Journal of Mines, Metals and Fuels, *71(12): 2641-2647; 2023. DOI: 10.18311/jmmf/2023/40596*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Effect of Additive on Engine Performance with SVO and Biodiesel Blend as Fuel

Sharanappa Godiganur[1], Veerbhadrappa Telgane[2]* and H. V. Srikanth[3]

[1]*Automoitve Engineering, Dhole Patil College of Engineering, Wagoli, Pune - 412207, Maharashtra, India*

[2]*School of Mechanical Engineering, REVA University, Bengaluru - 560064, Karnataka, India*

[3]*Department of Aeronautical Engineering, Nitte Meenakshi Institute of Technology, Bengaluru - 560064, Karnataka, India*

Abstract

In this study, experiments are carried out to explore the impact of incorporating Diethyl Ether (DEE) as an additive into biodiesel-Straight Vegetable Oil (SVO) blends derived from Pongamia seeds. Our objective was to assess the influences of additives on the engine performance characteristics of a CI engine. The different fuel blends such as BD80+SVO15+DEE5 (comprising 80% biodiesel, 15% SVO, and 5% DEE), BD80+SVO10+DEE10, BD60+SVO35+DEE5, and BD60+SVO30+DEE10 (consisting of 60% biodiesel, 30% SVO, and 10% DEE) are tested and compared these blends with conventional biodiesel and Straight Vegetable Oil blends (BD80+20% SVO and BD60+40%SVO). The inclusion of DEE as an additive had a noticeable impact on engine performance. It significantly improved brake power, reduced Brake-Specific Fuel Consumption (BSFC), lowered Brake Specific Energy Consumption (BSEC), and increased Brake Thermal Efficiency (BTE). Additionally, all the blends containing DEE as an additive demonstrated decreased emissions of Nitrogen Oxides (NOx) and Carbon Monoxide (CO), with a slight increase in Hydrocarbon (HC) emissions. This research highlights the comparative suitability of DEE as an additive for enhancing the suitability of biodiesel-SVO blends as a fuel source for diesel engines.

Keywords: *Diethyl ether, Emission, Pongamia, Performance, Straight Vegetable Oil*

1.0 Introduction

The need for cleaner and renewable fuels has become urgent as fossil fuel reserves deplete and emission regulations become stricter Performance[1]. These alternative fuels are blended with traditional diesel fuel in different ratios to both lower emissions and ensure acceptable engine performance[2,3]. Nevertheless, a complete shift from fossil fuels to renewable alternatives would require significant modifications to engine hardware due to operational and technical constraints associated with their combustion in engines[4]. Alcohols have been explored as potential alternative fuels for SI engines. Furthermore, it also can be used as a fuel additive for diesel. A lot of research is currently under investigation on CI engine. Among the various alcohol types, ethanol and butanol have been extensively studied. Results showed that ethanol and butanol have lower cetane numbers compared to diesel[5]. This raises questions about their suitability as fuel additives in CI engines. DEE and DME stand out as a better liquid fuel additive. at ambient temperatures, making it a more convenient choice as a diesel engine fuel additive without requiring extensive modifications, unlike DME, which is in gaseous form[6-8].

*Author for correspondence

Only a few studies have explored the possibility of using DEE as an alternative fuel supplement in diesel engines. Rakopols *et al.* [6-9] concluded research on this subject and found that the optimum is 24%. Moreover, the use of DEE does not change BTE but slightly increases BSFC[10,11].

Banapurmath *et al.* [12] discovered that incorporating up to 20% DEE into diesel fuel had a positive impact on engine brake thermal efficiency. Paul *et al.*,[13] delved into the effects of blending DEE with diesel fuel in varied proportions, and concluded that 5% addition of DEE shows better performance than 10%. Employing both 5% and 10% DEE led to diminished engine smoke and HC emissions when compared to using diesel fuel exclusively. Karabektas *et al.*,[14] conducted an investigation aiming to assess the potential of utilizing Diethyl Ether (DEE) as an additive in a dual-fuel CI engine with a 40% natural gas blend. Furthermore, the study demonstrated that the inclusion of DEE into biodiesel improves performance and emission characteristics[15,16].

