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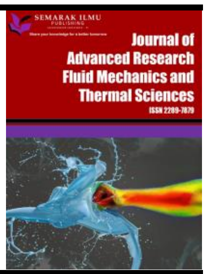

Esterified Papaya Oil and Flamboyant Oil as a Fuel on Single Cylinder Diesel Engine

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ABSTRACT

The future demand, increase in the price and environmental issues of fossil fuels necessitated the search of renewable alternate called biodiesel which reduces the dependence of fossil fuel import from other countries. The present research investigation outlines a detailed vision on the performance parameters and the exhaust characteristics of the methyl esters of papaya oil (POME) and flamboyant oil (FOME) and its blends on water cooled diesel engine comprising single cylinder running at 1500 rpm. The collected seeds are processed and found to contain oil percentage of 37% and 35% and they are esterified in a reactor to enhance its properties. From the result it is concluded that at maximum load, the blend B25 of papaya biodiesel accounted in better brake thermal efficiency than that of diesel with relatively less exhaust emission, such that the specific fuel consumption, brake thermal efficiency, exhaust gas temperature, smoke density, carbon monoxide emission, hydrocarbon emission and nitrous oxide emission are 0.27 kg/kW-hr, 31.46 %, 318°C, 49.02 Hsu, 0.095 %, 55 ppm and 988 ppm respectively.

1. Introduction

A country's national resilience is governed by its energy security. Fossil fuels, that are owned by a limited few nations and are sold at variable values that contribute to climate change, provide the majority of the world's energy. Many countries employ renewable energy to minimize environmental destruction and overcome energy dependence [37]. In the year 2015 the World's Total Primary Energy Consumption was above 150,000,000 Gigawatt-hour (Gwh) and it is said to increase about 57% in the next 40 years [1]. Fossil oils in general are produced from sources such as buried animals belonging to ancient times and from micro-organisms and hence, they are said to be non-renewable sources. It requires millions of years for the formation of fossil fuel [2]. The need for the use of renewable resources has indeed been facilitated by concerns with energy security, increasing energy

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costs, destruction of the environment, and the potential depletion of known fuel reserves. Higher costs of emissions and fossil fuels can have a substantial impact on a nation's economy. Fossil fuels produce useful energy and also harmful emissions. The health of individuals on our planet is being threatened by these harmful emissions. Employing renewable energy is the only reasonable solution, because it can be crucial to reduce these emissions [38]. Though there are several energy sources to replace the fossil fuel, biofuel is said to be highly appropriate to solve the problems associated with energy [3]. Renewable energy would be any energy obtained from natural, typically from the sun, wind, rain, tides, geothermal heat, biodiesel, and other biofuels. There has been a widespread depletion in fossil fuel reserves during the past few decades. Alternately, since there is not a significant amount of fresh fossil fuel formation, the accessible stocks are ultimately limited [39]. Australia has started to consider 5% of biodiesel into diesel, as the blend has similar properties as that of diesel [4]. In recent years the global production of biofuels has been growing rapidly and it is not economically feasible to derive biodiesel from edible oils [5]. In India the production of biodiesel from edible sources is limited that in turn made researchers to focus on extracting biodiesel from non-edible feedstock [6]. The non-edible feed stocks also called as second generation feed stock are said to be the effective substitute for edible feed stock for the production of biodiesel [7]. Because of high cetane number the biodiesels possess better flammability than that of diesel and they can be transported safely due to its high ignition temperature. Study conducted by varying the air temperature ranging 90°C, 100°C, 110°C, 120°C, 130°C, 140°C and 150°C revealed that the NO emission is enhanced with increase in air temperature with decrease in the specific fuel consumption, emission of smoke, CO and HC. It is also found that the efficiency of engine has been increased with increase in air temperature. [32]. The other advantages of biodiesel are its portability, availability, renewability and it emits fewer emissions when compared with diesel and moreover the biodiesels on behalf of its high cetane number make the vehicle to perform better [8]. According to the availability several countries uses different seed oils as feedstock for deriving biodiesel [9].

