Implementation of Improved Marine Engines in National Iranian Tanker Company (NITC) and Its Effect on Energy Consumption and Environmental Pollution

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ABSTRACT: *In this study, the performance of two generations of two stroke marine diesel engines namely, conventional and improved engines in terms of energy consumption and environmental concerns was investigated. The engines are operating in National Iranian Tanker Company (NITC). The comparison was made for different operating conditions and in various NITC supertankers, which were equipped with RTA type engine as the conventional type and RT-flex engine as the improved type (i.e. camshaft less). The data collection was performed based on daily fuel consumption and the rated fuel consumption was determined. The study showed that the rated fuel consumption of improved engines has been improved in comparison to conventional type and it is about 700 ton per month. Therefore, significant reduction in air pollution, which is about 38 tons of* CO_2 *per month, was achieved.*

Key words: Air pollution, Fuel consumption, Marine engines, NITC.

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1. Introduction

Ocean transportation is in charge of 90% of world wide good trading. The International Maritime Organization (IMO) has indicated that international seaborne trade has been increased about 500% over the last 40 years, with a commensurate rise in the amount of air pollutants and emissions of greenhouse gases from marine shipping (Ching, 2012).

The internal combustion engines play an important role in sea transportation; however, in recent years, serious concerns have been raised regarding the environmental impact of the gaseous and particular emissions arising such as: NO_x, SO_x, CO, NO_x Nitrogen Oxide and Sulphur Oxide ( ).1 ure(Fig, HC , and CO_2 & SO_x) are harmful to human health and cause respiratory diseases. N_2O or Nitrous Oxide, also known as laughing gas, is one of the air pollutants that cause global warming.

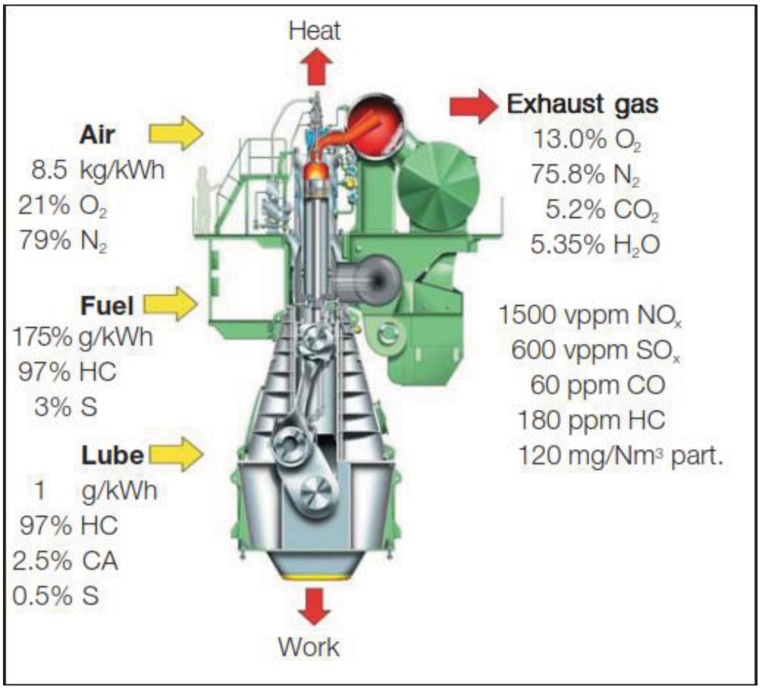


Figure 1. Input and output of a typical two stroke diesel engines (Emission Control MAN B&W Two-stroke Diesel Engines)

MARPOL 73/78 Annex VI, as “Regulations for the prevention of air pollution from ships”, entered into force on 19 May 2005, containing regulations on NO_x, SO_x and Particulate Matter (PM) emissions. On July 1, 2010 the revised MARPOL Annex VI entered into force and it contains new limits for NO_x emissions for both new and existing ships as well as reduced SO_x and PM emission for all ships (Revised MARPOL Annex IV, Regulations for the Prevention of Air Pollution from Ships and NO_x Technical Code 2008).

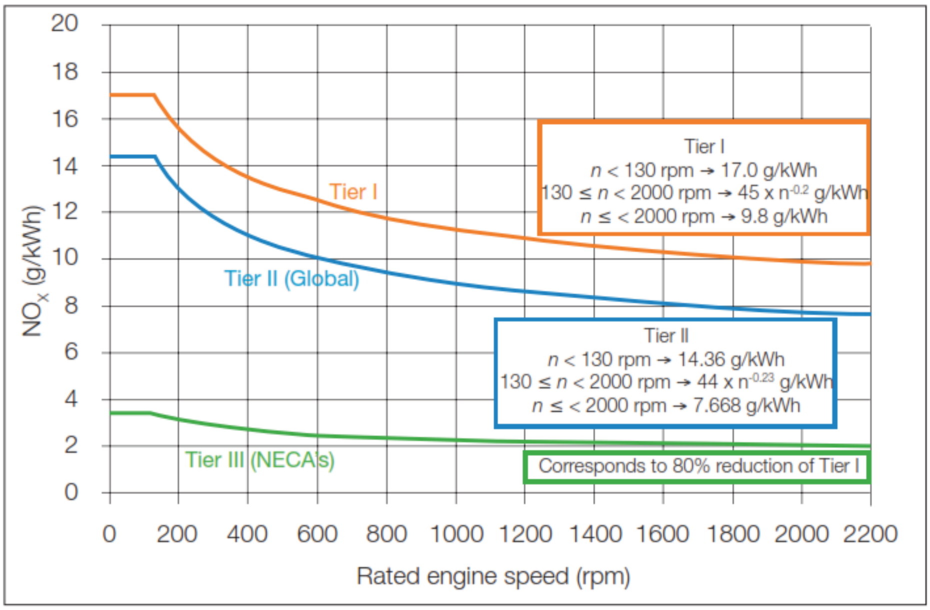


Figure 2. IMO NO_x limits (Exhaust Gas Emission Control Today and Tomorrow)

Allowable NO_x emissions are reduced to 14.4 g/kWh for large marines with low speed engines (below 130 rpm) from January 1, 2011 and onwards. However, according to the Tier III standard in designated emission control areas, the allowable NO_x emissions must be less than 4 g/kWh for engines installed on ships from January 1, 2016 and onwards (see Figure 2).

