VIABILITY OF USING ENGINE ROOM SIMULATORS FOR EVALUATION MACHINERY PERFORMANCE AND ENERGY MANAGEMENT ONBOARD SHIPS

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SUMMARY

The maritime institutions aim at contributing to reducing the adverse effects arising from the ships' machinery operation through the possibilities exit in the engine room simulators. The current paper explains the importance of engine room simulators in maritime education in general and focuses on their use in the field of evaluation and management of machinery within the engine room space. As a case study, an electric powered passenger ship and an oil tanker ship are investigated regarding applying ship energy management onboard. This investigation could be achieved using the possibilities available in TRANSIS ERS 5000. With reference to passenger ships, the results show the possibility of saving energy with a reduction of CO, SOx, CO_2 and C emissions by about 7.97, 10.54, 12.36, and 20.11%, respectively. However, regarding tanker ships, the results reveal that a reduction of speed by 10% will achieve fuel saving by about 25%.

ABBREVIATIONS

C	Carbon
CO	Monoxide Carbon
CO_2	Dioxide Carbon
ERS	Engine Room Simulator
IMO	International Maritime Organization
LCC	Large Crude Carrier
LNG	Liquified Natural Gas
NOx	Nitrogen Oxides
SOx	Sulfur Oxides
STCW	Standards of Training, Certification and Watch keeping

1. INTRODUCTION

There is no doubt that the training processes of engineering officers' onboard ships play a key role in achieving the highest degree of proficiency and efficiency in operation, in addition to ensuring safe operation. The International Maritime Organization (IMO) has contributed to supporting the training process in various ways. For example, using the engine room simulators to meet the professional aspirations of the engineers and in accordance with the international requirements stipulated in the International Convention Standards of Training, Certification and Watch keeping code (STCW), as amended in 2010 (IMO, 2017; IMO,1996; IMO, 2011).

Many research studies aim at showing the importance of engine room simulators as educational evaluation and assessment tools rather than the capability of computer-based training for engineering onboard commercial ships were carried out (Vasilios et al, 2014; Rafal et al, 2015; Liviu, 2014; Cengiz, 2002). The shifting from computer-based training to full mission's engine room simulator proved that the engine room simulator is an important tool for the practical exercise of trainers (Burak et al, 2017; Zun et al, 2017; Lu, 2014; Rafał, 2016). The use of simulators in maritime education was extended during the previous years to include a number of technical points that are difficult to imagine within the engine room space. It includes determining the different methods of improving fuel quality, combustion process inside the engine, and ship operational safety (Cwilewicz & Tomczak, 2008). With the use of simulators, the effect of fuel used for the main engine becomes clearer to establish a comparison between heavy fuel oil and liquefied natural gas (LNG) as a fuel for simulated ships (Burak & Caglar, 2015), which showed the necessary equipment that should be attached to operate LNG-fueled ship. Moreover, familiarization with the critical situations, such as explosion and fire prevention of marine diesel engines (Leszek et al, 2015) and their use in human error assessment (Cagatay et al, 2015) was helpful for engine crew.

Another area of using the simulators appears in the form of understanding the behavior and performance of a certain ship's type such as Offshore Supply Vessel (Radovan et al, 2012; Haosheng et al, 2017). The last steps regarding the development of engine room simulators appeared in the form of transferring to the virtual realistic (VR) simulator. This step is followed by starting to use the argument realistic concept through the simulator, which – without doubt – will achieve a revolution in the field of maritime training [11].