In recent days the plants bearing waste seed are gaining importance, some of such seeds are cotton seed, rubber seed, stone fruit seed, and papaya [10]. The papaya plants are mainly cultivated for its fruit and their seeds are discarded as waste, as they are not consumed by human or animals [11]. Many research studies have been conducted in deriving biodiesel from non-edible feedstocks, out of which a very least studies have been conducted on papaya seed oil [12]. The higher cetane number of biodiesels derived from papaya oil indicates that it can be used as a substitute to conventional fuel [13]. Energy derived from sources that are derived from continuous or renewable resources is said to as renewable energy. There are many advantages towards using renewable energy sources, such as the fact that they do not really harm the environment, there is no risk of running out, they can produce domestically on a limited scale, they depend less on exterior sources, and there are no demand security risks [40]. The objective of the ongoing study is to evaluate the performance and emission characteristics of diverse biodiesels and their blends, to find a technically proficient, widely available, and cost-effective alternative for conventional diesel fuel, to prepare biodiesel samples using the transesterification process from non-edible oils, to evaluate the biodiesel's physio-chemical properties and to take a gander into the performance, combustion, and exhaust emissions of conventional fuel and the prepared biodiesel samples. It was observed that few research have been conducted on papaya seed oil and flamboyant oil, despite the fact that many researchers have investigated the production of biodiesel from a diversity of feedstocks, with a focus on non-edible oil. Animals or humans need not consume papaya seeds; rather, they are discarded. The proportion of unsaturated fatty acids in papaya seed oil is higher than that of saturated fatty acids. As a result, when employed in engines, the oil won't easily solidify. Delonix regia trees produce a lot of pods containing seeds, but they are really not currently used anywhere. The low saponification value and higher molecular weight of Delonix regia seed oil will make it suitable for use as biodiesel feedstock.

2. Seeds of Papaya and Flamboyant as Feedstock

In the present investigation the plant species papaya and flamboyant were selected as a source of fuel for diesel engine. The annual global production of papaya ranges about 8-10 million tons, out of which nearly 40-44% is produce by India. The papaya seeds are generally discarded as waste after eating the fruit. These plants are about 10 to 30 feet tall and it grows in all types of soil. The fruits borne by this plant have large number of black coloured seeds at its mid portion. The fatty acid composition of papaya seed oil is lauric acid (0.4%), myristic acid (0.4%), palmitic acid (16.2%), stearic acid (5.0%), arachidic acid (0.9%), behenic acid (1.6%), hexadecenoic acid (0.8%), oleic acid (74.3%) and linoleic acid (0.8%) [14]. The unsaturated fatty acid content of papaya seed oil is more than the saturated fatty acid as a result the oil will not solidify when used as fuel in engines [15]. The seeds of papaya are shown in Figure 1.

Fig. 1. Seeds of papaya

Flamboyant belongs to family fabaceae, these trees are mainly found in the tropical regions and in India these trees are noticed mostly at the waste lands, grounds and parks. Soap nut, Hirda, Gulmohar, Hingot, Babool, Cotton, and other nontraditional fruit seeds are some of the feedstocks with high oil content can be used to make biodiesel [16]. In many tropical regions of the world the flamboyant tree is grown as an ornamental tree. In English it gained the royal name as royal Poinciana or flamboyant. The pods containing seeds, produced by this tree at its earlier stage will be green in colour and later it turns brown. Various studies have been conducted in an attempt to reduce the cost of biodiesel by using seed oil such as jatropha, coconut, bitter almond, palm oil, soybean, citrus seed, peanut, Flamboyant, and so on [17]. The flamboyant seeds are shown in Figure 2.

Fig. 2. Seeds of flamboyant

In India, these trees are found abundant especially in waste lands. The pods of this trees is nearly about 8 cm in wide and about 30-50 cm in long and each pod contains nearly about 15-25 small sized brown coloured seeds. The weight of the seeds ranges about 0.30-0.50 gram. The flowers of flamboyant are used in decorative purpose and its seeds in recent days find its application as a source to produce biodiesel. The oil content of these seeds in general ranges between 30-33%. The seeds were crushed and separated into raw oil and oil cake by the expeller, the flamboyant yield the same amount of oil ranging between 30 and 35% [18]. The predominant saturated fatty acid in both extracts was identified as palmitic acid. Smaller amounts of oleic acid and linoleic acid were found [19].

3. Processing of Test Seeds

In general, the papaya seeds discarded as waste are collected from the local fruit shops at free of cost and the flamboyant seeds are gathered from the road sides, play grounds and in the agricultural and waste lands. Both the test seeds are winnowed, washed well with water in order to remove the presence of impurities and dried in the absence of sunlight for 5 days. Table 1 shows the composition of test seeds.

