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REVIEW ON NANOPARTICLE ADDITIVES ON PERFORMANCE, COMPRESSION RATIO OF BIO-DIESEL, INJECTION PRESSURES

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ABSTRACT

Biodiesel, whose industrial production is generated for its high economic value, is gradually attaining much popularity and has great application in the replacement of diesel engines without any problems. The production of biodiesel from virgin oil and waste oil can be achieved economically and on a larger scale, giving it more advantages over traditional fuels. Biodiesel has been proved to be effective when used since it is renewable and biodegradable. It is produced from plant oils, and animal fats, as well as using algae as a third generation source. Such features allow the diesel produced from biological sources (B-Diesel) to be friendly to the environment. B-Diesel has been known to significantly lower greenhouse gas and other emissions, thus being an effective fighter for climate change. Further, due to its high compatibility to Diesel's chemistry, it can easily integrated in existing systems.

Keywords- Mahua biodiesel(B20), Combination of Nanoparticles, Pure Bio-Diesel (B100), Fuel Injection Pressure, Emissions, Combustion, Performance

Abbreviations:

B20 Blend of 20% biodiesel and 80% Diesel
HRR Heat Release Rate
EGT Exhaust Gas Temperature
FIP Fuel Injection Pressure
BTE Brake Thermal Efficiency
BSFC Brake Specific Fuel Consumption
CR Compression Ratio
CO Carbon Monoxide
HC Hydro Carbon
NO_x Oxides of Nitrogen

1. INTRODUCTION

Biodiesel, an alternative to petroleum diesel for transport which can come from vegetable oils, animal fats or recycled cooking oils. Higher compression ratios in biodiesel engines increase thermal efficiency and power output, leading to better fuel economy and lowering greenhouse gas emissions. That mean, the relationship between compression ratio and engine performance is complicated, as it depends on the specific biodiesel fuel type that was used, and also on the engine designated design and operating conditions [1-5]. Higher combustion temperatures and pressures are well known to improve the combustion of biodiesel fuels by increasing the CR. Research has indicated that increasing CRs leads to higher thermal efficiency and power output. On the other hand, though higher CRs correlates positively with significant NOx and CO2 emissions and negative effect on CO emission [6-10].

In general, with the increase of compression ratio, there is an improvement in fuel efficiency and more power output from the engine. On the other hand, it brings about that the fuel cetane number must be relatively high to avoid knocking (ignition before the piston reaches TDC) for effective running of the engine as intended. Higher cetane number, biodiesel has compared with diesel [11-15]. This can allow for higher compression ratios without knocking. In addition, other combustion characteristics should also give some different impacts on engine performance and efficiency. Properly optimized compression ratio for biodiesel can result in improved efficiency and reduced emissions of pollutants such as NOx and particulate matter compared to conventional diesel [16-20].

2. LITERATURE SURVEY:

In order to improve fuel qualities and lower emissions, the study investigates enhancing diesel engine efficiency with Mahua biodiesel mixed with TiO_2 nanoparticles Alumina, or aluminum oxide, is a chemical compound comprising aluminum and oxygen. It is a crystalline polymorph found naturally all over the world. Though it's considered a good insulating substrate, it is bad at thermal insulation and can efficiently transfer heat. Therefore, such characteristic has made alumina nanoparticles suitable for use in heaters as they help the process of heat exchange [1]. Researchers have experimented with alumina nanoparticles and tested the results on various diesel engines. It has been noted that with lower thermal efficiency, fewer emissions were emitted compared to the basic diesel engine. The fuel blend that contained nanoparticles of alumina performed better and had fewer emissions in terms of hydrocarbons, carbon monoxide, and smoke [2]. On the other hand, the application of alumina nanoparticles has downsides. Generally, most studies have determined that NOx emissions could expect a positive rise when using doped alumina nanoparticle -containing biofuel blends. This is because the addition of alumina nanoparticles increases the combustion temperature, thus creating a better opportunity for NOx formation. Nevertheless, when used as a catalyst, alumina can significantly reduce emissions of CO2, hydrocarbon, and smoke, thereby being a valuable tool in working toward more sustainable and environmentally benign energy solutions [3].