From the previous studies, it can be concluded that engine room simulators can play a role in the way of developing and enhancing the maritime education in many aspects. The current research paper investigates the role of engine room simulators in evaluating and improving the energy management system onboard ships in accordance with the international requirements set out through MARPOL convention Annex VI. This could be achieved using the possibilities available in the TRANSIS ERS 5000 that exists at the Arab Academy for Science, Technology & Maritime Transport AASTMT's main campus in Alexandria for two different ship types, namely electric-powered passenger and oil tanker ships. A set of ship parameters will be examined, namely ship speed, main engine revelations, electric load distribution, and other relevant parameters in relation to the ship energy efficiency. This will be carried out using the established engine room simulator scenarios, at different ship conditions. The expected outcome of the current paper is to single out main ship parameters that play a crucial role towards improving ship energy management, which can be achieved through estimating Energy Efficiency Design Index (EEDI) for one of the chosen scenarios.

2. RESEARCH METHODOLOGY

The methodology of this research aims at studying the possibilities available in the engine room simulator ERS 5000, through a detailed explanation of its components; studying two different scenarios; studying the performance of machinery at different operating conditions; measuring fuel consumption rates; and recording the amount of emissions followed by results analysis.

3. ERS 5000 SIMULATOR DISCRIPTION

This simulator provides the possibility of simulating the different types of machinery onboard various ships and is able to provide advanced training in marine engineering and ship operation in both natural and hazardous conditions. Moreover, it is used in teaching, training and evaluating the members of the machinery room, including engineers responsible for rotation, second engineers, and the chief engineer. The natural and behavioral realism of this simulator creates a professional climate for the following types of marine engineering training: definition and education, standard operation and rotation work, advanced operation and fault detection, and basic physical and technical knowledge. Finally, it is established to cope with STCW Code section A-1/12 and Section B-1/12, and International Safety Management (ISM) Code Section 6 and Section 8. The ERS 5000 is divided into three main spaces: engine control room, class room and instructor room space. Figure 1 simulates the realistic layout of main console where the machinery could be controlled.

Figure.1 ERS 5000 main console general view

4. CASE STUDIES

4.1 SCENARIO [1] AZIPOD DIESEL-ELECTRIC

The simulator is modeling the propulsion plant of total installed power 51,840Kw, electric power unit's steering control system, alarm monitoring system, remote wall mimic consoles, auxiliary systems, units and mechanisms of a Diesel-Electric AZIPOD prototype ship. Table 1 presents the main specification of the AZIPOD Diesel-Electric ship.

Table 1 Ship general characteristics:

Total installed power	51,840 kW
Tonnage	81,769 tons
Length (L.O.A.)	291 m (954.7 ft)
Height	57.83 m (189.73 ft) keel to funnel top
Beam	32 m (105.0 ft)
Draught max	7.80 m (25.59 ft)
Speed	(service at 22 knots maximum, 24 knot)

The simulator of a diesel-electric ship has the propulsion console and the virtual dedicated hardware console comprising the wall mimic panels. Selecting this scenario is due to the importance and the role that electric power propulsion system can play in the way of fuel reduction and the emissions elimination, where the electric propulsion system has the advantage of high-power supply, high energy efficiency, and low fuel consumption compared with the other conventional propulsion systems (Kripakaran & Gopi, 2017). The scenario was run by the trainees, in the case of supplying the ship with the necessary electricity power through five generators. This is followed by taking readings related to the quantities of emissions, mainly: Nitrogen Oxides (NOx), monoxide carbon (CO), Sulfur Oxides (SOx), dioxide-carbon (CO_2), and carbon (C), in addition to the amount of fuel consumed. Then the scenario is repeated using only four generators and recording the previous readings to show how to rationalize energy through optimal operations.

The main propulsion system of diesel-electric passenger powered ship is described as shown in Figure 2. However, Figures 3a & b and 4a & b demonstrate the power supply lay out and the registed emissions quantities for both condition five and four generators, respectively.