Table 1
Composition of test seeds

Property	Papaya Seed	Flamboyant Seed
Content of oil	31%	27.5%
Content of moisture	6.2%	5.26%
Lipid	28.3	25.02
Protein	25.63	8.75
Ash	8.27	8.4
Carbohydrates	30.51	48.34
Crude Fibers	0.603	8.32

From the dried seeds in its pure form, oil is recovered with the help of oil extracting machine. The seeds of papaya and flamboyant are found to contain 31% and 29% oil in it respectively. The seeds of papaya have 30% oil by dry weight. When compared with the oil content of soyabean (19.63%) and seeds of sunflower (22.23%), the oil content in the seeds of papaya is quite high [20]. As the free fatty acid content of papaya oil is 1.6, therefore no pre-treatment or acid esterification is required [21]. In flamboyant oil, the composition of fatty acid is found less than 2% [22]. The free fatty acid content of the flamboyant oil is 1.9. The findings revealed that the Flamboyant seed oil contains 29.0 percent oil. The acid value of Flamboyant seeds oil, on the other hand, is generally higher. A high acid value indicates the presence of oxidation products in the oil bath, which can result in corrosion and sludge in your system [23]. Table 2 shows chemical properties of oil derived from papaya seed and flamboyant seed.

Table 2
Chemical properties of oil derived from papaya seed and flamboyant seed

Properties	Papaya Seed Oil	Flamboyant Seed Oil	ASTM code	ASTM standard
Acid Value (mg KOH. g^{-1})	0.98	1.683	ASTM D 664	0.50 Maximum
Density (kg/m^3)	921	933	ASTM D 4052	880 Minimum
Kinematic Viscosity (mm^2. S^{-1})	27.3 (40°C)	36.65 (40°C)	ASTM D 445 04e	1.9 – 6.0
Saponification Value (mg KOH. g^{-1})	197	198.23	ASTM D 5558	370 Maximum
Flash Point (°C)	338	372	ASTM D 93	130 Minimum
Cetane Number	36	43	ASTM D4737	47 Minimum

As the rate of oil expelled is based on the type of extraction process and extraction machine involved, the simple, conventional and efficient mechanical extraction method is employed in this work. In general, the yield resulted by mechanical method is comparatively lower than the chemical method, but the purity of yield is comparatively high than the chemical method [11]. To remove the presence of solid debris, the flamboyant oil was filtered with a cartilage filter, and the distilled residual oil was heated at 100°C for 1 hour to remove any water molecules [24].

4. Transesterification

Though there are several techniques such as blending, pyrolysis and emulsification to reduce the viscosity, only the process of transesterification results as the better technique to reduce the viscosity of biodiesel and it also improves the properties of biodiesel [25]. Transesterification also known as alcoholysis is the simplest method employed for producing the methyl esters from plant seed/vegetable oil. The process of transesterification is expressed by the simple Eq. (1). The enzyme catalysis is highly efficient than the acid and alkali catalysis, but the complexity of enzyme structure, high cost limits its use in deriving biodiesel [26].

$$RCOOR' + R''OH \xrightleftharpoons{\text{Catalyst}} RCOOR'' + R'OH \quad (1)$$

A simple batch rector provided with a suitable magnetic stirrer is generally used to carry out the process of transesterification. A study conducted revealed that the highest yield of biodiesel was obtained at methanol/oil molar ratio of 6:1 [27]. The methanol to oil molar ratio is maintained at 6:1 to give better yield. 3% (by weight percentage) of NaOH in the form of powder is used as a catalyst. NaOH dissolves readily in methanol, due to its purity and less cost NaOH is opted instead of KOH and moreover only a little amount is required when compared with KOH [28]. In general, the base catalysts are sensitive to free fatty acid and water content, and moreover they are cheap and fast reacting [29]. The reaction temperature is maintained as 57°C under constant stirring of 400 rpm. Table 3 shows the properties of methyl esters of papaya oil and flamboyant oil.

