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Effects of Injection Pressure on Performance and Emission Characteristics of CI Engine using Waste Cooking Oil (WCO) Blend

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Abstract

For a long period of time, vegetable oil cannot be used directly in a direct injection diesel engine. The tolerance tests may indicate significant problems. The outcome of Injection Pressures (IP) on the performance and emissions of a diesel engine powered by waste cooking oil biodiesel were explored in this study. It is investigated and standard diesel results are compared to the performance characteristics and emission studies of a single cylinder, four-stroke, direct-injection diesel engine fueled with used cooking oil in 20% (on a mass basis) blends. This study established the appropriateness of using cooking oil. The experiment consisted of running at a constant speed of 1500 rpm and then loaded gradually. The tests were conducted at 5 different loading are 0%, 25%, 50%, 75%, and 100% of the load in kW, with compression ratios of 17.5:1. The result of adjusting the injection pressure to 185–235 bars with a gap of 25 bars, with the original IP set at 210 bar. Fuel injection pressure is critical in improving engine performance and emission characteristics. The diesel engine ran on Waste Cooking Oil (WCO) at various injection pressures, including 185 bars, 210 bars, and 235 bars. The engine tests were carried out to examine how a diesel engine operating on a WCO20 biodiesel blend performed and produced emissions at varied injection pressures. Except for NOx, biodiesel blends at 235 bars injection pressure performed better and had lower emissions than those at 185 bars injection pressure. Without any modifications, the optimal fuel blend can be considered for a compression ignition engine.

Keywords: *Biodiesel, Diesel Engine, Emission Analysis, Injection Pressure, Performance*

1.0 Introduction

Diesel fuel is utilised in all types of engines, both light and heavy duty. However, global demand for energy, particularly for petroleum fuels, is increasing. Today, fossil fuels, primarily petroleum products, meet 90% of global energy demand[1]. In the future, by the demands, we are not able to get the fuel to meet our needs or reasonable pricing. To alternate that we move to indigenous sources, and preferably renewable energy. Diesel-powered vehicles are popularized due to because of the greater fuel efficiency and minimal CO (carbon monoxide), HC (hydrocarbon) emissions (hydrocarbon). It emits a large amount of NOx (nitric oxides) and smoke. Diesel engines are commonly used in mobility, power stations, planning to build, and industry. WCO is another name for Waste Edible Oil (WEO). It is a vegetable oil-based

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product formed of vegetable material that has occurred to utilized in cooking as well as food preparation, after the certain usages this oil disposed directly. In most countries, managing of significant amounts of WCO has become a difficulty[2]. WCO should not be discharged into drains or sewers because it will cause obstructions, odours, insect infestations, and it may cause all form of pollution evidentially make their way to water or in dry lands, causing issues for wildlife. It is also a regulated substance that will cause issues. Each year, the world's selected countries generate more than 15 million tons of waste cooking oil. Nowadays, most major hotels, candies and bakeries, and so on, dispose of cooking oil in drainage after use[3]. It has an impact on plants, water, animals, and humans.

2.0 Method and Materials

2.1. Preparation of Fuel and Procedure

As an alternative fuel, Waste Cooking Oil (WCO) was chosen in this investigation due to its low cost. It also saves money on waste disposal. According to the articles, WCO20 is a better performance and emission metric. As a result, future research will focus on the WCO20 (80% diesel + 20% WCO)[4]. The engine's efficiency using the mixes was equivalent to the preliminary diesel fuel test. Compared to diesel fuel, waste cooking oil fuels significantly improved brake thermal efficiency and unburned hydrocarbon (HC) emissions in comparison to diesel fuel. Blends are the most convenient way for diesel to be used in diesel engines. At the rated speed, 80% of diesel fuel and 20% of waste Cooking blend was carried out the test in 5 different loading conditions are 0%, 25%, 30%, 75%, and 100% of the load in kW[5]. During each sample, the engine was started, and when it achieved Static Condition, essential setup is connected to the Engine. Performance and emission values are recorded for monitoring purpose[6]. The time taken for 15 cm^3 of Fuel Consumptions. The load was applied using a dynamometer and the Parameters of emission are identified using the gas Analyzer and Smoke meter. The engine's original Injection timing is 23° before Top Dead Center, and measurements for the three different Injection Pressures are 185 bars, 210 bars, and 235 bars at all 5 loading Condition[7]. The variation of Injection pressure is taken by adjusting the fuel injector spring

