Performance Analysis of Diesel Engine By Using Renewable Fuel Waste Wood Oil Blends With Diesel

[1]Ashish Barwal, [2]Dr. Anil Kumar Rao
[1]M.tech scholar Rabindranath Tagore University, Bhopal
[2]Assistant Professor Rabindranath Tagore University, Bhopal

* Corresponding Author: Ashish Barwal

Abstract: Cleaner Manufacturing is a proactive environmental initiative and is designed to minimize waste and emissions and maximize product output. Biofuels offer potential benefits in terms of environmental and social sustainability. Next-generation biofuels include biomass-derived bioethanol, algal biofuels, and biohydrogen, commonly referred to as second-, third and fourth-generation biofuels, respectively. The potential for exploitation of all these elements has been well elaborated and accepted. Fuels Waste wood oil (WWCO) obtained by pyrolysis processes has proven to be a substitute for diesel fuel to some extent. However, some disadvantages have been reported, such as higher amounts of carbon monoxide, hydrocarbons, and smoke emissions. This problem can be solved by mixing WWCO with a fuel that contains excess oxygen. Because the excess oxygen contributes to better combustion and results in less exhaust emissions. In this context, WWCO was mixed in variable proportions with Jatropha Biodiesel (JB), which has an oxygen excess of around 10%. WWCO was mixed with JB in varying percentages from 10% to 40% at regular 10% intervals on a volumetric basis. The purpose of this study is to examine the performance and emission characteristics of a DI diesel engine running on this blend and compare it to the base diesel fuel. Engine performance was evaluated in terms of brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, carbon monoxide emissions, hydrocarbon nitrous oxide emissions, and smoke opacity. The test result showed that the engine performance with the JBWWCO10 mixture (ie 90% JB and 10% WWCO) was better than with the other mixtures considered in the study.
Keywords: *Blending; Diesel Engine; Waste Wood Chips Oil; Jatropha biodiesel, Performance; Emission.*

I. INTRODUCTION

Energy is required for different need such as electricity for agriculture, house lighting, transportation, industry etc. Today humankind is in very big trouble which is energy crisis which means we are having less amount of fossil reserve to fulfill the requirements because population is increasing leaps and bound [6]. The accessibility and the nature's jolt of energy provisions will play a critical hand in the advancement of the communities worldwide and the geographical future of the earth. Usually, according to the recent times, humans are in search of instant gratification and these needs are met from petrochemical origins. They do not want to pay attention to the alternative resources that are being cultivated to tackle the 21st century major problem- climate change [7]. Energy at a worldwide level has skyrocketed by 20 fold in the last century, including the hydroelectricity and nuclear fusion, all origins of energy are no more infinite. Due to depletion of these sources, the cost of fossils fuels is flying high and we can see with the sudden natural disasters taking place, the whole environmental equilibrium has shifted from its fulcrum [8].

1.1 Classifications of Energy Sources

The different energy sources can be mainly classified in in two categories i.e. renewable energy sources and non-renewable energy sources. The general classification of different energy sources is given in Figure 1.

1.2 Problem Formulation

The financial and industrial growth of any country depends upon the source of energy. Also, the usage of petroleum fuels increased dramatically due to the rise in automobile vehicle and industrialization. India is a developing country and facing for acute fossil fuel consumption issue. One another prime trouble today is the disposal of waste. Conversion of waste products into useful energy has gained significant attention in the world. Already many research works have been carried out on conversion of waste products such as waste lubrication oil, waste plastics, used tires etc. In this research work fuel derived from waste wood chips (WWC) has been identified a potential fuel which can be used in conventional diesel engine.

