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A Review on Effect of Biodiesel on the Performance of CI Engine

Anup Kumar, Punam Kumar Agade

Madhyanchal Professional University

ABSTRACT

Diesel, being one of the primary fuels for internal combustion engines, has led to numerous environmental and human health issues. The increasing use of biodiesel as a substitute for fossil diesel, along with advanced after-treatment technology, is a key direction for the future development of diesel engines. To address these challenges, a growing number of researchers are focusing on alternative fuel studies. Biodiesel, a renewable and sustainable alternative fuel, shares similar characteristics with traditional diesel and can be blended with it. Studies have shown that blending biodiesel with pure diesel in specific proportions can effectively mitigate its negative impacts, enhance combustion efficiency, and reduce NOx and PM emissions. This review primarily examines the impact of biodiesel-diesel blends on engine combustion behavior and exhaust emissions.

Keywords: Bidiesel, CI Engine, pollutants, combustion.

Introduction

Biofuels have numerous advantages over traditional petroleum diesel. One significant benefit is that plants capture carbon dioxide during their growth and release it when the biofuel is burned. This makes vegetable oil fuels almost carbon neutral, which is crucial in the fight against greenhouse gas emissions. Additionally, biofuels are low in sulfur content and are a sustainable energy source, unlike finite resources that will eventually run out. Bio-diesel, an eco-friendly alternative to diesel, is created from renewable resources such as vegetable oils and animal fats. These natural oils and fats, primarily composed of triglycerides, undergo a process called transesterification to produce bio-diesel. In India, where there is a shortage of edible oils, non-edible oils like Jatropha curcas are considered the most promising source for bio-diesel production.

Biodiesel consists of mono alkyl esters produced from vegetable oils, animal or old cooking fats. Coconut biodiesel is fuel alternative produced from soybean oil. Biodiesel contains no petroleum diesel, but it can be blended with petroleum diesel.

Biodiesel is a natural fuel derived from tree-born oils through a chemical process known as Transesterification, which takes place in a Chemical Processing Plant. This process has been used for a long time and is a proven method of converting vegetable oils or fats into Biodiesel (Alkyl Esters of Fatty Acids) and Glycerin, along with some soaps. The transformation of fatty acid chains into Alkyl Esters of the respective fatty acids found in different feed oils, as well as the extraction of glycerol from the Triglyceride molecule in the oils and fats, is where the chemistry lies. Biodiesel does not contain any petroleum diesel, but it can be blended with petroleum diesel.

Literature Review

This article aims to explore the utilization of aluminum oxide ($Al2O3$) in combination with B20 to achieve specific fuel properties based on previous journal research. The objective is to enhance the performance characteristics of diesel engines and improve engine emissions control without requiring any modifications to the engine itself.[1]

A comprehensive analysis was conducted on a diesel engine, operating under various conditions, using different blends of Parinari polyandra biodiesel. The study measured exhaust emissions such as total hydrocarbons, carbon dioxide, carbon monoxide, sulphur dioxide, and nitrogen oxides. The properties of the biodiesel were found to be similar to those of fossil diesel. Among the blends tested, B10 was identified as the optimal blend for improving engine performance in terms of speed, power, and thermal efficiency. B30 demonstrated stable performance characteristics without necessitating any modifications to the diesel engine. The combustion of biodiesel blends resulted in lower exhaust emissions compared to diesel, with the exception of nitrogen oxides. Notably, there was a significant reduction in greenhouse gases, with carbon monoxide and carbon dioxide recording reductions of 81.7% and 65.7% respectively. The utilization of Parinari polyandra biodiesel for engine applications was deemed a viable approach to promote the adoption of sustainable biofuels and minimize pollutant emissions from the combustion of fossil fuels.[2]

