



## Numerical Investigation of the Effect of Biodiesel-Biogas Percentage on Performance Characters and Dual Fuel Engine Emissions as Green Technology on Ship

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Article Info	Abstract
<p><b>Keywords:</b> Alternative energy, Green shipping, Dual fuel, Biodiesel, Biogas, Emissions</p> <p><b>Article history:</b> Received: 13/01/2022 Last revised: 14/02/2022 Accepted: 28/02/2022 Available online: 28/02/2022 Published: 28/02/2022</p> <p><b>DOI:</b> <a href="https://doi.org/10.14710/kapal.v19i1.44125">https://doi.org/10.14710/kapal.v19i1.44125</a></p>	<p>The discourse on the application of green technology in the maritime sector is an interesting plan to implement. The development of the world of shipping transportation, which continues to experience an increase in numbers and services, creates new problems in terms of fuel supply and the resulting emissions. So the development of innovation and technology for the marine engine should be directly related to fossil fuel substitution technology, operational efficiency technology, improving performance, and reducing emissions from the machine itself to be achievements and targets. Good engine performance directly impacts increasing the operational efficiency of the ship and being a good carrying capacity in the environment with minimal emission levels. A dual-fuel engine is one of the engine system concepts with several advantages, such as simple and relatively easy modifications and the use of natural gas, which tends to be cleaner. Biodiesel and biogas are examples of alternative fuels expected to be promising solutions for ship engineering. This research uses a numerical study on the application of dual-fuel engines. The percentage of biodiesel-biogas is carried out with variations of 50:50 and 25:75, at a constant engine speed of 2200 RPM. The results showed that by increasing the rate of biogas from 0% to 50%, there is an increase in engine performance. The BTE value increased by 10.25%, while the level of fuel consumption decreased by 19%. Emission measurements show a decrease in NOx's value, which is very beneficial even though UHC still tends to increase. It is possible to add oxygen intake through a turbocharger or supercharger as auxiliary equipment.</p> <p>Copyright © 2021 KAPAL : Jurnal Ilmu Pengetahuan dan Teknologi Kelautan. This is an open access article under the CC BY-SA license (<a href="https://creativecommons.org/licenses/by-sa/4.0/">https://creativecommons.org/licenses/by-sa/4.0/</a>).</p>

### 1. Introduction

The complexity of the problems occurs in transportation, where most transportation on the land, sea, and air is highly dependent on fossil fuels. In shipping transportation itself, this is the majority. The availability of fossil fuels that continues to run out is not proportional to their increasing use. In addition to the growing gap in demand and availability, another problem that arises is emissions that have local and global impacts. Data shows that shipping contributes 2% of emissions and will continue to increase as the fleet grows [1]. Global warming and climate change are common problems that must be minimized immediately.

In response to this situation, the regulations continue to be amended and enforced more and more strictly. Regulations are made internationally through IMO Annexes I – VI. Annex VI contains regulations related to the energy efficiency design index (EEDI), energy efficiency operational indicators, and ship energy efficiency management plan (SEEMP). It was implemented starting in 2011 and applied to ships built-in 2013. The impact of the emergence of these various regulations has various responses from the researchers to answer the challenges of energy availability for sea transportation and the challenges of tackling the emissions that occur so that the ship can be licensed because it has met the required standards [2].

A dual-fuel is one of the engine modification innovations on the diesel engine. By making slight modifications to the intake manifold with a conversion kit, natural gas can enter the combustion chamber along with the air. Ignition comes from the compression of biodiesel fuel that is sprayed into the combustion chamber. The use of gas fuel, in this case, is biogas which is expected to reduce emissions because it is cleaner, while biodiesel is expected to be the driving force for the use of alternative energy that can replace the use of liquid fossil fuels for diesel engines [3-6]

The term green shipping refers to the designation of a ship as an environmentally friendly vehicle. Environmentally friendly on ships is currently defined as efforts to reduce greenhouse gases in ship operations and building. One of the things that are being strived for is the management of fuel efficiency in operations, including efforts to use alternative fuels [7]. The

decrease in fossil fuels, the level of price increases and fluctuations, increasingly stringent environmental policies and regulations, as well as the increasing demand for energy conversion as a substitute for fossil fuels, make the discourse of alternative fuels in internal combustion engines a necessity that attracts many parties [8,9]

