An impact of Surface Ignition on Performance, Emission and Combustion Characteristic of Mahua oil in LHR engine

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Abstract

Rising fuel demand in a variety of applications now poses a substantial threat to world emissions levels. Mahua oil is a biodiesel made from Mahua oil, which is a possible non-edible oil source in India and a potential diesel fuel substitute. Mahua oil is a fuel made out of fatty acid alkyl esters that is environmentally benign. The goal of this experiment was to investigate Low Heat Rejection with Delayed Injection Timing in a Mahua oil-powered diesel engine. The engine's piston, cylinder walls, and valves were coated with 0.5 mm of Partial Stabilized Zirconium (PSZ) material without compromising the engine's compression ratio. Experiments were carried out in the engine with and without coating, using diesel and Mahua oil. When comparing the Mahua oil with retarded timing coated engine to the conventional engine with plain diesel fuel, the results showed that specific fuel consumption was reduced by 7.4% and brake thermal efficiency was raised by 5.6 percent. The CO and UBHC emissions from the LHR engine are lower. The zirconia coating increased NOx emission. The combustion research revealed that the engine tested was superior to that of a normal diesel engine.

***Keywords**:*Diesel Engine, Mahua Oil, Surface Ignition, LHR, Performance, Emission, Combustion

1. Introduction

The environmental degradation of petroleum products, as well as their non-renewability, has prompted a global quest for renewable and greener internal combustion alternatives. Vegetable oils are one of these options, with the benefit of lowering most regulated emissions in reciprocating engines, such as carbon monoxide, unburned hydrocarbons, nitrogen oxides, and soot [1]. Vegetable oils are a renewable energy source with a similar energy content as diesel. The main issue with using vegetable oils as CI engine fuel is their increased viscosity, which is 10 to 20 times that of diesel fuel. This increased viscosity causes poor fuel atomization, inefficient combustion, and carbon deposition on the injector and valve seats, resulting in substantial engine fouling [3]. Blending, pyrolysis, transesterification, micro-emulsification, and other techniques can help reduce the increased viscosity of vegetable oils. They found that when methyl ester of MO was used instead of diesel fuel, the engine performance was significantly improved. When using neat MO biodiesel instead of neat diesel, they saw a minor drop in engine power and an increase in fuel consumption. They also discovered that when using the methyl ester of MO instead of diesel, the HC and CO emissions were significantly lower. For the performance and emissions of a Ricardo E6 engine, Raheman and Ghadge conducted an experimental investigation using MO biodiesel and its blends with conventional diesel [10]. They found that using biodiesel instead of MO with diesel resulted in lower brake specific fuel consumption and exhaust gas temperature, as well as increased brake power, when compared to using neat biodiesel (i.e.100 percent biodiesel). They also saw a reduction in smoke and CO emissions, as well as an increase in NOx, when biodiesel mixes with diesel were used. Senthilkumar and Arulselvan tried using Mahua oil in a diesel engine in a mixed form and in a dual fuel mode of operation using methanol as a supplemental fuel [11]. An LHR engine's insulation lowers heat transmission, resulting in a larger BTE and more heat being transferred to the exhaust gases. Due to its superior insulating and thermal expansion behaviour that is similar to that of metals, partially stabilised zirconium (PSZ) has been shown to be extremely beneficial for LHR engines. Coating durability is reduced when plasma-sprayed thermal coating thickness increases, necessitating coating structural change [12]. One of the hurdles in car technology is the development of low-emission diesel engines. Because of the greater temperature of the CC in diesel engines, NOx production is a big issue. NOx generation is influenced by high temperatures, oxygen availability, and residence duration. Better combustion elevates the temperature, which causes nitro-gen to interact with oxygen, which is inert at low temperatures. Ratnareddy et al. (2013) conducted an experimental study in a medium grade low heat rejection (LHR) diesel engine to examine the performance of Mohr oil in crude and biodiesel form under various operating situations. They came to an agreement. The best injection time was determined to be 31° bTDC for coated engines and 30° bTDC for LHR engines running on biodiesel. With biodiesel operation on the LHR engine, peak brake thermal efficiency rose by 12.5%, smoke levels reduced by 38%, and NOx levels increased by 35%. Akash Deep et al. (2017) looked at the effects of fuel injection time and pressure on a single cylinder C.I. engine running on a 20% castor biodiesel mix in diesel. The authors conducted a thorough comparison based on a variety of combustion, performance, and emission criteria. The results revealed that a 20% castor biodiesel mix in diesel may be utilised without any changes to the fuel injection system. However, to the best of the authors' knowledge, no article exists that examines the changes that have occurred in biodiesel engines. The purpose of this research is to look at the performance, emissions, and combustion characteristics of Retarded timings on a single cylinder LHR engine that runs on mahua oil biodiesel.