This research focuses on the mechanisms related to the CFP of biodiesel and emphasizes the factors that initiate and control the crystallization process. The study suggests that the CFP of biodiesel fuel can be enhanced through the use of various techniques. Winterization of certain biodiesel types has been proven to significantly improve CFP. Additionally, additives like polymethyl acrylate have shown to enhance CFP by 3-9 °C. Nevertheless, it is advised that methods for improvement in terms of fuel properties and efficiency should be thoroughly examined and tested before being applied in industrial settings, as this could potentially impact biodiesel yield, cetane number, and other factors.[3]

The evaluation of the engine's performance for emulsified fuel and biodiesel obtained from yellow oleander seed oil in a diesel engine with a single cylinder has been conducted in this study. The performance of these biofuels has been compared to that of diesel fuel. The findings indicate that the Brake Specific Fuel Consumption (BSFC) for the biofuels is greater than that of diesel. However, there is no discernible difference between the fuels in terms of power and torque.[4]

The experimental study was carried out following the ESC (European Stationary Cycle - Directive 1999/96/EC) 13-mode. By using biodiesel fuel, the average thermal efficiency is maintained at the level of conventional diesel fuel application. The average CO emissions are decreased by 13.6%, the average NOx emissions are increased by 27.6%, the average HC emissions are increased by 59.4%, and the average particles emission is reduced by 43.2%.[5]

The diesel engine underwent an experiment where it was tested at various engine loads ranging from zero to full load. The thermal efficiencies of waste cooking-oil biodiesel blends were found to be lower than that of diesel oil. Additionally, the specific fuel consumptions of biodiesel blends were higher compared to diesel fuel. Furthermore, biodiesel blends exhibited higher exhaust gas temperatures in comparison to diesel oil. The CO2 emissions for waste cooking-oil biodiesel blends were also higher than diesel oil. On the other hand, the CO and HC emissions for biodiesel blends were lower than diesel fuel. Lastly, the NOx emissions for biodiesel blends were higher than diesel fuel.[6]

The properties of biodiesel derived from Palm Kernel Oil Methyl Ester (PKOME), Jatropha Curcas Methyl Ester (JCME), and Coconut Oil Methyl Ester (COME), as well as their blends, have been analyzed for their suitability in a compression ignition direct injection (CIDI) internal combustion engine. The vegetable oils sourced from Ghana (PKOME, COME, and JCME) were converted into biodiesel through transesterification. The optimal combination of catalysts, including 1% H2SO4, 1% NaOH, and a methanol to oil ratio between 6:1 and 8:1, resulted in the highest biodiesel yields. These biodiesels were then tested in a VW diesel engine experiment. To determine the best blend for optimal physiochemical properties and engine performance, PKOME and COME were blended in proportions of 100%, 75%, 50%, and 25%. Additionally, JCME was blended with COME in the same proportions. The blend consisting of 75% COME and 25% PKOME exhibited the best values for exhaust emissions and fuel consumption, with a desirability rating of 97%. This blend achieved a brake specific energy consumption (BSEC) of 15.4 MJ/kWh, CO emissions of 0.39 Vol. %, HC emissions of 45 ppm, and NOx emissions of 146 ppm. The optimal blend of JCME and COME was found to be 75% JCME and 25% COME, with a BSEC of 13 MJ/kW h, CO emissions of 0.24 Vol. %, HC emissions of 65 ppm, and NOx emissions of 256 ppm. These values were obtained while maintaining a desirability rating of 97%. Comparing these blends to petroleum diesel, it was found that the blends closely matched the engine performance properties of petroleum diesel, with a BSEC of 11.8 MJ/kW h, CO emissions of 0.43 Vol. %, HC emissions of 103 ppm, and NOx emissions of 140 ppm. In conclusion, blending biodiesel derived from different feedstocks can significantly improve the performance of CIDI engines and reduce exhaust emissions. The blend of JCME (75%) and COME (25%) demonstrated superior engine performance compared to petroleum diesel, with an 80% reduction in CO emissions and a 58% reduction in HC emissions. The result show that blending biodiesel of different feedstock can improve CIDI engine performance and exhaust emissions.[7]