Cerium Oxide (CeO2) Nanoparticles: Cerium Oxide is the material gaining much attention as a potential combustion catalyst for such fuels as biofuel, being highly oxidizable, which may allow for complete combustion. The structure of CeO2 nanoparticles involves an ionic transition from the +4 valence state into the +3 valence state, at high temperatures, releasing oxygen. This property makes nanoparticles of CeO2 an effective catalyst for combustion, allowing fuels to burn out completely and efficiently [4]. Edible vegetable oil, commonly used for frying and cooking, becomes toxic when reused repeatedly; it forms polycyclic aromatic hydrocarbons and dioxins that cause extreme health issues. Thus, WCO is often reused as a value-added product, such as soap, lubricants, or domestic fuel [5]. Variation of CO emission for various fuels at different loads. CO emission is found to be minimum at part load conditions and maximum at full load conditions. This is due to the rich fuel-air mixture, with less oxygen at the time of full loading, leading to the formation of CO instead of CO2. The addition of nanoparticles such as Al2O3 and CeO2 to the fuel blend improves atomization and distribution of fuel, leading to reduced CO emissions. This is because Al2O3 has higher thermal conductivity due to its role as a heat carrier between the fuel droplets, whereas CeO2 affects combustion by reducing carbon activation temperature. Altogether, the combined effect of these nanoparticles reduces CO emissions significantly; the minimum emissions are observed for the B20 blend with 30 ppm Al2O3 and 50 ppm CeO2 [6].

HC emission varies in a similar trend as CO emission; lower HC emissions are recorded at part load conditions and rise when the load increases. Higher emissions of HC are due to poor atomization, poor distribution of fuel droplets, incomplete combustion, and lack of oxygen in neat B20. The addition of nanoparticles removes all these problems, thus lowering HC emission. The catalytic activity of CeO2 nanoparticles and the heat transfer characteristics of Al2O3 nanoparticles enhance combustion, reducing HC emissions. The B20 blend with 30 ppm Al2O3 and 50 ppm CeO2 offers the minimum emissions of HC as compared to other test fuel mixtures [7]. Carbon dioxide emission is an indicator of the combustion nature of the fuel injected, with higher CO2 emission indicating more complete combustion. The fuel injection is combusted based on atomization, dispersion, mixing of fuel droplets, and availability of oxygen. Nanoparticles improve the mixing and fuel distribution in the combustion chamber when added to the B20 blend, hence minimizing CO formation. The availability of Al2O3 nanoparticles enhances atomization and dispersion of fuel droplets, leading to higher heat transfer between them [8]. The factors influencing the formation of NOx emissions are combustion temperature, oxygen content, and residual time. Addition of metallic nanoparticles to fuel blends is proved to be an efficient method for reducing NOx emissions. Oxidation and reduction of CeO2 nanoparticles simultaneously result in the decrease of NOx emissions with enhanced engine performance, as heat is released from the oxidation reaction of HCs and COs [9].

Indicating lower soot formation at lower load conditions and a rapid increase near full load conditions. The B20 blend with 50 ppm of CeO2 and 30 ppm of Al2O3 nanoparticles showed a minimum smoke emission, which was 7.36% lesser than neat B20 operation. The catalytic action of CeO2 nanoparticles and the improved heat transfer characteristics of Al2O3 nanoparticles support efficient combustion, indicating lower smoke emissions [10]. This study focused on the impact of Al2O3 and CeO2 nanoparticles on engine exhaust emissions with a B20 biodiesel blend. Results showed that the B20 blend of 30 ppm Al2O3 and 50 ppm of CeO2 nanoparticles experienced the highest reduction in engine exhaust emissions. It was observed that the combustion of the simultaneous use of these nanoparticles decreased the CO, HC, and smoke emissions [11]. The catalytic effect of CeO2 decreased NOx emissions. The best fuel blend, B20 with 50 ppm CeO2 and 30 ppm Al2O3, reduced CO, HC, NOx, and smoke emissions by 57.3%, 22.3%, 24.3%, and 7.36%, respectively, as compared to neat B20 operation [12].

This study investigates the optimization process using the Taguchi method successfully identified the optimal combination of compression ratio, fuel fraction, and load for biodiesel combustion to enhance performance and reduce emissions. The results showed significant improvements in (BTE) and reductions in (BSFC) and nitrogen oxides (NOx) emissions. [13]. In this transesterification experiment, waste cottonseed oil was converted into biodiesel using a 250 mL round-bottom flask with a water-cooled condenser, oil bath, and stirrer. The reaction involved 100 g of oil, methanol, and a catalyst, and progress was monitored using thin-layer chromatography (TLC) by sampling every 15 minutes. The catalyst was separated via centrifugation, and the supernatant was analyzed using a hexane/ethyl acetate (90:10 v/v) solvent system.

