Biodiesel- An Innovative Alternate Fuel for Maritime Transportation

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***Abstract*- Biodiesel is a most favored as an alternative substitute for the conventional diesel fuel. Various feedstock of animal fat and plant oil are used for production of biodiesel. Biodiesel helps in completion of the carbon life cycle. Maritime transport is one of the most important mode of transport in the world. Maritime transport is increasing day by day and it plays a very important role in the world's maritime environment and economy. But consumption of the fuel in the maritime transportation, increases the harmful emissions and thereby caused the polluting sea environment. Because of the sea pollution the ecology and biodiversity of the marine environment cycle drastically disturbed. With the current trend in the fuel consumption by the marine sector, and associated industries and new regulations are in place related to fuel requirements, there is a very large and strong demand for the biofuel-biodiesel. The use of biodiesel in the marine sector, itself is an innovative opportunity, in order to reduce the GHG and harmful emissions from the marine environment. This will also give an opportunity to the associated marine industries to develop the sustainable supply chain in order to build strong bio based economy.**

***Index terms*- Maritime, Biodiesel, Biofuel**

INTRODUCTION

Biodiesel contains a long chain of alkyl esters. It is produced from vegetable oil or animal fats which are chemically reacting lipids with an alcohol producing a free fatty acid ester [3]. This process is called as trans esterification. It is not possible that the biodiesel produced from different biodiesel crops to produce same quality of vegetable oil and then biodiesel. They used to vary as per type of plant or animal fats. In cold weather conditions biodiesel generally used to form a gel with the fuel.

Biodiesel contains 10% higher nitrogen oxide as compared with other petroleum products [4]. If nitrogen oxides dissolved in atmosphere, then that may cause the chances of acid rain. So, different additives such as ethanol, methanol, and nanoparticles are used in order to reduce the harmful emissions. Addition of biodiesel additives in the fuel improves the blend properties, engine performance, and improved combustion and reduced the harmful emissions from the engines.

MARINE DIESEL ENGINE

Marine Diesel engines are generally internal combustion engines in which the chemical energy of the fuel is converted in to heat energy and heat energy gets converted in to mechanical energy by burning of the fuel by various combustion techniques. Marine diesel engines are mainly used for main propulsion and for an auxiliary power. In shipping sector there are crude oil tankers, bulk carriers, LNG vessels and container vessels which requires the huge amount of power to in order to propel these ships in the sea. Needless to say, more than 90% of the vessels are propelled by large and the slow speed marine engines which are coupled to the propeller. In last 10 years there are considerable developments in the field of design, carriage capacity, safety, fuel efficiency and maintenance of these large, low speed marine diesel engines which propels these huge ships. Also, IMO (International Maritime Organization) led down the stringent norms and regulation on the emissions from the marine diesel engines in order to secure pollution free sea environment. Figure 1 shows the total number of ship worldwide, by the size. Figure 2 shows the gross

tonnage of the ships worldwide, by the size. Similarly Figure 3 shows the world fleet-total number of ships, by age and size and figure 4 shows the Ship size growth (100 Index-DWT)

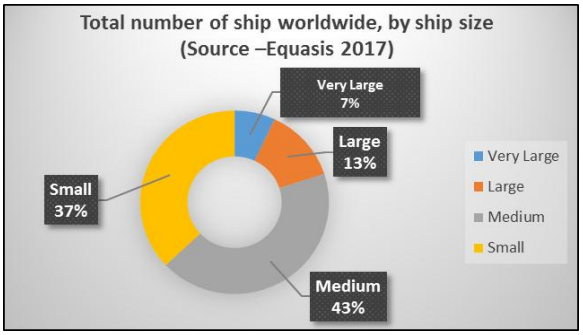

Figure 1- Total number of ship worldwide, by the size [1]

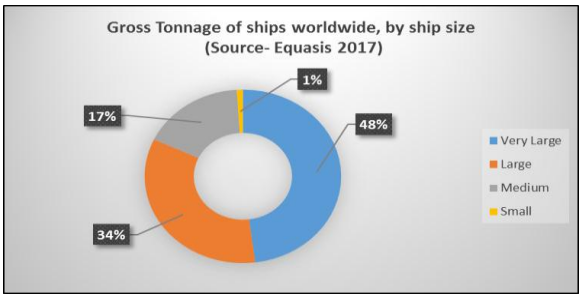

Figure 2- Gross tonnage of ships worldwide, by the size [1]