The global community is currently grappling with energy demand crises, escalating petroleum prices, and the depletion of fossil fuel reserves. Biodiesel, derived from vegetable oils, has emerged as a promising alternative fuel source. While research on blending diesel with single biodiesel has been conducted, limited studies have explored the combination of two different biodiesel blends with diesel, leaving ample room for further exploration in this field. This study presents an experiment involving two biodiesels extracted from pongamia pinnata oil and mustard oil, which were then blended with diesel at varying ratios. The impact of dual biodiesel blends on engine performance and exhaust emissions was evaluated using a single-cylinder, direct injection, air-cooled, high-speed diesel engine under different engine loads while maintaining a constant speed of 3000 rpm. Emission tests were conducted to analyze the effects of blends on CO, CO2, HC, NOx, and smoke opacity. The results indicated that blend A exhibited higher brake thermal efficiency compared to diesel. However, the emissions of smoke, hydrocarbons, and nitrogen oxides from dual biodiesel blends were higher than those from diesel. Interestingly, the exhaust gas temperature for dual biodiesel blends was lower than that of diesel. [8]

With the depletion of fossil fuels and the increase in greenhouse gases, the utilization of biodiesel has emerged. Biodiesel is a renewable and clean-burning diesel fuel that can be derived from vegetable oils. This particular project focuses on examining the emission and performance characteristics of a diesel engine using blends of Neem oil as biodiesel. The Neem oil is transformed into biodiesel through the transesterification process, with the addition of 1% v/v H2SO4. The tests were conducted on a single cylinder, 4-stroke diesel engine using B10, B20, and B30 blends. The results indicate that B10 exhibits lower emissions and higher performance compared to the other blends and conventional diesel fuel. Additionally, the brake thermal efficiency of B10 surpasses that of diesel, while the CO, HC, and NOX emissions are reduced by 23%, 8.5%, and 22% respectively, in comparison to diesel fuel. [9]

The study examined the performance and emissions of a single cylinder four-stroke variable compression multi-fuel engine running on blends of Karanja and diesel at 20%, 25%, and 30%, in comparison to standard diesel. Experiments were carried out at compression ratios of 15:1, 16:1, 17:1, and 18:1. The investigation focused on the influence of compression ratio on fuel consumption, brake thermal efficiency, and exhaust gas emissions. Utilizing response surface methodology, the experimental analysis determined that the optimal working condition is a blend of 25% biodiesel and diesel with a compression ratio of 18. [10]

The study showcases the performance of biodiesel blends in a single-cylinder water-cooled diesel engine. All tests were conducted at a constant speed of 1500 rpm, with biodiesel blends ranging from B10 to B100. The engine featured a variable compression ratio (VCR) mechanism. In the case of 100% Jatropha biodiesel, fuel consumption was 15% higher compared to diesel. Brake thermal efficiency for biodiesel and its blends was slightly superior to diesel across different load conditions. Specific fuel consumption increased from 2.75% to 15% for B10 to B100 fuels. The exhaust gas temperature rose with higher biodiesel blends, reaching a peak of 430°C with biodiesel at 1.5 kW, 2.5 kW, and 3.5 kW load conditions, while diesel peaked at 440°C. CO2 emissions from the biodiesel-fueled engine were 25% higher than diesel at full load. On the other hand, CO emissions were 15%, 13%, and 13% lower with Jatropha at 1.5 kW, 2.5 kW, and 3.5 kW load conditions, respectively. NOx emissions were 16%, 19%, and 20% higher at 1.5 kW, 2.5 kW, and 3.5 kW compared to diesel, respectively. [11]

A study [12] revealed that methyl ester of coconut oil can partially substitute diesel fuel in existing conventional diesel engines without requiring major modifications to engine components. Blends of up to 40% methyl ester of coconut oil showed engine performance comparable to that of diesel-fueled engines, with only minor differences. Fuel consumption rate, brake specific fuel consumption, and brake specific energy consumption were lower with methyl ester of coconut oil blending compared to neat diesel. However, long-term performance and endurance tests to evaluate engine durability with prolonged use of this blended fuel were not conducted. Given the limited experience with biodiesel usage overall, it is difficult to make assumptions about the effects of long-term use. Both Beer et al. and Hitchcock et al. reported problems with softening or failure of rubber engine components, but this issue can likely be avoided by replacing selective components with more compatible materials.