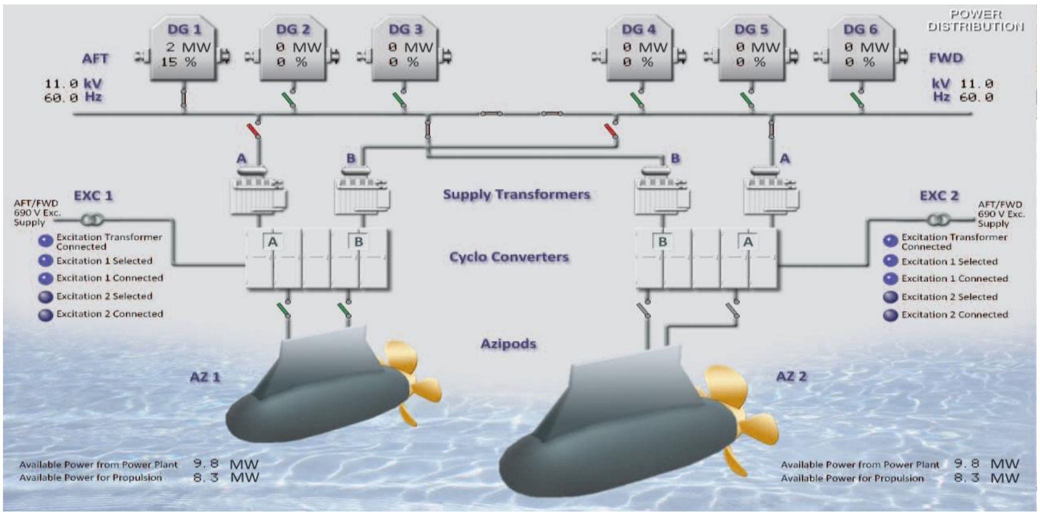

Figure.2 AZIPOD diesel electric propulsion system

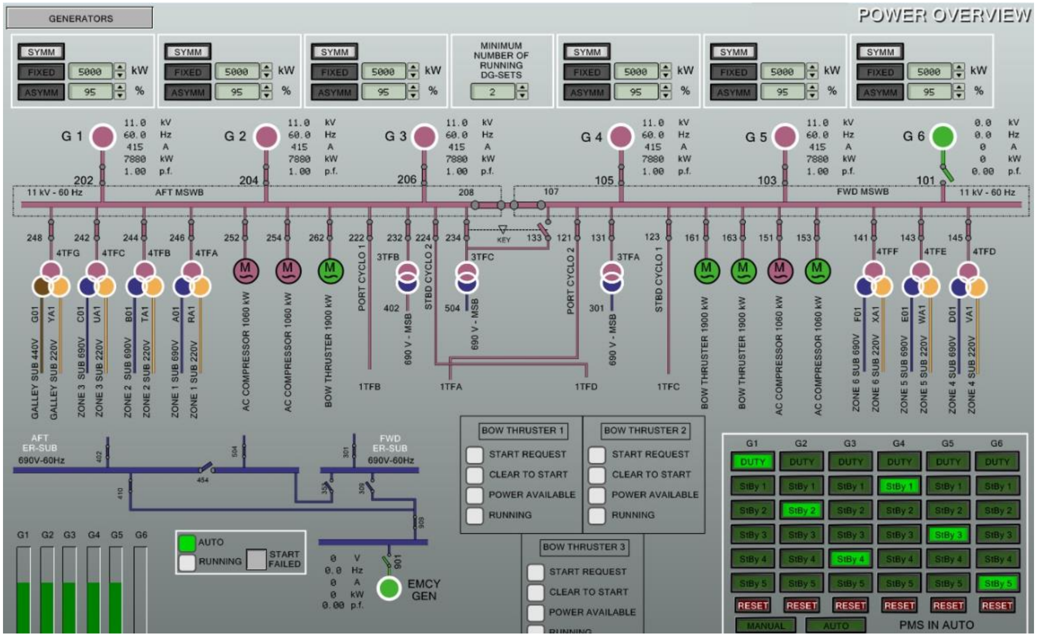

Figure 3a. Five-generators power supply

Figure 3b. Five-generator emissions quantity

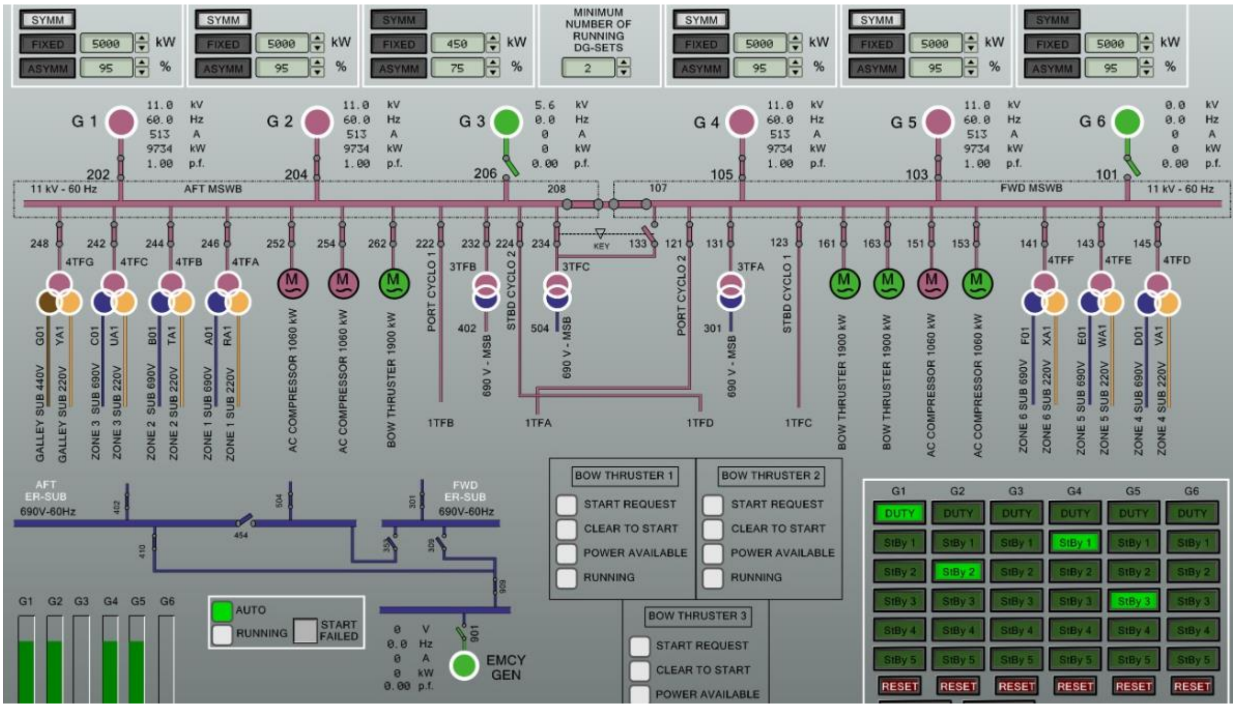

Figure. 4a. Four-generators power supply

Figure.4b. Four-generator emissions quantity

Figure 5 provides the trainees with the possibility of saving energy and reducing the amount of emissions by optimizing the generators' operating.

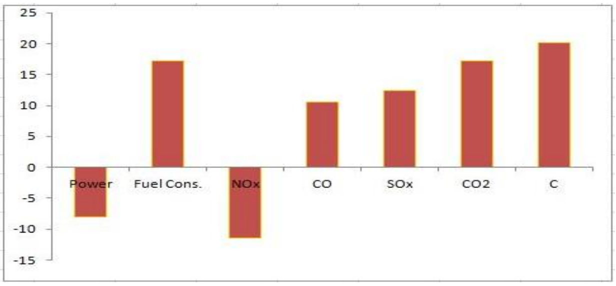

Figure.5 Ship's saving energy and the quantity of emission

The results show the possibility of saving energy in the form of power reduction by about 8% and achieving a reduction in the fuel consumption by about 17.5% of the total ship's fuel consumption. Moreover, it reveals that there is a reduction in the quantity of CO, SOx , CO_2 and C emissions by about 7.97, 10.54, 12.36, and 20.11%, respectively. On the other hand, the scenario shows that there is an increase in the quantity of NOx emissions by about 11.51%.