To get prepared for coming regulations, general investigations and extensive researches are carried out continuously. As shown in Figure 3, quite a number of emission control measures have already been developed, and are in use by the industry today (Emission Control MAN B&W Two-stroke Diesel Engines).

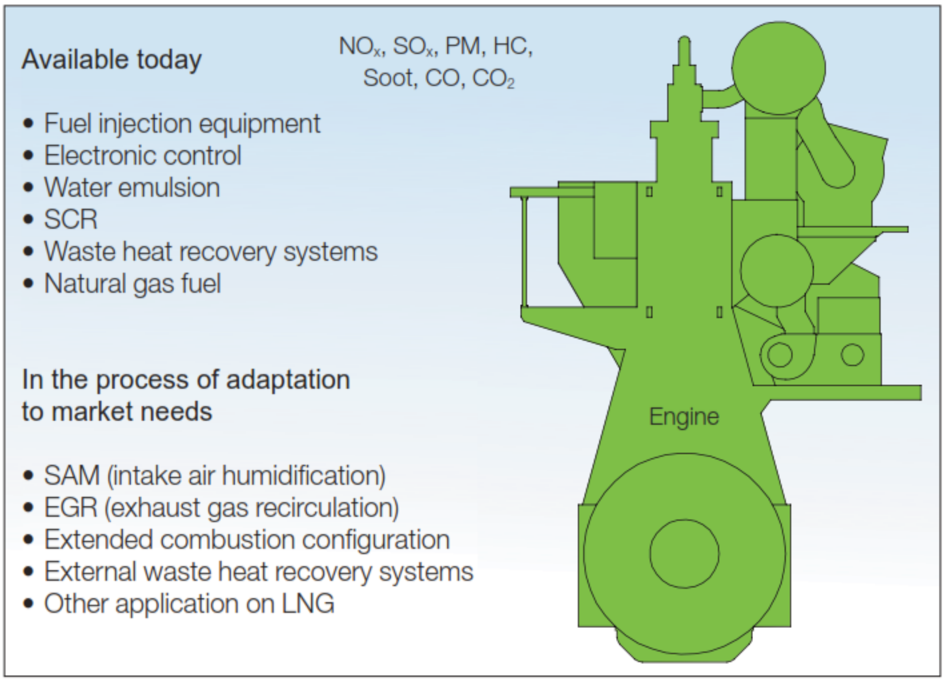


Figure 3. Emission reduction methods (Emission Control MAN B&W Two-stroke Diesel Engines)

One of the methods to meet these demands is using common rail system or electronically controlled system. Recent advances on electronically controlled engine have shown that the unique shaping of engines makes it possible to lower NO_x emissions with none or very little effect on fuel efficiency. So the expected NO_x limitations of MARPOL Annex VI will be met by engines.

Varioue reseach investigations to lower the engine emission have already been conduted, (Bianchi et al., 2002; Bruneaux, 2011; Celikten, 2003; Catania et al., 2008; Guang et al., 2012; Lee et al., 2005; Kuti et al., 2013; Payri et al., 2012; Tziourtzioumis and Stamatelos, 2012; Ubertini, 2006; Ye and Boehman, 2012;). For instance, Tziourtzioumis and Stamatelos (2012) introduced the common rail, high pressure direct injection engine, based on Electronic Control Unit (ECU). Celikten (2003) studied the effects of injection pressure on engine performance and exhaust gas emissions. In another study, Guang et al., (2012) investigated the effect of common rail system's injection timing and rail pressure on high-power diesel's fuel economy and emission characteristics. In a separate research, Bianchi et al., (2002) stated that the rail pressure is affected by the system dynamics due to the limited volume capacity of the rail. Bruneaux (2011) studied the diesel injection spray structure in common rail diesel engines and confirmed that the more the injection pressure increases the more distributed vapour mixing appears and as the result a better combustion was happened. The effect of water-fuel oil mixture on the exhaust gas emission was investigated by Sarvi et al., (2009). Lee et al., (2005) investigated the atomization and combustion characteristics of biodiesel blends in a common-rail diesel engine at various operating conditions.

The literature survey indicated that although there are valuable research studies on marine engine technology, the research studies on the energy performance of the installed engines in the Iranian shipping lines in real situation are limited and actually none. To this end, this study was conducted and the major purpose is to evaluate the performance of conventional and improved installed marine engines in terms of energy and environmental pollutions in real operating conditions. The study was conducted in NITC as the one of the major shipping lines in Iran.

2. Marine Engines

In this section, the technical specifications of the considered conventional and improved marine engines are explained. Figure 4 shows the schematic layout of the marine engines in this study.