Biogas is one of the potential renewable energies, has abundant possible availability, and will be a sanitary solution for the environment [10]. Biogas has a low cetane value and high auto-ignition, so it isn't easy to burn with compression. It requires good ignition with spark plugs on the spark engine and pilot fuel on the dual-fuel engine [11,12]. Many circles are still debating the potential of biogas to replace fossil fuels because the product produced is still very minimal in terms of energy. Biogas consists of 50-80% methane, 15-45% carbon dioxide, water, hydrogen sulfide, and nitrogen. The part that is used as fuel is methane, so many processes are needed to purify biogas.

Biodiesel or vegetable oil ethyl ester is one of the strongest candidates as a substitute for diesel fuel. Biodiesel is the name given to vegetable oil that has been transesterified and replaces diesel fuel [13]. In addition to its relatively abundant and renewable availability, it is somewhat cleaner than diesel fuel [14]. Biodiesel has advantages over diesel fuel in terms of sulfur content, flash point, aromatic content, and biodegradability [15]. However, it produces slightly lower power and consumes more fuel for the same power unit.

Various works related to biogas as fuel in diesel engines operated in dual fuel mode are explored in the literature. Cacua et al. investigated the effect of oxygen enrichment on the performance of a diesel engine converted to dual-mode using biogas with a composition of 60% CH<sub>4</sub> and 40% CO<sub>2</sub> [16]. The concentration of oxygen (O<sub>2</sub>) varied from 21% to 27% O<sub>2</sub> in the intake air. A four-stroke double cylinder with a rated power of 20 kW at a diesel engine speed of 3000 rpm coupled to a generator was used to experiment. Verma et al. [17] carried out a CFD simulation of adding hydrogen to biodiesel - biogas DF and getting results in the form of an increase in power and a decrease of up to 50% CO and UHC at low load. From these results, the authors determined that with the application of oxygen enrichment, thermal efficiency increased, and methane emissions and ignition delay decreased. Tipayawong et al. [18] analyzed the impact of long-term operation on the performance and wear of a dual fuel engine using a small on-farm diesel engine with dual fuel mode using biogas with a composition of methane concentration of 65,6%. Koten et al. [19] perform optimization using multiple objectives and analyze numerically related to the difference between biogas - biodiesel DF and SF, which results in a decrease in NO<sub>x</sub> in all variations and engine conditions. The authors conclude that complete diesel fuel can be substituted using biogas as fuel by observing these results. Meanwhile, due to the implementation of the supercharger mixing system, pilot fuel substitution and the thermal efficiency of the brakes have increased. Emissions of exhaust gases such as carbon monoxide and methane were observed to decrease. From the literature survey above, various authors have experienced positive results using biogas as an alternative fuel in diesel engines with dual fuel mode to reduce greenhouse gas emissions and replace depleting fossil fuels [20]. Based on the literature study that has been done, the potential for research development related to biodiesel-biogas is still very wide open. Using renewable fuels as a substitute for fossil fuels with low emissions is undoubtedly good news for the industry and the environment.

In this research, a numerical test will be conducted regarding how the effect of variations in the percentage of biodiesel-biogas in a dual fuel engine on the performance, combustion, and emissions it produces. It is hoped that the results of this study can provide input regarding the ideal conditioning of the biodiesel - biogas ratio that has good performance and low emission levels.