4.2 SCENARIO [2] MAN B &W 6S60MC-C DIESEL ENGINE TANKER LCC

The Tanker Large Crude Carrier (LCC) simulator model, with a maximum continuous rating of 13,736Kw at 105 RPM, has the propulsion console and Virtual Hardware console comprising all displays to control and monitor the ship's systems, units, and mechanisms.

The second scenario has been run, and some operations that were actually performed, such as depending on shaft generator for electricity demands or depending on main generators' operation were carried out. In addition, there are some operations that may be difficult to do practically but can be performed to improve the ship's energy management such as ship steaming operation, and the effect of moving the ship from an operating area to another area, the effect on air ambient temperature, and the effect of turbocharger blocking percent are investigated. The main purpose of the scenario is making the trainers more familiar with the optimum operation methods and how to cure some technical problems when they face them in order to understand the importance of ship's energy management. As shown in Table 2, in case of the use of shaft generator, there is an insensible change in ship's speed, power, engine speed, and it recorded an increment in fuel consumption by about (888 lit per day). However, on the other hand, there is a reduction of 1,500 lit/day due to stopping of one of the electric generators. This means that there is an availability to achieve a quantity of 0.612 kg per day due to depending on shaft generators as a source of electricity for ship during sailing.

Table 2 Effect of Shaft Generator

Ship's	Without shaft	With shaft
Ship speed	15.6	15.6
Power /Cylinder	2422	2315
R.P.M	105	105
Engine Load %	82	79
Fuel	2417	2454

In, addition, from Figure 6 a & b, with reference to the ship's emissions; the scenario gives an expected emission reduction of 436ppm, 118ppm, and 34ppm, 38gm/m^3 for NOx, CO, SOx, and C emissions, respectively.

Moreover, Table 3 summarizes the data collected during the steaming operation at various engine load percentages to evaluate the ship's performance due to speed reduction. The results reveal that a reduction of speed by 10% will achieve a reduction of fuel by about 25% and more speed reduction will be led to unlined reduction in fuel consumption.

Table 3 Effect of ship steaming

R.P.M	Ship's Speed [Knots]	Fuel Consumption [Lit/hr]	Power /Cycle [kW]	Emissions				
				NOx [ppm]	CO [ppm]	SOx [ppm]	CO_2 %	C [gm/m^3]
105	15.6	2427	2400	987	75	91	4.7	68
95	14.1	1776	1760	852	58	86	5	64
85	12.5	1180	1180	710	43	81	5.4	59
75	11	802	815	600	32	75	5.7	54
65	9.5	487	500	504	26	59	6.1	48