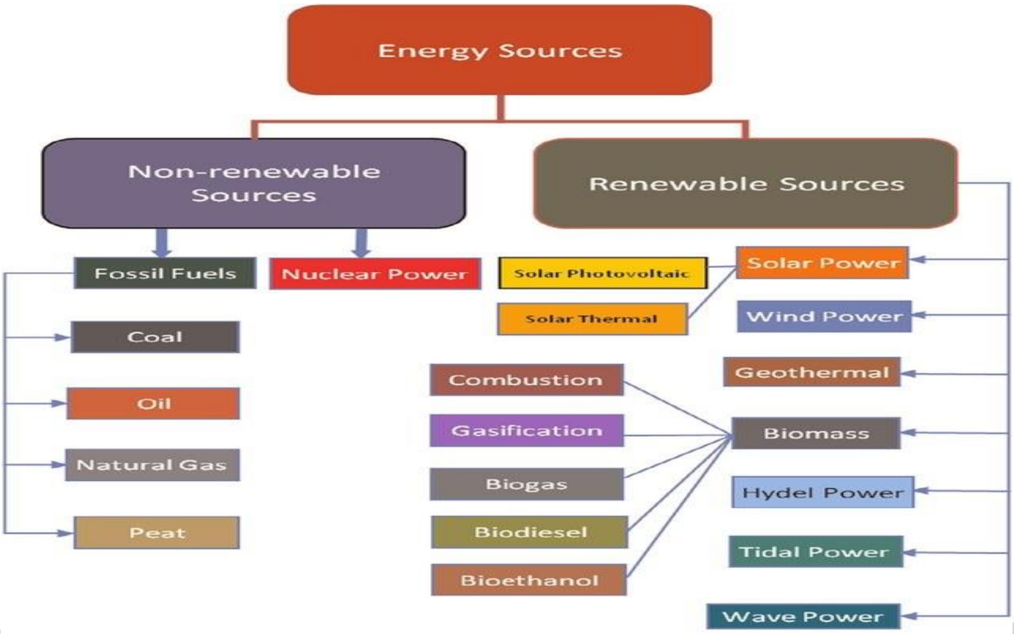

Figure 1. Broad classification of energy resources [6]

II. LITERATURE REVIEW

Due to depletion of fossil fuels, varying cost and environmental consequences of the exhaust gases from conventional engines, the need of alternative fuels has become crucial. Different alternative fuels have the properties similar to fossil fuel and can be used as partial replacement of diesel fuel. In most of the cases the biodiesel was blended with diesel in different proportions and used as diesel engine fuel. In some cases, elementary steps have been taken for the improvement of biodiesel properties. The research work related to utilization of different alternative fuels as diesel engine fuels has been discussed in this section:

Abdul Jabbar, et.al [2022] [1]: - They have discussed about Worsening air quality and pollution lead to numerous environmental health and sustainability issues in the South Asia region. This study analyzes India, Nepal, Bangladesh, Pakistan, Sri Lanka, and Nepal for air quality data trends and sustainability indicators. Methodology: By using a population-based study design, six South Asian countries were analyzed using a step-wise approach.

Suzihaque, et.al [2022] [2]: - Biodiesel is a source of new renewable energies and a substitute fuel with much potential in the future for petroleum-derived diesel. According to BP Statistical Review of World Energy, total global consumption of diesel from petroleum increasing in one decade which is 3.5 million tonnes in 2010 and 3.9 million tonnes in 2019.

Murugesan, **et.al [2022] [3]: -** This paper elaborates on the production of distilled biodiesel of standard EN14214 from waste cooking oil (WCO). Its economic viability is assessed and experimental investigations of a single-cylinder, four-stroke engine using a mixture of distilled biodiesel and diesel of Euro 5 standard are described.

Senthil Kumar M et.al [2001] [28]: - They have discussed about the formation of methyl ester by using Jatropha Oil (JO) by transesterification process. The JO was chemically reacted with an alcohol in presence of a catalyst to produce biodiesel. Further the JB was tested in a diesel engine. They reported brake thermal efficiency (BTE) decreased by about 5.5% compared to that of diesel, while increased by about 8.5% compared to that of Jatropha oil at full load.

Kritana Prueksakorn et.al [2006] [31]: - The research work was carried out in Thailand. The authors proposed JME as a potential substitute for fossil fuel. The also reported that some important issues such that food versus energy, energy consumption and environmental pollution control must be taken care.

Objective of the Present Work

It can be well understood that there is an acute shortage of fossil fuels. The waste accumulation is another issue. The production of oil from waste wood chips (WWC) can be potential substitute of fossil fuels. Only few works have been done in the area of fuel derived from WWC. Therefore, the present study was undertaken with following objectives:

(a) Production and characterization of fuel derived from waste wood chips

(b) To analyze the effect of waste wood chip oil (WWCO)-Biodiesel blend on diesel engine behavior.

III. TEST FUEL PREPARATION

For the present study two fuels, namely Jatropha biodiesel (JB) and waste wood chip oil (WWCO) derived through pyrolysis process are considered as a fuel for partial replacement of diesel. The production process of these two fuels is given in the following sections. The characterization of the test fuels is also provided in this chapter to emphasis their importance for use in a direct injection (DI) diesel engine.