## 2. Methods

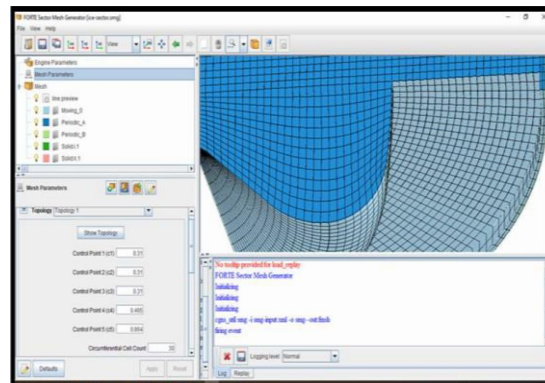
The research is carried out in the form of CFD simulations to test how the effect of variations in the percentage of biodiesel-biogas on the performance of a dual-fuel engine, including power, torque, fuel consumption, and combustion performance in the form of cylinder pressure, heat release rate and emissions that arise. The numerical simulation that will be carried out is used to see how the results of performance, combustion, and emissions when the engine uses 100% biodiesel fuel, hereinafter referred to as single fuel (SF) and 50% Biodiesel + 50% Biogas and 25% Biodiesel + 75% Biogas which hereinafter referred to as dual-fuel (DF). The following are the steps involved in the simulation test process in this research. The following is the engine specification data used

Table 1. Engine Spesification

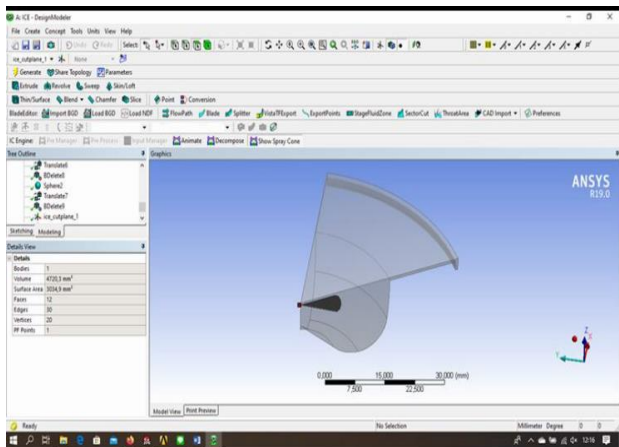
Spesification	Value
Cylinder	1
Combustion Syst	DI
Bore X Stroke	85x87 mm
Displacement	493 cc
Compression Ratio	18:1
Max engine speed	2200 Rpm
Continuous Power Output	7,5 kW
Spesific Fuel Consumption	171 gr/hp.h
Volume per Injection	0,07 ml

In this process, the model is made using solid work. The image made is an existing picture of the condition of the piston and combustion chamber. The next step is to input the main engine data, import images from solid work to Ansys forte, and

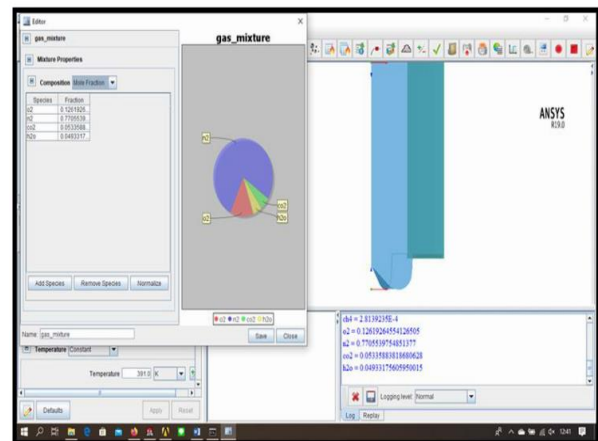
set the direction of the pilot fuel spray. The activity of meshing or forming into smaller cells for the next calculation process with the Ansys forte solver becomes an advanced process. The simulation is carried out using the parameter variation of the percentage of biodiesel fuel to biogas. It has input in the form of boundary condition data, the rate of fuel used, the timing of main and pilot fuel injection, the direction of the piston and the gas mixture, while the output of the simulation is in the form of performance combustion and emission data. The simulation control process includes determining the crank angle we want to display. The running process produces graphic visualization, while the rendering process will produce contour output as we want, such as displaying pressure, temperature, and velocity visualizations. While the final process is rendering the visual output on the forte monitor according to what we want to show, it can be in the form of velocity, temperature, or pressure contours (see Fig. 1).



