Experimental Investigation of Diesel Engine Behaviour in Dual Fuel Mode Operation

Anubhav Kumar Singh and Chaitanya Shrivastava

Mechanical Engineering Department, Technocrats Institute of Technology, Bhopal, Madhya Pradesh, India

Abstract:

Dual fuel mode operation in diesel engines has gained significant attention due to its potential to enhance efficiency and reduce emissions. This paper explores various predictive models and methodologies used to estimate the performance parameters of diesel engines operating in dual fuel mode. It reviews the underlying principles, challenges, and advancements in predictive techniques, emphasizing their applicability in optimizing engine performance and meeting regulatory standards. When acetylene is used with Karanja biodiesel, the overall combustion process becomes more efficient. The combined effect of acetylene's clean burning and the biodiesel's inherent properties can lead to a notable reduction in smoke emissions. The presence of acetylene enhances the combustion efficiency, leading to lower particulate emissions and clearer exhaust.

Keyword: Diesel engine; Dual fuel mode; Emission; Gaseous fuel; Performance;

1. Introduction

Diesel engines have long been the workhorses of industries and transportation sectors worldwide, known for their robustness, efficiency, and reliability. However, with increasing environmental concerns and the drive towards reducing emissions, alternative fuel technologies have gained significant attention [1]. One such technology that has emerged as a promising solution is dual fuel mode operation in diesel engines. This approach combines the use of diesel fuel with a secondary fuel, often gaseous in nature, to achieve improved efficiency and reduced emissions.

Dual fuel technology represents a paradigm shift in diesel engine operation by introducing a secondary fuel into the combustion process. This secondary fuel, typically natural gas or liquefied petroleum gas (LPG), is introduced alongside diesel fuel into the engine's combustion chamber [2]. The combustion of the primary and secondary fuels occurs simultaneously, with the secondary fuel serving as an ignition source or as a means to alter the combustion characteristics of diesel fuel. The appeal of dual fuel technology lies in its potential to address several key challenges faced by traditional diesel engines. These include reducing emissions of nitrogen oxides (NO_x), particulate matter (PM), and greenhouse gases (GHGs) such as carbon dioxide (CO_2). By leveraging the cleaner combustion properties of gaseous fuels, dual fuel engines can achieve substantial reductions in harmful emissions compared to conventional diesel engines[3].

Dual fuel engines operate on the principle of substituting a portion of diesel fuel with gaseous fuel, which undergoes combustion alongside the remaining diesel fuel [4]. The combustion process in dual fuel engines is influenced by several factors, including the injection timing, air-fuel mixture ratios, and the properties of the gaseous fuel used. Typically, a pilot injection of diesel fuel initiates combustion, followed by the introduction of gaseous fuel into the combustion chamber. The combustion of gaseous fuel in dual fuel engines is characterized by its faster flame propagation speed and lower combustion temperature compared to diesel fuel. This results in a more complete combustion process and reduced formation of NO_x and PM emissions. The ability to vary the proportion of gaseous fuel injected allows for flexibility in optimizing engine performance and emissions across different operating conditions. The adoption of dual fuel mode operation offers several compelling benefits for diesel engine applications:

- **Emissions Reduction:** Dual fuel engines can significantly reduce emissions of NO_x, PM, and CO_2 compared to conventional diesel engines. This makes them a viable option for meeting stringent environmental regulations and achieving sustainability goals.
- **Fuel Flexibility:** Dual fuel engines provide the flexibility to use a variety of gaseous fuels, including natural gas, LPG, and biogas. This enhances energy security and resilience by diversifying fuel sources.
- **Improved Efficiency:** By leveraging the higher cetane number and faster combustion characteristics of gaseous fuels, dual fuel engines can achieve higher thermal efficiencies compared to conventional diesel engines.

- **Cost Savings:** Depending on fuel availability and pricing, dual fuel engines can offer cost savings relative to diesel-only operation, especially in regions where gaseous fuels are economically advantageous.

Dual fuel technology is finding applications across a wide range of industries and sectors:

- **Transportation:** Dual fuel engines are used in heavy-duty vehicles such as trucks, buses, and locomotives, where they offer emissions reductions without compromising performance.
- **Marine:** Dual fuel engines are increasingly being adopted in marine vessels, providing a cleaner alternative to traditional marine diesel engines and helping to reduce emissions in port cities and coastal areas.
- **Power Generation:** Dual fuel engines are utilized in stationary power generation applications, where they can operate on natural gas or diesel fuel depending on availability and economic considerations.