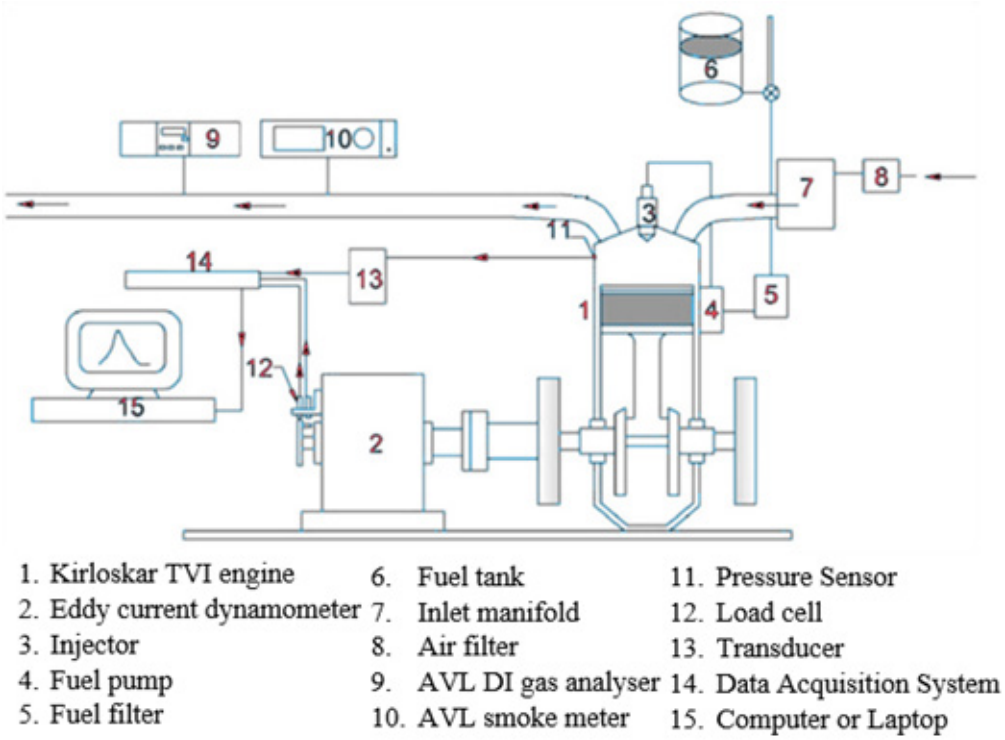


Figure 1. Experimental Setup.

tension[8]. The test-bench was used for all test runs. Engine speed and load were recorded during each run.

Diesel	-	100% of diesel fuel
WCO	-	Waste Cooking Oil
WCO20	-	20% of Waste Cooking Oil + 80% of diesel fuel
Diesel_210	-	Pure Diesel at 210 bars
WCO20_185	-	WCO20 at 185 bars
WCO20_210	-	WCO20 at 210 bars
WCO20_235	-	WCO20 at 235 bars

Table 1. Properties of Fuel

Sample Fuel	Calorific Value (kJkg^{-1})	Density, (Kgm^{-3})
Diesel	42,800	833.87
WCO	38481.892	910.64
WCO 20	41936.378	849.12

2.2 Engine Specification

Make	-	Kirloskar Oil Engine Ltd.,
Model	-	SV 1
No of stroke	-	4
No. of cylinder	-	Single Cylinder
Stroke	-	11 cm
Swept Volume	-	0.661 litre
SFC	-	250 g/kW-hr
Speed	-	1500 rpm
Compression ratio	-	17.5:1
Max. Power	-	5.2kW
Injection timing	-	23° bTDC
Cylinder Bore	-	87.5 mm
Injection Nozzle	-	3-hole Nozzle

