Numerical Comparison of B20 Biodiesel and Petroleum Diesel in terms of Performance, Combustion, and Emission at Constant Speed

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Numerical Comparison of B20 Biodiesel and Petroleum Diesel in terms of Performance, Combustion, and Emission at Constant Speed

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Abstract. To achieve energy efficiency and emission reduction in the shipping sector use of alternative marine fuel is one of the programs implemented. This study on alternative fuels is an active response to increasingly stringent emission regulations and the limited supply of fossil fuels. In addition, an operational feasibility study is an important thing. The method used in this research is computational fluid dynamics to see how the engine performance, combustion, and emissions when using biodiesel B20 at a constant speed of 2200 Rpm compared to when using petroleum diesel. From the results of the numerical comparison study, the use of B20 compared to petroleum diesel, there was an increase in engine performance the level of fuel consumption was higher. The use of B20 causes CO and UHC emissions to decrease while NOx increases compared to petroleum diesel.

Key words : Alternative Fuel, Biodiesel, Diesel, Emission, Marine Fuel,

1. Introduction

Using diesel engines is becoming increasingly popular because of its advantages, like better brake thermal efficiency and high output power, relatively lower fuel consumption levels, and quite acceptable reliability. The role of diesel engines in the shipping sector is also very dominant due to their better efficiency compared to gasoline engines. However, diesel engines still have problems, namely emissions and their availability which continues to decrease. The shipping sector has been one of the contributors to emissions that cause air pollution [1] reported by Bows-Larkin [2] that the shipping sector has contributed 2-3% of global gas emissions.

Emissions produced by marine transportation activities include Nitrogen Oxide (NOx), Sulfur Oxide (SOx), Carbon Monoxide (CO), Carbon dioxide (CO2), and particulate emissions have a local and global impact. The local effect is for various health problems such as lung, heart, cancer, pneumonia. The global impact is causing global warming and climate change. The International Maritime Organization (IMO) is one of the institutions under the United Nations that the authority to regulate maritime safety, shipping security, and prevention of marine pollution from ship operations. % of global emissions [3].

According to this scenario [4] is expected to triple by 2050, NOX and SOX emissions by 15% (19 million tonnes) and 13% (10.2 million tonnes) respectively, of global emissions if no control measures are in place. IMO issued Marpol Annex VI, to overcome this. One of the rules is to reduce the sulfur emission level from 3.5% to only 0.5% and effective from January 1, 2020. Meanwhile, the regulation of NOx emissions is regulated through Tier II and Tier III and has been valid since January 2016

In addition to the emission factor, the availability of fossil fuels is dwindling, and their price is increasing cause the use of renewable energy to become increasingly popular [5], [6]. Biodiesel is widely known as a vegetable oil fuel with the chemical name methyl ester until now is predicted as a candidate to replace diesel fuel [7]. The process aims to reduce the viscosity of oil and oxygen occurs because the transesterification process can convert large and branched molecules into smaller bio-oil structures and have straight chains.This straight-chain structure and small molecules are needed and suitable for diesel engine combustion. The use of biodiesel in compression engines can reduce the formation of sulfur oxides (SO_2), carbon monoxide (CO), hydrocarbons (HC), and smoke emission is due to the low sulfur, aromatic content, and the presence of oxygen compounds in biodiesel. In addition, biodiesel has other advantages because of its relatively high cetane value when compared to conventional diesel fuel [8], [9]

Ekrem Buyukayya [10] conducted an experimental study on rapeseed oil of 5%, 20%, and 70% against standard diesel fuel and found that engine performance increased and emissions were lower, the percentage of 20% gave optimal results but the advanced study still needed to reduce NOx. Several other researchers [11]–[14] stated that the oxidation in biodiesel during storage influences the properties and characteristics of biodiesel while it was an increase in the level of fuel consumption and a decrease in emissions when compared to using diesel fuel standards

The study conducted in this research is a numerical study to compare how the effect of using ASTM D6751 (Biodiesel), and ASTM D975 (Petro Diesel) at a constant speed of 2200 Rpm on the performance, combustion, and emissions of a single-cylinder diesel engine.