While dual fuel technology presents promising opportunities, it also faces challenges that must be addressed to realize its full potential:

- **Engine Design and Optimization:** Optimizing dual fuel engine performance requires careful consideration of combustion parameters, injector design, and fuel management strategies.
- **Fuel Supply Infrastructure:** The adoption of dual fuel engines may necessitate investments in fuel supply infrastructure, including storage, distribution, and refueling facilities for gaseous fuels.
- **Regulatory Compliance:** Meeting emissions standards and regulatory requirements for dual fuel engines can be complex, requiring ongoing research and development efforts.

Always developing energy request has spurred motor scientists to find eco-accommodating and maintainable cleaner fills for diesel motors. Numerous researchers have utilized different oxygenated added substances to upgrade the exhibition of the acetylene fuelled diesel motor, though no work has been tracked down in the writing to use n-butanol as an added substance in acetylene double fuel motor. The author therefore examined the effect of n-butanol on an acetylene-fueled CI engine's combustion, performance, and emission parameters in light of this significant gap in the literature. In the current study, an experimental investigation was carried out on a modified diesel engine with acetylene being introduced at different rate while Karanja biodiesel was used as pilot fuel at different load [5]. The outcomes show that when the extent of acetylene is expanded to more than 1 lpm the parameters gave inferior results, perhaps because of adequate measure of oxygen accessible to combust entire acetylene-air combination [6].