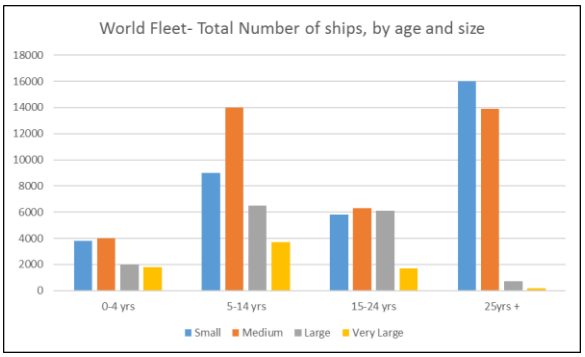

Figure 3 – World Fleet-Total number of ships, by age and size [1]

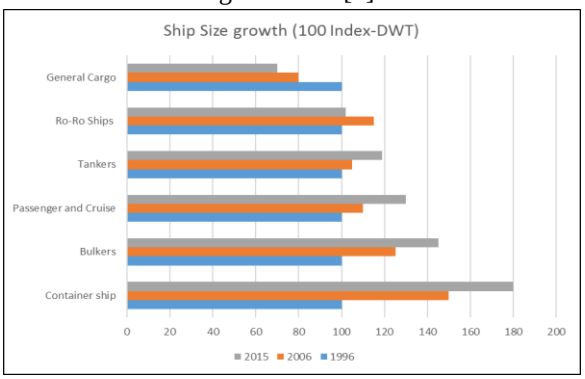

Figure 4- Ship size growth (100 Index-DWT) [1]

MARINE FUELS

Marine fuels are also called as bunker fuels and classified in to two different categories as heavy fuel oil and distillates. In latter stage distillates were known as marine gasoil (MGO). Specially gasoil contains the distillates. Marine gasoil are those type of fuels which condense from gas phase to liquid phase. They are used to be similar to diesel oil but possesses a high density. Heavy fuel oil includes low sulfur fuel oil, high sulfur fuel oil and ultra-low sulfur fuel oil. Generally, the heavy fuel oil used to blend with distillate and called as marine diesel oil (MDO) or intermediate fuel oils (IFO). Large ships are propelled with heavy fuel oil and marine diesel oil, whereas, smaller one such as barges used the marine diesel oil in place of heavy fuel oil as fuel. Heavy fuel oils are used in ships in ship for generation of power which propels the ship. In the MARPOL Marine Convention of 1973, heavy fuel oil is defined either by a density of greater than 900 kg/m³ at 15°C or a kinematic viscosity of more than 180 mm²/s at 50°C. Heavy fuels are mainly also called as marine fuel and now a day's marine fuels are used world widely in small to larger ship as well as in low speed to high speed ships as main fuel. The sulfur content in the marine fuel oils is the main differentiator between LSFO, HSFO and ULSFO. According to ISO 8217, their maximum sulfur content must not exceed 3.5%. The following main classes with regard to the sulfur content can be distinguished as shown in Table 1.

Table 1 Marine Fuels with limitation on Sulfur content.

Marine fuel	Max. sulfur content
High sulfur fuel oil (HSFO)	3.5%
Low sulfur fuel oil (LSFO)	1.0%
Ultra low sulfur fuel oil (ULSFO)	0.1%

Hence, to reduce the carbon footprints in the shipping sector, the cleaner fuel requirements are in line in the shipping sector by using the different types of biofuel such as biodiesel, methanol etc [9]. But the life cycle assessment of each fuel is required in this regard in order to justify a strong candidature of biofuel as

alternative fuel for shipping sector. Many scientist and researcher concluded that biodiesel is a cleaner fuel, less expensive and renewable fuel with no sulfur contain and able to give a clean emission as compared with other alternative fuel [10]. Figure 5 shows the annual fuel consumption of different types of ship or carriers in the shipping sector.