2. Materials and methods

2.1 Preparation of Mahua oil (MO)

Mahua seeds are gathered from Tamil Nadu and kept dry (less than 5% moisture), and Mahua oil is extracted using the expeller process. The pre-treatment and transesterification processes were carried out in a laboratory setting using a 1000cc inverted neck flask in airtight circumstances. The free fatty acid content of mahua oil was discovered to be around 18 percent using the titration method [5]. The reaction environment was kept at ambient temperature and heated to 50°C to 60°C with 5% concentrated sulphuric acid. The mixture was continuously swirled at 450 rpm for over 90 minutes, with 15-minute intervals. The base catalyst reaction is then carried out with Methanol and sodium hydroxide pellets as catalyst, which is then agitated for an hour. The oil is now transferred to a separating flask and allowed to cool so that the glycerol settles.

Fig. 1 Raw Mahua Oil

Fig. 1a Separating Flask

Table 1 shows the parameters of the fuel and the LHR material that was employed

Table 1 summarises the parameters of diesel and MO as determined by American Society for Testing and Materials (ASTM) standards.

Properties	Mahua oil	Diesel	STM test no.
Density (kg/m3)	904	840	D4052
Chemical formula	-	$C_{13}H_{24}$	-
Calorific value (kJ/kg)	7 735	43,000	-

Viscosity (cSt)Centi Stokes	38.86	2–5	D445
Flashpoint (C)	220	75	D93
Carbon residue (%)	-	0.1	-
Cetane number	50	45–55	-

2.2 Partially Stabilized Zirconia (PSZ)

The plasma spraying process is mainly the spraying onto the surface of the molten or thermal suppressed material for coating purposes. Zirconia is pumped into a plasma flame in powder form, which heats and speeds up rapidly. A mixture of zirconia polymorphs is partly stabilized zirconia. A smaller stabilizing portion of pure Zirconia can lead to a tetragonal phase of its structure, at a temperature greater than 1,000^{o}C. The partly stabilized zirconia, with the aid of a transporter gas, the coating material is pumped into powder by the feed machine. The particles are melted and attached as a coating to the base material being treated [8].

Figure 2. PSZ coated piston and valves

3. Experimental test

The Kirloskar TAF1 model was the test engine used, and the experimental setup is shown in Figure 3. Testing for different loads from no full load was performed for percent. It is worked for 15 minutes to stabilize the engine at and additional load. In the beginning, the test is performed by diesel and Mahua oil gasoline. The combustion and emission characteristics are noted for each particular load. The experiment is performed thrice, and the results are sufficient to find the repeatability of the measurement values. Every experiment uses approximately 1.3 litres of fuel. The combustion parameters of diesel fuel are first and foremost observed by enabling the engine to achieve a stable condition for each experiment.

