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Collective Effect of Mutated Piston and Different Injection Timing on Biodiesel Mixed Diesel Fuel in Diesel Engine

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Key words: Air movement inducement, biodiesel, combustion chamber, combustion improvement, mutated piston, injection timing

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Abstract: The commercial development of all nations builds upon the provision of energy. Sustained energy supply is extremely important for a developing country. Emerging awareness of air pollution and together with global warming is alarming us and making us to critically think about an alternative source of ecofriendly supply of energy. Thus, serious efforts are being done to produce new forms of fuels that can successfully replace the naturally occurring and rapid exhausting fuel. In this research, engine energized with non-edible vegetable oil ester blend is studied. Engine studies have been carried out using standard diesel and 20% mixture of Adelfa biodiesel [AOME20]. Data acquired from sustainable fuel AOME20 in the engine showed the reduction in thermal efficiency due to deprived air fuel mixing features and its superior viscosity. This urged the studies towards the furtherance of air fuel mixing by a novel Mutated Piston [MP]. Further studies were aimed towards the study of the collective effect of mutated piston and injection timing. About 1.23% progress in performance of engine energized with non-edible vegetable oil ester blend was obtained for retarded injection timing of 21°bTDC, as compared with the standard injection timing 21°bTDC. Hydro carbon, carbon monoxide and smoke intensity were diminished significantly for Mutated Piston [MP] with AOME20 with retarding injection timing whereas nitrous oxide and carbon dioxide emissions were elevated.

INTRODUCTION

Energy is vital for commercial, community and self-development of individualistic in any countries. The fossil fuels are deflating and their costs rises are hovering in the prevailing scenario. When fossil fuels are combusted, the environmental issues involved with the exhaust gas emission are survival-frightening to human well being. As a resolution to partly surpass such difficulties bothered with toxic emissions, the researchers have searched out biodiesel as recourse to diesel fuel (Xue *et al*., 2011). Under such precedence alternative fuel from edible and non-edible vegetable oil acts as an auxiliary for the internal combustion engine usually fuelled with diesel. Noticeably, in properties such as heating values and viscosity biodiesel straggles in race as a contender for diesel fuel. Researchers have made debatable descriptions on viscosity of biodiesel. Whereas few researchers have identified that it augmented fuel spray penetration, plenty have found that predominant viscosity results in the power deficiency due to an outrageous proposition of fuel injection. Whereas, the diminution of viscosity can be achieved by distinctive techniques as follows: Trans-esterification, pyrolysis emulsification and dilution. Compared to other techniques trans-esterification is extensively used all around the world due to its merits over the other ones. The amercement of using vegetable oil in a diesel engine was deprived fuel atomization, diminished mixing leading to incomplete combustion and elevated carbon deposit (Murugesan *et al*., 2009; Issariyakul and Dalai, 2014). A wide ranging research was carried out in the experimentation of bio fuelled diesel engine. It displayed an elevation in the specific fuel consumption, diminishing thermal efficiency and superiority of the combustion due to the higher oxygen content and diminution in the Carbon monoxide and Total Hydrocarbon (THC) exhaust emissions, even though there was a slight elevation in Nitrogen Oxides (NO_x) emissions (Lin *et al*., 2009; Rakopoulos *et al*., 2014; Yilmaz and Vigil, 2014; Agarwal *et al*., 2008). Ashraful *et al*. (2014) made a study on several non-edible biodiesel fuel cases and concluded that biodiesel would give superior thermal efficiency and diminishing specific fuel consumption. Diesel engine powered with vegetable oil shows leading trend of NO_x emission and carbon monoxide and particulate exhaust emissions displayed wiping out trend (Atabani *et al*., 2013). Rajamani *et al*. (2012) stated that the bowl diameter of piston and arc radius can play a noticeable role in nitrous oxide formation and particulate emissions. Jaichandar and Annamalai (2012a, b), stated that the geometry can improve the homogenous mixture formation and air motion which diminishes the specific fuel consumption and elevates the brake thermal efficiency. The re-entrant piston chamber could enhance the fuel economy and diminishes the ignition lag (Saito *et al*., 1986). Advanced provisioning of fuel injection leads to a diminishing of soot emission (Lim and Min, 2005). Genzale *et al*. (2008) researched the effect of late fuel injection in low temperature combustion diesel engine and stated that piston bowls with the diameters of 60, 70 and 80% of bore at a constant compression ratio and letting about 60, 70% of the fuel interaction regions to be transported into the center of the combustion chamber, could reduce UBHC emissions. The matching of swirl motion and injection pressure is important for the reduction in emission and improvement in performance (Mehta and Tamma, 1998). Lalvani *et al*. (2016) studied the effect of turbulence inducer piston in diesel engine and stated that brake thermal efficiency and combustion characteristics were improved, they also modified the injection pressure of the engine and found that smoke, carbon monoxide and hydro carbon emissions were reduced (Lalvani *et al*., 2015; 2016). When the injection timing is advanced, smoke level shows a depleting trend; if it is too advanced, the smoke level shows a dwelling trend due to reduction in brake thermal efficiency (Jayashankara and Ganesan, 2010). Advancing the fuel injection timing results in an increase in the ignition delay period and reduction in gas temperature which shows that ignition delay has a major effect on the injection timing rather than on the injection pressure (Kannan and Anand, 2011, 2012; Agarwal *et al*., 2013; Kannan, 2013). Mani and Nagarajan (2009) reported that on retarding the injection timing on the diesel engine running on waste plastic oil, NOx decreased at all loads, CO emission decreased by 25%, UBHC emission decreased 30%, whereas smoke increased by 35% and that injection pressure has increased on a percentage basis as engine speed and load were reduced.