Previous research has established that DEE can improve the performance of CI engine. It also reduces emissions when used as a fuel additive. However, the number of studies on DEE as a diesel engine fuel additive is limited. Therefore, further research is needed to comprehensively assess the impact of DEE[6-8]. While DEE can be commonly used for cold start assistance for CI engines. As it has a low auto-ignition temperature[17], it may cause increased wear and tear on the diesel injection system because of its exceptionally low viscosity. Hence, it is recommended to blend DEE with limited quantities of diesel or biodiesel as an additive to address this issue. Furthermore, concerns arise regarding DEEs as they lead to the formation of peroxides when it mixes with air[17,18].

The aim of this study was to perform an experimental analysis to assess how the inclusion of DEE as a fuel additive affects the performance and emission characteristics of diesel engines. The research involved mixing DEE as an additive, up to a 10% concentration, with biodiesel-Straight Vegetable Oil (SVO) blends derived from Pongamia seeds. The resulting blend's performance was evaluated on a single-cylinder diesel engine without any modifications

2.0 Methods and Materials

2.1 Pongamia Biodiesel Production

The initial step in biodiesel production involves acid transesterification. Pongamia oil has high FFA, hence acid esterification will increase the yield of production and reduce difficulties in transesterification. The optimized production was conducted in various samples. It was found stirring at 500-600 RPM, utilizing 30% methanol and 0.5% sulfuric acid and 60°C yielded the best. The final product was allowed to settle. Two distinct layers were found. The bottom layer found lower FFA levels, used for further processing. Transesterification is carried out using 30% methanol and a catalyst, KOH (11.22 grams) on a molar basis. The reaction was conducted for 2 to 3 hours. The resultant solution is allowed to settle in a separating flask. Excess alcohol and impurities are further removed through a water-washing process. The resulting product is then heated to above 110°C to eliminate any remaining moisture.

The biodiesel obtained is subjected to three rounds of warm water washing at 50-60 °C to remove any catalyst and soap content. Clear water indicates the absence of catalysts in the biodiesel. Finally, the product is heated to 110°C to obtain dry biodiesel, completely free from moisture. This thorough process results in the production of pure biodiesel.

2.2 Test Engine Setup

Figure 1 provides a visual representation of the experimental configuration utilized in the study. In this

Figure 1. Experimental test engine.

setup, fuel is delivered to the engine via a dedicated fuel tank linked through a fuel line, and the fuel flow rate is quantified using a burette. The engine is linked to an eddy current dynamometer, which, in turn, is connected to an electrical current source to impose a load on the engine. The dynamometer generates a counteracting electromagnetic force opposing the engine's rotational direction, thereby elevating the engine load. The engine's rotational speed remains constant throughout various loads, and observations are made regarding the time taken to deplete a specific amount of fuel and the applied torque. To initiate the engine, the fuel tank valve is opened, allowing fuel to be transported to the engine through the burette, following which the engine is cranked. The engine's output is connected to the eddy current dynamometer, which applies the opposing current to augment the engine's load. Additionally, a sensor is integrated to measure the torque applied to the engine.

3.0 Results and Discussions

3.1 Engine Performance

The engine performance with Pongamia biodiesel, Pongamia straight vegetable oil, and DEE blends have been evaluated in terms of BSFC, BSEC, and BTE, at different loading conditions of the engine.

3.1.1 Brake Thermal Efficiency

Figure 2 illustrates the relationship between load and Brake Thermal Efficiency (BTE) for various fuels. It's worth noting that an increase in load generally leads to higher BTE due to reduced heat loss and increased power output. Upon closer examination of Figure 2, it becomes evident that BD80SVO15DE5 and BD80SVO10DE10 exhibit superior BTE values compared to BD80SVO20. This can be attributed to the fact that BTE is inversely related to Brake Specific Fuel Consumption (BSFC). Despite BD80SVO15DE5 and BD80SVO10DE10 having lower calorific values, their effective atomization and combustion quality result in elevated BTE values. This trend is also observable in higher blends, such as BD60SVO35B5 and BD60P30DE10.