3.3 Transesterification of JCO

In the current study Jatropha curcas oil (JCO) is used as a raw material for biodiesel production. The process of transesterification of JCO is shown in Fig. 2. In the present study JB was produced by the transesterification process which is known as the most usual process of converting oil into biodiesel.

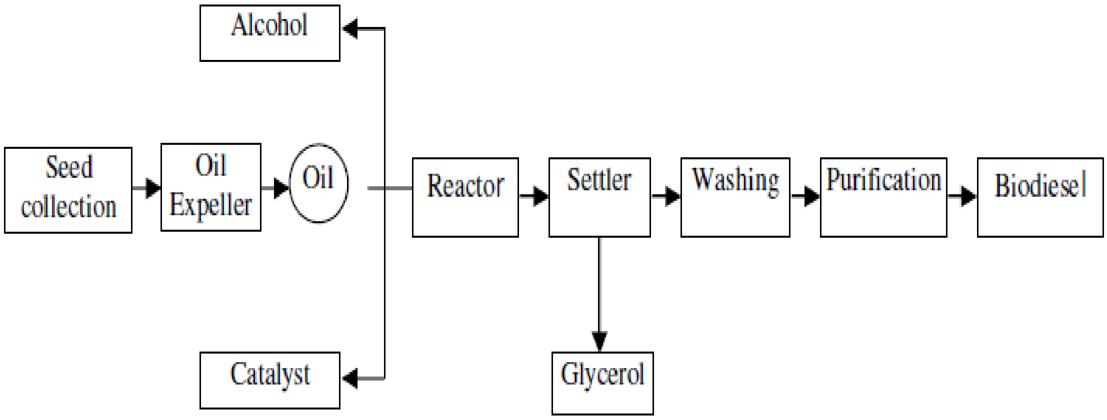

Fig. 2 Process of transesterification [49]

Transesterification process is also known as alcoholysis and this process is used worldwide for reducing the viscosity of vegetable oils [55]. This is a process of displacement of alcohol from an ester by another alcohol. The commonly used alcohols for this process are methanol or ethanol. The general process involved in the transesterification process of JCO is presented in Figure 3.1. The photograph of the JB is shown in Figure 3.

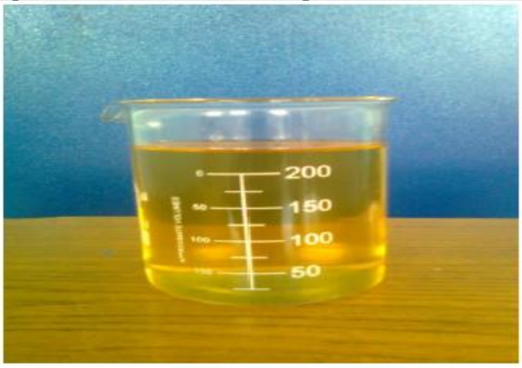

Fig. 3 Photograph of JB

3.4 Production of Fuel Derived through Waste Wood Chips

The waste wood chips were selected as feedstock for the fuel production. The schematic photograph of the pyrolysis set up is shown in Figure 4. The pyrolysis is the process where the feedstocks are heated in the absence of oxygen to convert into fuel [56]. The photograph of the pyrolysis reactor is shown in Figure. 4.

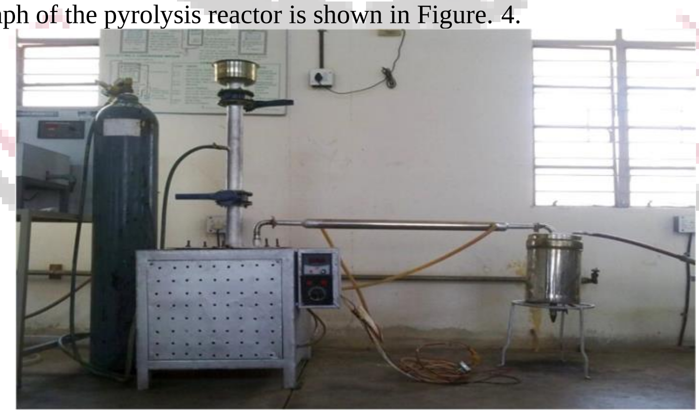

Fig. 4 Pyrolysis Set up

3.5 Preparation of Test Fuel Blend and their Characterization

For preparing the test fuels the JB and WWCO were blended in a regular interval of 10%, 20%, 30% and 40% by volume basis with mineral diesel. The percentage composition of JB, WWCO and diesel in the blends are given in Table 3.2. Table 1 provides the important physico-chemical properties of the test fuels used in this study.

