JOURNAL OF AERONAUTICAL MATERIALS
Vol. 42, Issue-05, 2022
pp.176-184

EVALUATION OF ENGINE PERFORMANCE AND EMISSION PARAMETERS OF VARIOUS BIODIESELS AND PISTON CONFIGURATIONS

V.Sai Srikanth [(a)] , Dr.S.Ganesan [(b)] , Dr.K.Vijaya Kumar Reddy [(c)]

a) Research Scholar,Sathyabama institute of Science and Technology (Deemed to be University),Chennai, **Email**:vemuri877@gmail.com,
b) Professor of Mechanical Engineering Department, Sathyabama institute of Science and Technology (Deemed to be University), Chennai, India, Email:gansumaa@gmail.com
c) Professor of Mechanical Engineering Department, JNTUH, Hyderabad, **Email**:kvijayakumarreddy@gmail.com

Abstract : Demand for energy has increased as a result of population expansion and industrialization. Rapid utilization of petroleum diesel products leads to depletion of petroleum products. Emissions from diesel engines have a significant influence on the environment. To overcome above problems focus towards the alternative sources. Biodiesel is one of the alternative fuel extracted from animal fats, vegetable oils and algae. Cashew nut shell methyl ester and Jack fruit methyl ester are tested in diesel engine with various piston shapes, including hemispherical, toroidal and double wedge. The tests are carried out on a single cylinder diesel engine. According to the test findings, brake thermal efficiency is enhanced while specific fuel consumption is decreased. The CO and HC, the engine emissions are lowered compared to diesel at full load but the NOx levels are increased.
Key words: toroidal, double wedge, Jack fruit methyl ester, cashew nut shell methyl ester, performance, emissions

Introduction

Increased demand for petroleum products are causing the depletion of fossil fuels. In today's world, fossil fuels are the most important parameter. Depletion of fossil fuels are occurring on a daily basis. To find a replacement for fossil fuels, the first step is to look for alternative fuels[1]. One of the most significant environmental factors is the discharge of engine exhaust from the combustion chamber. The emissions have more impact on human health and ecological system. Many factors like price of petroleum products hiking, world environment concern and depletion of petroleum products have supported to search alternative fuels [2]. The alternative fuels could be more feasible, environment friendly, economically competitive without compromising performance and produce lesser emission levels. With base diesel, vegetable oils have fatty acids with long carbon chains. These oils are high density, high viscous, but their calorific value is lower. In place of the fossil fuels the vegetable oils are alternate fuels used directly or blended with diesel [3].

Many studies have shown that biofuels have a significant influence on emissions, combustion, and engine performance. Chemical and physical properties play a major influence in engine performance and emission parameters as a result of this research. Biodiesel has a higher cetane number than diesel. Shorter delay period and other properties like fuel atomization, penetration and size of the fuel droplet were important parameters in the combustion process[4]. Biodiesel extracted from vegetable oils, collected a lot of concentration because without modification biodiesel used in diesel engines[5].

Single-cylinder diesel engines using Jatropha and Palm oil blends like D90JB5PB5 (90 percent diesel, 5 percent palm oil, and 5 percent jatropha oil), D80JB10PB10, and D70JB15PB15 were utilized. When compared to diesel, the braking power of D90JB5PB5 increased by 4.65%, although the specific fuel consumption decreased somewhat. Higher D20JB40PB40 blend enhanced brake thermal efficiency by up to 15%. For D90JB5PB5, D80JB10PB10 and D70JB15PB15 showed the CO emissions are reduced 7.1%, 17.7% and 14.5% respectively[6]. The experiments were conducted on three cylinder common rail engine used B20 RME(rapeseed methyl ester)blend at various engine speeds and loads. The data revealed that peak pressure and combustion noise were lower with B20 blend. The lower HC and CO emission were recorded for RME blend. Further the NO_x and PM emission was reduced with RME blend at high engine speeds[7].