3.1.2 Brake-Specific Fuel Consumption

Figure 3 illustrates the relationship between load and Brake-Specific Fuel Consumption (BSFC) for two different fuel blends. It is evident that, across all the tested fuels, there is a noticeable reduction in BSFC as the load increases. BD80SVO15B5 and BD80P10DE10 exhibit notably lower BSFC when compared to BD80SVO20, and this reduction in BSFC becomes more pronounced with an increase in the additives within the blends, despite their lower calorific values. This phenomenon can be attributed to superior atomization and combustion quality. This trend is also observed in higher blends, such as BD60SVO35B5 and BD60P30DE10.

3.1.3 Brake-Specific Energy Consumption

The concept of Brake Specific Energy Consumption (BSEC) offers a convenient parameter, as it remains unaffected by the type of fuel used. This allows for a

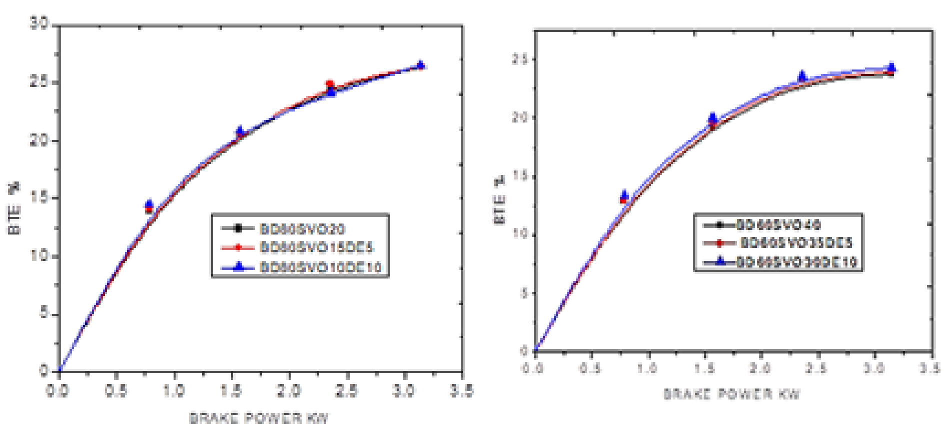

Figure 2. Comparison of BTE with BP for fuel blends and additives.

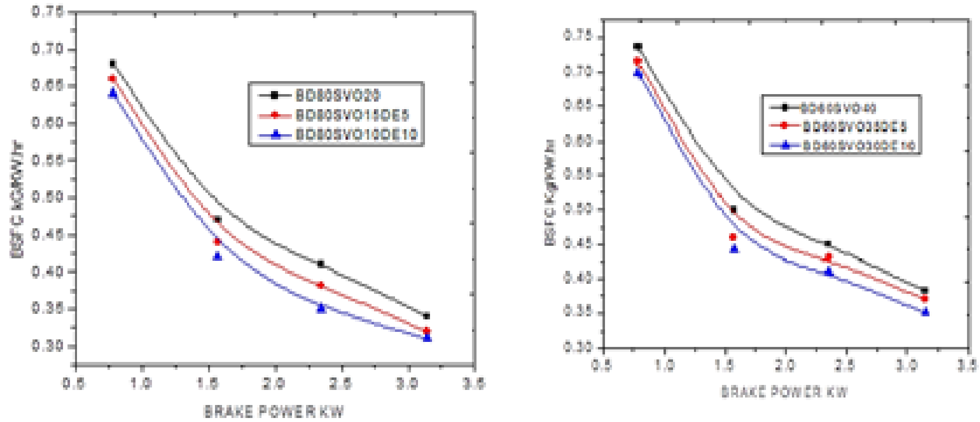

Figure 3. Comparison of BSFC with BP for fuel blends and additives.

