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Performance And Emission Characteristics Of Di Diesel Engine Using Blends Of Biodiesel (Cooking Oil Waste)

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Abstract— *The conventional fossil fuels for internal combustion engines will be available for few years only, due to tremendous increase in the vehicular population. Moreover, these fuels cause serious environmental problems by emitting harmful gases into the atmosphere at higher rates. Commonly pollutants released by engines are CO, Unburnt hydrocarbon, NOx, smoke and particulate matter. At present, alternative fuels like methyl ester of vegetable oil, alcohols etc. are in the line to replace the fossil fuels for IC engines. In the present study and experimental investigation were carried out with waste cooking oil as an alternative fuel in a compression ignition (CI) engine. The problem associated with vegetable oil are high viscosity , lowered volatility and high reactivity, but at the same time their higher cetane no, lower sulphur content , inherent oxygen concentration are the desirable properties to use as fuel in compression ignition engines. The process of transesterification of vegetables oil with methyl alcohol provides a significant reduction in viscosity, thereby enhancing the physical properties of vegetable oil. The present paper show a study carried to investigate the combustion, performance and emission characteristics of waste cooked oil methyl ester with diesel fuel on a single cylinder, four stroke, direct injection and water cooled diesel engine. The results of blends of biodiesel and diesel for different measurements such as BSFC, BSEC, BTE, Mechanical efficiency, EGT, A/F ratios, volumetric efficiency, CO, CO_2, HC, and NOx & smoke opacity are compared with that of pure diesel. Biodiesel can be blended with diesel in any volume percentage. The Properties of waste cooked biodiesel are determined and found that its properties are nearer todiesel fuel.*

Index Terms- Biodiesel, (UCOME) cooking oil Waste , thermalefficiency, emission, CI engine.

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I. INTRODUCTION

Energy is an essential and vital input for economical activity. It is also the lifeline of modern societies. Building a strong base of energy resource is a prerequisite for sustainable economic development. Due to scarcity and increasing costs of conventional fossil fuels, biodiesel as a fuel has become more attractive fuel. Experts suggested that current oil and gas reserves would tend to last only for few decades. To fulfill the rising energy demand and replace reducing oil reserves renewable fuel like biodiesel is within the forefront of other technologies. Biodiesel has proved to be a possible alternative for diesel in compression ignition engine. Biodiesel burns like petroleum diesel as it involves regulated pollutants. Diesel fuel can be replaced by biodiesel made from vegetable oils. Biodiesel is now mainly being produced from soybean, rapeseed, and palm oils. In developed countries, there is a growing trend towards using modern technologies and efficient bio energyconversion using a range of bio fuels, which are becoming cost wise competitive with fossil fuels [1]. India enjoys some special advantages in taking up plantation of tree-borne oil seeds for production of biodiesel due to vast unutilized land. The use of biodiesel results in substantial reduction of un-burnt hydrocarbon, carbon monoxide and particulate matters. It has almost no sulphur, no aromatics and more oxygen content [2], which helps it to burn fully.Its higher cetane number improves the combustion.In India vast research has been done on biodieselfrom different oil. As consumption of edible oil is very high in India, use of edible oil to produce biodiesel is beyond imagination; therefore it is proposed to use non-edible oil for producing biodiesel [3]. Non-edible vegetable oils such as Linseed oil, Mahua oil, Jatropha oil, Simarouba oil, Pongamia oil, etc. are potentially effective diesel substitute. Biodiesel is known as a carbon neutral fuelbecause the carbon present in the exhaust was originally fixed from the atmosphere [4].

It is important for an alternate fuel is to be technically acceptable, and economically feasible, environmentally acceptable and easily available. Among these alternate fuels, biodiesel and its derivatives received much attention in recent years for diesel engines. Biodiesel is an oxygenated fuel that can be obtained from vegetable oils and animal fat by conversion of the triglycerides to esters via transesterificatioin. Biodiesels has similar properties as that of fossil diesel fuel. Therefore, researches on biodiesel derived from vegetable oils and animal fat lead the studies that are aimed to alternate to diesel fuel. It has been reported by many researchers that biodiesel can be used in diesel engines with little or no modification of the engines (5), with comparable performance with that of diesel fuel. Besides it reduces the emissions such as carbon monoxide (CO)and hydrocarbons (HC), and smoke emissions [6, 7]. However, there is an increase in nitrogen oxide (NO_x) emissions [8, 9]. The results vary according to the process of biodiesel production and also with properties of biodiesel. Therefore different biodiesels and their blends were used and tested in diesel engines as well as under different test conditions.