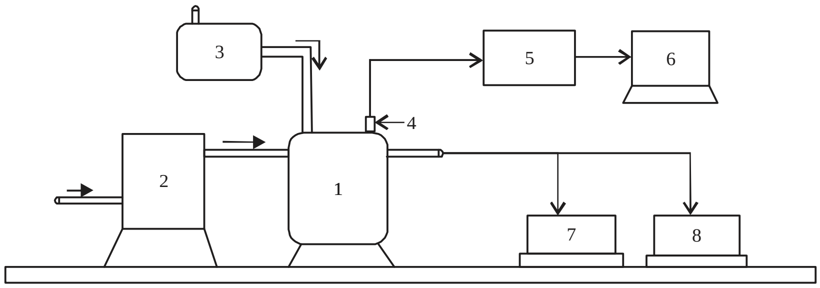
Combustion chamber, injection timing and injection pressure play an important role among various engine modifications (Heywood, 1988; Taylor, 1985; Glassman, 1996). The requirement of modification in an engine that befits the biodiesel blends without compromising on the combustion performance and emission characteristics needs to be studied. Apart from all blends, B20 is democratic since it does not require engine modifications, avoids cold-weather trouble and effectuates reduction in emissions. Hence, the main aim of this research article is to look into the collective effect of injection timing and mutated piston on D.I diesel engine energized with non-edible vegetable oil Adelfa biodiesel blend (AOME20).

MATERIALS AND METHODS

Subsection: The non-edible vegetable oil biodiesel blend chosen for the present investigation is Adelfa or Nerium oleander. In India TBOs (Tree Borne Oil seeds) are gaining major importance among various non-edible oils which are suitable for growing in wastelands. Adelfa which comes under the family Apocynaceae seeds were selected for the biodiesel production process. Nerium oleander an evergreen shrub with deep green straight sword like leaves, grows up to 6 m tall and blossoms of the shrub are in pinkish yellow white and yellow in colour. Nerium oleander seeds contain 67% oil. AOME is prepared by transesterification. The process in which reaction between triglyceride of Adelfa oil and methyl alcohol in the presence of catalyst converts into Adelfa oil methyl ester which has smaller, straight chain molecules

Table 1: Fuel properties

Property	Diesel	A0ME	AOME20	IS: 15607 specification
Density (kg m^{-3})	850	828	809	860-890
Kinematic viscosity (cSt)	3.9	6.5	4.4	2.5-6.0
Flash Pt (°C)	76	88	62	120
Cetane no	49	54	50	51
Calorific value (MJ kg^{-1})	44.12	42.652	43.09	44.12
Kinematic viscosity (cSt)	3.9	6.5	4.4	2.5-6.0



1. Engine
2. Volumetric efficiency setup
3. Fuel tank
4. Piezo electric pressure transducer
5. Combustion analyzer
6. Data acquisition system
7. AVL smoke meter
8. Crypton exhaust gas analyzer

Fig. 1: Schematic diagram of engine set-up

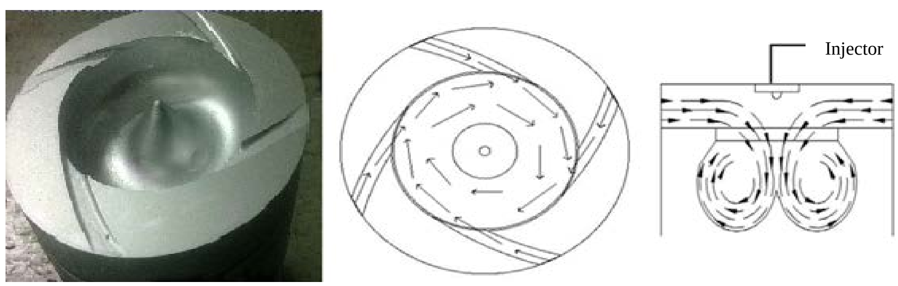


Fig. 2: Fabricated mutated piston and pictorial representation of air flow path in mutated piston

and glycerol as co-product is transesterification. The properties of Adelfa oil, AOME and its 20% blend with diesel are compared with the standard diesel in Table 1. Most of the properties of bio-fuels like calorific value, viscosity, density, flash point, fire point and cetane no are comparable with those of diesel. The properties of the raw Adelfa oil and AOME were experimentally evaluated. When compared with standard diesel, the calorific value of 20% AOME was found to be about 2.3% lower and viscosity was 13% superior.

Engine specifications: The standard Hemispherical open type Combustion Chamber (HCC) already existing in a standard DI diesel engine is operated my means of biodiesel. The improved air motion in the combustion chamber is achieved due to its mixing induced geometry profile which improves the mixture formation of biodiesel with air, thereby increasing brake thermal efficiency and lowering the specific fuel consumption. But when compared with diesel, the performance lags which is mainly due to the biodiesel air mixing. To overcome this problem in the present investigation the bowl volume was kept constant, so that, the compression ratio was the same for mutated geometry. This condition assures that changes in the emissions are caused by geometric variations only. Novel swirling grooves were provided in the piston top face to enhance the biodiesel air mixing by improving the swirling motion. Figure 1 shows the schematic diagram of engine set-up. The schematic diagram and the fabricated Mutated Piston (MP) are shown in Fig. 2. The dimensional details are shown in Fig. 3. Optimization was carried out by varying the injection timing. The injection timing was varied by changing the number of shims of the Mico jerk type pump. The standard engine was fitted with three shims to give standard injection timing of 23 (before Top Dead Center (bTDC). By changing the no of shims, the injection timings were varied to 20°, 21°, 22° and 24° bTDC.