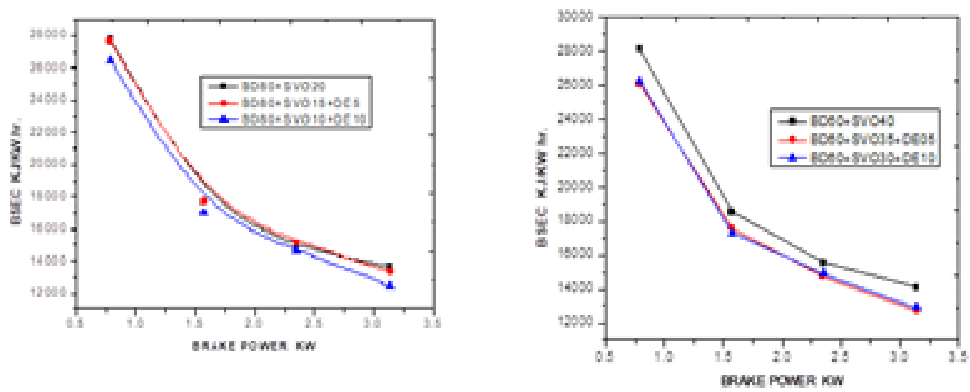

Figure 4. Comparison of BSEC with BP for fuel blends and additives.

straightforward comparison of energy usage rather than solely focusing on fuel consumption. Figure 4 provides a graphical representation of how BSEC varies with load for all fuels. Across all fuels tested, an increase in load consistently led to a decrease in BSEC. The data presented in Figure 4 reveals that BD80SVO15B5 and BD80P10DE10 exhibited lower BSEC values compared to BD80SVO20. This reduction in BSEC can be attributed to the higher concentration of additives in the fuel blend, which enhances atomization and combustion quality. This trend persists even in higher blends like BD60SVO35B5 and BD60P30DE10, where a decrease in BSEC is observed despite their lower calorific values.

3.2 Exhaust Emissions

3.2.1 Hydrocarbon Emission

Figure 5 depicts the influence of additives on hydrocarbon (HC) emissions. Within the combustion process, unburned HC emanates from various sources within the cylinder. The findings indicate that incorporating oxygenated compounds in biodiesel results in a reduction in HC emissions when combined with Straight Vegetable Oil (SVO). Nevertheless, the introduction of additives leads to an elevation in HC emissions when compared to the biodiesel and SVO mixture. To be more precise, HC emissions increase by up to 90% for BD80SV15DE05 and 120% for BD60SV35DE05.

3.2.2 Carbon Monoxide Emission

From Figure 6, it is evident that the emission of carbon monoxide (CO) in biodiesel and Straight Vegetable Oil (SVO) blends is lower than that in conventional diesel fuel, even in the absence of additives. Nevertheless, the inclusion of additives leads to a more pronounced reduction in CO emissions, as exemplified by the decreases

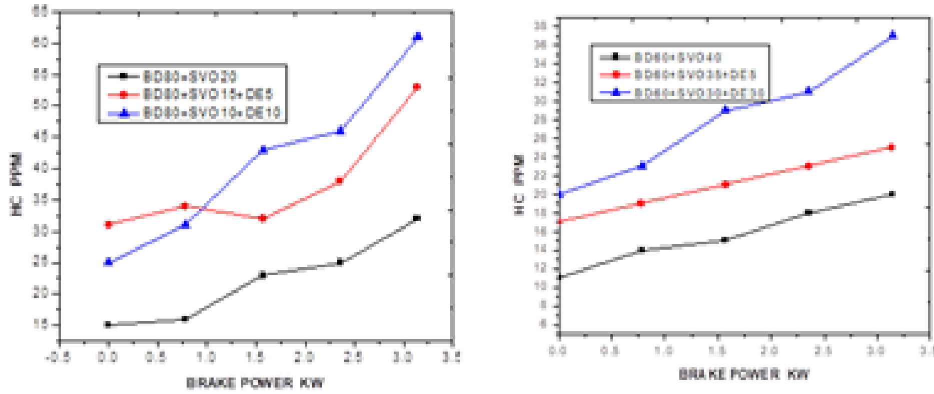

Figure 5. HC emission with BP for fuel blends and additives.