However major disadvantage of biodiesels which include the higher viscosity [10] and flash point cloud point, as well as lower heating value and volatility. For these reasons, it is generally not used in its pure form in the diesel engines. It is usually used as blend with diesel in different percentage volume 10%, 20%, 30%, 40% without modification in existing diesel engine [11]. These biodiesel properties affect on the performance and emissions of the engine. To study this effect, more research isrequired in order to ensure that pure biodiesel can be used in diesel engine without any major hardware modifications.

Diesel engines are used in a wide range of industry such as agriculture, transportation, building and energy production due to their high efficiency. Besides, with the development in electronics technology diesel engines are being more widely used in automobiles. Because of good number of diesel engines are being used in different applications, we are in need of petroleum diesel fuel more than ever. On the other hand it is commonly recognized today that the word petroleum resources are finite, thus it is necessary to find the alternate substitute for petroleum diesel fuel.

Thus many researchers have been carried out to find a suitable alternate fuels to substitute for petroleum based diesel fuel. Researches, on alternate fuels to petroleum based diesel fuels are increased because petroleum fuels are finite and also causing more pollution resulted from their combustion have seriouseffect on environment.

In this study, all the experiments are conducted without any engine hardware modifications. However, standard diesel engine running at constant speed of 1500 rpm with pre set compression ratio of 17.5, and injection timing of 23^0 bTDC and injection pressure of 200 bars is used. The thermal performance and emission characteristics of a diesel engine are investigated by using waste cooking oil biodiesel and diesel blends.

1. Biodiesel can be used in the existing engine without or with minimum modifications.
2. Biodiesel is made entirely from vegetable sources; it does not contain any sulfur, metals or crude oil residues
3. Biodiesels are oxygenated fuel; emissions of carbon monoxide and soot tend to reduce.
4. Unlike fossil fuels, the use of biodiesel does not contribute to global warming as CO_2 emitted is once again absorbed by the plants grown for vegetable oil /biodiesel production. Thus CO_2 is maintained.
5. The occupational safety and health administration classifies biodiesel as a non-flammable liquid.
6. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.
7. Biodiesel is produced from renewable vegetable oils/animal fats and hence improves the fuel or energy security and economic independence.

II. OBJECTIVES

In this paper importance of injection pressure on a performance & other emission characteristics of CI engine are studied. However the objectives are summarized as follow.

- Investigating the properties of the bio-diesel as wellas combinations of bio-diesel with diesel.
- Experimental investigation of the performance on single cylinder four stroke CI engine using UCOME bio-diesel and its blends.
- Smoke and various emissions are measured by the use of smoke meter and AVL gas analyzer.
- Evaluating the optimized performance variables for the maximum efficiency and minimum emissions.

III. BIODIESEL EXTRACTION

Waste cooking oil is selected for producing biodiesel. The biodiesel production method is shown in Fig,1. where 5.5 Grams potassium hydroxide (KOH) and 100ml Methanol (CH_3OH) were used foresterification of 250ml of Waste cooking oil. The catalyst is dissolved in the alcohol then the alcohol catalyst mixture is poured into the Waste cooking oil.The mixture is heated and mixed. Meanwhile the temperature and the mixing speed of the Waste cooking oil, alcohol and catalyst mixture was kept constant (60°C and 1250 rpm) during the esterification. When the transesterification is finished the mixture is taken to a tank to be settled. After the settlement of the biodiesel and the glycerin, the biodiesel washed for 12 hr with pure water to remove alcohol and catalyst residue. When the washing process is completed, it must be waited until biodiesel and water were separated into two different phases. Then the water is drained. To eliminate the water in the biodiesel this remains during washing,

Fig.1. shows solving of catalyst mixture in oil (60^0C

Table.1 shows the biodiesel properties with diesel.

properties	Diesel	UCO biodiesel
Density Kg/m^3	810	913
Viscosity mm^2/sec	2.6	5.4
Calorific value KJ/kg	44100	39800
Flash point in ^{0} C	58	168
Fire point in ^{0} C	67	180

It is to be dried by heating it up to 100^0 C for half an hour. The water in the biodiesel was evaporatedduring the drying process. Table.1 shows thebiodiesel properties.

