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Exhaust Measurement and Emission Control – Biodiesel Involvement in Diesel Engine

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Original scientific paper

This research focusing the performance and emission characteristics study on the application of biofuel emulsions as alternate fuel used Kirloskar AV1 Direct Injection Diesel engine. Diesel engine performance was compared using different fuels, namely Diesel, Jatropha Methyl Ester and Jatropha Methyl Ester Wood Pyrolysis Oil emulsion, by applying various loads. Emission characteristics were observed and measured by using MRU Exhaust gas analyzer, Optrons 1600 smoke meter. From this experimentation result shows that the biofuel emulsions improved better combustion efficiency with diesel engine performance. It is found that oxides of nitrogen emission of JE15 and smoke darkness of Y2JE10 was reduced 3% and 3.7%, when compared to diesel and other blends respectively. After evaluating the results, these kinds of biofuels are concentrated more and more environment support and safety.

Key words: Air pollutant, Biodiesel production, Exhaust emission, Emission control, Environment impact.

Mjerenje i nadzor ispušnih plinova - utjecaj biodizela na dizelski motor. Ovo istraživanje usmjereno je na ispitivanje performansi i svojstava emisije u primjeni emulzije biogoriva kao alternativnog goriva za Kirloskar AVI dizelski motor s direktnim ubrizgavanjem. Performanse dizelskog motora uspoređene su s drugim gorivima primjenjući različita opterećenja, točnije dizelom, Jatropha Metil Esterom i emulzijom Jatropha Metil Estera s uljem nastalog drvenom pirolizom. Karakteristike emisije praćene su i mjerene korištenjem MRU Exhaust analizatora plina i Optrons 1600 mjerača dima. Eksperiment je pokazao kako emisija biogoriva povećava učinkovitost unutarnjeg izgaranja u odnosu na performanse dizelskog motora. Pokazano je kako su se oksidi dobiveni emisijom JE15 i tamnoća dima Y2JE10 umanjili za 3% i 3.7% u usporedbi s dizelom i drugim derivatima. Uzimajući u obzir rezultate zaključujemo kako su ovakve vrste biogoriva više koncentrirane i sigurnije za okoliš.

Ključne riječi: zagađivači zraka, proizvodnja biodizela, ispušni plinovi, nadzor ispušnih plinova, utjecaj na okoliš.

1 INTRODUCTION

In present scenario air pollutants are very harmful to the nature, affect the entire environment as well as man made things. The global climate change has been recognized as most significant environmental challenges to be faced by research peoples and humanity in the present 21st century. Current world maximum people are concentrating on their research which passed away in the improvement of efficiency in Diesel engines. Those engines discover the different applications like transportation and agricultural fields due to improving thermal efficiency, maximum power to weight ratio, maximum fuel economy and uncomplicated construction techniques. Alternatively, the pollutant specifically the Oxides of Nitrogen (NO_X), Carbon Monoxide (CO), Oxides of Sulphur (SOx) and smoke produced by the experimentation in Direct Injection (DI) Diesel engines put in to the global warming, green house effect, create acid rains and induce the human respiratory system. At present days alternative fuels requirement is more because of diminution of fossil fuel assets in addition to the emission problems. Alternative fuel for diesel engine is bio-oil (Biofuel) [1].

Biofuel is extracted from animal fat, waste cooking oil, vegetable oil, domestic waste. It will act with diesel engines will show results in a considerable reduction of CO_2, CO, soot particles, SOx, polyaromatic hydrocarbons (PAH) and nitrated poly-aromatic hydrocarbons (n-PAH) than fossil fuels but raise in NO_X (oxides of nitrogen) emissions. Biofuels are balanced of mono alkyl esters of fatty acids. These kinds of chemicals have a high heating value as well as density, a low flash point and viscosity similar to diesel. Based on that, the special advantages are excellent biodegradability, lubricity, low toxicity & superior combustion efficiency [2]. By all means, it has definite demerits extremely as poor in oxidation stability, cold flow properties and increasing NO_X formation when it is used as a fuel in diesel engine. In India, minimum amount of feedstock is available for making biofuel as on date. So that biodiesel is the only possible source for biofuel. Biodiesels are derived from the variety of methodologies.