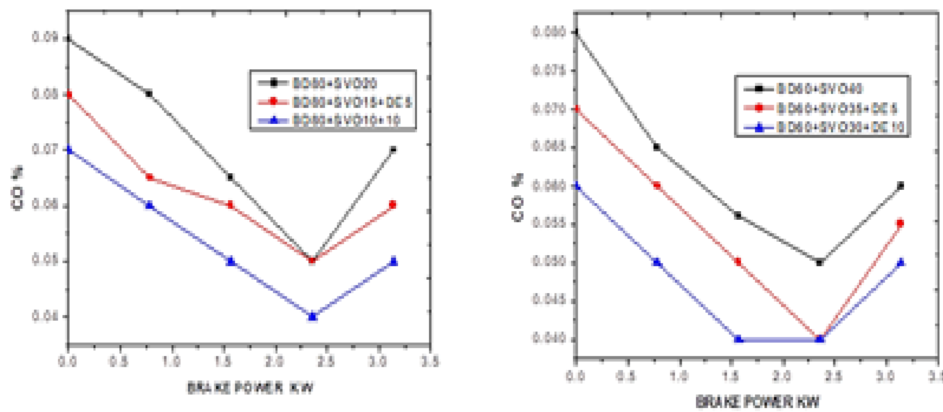

Figure 6. CO emission with BP for fuel blends and additives.

seen in blends like BD80SV15DE05 and BD60SV35DE05 when compared to blends lacking additives. Moreover, it was observed that as the proportion of additives in the blends increased, there was a corresponding increase in the magnitude of the reduction in CO emissions.

3.2.3 Nitrogen Oxide Emission

In Figure 7, a comparison of emissions for various blends is presented. The data demonstrates that as the speed decreases, NO emissions show an increase across

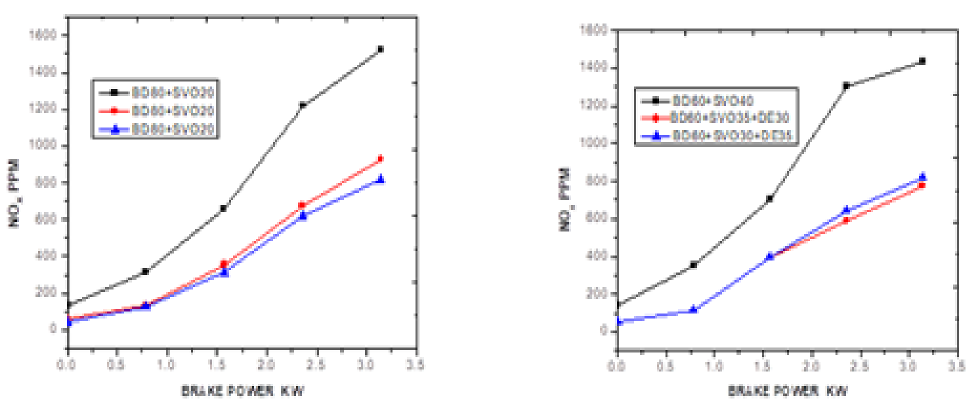

Figure 7. NOx emission with BP for fuel blends and additives.

