to a better operation and more structured maintenance plan. Energy efficiency through digitalisation bridge communication breakdown between ship and shore organisation. This advancement allows information to be transmitted accurately without misinterpretation and time lag. As a result, management vessels and fleet will be able to identify and focus on handling available resources from the information gathered. Standards and policies play an important role in driving better and improved energy system management. These different methodology adopted to carry out energy efficiency systems are reviewed, a discussion about the existing standards are also discussed to check the relevance and identify if there is any room to address a better and standardised plan of action. This methodology will outline the existing state of energy efficiency systems available and will allow identification of gaps and potential improvement.

3. CASE STUDY

An example of the application of this proposed methodology is looking at the variable of weather routing that contributes to energy efficient ships. Weather routing is important to predict the time of arrival of a vessel and avoiding dangerous weather windows. A proper routing can also shorten the voyage time up to a few days difference. For vessels such as passenger ferries or cruise, sailing through calmer weather conditions could provide better comfort and promote safety at sea. Accurate weather forecast at different location. Weather information and forecast can be obtained from different sources, where most of them provide updated forecast several times throughout the day, some forecast up to 15 days. Another information to consider is the data grid resolution of 0.25 degrees to 2.5 degrees. Some of the more common providers are such as the Global Forecast System (GFS). Table 1 shows the different parameters and resolution where weather forecasting models provide

(Sail, 2016; Sail, 2016). Weather data are normally stored as gridded binary files or files that can be sent with limited bandwidth connections. Provide best weather routing option.

Table 1 Parameters of weather forecasting model

Weather forecasting models	1 day, 7 days, 14 days High-resolution Numerical Mesoscales Model (NMM)
Coverage area	0 - 10 index scale
Grid resolution	0.25, 0.5, 1.0, 2.5
Update frequency	4 times a day – 0000, 0600, 1200, 1800
Other parameters	Wind speed (10m above sea level)
	Mean sea level pressure
	Significant wave height
	Mean wave direction
	Temperature
	Precipitation / rain
	Cloud cover

By combining the vessel speed data and weather information, the best route can be mapped. There are also certain constraints where weather routing is only effective if passage travelled is more than 1,500 miles. The vessel should also be able to operate in relatively large waters to allow adoptions of different route. A certain flexibility is also needed where the vessel is allowed to change routes with no restrictions of a specific route (Bowditch, 2017). Practical navigator handbook shows the performance curve of a vessel for head, beam, and following seas. This deviation is caused by the changes in ship resistance through water due to external influences (Bowditch, 2017). The total resistance experienced by the vessel is the total resistance when the vessel is in calm water, influenced by the Froude number and Reynolds number; and also the total added resistance due to external factors such as wind, wave and currents. The resistance when the vessel is moving in calm water can be calculated through analytical regression called the Holtrop method (Holtrop, 1982). Added resistance can be obtained through model testing (Kim, 2014) and numerical simulation such as the boundary element method or the finite element method. However, the numerical approach could be challenging when addressing higher order waves and fast pace changing time step when accounting for true weather conditions (Shen, 2013; Molland, 2017).

By combining the energy spectrum from the weather forecast and the mean response curve that can be identified through computational simulation and model testing, the added resistance of the vessel can be calculated. This value is significant as it contributes to an additional 15%-30% of the engine power compared to when the vessel operating in a calm water condition. The wind data can be used to calculate the added resistance induced on the superstructure and the top deck cargo. The added resistance caused by wind is more significant for larger vessels as the resistance increases in proportion to the large surface area exposed to the wind. By using the analytical approach to calculate added resistance on the vessel, it can be assumed that the added resistance is proportional to the square of the wave height. The motion and phase of the vessel and wave motion are also interdependent (Shao, 2012). However, it should be noted that weather forecasts are not always accurate, hence real-time monitoring systems that logs instantaneous weather data could be used and improve systems through mathematical modelling.

4. CONCLUSION

Vessel energy efficiency can be improved by using the SEEMP guidelines. However, there are different methods to realise each approach, through experimental methods, through theoretical and empirical calculations, utilising sea trials information, and real time monitoring. A clear understanding of each parameter and variables affecting vessel operation will allow users to choose the best methodology and approach with confidence. All these combined efforts contribute to the reduction of emissions and managing energy efficiently.

ACKNOWLEDGEMENTS

This work was conducted in collaboration with Royston Ltd and is funded by Innovate UK within the Whole Vessel Energy Management Project (project reference 102431).

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