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Analyzing Carbon and Particulate Matter Emissions in Compression Ignition Engines with Biodiesel and Nanoparticle Additives

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Abstract

Pollutants from vehicles pose a direct threat to our ecosystem due to the emission of hazardous gases. The increasing urbanization of the world has led to higher consumption of petroleum products. These products, such as diesel and petrol, are derived from crude oil, which has limited reserves, and natural gas stocks are also limited. Countries with low or no fossil fuel reserves face significant shortages of

gasoline, crude oil, and petroleum production and supplies. This study aims to evaluate the effects of using biodiesel as an additive in diesel engines for the analysis of carbon and particulate matter emissions. The results found that carbon emissions reduce 1.13% in biodiesel, 2.54% reduction in aluminum oxide and particulate matter emissions were 4.459 biodiesel 9.669% reduced in aluminum oxide with compared to diesel. Furthermore, the addition of nanoparticles to the biodiesel blend further reduced emissions.

Keywords: engines (D.E) engine, Diesel, Bio-Diesel, nanoparticles, carbon emission, particulate matter emission, NOx and Hydrocarbon

I.I Introductions

Transportation systems around the world are mostly dependent on diesel engine machinery. It encompasses all kinds of vehicles and machinery, such as heavy-duty transport vehicles, railway engines, agricultural-related machinery, construction machinery, power generation plants, etc. However, their emissions consist of different types of air pollutants that cause environmental and health repercussions. S (Bhangwar s., et al., 2022). Found that biodiesel had similar engine performance to diesel fuel, with a slight decrease in power output, and that the use of biodiesel had a negligible effect on engine performance in terms of power and torque output. However, both studies noted that the use of biodiesel resulted in lower engine efficiency and increased fuel consumption compared to conventional fuel. The reduction of carbon emissions is one of the primary motivations for the adoption of biodiesel as an alternative fuel. Several studies have investigated the carbon emissions of biodiesel compared to conventional fuels. (Khan, Z et al ,2022). Found that the use of biodiesel resulted in lower carbon emissions compared to diesel fuel. The study reported a reduction of up to 24% in CO2 emissions when using biodiesel. investigated the effect of biodiesel on the performance of a diesel engine. The study found that the use of biodiesel had

a negligible effect on engine performance in terms of power and torque output. However, the study reported that the use of biodiesel resulted in lower engine efficiency and increased fuel consumption compared to conventional diesel fuel. (Detho, A et al 2020).

Compared the engine performance of biodiesel and diesel fuel. The study found that biodiesel had similar engine performance to diesel fuel, with a slight decrease in power output. The study also reported that the use of biodiesel resulted in higher brake-specific fuel consumption compared to diesel fuel. investigated the engine performance of a diesel engine using biodiesel and diesel fuel blends. The study found that the use of biodiesel had a negligible effect on engine performance in terms of power and torque output. However, the study reported that the use of biodiesel resulted in higher brake-specific fuel consumption compared to diesel fuel. (Temizer, İ et al., 2020). Investigated the engine performance and emissions of a diesel engine using biodiesel and diesel fuel blends. The study found that the use of biodiesel resulted in lower NOx emissions but higher particulate matter emissions compared to diesel fuel. The study also reported a slight decrease in power output and engine efficiency when using biodiesel. (Gaur, A., et al., 2021). An experimental study was conducted to analyze the performance of a 4-stroke water-cooled diesel engine using biodiesel produced from different blends of coconut oil and cotton seed oil. Their study showed that blend B10 of coconut oil was one of the finest alternative fuel replacements for diesel fuel running in a four-stroke water-cooled diesel engine. The authors' findings suggest that the use of biodiesel produced from different blends of coconut oil and cotton seed oil can be a promising alternative source of energy for reducing greenhouse gas emissions and mitigating environmental impacts... (Bhangwar, S. et al., 2024; Saif, Y. et al., 2020). They analyzed 2750 publications from their data storage collection base at Web of Science Core from 2000 to 2020 using ArcGIS 10.2, VOS viewer. The data was