IV. EXPERIMENTAL SETUP ANDMETHODOLOGY:

A single cylinder, four strokes, direct injection, water cooled computerized diesel engine connected to eddy current dynamometer is used for the present study. The specifications of the engine are given in tabl-1. The setup includes necessary instruments for measurement of cylinder pressure, injection pressure, and crank angle. The test rig also incorporates exhaust gas analyzer, and smoke meter to measure t

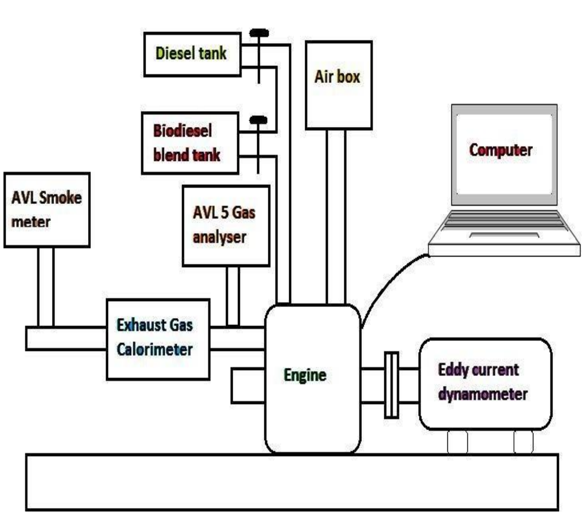

Fig. 2. Line diagram of experimental Setup

Table. 2. Engine specifications

Make	Kirloskar engine
Bore and stroke	87.5 X 110 mm
Type of cooling	Water cooled
Speed	1500 rpm
Compression ratio	17.5 :1
Number of cylinders	1
Rated power	5.2 kW
Injection timing	23^0 bTDC
Injection pressure	200 bar

he exhaust emissions and smoke intensity of the exhaust gases.

The engine is installed with piezo sensor for measurement of pressures. One sensor is placed in the cylinder head to measure the cylinder pressure and other is placed in fuel line near the injector to measure the injection pressure. A continuous water circulation is maintained for cooling the sensors and to maintain the required temperature by using water pump of required capacity. An eddy current dynamometer is connected to measure power output. AVL-444 gas analyzer is used to measure the exhaust emissions and AVL-437 smoke meter is used to measure the smoke density.

Experiments are conducted with Jatropha biodiesel and diesel blends having 10%, 20%, 30%, 40%, 60% and 80% (B10 – B80) on volume basis at different loads. Tests of engine performance on pure diesel are also conducted as a basis of comparison. The load and percentage of blends are varied and engine performance measurements such as fuel Consumption, air flow rate, exhaust gas temperature, and emissions are measured to investigate the behavior of diesel engine. Each time the engine is runfor few minutes before the measurements are taken. The experiments are repeated twice and the average value is taken for performance and emission measurements.

V. RESULTS AND DISCUSSIONS

The performance of CI DI engine using the bio-dieselnamely UCOME bio-diesel with diesel blends & pure diesel are studied at different loads & at different injection pressure. The performance & emissions of different blends & for pure diesel isworks on different loads & compared the results of various blends of bio-diesel & diesel with pure diesel fuel.