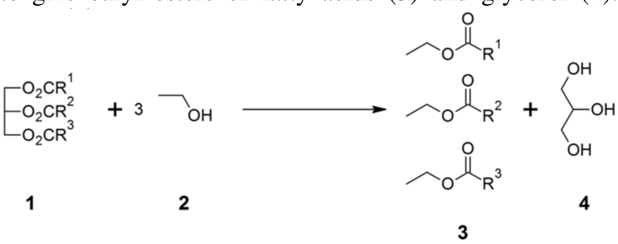
Basically Wood pyrolisis oil is a free flowing dark brown organic fluid escorted by a strong acid and stink. The WPO contains of different size of molecules which are obtained from depolymerization and fragmentation reaction. Three biomass build blocks are their. i.e., first one is hemicelluloses; second one is cellulose and finally lignin [3]. Biofuels has high moisture substance and oxygen content but a reduced instability, high viscosity, corrosiveness, and cold flow properties which boundary their uses as additives in transportation fuel somewhat it is used as transportation fuels themselves [4]. WPO cannot be made to mix directly with diesel due to poor miscibility, various surface tension and their hygroscopic qualities [5]. Main application of this emulsification idea has been found to be the best promising approach; it was used to reduce the creation of diesel engine exhaust emissions and also to improving the fuel consumption [6]. Different kinds of research works were carried to make emulsions with Wood Pyrolysis Oil with sole fuel (Diesel) to defeat problems of miscibility. Diesel engine performance and exhaust emissions when operating with different fuel Methanol-Diesel fuel blends and Ethanol-Diesel fuel blends have been experimentally investigated. This investigation focuses mainly break engine power decreases as the percentage of Ethanol and Methanol increases. This is due to lower energy contents in fuel blends. Conventional diesel fuel has higher brake engine power as compared to diesel blend fuels [7]. Here, in this investigation we are trying to replace the certain amount (%) of biodiesel with WPO, which pick up the financial scenario of biodiesel.

2 METHODOLOGY

The process of making biodiesel is known as transesterification. This method is attained by adding methanol to vegetable oil. The process needs a catalyst to increase the rate of the chemical reaction between the methanol and vegetable oil. The catalyst used in the formation of biodiesel is an alkaline. This can be either Potassium Hydroxide or Sodium Hydroxide. When the transesterification process is complete the catalyst can be recovered completely unaffected by the chemical reaction that it helped accelerate. This is all along with the glycerol separated from the vegetable oil.

2.1 Transesterification

Animal and plant fats and oils are composed of triglycerides, which are esters containing three free fatty acids and the trihydric alcohol, glycerol. In the transesterification process, the alcohol is deprotonated with a base to formulate it a stronger nucleophile. Normally, ethanol or methanol is used. As can be seen, the reaction has no other inputs than the triglyceride and the alcohol. Under usual conditions, this reaction will precede either exceedingly slowly or not at all, so heat, as well as catalysts (acid and/or base) is used to speed the reaction. It is essential to note that the acid or base are not consumed by the transesterification reaction, thus they are not reactants, but catalysts. Common catalysts for transesterification include sodium hydroxide, potassium hydroxide, and sodium methoxide. Approximately all biodiesel is produced from virgin vegetable oils using the base-catalyzed technique as it is the most economical process for treating virgin vegetable oils, requiring only low temperatures and pressures and producing over 98% conversion yield (provided the starting oil is low in moisture and free fatty acids). However, biodiesel produced from other sources or by other methods may require acid catalysis, which is much slower [8]. Since it is the predominant method for commercial-scale production, only the base-catalyzed transesterification process will be described. i.e., Triglycerides (1) are reacted with an alcohol such as ethanol (2) to give ethyl esters of fatty acids (3) and glycerol (4):



R1, R2, R3 : Alkyl group

The alcohol reacts with the fatty acids to form the mono-alkyl ester (biodiesel) and crude glycerol. The reaction between the biolipid (fat or oil) and the alcohol is a reversible reaction so excess alcohol must be added to ensure complete conversion. Figure 1 shows the preparation of biodiesel from base vegetable oil. R^1, R^2, R^3 : Alkyl group The alcohol reacts with the fatty acids to form the mono-alkyl ester (biodiesel) and crude glycerol. The reaction between the biolipid (fat or oil) and the alcohol is a reversible reaction so excess alcohol must be added to ensure complete conversion. Figure 1 shows the preparation of biodiesel from base vegetable oil.