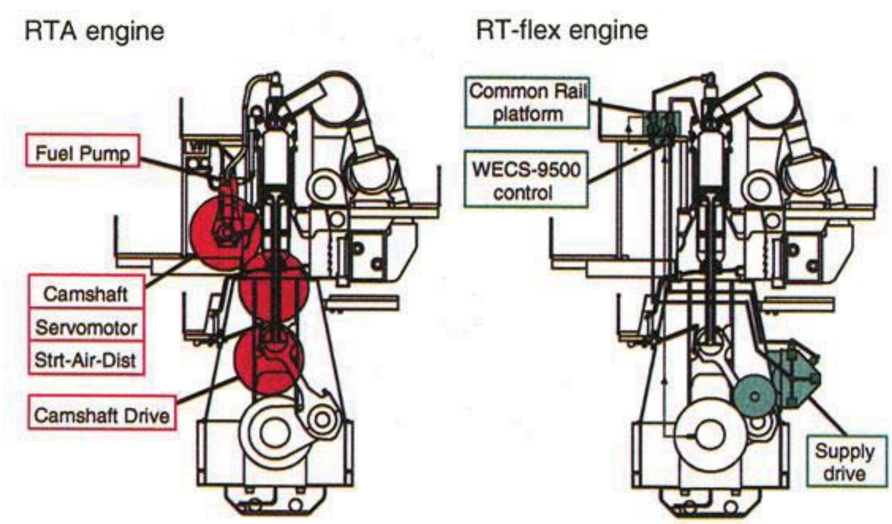


Figure 4. Schematic of the conventional (RTA) and improved (RT-flex) engines

2.1. Conventional design engines

Sulzer RTA-T engine as the conventional marine engines has been chosen as the case study in this study. Sulzer RTA-T series engines have a well-proven type of structure, with a 'gondola'-type bedplate surmounted by very rigid, A-shaped double-walled columns and cylinder blocks, all secured by pre-tensioned vertical tie rods. The whole structure is very sturdy with low stresses and high stiffness. The RTA-T has three fuel injection valves symmetrically distributed in the cylinder cover. Anti-corrosion cladding is applied to the cylinder covers downstream of the injection nozzles to protect the cylinder covers from hot corrosive or erosive attack. The piston of the RTA-T comprises a forged steel crown with a short skirt. Combined jet-shaker oil cooling of the piston crown provides optimum cooling performance. It gives very moderate temperatures on the piston crown with a fairly even temperature distribution right across the crown surface. There are three uncooled fuel injection valves in each cylinder cover. The RTA-T series is uniflow scavenged with air inlet ports in the lower part of the cylinder and a single, central exhaust valve in the cylinder cover.

2.2. Improved design engines

Sulzer RT-flex engines are essentially standard Sulzer RTA low-speed two-stroke marine diesel engines except that instead of the usual camshaft and its gear drive, fuel injection pumps, exhaust valve actuator pumps, reversing servomotors, and all their related mechanical control gear, they are equipped with a common-rail system for fuel injection and exhaust valve actuation, and full electronic control of engine functions (Figure 5).

There are four principal elements in the Sulzer RT-flex common-rail system: the rail unit along the side of the cylinders, the supply unit on the side of the engine, a filter unit for the servo oil, and the integrated electronic control system, including the crank angle sensor (Wärtsilä, 2004).

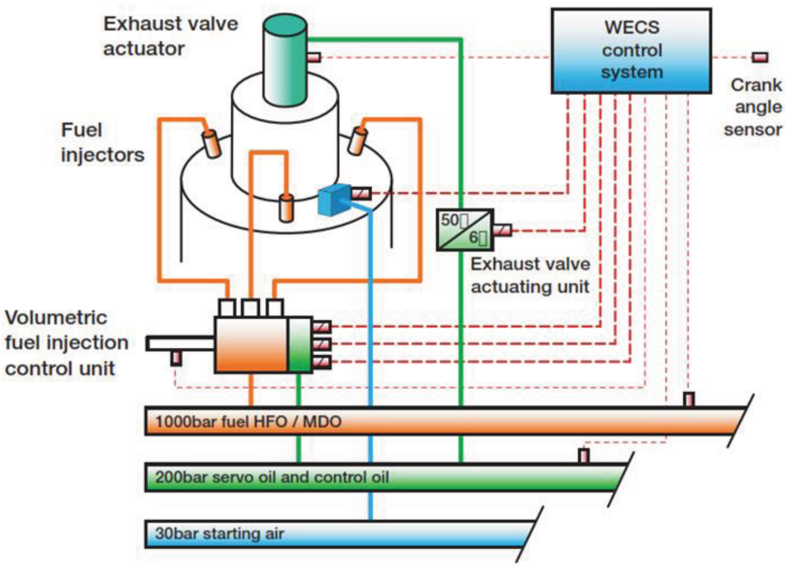


Figure 5. Schematic of the common-rail systems in Sulzer RT_flex engines (Wärtsilä, 2004)

3. Research Methodology

The present research work were conducted on NITC's tankers in seagoing condition for conventional (Sulzer RTA type) and improved (Sulzer RT-flex type) engines and data were collected from the first day of January till twenty second of April in 2013. The monitoring of main engine fuel consumption were made in ballast, full load conditions, maneuvering, and full steaming of seagoing conditions, which means when the engine is moving with its nominal consumption rate. In addition, the process of data collection is divided into three stages, which for each of them junior engineer takes the ullage of service tank and all storage tanks. The first stage is taking the ullage of all fuel tanks in the vessel before the ship goes to maneuvering condition. The second stage is when the ship leaves the maneuvering condition and prepared to stop or get full steaming in its way. The third stage is done at noon every day. The collected data in every ship is sent to NITC office everyday in the form of report.