2. Material & Methode

The workflow of this research begins with determining the model in which the data engine specification and fuel properties used can be seen in the following table:

Table 1. Engine Baseline [15]

Engine (four stroke cycle)	TF 85 MH
cylinder	1
Combustion system	Direct injection
Bore x stroke	85 x 87 mm
Displacement	493 cc
Compression ratio	18 : 1
Max engine at full speed	2200
Continuous power output	7,5 kw
Specific fuel consumption	171 gr/hph

Table 2. Fuel Properties [16]

Property	ASTM D975 Petro Diesel	ASTM D6751 Biodiesel
Density at 40^0 (g/cm^3)	0,834	0,85 – 0,90
Spesific Gravity at 40^0C	0,851	0,88
Flash Point (^{0}C)	60 - 80	100 - 170
Kinematic Viscosity, 40^0C	2,5	1,9 - 6
Iodine Value (g/100 g oil)	38,30	-

Acid Value (mg KOH/g oil)	0,34	0,8 (max)
Calorific Value (Kj/Kg)	42000	-

The process is to model the combustion chamber and injection system on solid work then the results are exported to Ansys. In addition, the engine data input and setting of the fuel spray direction are also carried out.

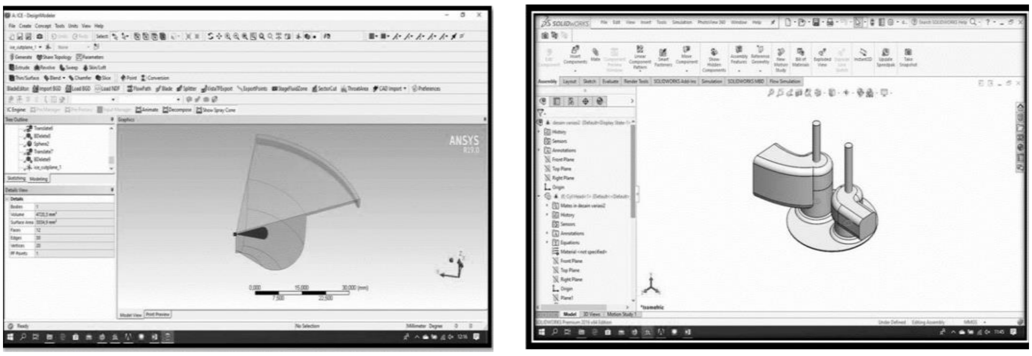
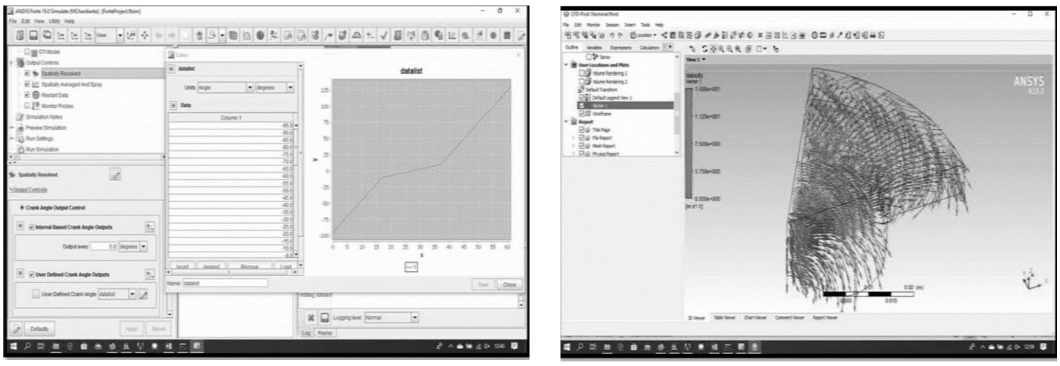


Fig.1. Modelling process in solid work

The process is meshing or forming into smaller cells for the calculation process with the Ansys Forte solver to start. The calculation begins by determining the fuel to be used, determining the injection timing and the mass of the fuel-injected, determining the boundary conditions and the direction of the piston motion, determining the initial and gas mixture. The simulation control process includes determining the crank angle to display, the running process produces graphic visualization, while the rendering process will produce contour output such as displaying pressure, temperature, and velocity visualizations



(a) (b)

Fig.2. Setting of Crank Angle (a) and Contour (b)

3. Result & Discussion

From the results of running numerical simulations, we got how to compare the characteristics, the performance, and emissions of the single-cylinder engine Yanmar TF 85 MHi when using ASTM D975 Petro Diesel and ASTM D6751 Biodiesel at a speed of 2200 RPM

Table 3. Comparison of performance and combustion values

Cylinder Index	ASTM D975 Petro Diesel	ASTM D6751 Biodiesel
Gross Indicated Power (kW)	7,589	7,685
IMEP (Mpa)	0,851	0,861
Fuel Mass (gr/cycle)	5,885	6,14
Gross ISFC (g/kW-h)	511,16	527,73
Combustion Eff	30,8	29,97
Thermal Eff	15,68	15,1
Max Pressure (Mpa)	13,9	13,9
Total Chemical Heat Release(J)	815,5	827,4