Table 1 Percentage of fuel available in different blends

Test Fuel	Diesel (%)	JB %)	WWCO (%)
Diesel	100	-	-
JB	-	100%	-
JBWWCO10	-	90	10
JBWWCO20	-	80	20
JBWWCO30	-	70	30
JBWWCO40	-	60	40

IV. EXPERIMENTATION

Engine Experimental Setup

The recent research work was carried out on a single cylinder, four stroke, constant speed, air cooled, naturally aspirated, direct injection (DI) diesel engine. The schematic diagram of the test set up is shown in Figure 5. The load on the engine was applied by means of load cell which was coupled with a single phase, 220 V AC alternator. The motor is interfaced with information obtaining framework for the estimation of burning boundaries. It is given important instruments for burning weight and wrench point estimations

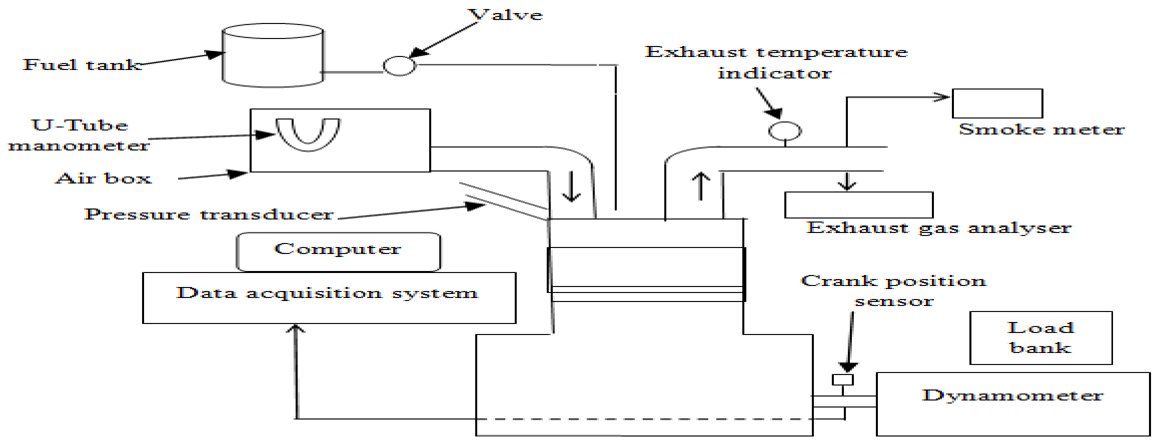

Fig. 5 Schematic representation of the experimental setup

These signs are interfaced to PC through control board. Arrangement is additionally accomplished for computation of wind current, fuel stream, fumes gas temperature estimation and so on The fumes gas temperature is estimated utilizing a K type (Chromel-Aluminum) thermocouple associated with a computerized marker. The Kistler type piezoelectric weight transducer is mounted on the chamber head for the estimation of the chamber pressure. The wrench point position is dictated by utilizing a11 bit 2050 wrench point encoder with top perfectly focused marker.

V. RESULT AND DISCUSSION

The current study focused on the possible usage of fuel obtained from the pyrolysis of waste wood chips i.e. WWCO. Tests were conducted on a computerized diesel engine run on different test fuels i.e. distinctive Jatropha biodiesel (JB)- WWCO mixes, and the outcomes are contrasted and diesel. The WWCO with little volumes (10-40% at customary time frames on a volume premise), was blended in with the JB at 90 to 60% individually. At first the motor was run on diesel and JB to get base perusing. Further, the tests were directed utilizing JBWWCO mixes. The consequences of the presentation and emanation attributes of the motor sudden spike in demand for JBWWCO mixes were examined and related with those of the base readings a similar motor. The assignments of the test fills and their structures utilized in this test are given underneath

Test Fuel	Diesel (%)	JB %)	WWCO (%)
Diesel	100	-	-
JB	-	100%	-
JBWWCO10	-	90	10
JBWWCO20	-	80	20
JBWWCO30	-	70	30
JBWWCO40	-	60	40