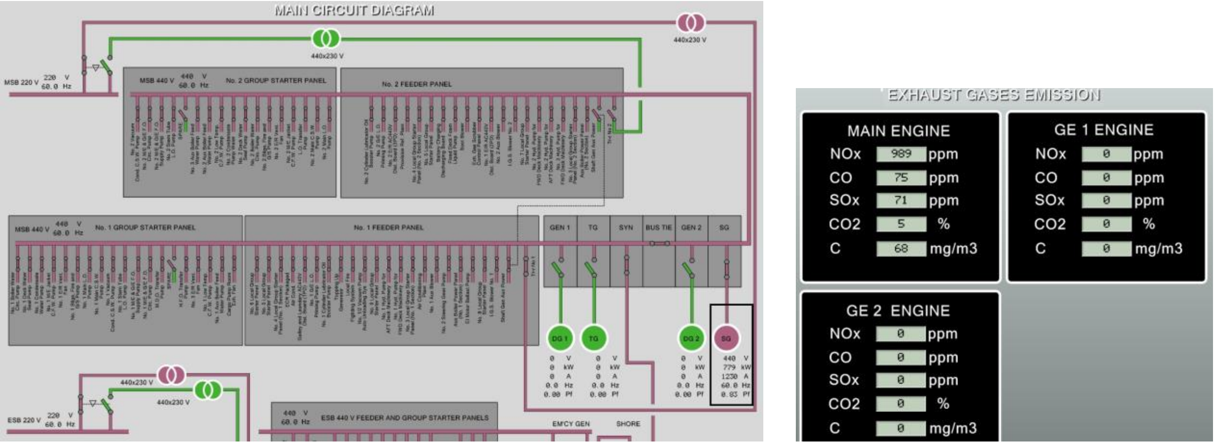

Figure.6a Ship performance @ shaft generator electric power supply

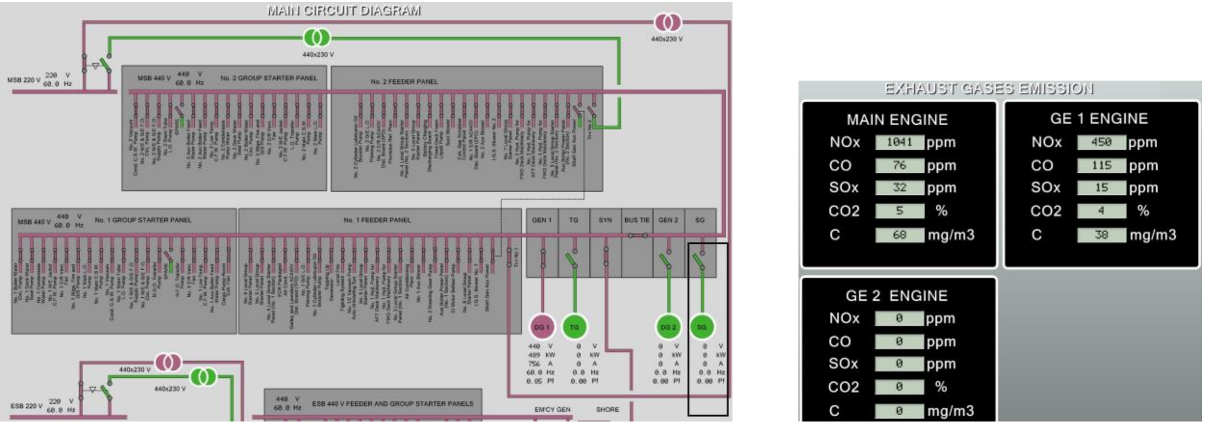

Figure.6b Ship performance @ main electric generator power supply

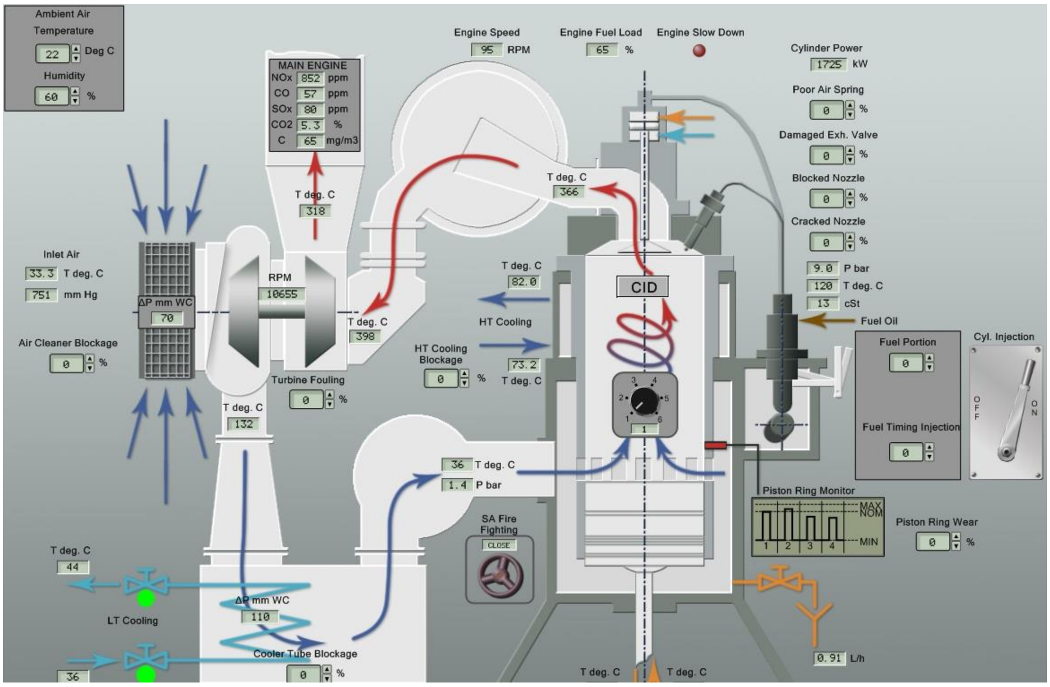

Figure.7 Engine performance at speed steaming

In addition, the table illustrates the gain of speed reduction from the perspective of ship's emissions. It is clear that as the ship's speed decreases, the amount of ship emission decreases for SOx, NOx, CO, and C. However, as the percentage of CO_2 increased, ship speed decreased. Moreover, Figure 7 illustrates the engine performance regarding engine revolution, engine power, and fuel consumption at speed of 14.1 knot.

Figures 8 and 9 show the gain of energy management onboard the case study. Figure 8 illustrates the dramatic reduction in fuel consumption with speed reduction; however, Figure 9 shows the effect of speed reduction on ship emissions reduction percentage.