The variety of PP (plastic pyrolysis) oil blends were utilized in the four cylinder DI diesel engine at varied loads. Combustion, emissions, and performance of the engine were analyzed and compared to those of the basic fuel. However, the PP oil brake thermal efficiency was somewhat lower than that of a diesel engine, and its nitrogen oxide emissions were greater. Various blends of pongamia biodiesel (B20) with ferrofluid as a fuel additive was explored as fuel. The engine emission and performance parameters were analyzed by addition of ferrofluid, brake specific fuel consumption was decreased by 8% correlated to non additive fuel. The HC and CO emissions were lowered for nano additive biodieel compared to the base biodiesel blend. The 1% ferro fluid with blend B20 showed maximum efficiency and lowered emissions compared to remaining all fuel blends[9].

The alcohol blends attained by preparation of 10% methanol, ethanol and butanol with diesel fuel and pure diesel were utilized as fuels in diesel engine. The low cetane number of alcohol fuels resulted in a greater ignition delay than base diesel, according to the study's findings. Compared to diesel fuel, the cylinder pressure is greater at all load levels. CO emissions and smoke were reduced as a consequence of the addition of alcohol to fuel. There was a small rise in NOx emissions[10]. POME blend was tested with different piston configurations as HCC (Hemispherical Combustion Chamber), CCC (Cylindrical Combustion Chamber), SCC (Shallow Depth Combustion Chamber) and TCC (Turbo Combustion Chamber) on a single cylinder 4 stroke DI engine (Toriodal combustion chamber). Compared to the standard engine, the unburned hydrocarbon emissions and NOx emissions were decreased with TCC and SCC. The emission of CO were decreased with CCC and CO_2 emissions were higher using all modified piston shapes in the engine[11].

Pumpkin seed and moringa oleifera oils were tested in diesel engines with different piston geometry configurations such as TRCC (Trapezoidal Combustion Chamber) and TCC (Trapezoidal Combustion Chamber) (Toriodal combustion chamber). The TCC has higher performance characteristics than the other piston configurations when compared to all the other geometries. TCC behaviour with high squish and swirl contributes to enhanced fuel-air mixing and complete combustion in the cylinder. Except NO_x the all engine emissions were reduced with TCC[12]. Tests were carried out with DI diesel engines using toroidal piston geometry and Jute methyl ester and Neem methyl ester as fuels; the results showed that Jute methyl ester and a toroidal piston arrangement improved the thermal efficiency. Improved results were achieved using the TCC with LHR 300 microns and Jute methyl ester[13]. The swirl piston and reentrant piston bowls were tested on the diesel engine. The emissions were reduced and combustion process were improved with DSB(double swirl piston bowl) and MSB(Multi swirl piston bowl)[14]. Using diesel fuel, researchers evaluated the MCC and SCC combustion chambers. With MCC, CO emissions were reduced by 6%. With MCC, NOx emissions were lowere by 11%[15].

The main aim of this study is to evaluate the performance parameters (SFC,BTE and ME), emissions(CO_2,CO,HC and NO_x) of a diesel engine with various piston configurations and two different types of biodiesels.

2.Material and Methodology

CNS(Cashew nut shell methyl ester) and JF(Jack fruit methyl ester) are used in the investigations, the properties of fuels such Specific gravity, kinematic viscosity, heating value, flash and fire points are measured. A portable density metre is used to measure the fuel density. The redwood viscometer is used to determine the kinematic viscosity. Table 1 lists the characteristics of the test fuels. A bomb calorimeter is used to measure the heating value. Cleveland's device is used to measure the flash and the fire points. CNS, JF and diesel are tested in a single cylinder four stroke CI engine operating at 1500 rpm constant speed for emissions and performance. Table 2 lists the technical details of the engine. The brake thermal efficiency, and specific fuel consumption are measured. The AVL 5 gas Analyzer is used to monitor CO2, CO, HC, and NOx emissions. Standard fuel injection pressure is maintained for diesel, JF, and CNS engines with varied piston designs, such as Hemispherical, toroidal and double wedge. The test engine is shown in fig 1.