The conventional engines type, which is under operation in NITC is Sulzer 7RTA-84 and the improved engine is 7RT-flex82 at which 84 and 82 indicate cylinder liner bores (840 mm and 820 mm) and the number 7 indicates the number of cylinders.

4. Results and discussion

4.1. Conventional engines

The Sulzer RTA engine fuel consumption in ballast and full condition and also in maneuvering and full steaming seagoing condition were collected and were reported in a course of several months. Then, data were categorized in the form of general fuel consumption and distance covered by main engine and also the average speed of them, which were divided into separated conditions.

In Figure 6, the fuel consumption for two supertankers namely, HORMOZ and HENGAM is shown and the rated fuel consumption can be calculated using the following equation:

Rated fuel consumption= Fuel consumption / Distance covered by Main Engine (M/E)

Therefore, the rated fuel consumption is 0.163 Ton/Mile and 0.179 Ton/Mile for HORMOZ and HENGAM, respectively in ballast and maneuvering condition, (see Figure 6).

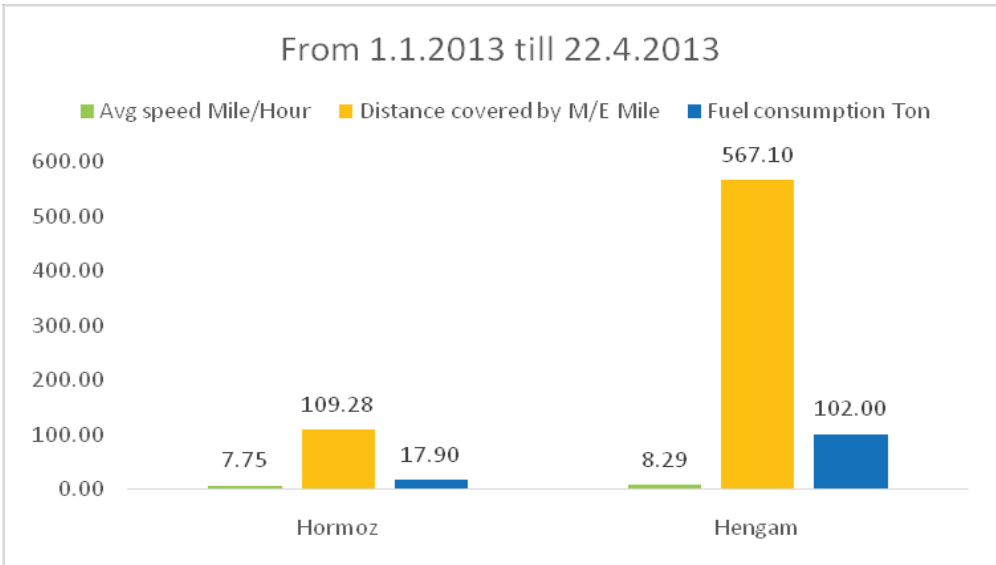


Figure 6. NITC supertankers main engine fuel consumption (Sulzer 7RTA84) in ballast and maneuvering condition

And also the rated fuel consumption for four NITC tankers in full load and maneuvering conditions are 0.205 Ton/Mile for HORMOZ, 0.343 Ton/Mile for HAMOON, 0.175 Ton/Mile for HENGAM, and 1.052 Ton/Mile for HARSIN, see Figure 7.

The data in maneuvering condition showed increasing rated fuel consumption, while the average speed increased and also the rated fuel consumption is directly affected by the draft of vessel which means that if draft of the vessel increased due to load on it, then the rated fuel consumption will be increased because of high resistance of sea water.

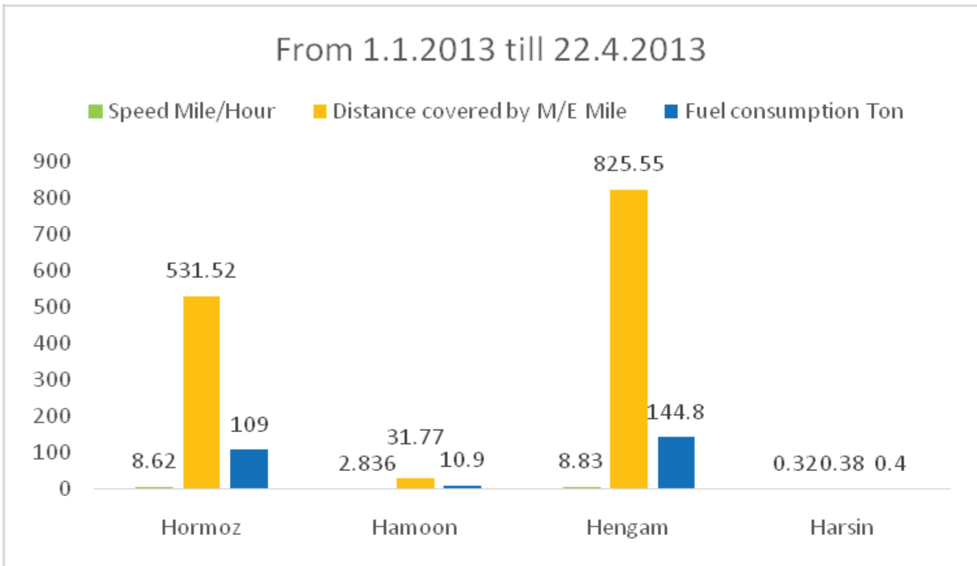


Figure 7. NITC supertankers main engine fuel consumption (Sulzer 7RTA84) in full load and maneuvering condition

According to Figures 8 and 9, the rated fuel consumption of conventional engines in full steaming condition in ballast and full load condition are as below:

- In ballast condition: 0.193 Ton/Mile for HORMOZ and 0.194 Ton/Mile for HENGAM.
- In full load condition: 0.190 Ton/Mile for HORMOZ, 0.278 Ton/Mile for HAMOON, 0.202 Ton/Mile for HENGAM and 0.164 Ton/Mile for HARSIN.

