Energy Efficiency in Maritime Transport

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Abstract. The maritime industry has developed immensely in the 21st century. One term that has a great importance and basis in the various aspects of shipping and maritime operations is fuel propulsion. Fuel propulsion is the fundamental rock that any machinery and shipping procedure is set upon nowadays. Despite the improvement in the maritime industry, there is still a major issue to tackle, which is the effect of using non-efficient energy sources (propulsion methods) (non-friendly). Per example, fuel oil is the main energy source for propulsion onboard most of the ships producing harmful emissions such as CO_2, SO_x and NO_x, GHG. This has a direct negative impact on the marine and air environment in different ways.

As a result, the IMO exerted great efforts in enhancing the energy efficiency aspect in order to save as much energy as possible from the shipping industry. These efforts appear vividly in the conventions and regulations adopted by the IMO and its amendments in different shapes, such as:

- The Energy Efficiency Design Index (EEDI).
- The Ship Energy Efficiency Management Plan (SEEMP).

All the ships must have an "energy efficiency management plan" that includes steps to insure the optimum energy saving during their voyage, these steps include; regular maintenance and checkups as well as energy efficient habits to be strictly followed by the crewmembers onboard.

This paper will formulate the energy efficiency policies and will discuss how to implement these policies and the measures that can be taken to comply with it. Also, the paper will focus more on the technical solutions such as using alternative energy source and introducing new energy efficiency modifications for the ships with the main aim to save energy, reduce the harmful air emission and their effect on the environment.

Key words: Energy efficiency - non-efficient energy sources - Sox, NOx –
Energy Efficiency Design Index - Ship Energy Efficiency Management Plan.

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1. Introduction

In shipping operations, there are many terms of great importance, but the one with significant importance is "Energy Efficiency". It has become the root of setting up or planning any machinery or procedure, from the main engine to cargo operations. The effects of not being efficient on ships have been affecting the environment. However, these effects can be avoided by using renewable energy sources. An alternative to the bunker fuel has been introduced to the maritime industry, to be more environmentally friendly. Furthermore, regular maintenance is required to keep the ships up to date and in their best conditions. Moreover, few rules have been introduced to the maritime sector by the International Maritime organization (IMO) on how to improve energy efficiency on ships. Further modifications have been made in ships to cause a reduction in the resistance of the ship, thus less fuel is burned.

No thoughts or actions have been taken in cutting out the emissions of CO2, which the global marine shipping contributes in. However, worrying levels of harmful air pollutants have been discovered by the international maritime organization's assessment on the effects of shipping. According to a 2009 United Nations' and IMO expert group report, international shipping in 2007 was responsible for 870 million tonnes of CO2, which is around 2.7% of total global CO2 emissions. Emissions from shipping have been growing rapidly, and are predicted to rise to 1,475 million tonnes (or approx. 6% of the total) by 2020 [1]. Moreover, the bunker fuel that is being used by large ships releases sulphur that in turn helps acid rain and particulate matter to form, that can lead to fatal diseases. In addition to air pollution, noise pollution also happens to contribute in affecting the environment; this is due to the increase in shipping enterprises, causing harm to marine life that relies on sound to survive. Whales, for example, are challenged with this pollution, and start to behave in ways which may cause their death; swimming close to the shore. Moreover, movement patterns, communication and even physical damage are caused to marine life due to the pollution. Furthermore, it is noticeable that the prices of fuel are increasing, and these resources are being wasted as they are not used efficiently. This has a negative impact on the income and the profit of companies as they are funding for the fuel of the ships.

2. Effects of Energy Inefficiency

To save up more money and electricity on ships, LED lighting is being utilized instead of conventional lamps and tube lights. There are numerous advantages of LED lights including that it has better performance than an incandescent globe or fluorescent lamp. An incandescent globe has a much shorter lifespan than LED lights; they're lit up for 7500 hours, whereas LED lighting can function for 50,000 hours and consume 60% less energy. The use of LEDs for lighting enables weight savings of up to 30%, which means the overall weight, can be reduced by up to 8 tonnes. For a cruise ship with 50,000 light sources, the use of LED solutions can allow a reduction of CO_2 emissions of up to 3,000 tonnes per year and an annual cost saving of up to EUR 200,000 [2]. In addition, slow steaming is now used to cut down carbon emissions and fuel consumption by purposely slowing down the speed of cargo ships. The usual speed of a container ship is 20-24 knots which are reduced to 12-19 knots in slow steaming; this reduces fuel consumption and engine power. There are a lot of cases in which there is the optimal utilization of fuel used for the main engine on board ships; this includes the increasing interest in emission reduction, ship operating costs reduction, and the newly adapted IMO Energy Efficiency Design Index (EEDI) rules. Because of the heat flow and temperature of the main engine exhaust gas energy, it is the main waste heat resource of a ship. By utilizing this exhaust gas energy, it is possible to generate an electrical output of up to 11% of the main engine power in a waste heat recovery system comprising both steam and power turbines.

3. Regular maintenance

Mechanical equipment on a ship requires regular maintenance to keep the machinery up to date and in a great condition. Under water hull cleaning helps ships to restore their efficiency without the requirement of dry docking, this process helps vessels to reestablish an act as close as possible to its optimum condition and offers ship owners extensive investment funds in fuel. The objective behind underwater hull cleaning is to expel organic unpleasantness or fouling. Moreover, the accumulation of marine fouling can increase drag, altering the hydrodynamic performance of the vessel. The underwater propeller polishing is vital to save energy and optimize the performance of the ship. Propeller cleaning gets rid of marine growth from the blades' surfaces, which may fundamentally lessen fuel utilization, improve reliability and enhance the maintenance cycles of the vessels. Research has shown that the adoption of a propeller polishing routine generates significant savings. For example, it is typically believed that proper propeller maintenance should result in fuel savings per annum of at least 10% depending on vessel activity and extent of layups [3]. Anti -fouling coating is a waterproof hull paint that is applied as the outer layer to the hull of a ship, to slow the growth of sub aquatic organisms that can affect the performance and sturdiness of a vessel. Furthermore, this type of coating acts as a barrier against corrosion of metal hulls and improves the flow of water past the hull and this increases the efficiency of the fuel.