5.1 Brake Thermal Efficiency

The variation of brake thermal efficiency (BTE) with respect to brake power for all the test fuels is shown in Fig. 6. The brake thermal efficiency is the ratio of power output or work done by the engine with respect to heat supplied to it [57]. It is also called as fuel conversion efficiency. The thermal efficiency of the engine increases with increase in brake power for all the fuel operations. The engine BTE at full load (brake power of 4.4 kW) for diesel, JB, JBWWCO10, JBWWCO20, JBWWCO30, and JBWWCO40 were 30.6%, 28.4%, 29.1%, 28%, 27.6%, and 26.5% respectively.

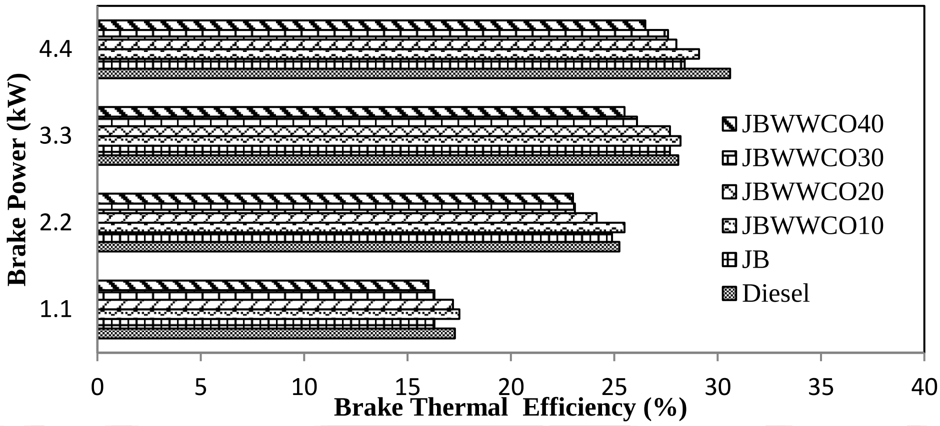

Fig. 6 Variation of brake thermal efficiency for diesel, JB and JB-WWCO blends at full load

5.2 Brake Specific Energy Consumption

The BSFC is the mass of fuel consumed per unit power output in a diesel engine. It is correlated with viscosity, CV, CN, heating content and specific gravity [60]. Figure 7 shows the When all is said in done, the BSEC estimations of the bio-diesel fills and their mixes are somewhat higher than that of diesel for all the BP and are expanded with increment in mix rate [61]. The BSEC of diesel motor relies upon the connection among the fuel thickness, the consistency, the volumetric fuel infusion framework.

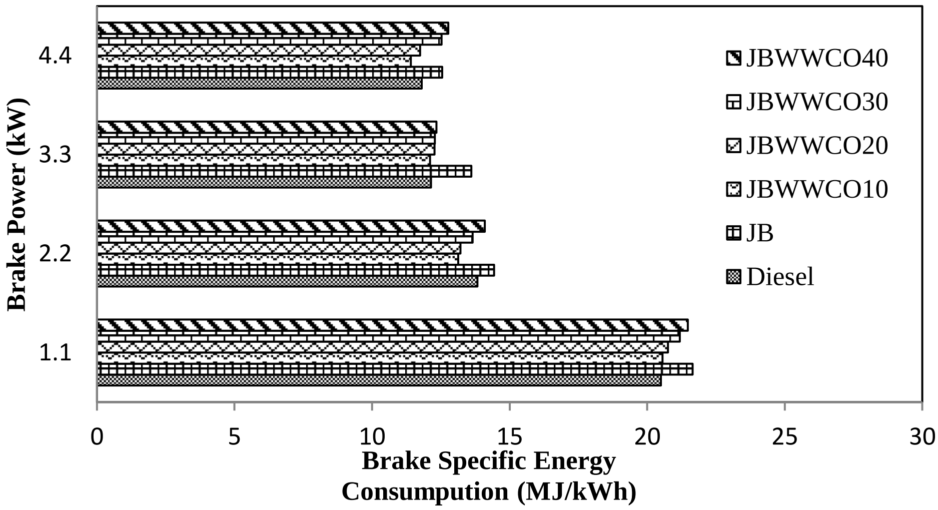

Fig. 7 Variation of brake specific energy consumption for diesel, JB and JB-WWCO blends at full load