1. a. Performance characteristics:

1.1.1 BSFC for UCOME blends:

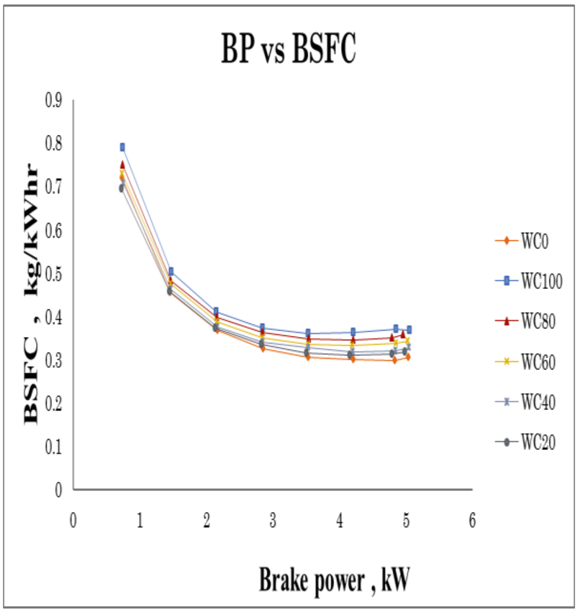

Fig 1.1.1 variation of BP on BSFC for diesel and UCOME blend at 220bar injection pressure.

The variation of BSFC with change in BP at 220 bar injection pressure is presented in fig.1.1.1. It is seen from fig. that as power output of the engine increases the BSFC decreases. BSFC of all the bio- diesel (UCOME) and diesel blends are higher compared to that of pure diesel fuel. The high BSFC of bio-diesel (UCOME) and diesel blends may be due lesser heating value of bio-diesel fuel. It can be seen from fig. that the BSFC of pure diesel fuel isthe least and that of pure bio-diesel (UCOME) isthe highest and for other blends of bio-diesel and diesel are in between the pure diesel and pure bio- diesel. The BSFC of UC20 bio-diesel blend is close to that of pure diesel. and for all other blends BSFC is higher. Comparing B0, BSFC for UC20, UC40, UC60, UC80 and UC100 blends increases by 3.57%, 5.38%, 9.61%, 13.11% and 17.11%
respectively. This may because of higher viscosity and less calorific value of biodiesel fuels. The high BSFC with the bio-diesel (UCOME) and diesel blends may be because of more fuel is to be supplied to get the same power output as that ofpure diesel fuel.

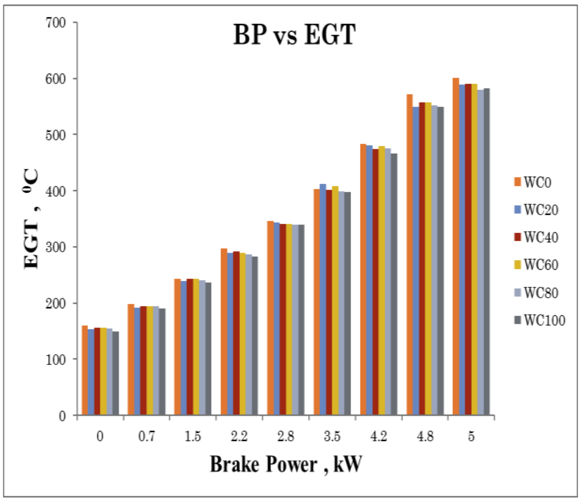

Fig 1.1.3 variation of the EGT with BP for diesel & UCOME blends at 220bar.

Brake Tharmal efficiency for UCOME: The variation of BTE with change in BP at 220 bar injection pressure is presented in fig.1.1.2.

It is seen from fig. that as the BP increases the BTE increases. The BTE of pure diesel fuel is the highest and that of pure bio-diesel (UCOME) is the least. The BTE of other bio-diesel (UCOME) and diesel blends are in between the neat diesel fuel and pure bio-diesel. The less BTE of bio-diesel and diesel may be due the less heating value of bio-diesel

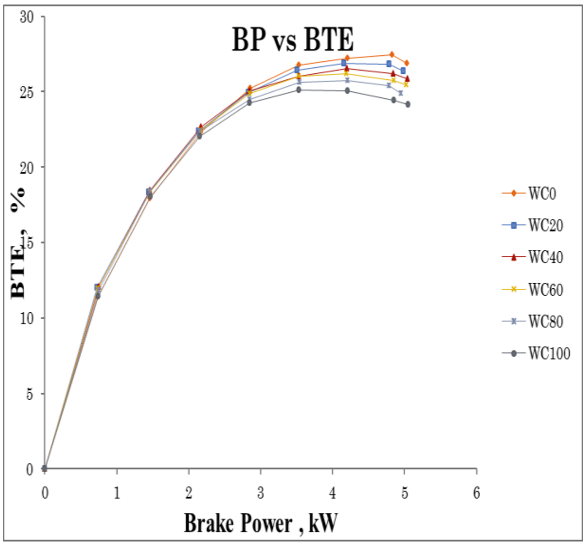

Fig 1.1.2 effect of BP on BTE for diesel and UCOME blend at 220bar injection pressure.