categorized into three phases: the initial age of research on biofuels from waste cooking oil (2000–2007), the exploration age (2008–2015), and the stable age (2016–2020) when actual gains started to emerge. (Ali, U. et al., 2022, and Adam, A. et al., 2022). However, it also highlights some limitations in the area of research. The authors suggest that the original data for further research must come from the Web of Science database, which may exclude critical data from other databases such as Scopus and Wiley. They also encourage the use of new methods and tools for further research on biodiesel production from waste cooking oil for more comprehensive results. This research shows that more avenues can be explored through specific development, such as its application in business and climate change policy-making, which also demands further studies in the area. (Mahaser, J. et al., 2023). A research study to review the variables that have a direct impact on the production of biodiesel fuel from waste cooking oils (WCO) from an Indian perspective. They also discussed the waste disposal problem of WCO, its proposed methodology for collecting WCO from different places, and its ability to produce biodiesel. The authors reviewed multiple studies and established data that indicated homogenous catalysts can produce a biodiesel yield of 97.76%, 96.16%, 72.5%, and 63.5% with lower temperature requirements than heterogeneous catalysts. The group of diverse catalysts can increase the reaction rate by using the PI technique to obtain higher yields, such as 97.8%, 98%, 99.19%, and 98.01%, due to their sustainability factor. The majority of catalysts belonged to block superfluous materials; therefore, such results were obtained by the PI technique, which is like an ultrasound-assisted microreactor that shows better results than conventional methods. (Bhutto, A et al., 2023; Fahal, N et al., 2024). The results of the study could be useful in optimizing the production process of biodiesel and improving its performance in diesel engines. The authors presented their outcomes for WCO, whose samples were collected from various sources. The quantity of

catalyst was found to be one of the prime factors to consider in the yield of biodiesel composition. The viscosity obtained from the samples was homogenous in most of the samples of biodiesel that were analyzed in their research work. The most important factor to consider was the dosage of the catalysts in the composition process of biodiesel fuel from WCO. (Bhangwar, S. et al., 2023; Abbasi, A. et al., 2023; and. Pervaiz, S. et al., 2023).

The use of nanoparticles, particularly aluminum oxide (AlO2), as an additive in compression ignition (CI) engines has been a subject of interest in recent research. The key focus of such studies is to evaluate the impact of these nanoparticles on the performance and emissions of CI engines. Here is a comprehensive reflection based on a literature review:

2. Research methodology

Three oil samples were tested in a diesel engine as part of a study that investigated three key areas: particulate matter emissions, carbon emissions, and NOx of diesel engine. Fuel characteristics were determined using ASTM criteria to ensure accuracy. The analysis particulate matter emissions, carbon emissions and NOX were conducted under various loads and constant speed, all tests were conducted in the thermodynamics laboratory of the Department of Mechanical Engineering at Quaid-e-Awam University of Engineering, Science, and Technology Nawabshah.

2.1 CARBON EMISSION LEVEL:

In the experimental work involving an internal combustion engine, a flue gas analyzer was used. This analyzer is portable and widely applicable in industrial emission analysis. Its flexibility and ease of transport make it an ideal choice for various testing environments.

The flue gas analyzer used in this study, specifically the model 350-XL, includes a control unit that allows for precise management and monitoring of the equipment during tests. The primary focus of this experiment was to

analyze carbon emissions at a constant engine speed (rpm) while varying the load applied to the engine.

2.2 Particulate matter emissions:

The Aerocet 531S is a portable device that can measure the amount of particulate matter in the air. It is small and handheld, and it can be operated using batteries, making it easy to use in the field or on-site. The device can measure particle counts or mass PM (particulate matter) measurements and store the results as data logs, real-time networked data, or printed reports. The Aerocet 531S can measure four important mass size ranges of particulate matter: These ranges are displayed in mass mode, which means that the device measures the weight of the particulate matter in each range. Additionally, the device can measure four popular cumulative particulate size ranges (>0.5, 1.0, 2.5, 5.0, and 10.0 microns) in count mode, which means that the device counts the number of particles in each size range. The device measures particulate matter at a distance of four feet from the source, which is where the tests were conducted in this case. The tests were conducted on different blends of fuels and under various load conditions and the results were found to be within the desired specifications. Overall, the Aerocet 531S is a useful tool for measuring particulate matter in the air and can provide valuable information about air quality.