Engine modifications: In the present research, the piston bowl has been mutated by providing air movement induced grooves to study the effect of injection timing on the

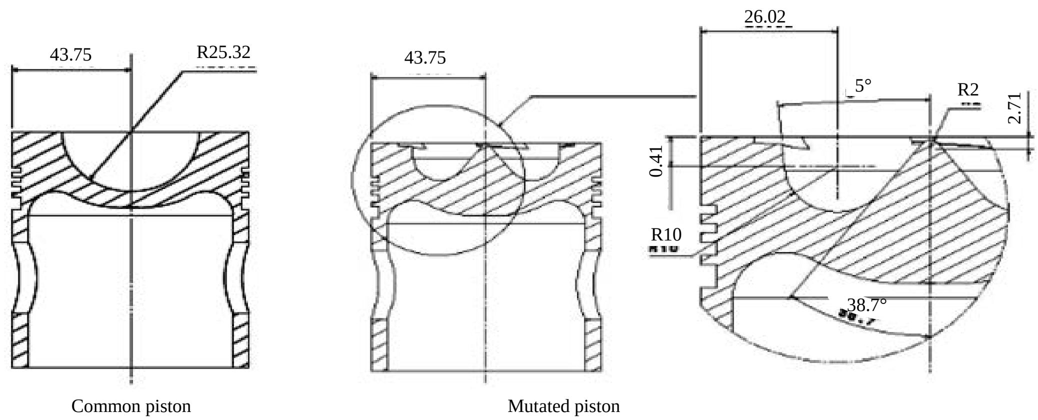


Fig. 3: Dimensions of the common and mutated piston

Table 2: Engine specification

Engine make	Kirloskar TV1
Nozzle hole diameter and number	0.3 mm and 3 holes
Displacement	661 cc
Bore and stroke	87.5 and 110 mm
Compression ratio	17.5:1
Fuel	Diesel
Rated brake power	5.2 kW @ 1500 rpm
Ignition system	Compression ignition
Injection timing	23 bTDC (rated)
Injection pressure	200 bar
Combustion chamber	Hemispherical combustion chamber
Injection opening pressure	200 bar

Table 3: Uncertainties in the measured parameters

Parameters	Systematic errors (±)
Speed	1± rpm
Load	±0.1 N
Time	±0.1 sec
Brake power	±0.5 kW
Temperature	±1°
Pressure	±1 bar
NO_X	±10 ppm
CO	±0.02%
CO_2	±0.02%
HC	±11 ppm
Smoke	±1 HSU

emission and performance characteristics of non-edible Adelfa biodiesel fueled DI diesel engine. The engine used for testing was a single cylinder, four stroke, and Direct Injection (DI) Kirloskar TV1 model diesel engine which developed 5.2 kW and operated at a constant speed of 1500 rpm. The engine was water cooled and was coupled to a Benz eddy current dynamometer. It was equipped with a MICO in-line injection pump which pressurized and injected the fuel at a of pressure 200 bar. Both the pressure transducer and the encoder signal were connected to the charge amplifier to condition the signals for combustion analysis using the combustion analyzer. The technical specifications of the test engine are given in Table 2. The ideal engine had a Hemispherical Combustion Chamber (HCC) with the overhead valve arrangements. Piezo electric pressure transducer fitted on the engine cylinder head was used to measure cylinder pressure. AVL 437C Smoke meter was used to measure the smoke intensity. Cylinder combustion characteristics were determined using the engine combustion analyzer. Crypton 290 series emission analyzer was used to measure the emissions, namely UBHC, CO and CO. NO_x emissions were measured using chemiluminescent type SIGNAL heated vacuum NO_x analyzer.

Test methods: Test method was carried out for Diesel and non-edible biodiesel blend. Initially, the engine was fuelled with diesel and AOME20 having HCC with fuel injection pressure and timing of 200 bar and 23°bTDC (manufacturer recommended) respectively to determine the baseline parameters. Circulating water through the jackets of the engine block and the cylinder head ensured the cooling of the engine. With the ideal pressure of 200 bar being kept constant, the injection timing was varied for the present study. Experiment was also carried out at different injection timings of 20°, 21°, 22° and 24° bTDC and the results were compared. The engine tests were carried out for the loads 0, 25, 50, 75 and 100%. By changing the number of shims the injection timing was varied from the standard 23° bTDC. In the present investigation, instruments and different equipments were used for measurement of various factors. Uncertainties and errors in the test may occur due to the selection of instruments, working conditions, method of conduct of the tests, observation and environment. Uncertainty analysis is essential to prove the quality of the experiment. Different manufacturers use different technologies to make their equipments. Hence, the uncertainty takes place due to random or fixed errors of the manufactures and observers. The uncertainties in the measured parameters were estimated based on analytical methods. Table 3 shows the uncertainties computed for the measured quantities.

RESULTS AND DISCUSSION

The combustion, emission and performance characteristics of the base engine with HCC and engine with mutated piston and at different injection timings were determined, compared and analysed for combustion