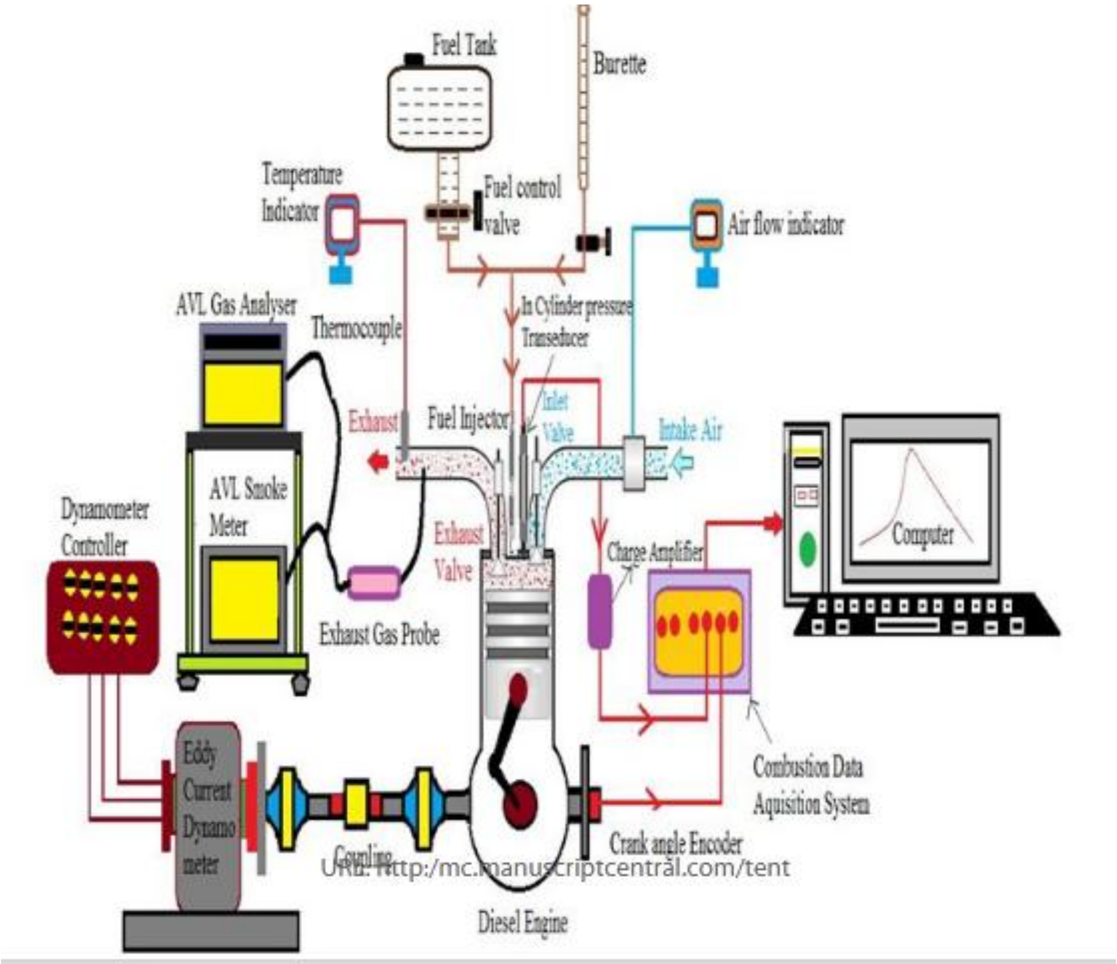

Figure 3 Experiment set up

4.Results and Discussion

4.1 Brake Thermal Efficiency

The difference in brake thermal efficiency between normal and LHR engines is seen in Illustration 4. The Mahua oil brake thermal efficiency at full load is 26.52, 25.03, and 29.20 percent for normal engines and retarded injection timing with ceramic coating, respectively. It was found that the partially stable Zirconia LHR had a higher thermal efficiency than the ceramic coating as a barrier for heat transfer from the engine to the atmosphere. The engine's power and thermal efficiency gradually increased as heat loss was reduced [10].

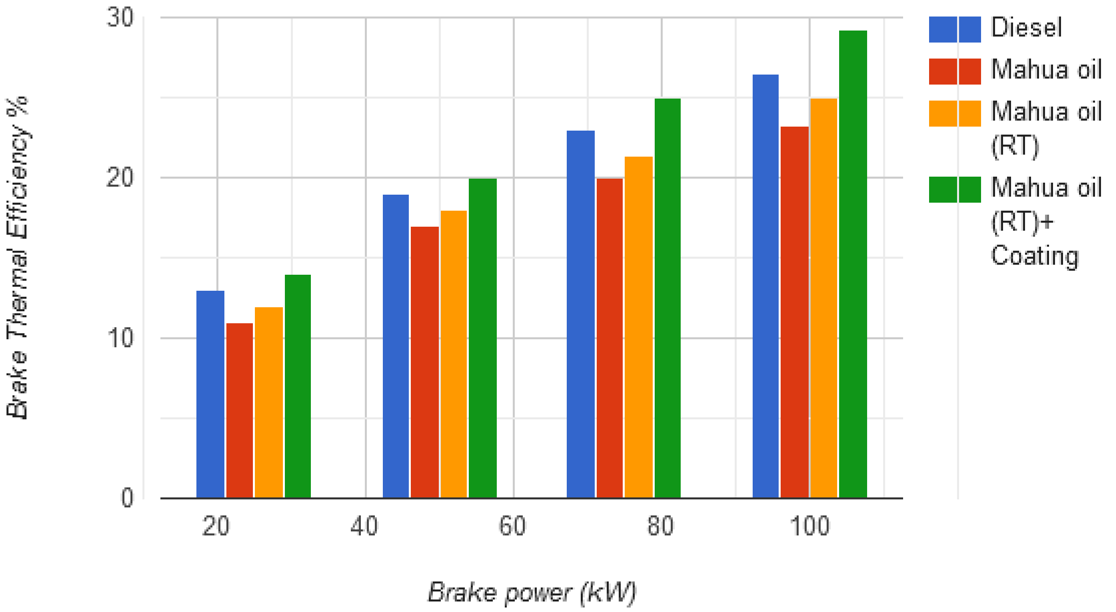

Figure 4 Brake Thermal Efficiency

4.2 Brake Specific Energy Consumption

Before using cooling and exhaust in the internal combustion engine, much of the usable energy is exhausted externally. Illustration 5 shows the difference in brake specific energy consumption for standard and LHR engines. The Mahua oil fuel low heat rejection in maximum heating conditions, a decrease in the retarded timing engine was 5.63% and 3.21% compared to the standard, retarded injection-time Mahua oil.