2.2 Preparation and Fuel Properties

Wood Pyrolysis Oil used in this investigation is obtained from vacuum Pyrolysis process of soft pine wood [9]. The soft pine wood obtained from the packing container boxes were collected as feed stock. The Pyrolysis process for deriving Wood Pyrolysis Oil was carried out at 495°C. The products of Pyrolysis in the form of vapour were sent to a condenser (Water Cooled) and the condensed liquid was pulled together in a container.

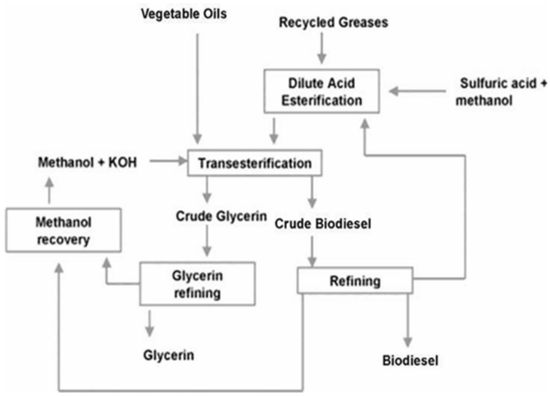


Fig. 1. Preparation of Biodiesel.

2.3 Emulsification of WPO and Diesel

In this research experimentation, four different type of emulsions are prepared, i.e., placed in Table 1.

Table 1. Emulsification of Test Fuel

Emulsions	WPO	JME
Single Surfactant I-1-80 (Span 80)		
JE10	10% volume of WPO	90% Volume of JME
JE15	15% volume of WPO	85% volume of JME
Diverse Surfactant I-2-80 (Span 80 & Tween 80)		
Y2JE10	10% volume of WPO	90% Volume of JME
Y2JE15	15% volume of WPO	85% volume of JME

After getting the mixture, with the support of Mechanical stirrer resultant mixture was stirred around 30 minutes. The blends were produced and observed visually. Emulsification of Wood Pyrolysis Oil and diesel was carried out with a support of homogenizing unit. Energy input for homogenizing can be précised by either shaking or stirring. For the mixture preparation, initially the surfactant was added to the sole fuel (diesel) and then the Pyrolysis oil was added. The resultant mixtures are shaken well to make a steady blend. 3% by volume of surfactant was used to emulsify 10% of Wood Pyrolysis Oil with 90% of diesel fuel. Finally the performance, combustion and emission strategies were studied with the use of resultant emulsion for alternate in Diesel engine. Table 2 shows the properties of Diesel and Teat fuel.

3 EXPERIMENTAL SETUP

Figure 2 shows the pictorial view of the experimental setup. Table 3 gives a specification of the test.

Table 2. Properties of Diesel with Test Fuel

Sl. No	Properties	Diesel	JME	WPO
1.	Cetane number	50	55	27
2.	Specific Gravity at 15°C	0.825	0.880	1.145
3.	Flash Point (°C)	48	117	96
4.	Fire Point (°C)	55	125	107
5.	Calorific Value (kJ/kg)	43.8	38.998	20.575
6.	Kinematic Viscosity at 40°C (cSt)	2.57	4.5	25.5
7.	Moisture content (wt %)	0.025	-	27
8.	Pour Point (°C)	-5.5	-0.95	1.85

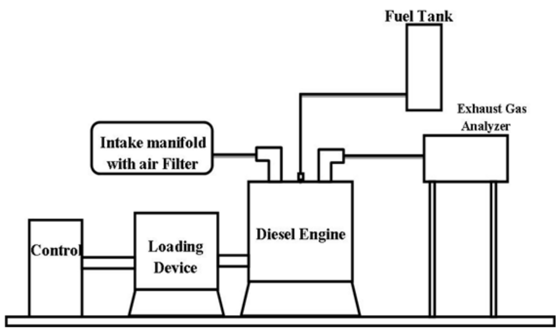


Fig. 2. Experimental Set up.

Table 3. Test Engine Specifications.