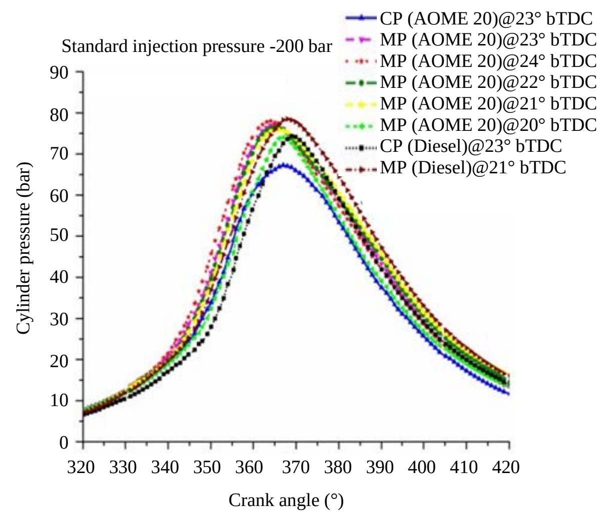


Fig. 4: Cylinder pressure variation

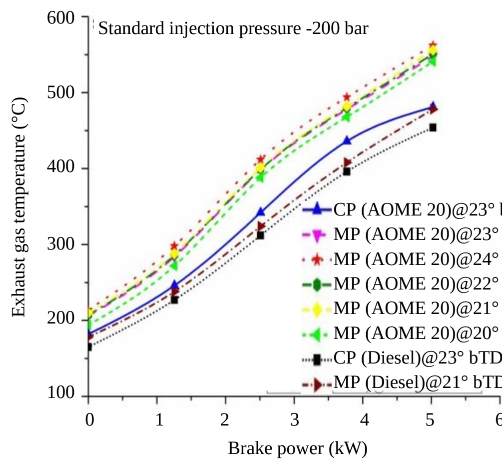


Fig. 5: Exhaust gas variation

parameters such as cylinder peak pressure, exhaust gas temperature, rate of heat release, cumulative heat release, and ignition delay. The emissions of carbon monoxide, oxides of nitrogen, unburnt hydrocarbon, carbon di-oxide, smoke and the performance characteristics, namely brake thermal efficiency and brake specific fuel consumption were considered. Eight different readings were considered and compared for the analysis and discussion then with the mutated piston the characteristics were noted for the following timings 20°, 21°, 22° bTDC (retarding the timing from standard) and 24° bTDC (advancing the timing from standard) with biodiesel. Further, the characteristics with mutated piston at 21° bTDC and 200 bar pressure fuelled with diesel were noted for better understanding.

The cylinder Pressure (P): The cylinder Pressure (P) variations with crank angle for the Common Piston (CP) and the Mutated Piston (MP) operated engine with AOME20 and Diesel fuel at different injection timing are is shown in Fig. 4. The pressure variations of the both mutated and common piston operated with AOME20 followed a pattern of the pressure rise similar to that of standard specification. A maximum cylinder gas pressure of 78.002 bar at 364.11° CA was observed with biodiesel blend at 200 bar injection pressure and 24° bTDC injection timing which was close to diesel. Superior pressure value was obtained for the mutated piston when compared with the common piston due to better combustion achieved by the provision of tangential groves for enhancement of biodiesel air mixing. The results also indicated that cylinder pressure decreased with retarding the injection timing 20°, 21°, 22° bTDC and increased with advancing the timing to 24° bTDC. This reduction in pressure was due to shorter ignition delay of the biodiesel at which lesser amount of heat is released in the premix and major part of the combustion progress in the diffusion phase of AOME20. The cylinder gas pressure of the biodiesel blend for all the test conditions lay below the diesel profile. This result could be due to the 2.3% lower calorific value of AOME20 as compared with diesel.

Exhaust gas temperature: Figure 5 shows the variations of exhaust gas temperature for the mutated piston and the common piston with diesel fuel and AOME20 at different injection timings. As illustrated the maximum exhaust gas temperatures obtained for AOME20 were 541°, 556°, 551°, 548° and 562°C for the injection timings of 20°, 21°, 22°, 23° and 24° bTDC, respectively. It was noted that the exhaust gas temperature of the AOME20 blend was superior to that of diesel fuel. This result was due to more complete combustion, as a result of the presence of oxygen in the AOME20, compared with diesel. For both the piston geometries, exhaust gas temperature increased linearly with load. This could be attributed to the temperature of the engine that rose due to continuous working of the piston (Friction) and the heat generated due to the combustion.

Heat Release Rate (HRR) and Cumulative Heat Release (CHR): The heat release rate and cumulative heat release rate variations with crank angle for the Common Piston (CP) and the Mutated Piston (MP) operated engine with AOME20 and Diesel fuel at different injection timings are shown in Fig. 6 and Fig. 7, respectively. As illustrated the maximum HRRs obtained for AOME20 were 78.6 (at 6° CA bTDC), 85.2 (at 8°CA bTDC), 86.2 (at 8° CA bTDC), 87.6 (at 9° CA bTDC), and 88.3 J/deg (at 10° CA bTDC) for the injection timings of 20, 21, 22, 23 and 24° bTDC, respectively. For diesel fuel owing to longer ID, longer premixed combustion phase occurred. For AOME20 the diffusion burning phase was greater as compared with to premix due to shorter ignition delay. The maximum CHRs of AOME20 were 1202, 1237.6, 1219.8, 1219.6 and 1245.1 J for the injection timings of 20°, 21°, 22°, 23° and