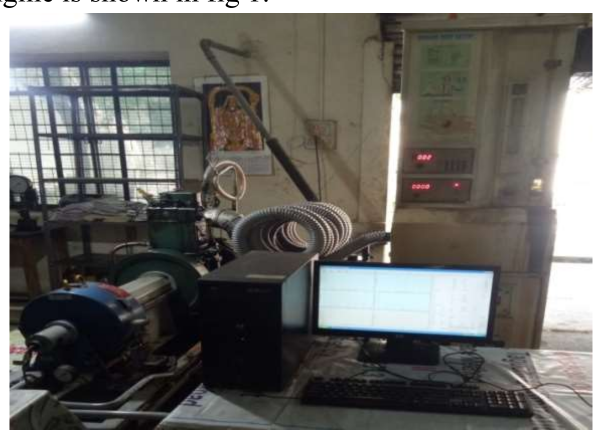

Fig 1. Test Engine

Parameters	Jackfruit methyl ester	Cashew Nut shell methyl ester	Diesel fuel	Standards
Specific gravity	0.87	0.89	0.83	ASTM D 1298
Density - kg/m^3	889	931	831	ASTM D 1298
Heating value MJ/kg	38.81	37.5	42.5	ASTM D 5865
Kinematic Viscosity at 40 ºC (cSt)	5.52	6.8	2.94	ASTM D 445
Fire point (ºC)	183	198	61	ASTM D 92

Flash point (°C)	175	181	52	ASTM D 92

Table 1: Properties of fuels

Rated Speed	1500 rpm
Cylinder Bore	87.5 mm
Swept Volume	562 cc
Stroke Length	110mm
Stroke Type	Four
Speed Type	Constant
No. of Cylinders	1
Cooling Type	Water
Loading Type	Eddy Current

Table 2: Specifications of the Test engine

3.Results and discussion

3.1 Specific fuel consumption

. Figure 2 shows the variation of SFC with brake power. For comparing fuel impacts on engine performance, specific fuel consumption (SFC) is the essential basic measure. SFC drops when brake power is increased due to homogeneous fuel air mixture[16]. The specific fuel consumption for toroidal jack fruit methyl ester(TJF) is lower compare to remaining piston configurations and cashew nut shell methyl ester. The toroidal cashew nut shell methyl ester(TCNS) is higher specific fuel consumption at peak load compare to remaining piston configurations and biodiesel.

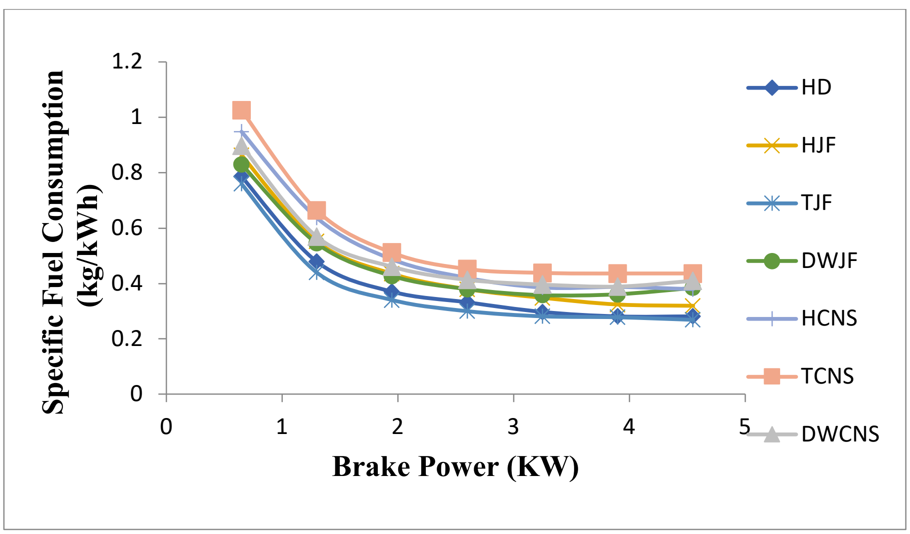

Fig 2. BP Vs SFC

3.2 Brake thermal efficiency

Figure.3 illustrates the relationship between brake thermal efficiency (BTE) and brake power (BP). The BTE is a indication of engine ability to convert the chemical energy stored in the fuel to engine shaft work[17]. For all of the test fuels and piston configurations, the BTE rises with the increased engine load. The brake thermal efficiency for toroidal jack fruit methyl ester is 29% at peak load condition. The BTE for other fuel(CNS) using hemispherical and double wedge piston configurations nearer to the toroidal piston configuration with jack fruit methyl ester. The main cause for lowering thermal efficiency is shorter ignition delay period.