The product was identified by comparing its retention factor with methyl oleate, and the fatty acid methyl ester (FAME) yield was quantified using proton NMR, achieving an accuracy of ±2%. [14 The methodology for bio-oil production from Crotalaria juncea L. seeds involved several key steps. First, the seeds, known for their high oil content of approximately 50%, were sourced from Andhra Pradesh and dried in sunlight to reduce moisture content. After harvesting, the seeds were stored in jute bags under cold storage conditions and pretreated to remove soil contaminants and dust. A cold pressing machine was employed to extract raw hemp oil by crushing the seeds under hydraulic pressure of 207-414 MPa without heat, followed by filtration to remove residual seed waste. [15].

This study explores the testing an engine setup with specifications outlined. An electrical dynamometer was utilized to apply varying loads on the engine, ranging from no load to full load, while maintaining a constant speed of 1500 rpm. PME20 could be used as alternative fuel for operating CI engine at compression ratio of 19:1, higher injector opening pressure of 240bar and advanced injection timing of 27ºbTDC for better engine performance. The maximum brake thermal efficiency is found to be PME20 at 27ºbTDC , 240bar and compression ratio of 19 [16]. This study investigates the conducting partial oxidation (POx) reactions in a laboratory-scale reforming mini reactor. The catalyst, composed of a high cell density cordierite substrate coated with 2% platinum and 1% rhodium, was positioned in the center of the reactor. The reactor's inlet temperature was maintained at 300°C, simulating diesel engine exhaust conditions, while hydrocarbon injection flow rates ranged from 14 to 26 ml/h, with a fixed oxygen concentration of 14% by volume. [17].

The study evaluated the combustion, performance, and emission characteristics of biodiesel blends (B10, B20, B30, B50) and pure diesel (B0) on a Tec-Quipment TD43F single-cylinder, variable compression ratio diesel engine. Tests were conducted at compression ratios of 14, 16, and 18, with engine speeds ranging from 1000 to 2000 rpm at full load. Emissions (CO, CO2, NOx, HC, O2) were measured using a Techno-Test 488 analyzer, and combustion parameters were analyzed using cylinder pressure-crank angle data. [18].

This research explores the emission, performance, and combustion characteristics of biodiesel produced from non-edible oils, such as jatropha, karanja, and waste cooking oil, when used in variable compression ratio (VCR) diesel engines. The methodologies involved varying the compression ratio (ranging from 6:1 to 19:1). Specific studies reported reductions in CO and HC emissions by up to 41.97% and 42.99%, respectively, with biodiesel blends compared to diesel. [19]. The experimental investigation has been conducted in variable compression ratio diesel engine. Initially, the performance of the engine was determined with diesel fuel under different load conditions. Thereafter, the diesel engine performance was compared with the different biodiesel namely Rapeseed biodiesel (RA), Mahua biodiesel (MU), Dual biodiesel (RM) and its different blends with diesel (BL20, BL40, BL60 and BL80) at different loading conditions such as 0%, 20%, 40%, 60%, 80% and 100%. [20]. In the present study Cocklebur seed oil biodiesel blended with Karanja oil biodiesel is used as fuel. Karanja biodiesel is easily available in larger quantities. The seeds were removed from fruits of Cocklebur collected in December. The two fuels namely Fuel-1(Karanja biodiesel 80%+Cocklebur Biodiesel 20%) and Fuel-2(Karanja Biodiesel 100%) are tested in Variable Compression Ratio Diesel Engine with variation in Engine parameters [21].

The study investigates the (CR) and injection timing (IT) of an engine to optimize performance and reduce (NOx) emissions. To adjust the CR, a 1 mm thick copper washer was used to increase the clearance volume and reduce the CR, while a specially machined copper washer with an extended inner diameter was utilized to increase the CR by reducing the clearance volume. Tests were conducted at CRs of 17:1 (reduced), 19:1 (base), and 21:1 (increased) [22]. The performance and emissions of a VCR CI engine are examined in relation to bioethanol-diesel blends containing Al2O3 nanoparticles. It talks about how nanoparticles can improve combustion and reduce emissions, as well as the advantages of bioethanol as a renewable fuel. Utilizing nano fuels increased NOx emissions while decreasing CO and HC emissions and improving energy efficiency [23].