3.0 Discussion of the Results

3.1 Thermal Efficiency

Figure 2 compares the Brake Thermal Efficiency (BTE) of blends of 20% used cooking oil and 80% diesel at various injection pressures. At all fuel injection pressures, the BTE of WCO20 fuel increases with increasing load[9]. Maximum BTE of 32.0814% was obtained at 235 bars injection pressure at 100% load condition, which was 4.8% higher than that of 210 bars injection pressure (WCO20_210),

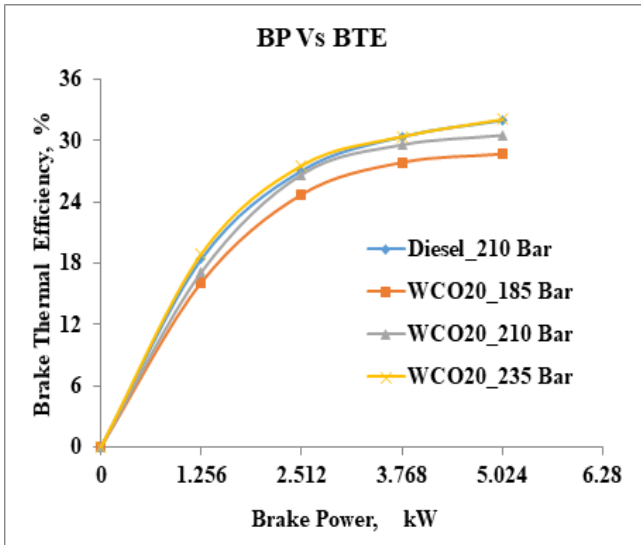


Figure 2. Brake thermal efficiency.

and 10.5% Lesser than that of WCO20_185 bars injection pressure. WCO20 at 235 bars (WCO_235) is obtained 0.25% lesser compare to Diesel at 210 bars. This might be as a result of improved combustion brought on by correct atomization brought on by the increase in injection pressure[10]. Brake Thermal Efficiency for injection pressure 235 bars is slightly higher than of other two injection pressure 185 & 210 bars. Due to the low momentum of the finely distributed fuel at increasing fuel injection pressure, the penetration of the spray tip will inevitably increase[11]. This leads to incomplete combustion, incorrect atomization, and reduced heat release.

3.2 Specific Fuel Combustion

From the Impression of Figure 3, while increasing the Brake Power with decreases in specific fuel consumption[12]. The reading for specific fuel Consumption at 235 bars are 0.2662, 0.2671, 0.2874, and 0.2934 kg/kWh for the fuels are WCO20_ 235 bar, Diesel _210 bar, WCO20_185 bars and WCO20_210 bars respectively. The Minimum Specific fuel consumption is 0.2662 kg/kWh at 235 bars in maximum loading condition. While Comparing to Diesel, WCO20_235 bars is 3.21% Lesser, WCO20_185 bars is 7.49% higher Comparing to diesel_210 bars, and WCO20_210 bars is 9.74% is higher[13]. The Variation on the specific fuel on the Consumption may be result from properly combining WCO20 and air, the size and number of droplets are also taken into consideration[14].

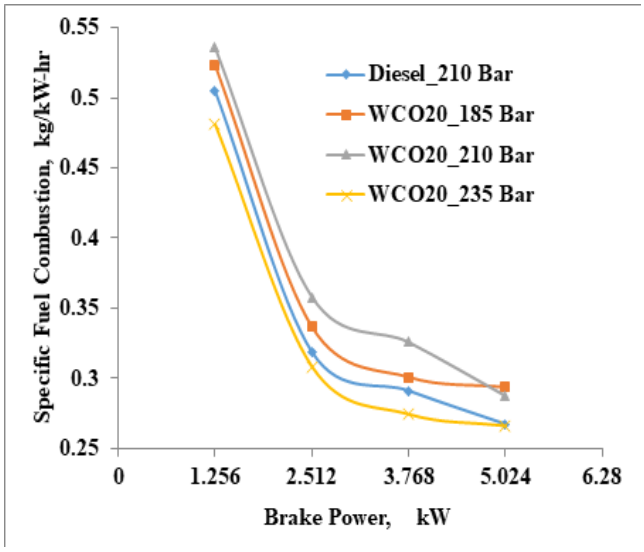


Figure 3. Specific fuel combustion.

The injection Pressure is various, meanwhile the size of droplet and Number of droplets also varied depends on the injection Pressure.