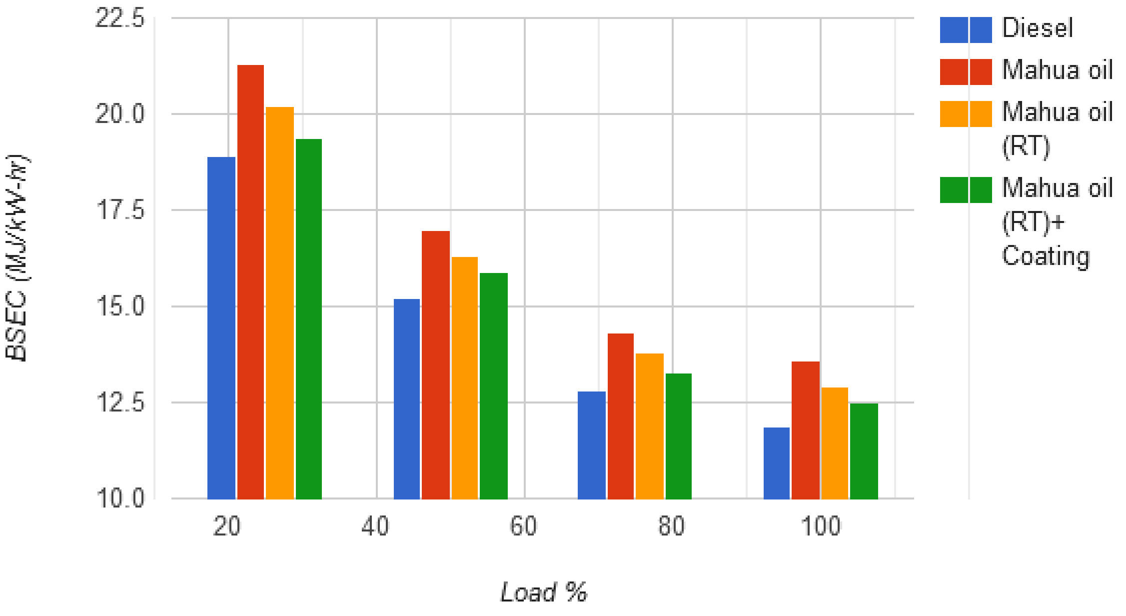

Figure 5 Brake Specific Energy Consumption

4.3 Exhaust gas temperature

From fig 6.The EGT for standard engines and retarded injection timing with ceramic coating the Mahua oil at no load condition are 135°C, 124°C,and 164°C,respectively. The same at full load operation are 389°C, 364°C,and 438°C. When compared to the Mahua oil-fueled uncoated engine with standard and retarded injection timing, the EGT of the ethanol-fueled low heat rejection – retarded timing engine rose by 18.64 percent and 13.27 percent at maximum load. The decrease in heat losses into the cooling system and transfer of this heat to the exhaust gas as a result of thermal barrier coating may explain the rise in exhaust gas temperature in coated engines compared to uncoated engines [11].

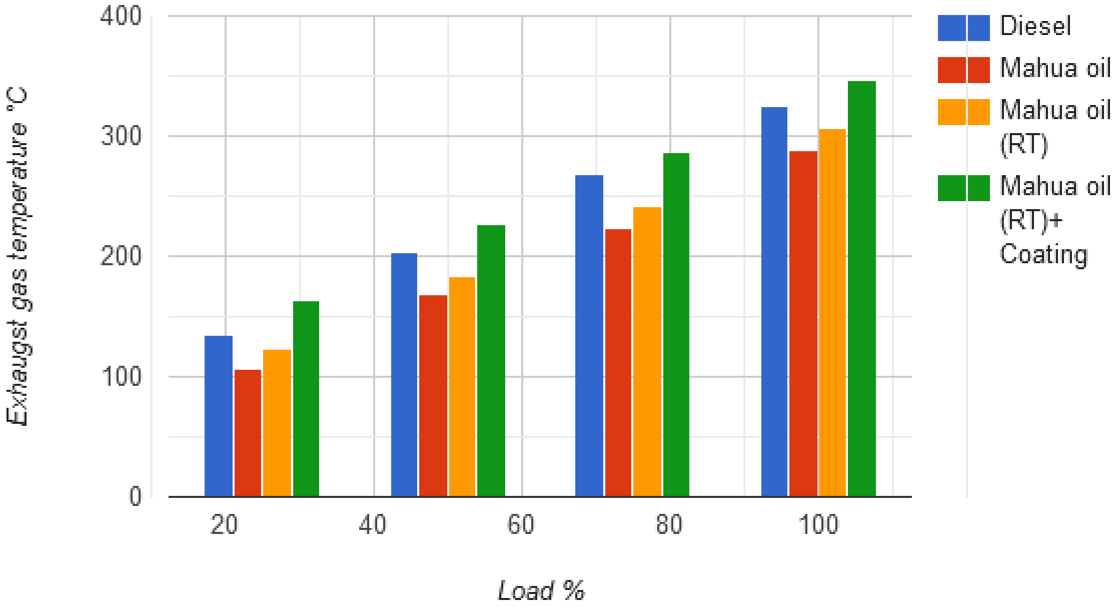

Figure 6 Exhaust gas temperature

4.4 Carbon Monoxide Emission

Illustration 7 shows variations of carbon monoxide emissions for standard and LHR engines regarding load. It is observed that the Mahua oil CO emission was powered by low heat rejects during full load; the retarded time engine was down by 20.35% and 14.80% as opposed to the standard and retarded injection time-driven Mahua oil. The rise in the chamber temperature due to the idolizing effects of the injected Mahua oil helps boosts vaporization of fuel [12].