(UCOME) fuel. As the volume % of bio-diesel in the blend increases, there is decrease in BTE of the blends. The BTE is found to be high for dieselwhich is 27.22%. The BTE is found to be less for UCOME. This may because of less energy contentof bio-diesel fuel compared that of diesel and also may be because of the smaller atoms of fuel is formed during the injection because of higherinjection pressure. Because of the smaller atoms of fuel, may not penetrate more into the combustion chamber this may cause incomplete combustion of blends. Amongst all the blends UC20 shows the high BTE that values matches nearly to diesel which is found to be 26.84% at 4.2kw BP. Comparing UC0, the BTE for UC100, UC80, UC60, UC40 and UC20 is reduced by 1.39%, 2.53%, 3.78%, 5.54% and8.04% respectively

EGT for UCOME blends at 220bar:

The variation of EGT with change in BP at 220 bar injection pressure is presented in fig.1.1.3. It can be seen from fig. that the EGT of diesel is the highest compared bio-diesel (UCOME) and diesel blends. The less value of EGT may be due better combustion in case of bio-diesel (UCOME) and diesel blends. The complete combustion may because of thepresence of O2 in the bio-diesel, may help in better combustion of bio-diesel (UCOME) and diesel blends comparing that of pure diesel fuel. This may be also because of the reduced delay period with bio-diesel (UCOME) and diesel blends because of high Cetane number of bio-diesel fuel. Because of thereduced ignition delay in case of bio-diesel and diesel blend the exhaust gas temperature may be lesser for biodiesel and diesel blends compared to that of diesel.

b. Emission Characteristics
CO for blends of UCOME at 220bar:

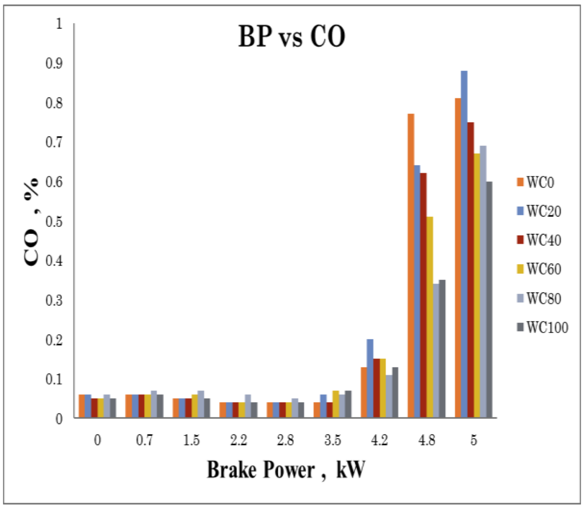

Fig 1.2.1 variation of BP on CO for diesel & UCOME blend at 220bar injection pressure.

The variation of CO with change in BP at 220 bar injection pressure is presented in fig.4.3.b.1. It is seen from fig. that for all the bio-diesel and diesel blends the emission of CO is lower compared to that of pure diesel fuel. For some of the bio-diesel and diesel blends the emission of CO is more than that of pure diesel. This may be because of incomplete combustion of bio-diesel and diesel blends. The incomplete combustion may be because of smaller atoms of fuel formed during the injection of fuel. Thesmaller atoms of fuel droplet may be because of highinjection pressure. The smaller atoms of fuel may not penetrate in to the combustion chamber; this maytake more time for fuel to come in contact with O_2 particles this may delay the combustion and hence CO emissions are high. At higher power output the CO emissions are lesser for all the bio-diesel and diesel blends comparing that of pure diesel. This maybe due the presence of O_2 in the molecular structure of bio-diesel, takes part in combustion. The complete combustion converts CO to carbon dioxide. Amongstall the blends, UC20 have shown highest CO compared to other blends. This may be because of incomplete combustion, at higher loads which resultsin higher CO emissions. It is also seen that the CO emission decreases with increase in % of bio-dieselin the blends. From the graph it is clear that the pure UCOME blend has lowest CO up to 4.2kw because of complete combustion and at higher power CO emission increases because of incomplete combustion.