3.3 Carbon Monoxide

The CO emission with 235 bars (WCO_235) injection pressure is somewhat lower than for Diesel 210 bar at the same loading condition[15]. The Injection Pressure is reduced to WCO20_210 bars and WCO20_185 bar, emission gradually increases at 7.62% and is 15.25% respectively compared to diesel at 210 bars (Diesel_210 bars). The droplet size was finally enhanced by incomplete combustion, a slower rate of premixed combustion, a higher WCO viscosity, and poor atomization could all be contributing factors to the variation in CO emission as shown in Figure 4. Increased injection pressure improves fuel-air mixing, which enhances combustion and lowers CO_2 emissions when poor atomization, which causes incomplete combustion, worsens[16]. Low injection pressure results in large CO emissions, while high injection pressure results in low CO emissions and inefficient diffusion flame combustion[17].

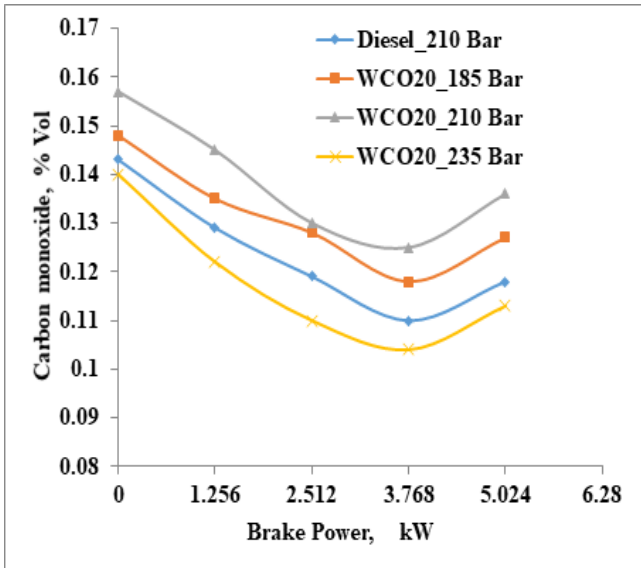


Figure 4. Carbon monoxide.

3.4 Unburnt Hydro Carbon

From the Impression of Figure 5, the HC emission for Injection Pressure WCO20_235 bars are lesser than the other two Injection Pressures are WCO20_210 bars and WCO20_185 bar. The HC Emission in maximum loading Condition for WCO20_235 bars are Lesser Compare to Diesel_210 bar. The unburnt Hydrocarbon increases with reducing the Injection Pressure[18]. The B2O_210 bars are 1.88% higher and 5.66% higher for WCO20_185 Compared to Diesel_210 bar. This might be the result of weak atomization or total combustion. Low injection pressure results in poor atomization, significant droplet formation, and vaporized HC in the exhaust[19]. Due to incomplete combustion caused by low combustion efficiency, HC emission is increased[20]. Inefficient combustion results in delayed combustion and a slower burn rate.

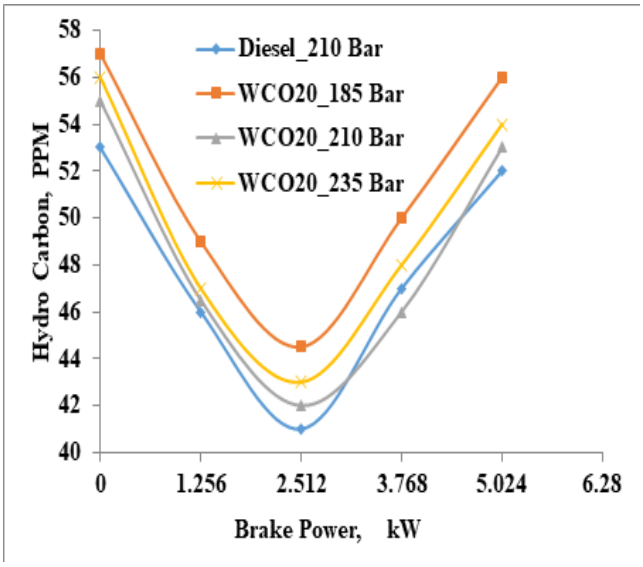


Figure 5. Hydro carbon.