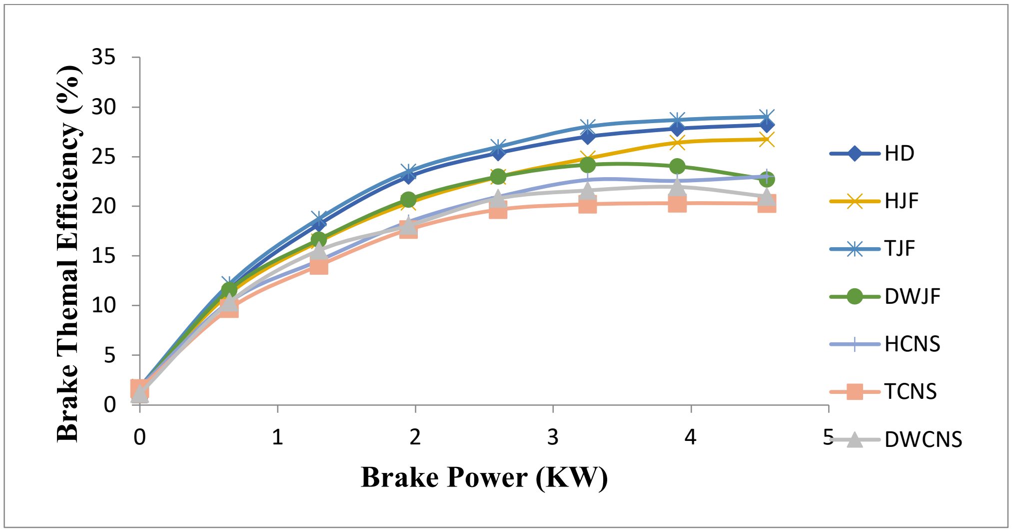

Fig 3. BP Vs BTE

3.3 CO Emission

Carbon monoxide(CO) emissions with brake power are shown in Fig. 4. The carbon monoxide emissions are based on carbon content, oxygen content and combustion efficiency. The CO emission of the biofuel is lower than the base fuel because of more oxygen content of the biodiesel[18]. The CO emissions of toroidal jack fruit methyl ester is lower compared other piston configurations and biodiesel. The higher CO emissions observed for double wedge cashew nut shell methyl ester.