5.3 Exhaust Gas Temperature

Figure 8 shows the deviation of fumes gas temperature (EGT) concerning brake power for various fills utilized in this test. The EGT increments with increment in brake power for all the test fills. The investigation of EGT is significant as it portrays about those warmth which are not used for delivering power [62]. The most elevated EGT esteem concerning all the forces was recorded for the mix which has higher level of WWCO. This outcome is relied upon because of present of dampness content in WWCO. Yet, up to 20% WWCO in mix, the estimation of EGT of JBWWCO20 mix is near diesel perusing.

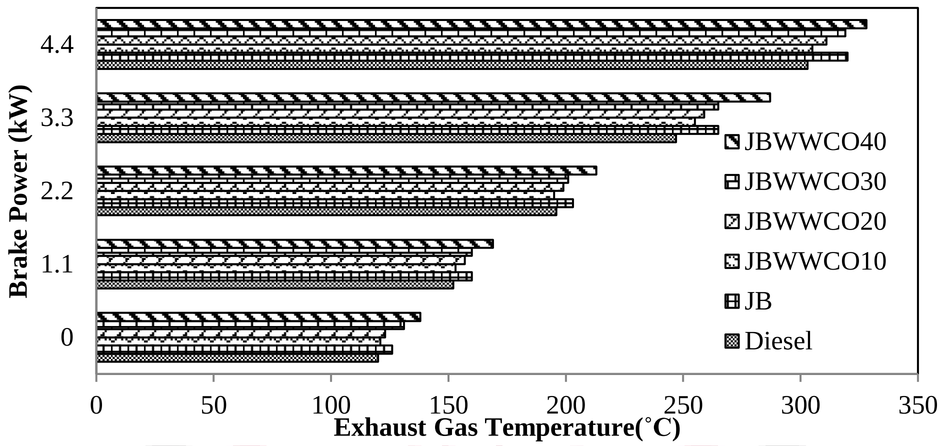

Fig. 8 Variation of exhaust gas temperature for diesel, JB and JB-WWCO blends at full load

5.4 Carbon Monoxide Emission

Carbon monoxide (CO) is exceptionally harmful, vapid, scentless and bland gas. Complete ignition of fuel within the sight of adequate oxygen will give carbon dioxide (CO2) and water as items. Development of CO additionally implies a misfortune in synthetic energy [63]. The causes which lead to the development of CO in CI motor cycle are fuel thickness, thickness and burning productivity.