3.5 Nitric Oxides

From the Impression of figure 6, the temperature of the cylinder gas and the amount of oxygen present during the combustion event have a substantial impact on NOx formation[21]. By raising the injection pressure, the Nitrogen Oxides (NOx) emission is found to be trending upward. Loads should be increased when NOx emissions rise[22]. Compared to the other two injection pressures of 185 and 210 bars, the NOx emission for injection pressure 235 bars is a little bit greater. When compared to injection pressure 210 bars for diesel, the NOx emission at 235 bars is 3.89% higher. The formation of NOx for WCO20_185 bars of is 6.71% lesser and 2.82% lesser for WCO20_210 bars Compared to typical Diesel_210 bars. This might be due to the oxygen presence in biodiesel, the concentration of the blend in diesel tends to raise the NOx levels during combustion[23].

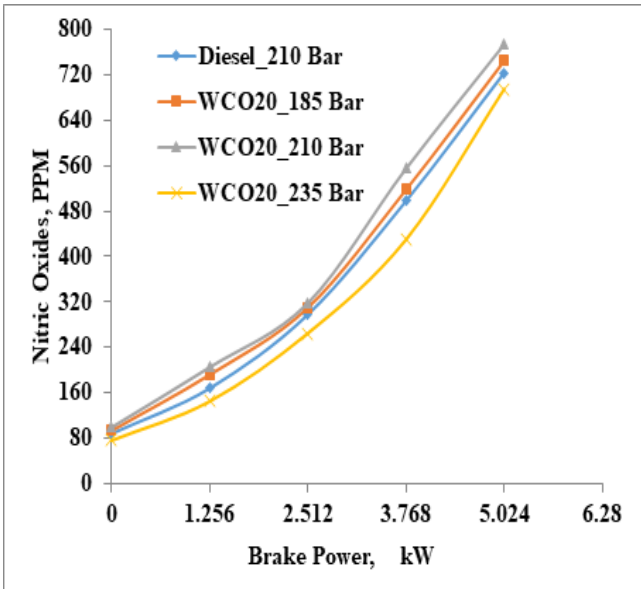


Figure 6. Oxides of nitrogen.

3.6 Smoke

Figure 7 depicts the variation in smoke emission from WCO20 fuels at different injection pressures. The findings indicated that as loads grew, so did the smoke emission level. At 235 bars injection pressure, smoke emission was found to be 3.24% lower with WCO20 biodiesel[24]. This might be because to the increased oxygen content and lower carbon to hydra ratio. The micro fuel droplets that develop during the expansion stroke, which is when the soot particles are oxidized, are made to persist longer by raising the injection pressure[25].

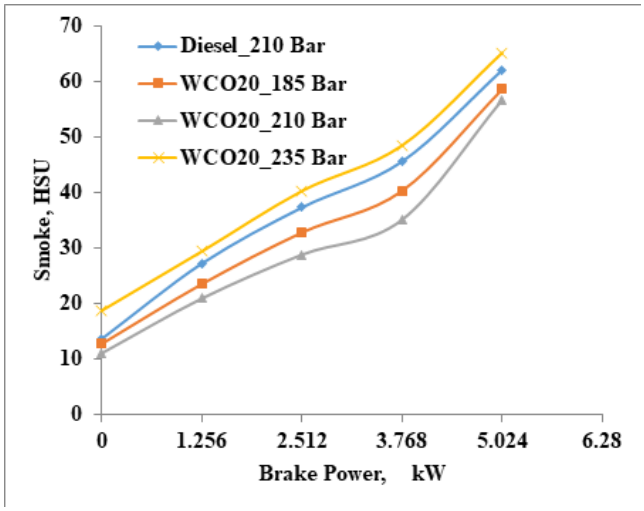


Figure 7. Smoke.