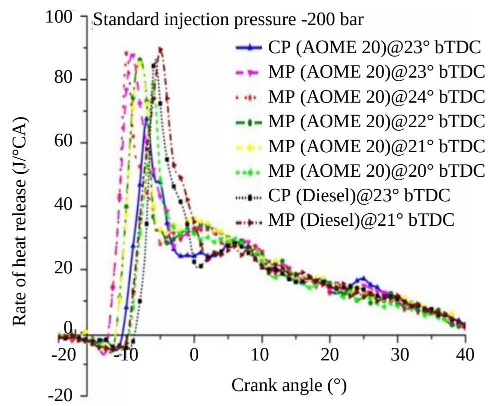


Fig. 6: Heat release rate variation

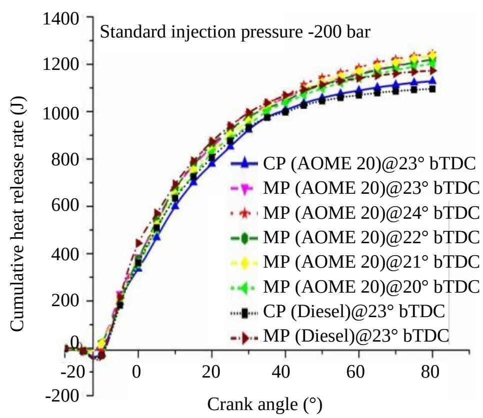


Fig. 7: Cumulative heat release rate variation

24° bTDC, respectively. This was mainly due to superior kinematic viscosity (cSt) and lower latent heat of vaporization of the biodiesel when compared with the diesel fuel. The cumulative heat release rate for biodiesel was is superior to that of diesel and the trend fell for retarding the injection timings but did not stay below the diesel trend. This result could be attributed to better diffusion phase combustion, as compared with diesel.

Ignition delay: Figure 8 shows the variations of ignition delay for the mutated piston and the common piston with diesel fuel and AOME20 at different injection timings. The values of ID for AOME20 operation at the full load condition were 6.9°, 6.4°, 6.1°, 5.9° and 5.8° CA for the injection timings of 24°, 23°, 22°, 21° and 20° bTDC, respectively but for diesel at 23° bTDC ID was 7.8° CA. It was found that the ignition delay period of AOME20 was significantly lower due to the superior cetane number. For all the test fuels the values of ignition delay of the mutated piston operated with biodiesel were lower than those for the common piston operated with diesel fuel and decreased as load increased. This result was due to superior

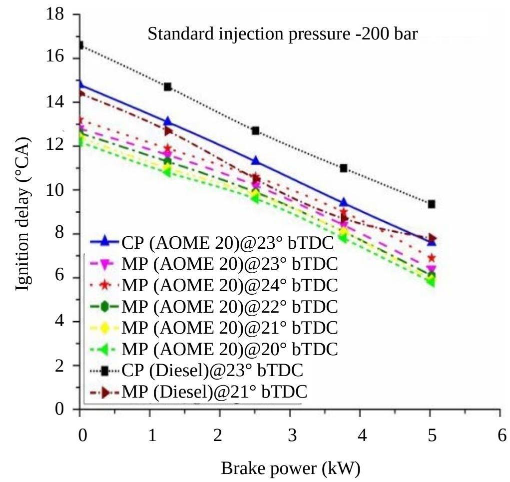


Fig. 8: Ignition delay variation

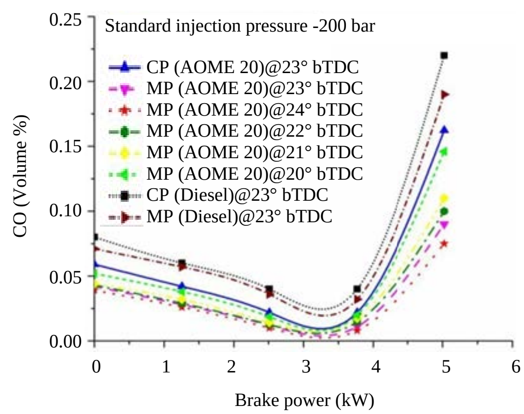


Fig. 9: Carbon monoxide variation

combustion chamber wall temperature at superior loads and due to the presence of oxygen in biodiesel which enhanced the combustion efficiency.

Carbon monoxide emission: The carbon monoxide emission variations with brake power for the Common Piston (CP) and the Mutated Piston (MP) operated engine with AOME20 and diesel fuel at different injection pressures are shown in Fig. 9. When compared with diesel fuel for all ranges of load and injection timing carbon monoxide emissions were lower for AOME20 blend when operated with the mutated piston. This was mainly due to better combustion which would have led to improvement in emission reduction. The CO emissions obtained at full load condition were 0.075, 0.09, 0.1, 0.11 and 0.146% for the injection timings of 24°, 23°, 22°, 21° and 20° bTDC, respectively. This result shows that there is a slight improvement in CO emission. This may be attributed to inadequate premix combustion.

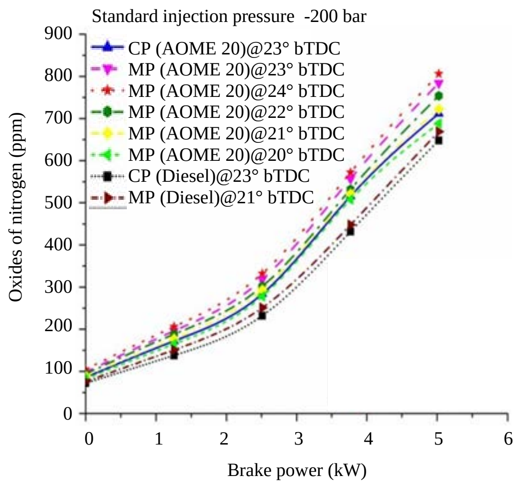


Fig. 10: Oxides of nitrogen variation

Oxides of nitrogen (NOx): The Oxides of Nitrogen (NO_x) emission variations with brake power for the Common Piston (CP) and the Mutated Piston (MP) operated engine with AOME20 and Diesel fuel at different injection timings are shown in Fig. 10. The emissions obtained for full load condition were 806 ppm, 784, 754, 722 and 688 ppm for the injection timings of 24°, 23°, 22°, 21° and 20° bTDC, respectively. The emission of (NO_x) of the test fuel increased with the retarding of the injection timing and it was due to decline in ignition delay for retarding timing. As ignition delay gets shorter, the premix combustion phase turns improper and produces lower cylinder pressure and temperature in an uncontrolled combustion region, compared with diesel, which has a direct impact on NO_x emission. Biodiesel blends produce superior NO_x emission, compared with diesel fuel for all test conditions. The presence of oxygen and the inducement of air fuel mixing over the piston crown enhance the combustion and the cylinder temperature.