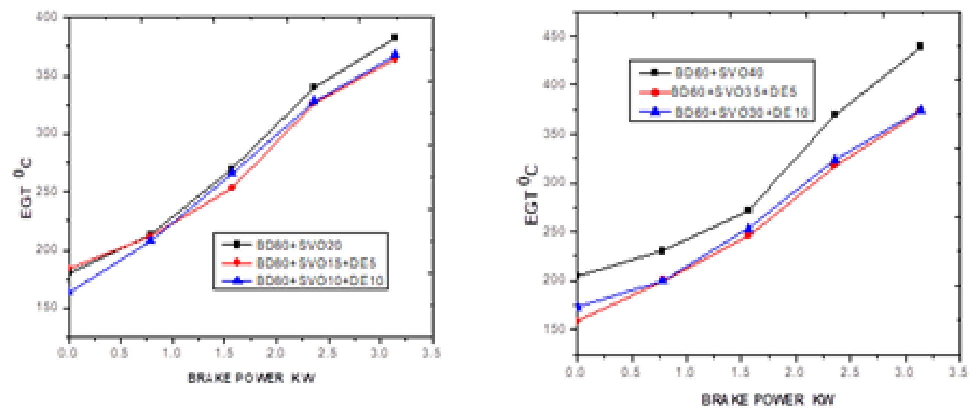

Figure 8. EGT emission with BP for fuel blends and additives.

all blends. Furthermore, the introduction of additives in the blends results in a noteworthy reduction of NOx emissions, with blend BD80SV10DE10 experiencing up to a 46% decrease and blend BD60SV35DE05 achieving an impressive 53% reduction in NOx emissions.

3.2.4 Exhaust Gas Temperature (EGT)

Figure 8 displays a chart depicting exhaust gas temperatures for various fuel blends. The data clearly shows that both BD and SVO blends yield elevated EGT values. Nonetheless, it is feasible to reduce EGT by introducing additives into these fuel blends.

4.0 Conclusions

From the preceding discussions, we can draw the following conclusions: Fuel additives have demonstrated their capacity to enhance the characteristics of fuel blends, encompassing density and viscosity, thereby leading to superior atomization and improved combustion attributes, resulting in elevated engine brake power, reduced BSFC, and increased BTE. Within this spectrum of additives, Diethyl ether stands out as the most notable contributor to these enhancements, thanks to its lower density and viscosity profile and its elevated calorific value. Brake thermal efficiency rises with the augmentation of additive proportions in Biodiesel but remains comparatively lower when dealing with pure Biodiesel. BSFC attains its peak with pure Biodiesel under all load conditions due to its high density, pronounced volatility, and diminished heat content. Nevertheless, as the percentage of additives increases, BSFC diminishes owing to the more efficient combustion process. Diesel fuel registers the highest CO and HC emissions, whereas pure Biodiesel exhibits the lowest levels, attributable to its heightened oxygen content. Yet, with an increase in additives in Methyl ester, both CO and HC emissions exhibit a downward trend. Pure Biodiesel presents the highest levels of smoke and NOx emissions, owing to its elevated viscosity, volatility, and decreased heat content in comparison to diesel fuel. Nevertheless, as the additive percentage rises in Biodiesel, the levels of smoke and NOx emissions decrease. The exhaust gas temperature reaches its zenith with pure Biodiesel, primarily due to its elevated combustion temperature arising from the heightened oxygen content. Nonetheless, as the additive percentage escalates, the exhaust gas temperature experiences a corresponding decline. Consequently, Diethyl ether emerges as a viable and effective fuel additive for biodiesel and straight vegetable oil when used in diesel engines, requiring no hardware modifications.

5.0 References

1. Devaraj J, Robinson Y, Ganapathi P. Experimental investigation of performance, emission, and combustion characteristics of waste plastic pyrolysis oil blended with diethyl ether used as fuel for diesel engine. Energy. 2015; 85:304-9. https://doi.org/10.1016/j.energy.2015.03.075
2. El-Adawy M, Ibrahim A, El-Kassaby MM. An experimental evaluation of using waste cooking oil biodiesel in a diesel engine. Energy Technol. 2013; 1(12):726-34. https://doi.org/10.1002/ente.201300100