Table 3
Properties of methyl esters of papaya oil and flamboyant oil

Property	Papaya Oil Methyl Ester	Flamboyant Oil Methyl Ester	ASTM code	ASTM standard
Density	859 kg. mm^{-3}	875 kg. mm^{-3}	ASTM D 4052	880 Minimum
Kinematic viscosity (40°C)	3.53 mm^2 S^{-1}	4.1 mm^2S^{-1}	ASTM D 445 04e	1.9 – 6.0
Flash Point	105°C	117°C	ASTM D 93	130 Minimum
Fire Point	117°C	126°C	ASTM D 92	-
Calorific Value	37119.52 kJ/kg	37992.81 kJ/kg	ASTM D 240 02	-
Specific Gravity	0.896	0.91	ASTM D 287	-
Cetane Number	53	51	ASTM D4737	47 Minimum
Vaporization temperature (°C)	350	343	-	-
Self-ignition temperature (°C)	354	362	-	-

The process of transesterification results in two end products namely the methyl esters of papaya oil and flamboyant oil along with glycerol as byproduct. The glycerol thus formed as byproduct is removed from the methyl esters formed by the method of gravity separation.

5. Purification of Methyl Esters

The presence of water particles and the traces of methanol and catalyst in the resulted methyl esters produced by the transesterification can be removed by the process of washing and drying. In order to remove these traces, the POME and FOME are employed for washing with the aid of water (distilled water), the process is repeated until the water colour remains normal. After the completion of washing process, the resulting POME and FOME is heated slightly above the boiling temperature of water to eliminate presence of water particles.

6. Experimental Setup

In the present work, the experiment is done on a diesel engine comprising single cylinder cooled by water and loaded by electrical dynamometer and equipped suitable with acquisition system for recording performance data, gas analyzer and a smoke meter. The engine is made to run constant at 1500 rpm throughout the test. From no load to full load, the engine load is increased in steps of 20%. Figure 3 shows the photographic view of test engine.

Fig. 3. Experimental setup

The orientation of cylinder in the test engine is vertical and the ratio of compression is maintained constant throughout as 17.5. The bore diameter and the stroke length of the test engine is 87.5 mm and 110 mm respectively. The injection of fuel is achieved by direct injection method and is injected 23^0 before the top dead center and the pressure of fuel at the time of injection is maintained as 220kgf/cm^2. To enable the test biodiesel and its blends in commercial application, the injection timing and injection pressure is unaltered and maintained as standard value.

7. Preparation of Test Fuels

The fuels are being prepared first before conducting the experimental investigation, the fuel samples for the investigation include; conventional fuel (diesel), POMEB25 and FOMEB25 (25% of the respective biodiesel and 75% of conventional fuel), POMEB50 and FOMEB50 (50% of the respective biodiesel and 50% of conventional fuel), the POME75 and FOME75 (75% of the respective biodiesel and 25% of conventional fuel), POME100 and FOME100 (neat biodiesel).

8. Result and Discussion

8.1 Specific Fuel Consumption

The specific fuel consumption indicates the rate of energy stored in the fuel in chemical form. It is quiet common that for any fuel it increases with increase in engine load or else with the proportion of esterified oil in the blend. The increase in specific fuel consumption of test biodiesel and its blends is due to its less calorific value, less ignition temperature and high viscosity. Figure 4 depicts the variation of specific fuel consumption with respect to brake power.