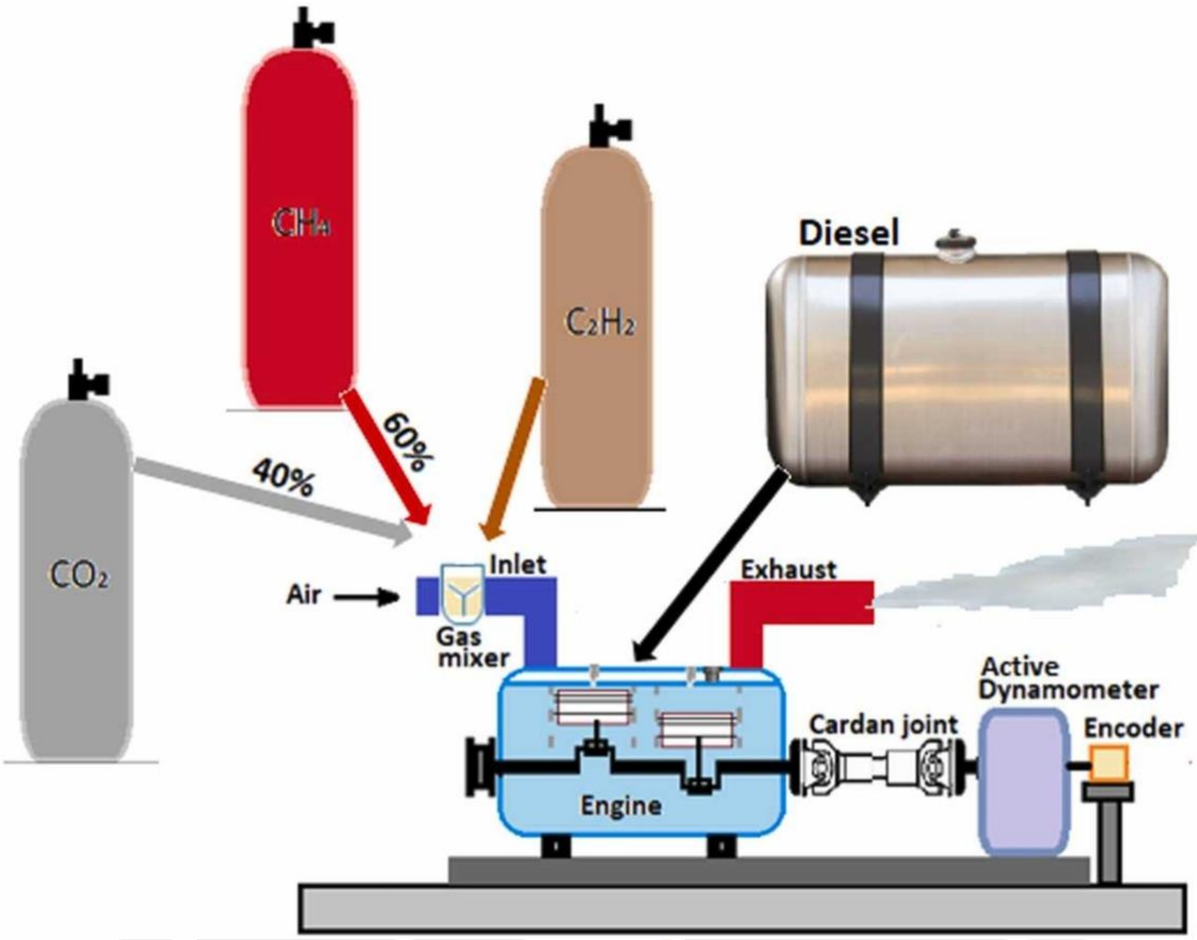

Fig.1 Use of acetylene gas with EGR

BSEC increments possibly during acetylene acceptance due to the higher fire speed of acetylene. For the entirety of the loading conditions when the engine is in dual fuel mode, the EGT is lower than normal diesel [4]. The most noteworthy worth of pinnacle chamber pressure is 77.87 bar and the HRR is 53 J/ºCA when the B10 fuel is infused as pilot fuel. In addition, at maximum load, the CO value decreases by 23% compared to baseline diesel, whereas the HC value increases by 8% compared to normal diesel at full load conditions [7]. However, when injecting B10 blend, NO_x levels drop significantly by 18%—at peak loads, which may be due to the lower combustion temperature caused by the higher latent heat of vaporization of n-butanol/diesel blend. The smoke mistiness is least for example 44% lower than typical diesel at most extreme burden while infusing B10 mix in DFE [8]. The proportion of acetylene's total energy.

2. Experimental Analysis

At a constant speed of 1500 rpm, an injection pressure of 200 bar, and an injection angle of 23° BTDC, Kirloskar's modified TAF engine with acetylene dual-fuelled CI engine underwent a series of tests to determine the effects of using with Karanja biodiesel.