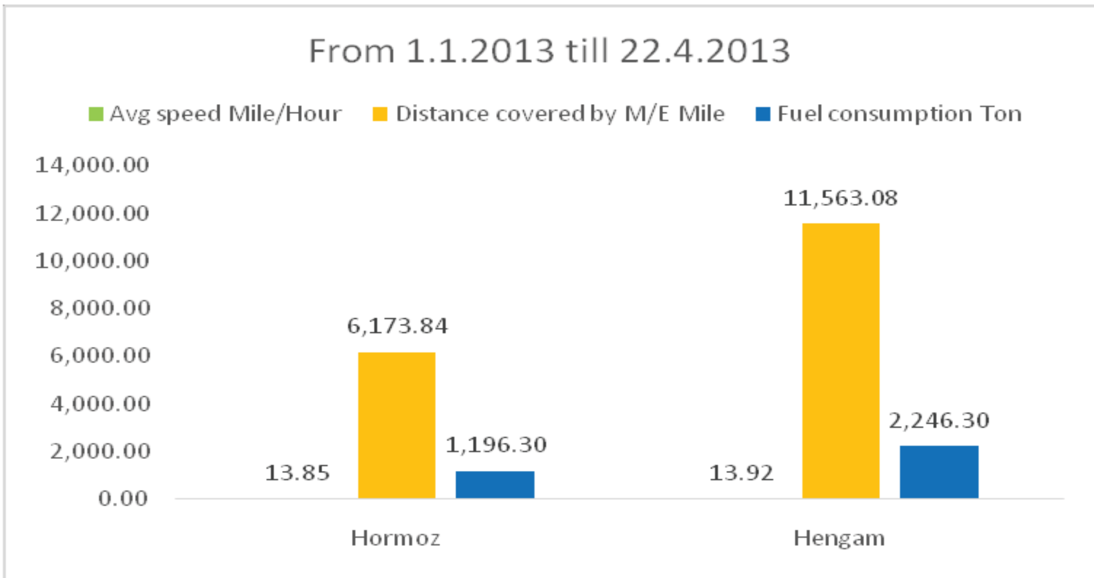


Figure 8. NITC supertankers main engine fuel consumption (Sulzer 7RTA84) in ballast and full steaming condition

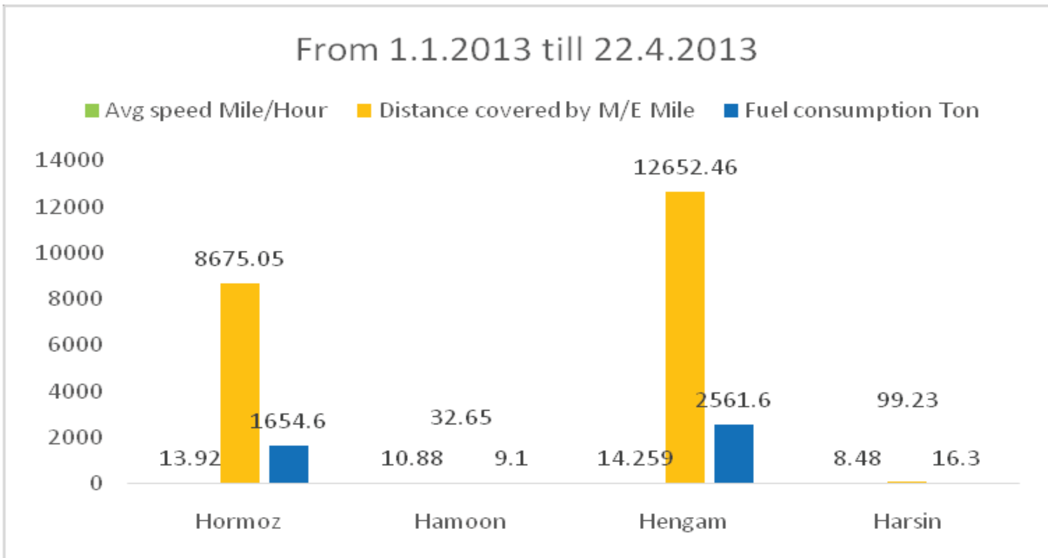


Figure 9. NITC supertankers main engine fuel consumption (Sulzer 7RTA84) in full load and full steaming condition

4.2. Improved engines

The Sulzer RT-flex engine fuel consumption data in ballast, full load, maneuvering, and full steaming conditions were collected and are presented.