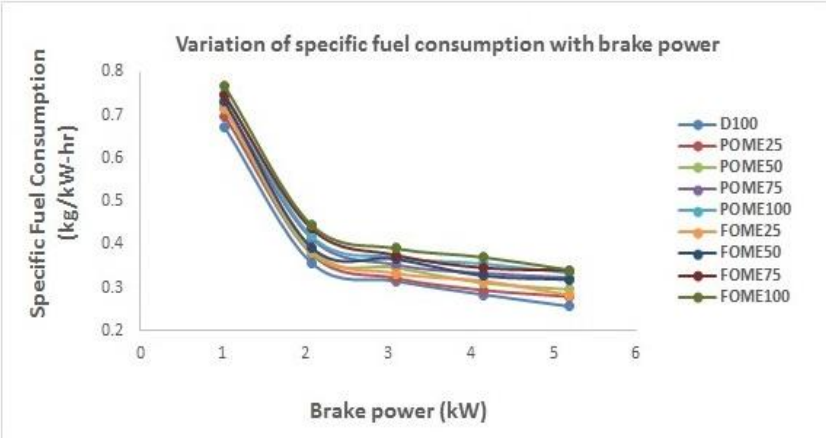

Fig. 4. Specific fuel consumption with respect to brake power

Diesel at all load levels recorded less rate of specific fuel consumption than the test biodiesel and its blends. High ignition temperature and viscosity resulted in high consumption of fuel in the case of biodiesel blends. At maximum load the specific fuel consumption of conventional fuel is 0.25 kg/kW-hr, for POME25, POME50, POME75 and POME100 it is 0.27, 0.29, 0.32 and 0.33 kg/kW-hr and that for FOME25, FOME50, FOME75 and FOME100 it is 0.28, 0.31, 0.34 and 0.35 kg/kW-hr. According to the impacts of different fuel parameters, biodiesel B30 lowers power and effective torque. Biodiesel enhanced brake-specific fuel usage by 5% as compared to diesel. The outcome of using biodiesel B30 fuel enhanced NOx emissions. The CO emissions declined with the use of biodiesel B30 [36].

8.2 Brake Thermal Efficiency

In general, the ratio between the brake powers of an engine to the input of fuel heat is termed as brake thermal efficiency. It is found to increases with increase in load for all the test fuels and to decrease with increase in blending proportion of biodiesel. The investigation on determining the combustion, performance and emission of CSO20, CSO40, SCO60, CSO80 and CSO100. CSO in a diesel engine revealed that the blends CSO20 and CSO40 are found to contain better fuel properties with better performance and combustion with enhancement in NO emission [31]. The variation in brake thermal efficiency with respect to brake power is depicted in Figure 5.

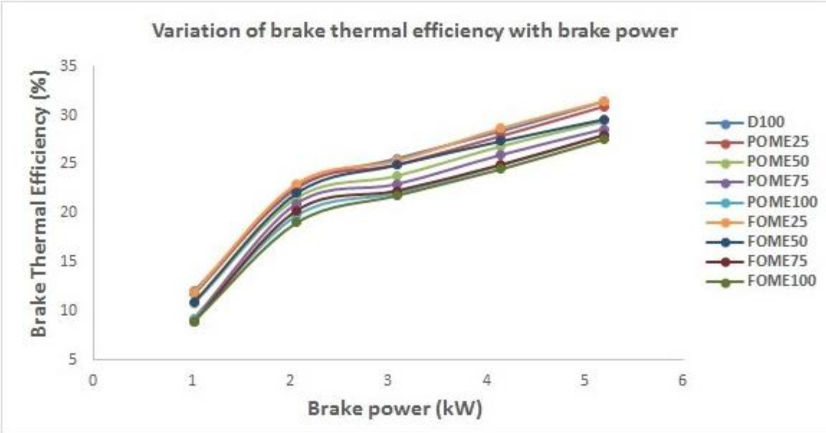

Fig. 5. Brake thermal efficiency with respect to brake power

Diesel at all load level revealed better rate of brake thermal efficiency and the neat test methyl esters recorded relatively less brake thermal efficiency than the other test fuels. Diesel due to its relatively less viscosity, high calorific value and less ignition temperature resulted in better atomization and brake thermal efficiency. The lower biodiesel blends of flamboyant oil had no discernible negative effect on engine performance [30]. At full load condition, the brake thermal efficiency of conventional fuel is 31.44%, for POME25, POME50, POME75 and POME100 it is 31.46, 29.39, 28.61 and 27.97%. Similarly, for FOME25, FOME50, FOME75 and FOME100 it is 30.93, 29.59, 28.01 and 27.56%.

8.3 Emission of Carbon Monoxide

During the process of combustion, the presence of excess air and the poor rate of combustion lead to formation of carbon monoxide. It is found that the rate of emission is directly proportion to the load applied to the test engine and the emission rate is declined with increase in the proportion of esterified test oil. This is due to the increase in concentration of oxygen present in the biodiesel, which results in the formation of carbon dioxide due to better oxidation. The variation in carbon monoxide emission with respect to brake power is depicted in Figure 6.