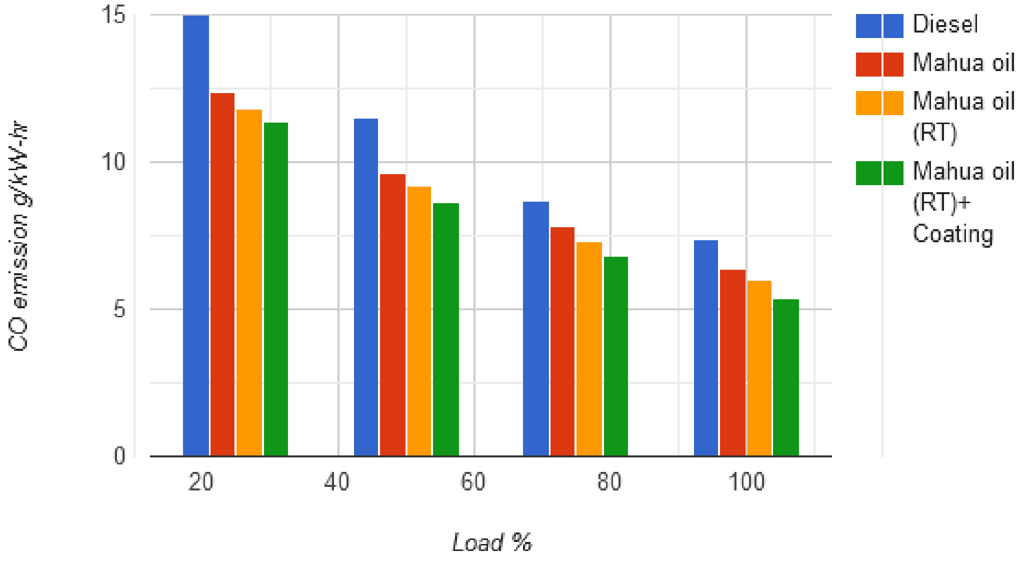

Figure 7 Carbon Monoxide Emission

4.5 UBHC Emission

Illustration 8.Shows UBHC in terms of load in standard engines and LHR. The figure shows that the LHR engine has achieved less than the traditional engine's hydrocarbon emissions. UBHC's emissions from the Mahua oil at full load conditions fuelled LHR. The retarded timing engine was 12.28 percent and 6.84 percent lower the normal and retarded injection-time Mahua oil powered by standard uncoated engine. The reduction in HC emissions in the coated engine is attributed to the rise in post-combustion temperatures resulting from reduced heat loss in the cooling, which induces the additional combustion of more unburned HC [13].