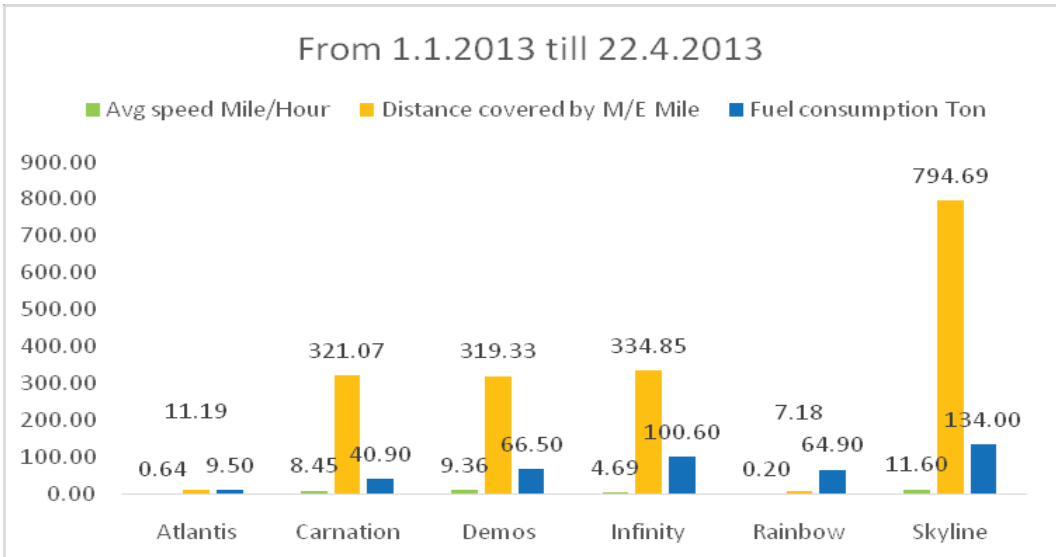


Figure 10. NITC supertankers main engine fuel consumption (Sulzer RT-82flex) in ballast and maneuvering condition

Based on Figure 10, the rated fuel consumption of NITC tankers can be determined as below:

- 0.848 Ton/Mile for ATLANTIS, 0.127 Ton/Mile for CARNATION, 0.208 Ton/Mile for DEMOS, 0.3 Ton/Mile for INFINITY, 0.168 Ton/Mile for SKYLINE.

And based on Figure 11 the rated fuel consumption are as below:

- 0.318 Ton/Mile for ATLANTIS, 0.162 Ton/Mile for CARNATION, 0.103 Ton/Mile for DEMOS, 0.157 Ton/Mile for INFINITY, 0.231 Ton/Mile for SKYLINE.

According to the determined values, the rated fuel consumption is normally increases in full load condition compared with ballast condition.

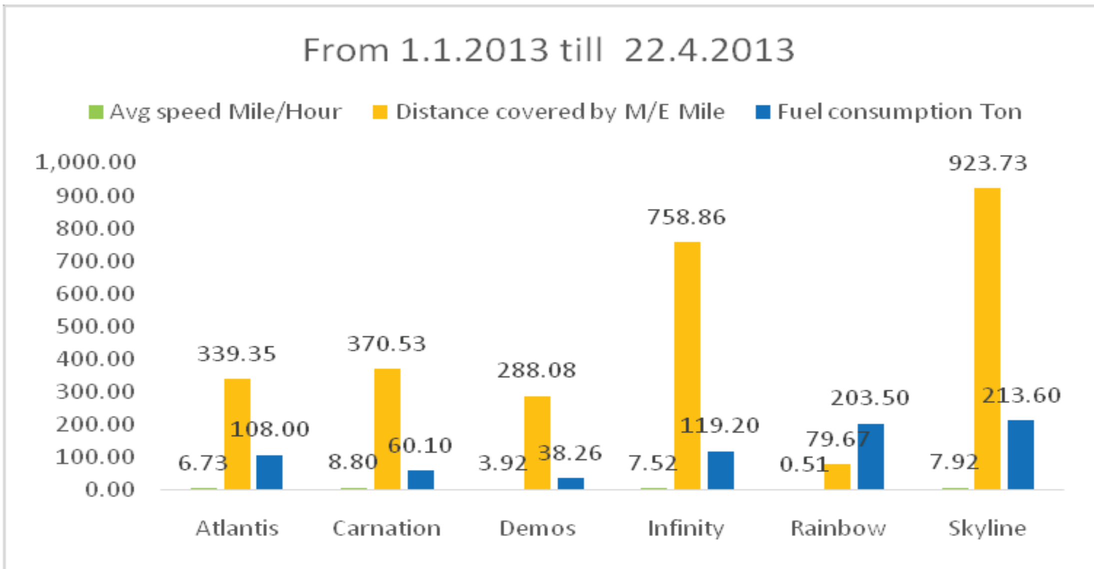
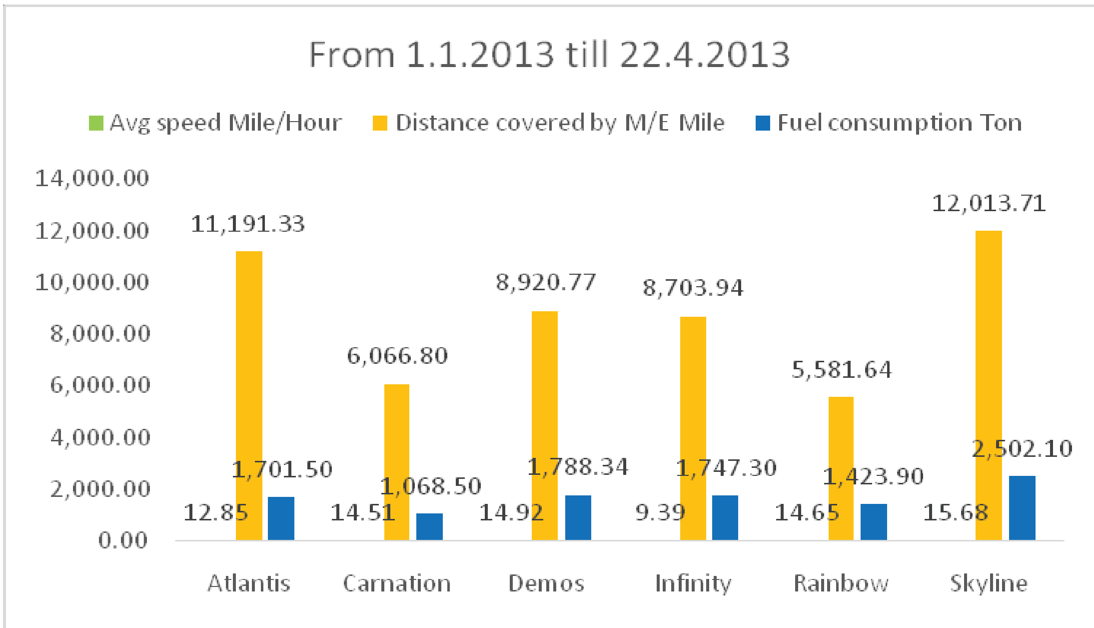