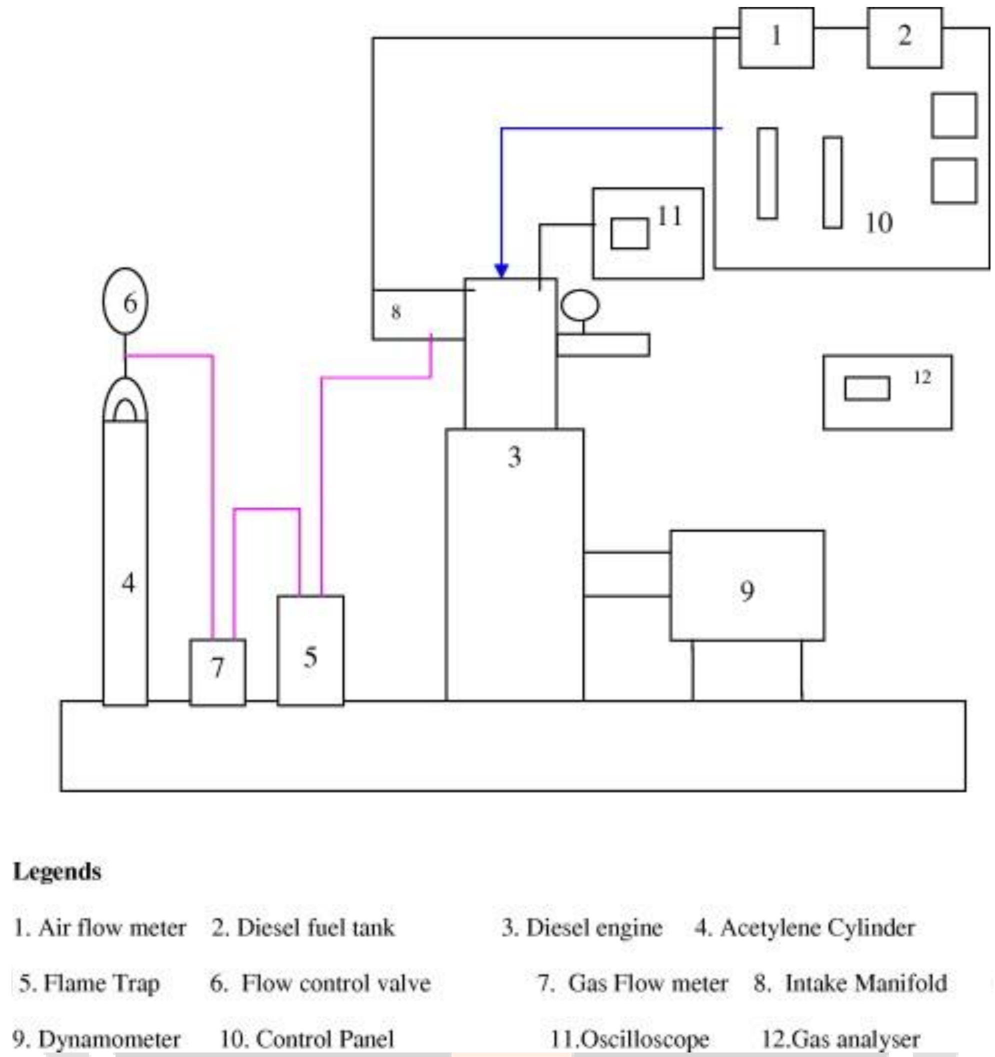

Fig.2 Schematic representation of test setup

A modified CI engine, dynamometer, gas flow meter, liquid flow measuring device, K type thermocouple pressure transducer, crank angle encoder, AVL di-gas analyzer, smoke meter, and the data acquisition (DAQ) system make up the experimental setup. The itemized motor determinations are exhibited in subsequent section. A DC dynamometer was used to measure the engine's speed, torque, and brake power. The test motor was changed marginally to work on double fuel mode by enlisting acetylene at variation of 1 LPM by the assistance of gas stream meter. The release pressure is kept up with at 0.7 bar with the assistance of a twofold stage pressure controller. The flame arrestor and the flame trap were used to ensure smooth operation and to prevent serious problems like backfiring and overheating. Air was presented in the blending chamber in addition the admission of air was estimated utilizing a wind current sensor associated with the air consumption. A stopwatch and a burette that had been calibrated were used to measure the amount of pilot fuel. A K-type thermocouple was attached to the engine's exhaust end to measure the EGT.

3. Results and Discussions

Figure 3 shows the pattern for BTE with brake power (BP) When acetylene was used in dual fuel mode operation. shows how BTE changes when BMEP is changed for different flow rate of acetylene with Karanja biodiesel blend while injecting biodiesel as piolet fuel in a modified CI engine [9]. From no load to full load, the BTE of an acetylene-fueled normal diesel engine ranges from 3% to 29%; however, it is lower than that of baseline diesel (4%–30%). This may be because acetylene burns more quickly due to its higher flame velocity. Moreover, when the n-butanol-diesel mix is utilized as pilot fuel burning improves slowly, this may be because of an adequate measure of oxygen accessible for legitimate touching off of acetylene air combination in the end expanding the BTE. BTE varies from 3% at zero loads to 31% at peak loads for the B05 blend acetylene engine, whereas when the n-butanol percentage is increased to B10, BTE varies from 4% to 32% at no load to full load conditions. At peak loading conditions, the BTE of the blended fuel in both cases (B05 and B10) is higher than that of regular diesel. Due to improved combustion, the BTE of the B10 blend-fueled acetylene engine is greater than that of any other tested fuel. Different pieces of research have reported outcomes that are comparable In general, it can be deduced that when biodiesel is used to replace diesel, efficient and stable combustion occurs, resulting in improved acetylene fuel utilization.

The EGT diminishes with the enlistment of acetylene in contrast with typical diesel mode; this could because of the greater fire speed of acetylene causing higher HRR in the long run expanding heat move misfortunes from the chamber wall to the environmental factors [9]. During combustion analysis, the cylinder pressure graph mentioned earlier also confirms this result. The fumes gas temperature at full burden, portrayed in figure 3, arrives at 368 °C in acetylene acceptance procedure and 444 °C on account of benchmark diesel activity [9].