3. Ibrahim A, El-Adawy M, El-Kassaby MM. The impact of changing the compression ratio on the performance of an engine fuelled by biodiesel blends. Energy Technol. 2013; 1(7):395-404. https://doi.org/10.1002/ente.201300048
4. Kumar BR, Saravanan S. Use of higher alcohol biofuels in diesel engines: A review. Renewable and Sustainable Energy Reviews. 2016; 60:84-115. https://doi.org/10.1016/j.rser.2016.01.085
5. Ibrahim A. Performance and combustion characteristics of a diesel engine fuelled by butanol-biodiesel-diesel blends. Appl Therm Eng. 2016; 103:651-59. https://doi.org/10.1016/j.applthermaleng.2016.04.144
6. Rakopoulos DC, Rakopoulos CD, Giakoumis EG. Impact of properties of vegetable oil, bio-diesel, ethanol, and n-butanol on the combustion and emissions of turbocharged HDDI diesel engine operating under steady and transient conditions. Fuel. 2015; 156:1–19. https://doi.org/10.1016/j.fuel.2015.04.021
7. Rakopoulos DC, Rakopoulos CD, Giakoumis EG, Papagiannakis RG, Kyritsis DC. Influence of properties of various common bio-fuels on the combustion and emission characteristics of high-speed DI (direct injection) diesel engine: Vegetable oil, bio-diesel, ethanol, n-butanol, diethyl ether. Energy. 2014; 73:354-66. https://doi.org/10.1016/j.energy.2014.06.032
8. Rakopoulos DC, Rakopoulos CD, Giakoumis EG, Dimaratos AM. Characteristics of performance and emissions in high-speed direct injection diesel engine fueled with diethyl ether/diesel fuel blends. Energy. 2012; 43:214-24. https://doi.org/10.1016/j.energy.2012.04.039
9. Rakopoulos DC, Rakopoulos CD, Giakoumis EG, Dimaratos AM. Studying combustion and cyclic irregularity of diethyl ether as a supplement fuel in diesel engines. Fuel. 2013; 109:325–35. https://doi.org/10.1016/j.fuel.2013.01.012
10. Barik D, Murugan S. Effects of diethyl ether (DEE) injection on combustion performance and emission characteristics of Karanja methyl ester (KME)–biogas fueled dual fuel diesel engine. Fuel. 2016; 164:286–96. https://doi.org/10.1016/j.fuel.2015.09.094
11. Sezer I. Thermodynamic, performance and emission investigation of a diesel engine running on dimethyl ether and diethyl ether. Int J Therm Sci. 2011; 50:1594-603. https://doi.org/10.1016/j.ijthermalsci.2011.03.021
12. Banapurmath NR, Khandal SV, Swamy RL, Chandrashekar TK. Alcohol (ethanol and diethyl ethyl ether)-diesel blended fuels for diesel engine applications-a feasible solution. Adv Automob Eng. 2015; 4:117. https://doi.org/10.4172/2167-7670.1000117
13. Paul A, Bose PK, Panua RS, Debroy D. Study of performance and emission characteristics of a single cylinder CI engine using diethyl ether and ethanol blends. J Energy Inst. 2015; 88:1-10. https://doi.org/10.1016/j.joei.2014.07.001
14. Karabektas M, Ergen G, Hosoz M. The effects of using diethyl ether as an additive on the performance and emissions of a diesel engine fuelled with CNG. Fuel. 2014; 115:855–60. https://doi.org/10.1016/j.fuel.2012.12.062
15. Imtenan S, Masjuki HH, Varman M, Fattah IMR, Sajjad H, Arbab MI. Effect of n butanol and diethyl ether as oxygenated additives on combustion–emission-performance characteristics of a multiple cylinder diesel engine fuelled with diesel–jatropha biodiesel blend. Energy Convers Manage. 2015; 94:84–94. https://doi.org/10.1016/j.enconman.2015.01.047
16. Qi DH, Chen H, Geng LM, Bian YZ. Effect of diethyl ether and ethanol additives on the combustion and emission characteristics of biodiesel-diesel blended fuel engine. Renew Energy. 2011; 36:1252-58. https://doi.org/10.1016/j.renene.2010.09.021
17. Balley B, Eberhardt J, Goguen S, Erwin J. Diethyl ether (DEE) as a renewable diesel fuel. SAE Paper. 972978.
18. Sezer I. A review study on using diethyl ether in diesel engines: Effects on fuel properties, injection, and combustion characteristics. Energy and Environment. 2019; 1–36. https://doi.org/10.1177/0958305X19856751