Research conducted in both the United States and Europe has consistently shown that the combination of Biodiesel and petrodiesel leads to slight reductions in the overall power output of engines. Notably, there have been only two studies conducted specifically on marine engines. One study was carried out by Dr. Claus Breuer, a German scientist, as part of his Ph.D. thesis at the Technical University in Hannover in 2001. The other study was conducted by Alvin Womac's group at the Department of Agricultural Engineering at the University of Tennessee. [13]

The German study involved a Deutz 4 cylinder marine diesel engine (direct injection) found on fishing boats in Europe and the Tennessee study evaluated a 110 HP Volvo marine diesel engine, also used in work boats and fishing boats. Volvo also makes smaller single and double cylinder diesel engines for recreational sailboats.[14]

The findings of the German study align with those of Mercedes Benz, demonstrating that the torque curve of an engine under load remains largely unchanged when using rapeseed methyl esters instead of pure petro diesel. Despite biodiesel having a lower volumetric heating value and consequently a lower maximum power output, the practical results are comparable. A 20% blend of biodiesel would likely not result in any noticeable difference in power output. Biodiesel and its blends exhibit good performance in fuel combustion, leading to a smoothly running engine. In a study conducted on a Volvo marine diesel engine in Tennessee, power outputs were measured using a tractor dynamometer under specific loads and through an engine-mounted reverse drive gear. Exhaust emissions and fuel consumption were also tested under various loads. The conclusions drawn from these tests indicate that power produced from 100% soy methyl ester biodiesel was slightly lower, ranging from 2% to 7%, compared to petro diesel, depending on the load-speed point. However, at or near maximum throttle, the performance of the two fuels was similar. Interestingly, at the lowest engine speed and under heavier load, there was a 13% increase in power when using biodiesel compared to petro diesel. The Tennessee study suggests that using 100% biodiesel in marine direct-injection diesel engines, with similar design and construction to the Volvo test engine, can be recommended without any significant noticeable differences in operation, power performance, and fuel usage.[15]

Study at the Southwest Research Institute in 2003, on Biodiesel effects on diesel engine performance, engine power in the 2001 Cummings truck engine operating on the B-20 blend was at 98.5% of the power attained with low sulfur No. 2 diesel. At 100% Biodiesel, the engine generated 92% of the power. For a Detroit Diesel truck engine (2001), the power was 98% with the B-20 and 92% with the neat Biodiesel.[16]

Biodiesels consist of mono-alkyl esters with around 10% oxygen content by weight. While the oxygen enhances combustion efficiency, it does occupy space in the blend, leading to a slight increase in the apparent fuel consumption rate when using Biodiesel in an engine. According to the Southwest Research Institute study from 2003, fuel consumption only rose by 2% with a B-20 blend containing methyl esters, but increased by 14% when using 100% methyl ester Biodiesel in the Cummins test engine under heavy transient loads. The brake-specific fuel consumption was 0.43 lb./HP-Hr for regular petro diesel no. 2, 0.44 lb./HP-Hr for the B-20 blend, and 0.50 lb./HP-Hr for neat RME Biodiesel. [17]

During the 4-year period of testing Biodiesel in the CytoCulture Mercedes Benz diesel station wagon, there was a recorded 15% decrease in mileage when using pure Biodiesel compared to petro diesel. Despite this, no alterations in power, acceleration, or engine temperature were detected. However, it was noted that the engine operated more quietly and smoothly at idle when running on Biodiesel. When Biodiesel was blended at a 20% ratio with petroleum diesel, the discrepancies in fuel consumption were nearly imperceptible.