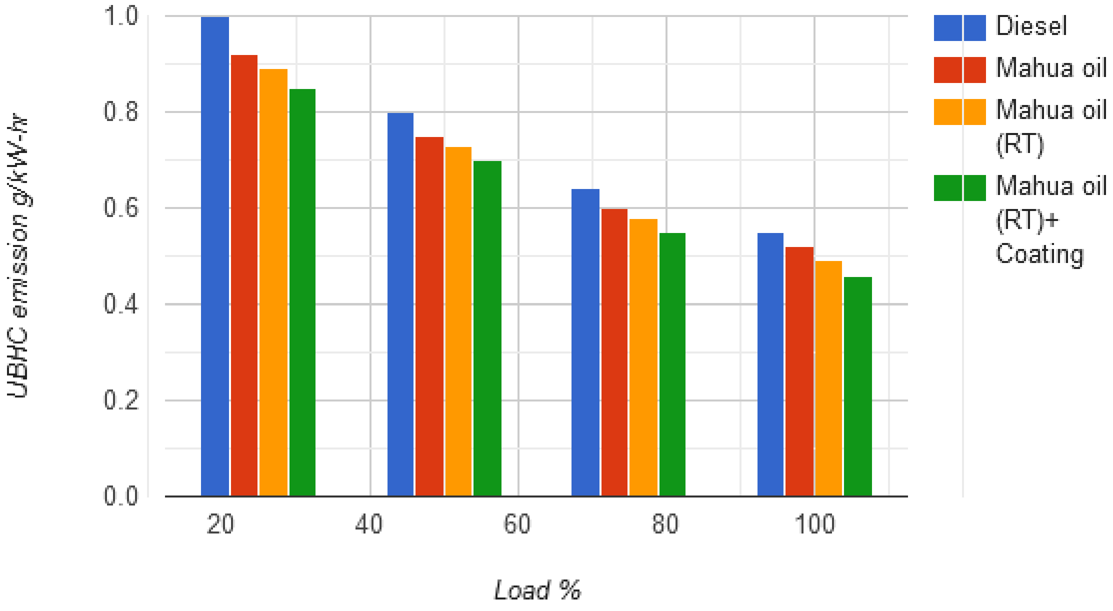

Figure 8UBHC Emission

4.6 NOx Emission

Illustration 9.Exhibits nitrogen-emission oxides variance about load for standard and LHR.Mahua oil NOx emissions fuelled low rejection of the heat 5.36% and 14.38% improvement in the retarded timing engine compared to the standard in the highest load retarded injection timing unloaded Mahua oil engine. The increased NOx emissions to the coated engine might enhance the zirconia coating post-combustion temperature.

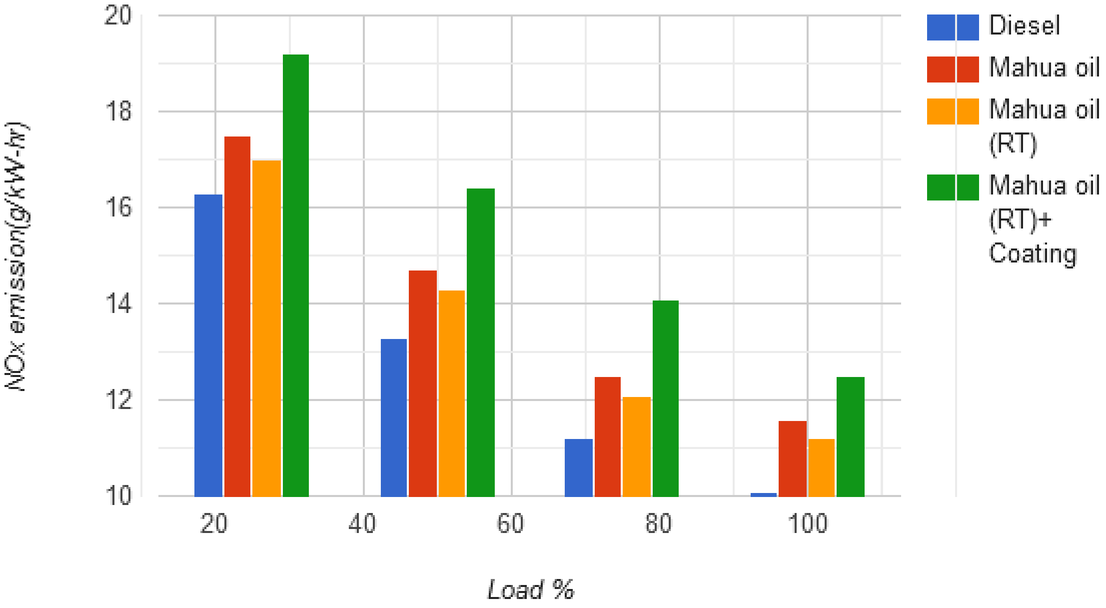

Figure 9 NOx Emission

4.7 Smoke Opacity

Illustration 10.Displays smoke-emission differences for standard and LHR concerning brake power. At the height of the load, a low-heat rejection was fuelled by Mahua oil retarded of 7.45% and 5.28%, contrasted with the uncoated normal and retarded injection timing. The higher temperature occurred in the incinerator because of its sections' thermal barrier, resulting in more carbon particles. As already suggested, smoke emissions result from incomplete combustion of carbon particles. The combustion chamber's coating increases combustion efficiency because the combustion chamber has higher temperatures [14].

