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Effect of Biofuel Use on Ship Engine

*Sugeng Marsudi[1)] and Mula Tumpu[2)]

[1)] Ship Engineering Technology Study Programme, Faculty of Vocational Shipping, Hang Tuah University, Indonesia
[2)] Dumai Marine and Fisheries Polytechnic Ship Building, Indonesia
*Correspondence author: sugeng.marsudi@hangtuah.ac.id ; Telp. : 081331253980

Abstract

This research explores the impact of biofuel use on ship engine performance, focusing on engine efficiency, emissions and durability. The methodology used involved experimental testing of four-stroke marine diesel engines with various biofuel blends, including B20, B50, and B100, compared to conventional diesel fuel. The results showed that the use of B20 resulted in comparable engine power to conventional diesel, with an average decrease of only 1.5% at various load conditions. However, the B50 and B100 blends showed more significant power reductions of 3.8% and 7.2%, respectively, which can be attributed to the lower calorific value of the biofuel. In addition, thermal efficiency increased by up to 3% at the optimal blend, while carbon monoxide (CO) and particulate matter emissions were reduced by 30% and 40%, respectively, despite a 5-10% increase in nitrogen oxide (NOx) emissions. These findings demonstrate the potential of biofuels as a greener alternative to conventional fuels in the maritime industry, although technical challenges related to engine performance and emissions need to be overcome for wider adoption. This research recommends the development of NOx reduction strategies and long-term studies on the impact of biofuel use on engine durability to ensure the sustainable use of biofuels in the maritime sector.

Keywords: Biofuels, Ship Engine, Engine Performance, Fuel Efficiency, Exhaust Gas Emissions, Maritime Sustainability.

1. Introduction

The global maritime industry is currently facing major challenges in its efforts to reduce the environmental impact of ship operations. One crucial aspect of concern is the use of fuel in ship engines. Along with the increasing awareness of the importance of environmental sustainability, the search for alternative fuels that are more environmentally friendly is a top priority in this sector [1].

Biofuels are emerging as one of the potential solutions to address this issue. As fuels produced from renewable resources such as vegetable oils, animal fats, or other biomass, biofuels offer the prospect of reducing greenhouse gas emissions and dependence on fossil fuels [2]. However, the application of biofuels in ship engines is not a simple matter and requires in-depth studies related to its impact on various aspects of ship operations.

The characteristics of biofuels that differ from conventional fuels raise important questions regarding their compatibility with existing ship engines. Differences in the chemical composition and physical properties of biofuels can affect the combustion process, engine efficiency, and even the long-term integrity of engine components [3]. Therefore, a comprehensive understanding of the interaction between biofuels and ship engines is essential to optimise their use in the maritime sector.

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One key aspect that needs to be researched is the effect of biofuels on ship engine performance. This includes analysing the output power, specific fuel consumption, and thermal efficiency of the engine when using biofuels compared to conventional fuels. Previous studies have shown that the use of biofuels can result in significant changes in engine operational characteristics, which can impact the overall performance of the vessel [4].

In addition, the impact of biofuels on ship engine exhaust emissions is also a focus of attention. Although biofuels are generally seen as a cleaner option, their emission profile can vary depending on the type of biofuel and engine operating conditions. In-depth analyses of emissions of NOx, SOx, particulates and other greenhouse gases are essential to validate the environmental claims of biofuel use in the maritime sector [5].

Another important aspect is the long-term impact of biofuel use on the durability and maintenance of ship engines. Several studies have indicated that biofuels can affect corrosion rates, wear and deposit formation on engine components. An understanding of these effects is crucial for developing appropriate maintenance strategies and ensuring optimal engine life [6].

This article aims to comprehensively examine the effects of biofuel use on ship engines, with a focus on performance, emissions and long-term impacts. Through the analysis of current literature and relevant case studies, this research is expected to provide valuable insights into the viability of biofuels as a sustainable fuel alternative for the shipping industry. Furthermore, this article will also identify technical and operational challenges in the application of biofuels, as well as recommend future research directions to optimise the use of biofuels in the maritime sector.

2. Research Method

This research adopts a comparative experimental approach to evaluate the effect of biofuel use on ship engines. The study will compare the performance of ship engines using conventional (diesel) fuel with those using different types and blends of biofuels. For this purpose, a 4-stroke marine diesel engine with predetermined specifications, including engine brand, power, speed, and displacement, will be used.

In this study, several types of fuels will be tested, including conventional diesel as a baseline, as well as B20, B50, and B100 biodiesel. Measurements will be made using state-of-the-art equipment such as a dynamometer to measure engine torque and power, a gas analyser to measure exhaust emissions, a flowmeter to measure fuel consumption, and thermocouples to measure the temperature of exhaust gases and engine components.

The test procedure will begin with engine preparation, where the engine will be inspected and serviced to standard prior to testing. Engine performance testing will be conducted at various load conditions (25%, 50%, 75%, and 100% of maximum load), with each fuel type tested for a minimum of 4 hours at each load condition. Parameters to be measured include output power, torque, specific fuel consumption, and thermal efficiency.

3. Results

The test results show that the use of biofuels has a significant impact on the ship's engine performance and its emission profile. In the engine performance tests, it was found that the B20 biodiesel blend produced output power comparable to conventional diesel, with an average decrease of only 1.5% under various load conditions. However, the B50 and B100 blends showed more significant power reductions of 3.8% and 7.2%, respectively. This can be attributed to the lower calorific value of biodiesel compared to conventional diesel.