(a)



(b)



(c)

Figure 1. The process of Meshing (a), determining injection (b), initial conditions, and gas mixture (c)

### 3. Results and Discussion

In Fig. 2, it is seen that the increase in the percentage of biogas causes an increase in engine performance. The increase in gross indicated power by 23.4% while IMEP increased by 23.2% occurred with a change in the biogas percentage setting from 0% to 50%. It is proof that biodiesel – biogas is worthy of being used as an alternative fuel. Increasing the rate of biogas has a good impact on the maximum operating speed of the engine rotation. The lower level of fuel consumption for higher power output causes the thermal brake efficiency (BTE) value of dual-fuel with a percentage of 50% biodiesel–biogas to be optimal for DF operations at 2200 RPM. The increase in BTE was 10.25%, with a decrease in indicated specific fuel consumption of 19%. The trend of increasing IMEP on increasing biogas injection in dual-fuel engines is also found in the research [21,22], which stated that there was a trend of improving overall performance by increasing biogas injection on dual-fuel engines. The same result was also reported by Ambarita, which stated that at the same load and speed, the CI output power running in dual fuel mode was higher than in pure diesel mode [20]. Adding hydrogen to biodiesel - biogas DF and getting results in an increase in power and a decrease of up to 50% CO and UHC at low load [4,17].

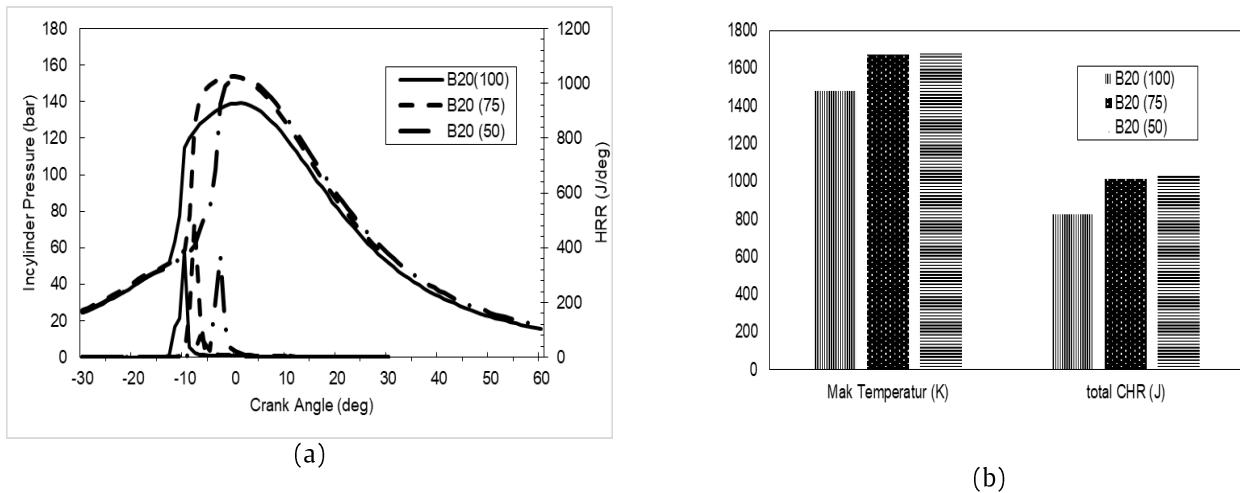


Figure 2. Graph of combustion in-cylinder pressure, HRR (a) and Max temperature, CHR (b) in a variation of percentage of biodiesel - biogas

The increased in-cylinder pressure and temperature make the energy release rate and the combustion process better at 50% biodiesel - biogas percentage. The increase in temperature occurs by 13% in conditions of 0% biogas to 50% biogas. While the increase in cylinder pressure occurs by 10%. It is in conditions of a maximum engine speed of 2200 rpm. The increase in temperature impacts the increase in the total cumulative heat release (total CHR). A 13.3% increase in temperature from 0% biogas to 50% causes a 23.9% increase in total CHR. Meanwhile, the combustion pressure decreases with the addition of biogas fuel injection, as is the trend of the results obtained in the research of Park et al. [21]. The increase in pressure and temperature makes the energy release rate and the combustion process better at the 50% biodiesel - biogas percentage.