Hydro carbon emission: The variations of hydro carbon emission with brake power for the Common Piston (CP) and the Mutated Piston (MP) operated engine with AOME20 and diesel fuel at different injection timings are shown in Fig. 11. When compared with diesel fuel for all ranges of load and injection timings, HC emissions were lower for biodiesel blend. It was observed that mutated piston geometry operated biodiesel blend exhibited better combustion and improvement in emission reduction. This result was obtained due to introducing oxygen in the combustion which is present in AOME20 blend and tends to improve the combustion efficiency. Further, enhancement of air in the fuel was provided by the tangential grooves. The emissions obtained for full load condition were 43.6, 46, 47.3, 48 and 49.8 ppm for the injection timings of 24°, 23°, 22°, 21° and 20° bTDC, respectively. On retarding the injection timing, the hydrocarbon emission increased further due to major drop off in the premix phase of combustion.

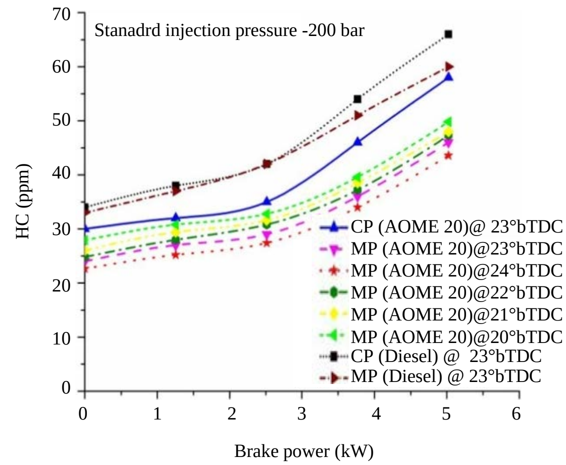


Fig. 11: Hydrocarbon variation

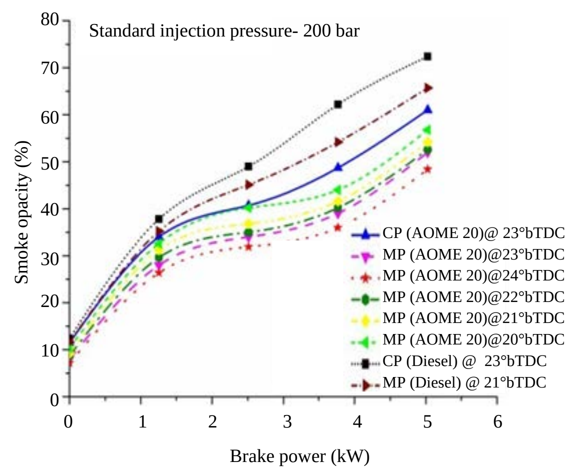


Fig. 12: Smoke opacity variation

Smoke intensity: Figure 12 shows the variations of smoke intensity for the MP and the CP with diesel fuel and AOME20 at different injection timings. Smoke emissions for the blend decreased significantly, for all geometries considered and all ranges of loads of experiments. This result was obtained due to the presence of oxygen in the biodiesel blend which oxidises the cluster of soot particles. It was noticed that for retarding the injection timing from 23° bTDC to 20° bTDC there was significant improvement in the smoke emission. As the timing of fuel gets retarded, pressure and temperature of the air ready for combustion at the end of compression stroke tends to increase and this reduces the ignition delay. Shorter ignition delay of biodiesel tends to increase the diffusion combustion phase rather than premix and hence there is a low temperature in the cylinder leading to improvement in smoke emission.

Carbon dioxide: Figure 13 shows the variations of carbon dioxide emission for the MP and the CP with diesel fuel and

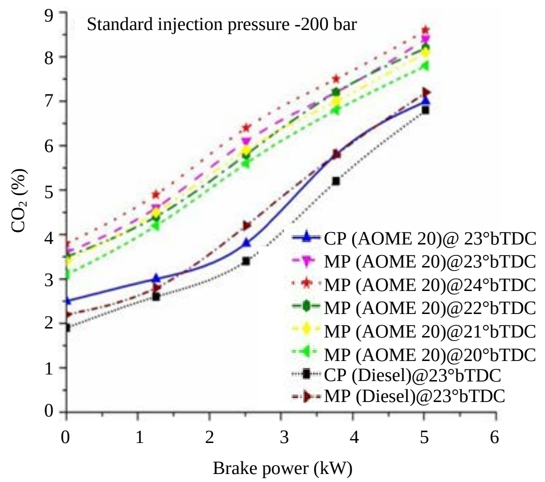


Fig. 13: Carbon dioxide variation

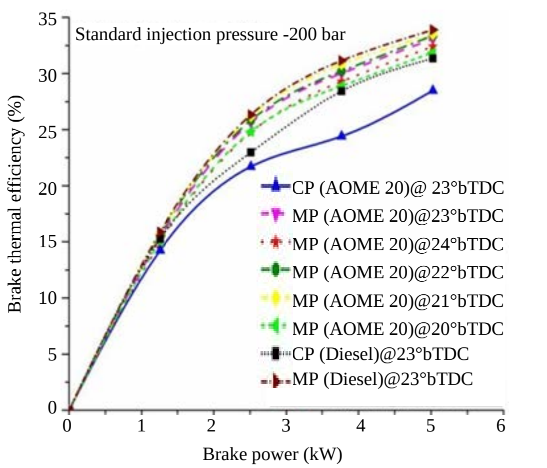


Fig. 14: Brake thermal efficiency variation

AOME20 at different injection timings. Biodiesel blends exhibited superior CO_2 emission when compared with diesel at all injection timings that is, both on retarding and advancing, due to of better atomization and vaporization of the droplets caused by the provision of grooves and the presence of oxygen. As the combustion of the hydrocarbon fuel will produce water vapor and carbon dioxide, it is known as complete combustion. Moreover, retarding the injection timing from 23° bTDC to 20° bTDC caused a significant reduction in the carbon dioxide emission. This result occurred due to step-down combustion in the premix phase.