4. IMO Requirements

Due to the greenhouse gas emissions from the international shipping, the IMO has implemented some rules to reduce these emissions. The Ship Energy Efficiency Management Plan (SEEMP) is a management tool that helps the owners maintains the efficiency of their ships. Furthermore, the IMO adopted the single most important technical measure aimed at promoting the use of more energy efficient equipment and engines which is known as the EEDI. It is used to calculate the energy efficiency of a vessel, by a complicated formula which takes the ship's emissions, capacity and speed into consideration. However, the lower a ships EEDI, the more energy efficient it is and the lower its negative effect on the environment. IMO regulations stipulate that ships must meet a minimum energy efficiency requirement, so their EEDI must not exceed a given threshold [4].

5. Wind Energy

The Wind is a major energy carrier, and there are a lot of ways for harvesting its kinetic energy. For instance, there has been a new system in the maritime transport field called skysails system. The system consists of a towing kite, a launch, a recovery system and a control system. The towing kite is placed on a telescoping mast to be lifted to a sufficient height so that it unfolds and launched. After launching, the winch releases the ropes until the kite reaches its ultimate altitude between 100 and 300 meters high. When the system is no longer in need, the process is carried in reverse to retrieve the kite back from the sky [5]. Another way to benefit from wind's energy is by using the rotor sails technique. The system is mainly about spinning cylinders, using electric energy the cylinders are rotated so that they can harness the wind's energy with the help of the Magnus effect. When the wind passes through the cylinders, it creates a thrust force in a direction perpendicular to the wind's direction to be used for assisting the propulsion [6]. Wind assisting the ship's propulsion reduces the load on the main engine. Therefore, less fuel is consumed, money is saved, and fewer emissions are produced.

Another major fuel saving strategies on board ships are ship resistance reduction, which could be implemented in multiple ways. For example, the friction between the ship's hull and sea water can be reduced by generating a layer of air bubbles underneath the ship's hull. The system uses oil free compressors to compress the air, which is then released under the hull as micro bubbles resulting in less resistance. It can be observed that the ship's shaft power is reduced and the speed is increased, once the system is turned on.

6. Alternative Energy Sources

Hydrogen is the most abundant element in the universe and can be used as a clean and efficient source of energy. It can be obtained by one of two means: firstly, hydrogen can be used in an internal combustion engine to be burnt with the sufficient amount of oxygen to produce vast amount of heat energy per unit mass when compared to hydrocarbon fuels. The end product of this reaction is merely water, creating no harm to Mother Nature. Secondly, hydrogen can be entered in a fuel cell generating electricity which can also be used in the ship's propulsion using a DC motor. Unfortunately, using hydrogen as a fuel isn't as easy as it sounds as there are major difficulties to conquer such as storing it onboard [7]. The process of storing hydrogen is extremely dangerous and way too expensive therefore it's challenging to replace hydrocarbons with hydrogen nowadays.

Fortunately, there is a clean way to produce hydrogen onboard the ship using electrolysis. This method is carried inside a brown gas generator where sea water is entered and then separated to hydrogen and oxygen molecules. The process of water electrolysis requires an input of electricity, so the presence of an electric source is required as well as the presence of electrodes where Oxygen and hydrogen are formed [8].

$$2H_2O + \text{Electric Energy} \rightarrow 2H_2 + O_2.$$

Electricity required to carry out this procedure can be obtained from a battery specified and charged only to carry out this reaction. The process mainly converts water to a renewable fuel reducing the amount of fuel consumed along with the ship's emissions. Speaking of energy sources produced from sea water, researchers at the U.S naval research laboratory (NRL) have accomplished forming hydrocarbon fuels by obtaining carbon dioxide and forming hydrogen from sea water using an Electrolytic Cation exchange module [9]. Moreover, fuel can be made from waste food oils known as biofuels or biodiesel which is a source of renewable fuel. The process of manufacturing biodiesel is carried out by alkali trans-esterification of waste oils along with the addition of sodium hydroxide and methane [10]. Biodiesel is a non-toxic, renewable and a biodegradable fuel that produces fewer greenhouse emissions.

There are ways for reducing the fuel consumption from the bridge. For instance, weather routing can be helpful to the ship's fuel efficiency, as deck officers set their optimum voyage route based on the weather forecast [11]. Moreover, a device could be installed on the bridge called the Advanced Ship Autopilot System (ASAS). This device is like a computer that requires the insertion of the following to work: way points, wind speed, and direction, ship's position and speed through the GPS, speed through water from the speed log, the heading through the gyro and depth. Further measurements are introduced to the device including the rudder angle and the propeller's rpm. After

all these measurements, the device then calculates the ultimate path through which the autopilot sails [12].

7. Conclusion

All in all, there are numerous ways to increase energy efficiency in the maritime transport field. Reduction in fuel consumption can be achieved by modifying the ship's construction phase by adding the bulbous bow and the air lubrication system to the ship's hull. Also, switching from the existing lighting system to the more efficient LED lighting, slow steaming, and regular maintenance. Also, harnessing wind energy via skysails or Flettner rotor technique and manufacturing a synthetic fuel from water or waste cooking oil. Finally, replacing hydrocarbons with hydrogen or by introducing the ASAS device onboard the ship. These techniques are both economical and environmentally friendly since they save money spent on fuel and limit the ship's emissions.

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