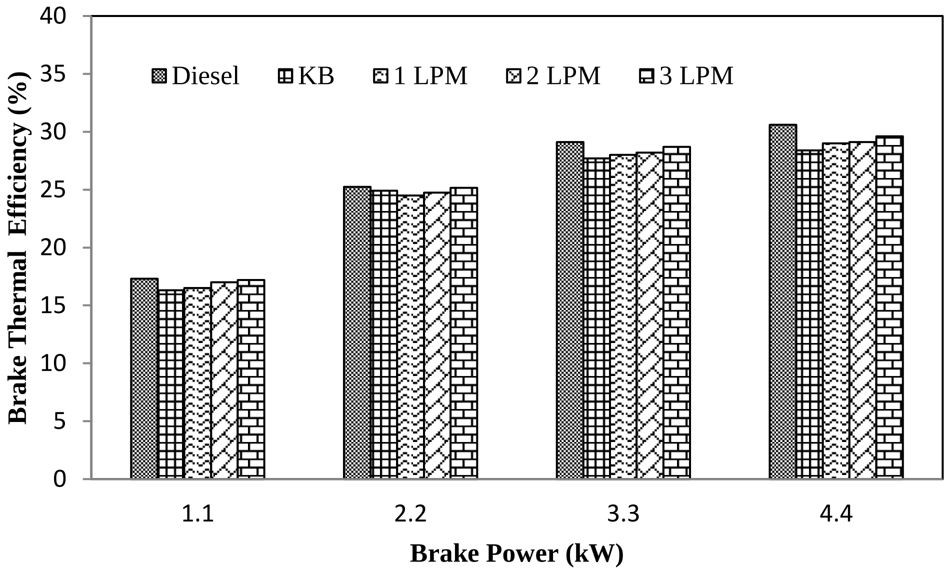

Fig. 3 BTE Variations

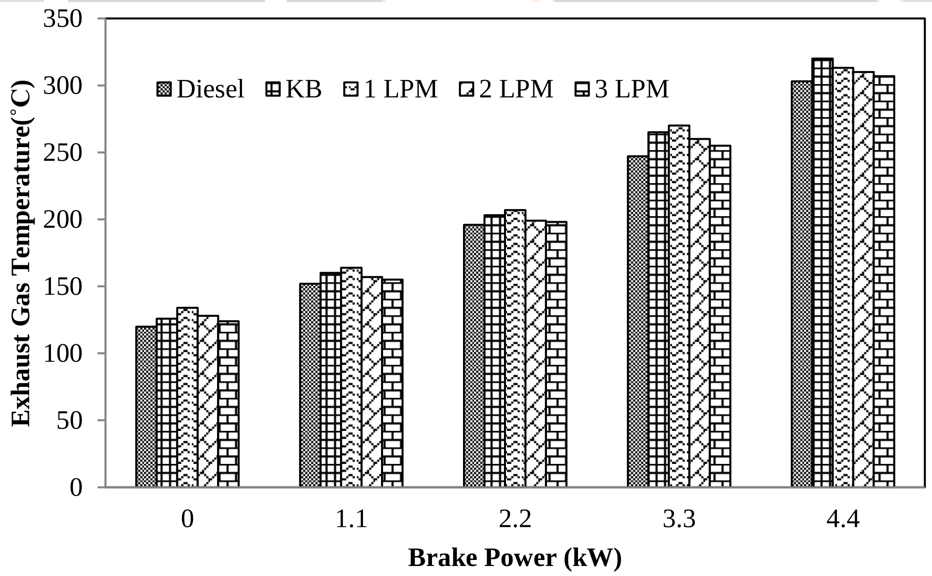

Fig.4 EGT Variations

Acetylene acceptance diminished the fumes gas temperature at all heaps, demonstrating the progression of energy discharge in the cycle and higher fire speed. This was confirmed by the cylinder pressure diagram, which showed that when acetylene and intake air were introduced earlier in the cycle, maximum pressure was observed.