Brake thermal efficiency: Figure 14 shows the variations of brake thermal efficiency for the MP and the CP with diesel fuel and AOME20 at different injection timings. The test was carried out for four different injection timings other than the standard timing (23°bTDC), namely in retarding

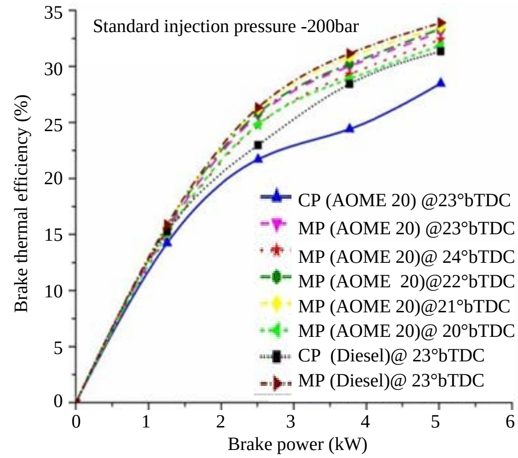


Fig. 15: Brake Specific energy consumption rate variation

(22°-20° bTDC) and in advancing (24°bTDC). It was noted that at full load condition, compared with standard timing (23°bTDC) there was an improvement in performance by 0.81% for 22° bTDC and 1.23% for 21° bTDC. Similarly the performance dropped by 3.69% for 20° bTDC and 1.23% for 24° bTDC. This resulting improvement in performance on retarding was due to shorter ignition delay of the biodiesel. When the timing is retarded close to TDC, the possibility of occurrence of combustion lies close to TDC and this leads to the improvement in performance. On advancing there is a decline in performance and it is due to the occurrence of combustion before TDC and it increases the compression work. The event shows that efficiency of the biodiesel blend operated with mutated piston with 200 bar pressure and injection timing of 21° bTDC gives the maximum brake thermal efficiency of 33.50% which is closer to diesel fuel.

Brake specific energy consumption: Figure 15 shows the variations of brake specific energy consumption for the MP and the CP with diesel fuel and AOME20 at different injection timings. The test was carried out for four different injection timings other than the standard timing (23° bTDC), namely in retarding (22° bTDC to 20° bTDC) and in advancing (24° bTDC). It was noted that at full load condition, compared with standard timing (23° bTDC) there was an improvement in energy consumption by 0.81% for 22° bTDC and 1.21% for 21° bTDC. Similarly, the performance dropped by 3.83% for 20° bTDC and 2.09% for 24° bTDC. For all biodiesel blends operated with mutated piston, the trend lies above diesel fuel due to lower calorific valve of the AOME20.

CONCLUSION

In this study, an experimental investigation was carried out to analyse the collective effect of combustion chamber modification by turbulence induced grooves over the piston crown and injection timing variation on the combustion, emission and performance characteristics of biodiesel blend and the results were compared with diesel. Based on the test results, the following conclusion can be drawn.

Esterified non edible Adelfa oil of 20% blend as a fuel for diesel engine optimum injection timing was found to be 21° bTDC which provided superior engine power output and reduced BSEC (Brake Specific Energy Consumption) for the considered test condition.

HC, CO and smoke intensity were reduced significantly for TIP with AOME20 with retarding injection timing due to presence of oxygen in the blend in improvement fuel air enhancement by turbulence induced grooves. NO_x and CO_2 emissions were increased due to improved combustion rate and combustion chamber temperature.

The ignition delay period of AOME20 was significantly lower as compared to diesel fuel due to the superior cetane number. Hence, the injection timing has been retarded to 21° bTDC close to TDC for superior performance. The cylinder gas pressure of the AOME operated with turbulence induced piston results were merely close to diesel.

The present investigation reveals amended injection timing for AOME20 as a fuel for diesel engine with Turbulence induced piston is 21° bTDC and 200 bar pressure.

ACKNOWLEDGMENT

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NOMENCLATURE

A20	:	Fuel blend of 80% of diesel and 20% of Adelfa biodiesel
BP	:	Brake Power
BSEC	:	Brake Specific Energy Consumption
BSFC	:	Brake Specific Fuel Consumption
BTE	:	Brake Thermal Efficiency
CA	:	Crank Angle
CHR	:	Cumulative Heat Release
CI	:	Compression Ignition
CO	:	Carbon Monoxide
CO_2	:	Carbon Dioxide
DI	:	Direct Injection
HC	:	Hydrocarbon
ID	:	Ignition Delay
MP	:	Mutated Piston
NO_X	:	Oxides of Nitrogen
ppm	:	Parts per million
ROHR	:	Rate of Heat Release
HCC	:	Hemispherical Combustion Chamber
TCC	:	Toroidal Combustion Chamber
TDC	:	Top Dead Centre
TRCC	:	Toroidal Re-entrant Combustion Chamber

REFERENCES

Agarwal, A.K., D.K. Srivastava, A. Dhar, R.K. Maurya and P.C. Shukla *et al*., 2013. Effect of fuel injection timing and pressure on combustion, emissions and performance characteristics of a single cylinder diesel engine. Fuel, 111: 374-383.