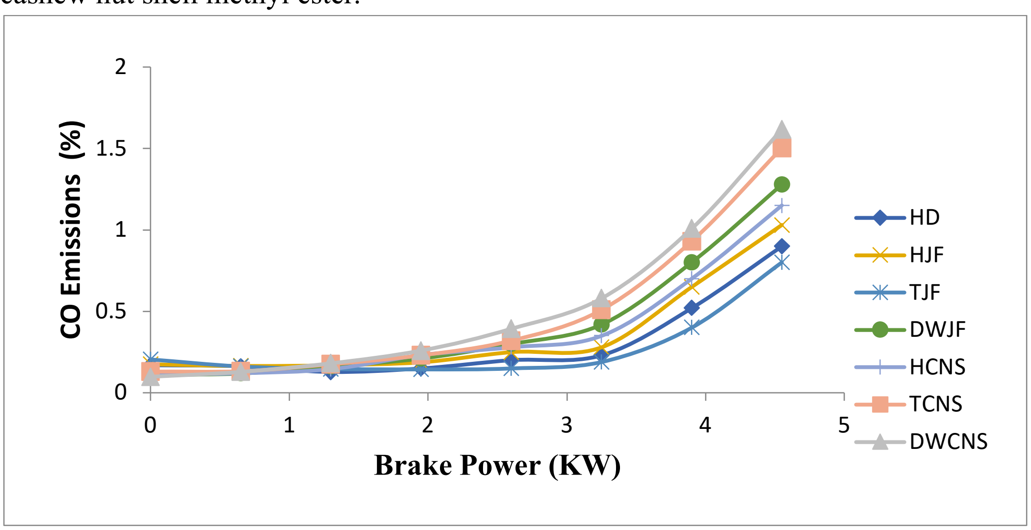

Fig 4. BP Vs CO

3.4 CO_2 Emission

The transportation engine emissions are effect the green house gases. Partially substituting fossil fuels with alcohol and biodiesel produces harmful emissions[19]. Figure 5 depicts the change in CO_2 emissions as a function of brake power. The CO_2 emissions in this graph shows from a no-load to a fully loaded condition. The CO_2 emissions for toroidal jack fruit methyl ester is lower and is about 9.5% compared to other fuel and piston configurations. It is also observed that in the plot CO_2 emissions for base fuel is slightly higher compared to remaining fuels.

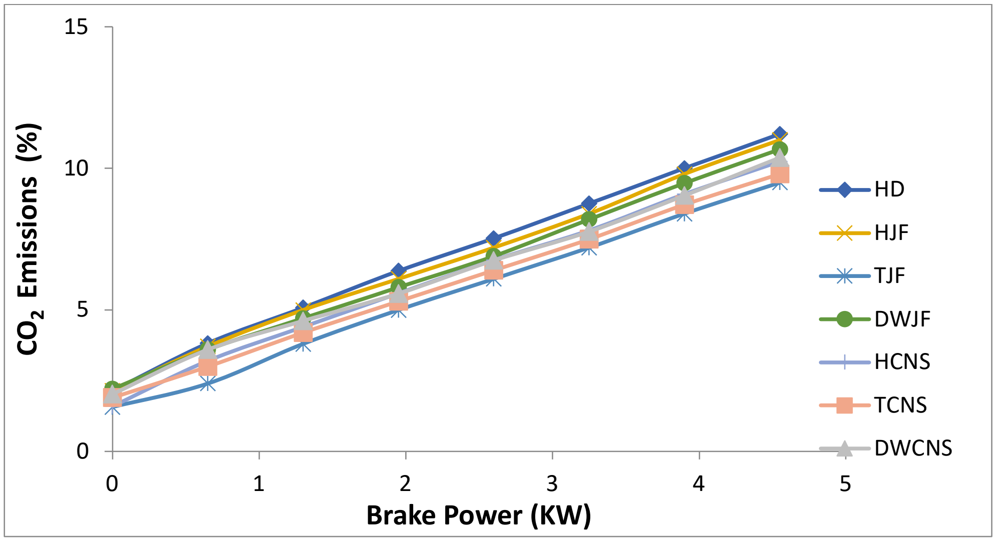

Fig 5. BP Vs CO_2

3.5 NO_x emission

From Figure.6 depicts the NOx emissions from several tested fuels at increasing brake power. For all tested fuels, increasing brake power increases NOx emissions [20]. The NO_x emissions are lower for base fuel compared to other fuels The other fuels are not largely different due to minimum incylinder temperature. The biodiesels are more oxygenated fuels, these fuels emits high NO_x emissions.