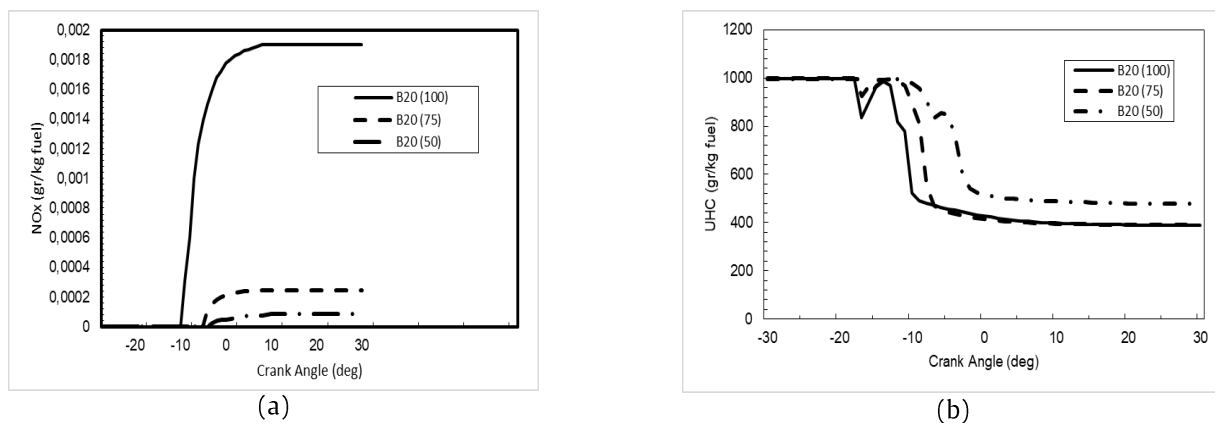


Figure 3. Graph of Emission NOx (a) and UHC (b) in variation percentage of biodiesel - biogas

An increase in biogas intake in a dual fuel engine operating system generally causes a decrease in emissions, a better level of combustion efficiency being one of the factors that underline that the use of dual-fuel can be used as an alternative. The increase in the percentage of biogas causes the concentration of gas in the combustion chamber to become more so that it reduces the portion of the oxygen space. This tends to cause an increase in unburned hydrocarbons at a higher percentage of biogas. By increasing the percentage of biogas to 50%, there is an increase in UHC of 88% compared to 0% in 10 BTDC and continues to decrease at TDC only increasing in the range of 20%. An increase in cylinder pressure and temperature cause the gas to burn better. The same trend of results was stated in the reference [20-22]. Meanwhile, NOx decreased with the increasing percentage of biogas in dual fuel, by increasing the percentage of biogas to 50%, there is a decrease in NOx reaching 97% at TDC conditions in line with that obtained by Park et al. [21] and Jagadish & Gumtapure [22]. The presence of CO<sub>2</sub> in biogas reduces the peak cylinder temperature because CO<sub>2</sub> has a higher specific heat. The combination of these factors promotes lower NOx emissions for mixed biogas. On the other hand, NOx emission levels are found to be equivalent at higher loads due to increased and faster biogas combustion compared to lower loads after high temperatures and peak pressures Das et al. [23].

