Tugboat Engine Modification Using Biodiesel Fuel: Bridging the Policy-Industry Gap in Indonesia

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Abstract. Transitioning the use of fossil fuels to biofuels such as biodiesel is one solution for the country to ensure energy security, environmental quality, security and poverty alleviation. Indonesia is one of the countries that is trying to implement the use of biodiesel with the support of adequate natural resources and biofuel producing industries. The transportation sector, especially ships, is one of the largest markets for biodiesel consumers. The sustainability of biodiesel use is very dependent on government policies and industry. In using biodiesel, especially on ships, there are several obstacles. One of them is damage to machinery components which has an impact on reducing ship performance. This research examines the strategies used by the shipping industry to overcome the impact of biodiesel use on ships, then several recommendations are also given to the government to support the commercial use of biodiesel. From the research conducted, it was concluded that the addition of a fuel filter makes the quality of biodiesel cleaner and clearer and minimizes damage to engine components. Furthermore, it is necessary to increase research in the field of biodiesel production technology, for example non-catalytic processes to commercially produce biodiesel with good quality and competitive prices with fossil fuels.

Keywords: ship; diesel engine; biodiesel; maintenance

1 Introduction

In 2021, Indonesia's primary energy sources, around 87.8% of the total, depend on coal, oil and natural gas. In addition, the transportation sector, which is the largest energy consumer, meets 93.8% of its needs with petroleum-based fuel (Adi, 2021). High dependence on fossil fuels has two significant implications: first, this puts pressure on foreign exchange reserves due to the need for imports (Fitriana, 2021), and secondly, it can cause an increase in greenhouse gas (GHG) emissions as a result of burning hydrocarbons originating from fossil energy sources. Furthermore, the Paris Agreement mandates that the Indonesian government is obliged to submit a report on its contribution to reducing GHG emissions as detailed in the Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCC). Therefore, several policies have been established by the government in order to transition the use of fossil fuels to biofuels, thereby ensuring security and energy resilience, alleviating poverty, and improving the quality of the environment (Wirawan, 2023).

P. M. Latuheru et al. (eds.), *Proceedings of the International Conference of Inland Water and Ferries Transport Polytechnic of Palembang on Technology and Environment (IWPOSPA-T&E 2023)*, Advances in Engineering Research 236,
https://doi.org/10.2991/978-94-6463-484-6_8

Biodiesel is a potential alternative fuel obtained from vegetable oils, animal fats or waste oils processed through esterification with alcohol. Biodiesel B30 is a mixture of 30% biodiesel with 70% solar-type fuel, which produces a biodiesel product B30 (Must, 2018). Besides, biodiesels are an alternative fuel specifically formulated for diesel engines with a variety of advantages, including no need for engine modification, easy to use, environmentally friendly, mixed with solar, has high cetane number, has a high lubricant, biodegradable, high flash point so safe from fire at room temperature, non-toxic, free of sulphur and aromatic substances (Soerawidjaja, 2015).

Biodiesel has the same physical properties as diesel fuel, so it can be used as a substitute fuel for diesel engine vehicles (Knothe, 2005; Mittelbatch, 2004). Apart from that, biodiesel is also more environmentally friendly and the raw material is abundant in Indonesia.