Nitrogen oxides (NOx) UCOME at 220bar:

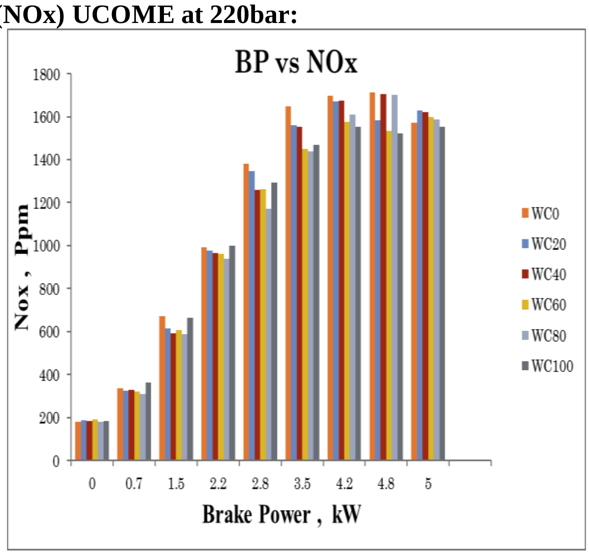

Fig 1.2.2 variation emission of nitrogen oxides (NO_x) for diesel and UCOME blend at 220bar

The variation of emission of oxides of nitrogen at 220 bar injection pressure is presented in fig 1.2.2. Itis seen that emission of oxides of nitrogen is less for the all the bio-diesel and diesel blends compared to the pure diesel at all the loads. The lower emission of NO_x may be due lower combustion temperature of biodiesel and diesel blends. The lesser emission of oxides of nitrogen may be because of the absence of aromatics in the bio-diesel. The aromatics are themain component of fuel that may form the oxides of nitrogen. At less power output the formation of NOx for all the bio-diesel and diesel blends are less compared to that of pure diesel. At 4.2KW the reduction in NO_x compared diesel and for blendsUC20 and UC40 by is increased by 12.41% and 4.32%.

Smoke opacity for UCOME blend at 220bar:
The variation of smoke density with change in BP at 220 bar injection pressure is presented in fig.1.2.3. It is seen from fig. that smoke density is lower at the lower loads.

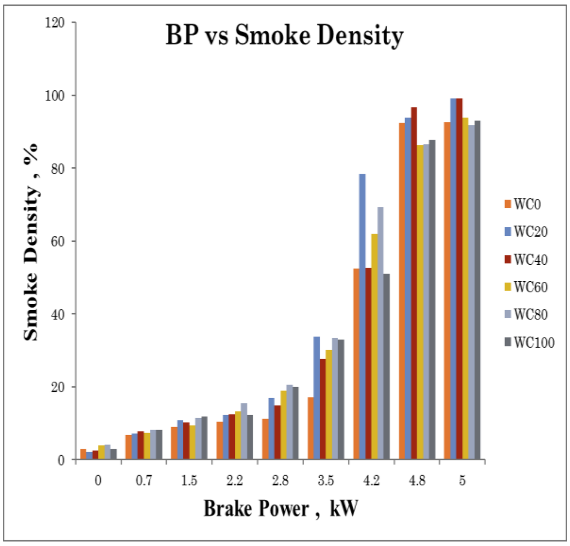

Fig 1.2.3 variation of BP on smoke density for diesel & blend at 220bar injection pressure.