The TiO2 nanoparticles enhanced fuel properties by improving combustion efficiency and reducing emissions due to their catalytic activity. CO emissions reduced by 9.3% at peak power. HC emissions dropped by 3.8%. NOx emissions saw a 6.6% reduction. Smoke emissions fell by 2.7% [24]. ZnO_2 nanoparticles enhance diesel engine performance and efficiency. Brake thermal efficiency increased by 16.4% with MOME2030. Brake-specific fuel consumption was reduced by 10.9% for D10030. The emissions of smoke, CO, HC, and NOx decreased significantly. Cylinder pressure improved by 17.1% with MOME2030. Modified injector design improved fuel mixing and combustion [25].

3. CONCLUSION

In conclusion, this work demonstrates that the inclusion of nanoparticles, namely combinations of Nanoparticles, may effectively enhance the performance and emission characteristics of mahua biodiesel in compression ignition (CI) engines. Nanoparticles also enhance the fuel spraying characters and atomization in terms of the injection pressures which in turn enhances the combustion process and lowers particulate and unburnt hydrocarbon emissions. Their catalytic characteristics are also beneficial as they allow for burning at higher pressures which reduces knocking, for instance. Tests at fuel injection pressures of 200 and 220 bar show that these nanoparticle additions optimize brake thermal efficiency (BTE), boost combustion efficiency, and reduce harmful emissions such as NOx, CO, and HC. The results demonstrate that combinations are particular was highly effective in achieving combustion improvements and emissions reductions, indicating the viability of mahua biodiesel as a sustainable alternative fuel source for CI engines when optimized with nanoparticle additions. This work provides valuable new insights into the usage of biofuels enhanced with nanoparticles to increase engine efficiency and produce cleaner combustion.

4. REFERENCES

[1] Sarma, C. J., Sharma, P., Bora, B. J., Bora, D. K., Senthil kumar, N., Balakrishnan, D., & Ayesh, A. I. (2023). Improving the combustion and emission performance of a diesel engine powered with mahua biodiesel and TiO2 nanoparticles additive. Alexandria Engineering Journal, 72, 387-398.

[2] Simhadri K., Rao, P. S., & Paswan, M. (2024). Improving the combustion and emission performance of a diesel engine with TiO2 nanoparticle blended Mahua biodiesel at different injection pressures. International Journal of Thermo fluids, 21, 100563.

[3] Muniyappan, S., & Krishnaiah, R. (2024). The influence of TiO2 nanoparticles on the performance, combustion, and emissions on ternary blends of n-heptane, mahua biodiesel and diesel-fuelled engine using response surface methodology. Case Studies in Chemical and Environmental Engineering, 100900.

[4] Mofijur, M., Ahmed, S. F., Ahmed, B., Mehnaz, T., Mehejabin, F., Shome, S., ... & Kamangar, S. (2023). Impact of nanoparticle-based fuel additives on biodiesel combustion: An analysis of fuel properties, engine performance, emissions, and combustion characteristics. Energy Conversion and Management: X, 100515.

[5] Elumalai, P. V., Parthasarathy, M., Lalvani, J. S. C. I. J., Mehboob, H., Samuel, O. D., Enweremadu, C. C., ... & Afzal, A. (2021). Effect of injection timing in reducing the harmful pollutants emitted from CI engine using N-butanol antioxidant blended eco-friendly Mahua biodiesel. Energy Reports, 7, 6205-6221.

[6] Mohapatra, T., Mishra, S. S., Sahoo, S. S., Albani, A., & Awad, M. M. (2023). Performance, emissions, and economic evaluation of a VCR CI engine using a bio-ethanol and diesel fuel combination with Al2O3 nanoparticles. Case Studies in Thermal Engineering, 49, 103375.

[7] A. Avinash, D. Subramaniam, A. Murugesan, Bio-diesel - a global scenario, Renew. Sustain. Energy Rev. 29 (2014) 517e527, https://doi.org/10.1016/j.rser.2013.09.007. Elsevier.

[8] Bidir, M. G., Millerjothi, N. K., Adaramola, M. S., & Hagos, F. Y. (2021). The role of nanoparticles on biofuel production and as an additive in ternary blend fuelled diesel engine: A review. Energy Reports, 7, 3614-3627.

[9] Wang, W.G.; Lyons, D.W.; Clark, N.N.; and Gautam, M. neuro-fuzzy inference system, artificial neural network and response “Emissions from nine heavy trucks fuelled by diesel and biodiesel surface methodology in modeling biodiesel synthesis from palm blend without engine modification”. Environmental Science kernel oil by transesterification”, Biofuels 1–16. (2018).