A number of studies have investigated the sustainability of biodiesel, examining aspects such as supply, implementation, policy, economic implications and environmental impacts. In particular, certain studies focus on specific cases in Indonesia. Yana et.al (2021) have studied the development of biomass as renewable energy in Indonesia by examining the challenges and conflicts for its sustainability. A sustainable balance between resilience and energy justice, as well as environmental issues is the key to achieving sustainable biodiesel application in the long term (Rahman, 2021). The economic impact of the current biodiesel mandate shows a positive effect for Indonesia, however further increasing of blending ratio must consider energy security, in addition to economic and environmental impacts to establish long-term sustainability policies (Sahara, 2022; Halimatussaidah, 2021). The increasing demand for biodiesel must be balanced by securing the supply side by diversifying its sources. Nabila et. all. (2023) have discussed increasing waste biomass by torrefaction and pyrolysis to obtain high quality fuel. In addition, collaboration between the State Electricity Company (PLN) and the palm oil industry can be considered to find cost-optimal pathways to achieve the sustainability environmentally friendly electricity (Sani, 2021). Similar results were presented by Usmani et al. (2023) who stated that biodiesel is a promising fuel but is not the only solution to replace fossil fuels, therefore it is necessary to explore other possibilities for sustainable fuels. (Khan, 2023). Furthermore, unsustainable biodiesel programs in other countries could be influenced by an imbalance between demand and supply, as well as inadequate regulations and fiscal policies (Li, 2023; Mutascu, 2023; Sosa-Rodríguez, 2021; Ewunie, 2021). In addition, Lo SLY et. all. (2021) have explained uncertainties in biomass supply, including availability, quality, transportation costs, market demand, and unstable prices and wages for workers. Brazil, Argentina, and Uruguay stand out as South American countries that have successfully implemented and gained positive impacts from biodiesel programs due to their good supply and supportive regulations. Meanwhile, other countries continue to struggle with challenges such as lack of biodiesel supply, dumping problems, inappropriate policies, and lack of technology (De Souz, 2022).

Indonesia has begun implementing the policy of biodiesel utilization through Minister of Energy and Mineral Resources (ESDM) Regulation No. 32/2008 which was later updated with Regulation No. 25/2013 as the first amendment, No. 20/2014 as the second amendment and continued with Regulation Number 12/2015 as the 3rd

amendment. The use of B20 is determined based on the Minister of Energy and Mineral Resources (ESDM) Regulation No. 12 of 2015, the mandatory biodiesel policy was accelerated from B10 in 2014 to B15 in 2015 and increased to B20 in 2016 to B30 starting in 2020 (Wibowo, 2019). Furthermore, based on the circular letter of the Directorate General of EBTKE No. 10.E/EK.O5/DJE/2022, in order to increase the supply of sustainable clean energy, the use of B35 is mandatory starting February 1st , 2023. So that, the government requires the use of biodiesel for sea transportation. The phasing of the minimum obligation for the use of biodiesel (B100) as a mixture of diesel fuel based on MEMR Regulation No. 12/2015, which is referred to today, is shown in Table 1.

Table 1. The phasing of the minimum obligation to utilize biodiesel (B100) as a mixture of diesel fuel based on MEMR Regulation No. 12/2015

Sector	April 2015	January 2016	January 2020	Januar 2025
Micro business, fishery, transportation and PSO	15 %	20 %	30 %	30 %
Non-PSO transportation	15 %	20 %	30 %	30 %
Power plants	25 %	30 %	30 %	30 %
Industrial and commercial	15 %	20 %	30 %	30 %

In the shipping, ship is one of the means of maritime transport that plays an important role in connecting territories or islands. Nowadays, the competition in maritime transport services is very severe, so the shipping companies prioritize good and satisfactory transportation services, including punctuality, security and safety of ship operations (Kadarisman, 2017).

Some merchant vessels operating today use diesel engines as both primary and auxiliary engines, thus greatly influencing the smooth operation of the vessel. In order to achieve good diesel motor performance, the perfect combustion process in the engine must involve the principle of the fire triangle, namely fuel, air and heat (Herlina, 2019). An inappropriate fire triangle ratio in the engine combustion chamber will result in the combustion process being incomplete. This causes a decrease in the performance of the diesel engine because not all of the fuel injected by the injector is burned, so that fuel consumption becomes inefficient and causes the power produced to be not optimal (Paliaky, 2021). Therefore, fuel quality greatly influences the smooth operation of the ship.

Along with the government's efforts to encourage renewable energy, the shipping industry face several obstacles, especially the performance of ship engines. This happens because biodiesel is characterized by high saturated fatty acid level, hygroscopicity, high viscosity, and metal contaminants from the production process. These properties can cause damage to the engine components when biodiesel fuel is used (Wirawan, 2023). One of the constraints found is that the biodiesel characteristics have a viscosity 10 to 20 times higher when compared to fossil fuels. (Suharto, 2017).