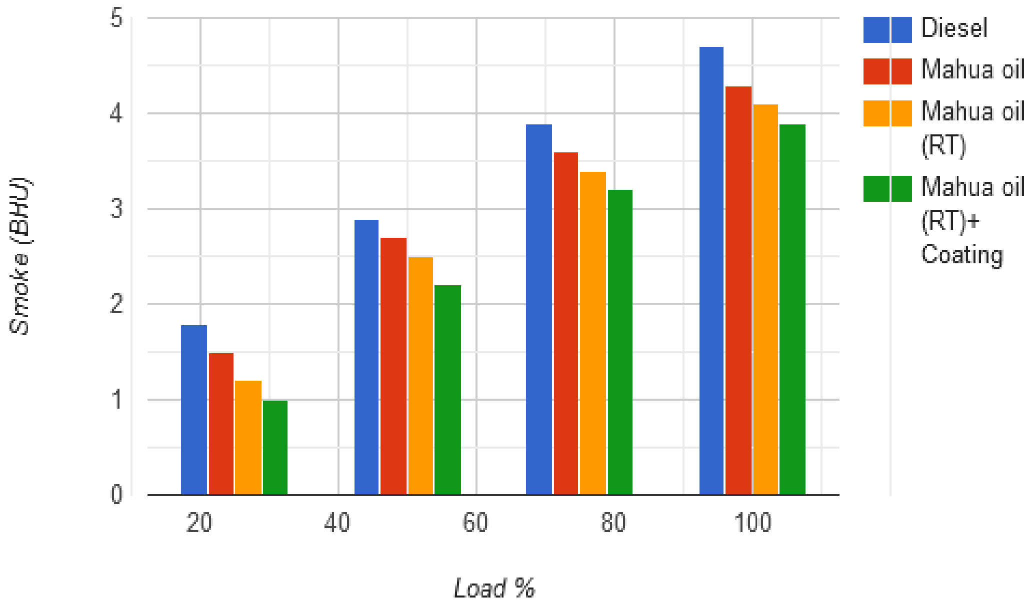

Figure 10 Smoke Opacity

4.8 Ignition Delay

Figure 11 depicts the effect of ignition delay on brake power for conventional and LHR engines. Because of the LHR engine's heat combustion chamber, the Mahua oil ignition retardation resulted in low heat rejection at full load; retarded reductions compared to the standard and retarded injection time of the Mahua oil fuel uncoated engine. As a result, the LHR engine runs smoother than the conventional engine.

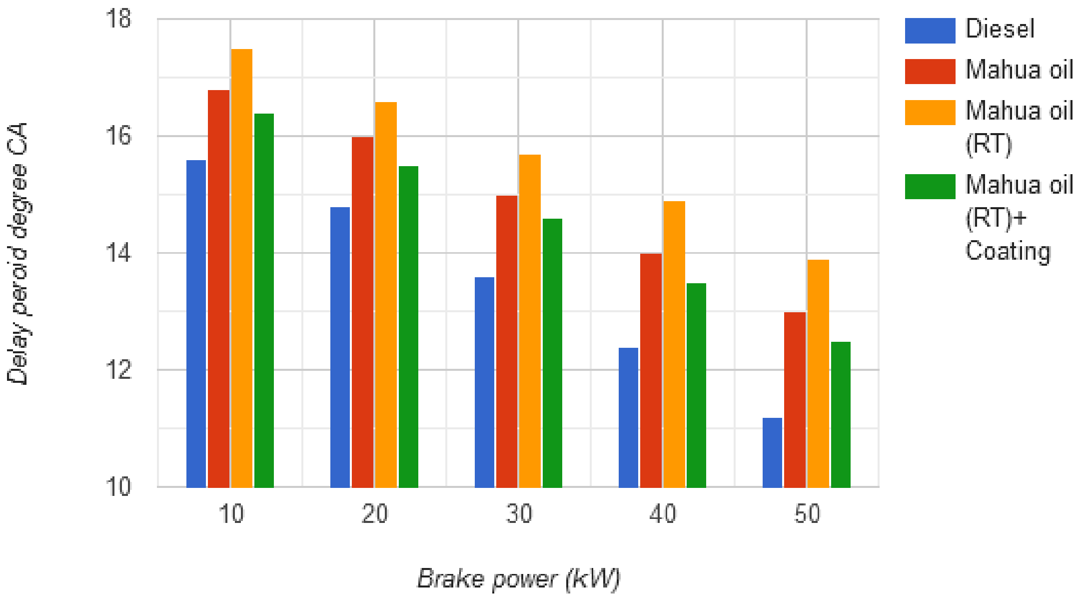

Figure 11 Ignition Delay

4.9 Cylinder Pressure

The standard and LHR engine of the cylinder pressure in terms of the crank angle are shown in Figure 12. The maximum pressure increases with increasing engine load. The higher LHR engine temperature produces maximum stress of 73.4 bar after TDC, which in the traditional CI engine was nearer to diesel (71.5 bar), after 13°CA. Following zirconia coating, Mahua oil has significantly increased the maximum pressure due to an increasing temperature, which accelerates the combustion phase of the in-cylinder. The high pressure of the cylinder provides improved combustion and heat release [15].