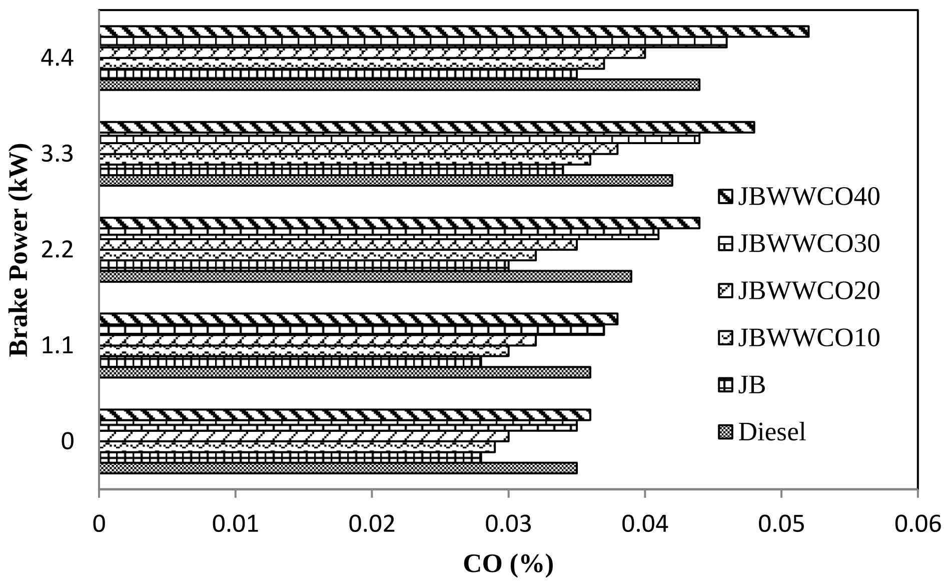

Fig. 9 Variation of CO emission for diesel, JB and JB-WWCO blends at full load

5.5 Hydrocarbon Emission

Hydrocarbon (HC) discharge in motor fumes shows the deficient ignition of any hydrocarbon fuel. Different sources which add to the arrangement of HC discharges are: combinations in hole about 38%, oil stores and oil layers about 16%, fire extinguishing about 5%, fluid fuel impacts inside the chamber about 20% and spillage in exhaust valve about somewhat less than 7% [64-65]. Subsequently, it very well may be inferred that HC outflows development in a motor relies on motor setup, living arrangement time, oxygen accessibility and the structure of fuel. Figure 10 shows variety of HC outflows of different fuel mixes tried at speed scope of 1500 rpm to and from no heap to full load condition.

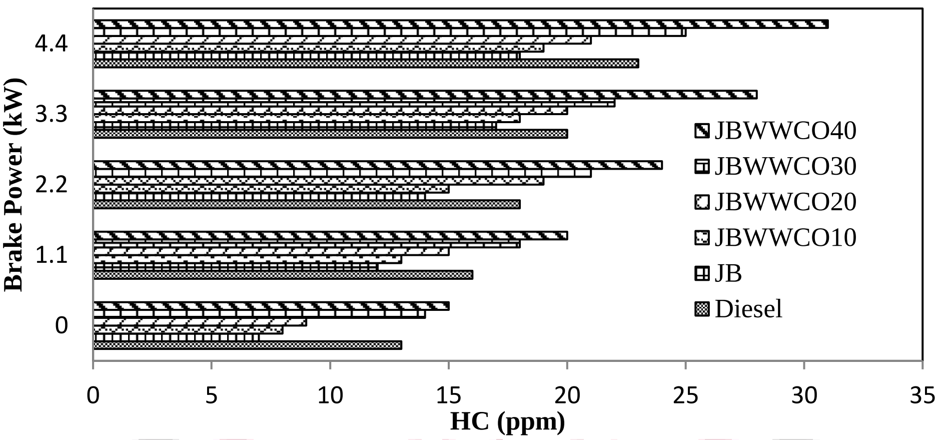

Fig. 10 Variation of HC emission for diesel, JB and JB-WWCO blends at full load

5.6 Nitric Oxide Emission

The theory of NO_x formation is described by Zeldovich mechanism which consists following set of equations:

$$O + N_2 = NO + N$$
$$N + O_2 = NO + O$$
$$N + OH = NO + H$$

The theory says that thermal NO_x is generally formed as result of oxidation of nitrogen [66]. It was also noted down that due to triple bond in nitrogen is difficult to break the NO_x formation generally happens at high temperatures (greater than 1800 K). The free oxygen atoms produced because of dissociation of O_2 molecule at higher temperatures, attack nitrogen molecules and will result in a simple chain mechanism postulated by Zeldovich. Figure 11, compares the variation of NO_x emissions with engine load for JB/WWCO blends.

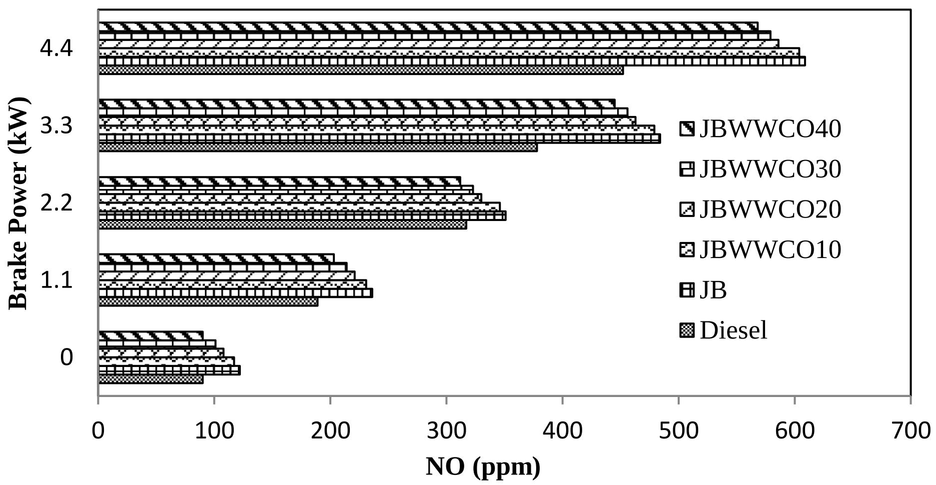

Fig. 11 Variation of NO emission for diesel, JB and JB-WWCO blends at full load

5.7 Smoke density

The smoke generation from diesel engine depends on the load applied on the engine. It was observed that with the increase in load the smoke density increases [67]. The smoke density value at different load is depicted in the form of graph in Fig.12.