Engine	Kirloskar AV1 engine
Type	Single cylinder, vertical, four stroke, water cooled, Diesel engine
Bore	80 mm
Stroke	110 mm
Max power	3.7 kW (5HP)
Speed	1500 rpm
Injection timing	23° bTDC
Injection pressure	215.82 bar
Compression Ratio	16.5 : 1
Cylinder pressure	0–200 bar
Fuel Line Pressure	0–2000 bar
Number of hole in nozzle	3
Fuel flow Measurement	Burette with digital Stop Watch

A dynamometer is coupled with an engine to supply the loading. Control panel is located close to the test en-

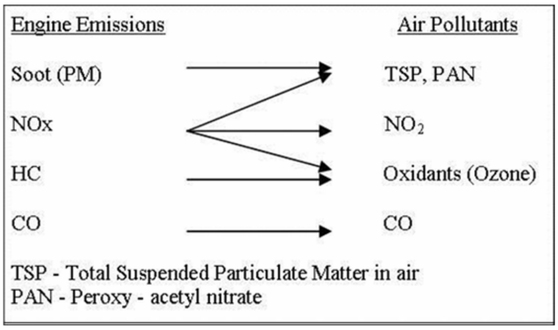


Fig. 3. Linkage of Engine Emission and Air pollutants.

gine which helps to control the alternator to supply the load to the engine by a loading switch. From the exhaust pipe temperature thermocouple is fitted to measure the exhaust gas temperature. Burette and stop watch are used to measure the fuel consumption of the test engine. Initially atmospheric air is passed through the air filter and then to the air box. U tube manometer is fitted in the air box to measure the air intake. Engine speed sensor is located near the engine flywheel to measure the speed. Exhaust Gas Analyser (MRU, DELTA 1600S) is connected at the exhaust pipe to measure the exhaust emissions. i.e., Carbon Monoxide (CO), Oxides of Nitrogen (NO_X), and un-burnt hydro carbons (HC). CO is measured in percentage where as HC & NO_X emissions are measured in ppm.

The smoke darkness of the diesel engine exhaust is measured by the MRU, Optrons 1600 Smoke Meter. At first the test engine is operated with neat Jetropha Methyl Ester (JME) for attaining experimental data. The diesel engine performance and exhaust emission parameters are assessed. Then, the engine was permitted to run with the emulsions made with JE10, JE15, Y2JE10, and Y2JE15. The experimental test is conducted three times repeatedly and the repeatability of the final results is coincided more than 96%. In the end, results are compared with sole fuel (diesel fuel) and Jatropha fuel operations.

4 POLLUTANTS AND ITS CONTROL

Engine emissions undergo chemical reactions in atmosphere known largely as 'photochemical' reactions and give rise to other chemical species which are hazardous to health and environment. Linkage of engine emissions and air pollutants is shown in Figure 3.

The effect of pollutants on human health depends on pollutant concentration in the ambient air and the duration to which the human beings are exposed. Adverse health effects of different pollutants on human health are given in Table 3 for short term and long term exposures. Carbon Monoxide on inhalation is known to combine with hemoglobin at a rate 200 to 240 times faster than oxygen thus reducing oxygen supply to body tissues and results in CO intoxication. Nitrogen oxides get dissolved in mucous forming nitrous and nitric acids causing irritation of nose throat and respiratory tract. Long term exposure causes nitrogen oxides to combine with hemoglobin and destruction of red blood cells. Long term exposure resulting in more than 10% of hemoglobin to combine with nitrogen oxides causes bluish colour of skin, lips and fingers etc.

4.1 Particulate Emission

Soot is a carbonaceous particulate matter and is produced during combustion of the rich fuel – air mixtures. Appearance of black smoke in the exhaust indicates high concentration of soot in the exhaust gases. In this research includes particulate emissions from the diesel engines as these are of major health concern and are more difficult to control. Soot emissions have been associated with respiratory problems and are thought to be carcinogenic in natural history. The soot (particulate matter) size is important as the particles smaller than $2.5\,\mu$ can reach lungs along with breathe in air and cause human health problems. The soot particles smaller than $2.5\,\mu$ constitute more than 90 percent mass of the total particulate matter in the diesel exhaust [10].