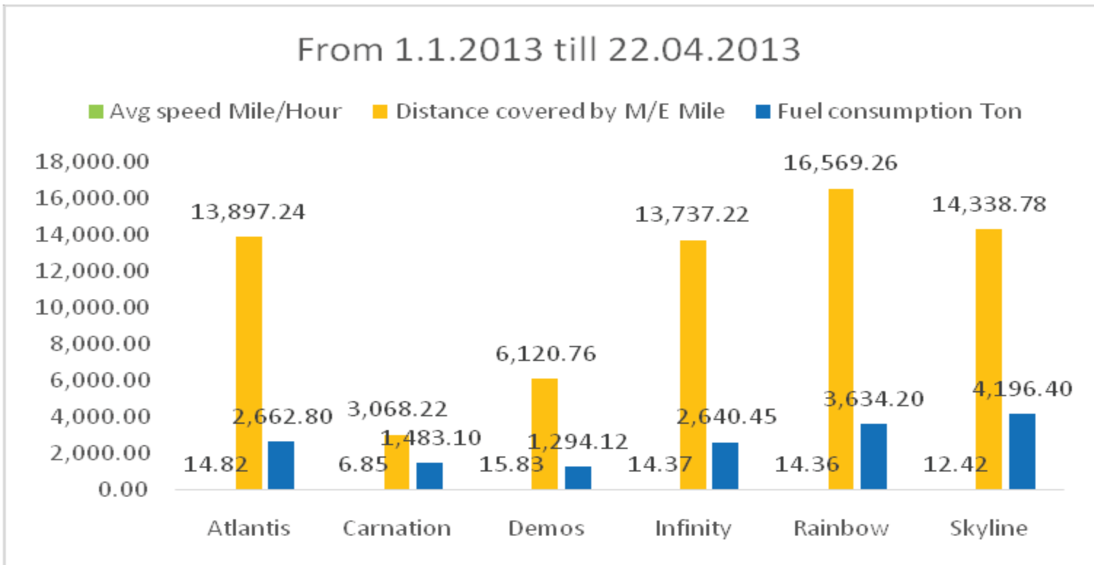
Figure 11. NITC supertankers main engine fuel consumption (Sulzer RT-82flex) in full load and maneuvering condition

In the full steaming condition, when the vessels are in ballast or in full load condition, the rated fuel consumption is as (Figures 12 and 13):

- In ballast condition: 0.191 Ton/Mile for ATLANTIS, 0.176 Ton/Mile for CARNATION, 0.2 Ton/Mile for DEMOS, 0.2 Ton/Mile for INFINITY, 0.254 Ton/Mile for RAINBOW, and 0.208 Ton/Mile for SKYLINE.
- In full load condition: 0.191 Ton/Mile for ATLANTIS, 0.483 Ton/Mile for CARNATION, 0.211 Ton/Mile for DEMOS, 0.192 Ton/Mile for INFINITY, 0.219 Ton/Mile for RAINBOW ,and 0.292 Ton/Mile]for SKYLINE.



Figures 12. NITC supertankers main engine fuel consumption (Sulzer RT-82flex) in ballast and full steaming condition



Figures 13. NITC supertankers main engine fuel consumption (Sulzer RT-82flex) in full load and full steaming condition

The overall fuel consumption and rated fuel consumption for the conventional and the improved marine engines are illustrated in Figure 14 to make the comparisons more convenient. In Figure 14, the rated fuel consumptions in different operating conditions are shown.