These local observations were confirmed by the 2004 engine performance studies at the Southwest Research Institute. Fuel consumption in a1995 Cummings B-5.9 truck engine increased by 9% with the B-20 blend, and by 18% with the neat Biodiesel. Better fuel economy was noted for a 1997 Cummings N-14 truck engine with a 3% drop in fuel consumption using B-20 and a 13% increase with the neat Biodiesel.[18]

The methyl esters of vegetable oil, when oxygenated, exhibit remarkable solvent properties towards natural rubber and certain soft plastics, resulting in the biodiesel having strong solvent effects. This can lead to the gradual deterioration of old rubber fuel lines, seals, and gaskets in the presence of higher concentrations of biodiesel. However, it is worth noting that these solvent effects are rarely observed in a B-20 blend, and most of the issues associated with the solvent effects occur when using 100% neat biodiesel, particularly in boats. When fuel lines or gaskets are affected, they tend to become sticky, soften, or swell over time, causing fuel to leak from connections. For instance, a rubber fuel line on a Yanmar sailboat engine became tacky after operating on 100% biodiesel for 4 years, although it did not leak. The most effective solution is to replace the affected lines and gaskets with modern synthetic hoses and seals. Conventional US Coast Guard approved fuel lines have proven resistance to neat biodiesel and have been successfully tested on sailboats over the past 3 years. In California, a readily available approved fuel hose in marine stores is the "Trident Barrier Fuel Hose, USCG Approved Type A-1, and SAE J1527 (2/93)."[19]

During bench top studies carried out at Cyto Culture, it was found that the Trident hose exhibited resistance to pure Biodiesel for several months. However, the hose did absorb Biodiesel and experienced slight swelling (tightening under hose clamps). No issues have been reported with these new fuel hoses when used with 20% blends. Even when subjected to 100% Biodiesel, only minor swelling has been observed on the Trident Barrier fuel hoses used in test engines operating on pure Biodiesel for multiple years.[20]

Research conducted by the National Biodiesel Board on the compatibility of Biodiesel with various materials has determined that Viton is the only hose and gasket material that is truly resistant to the solvent effects of methyl esters. While Viton fuel hoses can be specially ordered for boats, they tend to be expensive, costing over $5.00 per foot for a 5/16" line. However, there is only one known boat in the San Francisco area that has converted to Viton fuel lines as a precautionary measure. In a 1997 survey conducted by CytoCulture, it was found that 2% of boaters in the San Francisco Bay area experienced issues with swelling gaskets and seals, primarily at the fuel filter, resulting in drips. However, replacing these gaskets with modern synthetic materials seemed to resolve the problem. Raycor filters, for instance, have been functioning normally with 100% Biodiesel and have not encountered any gasket issues in engines operated with neat Biodiesel over the past four years. The survey results can be found on the CytoCulture website. According to the survey, 5% of boaters reported minor problems with Biodiesel if it was spilled on decks, engines, or into bilges. The esters in Biodiesel have solvent properties that can loosen old paint on engines or painted surfaces in the bilge. Additionally, Biodiesel can stain raw wood surfaces and is particularly harmful to teak decks with polysulfide seams. Extra caution should be exercised when filling tanks via deck ports to avoid any damage. Furthermore, if Biodiesel is spilled and not promptly cleaned up, it could potentially harm rubber engine mounts. It is recommended to use paper towels or absorbent pads to remove spilled Biodiesel and thoroughly clean the affected surfaces with warm soapy water. [21].

Conclusion

The utilization of biodiesel has the potential to decrease the reliance on crude oil resources, leading to a reduction in its consumption. Biodiesel usage can result in lower emissions and less environmental harm. Biodiesel can be incorporated into current engines without the need for any adjustments, thus cutting down on the expenses related to engine modifications. When biodiesel is blended with diesel in diesel engines, it can enhance engine performance and notably decrease emissions. The most widely used method for producing biodiesel is transesterification. During the transesterification process, esters and glycerol are produced through the reaction of oil and alcohol, and this method can also lower the density and concentration of biodiesel. As the engine load rises, the braking thermal efficiency, exhaust gas temperature, and all exhaust emissions increase. In comparison to diesel, biodiesel has a lower calorific value but higher flash point, density, viscosity, and cetane number.

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