Then, in the ship's machinery, several engine parts were found to be damaged, especially the filter which were quickly broken and had to be replaced immediately (Hidayat, 2019).

To address existing research gaps, this study explores various aspects that contribute to the successful implementation of biodiesel in Indonesia. Furthermore, modifications of diesel engines on tugboats by adding fuel filters are discussed in this article. Then, recommendations were also submitted to the government for the sustainability of the biodiesel program in Indonesia.

In this study, a comprehensive review of relevant regulations, review articles, research papers, reports, book chapters, and other online resources was conducted to provide an up-to-date assessment. To collect and organize essential resources, various sources are carefully reviewed and critically evaluated. Before being submitted to critical review, these selected sources were involved in a thorough assessment to ensure representation of the latest and most reliable information available.

2 Results and Discussion

Based on the observations on tugboat operation, it was found that the pressure of the fuel pump that sucked the fuel from the storage tank decreased, resulting in the low-pressure FO pump alarm being activated. From the observations made, damage was found to the injector nozzle and injection pump plunger. An indicator that can be observed is a dirty fuel filter which causes the plunger on the injection pump and the nozzle on the injector to become stuck. Then the low quality of the fuel in the settling tank was due to the ship's fuel being mixed with water as shown in Figure 1.1.

(a) (b) (c) (d)

Figure 1.1 (a) Dirty fuel filters, (b) Nozzle damage, (c) Plunger damages, (d) Mixing of ship fuel with water

The inspection continued on the fuel storage system in the tank, because the fuel being pumped came from the fuel storage tank. After conducting extensive inspections of the settling tank and daily tank, it was found that there were large deposits of mud and water in the tank. Further, an inspection was carried out by removing the injector to adjust the pressure using a pressure testing device (test pump). It was found that the nozzle was stuck, which was indicated by the formation of droplets on the nozzle so that complete injection of fuel did not occur.

The decrease in the performance of the diesel engines on the tugboat is due to the lack of planned maintenance by the crew in maintaining the cleanliness of fuel storage tanks and also a lack of discipline in carrying out the replacement of fuel filters in accordance with the established procedures (Ardhi, 2018).

The handling of fuel in the fuel storage tank runs through fuel filtration using a filter before the fuel leaves the storage tanks in the engine room. Due to the difference in density between oil, water and mud, there is a sediment the bottom of the tank in the form of water and mud (Marsudi, 2020). The low quality of fuel that occurs in the fuel storage tanks both in the settling tank and in the daily tank, causes the smoothness of fuel handling on board the ship to be disturbed (Almuzani, 2020).

The observations found the following facts:

1. The abundance of mud and water deposits at the bottom of the settling tank.

In fuel storage tanks, especially in settling tanks, there is a lot of mud and water impurities, so settling at the base of the tank of storage. Over time, this sediment will get thicker and can affect the quality of the fuel stored in the settling tank.

2. Fuel filter does not work properly

In general, there are three types of fuel filter, namely:

a) A rough filter, placed before the transfer pump.
b) A fine filter is placed after the transfer pumps.
c) A very fine filter, located before the injection pump.

From the observations was found that the fuel contained a lot of water, mud, sulphur and carbon. Besides, the fuel filter is rarely replaced due to irregular maintenance. This causes the coarse filter, fine filter and very fine filter to become dirty so that fuel flow is blocked from entering the injection pump and injector, as shown by Figure 1.2.

Figure 1.2 Drain process of sludge from the daily tank

Then, the clogging of the movement of the plunger and the injector nozzle could be caused by fuel contaminated by water or residual dirt coming from the fuel tank. There was an abnormality of the injector performance on the diesel engine, resulting in a number of signs indicating that the diesel motor is in a state of non-maximum operation, namely:

1. Black smoke

The fuel that has been in the cylinder partially does not burn at all and comes out with the combustion gas at the discharge, so that the fuel burns in the exhaust valve.

2. A knocking sound
This is because the injector is dripping, if the mixture of fuel and air has ignited, the fuel that is sprayed during the ignition delay will burn quickly so that there will be a rapid increase in the pressure of the fuel burning gas, due to the rapid increase in pressure on the piston, then the entire motor drive moves and the vibrations can be heard from outside.