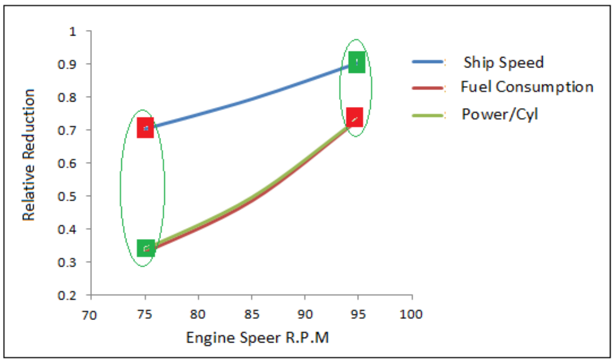

Figure. 8 The relation between ship speed and fuel reduction percent

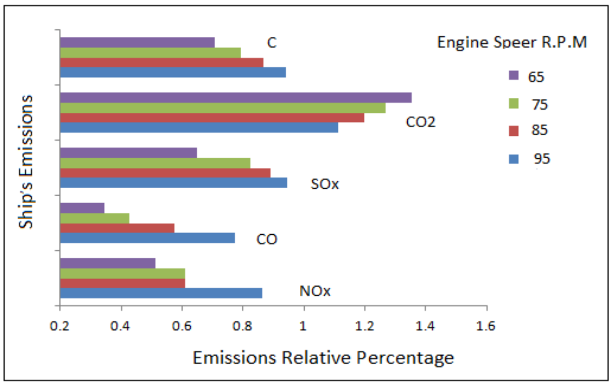

Figure. 9 Effect of speed reduction on Ship emissions Reduction percent

4.2.(a) Using of simulator to estimate EEDI for tanker

EEDI is used to ensure an energy-efficient design for specific ships. These ship types are defined in Regulation 2.23 and Regulation 20 of MARPOL Annex VI. EEDI is applied to ships of 400 metric gross tonnages and above and delivered on or after January 2015. Also, it can be calculated for the specified existing ship types in operation. It shows the impact of shipping on the environment compared with its benefits for the society. It is measured by the mass of CO_2 emitted per unit transport work (Nader,2019). The following calculations may be used to estimate the value of attainted EEDI.