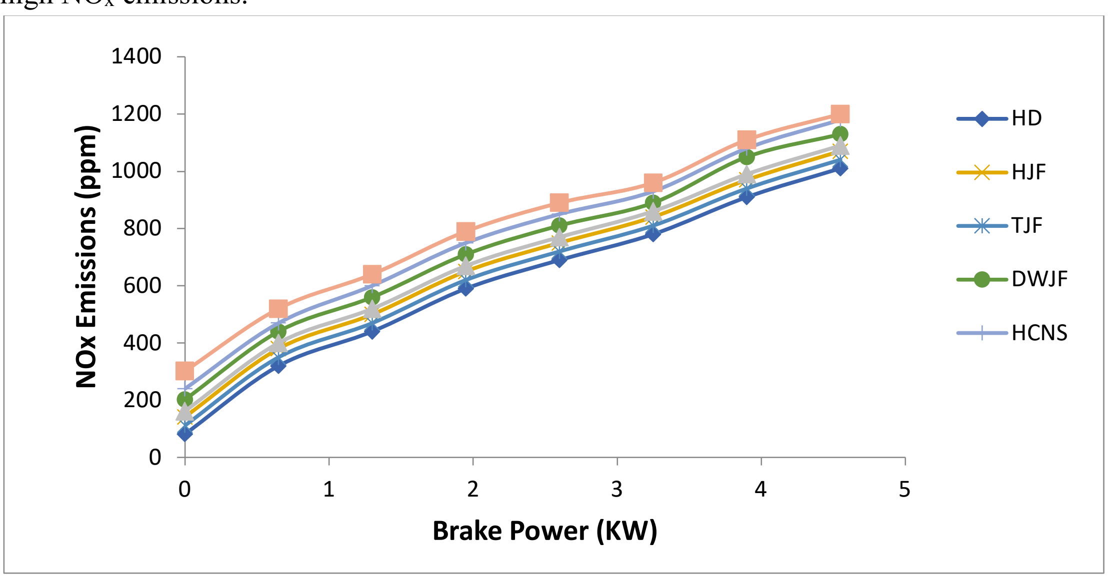

Fig 6. BP Vs NO_x

3.6 HC Emissions

Fig 7. represents HC emissions vs brake power. The main reason for decrease in HC emission in the engines is due to proper combustion of fuels inside the combustion chamber because of oxygen content in the biodiesel [21]. The HC emissions for toroidal jack fruit methyl ester is lower and is about 80 ppm. Toroidal cashew nut shell methyl ester emits more hydrocarbons (HC) than other fuels and piston configuration.

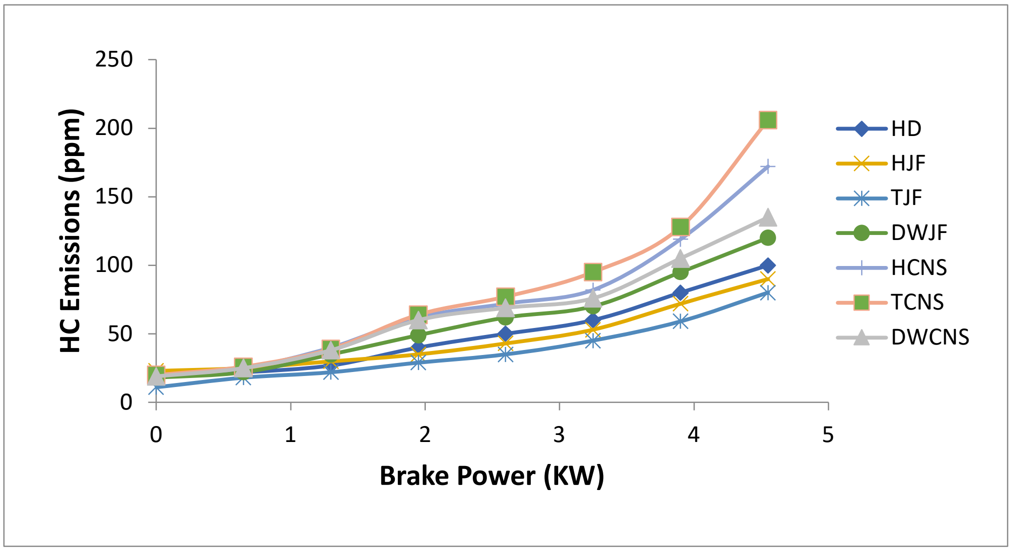

Fig 7. BP Vs HC

4.Conclusions

Cashew nut shell methyl ester and jack fruit methyl esters are alternative fuels that show high engine performance and lowered emissions when tested in base engine without engine modifications.

- The specific fuel consumption for toroidal jack fruit methyl ester is lower and is about 0.269 kg/kWh. This is due to complete combustion inside the engine cylinder.
- The BTE increased for toroidal jack fruit methyl ester and is about 2.83% higher compared to diesel. This is due to higher swirl in combustion chamber.
- The CO and HC emissions are no much variation at intial load condition but with increasing load the emission are increased drastically.
- The biofuels having more oxygen content, The NO_x emissions for cashew nut shell methyl ester and jack fruit methyl esters higher compared to diesel.

References

1. Ramalingam, Senthil, et al. "Effect of leaf extract from Pongamia pinnata on the oxidation stability, performance and emission characteristics of calophyllum biodiesel." *Fuel* 180 (2016): 263-269.