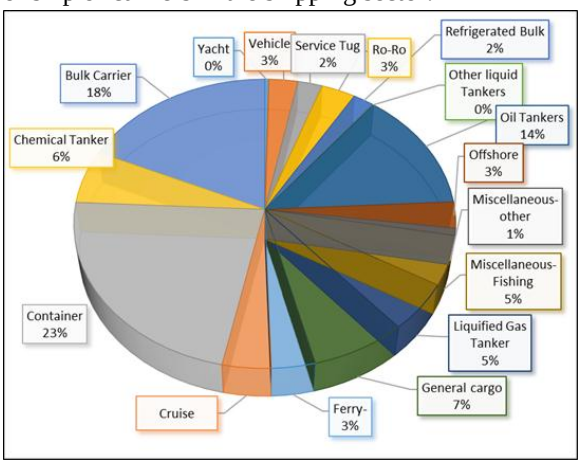

Figure 5 Annual fuel consumption of different types of ships

BIODIESEL APPLICATION

Although the biodiesel proves himself a strong alternative fuel, still there are limited usage of biodiesel as main fuel despite its low emission characteristics, low sulfur contains [5]. Biodiesel suppliers market has huge potential to fulfill the need of marine shipping sector and at the same time to satisfy the stringent regulations which are laid down by international bodies of shipping sector such as IMO. There are other engine technology which allows the blending of biodiesel up to 20% as per ISO 8217:2017 [7]. Table 2 shows the different application of the biofuel in concerned of shipping sector. Despite of all these advantages, the cost of the biofuels and availability of the biofuels in order to meet global demand, are the two major barriers to have them as fuel in the marine shipping sector [6]. Table 3 shows the biodiesel requirements for 6% biodiesel (B6) to 20% biodiesel (B20) as and listed in ASTM D7467.

Table 2 Application of the biofuels [2]

Biofuel	Application
Bio-DEE/DME (Dimethyl ether, Diethyl ether)	Carriers and cargo ships
Straight vegetable oil (SVO)	Carriers and cargo ships, Ferries
Bio-LNG	LNG carriers, ferries, support vessels, tugboats ,cruise ships
Bio-Alcohols	Cruise ships, tankers, passenger ships
Biodiesel	Tugboats, small carriers, cargo ships

Table 3 Biodiesel requirements for 6% biodiesel (B6) to 20% biodiesel (B20) as and listed in ASTM D7467 [2]

Property	Test Method	Grade B6 to B20 S15 B6 to B20 S500 j B6 to B20 S5000		
Acid number, mg KOH/g, max.	D664	0.3	0.3	0.3
Viscosity, mm^2/s at 40°C	D445	1.9-4.1	1.9-4.1	1.9-4.1
Flash point, °C, min	D93	52	52	52
Cloud point, °C, max or LTFT/CFPP, °C, max	D2500, D4539, D6371			
Sulfur Content, (µg/g or ppm) mass %, max. mass %, max.	D5453 D2622 D129	15— —	— 0.05 —	— — 0.50
Distillation temperature, °C, 90% evaporated, max	D86	343	343	343
Rams bottom carbon residue on 10% bottoms, mass %, max.	D524	0.35	0.35	0.35
Cetane number, min	D613	40	40	40
(1) Cetane index, min	D976-80	40	40	40
(2) Aromaticity, vol %, max.	D1319-03	35	35	—
Ash Content, mass %, max.	D482	0.01	0.01	0.01
Water and Sediment, vol %, max.	D2709	0.05	0.05	0.05
Copper Corrosion, 3 h @ 50°C, max	D130	No. 3	No. 3	No. 3
Biodiesel Content, % (V/V)	D7371	6.–20.	6.–20.	6.–20.
Oxidation Stability, hours, min.	EN15751	6	6	6

Lubricity, HFRR @ 60°C, (micron µm),	D6079	520	520	520
Conductivity (pS/m) or Conductivity Units (C.U.), min	D2624/D 4308	25	25	25

ADVANTAGES OF BIODIESEL [11]

1. Produced from the existing renewable resources.
2. Biodiesel can be used in existing marine diesel engine without any modification.
3. GHG emissions are less in case of biodiesel combustion.
4. Feedstock of biodiesel can be grown, produced and distributed locally.
5. They are cleaner fuel and non-toxic.
6. They are able to give and sustain good fuel economy.
7. Use of biodiesel in the shipping, will able to provide a good and long term economic gain to the ship owner.
8. Less dependency on import of oil from the other countries.
9. And most importantly good health and environmental impacts on usage.