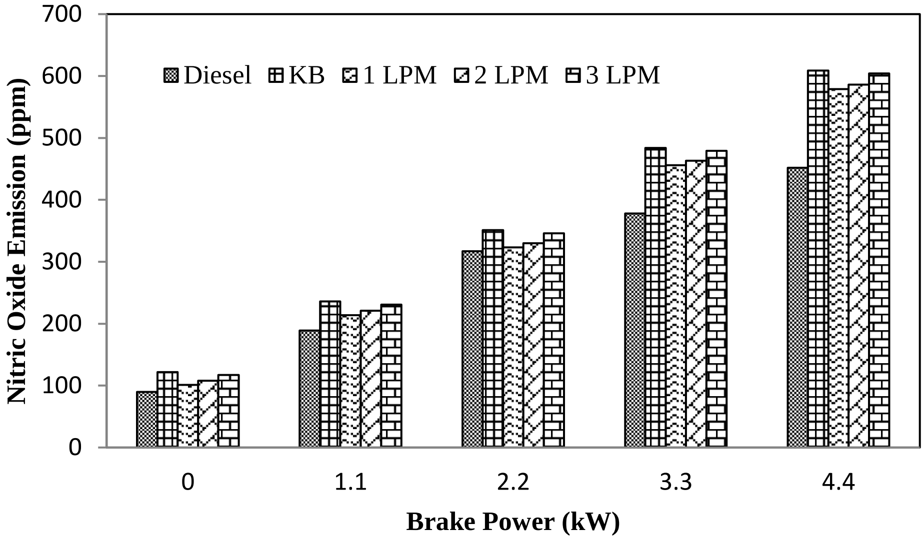

Fig. 5 NO_x variations

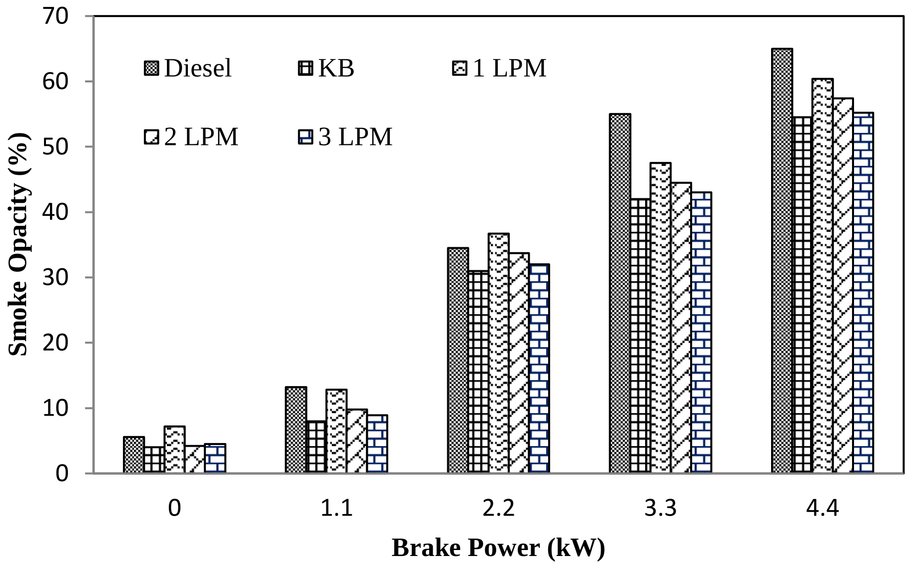

Fig.6 Smoke variations

Acetylene is known for its high flame temperature, which can lead to higher combustion temperatures in the engine. This increase can cause an elevation in NO emissions because NO is formed more readily at higher temperatures. Diesel engines, when fueled with acetylene, can experience a shift towards higher NO production. The formation of NO is highly temperature-dependent, and acetylene's contribution to higher temperatures can result in increased NO formation in the engine exhaust [10]. Karanja biodiesel tends to have a lower combustion temperature compared to conventional diesel due to its lower energy density and different combustion properties. When combined with acetylene, the overall effect might be a bit nuanced. If the acetylene boosts the combustion temperature significantly, it may offset the lower temperature effect of the biodiesel. Given that acetylene generally raises combustion temperatures, and considering that Karanja biodiesel might not fully counteract this effect, the net result is likely an increase in NO emissions. However, the extent of this increase can vary based on the proportion of acetylene used and the engine operating conditions.

Acetylene has a high combustion efficiency and burns with a clean flame. This can reduce smoke emissions by improving the combustion process and reducing incomplete combustion. As acetylene helps in better atomization and mixing of the fuel-air mixture, it can reduce the number of unburned hydrocarbons and particulates that contribute to smoke. Karanja biodiesel generally produces lower smoke emissions compared to traditional diesel fuel [11]. It has better combustion properties and higher cetane numbers, which contribute to more complete combustion and less smoke. When acetylene is used with Karanja biodiesel, the overall combustion process becomes more efficient. The combined effect of acetylene's clean burning and the biodiesel's inherent properties can lead to a notable reduction in smoke emissions. The presence of acetylene enhances the combustion efficiency, leading to lower particulate emissions and clearer exhaust.