4.0 Conclusion

The Current study of effect of Injection Pressure on Performance and emission assessments of various Injection pressure yields the following results for the fuel of 20% of waste Cooking oil - 80% of diesel fuel. The Sample Fuels Possible to operate without any changes changing the Parameters of the diesel engine. When running at full capacity, waste cooking oil with diesel had improved emission characteristics due to the high fuel injection pressure of 235 bar. In comparison to the other two injection pressures of 185 bars and 210 bar, injection pressure 235 bars produces the best performance and emission results out of the three. NOx and smoke emissions are higher at 235 bars injection pressure than at 185 and 210 bars injection pressures. It is due to size of the droplets. The CO emission is higher for injections pressure of 210 bars than other two injection pressure such as 185 bars and 235 bars. The decreased rate of premixed combustion was the cause of this, with a 20% of waste cooking oil and 80% of diesel blend, inlet valve opening time of 13° before top dead center, and injection pressure of 235 bar, this results in improved performance and harmful emissions.

5.0 References

1. Adhikesavan C, Ganesh D, Charles Augustin V. Effect of quality of waste cooking oil on the properties of bio-diesel, engine performance and emissions. CLCE. 2022;

4:100070. ISSN 2772–7823, https://doi.org/10.1016/j.clce.2022.100070.
2. Lin Y.-S., Lin H.-P. Study on the spray characteristics of methyl esters from waste cooking oil at elevated temperature. Renew Energy. 2010; 35:1900–1907. https://doi.org/10.1016/j.renene.2010.01.014.108.
3. Karthikayan S, Sankaranarayanan G, Karthikeyan R. Green technology effect of injection pressure, timing and compression ratio in constant pressure heat addition cycle by an eco-friendly material. Ecotoxicol Environ Safe. 2015; 121:63–6. https://doi.org/10.1016/j.ecoenv.2015.05.015.
4. Lalvani JIJ., Kirubhakaran K, Parthasarathy M, Sabarish R. and Annamalai K. "Performance characteristics and emission analysis of a single cylinder diesel engine operated on blends of diesel and waste cooking oil". 2013 International Conference on Energy Efficient Technologies for Sustainability, Nagercoil, India. 2013; pp. 781–785, https://10.1109/ICEETS.2013.6533484.
5. Gölcü Mustafa, Sekmen Yakup, Erduranlı Perihan, Salman M. Sahir. Artificial neural-network based modeling of variable valve-timing in a spark-ignition engine. Applied Energy. 2005; 81(2):187–97. ISSN 0306–2619, https://doi.org/10.1016/j.apenergy.2004.07.008.
6. Sabarish R, Prem Jeya Kumar M, Rajasekar R. Experimental investigation on direct injection diesel engine fuelled by JFO with nano additives. Materials Today: Proceedings. 2022; 62(4):1821–9. https://doi.org/10.1016/j.matpr.2021.12.456.
7. Kannan GR, Anand R. Experimental evaluation of DI diesel engine operating with diestrol at varying injection pressure and injection timing. Fuel Process Technol. 2011; 92(12): 2252–63. ISSN 0378-3820, https://doi.org/10.1016/j.fuproc.2011.07.015.
8. Quadri PSA., Masood M. Kumar PR. Effect of pilot fuel injection operating pressure in hydrogen blended compression ignition engine: An experimental analysis. Fuel. 2015; 157:279–84. https://doi.org/10.1016/j.fuel.2015.04.068.
9. Harikrishnan SN, Sabarish R. Experimental analysis of direct injection diesel engine using rubber seed oil. Middle East J Sci Res. 2014; 20(6):709–14. https://www.idosi.org/mejsr/mejsr20(6)14/10.pdf.
10. Syed A, Azam S, Quadri P, Rao GAP, Wajid M. Experimental investigations on DI (Direct injection) diesel engine operated on dual fuel mode with hydrogen and Mahua oil methyl ester (MOME) as injected fuels and effects of injection opening pressure. Appl Therm Eng. 2016; 114:118–129. https://doi.org/10.1016/j.applthermaleng.2016.11.152.
11. Raheman H, Ghadge SV. Performance of diesel engine with biodiesel at varying compression ratio and ignition timing. Fuel. 2008; 87(12):2659–2666. ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2008.03.006.
12. Suryawanshi J, Deshpande N. Effect of injection timing retard on emissions and performance of a pongamia oil methyl ester fuelled CI engine, SAE Technical Paper 2005-01-3677. https://doi.org/10.4271/2005-01-3677.
13. Yesilyurt Murat Kadir. The effects of the fuel injection pressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel-diesel blends. Renew Energy. 2019; 132:649–666. ISSN 0960-1481, https://doi.org/10.1016/j.renene.2018.08.024.
14. Srinivas K, Naik DBB, Radha DKK. Impact of fuel injection pressure and compression ratio on performance and emission characteristics of VCR CI engine fuelled with palm kernel oil-eucalyptus oil blends. Mater Today: Proc. 4. 2017; pp. 2222–2230. https://doi.org/10.1016/j.matpr.2017.02.069.
15. Christopher M, Sabarish R. Emission analysis of a single cylinder DI engine running on biodiesel blend as fuel. Middle-East J Scientific Research. 2014; 20(6):681–4. https://10.5829/idosi.mejsr.2014.20.06.11377.
16. Sener Ramazan, Yangaz Murat Umut, Gul Mehmet Zafer. Effects of injection strategy and combustion chamber modification on a single-cylinder diesel engine. Fuel. 2020; 266:117122. ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2020.117122.
17. Gumus M, Sayin C, Canakci M. The impact of fuel injection pressure on the exhaust emissions of a direct injection diesel engine fuelled with biodiesel – diesel fuel blends. Fuel. 2012; 95:486–494. https://doi.org/10.1016/j.fuel.2011.11.020.
18. Padmanaba Sundar S, Vijayabalan P, Sathyamurthy Ravishankar, Said Zafar, Thakur Amrit Kumar. Experimental and feasibility study on Nano blended waste plastic oil based diesel engine at various injection pressure: A value addition for disposed plastic food containers. Fuel Process Technol. 2023; 242:107627. ISSN 0378-3820, https://doi.org/10.1016/j.fuproc.2022.107627.
19. Song L, Liu T, Fu W, Lin Q. Experimental study on spray characteristics of ethanol aviation kerosene blended fuel with a high-pressure common rail injection system. J Energy Inst. 2016 (In Press), Corrected Proof. https://doi:10.1016/j.joei.2016.12.004.