This may be because of the less fuel is supplied to the engine at the lower loads. As the load on the engine increases, the smoke density increases for all the bio-diesel and diesel blends and as well as for pure diesel. The smoke is formed because ofincomplete combustion of fuel supplied duringcombustion. As the load on the engine increases, smoke density for all the bio-diesel and diesel blends increases in comparison with diesel. This may be due the smaller atoms are injected. Smaller atoms of injected fuel may be because of the high injection pressure. Smaller atoms of fuel formed during injection have lesser inertia; because of this the atoms cannot penetrate the combustion chamber. This may take longer time for combustion or even there is an incomplete combustion, because of this there is an increase in smoke density in case of bio- diesel and diesel blends at all the loads. Because of the increase in fuel consumption the smoke density increases. It can been seen that from graph that the smoke density decreases for UCOME as comparing diesel, this is because of better combustion of blendsbecause of the presence of O_2 in the UCOME.

2. Variation of Cylinder pressure with crank angle:

The variation of cylinder pressure with change in crank angle for 220 bar injection pressure is presented in fig.2. It is seen from fig. that the cylinder pressure is maximum for the pure bio-diesel compared to pure diesel. This may be because of the

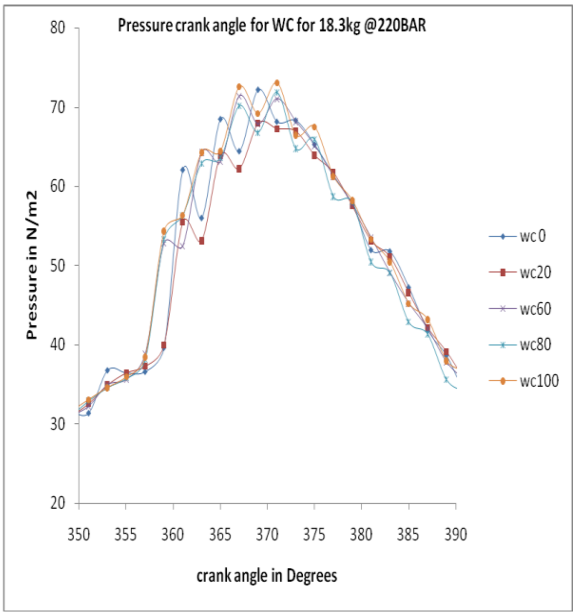

Fig 2 comparison of In-Cylinder pressure at 220bar injection pressure for blends UCOME at rated load.

Complete combustion of bio-diesel fuel. Complete combustion of bio-diesel may be because of inherent O_2 molecules present in bio-diesel fuel. The inherent O_2 molecules will help in better combustion and conversion chemical energy of fuel in to heat energy. This increases the maximum pressure. The ignition delay for the bio-diesel blends is lesser compared to that of pure diesel and blend UC20. The lesserignition delay may be because of the higher Cetane number of bio-diesel fuel compared that of diesel. It is observed that for biodiesel blends the ignition delay decreases. The decrease in ignition delay is increased as the percentage of biodiesel in the blend increases.

It is seen that the peak pressure for UC100 is 73.05 bar and occurs at 11° ATDC. Whereas, for pure diesel peak pressure is 72.2 bar and occurs at 9°ATDC. The shift of peak pressure location from TDC with increase in bio-diesel proportion may be due to slower combustion of the bio-diesel fuel because of their lower volatility and higher viscosity.

VI. CONCLUSIONS

From the experimental investigation and emission measurements for the blends of biodiesel and diesel and for pure diesel the following conclusions are drawn.

- Neat waste cooking oil has higher viscosity and lower volatility makes the oil not suitable for diesel engine.
- The viscosity of oil can be reduced by transesterification process.
- Waste cocking oil biodiesel (UCOME) are having lower heating value compared to that of dieselfuel.
- Flash point and fire point of waste cocking oil biodiesel (UCOME) are higher compared to that of pure biodiesel.
- By transesterification process the wastecocking oil is converted to biodiesel.
- Biodiesel fuel properties are very close to that of diesel fuel.
- The brake specific fuel consumption of biodiesel (UCOME) and diesel blends higher are higher compared to diesel fuel.
- The brake thermal efficiency of waste cocking oil biodiesel (UCOME) is lower compared to that of diesel.
- The emissions of CO, UBHC and NO_x are lower compared to that of diesel fuel.
- As the percentage of biodiesel in the blend increases the reduction in emissions are higher.

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