5 RESULTS AND DICSUSSIONS

5.1 Performance analysis

The variation of brake thermal efficiency (BTE) with brake power is given in figure 4. In this, thermal efficiency mainly an input as heat content of a fuel is inspired. The desired output is mechanical work, or heat, or probably the both. Variety of results were observed from the experimentation, After the evaluation to plot a graph, in that figure the brake thermal efficiency of the JE10 and JE15 emulsions are 6.5% and 11.5% percentage higher than sole (Diesel) fuel at maximum load.

In case of Y2JE10 emulsion, the efficiency around 5.5% is compared to diesel. Also the Y2JE15 emulsion practiced a fall in the brake thermal efficiency by 11.5%. The increase in brake thermal efficiency of JE10, JE15 and Y2JE10 are the development of the combustion process on report of better oxygen content in the different fuels [11]. In case of Y2JE15 emulsions, thermal efficiency is fall down with minimum calorific values of the fuel blends and poor mixture creation.

Figure 5 shows that the BSFC with brake power. BSFC is the ratio between mass of fuel consumption and brake power. The Break Specific Fuel Consumption of diesel, JME, JE10, JE15, Y2JE10 and Y2JE15 at full load are 0.269, 0.302, 0.315, 0.319, 0.31 and 0.368 kg/kWh respectively. It can be noted the BSFC values of JME and its variant mixtures with Wood Pyrolysis Oil are higher than the

Table 4. Properties of Diesel with Test Fuel

Sl. No	Pollutants	Long Term health Effect	Short Term health Effect
1.	Particulate Matter (Soot)	Several elements specially poly-organic matter are toxic and carcinogenic, contribute to silicosis, brown lung	Improved susceptibility to other pollutants
2.	Oxides of Nitrogen (NOx)	Improvement of cyanosis mainly at lips, toes and fingers, adverse changes in cell structure of lung wall	Soreness, Eye irritation, coughing and chest discomfort
3.	Carbon Monoxide (CO)	Effects on brain and central nervous system, nausea, vomiting, cardiac and pulmonary functional changes, loss of consciousness and death	Headache, shortness of breath, dizziness, impaired judgment, lack of motor coordination
4.	Oxides of Sulfates	Reduced lung function when oxidants are present	Increased asthma attacks
5.	Oxidants	Impaired lung function, increased susceptibility to respiratory function	Difficulty in breathing, chest tightness, eye irritation

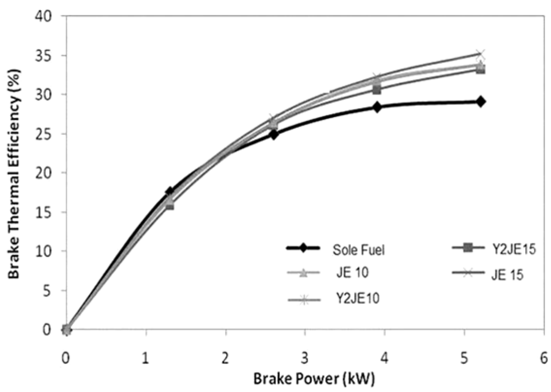


Fig. 4. Brake Power Vs Brake Thermal Efficiency.

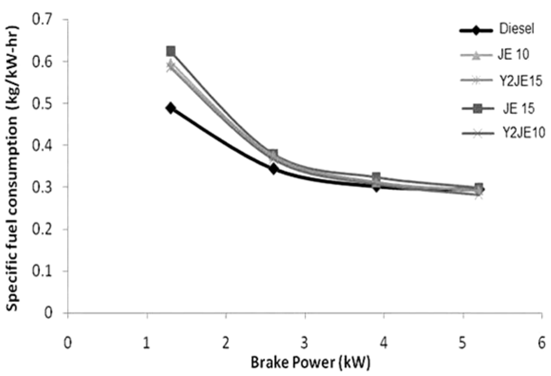


Fig. 5. Brake Power Vs Break Specific fuel Consumption

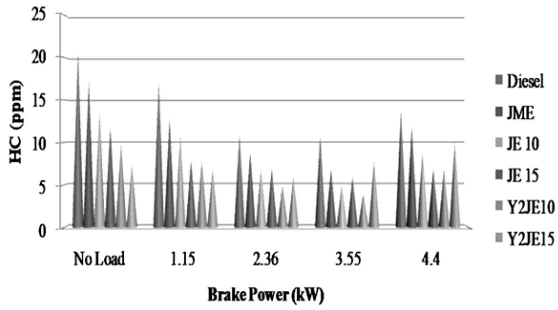


Fig. 6. Brake Power Vs HC Emission.

sole fuel operation. It may be due to the collective effects of lesser heating value and the advanced fuel flow rate it shows high density of the biofuel and its emulsions with WPO [12].