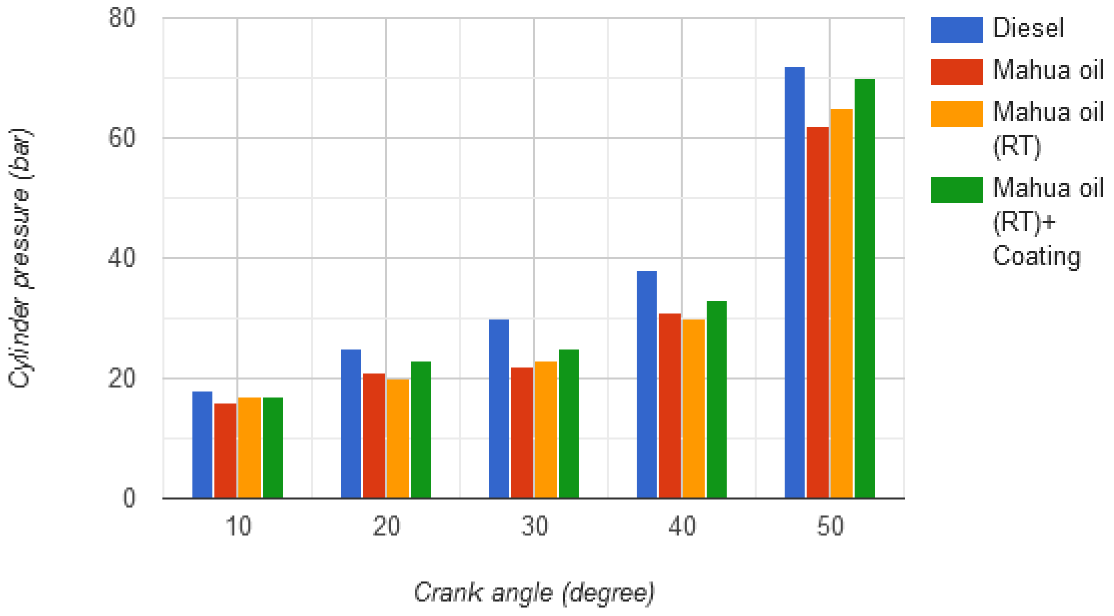

Figure 12Cylinder Pressure

4.10 Heat Release

The test results for the cylinder pressure in terms of crank angle for the standard and LHR engines are shown in Figure 13. Because Mahua oil was less atomizing and vaporising than fuel mixing rates, the peak heat release rate of Mahua oil was lower than that of clean diesel fuel [16]. In optimum loading conditions, a low heat rejection was fuelled with the heat release rate of the Mahua oil, which was delayed by a 13.65% and 18.22% lower than a standard uncoated engine with a retarded injection timing fired with the Mahua oil.

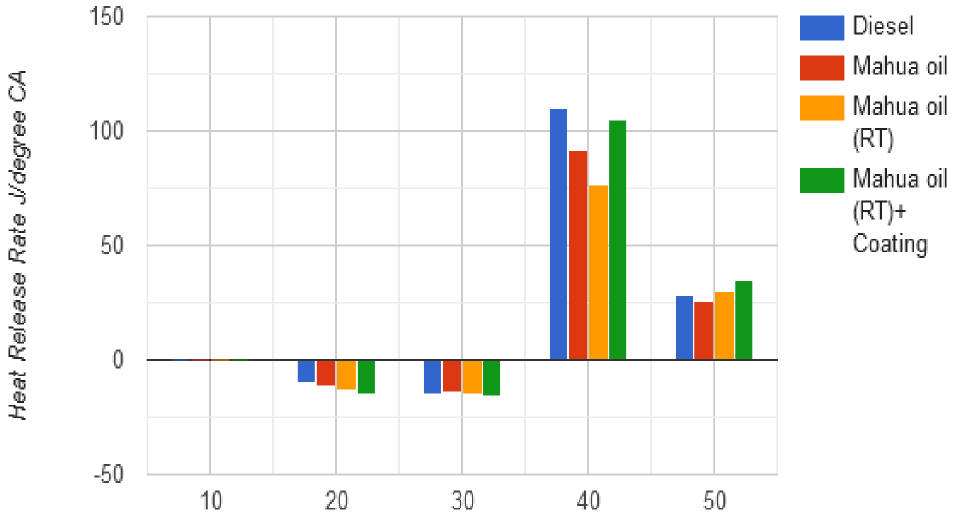

Figure 13 Heat Release

Conclusion

Experiments with neat diesel and Mahua oil biodiesel with and without coating were carried out on a single cylinder, water-cooled, direct injection, four-stroke diesel engine. The following conclusions are drawn based on the experimental findings. In comparison to diesel fuel, Mahua oil has a higher specific fuel consumption and a lower brake thermal efficiency. However, when compared to conventional engines, the LHR engine's specific fuel consumption is low and its braking thermal efficiency is great. By using a ceramic coating in the engine, the Mahua oil was able to reduce CO, HC, and smoke emissions while increasing NOx emissions. During the premixed combustion phase, biodiesel (Mahua oil) of diesel-biodiesel is shown to have lower heat release rates than diesel. When compared to diesel, the ignition delay and combustion duration are longer with diesel-biodiesel fuel. Future research is needed to look into the effects of different compression ratios and to distinguish between the combustion behaviour of diesel and biodiesel with varied EGR rates.

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