In table 3 the comparison by changing petrodiesel to biodiesel B20 increased 1.26% and 1.17% in power and IMEP was not too significant. Research conducted by [10], where at higher speeds, the torque delivered with B5 fuel is on average about 2 Nm than the torque produced by diesel fuel. The use of biodiesel causes an increase in fuel consumption rates of up to 3.2% compared to petrodiesel. Most researchers [16]–[19] agreed that engines require more fuel to achieve the same power when using diesel fuel. In addition, lower heating in biodiesel makes the engine consume more fuel to compensate. The higher density of biodiesel causes a higher mass injection for the same volume [20]

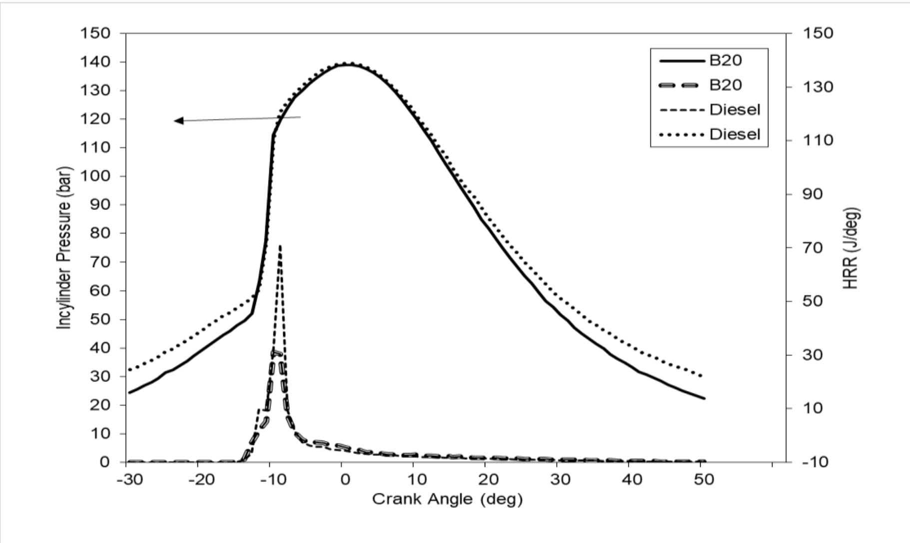
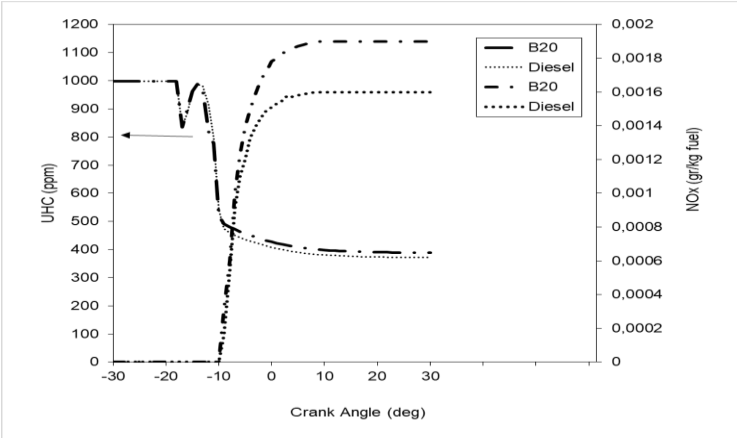


Fig.3. In cylinder Pressure and Heat Release rate

In the graphical of cylinder pressure, there is no significant difference between petrodiesel and biodiesel, with a maximum pressure value of 139 bar. However, for HRR, there is a slight difference where the peak heat increases by 1.45% and the ignition delay value slightly late compared to petrodiesel. One of the causes is because the flashpoint of biodiesel is higher.



(c) (d)

Fig.4 UHC and Nox emission

Carbon monoxide is a dangerous gas produced from an incomplete composition. CO emissions have decreased, in line with what was conveyed by [21] that one of the factors causing the decrease in CO is the higher oxygen content that improves combustion quality. On the other hand, the NOx emission increased by 18.75%, similar to that conveyed by Biodiesel, which generally produces NOX is slightly higher in emissions petroleum-based diesel as reported by many researchers. Murillo et al. recorded an increase of up to 16% when tested with recycled oil biodiesel in marine engines[21].

4. Conclussion

In terms of performance, the use of biodiesel at a high engine speed of 2200 rpm causes an increase in power of 1,27 % and 1,17 % in IMEP, higher biodiesel density, and lower temperature causes an increase in fuel consumption which is higher by 3,2% to achieve the same power output. There is no significant increase in-cylinder pressure, the use of biodiesel causes CO and UHC emissions to decrease while NOx increases 18,75% compared to petroleum diesel

5. Acknowledgement

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