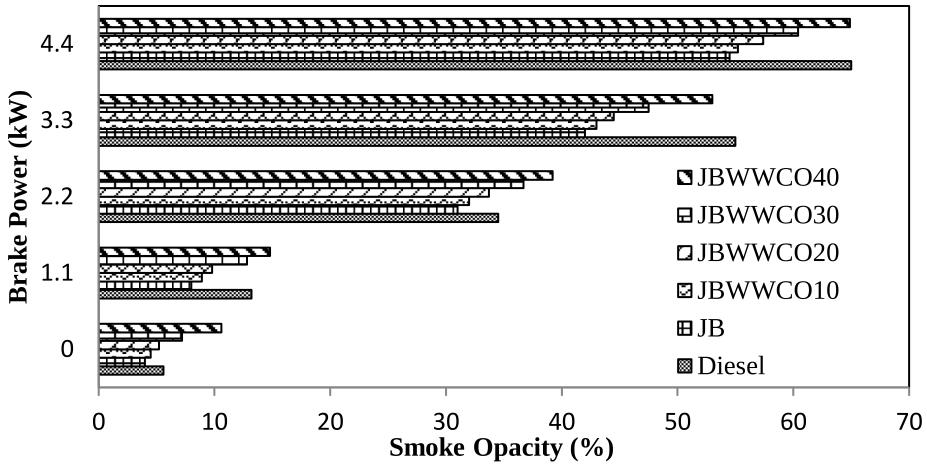

Fig. 12 Variation of smoke density for diesel, JB and JB-WWCO blends at full load

The base and greatest smoke densities delivered during the test for diesel, JB and JB-WWCO mixes were in the scope of 4% and 65% individually. At full burden condition, the most extreme increment of smoke thickness was watched for diesel. It is seen from the figure that the smoke thickness esteem increments with the expansion in the level of WWCO in the JB-WWCO mixes, which is higher than the smoke thickness of unadulterated JB. The smoke thickness of diesel and JB is recorded as 65% and 54.5% at evaluated load. If there should be an occurrence of JBWWCO10, JBWWCO20, JBWWCO30 and JBWWCO40 blends the values are 55.2%, 57.4%, 60.4% and 64.9% at full load. The increase in smoke emission is caused by poor atomization of the WWCO molecule present in the blend. The factors which cause higher amount of smoke emission are the higher viscosity, bulk fuel molecules, low volatility and presence of aromatic of waste plastic oil constituted in reduced atomization of fuel [68].

VI. CONCLUSIONS

The characterization results of the JBWWCO blends the norms of diesel engine. The results of this study indicate that engine can be run smoothly by using different JBWWCO blends without any problem. The mail conclusions of this study can be drawn as follows:

- The obtained physical properties of the WWCO is unique as it improves the cold flow properties of biodiesel. Also, it was found that unsaturated fatty acid components were more in WWCO compared to other types of biodiesel available. The availability of more unsaturated fatty acid reduces the oxidation stability of the fuel. The higher value of iodine value and longer delay period assures the minimum NO emission for JBWWCO than that of biodiesel which contains more saturated fatty acid.

- The oxygen content of JB promotes the early start of combustion and results shorter delay period for JB and its blends.

- The magnitude of calorific value was lower for blends while cetane number was higher than diesel. The higher cetane number signifies the shorter ignition delay. The ignition delay has vital impact on combustion parameters of diesel engine.

- The engine gave maximum BTE for diesel fuel. The JBWWCO10 gave BTE near to diesel. The other blends gave lower BTE than diesel. This may be due to poor miscibility which causes heat loss during exhaust.

- The decrease of 30%, 4.4% and 7.6% in soot formation, CO and HC emission was recorded with JBWWCO10 blend. But the negative aspect with JBWWCO was 13% higher NO emission compared to diesel.

- Overall, it can be accepted that engine can be run by using SSB and its diesel blends without any issues.

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