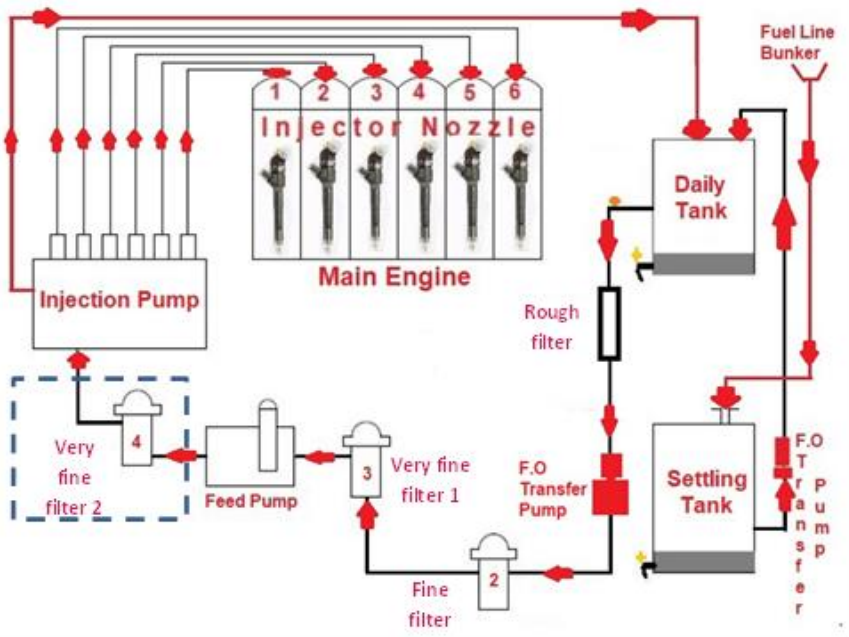
3. High exhaust gas temperature
At the end of the effective pressure stroke of the fuel pump, all high-pressure fuel will lose pressure quickly while spraying will thus also end. At that time not all the fuel in the cylinder is burned so it will be followed by additional combustion in the first part of the working stroke. If the additional combustion continues for a long time, it will result high exhaust gas temperature.

Basically, in the fuel there are elements of mud and water, both of these factors are very bad influence on the quality of the fuel (Hidayat, 2019). To overcome this condition, the author's strategy to improve the quality of fuel before entering the ship's diesel engine is to modify and add a filter. The additional filter types are the racor filter Parker 2020 PM and the FG FH 1000 racor tube, as shown in Figure 1.3.

(a) (b) (c)

Figure 1.3 (a) Parker 2020 PM Racer Filter, (b) FG FH 1000 Racer Tube, (c) Modification of the addition of fuel filters on the tugboat

As for the diagram of the tug boat ship's fuel system after the modification and addition of the fuel filter is presented in Figure 1.4.



Description: The line - - - - - - - indicates the modification made

Figure 1.4 Diagram of the Tugboat fuel system

Figure 1.4 shows that the fuel from the settling tank is transferred through the F.O transfer pump into the daily tank, then the fuel of the daily tanker through the first filtration process, i.e. on the rough filter before entering the fuel transfer pump. After that, the fuel goes through a second filtration process on a fine filter. Then the fuel is filtered again through the third filtration procedure on the very fine filter, and the fuel enters the feed pump then the fuels are filtered through the fourth filtration of the extremely fine filter before the fuel being channel into the injection pump. Then the injection pump presses the fuel oil up into the injector nozzle in the main engine to be atomized, so that the combustion process occurs in the cylinder combustion chamber on the diesel motor. The modification is the addition of a filter after the feed pump and before the injection pump, which can lead to a cleaner fuel.

By modifying the fuel pipe and adding a filter, the fuel is cleaner and clearer before entering the injections pump, thus minimizing the damage to the components of the pump and injector. Furthermore, injection in the pump and absorption in the injector nozzle remained maximum. Next, a picture of the Tugboat diesel motor that has been given the addition of the filter as showing in Figure 1.3 (c).