DISADVANTAGES OF BIODIESEL [11]

1. Not suitable to use as it is because of higher cloud and pour point.
2. Quality of biodiesel depends on the type of feedstock.
3. It may cause the problem of food shortage.

CONCLUSIONS

Within the transportation industry, maritime shipping is the fastest mode of developing sector and also able to contribute to the world's economy. In order to sustain in the market maritime shipping always depends on the cost effective solutions towards the machinery, human resource and also fuel consumption.

In order to meet current regulation related to the engine emission, maritime industry has to look towards the alternative fuels. Biodiesel is the most efficient and proved candidature for the maritime shipping as fuel because his advantages and low emissions characteristics. The use of biodiesel in the maritime shipping will able to develop the huge amount of infrastructure, supply chain management, transportation and distribution and sustainable bio-economy.

REFERENCES

[1] IRENA (2019), Navigating to a renewable future: Solutions for decarbonising shipping, Preliminary findings, International Renewable Energy Agency, Abu Dhabi

[2] IEA Bioenergy (2017), Biofuels for the marine shipping sector: An overview and analysis of sector infrastructure, fuel technologies and regulations,Chia-wen Carmen Hsieh, Claus Felby, Innovation Fund Denmark

[3] Madiwale, S., Karthikeyan, A. & Bhojwani, V. 'Properties investigation and performance analysis of a diesel engine fuelled with Jatropha, Soybean, Palm and Cottonseed biodiesel using Ethanol as an additive'. Materials Today: Proceedings. 5, 657–664 (2018).

[4] Madiwale, S., Bhojwani, V., 'An Overview on Production, Properties, Performance and Emission Analysis of blends of Biodiesel', Procedia Technology 25, 963 – 973, 2016.

[5] Mo, M., Rasul, M. G., Hyde, J., Azad, A. K., Mamat, R., & Bhuiya, M. M. K. (2016). Role of biofuel and their binary (diesel – biodiesel) and ternary (ethanol – biodiesel – diesel) blends on internal combustion engines emission reduction, 53, 265–278.

[6] Shahir, S. A., Masjuki, H. H., Kalam, M. A., Imran, A., Fattah, I. M. R., & Sanjid, A. (2014). Feasibility of diesel–biodiesel–ethanol/bioethanol blend as existing CI engine fuel: An assessment of properties, material compatibility, safety and combustion. Renewable and Sustainable Energy Reviews, 32, 379–395.

[7] Agarwal, A. K. (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science, 33(3), 233–271. doi:10.1016/j.pecs.2006.08.003

[8] Aransiola, E. F., Ojumu, T. V, Oyekola, O. O., & Madzimbamuto, T. F. (2013). ScienceDirect A review of current technology for biodiesel production : State of the art. Biomass and Bioenergy, 61, 276–297. doi:10.1016/j.biombioe.2013.11.014

[9] Ashraful, A. M. M., Masjuki, H. H. H., Kalam, M. A. A., Fattah, I. M. R., Imtenan, S., Shahir, S. A. A.,Mobarak, H. M. M. (2014). Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: A review. Energy Conversion and Management, 80, 202–228. doi:10.1016/j.enconman.2014.01.037

[10] Rashedul, H. K., Masjuki, H. H., Kalam, M. A., Ashraful, A. M., Ashrafur Rahman, S. M., & Shahir, S. A. (2014). The effect of additives on properties, performance and emission of biodiesel fuelled compression ignition engine. Energy Conversion and Management, 88, 348–364. doi:10.1016/j.enconman.2014.08.034

[11] Saxena, P., Jawale, S., & Joshipura, M. H. (2013). A Review on Prediction of Properties of Biodiesel and Blends of Biodiesel. Procedia Engineering, 51(NUiCONE 2012), 395–402. doi:10.1016/j.proeng.2013.01.055