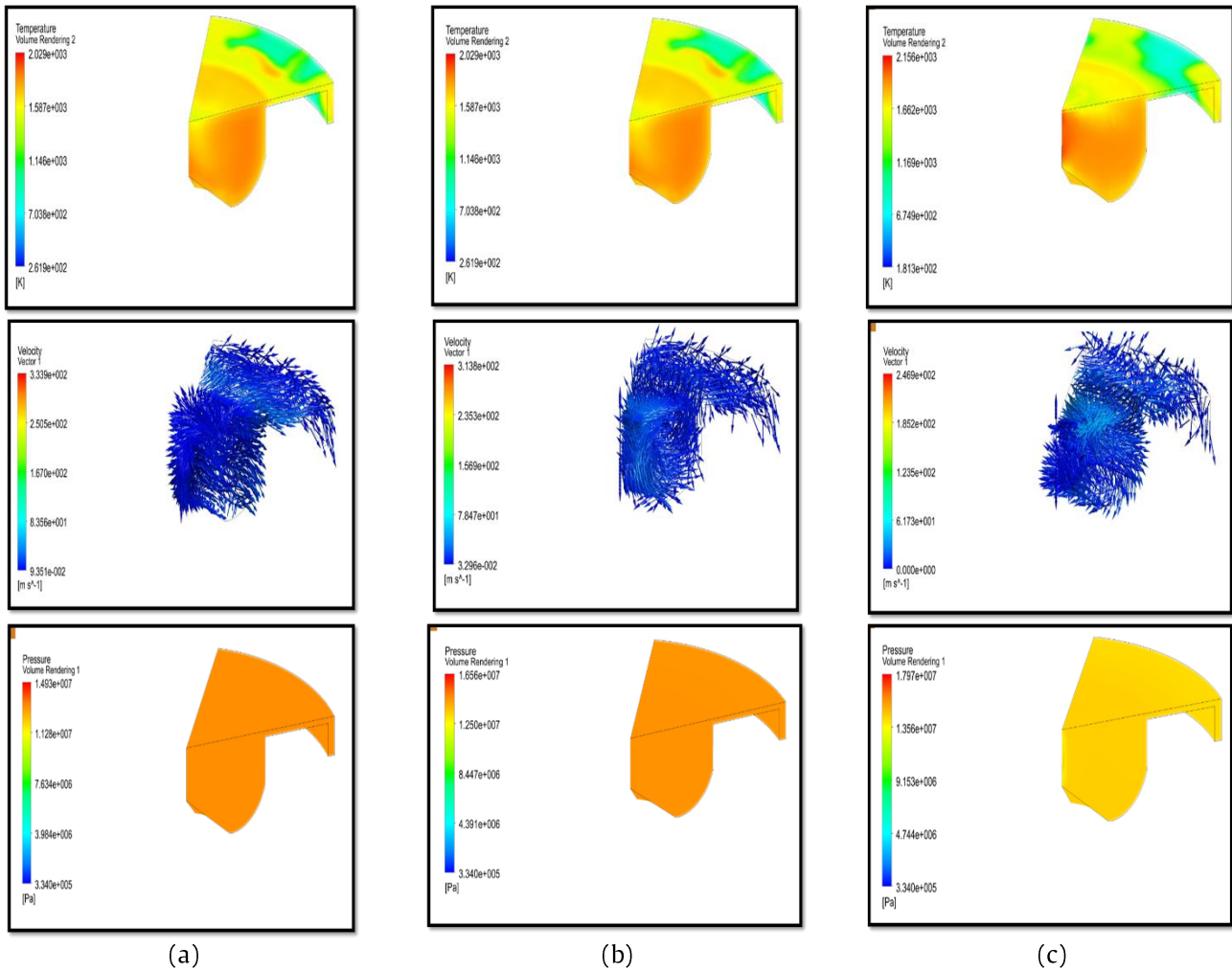


Figure 4. Contour of Temperature (a), Velocity (b) and contour of pressure (c) from 0% to 50% biogas

In Fig. 4, respectively (a), (b), and (c) with variations in the percentage of biodiesel - biogas from 0%, 25%, and 50%, it can be seen that there are several changes in behavior from the temperature and pressure contours. The increase in biogas intake from 0% to 50% at the maximum rotational speed of the DF engine increases engine performance.

#### 4. Conclusion

There are several conclusions regarding the performance and emission characteristics of the variation in the percentage of biodiesel - biogas from 0%, 25%, and 50% biogas at 2200 RPM engine speed. The increase in engine performance occurs along with the increase in the percentage of biogas from 0% to 50%. The increase in BTE, IMEP, and power and a decrease in the level of ISFC indicate that biodiesel - biogas is worthy of consideration as an alternative solution for reducing the use of fossil fuels. Meanwhile, the decreasing value of NOx with an increase in the percentage of biogas from 0% to 50% is good news. Increasing unburned hydrocarbons at a higher percentage of biogas can be tried to add oxygen intake to the engine either through a turbocharger or a supercharger.

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