The advantages of modifying the fuel filter are: cleaner and clearer fuel quality, minimizing damage to components on injection pumps and injectors, and maximum injections on injection pumps as well as absorption on the injector nozzles. However, on the other hand, modifications of course cause additional costs for purchasing pipes or hoses to modify fuel pipes and purchasing racor filters.

Furthermore, the quality of the fuel stored in the fuel tank must be maintained, so that during the fuel storage process the quality of the fuel can be maintained (Cakrawardana, 2021). Efforts can be made to maximize the process of fuel treatment in terms of the storage process in fuel storage tanks includes:

a. Cleaning of settling tanks and daily tanks (daily tanks) (Immanuel, 2019). And for the daily tank that's in the Engine Room it's best to clean at least once in two weeks, so that the fuel in the Daily tank is cleaner and cleaner than the fuel. The daily tank should always be filled with at least 75% - 80% of the tank's capacity, this is to minimize the air in the tank so that moisture inside the tank can be minimized.

b. Fuel storage in the settling tank. Due to the deposition of fuel deposited in the sludge tank, impurities will settle due to having a large specific gravity Sludge or mud has a specific gravity that is greater than the specific gravity of oil, so the sludge will settle so it can be easily disposed of by drain it out of the tank. It is recommended that the drain process of the fuel tank be done every four hours, at the time of every maintenance duty. The draining process is carried out in the sediment tanks and daily tanks on board (Salsabila, 2019).

c. Fuel Filters Replacement. Fuel filters in fuel installations, both before entering the storage tank and after leaving the storage tank, are very useful for separating impurities from the fuel (Wahyudi, 2020). The filters are usually placed before the transfer pump and also before the fuel enters the injection pump. This requires a regular replacement of the filter so as not to interfere with the operation of the main propulsion diesel engine, and so that the ship runs normally without any interference caused by the fuel (Gusrah, 2021).

The function of injection pump is to supply the fuel as well as the fuel pressure provider which is subsequently forwarded to the injector to be drawn into the combustion chamber in the cylinder (Syahyuniar, 2017). The effect of incomplete combustion is the thickness of smoke in diesel engine exhaust gas, usually physically the smoke looks thicker or more concentrated (Triawan, 2014). The thickness of smoke in diesel engine exhaust emissions is called opacity (smoke opacity). To overcome damage to the nozzle, do the following:

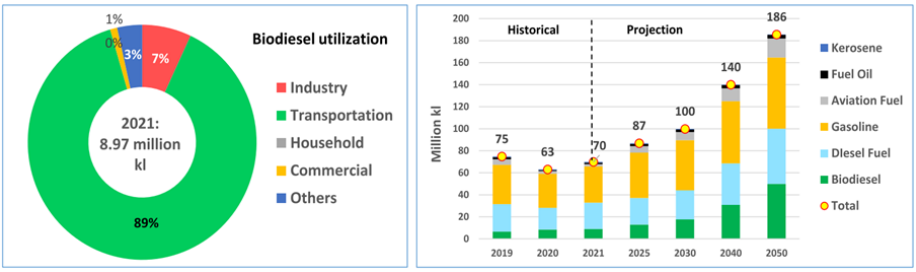
a. Installing the injector nozzles properly

If the injection nozzle is not adjusted to the standard, then the fuel injection will be imperfect resulting in the exhaust gas temperature and the fuel usage will be inefficiency. This leads to the formation of carbon dioxide in the combustion chamber due to the excessive discharge of the fuel so that it decomposes (Agus, 2015).

So, when adjusting the fuel atomizer, it must be in accordance with the correct standards and according to the ship's instruction manual book. To determine a good fuel spraying, it can be done by dropping the injector using the test pump test tool (test pump injectors/tester nozzles), the pressure setting on each injector is 280 – 300 kg/cm2. Fuel spray indicators are categorized well when no fuel drops come out of the end of the nozzle.

b. Routine maintenance of the injector nozzle must be carried out periodically and thoroughly.