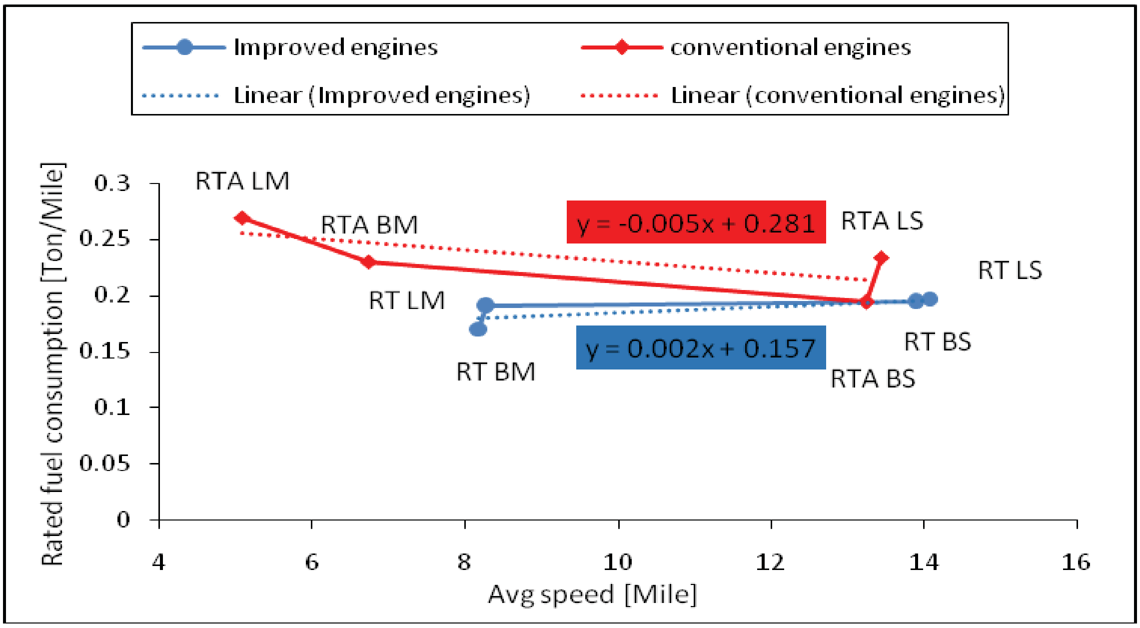


Figure 14. The rated fuel consumption for the conventional and improved engines; LM (load and maneuvering), BM (Ballast and maneuvering), LS (Load and steaming), and BS (Ballast and steaming)

According to the Figure 14, the rated fuel consumption of improved engines are lesser than conventional one and this situation is more obvious when the engine is running in low power or RPM. In another words, the improved engines operate more efficient than the conventional engines. However, in speeds higher than 13 Mile/Hour the rated fuel consumption in improved engines are approximately equal to conventional ones.

A correlation is also presented for the engines to predict the rated fuel consumption at different speeds, which x stands for speed in Mile per hour and Y is for rated fuel consumption in Ton/Mile.

4.3. Environmental Protection

As mentioned above, by employing the improved engines, a great amount of energy could be saved. In this section, the roll of improved engines in environmental protection is presented. For this purpose, the composition of the exhaust gas products of a diesel engine is considered. Figure 15 shows the composition of the exhaust gas products of a diesel engine burning fuel with an average 3% Sulphur content.

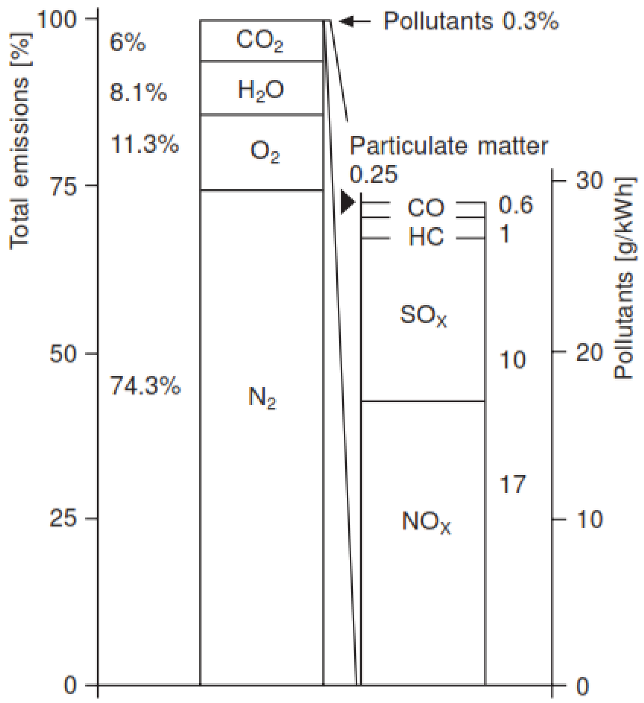


Figure 15. Typical composition of the exhaust gas products of a diesel engine burning fuel (HFO) with an average 3% Sulphur content (Woodyard, 2004)

The analysis indicates that NITC has saved up to 2900 Ton of HFO (fuel) within 1.1.2013 till 22.4.2013, which is about 700 ton/month. By application of Figure 15, the amount of reduction in exhaust gas emission were determined and tabulated in Table 1.

It is clear that the improved engines plays an important role in marine pollution reduction and also helps ship owners to comply with IMO regulation for prevention of ships air pollution (Annex VI).

Table 1. The exhaust gas emission reduction (Tone) in NITC supertankers equipped with improved engines

	NO_x	SO_x	CO_2	CO	HC
ballast &maneuvering	0.234	0.093	8.624	0.0093	0.0281
ballast & full steaming	0.468	0.186	17.248	0.0186	0.0562
load &maneuvering	0.170	0.068	6.272	0.0068	0.0204
load & full steaming	0.192	0.076	6.272	0.0076	0.023
Overall	1.064	0.423	38.416	0.0423	0.1277

5. Conclusion

In this research, the rated fuel consumption in two generations of the marine engines being employed in NITC was compared. To this end, data were collected from some under operation engines and data were analyzed in different operating conditions namely, load and maneuvering, ballast and maneuvering, load and steaming, and ballast and steaming. Data were categorized and the rated fuel consumptions were determined. The study showed that by implementation of improved engines, NITC is capable of saving great amount of fuel, which is estimated to be about 700 ton/month.

The effect of improved engines on the air pollution was also studied. The study revealed that by employing improved marine engines, a significant amount of reduction may happen in exhaust gas emissions, which improve the shipping line compatibility with the IMO regulations in prevention of air pollution of ships.

6. Acknowledgment

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