3. RESULTS AND DISCUSSION

3.1 Carbon Monoxide (CO) Emissions

The results indicated that the use of pure diesel (D100) resulted in higher emissions of carbon monoxide (CO). This is likely due to the higher carbon content in pure diesel, which leads to incomplete combustion and thus more CO production Ali, U. et al., 2022. In contrast, the B25 blend showed lower CO emissions. Biodiesel generally contains more oxygen, which can promote more complete combustion and reduce CO emissions shown in figure 1.
shown in figure 1.

3.2 Carbon Dioxide (CO2) Emissions Analysis

When using the B25 blend, the CO2 emissions were found to be lower than those produced by D100. Biodiesel generally has a lower carbon content compared to pure diesel, which contributes to reduced CO2 emissions. Additionally, the oxygen content in biodiesel promotes more complete combustion, further lowering CO2 emissions. The incorporation of nanoparticles into the B25 blend was found to further reduce CO2 emissions. Nanoparticles can enhance the combustion process by improving fuel atomization and promoting more efficient burning (Bhutto, A et al., 2023). This results in a more complete combustion process, which reduces the amount of CO2 generated shown in figure 2.

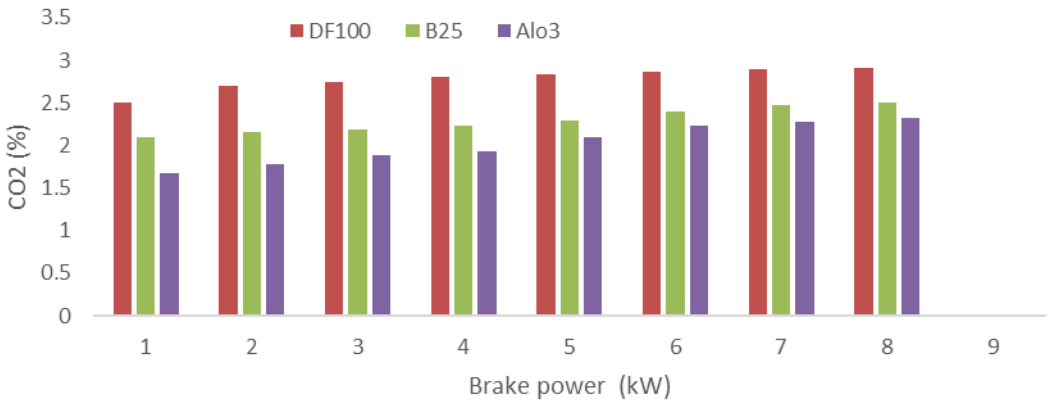

figure .2 Carbon Dioxide Emissions Vs Brake Power

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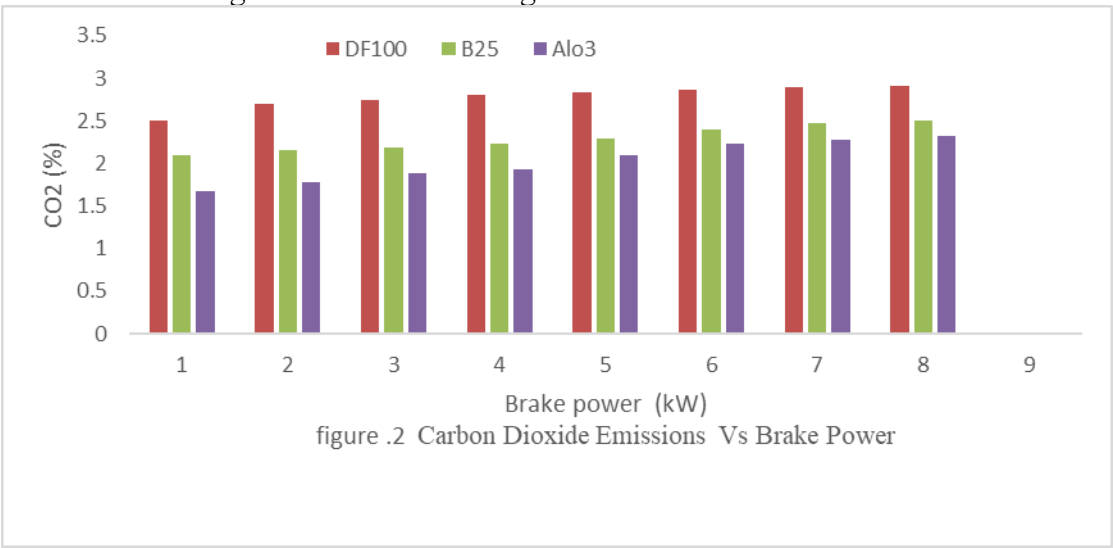