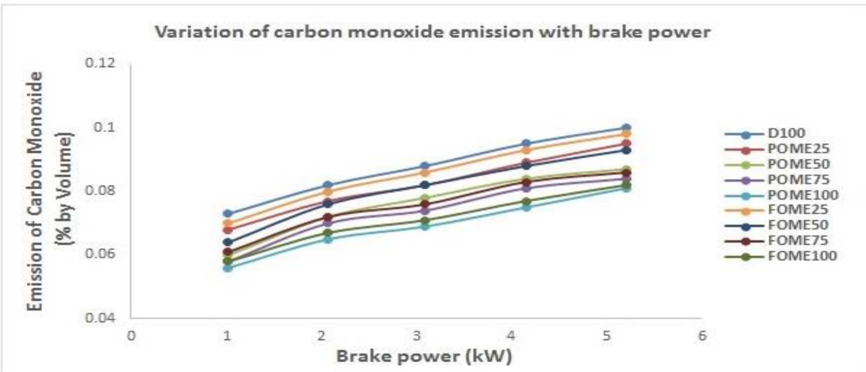

Fig. 6. Carbon monoxide emissions with respect to brake power

At maximum load the conventional fuel recorded maximum exhaust and it is 0.1% (by volume). At all load levels the conventional fuel resulted in high rate of carbon monoxide emission when compared with the test biodiesel and its blends. At maximum applied load, the carbon monoxide emission of conventional fuel is 0.12%, for POME25, POME50, POME75 and POME100 it is 0.095, 0.087, 0.084 and 0.081% and that for FOME25, FOME50, FOME75 and FOME100 it is 0.098, 0.093, 0.086 and 0.082%. As the rate of CO emission is decreased due to enhancement in oxidation and hence the rate of carbon dioxide emission is enhanced. The emission of CO_2 at maximum load for standard fuel is 5.2% (by volume), for the esterified blends of papaya oil is 6, 6.9, 7 and 7.3% (by volume) and that for the esterified blends of flamboyant oil is 5.6, 6.4, 6.8 and 6.9% (by volume).

8.4 Emission of Hydrocarbon

During the combustion of fuel, the presence of gaseous hydrocarbons at the cylinder wall and cervices lead to the formation of hydrocarbon. The rate of hydrocarbon emission is found to increase with increase in load and it is also found to decrease with increase in the proportion of biodiesel in the test fuel. The blends of the methyl esters of papaya oil due to its reduced viscosity and the presence of excess oxygen molecules resulted in less exhaust than that of the other test fuels. The variation in hydrocarbon emission with respect to brake power is depicted in Figure 7.

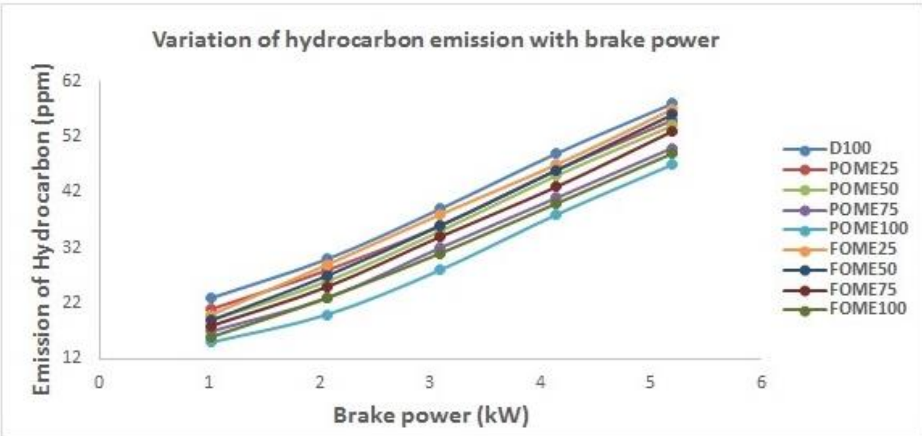

Fig. 7. Hydrocarbon emissions with respect to brake power

At maximum load, the hydrocarbon emission of diesel is 58 ppm, for POME25, POME50, POME75 and POME100 it is 55, 54, 50 and 47 ppm and that for FOME25, FOME50, FOME75 and FOME100 it is 57, 56, 53 and 49 ppm.

8.5 Emission of Nitrous Oxide

The formation of nitrous oxide emission during the process of fuel combustion is due to the temperature of gas developed inside the cylinder and the presence of oxygen inside the cylinder. The emission of nitrous oxide is found to increases with the load applied to the engine. The investigation on the operation of HCCI engine at various charge temperature 80°C, 90°C, 100°C, 110°C and 120°C from no load to maximum load revealed that the rate of No emission is increased with increase in charge temperature. The charge of 100°C, resulted in reduced smoke emission and is 23 HSU, while the emissions of CO and HC were reduced with enhancement in charge temperature [34]. The variation in nitrous oxide emission with respect to brake power is depicted in Figure 8.