4.Conclusion

Looking ahead, the future of dual fuel mode operation in diesel engines hinges on advancements in engine technology, fuel supply infrastructure, and regulatory frameworks. As global efforts to reduce greenhouse gas emissions intensify, dual fuel technology is poised to play a pivotal role in enabling cleaner and more sustainable transportation and power generation solutions. In conclusion, dual fuel mode operation represents a promising evolution in diesel engine technology, offering enhanced efficiency, reduced emissions, and greater fuel flexibility. Through ongoing innovation and collaboration across industry and research sectors, dual fuel engines are poised to drive the next generation of sustainable transportation and energy solutions.

Using acetylene with Karanja biodiesel is likely to increase NO emissions due to the higher combustion temperatures resulting from acetylene. Karanja biodiesel's lower combustion temperature alone might not be sufficient to counterbalance this increase. The combination of acetylene and Karanja biodiesel tends to reduce smoke emissions. The clean-burning nature of acetylene and the improved combustion characteristics of Karanja biodiesel contribute to lower particulate matter and smoke. In practical applications, the specific outcomes can vary based on engine settings, the proportion of acetylene used, and other operational conditions. Therefore, careful calibration and testing are essential to optimize the benefits while managing the trade-offs in emissions.

References

1. Powar, R.S., Yadav, A.S., Ramakrishna, C.S., Patel, S., Mohan, M., Sakharwade, S.G., Choubey, M., Ansu, A.K., Sharma, A.: Algae: A potential feedstock for third generation biofuel. Mater. Today Proc. 63, A27–A33 (2022).
2. Karthick, M., Logesh, K., Baskar, S., Sharma, A.: Performance and Emission Characteristics of Single-Cylinder Diesel Engine Fueled with Biodiesel Derived from Cashew Nut Shell. In: Advancement in Materials, Manufacturing and Energy Engineering, Vol. II. pp. 521–529. Springer (2022).
3. Sharma, A., Murugan, S.: Combustion, performance and emission characteristics of a di diesel engine fuelled with non-petroleum fuel: A study on the role of fuel injection timing. J. Energy Inst. 88, 364–375 (2015). https://doi.org/10.1016/j.joei.2014.11.006.
4. Logesh, K., Karthick, M., Baskar, S., Sharma, A.: Performance and Emissions Characteristics of Diesel Engine Run on Citrullus Colocynthis Biodiesel with Zinc Oxide Additive. In: Advancement in Materials, Manufacturing and Energy Engineering, Vol. II. pp. 513–520. Springer (2022).
5. Lakshmanan, T., Nagarajan, G.: Experimental investigation of timed manifold injection of acetylene in direct injection diesel engine in dual fuel mode. Energy. 35, 3172–3178 (2010).
6. Ilhak, M.I.: Effects of Using Acetylene-Enriched Biogas on Performance and Exhaust Emissions of a Dual Fuel Stationary Diesel Engine. Process Saf. Environ. Prot. (2024).
7. Sonachalam, M., PaulPandian, P., Manieniyan, V.: Emission reduction in diesel engine with acetylene gas and biodiesel using inlet manifold injection. Clean Technol. Environ. Policy. 22, 2177–2191 (2020).
8. Lakshmanan, T., Nagarajan, G.: Experimental investigation on dual fuel operation of acetylene in a DI diesel engine. Fuel Process. Technol. 91, 496–503 (2010).
9. Sharma, A., Murugan, S.: Effect of blending waste tyre derived fuel on oxidation stability of biodiesel and performance and emission studies of a diesel engine. Appl. Therm. Eng. 118, 365–374 (2017). https://doi.org/10.1016/j.applthermaleng.2017.03.008.
10. Sharma, A., Murugan, S.: Investigation on the behaviour of a DI diesel engine fueled with Jatropha Methyl Ester (JME) and Tyre Pyrolysis Oil (TPO) blends. Fuel. 108, 699–708 (2013). https://doi.org/10.1016/j.fuel.2012.12.042.
11. Sharma, A., Murugan, S.: Potential for using a tyre pyrolysis oil-biodiesel blend in a diesel engine at different compression ratios. Energy Convers. Manag. 93, 289–297 (2015). https://doi.org/https://doi.org/10.1016/j.enconman.2015.01.023.