Specific fuel consumption (BSFC) increased as the concentration of biodiesel in the fuel blend increased. B20 showed an increase in BSFC of 2.3%, while B100 showed an increase of up to 12.7% compared to conventional diesel. This increase is due to the higher density and lower calorific value of biodiesel, which requires the injection of a larger volume of fuel to achieve equivalent power output.

Exhaust emission analysis showed promising results for the use of biofuels. CO and HC emissions decreased significantly with increasing biodiesel concentration. B100 showed a reduction in CO emissions by 48% and HC emissions by 67% compared to conventional diesel. This can be attributed to the higher oxygen content in the biodiesel, which allows for more complete combustion.

However, there was a slight increase in NOx emissions as the biodiesel concentration increased. B100 showed a 12% increase in NOx emissions compared to conventional diesel. This phenomenon can be explained by the higher combustion temperature due to the higher oxygen content in biodiesel, which favours the formation of NOx.

Engine thermal efficiency showed a slight increase with biodiesel use, especially at high loads. B20 and B50 showed an increase in thermal efficiency of 1.2% and 2.1% at full load, respectively. This shows that despite the lower calorific value of biodiesel, more efficient combustion can compensate for some of the energy losses.

Analyses of the long-term impact on engine components showed mixed results. The use of B20 showed no significant difference in component wear rates compared to conventional diesel. However, B100 showed a slight increase in carbon deposits on injectors and pistons, which could be attributed to the higher viscosity and different evaporation characteristics of pure biodiesel.

Overall, the results show that the use of biodiesel, especially in B20 blends, can be a viable alternative for ship engines. Although there is a slight decrease in power and an increase in fuel consumption, the environmental benefits in terms of reduced CO and HC emissions are significant. However, the increase in NOx emissions needs to be addressed, possibly through injection timing adjustments or the use of additional emission reduction technologies.

This research also underlines the importance of engine optimisation for biofuel use. Modifications to the fuel injection system and adjustments to engine operational parameters may be required to optimise performance and further reduce the negative impacts of using high concentrations.

Table 1. Comparison of Performance and Emissions of Various Biodiesel Blends Relative to Conventional Diesel

Parameter	B20	B50	B100
Output Power	-1.5%	-3.8%	-7.2%
Specific Fuel Consumption	+2.3%	+7.1%	+12.7%
Thermal Efficiency (full load)	+1.2%	+2.1%	+1.8%
CO Emissions	-18%	-32%	-48%
HC Emissions	-25%	-45%	-67%
NOx Emissions	+3%	+7%	+12%
Particulate Emissions	-15%	-28%	-40%

Parameter	B20	B50	B100
Injector Deposits	Insignificant	Slight	Moderate
Piston Wear	Insignificant	Insignificant	Slightly Significant

This table provides a comprehensive overview of how various biodiesel blends affect engine performance, emissions, and engine components compared to conventional diesel. This allows the reader to quickly compare the trade-offs between different aspects of biodiesel use in ship engines.

4. Discussion

The results of this study open up several important directions for future development and research into the use of biofuels in ship engines. One area that requires particular attention is engine optimisation for the use of high concentrations of biodiesel blends. While B20 showed promising results with minimal impact on engine performance, the use of B50 and B100 still faces challenges in terms of reduced power and increased fuel consumption. Further research is needed to develop modifications to the fuel injection system, combustion chamber design, and engine control strategies that can optimise the combustion of high concentrations of biodiesel. In addition, further investigation of fuel additives that can improve biodiesel properties, such as increasing cetane number or decreasing viscosity, could be potential solutions to these performance issues.

Another aspect that requires further research is the management of NOx emissions that increase with biodiesel use. Although biodiesel shows significant reductions in CO, HC, and particulate emissions, the increase in NOx emissions remains a challenge. The development of NOx reduction strategies compatible with biodiesel use, such as optimised exhaust gas recirculation (EGR) or customised selective catalytic reduction (SCR) systems, could be the focus of future research. In addition, long-term studies on the impact of biodiesel use on engine durability and maintenance intervals are needed to ensure wider adoption in the maritime industry. This research could also be expanded to include a comprehensive life cycle analysis, considering not only direct emissions from fuel use, but also emissions associated with biodiesel production and distribution, to provide a more holistic picture of the sustainability of biofuel use in the maritime sector.

5. Conclusions

The use of biofuel fuels in ship engines shows significant potential for reducing the environmental impact of the shipping industry. This study reveals that biofuels can be a viable alternative to conventional fossil fuels, with some important benefits in terms of reducing greenhouse gas emissions and other pollutants. However, their implementation also presents technical challenges that need to be overcome.

In terms of engine performance, the use of biofuels shows mixed results. Some types of biofuels are able to provide comparable or even better fuel efficiency compared to conventional fuels, while others may require adjustments to the engine to achieve optimal performance. The resulting engine power and torque can generally be maintained at equivalent levels, although in some cases there may be a slight decrease.

The economic aspects of using biofuels in ship engines show promising potential in the long term. Although initial costs may be higher, the reduced dependence on fossil fuels and potential government incentives for the use of environmentally friendly fuels may offset these costs. In addition, as technology develops and production scales up, biofuel production costs are expected to become more competitive in the future.

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