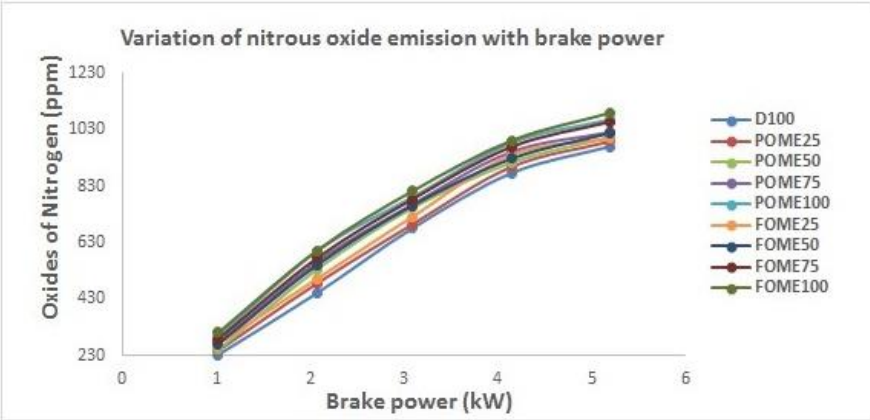

Fig. 8. Nitrous oxide emissions with respect to brake power

In case of esterified papaya oil and its blends, due to adequate presence of oxygen the rate of emission is found to enhance with increase in proportion of blending at all load level. The presence of nitrogen in relatively high proportion in the air drawn, and the presence of oxygen molecules in the test biodiesel and its blends and their operation in high inline temperature has enhanced the emission of nitrous oxide. The investigation to determine the performance and emission of mango seed methyl ester under standard condition and EGR with three different percentages 15%, 30% and 45% revealed that the BTE is high with reduction in specific fuel consumption at 15% EGR than the other percentages. It is also observed that the HCCI engine resulted in less emission of NO [35]. The exhaust rate of conventional fuel is found lower than the other fuels and at maximum load it is 970 ppm. At the same load, the nitrous oxide emission of POME25, POME50, POME75 and POME100 is 988, 1003, 1021 and 1066 ppm and for FOME25, FOME50, FOME75 and FOME100 it is 998, 1018, 1058 and 1089 ppm.

8.6 Heat Release

From the result it is concluded that the negative heat release occurs by fuel gathering during the period of ignition delay. This period is nothing but the period between the start of fuel injection and the start of fuel combustion. Study conducted to analyse the combustion and knocking and on the impact of homogeneous charge and heat release rate revealed that the property of fuel, temperature of drawn air, EGR and variation in compression ratio has strong impact on the above said parameters. It is also found that HCCI engine resulted in less NO and particulate emission with enhanced emission of UHC and CO [33]. Figure 9 depicts the rate of heat release variation with respect to the crank angle.