20. Agarwal AK, Dhār A, Gupta JG, Kim WI, Choi K, Lee CS, Park S. Effect of fuel injection pressure and injection timing of Karana biodiesel blends on fuel spray, engine performance, emissions and combustion characteristics. Energy Conv Manga. 2015; 91:302–314. https://doi.org/10.1016/j.enconman.2014.12.004.
21. Rajak Upendra, Subhaschandra Singh Thokchom, Nashine Prerana, Chaurasiya Prem Kumar, Verma Tikendra Nath, Khan Anish, Asiri Abdullah M. 2 - Influence of fuel injection pressure for diesel-waste cooking oil cofuel in a research engine, Editor(s): Anish Khan, A. Pizzi, Mohammad Jawaid, Naved Azum, Abdullah Asiri, Illyas Isa, Advanced Technology for the Conversion of Waste Into Fuels and Chemicals. Woodhead Publishing, 2021, pp. 21–40. ISBN 9780323901505, https://doi.org/10.1016/B978-0-323-90150-5.00004-2.
22. Rajak U, Nashine P, Verma TN. Effect of fuel injection pressure of microalgae spirulina biodiesel blends on engine characteristics. J Comput Appl Res Mech Eng. 2019. https://doi.org/10.22061/jcarme.2019.4767.1578.
23. Mohan B, Yang W, Raman V, Sivasankaralingam V, Chou SK. Optimization of biodiesel fuelled engine to meet emission standards through varying nozzle opening pressure and static injection timing. Appl Energy. 2014; 130:450–457. https://doi.org/10.1016/j.apenergy.2014.02.033.
24. Thiruvenkatachari S, Saravanan CG., Raman V, Vikneswaran M, Josephin JSF, Varuvel EG. An experimental study of the effects of fuel injection pressure on the characteristics of a diesel engine fueled by the third generation Azolla biodiesel. Chemosphere. 2022 Dec; 308(Pt 1):136049. https://doi:10.1016/j.chemosphere.2022.136049.
25. Agbulut Ü. Ayyıldız M, Sarıdemir S. Prediction of performance, combustion and emission characteristics for a dual fuel diesel engine at varying injection pressures. Energy 2020; 117257.