5.2 Emission parameters

Emission parameters like HC, CO, NO_X and smoke darkness were observed by various brake powers, like idle, 1.15 kW, 2.36 kW, 3.55 kW and $4.4k$ W. After the experimentation the following parameters were discussed.

5.2.1 HC Emissions

Figure 6 shows that the HC emissions of JME are found to be lower than that of sole (diesel) fuel. While, the higher oxygen content of the JME leads to further entire burning than diesel fuel.

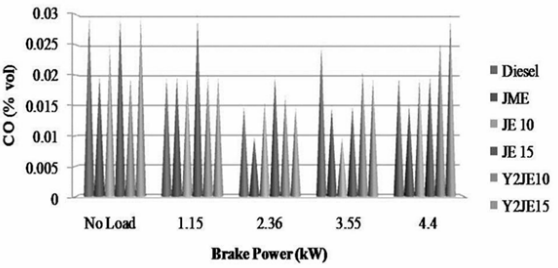


Fig. 7. Brake Power Vs CO Emissions.

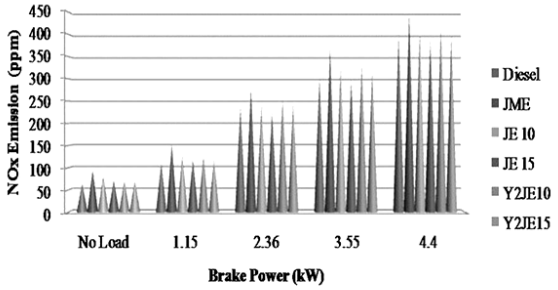


Fig. 8. Brake Power Vs NO_X Emissions.

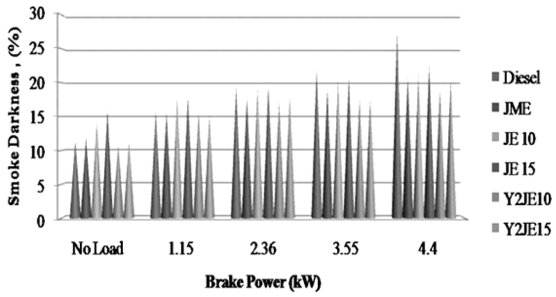


Fig. 9. Brake Power Vs Smoke Darkness.

Biodiesels involvement shows a variety of results, which contains HC emissions, are found to be lower than JME. At final load condition, HC emissions of various blends like JME, JE10, JE15, Y2JE10 and Y2JE15 are lower by 14.5%, 34.6%, 49%, 49% and 27% than diesel fuel. Once comparing JE15 and Y2JE15 mixtures, higher HC emission is observed with Y2JE15 blend at full load. It is attained, higher air fuel ratio and poor mixing of blends with air.

5.2.2 CO Emissions

The following graph shows CO emissions level with brake power is in Figure.7. The oxidation rate of emission like CO is significantly influenced by the burning temperature in the engine cylinder. Higher combustion temperature was accelerated oxidization rate of CO to form CO2 & result shows less CO in the exhaust gases of the diesel engine [13]. This investigation identified the CO emission of bio-fuel (JME) is lower than diesel fuel due to oxygen content availability in fuel, it make the whole combustion is complete.

The variations of CO emissions are identified, at maximum at 24% and 48% in Y2JE10 and Y2JE15 emulsions while compared the diesel, JE10 and JE15 emulsions. The conversion of CO into CO_2 takes place due to the reduction in oxidation time.

5.2.3 NO_X Emissions

Figure.8 shows Brake Power vs NO_X Emission. An oxide of Nitrogen is shaped by chain reactions involving nitrogen and oxygen in the atmospheric air. Generally diesel engines are operating with excess amount of air because it only having fuel injector. NO_X emissions are principally a function of gas temperature. Below figure shows that NO_X emissions of the JME and its blends operation were highly compared to JME-WPO mixture as well as diesel operation.