2. Mofijur, M., et al. "Evaluation of biodiesel blending, engine performance and emissions characteristics of Jatropha curcas methyl ester: Malaysian perspective." *Energy* 55 (2013): 879-887.
3. Agarwal, Avinash Kumar, and Atul Dhar. "Experimental investigations of performance, emission and combustion characteristics of Karanja oil blends fuelled DICI engine." *Renewable energy* 52 (2013): 283-291.
4. Ogunkoya, Dolanimi, et al. "Investigation of the effects of renewable diesel fuels on engine performance, combustion, and emissions." *Fuel* 140 (2015): 541-554.
5. Özener, Orkun, et al. "Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics." *Fuel* 115 (2014): 875-883.
6. Nalgundwar, Ankur, Biswajit Paul, and Sunil Kumar Sharma. "Comparison of performance and emissions characteristics of DI CI engine fueled with dual biodiesel blends of palm and jatropha." *Fuel* 173 (2016): 172-179.
7. Magno, Agnese, Ezio Mancaruso, and Bianca Maria Vaglieco. "Effects of a biodiesel blend on energy distribution and exhaust emissions of a small CI engine." *Energy Conversion and Management* 96 (2015): 72-80.
8. Kalargaris, Ioannis, Guohong Tian, and Sai Gu. "Combustion, performance and emission analysis of a DI diesel engine using plastic pyrolysis oil." *Fuel Processing Technology* 157 (2017): 108-115.
9. Kumar, Shiva, P. Dinesha, and Ijas Bran. "Influence of nanoparticles on the performance and emission characteristics of a biodiesel fuelled engine: An experimental analysis." *Energy* 140 (2017): 98-105.
10. Emiroğlu, A. Osman, and Mehmet Şen. "Combustion, performance and emission characteristics of various alcohol blends in a single cylinder diesel engine." *Fuel* 212 (2018): 34-40.
11. Shivashimpi, Mahantesh M., et al. "Combined effect of combustion chamber shapes and nozzle geometry on the performance and emission characteristics of CI engine operated on Pongamia." *Energy* 154 (2018): 17-26.
12. Karthickeyan, V. "Effect of combustion chamber bowl geometry modification on engine performance, combustion and emission characteristics of biodiesel fuelled diesel engine with its energy and exergy analysis." *Energy* 176 (2019): 830-852.
13. Valiveti, Siva Rama Krishna, Hussain Shaik, and K. Vijaya Kumar Reddy. "Analysis on impact of thermal barrier coating on piston head in CI engine using biodiesel." *International Journal of Ambient Energy* (2020): 1-8.
14. Sener, Ramazan, Murat Umut Yangaz, and Mehmet Zafer Gul. "Effects of injection strategy and combustion chamber modification on a single-cylinder diesel engine." *Fuel* 266 (2020): 117122.
15. Temizer, İlker, and Ömer Cihan. "Analysis of different combustion chamber geometries using hydrogen/diesel fuel in a diesel engine." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 43.1 (2021): 17-34.
16. Sanli, H., et al. "Effects of iste frying oil based methyl and ethyl ester biodiesel fuels on the performance, combustion and emission characteristics of a DI diesel engine." *Fuel* 159 (2015): 179-187.

17. Ogunkoya, Dolanimi, et al. "Investigation of the effects of renewable diesel fuels on engine performance, combustion, and emissions." *Fuel* 140 (2015): 541-554.
18. Ramalingam, Senthil, et al. "Effect of leaf extract from Pongamia pinnata on the oxidation stability, performance and emission characteristics of calophyllum biodiesel." *Fuel* 180 (2016): 263-269.
19. Fayyazbakhsh, Ahmad, and Vahid Pirouzfar. "Investigating the influence of additives-fuel on diesel engine performance and emissions: Analytical modeling and experimental validation." *Fuel* 171 (2016): 167-177.
20. Xiao, Helin, et al. "Combustion performance and emissions of 2-methylfuran diesel blends in a diesel engine." *Fuel* 175 (2016): 157-163.
21. Lei, Tingzhou, et al. "Performance and emission characteristics of a diesel engine running on optimized ethyl levulinate–biodiesel–diesel blends." *Energy* 95 (2016): 29-40.