Replace the nozzle if it is no longer worthy of use. Selection and use of a good quality spare part nozzle according to the diesel engine used (Ismail, 2016). In terms of the sustainability of biodiesel application in Indonesia, it is necessary to examine several aspects, including clustering of biodiesel utilization and selection of biodiesel technology in Indonesia. The share of pure biodiesel utilization in 2021 and the projected demand for fuel oil for the period 2021–2050 are shown in Figure 1.5.



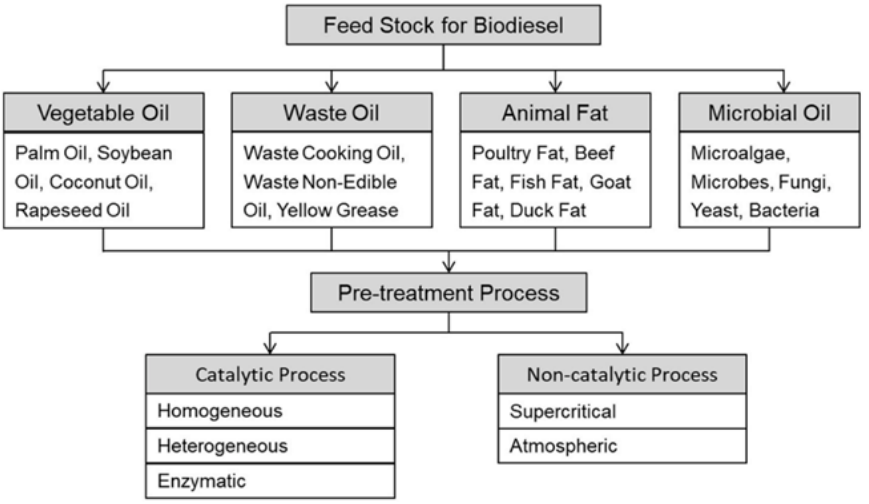
(a) (b)

(Source: Wirawan, 2023)

Fig. 1.5 Share of biodiesel utilization (a) and oil fuel demand projection (b)

The share of biodiesel demand in the long term is quite large compared to other fuels. Biodiesel is widely used in the transportation sector, especially ships which still rely on fossil fuels. Therefore, the biodiesel market segmentation to meet the needs of the shipping industry is very large, especially in Indonesia. This is supported by the high production and productivity of palm oil, because Indonesia has an established oil industry in the plantation and production sectors to supply biodiesel production.

Biodiesel can be produced from the transesterification process of vegetable oils or animal fats and short chain alcohols such as methanol. Therefore, the choice of production technology must be linked to the quality of raw materials. In figure 1.6, various biodiesel raw materials and biodiesel processing technologies are presented.



(Source: Wirawan, 2023)

Fig. 1.6 Various oil sources can be utilized to produce biodiesel fuel via the trans-esterification process.

One of the most established technologies for producing biodiesel is the catalytic process (Mittelbach, 2004). In practice, refining the catalyst to produce biodiesel commercially requires quite large costs. In addition, the lifetime, reaction rate and cost of catalyst synthesis must be considered. Apart from that, the recommended technology for producing biodiesel is a non-catalytic process (Kusdiana, 2001). The non-catalytic process using a bubble column reactor, biodiesel can be produced from triglycerides and fatty acids using superheated methanol (Joelianingsih, 2012). Without the use of a catalyst, biodiesel production costs are more affordable and reduce pollution. So, the development of biodiesel processing technology must reduce raw material costs, capital costs and chemical costs. The use of non-edible oil from existing plantations as well as waste oil or oil with high fatty acid level would be a promising solution to reduce raw material costs.

3 Conclusion

In order to maintain the sustainability of biodiesel use in Indonesia, high quality biodiesel use and production technology is needed at competitive prices than fossil fuels. In terms of using biodiesel on tugboats, modification and addition of fuel filters make the quality of the biodiesel cleaner and clearer, as well as minimizing damage to components in the machinery. Then, it is necessary to increase research in terms of biodiesel production technology, for example non-catalytic processes to commercially produce of biodiesel with good quality and competitive prices compared fossil fuels.

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