Agarwal, D., L. Kumar and A.K. Agarwal, 2008. Performance evaluation of a vegetable oil fuelled compression ignition engine. Renewable Energy, 33: 1147-1156.

Ashraful, A.M., H.H. Masjuki, M.A. Kalam, I.M.R. Fattah, S. Imtenan, S.A. Shahir and H.M. Mobarak, 2014. Production and comparison of fuel properties, engine performance and emission characteristics of biodiesel from various Non-edible vegetable oils: A review. Energy Conver. Manage., 80: 202-228.

Atabani, A.E., A.S. Silitonga, H.C. Ong, T.M.I. Mahlia, H.H. Masjuki, I.A. Badruddin and H. Fayaz, 2013. Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production. Renew. Sustain. Energy Rev., 18: 211-245.

Genzale, C.L., R.D. Reitz and M.P. Musculus, 2008. Effects of piston bowl geometry on mixture development and late-injection low-temperature combustion in a heavy-duty diesel engine. SAE. Intl. J. Eng., 1: 913-937.

Glassman, I., 1996. Combustion. 3rd Edn., Academic Press, San Diego, CA.

Heywood, J.B., 1988. Internal Combustion Engine Fundamentals. McGraw-Hill, New York, USA., ISBN-10: 0-07-028637-X, Pages: 601.

Issariyakul, T. and A.K. Dalai, 2014. Biodiesel from vegetable oils. Renew. Sustain. Energy Rev., 31: 446-471.

Jaichandar, S. and K. Annamalai, 2012. Effects of open combustion chamber geometries on the performance of pongamia biodiesel in a DI diesel engine. Fuel, 98: 272-279.

Jaichandar, S. and K. Annamalai, 2012. Influences of re-entrant combustion chamber geometry on the performance of Pongamia biodiesel in a DI diesel engine. Energy, 44: 633-640.

Jayashankara, B. and V. Ganesan, 2010. Effect of fuel injection timing and intake pressure on the performance of a DI diesel engine a parametric study using CFD. Energy Convers. Manage., 51: 1835-1848.

Kannan, G.R. and R. Anand, 2011. Experimental evaluation of DI diesel engine operating with diestrol at varying injection pressure and injection timing. Fuel Process. Technol., 92: 2252-2263.

Kannan, G.R. and R. Anand, 2012. Effect of injection pressure and injection timing on DI diesel engine fuelled with biodiesel from waste cooking oil. Biomass Bioenergy, 46: 343-352.

Kannan, G.R., 2013. Effect of Injection Pressures and Timings on the Performance Emission and Combustion Characteristics of a Direct Injection Diesel Engine using Biodiesel-Diesel-Ethanol Blend. SAE International, Troy, Michigan,.

Lalvani, J.I.J., M. Parthasarathy, B. Dhinesh and K. Annamalai, 2015. Experimental investigation of combustion, performance and emission characteristics of a modified piston. J. Mech. Sci. Technol., 29: 4519-4525.

Lalvani, J.I.J., M. Parthasarathy, B. Dhinesh and K. Annamalai, 2016. Pooled effect of injection pressure and turbulence inducer piston on performance, combustion and emission characteristics of a DI diesel engine powered with biodiesel blend. Ecotoxicol. Environ. Saf., 134: 336-343.

Lim, J. and K. Min, 2005. The Effects of Spray Angle and Piston Bowl Shape on Diesel Engine Soot Emissions using 3-D CFD Simulation. SAE International, Troy, Michigan,.

Lin, B.F., J.H. Huang and D.Y. Huang, 2009. Experimental study of the effects of vegetable oil methyl ester on DI diesel engine performance characteristics and pollutant emissions. Fuel, 88: 1779-1785.

Mani, M. and G. Nagarajan, 2009. Influence of injection timing on performance, emission and combustion characteristics of a DI diesel engine running on waste plastic oil. Energy, 34: 1617-1623.

Mehta, P.S. and B. Tamma, 1998. Effect of Swirl and Fuel Injection Characteristics on Premixed Phase of Diesel Combustion. SAE International, Troy, Michigan,.

Murugesan, A., C. Umarani, R. Subramanian and N. Nedunchezhian, 2009. Bio-diesel as an alternative fuel for diesel engines-a review. Renewable Sustainable Energy Rev., 13: 653-662.

Rajamani, V.K., S. Schoenfeld and A. Dhongde, 2012. Parametric Analysis of Piston Bowl Geometry and Injection Nozzle Configuration using 3D CFD and DoE. SAE International, Troy, Michigan,.

Rakopoulos, D.C., C.D. Rakopoulos, E.G. Giakoumis, R.G. Papagiannakis and D.C. Kyritsis, 2014. 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, 73: 354-366.

Saito, T., Y. Daisho, N. Uchida and N. Ikeya, 1986. Effects of Combustion Chamber Geometry on Diesel Combustion. SAE International, Troy, Michigan,.

Taylor, C.F., 1985. The Internal-Combustion Engine in Theory and Practice. Vol. 2, MIT Press, Cambridge, Massachusetts, UK., ISBN:0-262-70027-1, Pages: 762.

Xue, J., T.E. Grift and A.C. Hansen, 2011. Effect of biodiesel on engine performances and emissions. Renewable Sustainable Energy Rev., 15: 1098-1116.

Yilmaz, N. and F.M. Vigil, 2014. Potential use of a blend of diesel, biodiesel, alcohols and vegetable oil in compression ignition engines. Fuel, 124: 168-172.