In the occurrence of oxygen molecule in biodiesel sources an increase in combustion gas temperature resulting increases in NO emissions [14]. The oxides of nitrogen emissions of JME, JE10, Y2JE10 and Y2JE15 are slight higher the rate of 12.6%, 2.2%, 3.1% and 1.6% at full load. Compared to diesel fuel JE15 blend, the NO emissions are lower by 3% NO emissions are lower with totaling of WPO in JME when compared to JME operation. Water content was present in the WPO which may reduce the combustion temperature [15].

5.2.4 Smoke darkness

A Diesel engine, smoke formation is generally occurs in the fuel wealthy zone at high temperature, specifically within the core section of fuel spray. Figure 9 represents brake power vs smoke darkness.

In this present investigation was analyzed and the graph was plotted break power vs smoke darkness. From the above figure the smoke darkness of JME, JE10, JE15, Y2JE10 and Y2JE15 are lower by 21%, 21.6%, 23%, 19.3% and 20.5% correspondingly than diesel fuel at full load condition. The smoke emission is reduced because of the presence of O_2 in JME and JME-WPO emulsion. The Y2JE10 and Y2JE15 experience more reduction in smoke density than JE10 and JE15.

5.2.5 Health Environment

Diesel engine exhaust is a complex mixture of variety of gases and fine particles (commonly known as soot) that contains toxic air contaminants. This kind of contaminant as suspected cancer-causing materials, such as benzene, arsenic and formaldehyde. It's contains some dangerous pollutants, including oxides of sulphur, carbon monoxide and Oxides of Nitrogen. Diesel Risk Reduction Plan, when fully implemented, will result in and around $70-72\%$ reduction in particle emissions from diesel equipment by 2010 (compared to 20th century beginning), and an $80-84\%$ reduction by coming years. This outset shows usage of environment support diesel fuel, available in existing engines with particulate matter filters, and the use in new diesel engines of advanced technologies that produce nearly 85% fewer particle emissions, as well as the use of supporting fuels. Those fuels like natural gas, biofuels and electricity offer alternatives to diesel fuel. All of them produce smaller amount of polluting emissions than current formulations of diesel fuel [16]. As a result of local air-quality regulations, public transit agencies throughout this region are using increasing numbers of passenger buses that operate with substitute fuels or retrofitted equipment.

After the evaluation of this research focus the health effects of diesel engine exhaust specially the (soot) particulate matter components. Severe effects of diesel engine exhaust emission experience irritation of the nose and eyes, changes in lung function, respiratory problems, severe headache and nausea. Constant exposures are connected with cough, lung function decrements and a mixture of saliva and mucus coughed up from the respiratory tract, typically as a result of infection production. This observation supporting the hypothesis that DI diesel engine exhaust is one of the main important factor contributing to the allergy diseases. A large amount of the research on unfavorable effects of diesel engine exhaust, both in vivo and in vitro, has however been conducted in animals. While using biofuels blends are used in diesel engines shows a cleaner environment and it will support to human health.

6 CONCLUSION

Experimentation has been conducted and looks at the performance and emissions of biodiesel mixtures on Kirloskar AV1 DI diesel engine. The results show the following conclusions:

- Brake thermal efficiency is higher than diesel fuel for different blends like JE10, JE15 and Y2JE10 are 6.5%, 11.3% and 5.3%. Brake thermal efficiency was observed 11.6% at Y2JE15. BSFC values of JME and JME-WPO blends are maximum while compare with diesel fuel operation.

- Biofuels were emits low HC emission to the atmospheric environment. Comparison between JE15 and Y2JE15 blends, high HC emission and increasing CO emissions were experienced by Y2JE15 blends at maximum load conditions.

- Oxides of nitrogen emission were low in the rate of 3% at JE15 emulsion compared with diesel fuel with same load. Smoke density values were low in JME and JME-WPO blends than diesel fuel operation in diesel engine. Hence, it is showed that Y2JE10 and Y2JE15 experience more reduction in smoke density than JE10 and JE15.

The use of biofuels as IC engine fuels can play a very important role in helping the developed and developing countries like India to reduce the environmental impact of fossil fuels. Finally, in overall to make the environment is greener we can use bio-diesel.

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