$$EEDI_{attained} = \frac{E_{PM} + E_{AE} + E_{SG} - E_{WHR}}{C_T * f_c * f_0 * V_{ref} * f_W} \qquad (1)$$

Where, (E_{PM}), (E_{AE}), and (E_{SG}), are the emissions quantity of CO_2 emissions which results from the prime mover, auxiliary engines and shaft generator, respectively. However, (E_{WHR}) the quantity that could be deduced in case of applying waste heat recovery. (C_T) is the capacity in tones, (f_c) is the capacity factor, (f_0) is the cubic capacity correction factor and should be assumed to be one (1.0) if no necessity of the factor is granted, (f_1) is the factor for general cargo ships equipped with cranes and other cargo-related gear to compensate in a loss of deadweight of the ship, (V_{ref}), and (f_w) is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed. To determine the value of required EEDI, the following equation may be used:

$$EEDI_{Required} = \left[1 - \frac{x}{100}\right] * a * (Capacity)^{-c} \qquad (2)$$

Where, (a and (b) are constant for each specific are 1218.8 and 0.488 for oil tanker ships, respectively, and (x) is the required reduction percentage according to the regulations. Using the technical data of Diesel Engine Tanker LCC, by substitution in equation (1& 2), Figure 10 can be extracted.

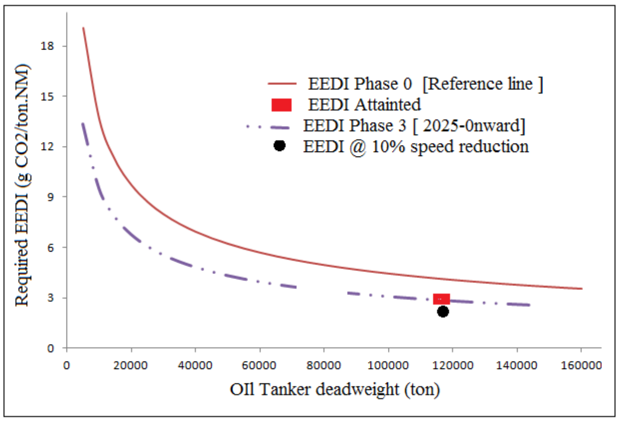

Figure.10 Effect of speed reduction at EEDI for tanker LLC

As shown in the figure, it is clear that with applying a reduction of ship speed by 10%, the value of EEDI will be still below (phase 0) and (phase 3). This simulation contributes in understanding the process of EEDI estimation. The results recorded through the engine room simulator may be difficult to obtain through the actual operation of the ship due to many factors, most notably: the lack of time to conduct real experiments on the ship in addition to the cost needed by those operations. On the other hand, the importance of the simulator for the marine environment is evident in the important role that it can play in the process of identification, training and optimal operation.

5. CONCLUSION

Engine room simulator became an effective element through the maritime educational system. ERS enhances the trainers with many technical operations onboard ships including: Waste Heat Recovery System –Exhaust Gas, Shaft Generator, Power Management System, Sankey Efficiency Calculator –Real Time, Marine Auto Load Program, and Electronic Fuel Injection. This paper discusses the importance of ERS to evaluate the engine performance and simulate the different processes that could be used to improve the ship performance through following the energy management. Electric power management system and ship steaming process were selected for passenger and tanker ships, respectively, as a step in the way of energy conservation and reduction of ships' emissions. With reference to passenger ships, the results show the possibility of saving energy with achieving a reduction of CO, SOx, CO_2 and C emissions by about 7.97, 10.54, 12.36, and 20.11%, respectively. However, regarding to tanker ship, the results reveal that a reduction of speed by 10% will achieve fuel reduction by about 25%. This result is considered valuable, especially with the new restricted regulation issued by IMO to eliminate the adverse effects of ship emissions.

6. ACKNOWLEDGEMENTS

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