figure .2 Carbon Dioxide Emissions Vs Brake Power

3.3 Analysis of Particulate Matter Emissions

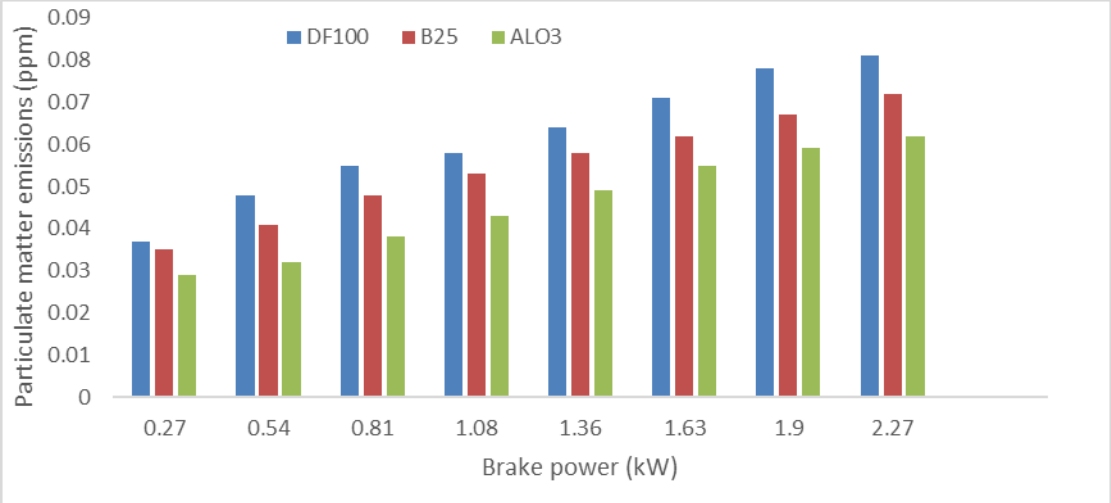


Figure 3 Particulate Matter Emissions Vs Brake Power

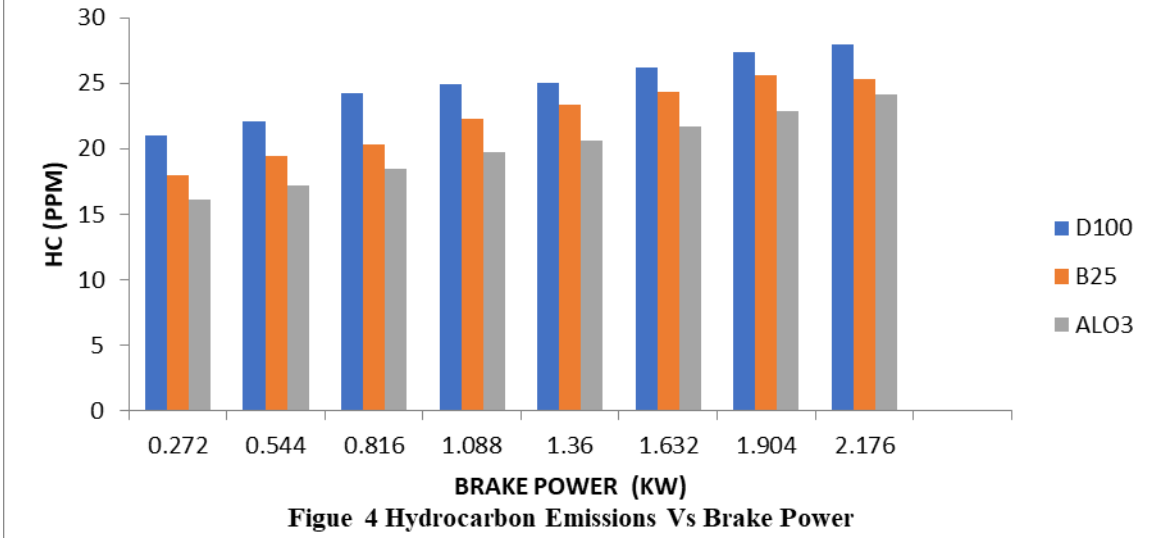
3.4 Particulate Matter Emissions:

In figure 3 shown when using pure diesel (D100), the particulate matter emissions are relatively higher. This is due to the incomplete combustion of diesel fuel, which results in the formation of more soot and particulate matter. The use of B25 (25% biodiesel blended with 75% pure diesel) results in lower PM emissions compared to pure diesel. Biodiesel has a higher oxygen content which promotes more complete combustion, reducing the formation of soot and particulate matter. When aluminum oxide nanoparticles are added to the biodiesel blend (B25), there is a further reduction in particulate matter emissions. Aluminum oxide nanoparticles enhance the combustion process by improving the fuel's atomization and ensuring more efficient burning. This leads to a more complete combustion, significantly reducing the formation of particulate matter.

3.5 HYDROCARBON EMISSIONS

As shown in Fig 4 for Diesel, the HC emission decreases with increase of engine load, due to the increase in combustion temperature associated with higher engine load. For biodiesel blended fuel, the HC emission is lower than

that of diesel and decreases with decrease of biodiesel in the fuel (Bhutto, A et al., 2023). However, for the biodiesel blended with aluminium oxide fuel, the HC emission is decrease as compared with diesel fuel and biodiesel blended fuel samples.



Figue 4 Hydrocarbon Emissions Vs Brake Power

3.6 NOx EMISSIONS

Figure 5 shows that biodiesel blended fuel has higher NOx emissions as compare with diesel fuel because biodiesel presence of mono-unsaturated and poly-unsaturated fatty acids present in the biofuel. Further aluminum oxide added in biodiesel blends fuel sample NOx emissions reduced as compared with biodiesel and diesel sample.

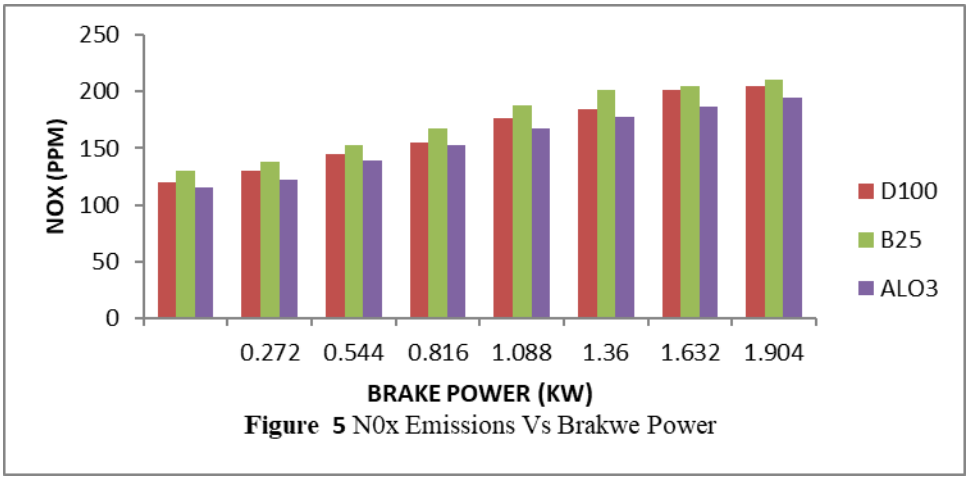


Figure 5 N0x Emissions Vs Brakwe Power

4.1 Conclusion

The research aimed to evaluate emission of diesel engine using biodiesel and nanoparticles as additive. Carbon monoxide 1.13% reduction when biodiesel blended fuel used as compared with diesel fuel and 2.54% reduction in aluminum oxide as compared with diesel fuel. Carbon dioxide reduced 6.86% in biodiesel and 10.83 % reduced in aluminum oxide as compared with diesel fuel. The study also conducted an analysis of engine particulate matter emissions. The results 4.45% reduction in biodiesel and 9.669% reduction in aluminum.

4.2 Future Recommendations

In this analysis of carbon and particulate matter emission were analyzed of compression ignition engine using biodiesel a nanoparticle as additives. Further enhance the research to analysis the performance and carbon deposition of compression ignition engine using nanoparticles.

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