[10] N. Panigrahi, M. K. Mohanty and A. K. Pradhan, “Non-edible karanja biodiesel – a sustainable fuel for C.I. engine,”Int J Eng Res Appl, vol. 2, pp. 853–860, 2012.

[11] Pandian, A. K., Ramakrishnan, R. B. B., & Devarajan, Y. (2017). Emission analysis on the effect of nanoparticles on neat biodiesel in unmodified diesel engine. Environmental Science and Pollution Research, 24, 23273-23278.

[12] Sarma, C. J., Sharma, P., Bora, B. J., Bora, D. K., Senthil kumar, N., Balakrishnan, D., & Ayesh, A. I. (2023). Improving the combustion and emission performance of a diesel engine powered with mahua biodiesel and TiO2 nanoparticles additive. Alexandria Engineering Journal, 72, 387-398.

[13] Hameed, A. Z., & Murali dharan, K. (2023). Performance, emission, and catalytic activity analysis of AL2O3 and CEO2 nano-additives on diesel engines using mahua biofuel for a sustainable environment. ACS omega, 8(6), 5692-5701.

[14] Soudagar, M. E. M., Banapurmath, N. R., Afzal, A., Hossain, N., Abbas, M. M., Haniffa, M. A. C. M., ... & Mubarak, N. (2020). Study of diesel engine characteristics by adding nanosized zinc oxide and diethyl ether additives in Mahua biodiesel–diesel fuel blend. Scientific reports, 10(1), 15326.

[15] Backiyaraj, A., Parthasarathy, M., Nachippan, N. M., Senthilkumar, P. B., & Kumaran, T. (2023). Influence of nano AL2O3 on compression ignition engine characteristics fuelled with Mahua biodiesel. Materials Today: Proceedings, 72, 2238-2244.

[16] Parida, M. K., Mohapatra, P., Patro, S. S., & Dash, S. (2024). Effect of TiO2 nano-additive on performance and emission characteristics of direct injection compression ignition engine fueled with Karanja biodiesel blend. Energy sources, part A: recovery, utilization, and environmental effects, 46(1), 7521-7530.

[17] Kumar, N., & Raheman, H. (2021). Combustion, performance, and emission characteristics of diesel engine with nanocera added water emulsified Mahua biodiesel blend. Environmental Progress & Sustainable Energy, 40(4), e13572.

[18] Sahu, D. K., Patel, C. H., Uppara, S. K., Kanchan, S., & Choudhary, R. (2022). Parametric evaluation of B20 blend of mahua biodiesel with nanomaterial additives. Materials Today: Proceedings, 50, 804-811.

[19] Y. Jamal, and M.L. Wyszynski, “On-board generation of hydrogen-rich gaseous fuels—a review” Int J Hydrogen Energy (1994); 19:557. IEEE Access.

[20] Deepak Agarwal and Avinash kumar Agarwal “Performance and emission characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine” Elsevier –Applied Thermal Engineering(2007)2314-2323.

[21] Shaisundaram, V. S., Chandrasekaran, M., Muraliraja, R., Shanmugam, M., Baskar, S., & Bhuvendran, A. (2021). Investigation of tamarind seed oil biodiesel with aluminium oxide nanoparticle in CI engine. Materials Today: Proceedings, 37, 1417-1421.

[22] Seid Mohammadi, M., Moghadasi, J., & Naseri, S. (2014). An experimental investigation of wettability alteration in carbonate reservoir using γ-Al2O3 nanoparticles. Iranian Journal of Oil and Gas Science and Technology, 3(2), 18-26.

[23] Rani, G. J., Rao, Y. H., & Balakrishna, B. (2018). Investigation of fuel injection pressure impact on CI engine performance and emissions using biodiesel blend with alumina nano additives. Int J Mech Eng Technol, 9(6), 922-928.

[24] Dinesha, P., Mohan, S. and Kumar, S., 2021. Impact of alumina and cerium oxide nanoparticles on tailpipe emissions of waste cooking oil biodiesel fuelled CI engine. Cogent Engineering, 8(1), p.1902067.

[25] Rao, S. C., Saravanakumar, A., & Sekhar, G. C. (2017). Influence of nano added MME blends on CI engine based on doe concept. International Journal of Mechanical Engineering and Technology, Volume, 8, Issue, 7, 860-868.