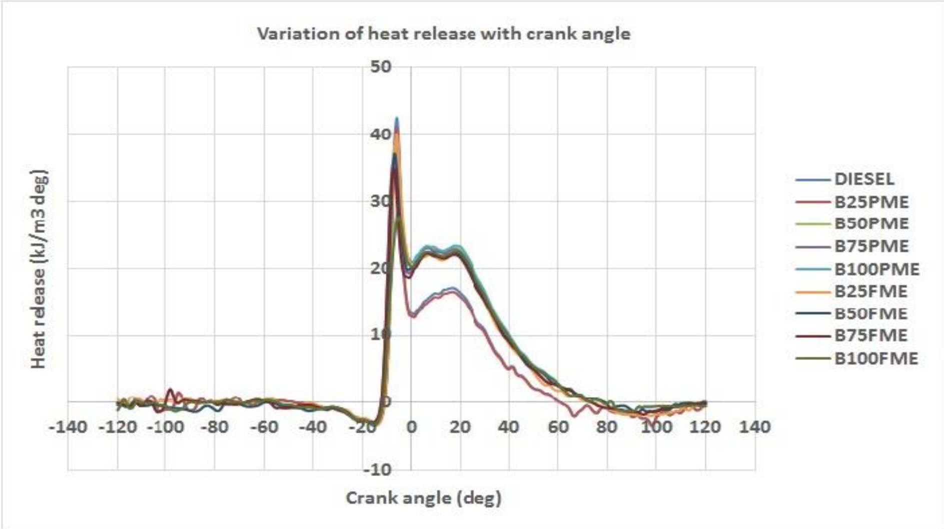

Fig. 9. Rate of heat release rate with respect to crank angle

The rate of heat release is high for conventional fuel at maximum load and it is 42.53 kJ/m^3 deg. The rate of heat release of POME25 is 41.06 kJ/m^3 deg, which is closer to the value of diesel. The enhancement in the mixing of air and fuel leads to delay in ignition for the POME25. The shorter ignition delay period because of high cetane number and viscosity of other test fuels except conventional fuel and B25 of esterified papaya oil resulted in less value of heat release. At maximum load the rate of heat release for standard fuel is 42.53 kJ/m^{3}deg, for POME25, POME50, POME75 and POME100 it is 28.72, 36.07, 38.41 and 41.06 kJ/m^{3}deg and for FOME25, FOME50, FOME75 and FOME100 it is 27.73, 34.82, 37.08 and 39.97 kJ/m^{3}deg.

8.7 Cylinder Pressure

The calorific value of fuel determines the pressure of in-cylinder gas. Due to decline in stoichiometric proportion of air and fuel, the blend B25 of esterified papaya oil resulted in cylinder pressure lower than the conventional fuel. The pressure of the cylinder resulted due to the combustion of test fuels is depicted in Figure 10.

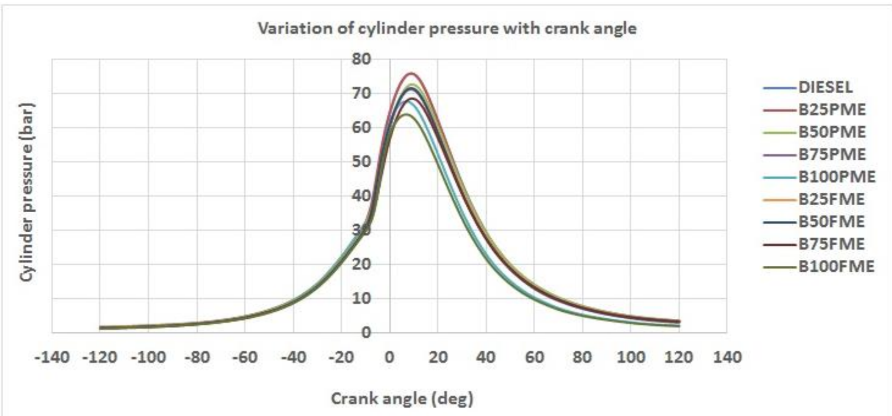

Fig. 10. Cylinder pressure with respect to crank angle

The cylinder pressure for conventional fuel at maximum load is 75.92 bar and that for POME25 it is 75.84 bar. It is also found that the combustion period of other test fuels except conventional fuel and the blend POME25 are quiet longer on behalf of the formation of low volatility compounds by the process of polymerization that takes place at high temperature. During the process of combustion, it is quite difficult to combust the volatility compounds as they are heavy and these difficulties results in the process of slow combustion. At maximum load, the pressure developed in the cylinder for the conventional fuel is 75.92 bar, for POME35, POME50, POME75 and POME100 it is 67.73, 71.23, 72.68 and 75.84 bar and that for FOME25, FOME50, FOME75 and FOME100 it is 63.90, 68.56, 71.55 and 71.62 bar.

9. Conclusion

The results of investigation concluded that POME25 performed better in terms of performance and emission than the other blends except the emission of nitrous oxide. The important conclusions of the present experimental investigation at full load condition are outlined as follows: the specific fuel consumption of conventional fuel, POME25 and FOME25 is 0.25, 0.27 and 0.28 kg/kW-hr. the brake thermal efficiency of the optimum blend (31.46%) is found higher than that of diesel (31.44%). The exhaust gas temperature of the standard and optimum fuel is 321°C and 318°C with smoke emission of 50.62 and 49.02 Hsu. While the emission of carbon monoxide, hydrocarbon and nitrous oxide for the standard fuel is 0.1 (% by volume), 58 ppm and 970 ppm, the similar emissions for POME25 are 0.095, 55 ppm and 988 ppm and that for FOME25 it is 0.098, 57 ppm and 998 ppm.

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