

# Experimental Investigation of Working and Emission of B20 Fish Biodiesel and Waste Plastic Oil Blend as a Fuel for a Diesel Engine

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## Abstract

Depletion of fossil fuels and environmental pollution are major challenges in the present world. Main pollution sources are the Plastic waste and automotive emissions. The present work deals with usage of the oil obtained from waste plastic blended with Fish Biodiesel. In order to carry out the study on plastic wastes, pyrolysis process was used. Pyrolysis runs without oxygen and in high temperature of about 250-300 °C. Fish Biodiesel was obtained from waste fish leftovers and transesterification was used to obtain Fish Oil Methyl Ester (FOME). B20FOME is obtained by blending 20% FOME with 80% Diesel. The 10% of fuel obtained from waste plastic is blended with B20FOME to obtain B20FOME10WPO. For conducting the various experiments, 10HP single cylinder 4 stroke direct injection water cooled diesel engine is employed. The engine is made to run at 1500rpm and the load is varied gradually from 0-100%. The performance, emission and combustion characteristics are observed. It reveals that fuel properties are comparable with petroleum products. Converting waste plastics into fuel hold great promise for both the environmental and economic scenarios.

**Keywords:** plastic oil; B-20 Fish oil; Biodiesel; Performance; Combustion; Emission.

## 1. INTRODUCTION

A steep increase of transportation vehicles in the world has led to lavish usage of petroleum fuels. Countries' economy is suffered due to heavy usage of fossil fuels. At present, the government has a tough challenge on their hands to overcome the import of crude petroleum from the other petroleum oil producing countries. On the other hand the environmental pollution from the transportation vehicles has a big problem of climate change and acid rain. Hence governments in the world have been focusing on the utilization of renewable energy sources. The Exhaust gas emissions from diesel engine have become serious problem to the researchers. Hence there is a need for finding the solution for reduction of emission from the automobile engines. Now-a-days, fuels of bio-origin, such as alcohol, vegetable oils, biomass, biogas, biodiesels, etc. Are becoming important because of their renewable and environmental friendly nature. Some of these fuels can be used directly, while others need some sort of modification before they are used as substitute to conventional fuels. Biodiesel is a cost effective, environmental friendly, renewable alternative to conventional fuels [1]. Application of biodiesel, as a fuel in transportation vehicles, has nowadays become common in almost all oil importing nations. [2]. The principal advantage of biodiesel is that it reduces or suppresses the formation of CO, HC and PM emissions during the combustion process due to its low aromatic content and the presence of oxygen-containing compounds. The abbreviations and symbols are shown in Table 1.

**Table 1. Abbreviation and Symbol**

|      |                          |
|------|--------------------------|
| BP   | Brake Power              |
| BTDC | Before Top Dead Center   |
| BTE  | Brake Thermal Efficiency |
| HRR  | Heat Release Rate        |

|               |   |
|---------------|---|
| B20           | 20% biodiesel + 80% Diesel              |
| FOME          | Fish Oil Methyl Ester                   |
| EGT           | Exhaust Gas Temperature                 |
| UBHC          | Unburnt Hydrocarbon                     |
| NOx           | Oxides of Nitrogen                      |
| ppm           | Parts per million                       |
| LPH           | Liters per hour                         |
| WPO           | Waste Plastic Oil                       |
| B20FOME       | 20% Fish Oil Methyl Ester + 80 % Diesel |
| B20FOME10 WPO | 10% Waste Plastic Oil + 90% B20FOME     |

A primary type of biodiesel is fish oil. Crude marine fish oil can be extracted from the discarded parts of marine fish like viscera, fins, eyes and tails etc. known as soap stock.[3] Plastics are widely used in many day to day applications such as clothing, house-hold appliances, automotive-products and in aerospace. The treatment of waste plastics becomes an unavoidable and imminent issue. Hence there is an urgent need to effectively recycle plastic waste. The results showed that the waste plastic oil when mixed with heavy oils reduces the viscosity significantly and improves the engine performance [4]. Similar to petroleum derived cracking products, the fractions from plastics processing contains appreciable quantities of aromatics and unsaturated hydrocarbons [5]. The properties of the fuels are shown in Table 2.

**Table 2. Properties of fuels used for testing**

| Property | Straight Diesel | Fish Oil (B100FO ME) | Fish Biodiesel (B20FO ME) | WPO-Biodiesel Blend |
|----------|-----------------|----------------------|---------------------------|---------------------|
|----------|-----------------|----------------------|---------------------------|---------------------|

|                                     |       |       |         | (B20FOME10WPO) |
|-------------------------------------|-------|-------|---------|----------------|
| Density (kg/m <sup>3</sup> )        | 850   | 873   | 854.6   | 852.64         |
| Kinematic Viscosity (at 40 °C, cst) | 2     | 4.97  | 2.594   | 2.5866         |
| Calorific Value (kJ/kg)             | 42000 | 40839 | 41767.8 | 42025.02       |
| Flash Point (°C)                    | 50    | 152   | 70.4    | 67.56          |
| Cetane Index                        | 55    | 57    | 55.4    | 54.96          |

A mixture of biodiesel and plastic fuel provides an innovative product blend for usage in CI engine to give an optimum emission as well as considerable efficiency [6]. The study involves preparing the blend of B20FOME with 10% waste plastic oil (WPO) and testing it along with B20FOME and conventional Diesel on a direct injection 4-stroke CI diesel engine and analysing Performance, Emission and Combustion parameters of each fuel. On comparing the stated characteristics of the fuels it was evident that B20FOME10WPO resulted in best performance and reduced emission. This new blend can be used as a fuel for diesel engine as it has two significant advantages, firstly, the process of converting waste plastic into value added fuels tackles problem of waste plastic disposal. Secondly renewable fuels like Fish oil and plastic oil can partially eliminate the limited diesel.

## 2. EXPERIMENTAL SETUP

The setup consists of single cylinder, four-stroke Constant Speed Research engine connected to eddy current

Dynamometer. Rotameters are provided for cooling water and calorimeter water flow measurement as shown in Fig. 2. The experiments were conducted at the designed injection timing of 23 degrees bTDC (230 was chosen as it is proven to have best performance and emission), constant speed of 1500 rpm and 17.5:1 compression ratio. The setup has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rotameters are provided for cooling water and calorimeter water flow measurement.

## 3. RESULTS AND DISCUSSION

### 3.1 Performance Analysis

#### 3.1.1 Brake Thermal Efficiency

The variation of Brake Thermal Efficiency (BTE) with load for tested fuels is shown in Fig.3. For all fuels the general trend is that BTE improved with increase in load, this was due to reduction in heat loss and increase in power with increase in load. It is observed that among the fuels the B20FOME10WPO showed maximum BTE with 34.48% at full load, while B20FOME showed 32.54% and Diesel showed 31.34%. Thus B20FOME10WPO showed an increase in BTE with respect to Diesel by 9.8 %. The main reason is due to the finer spray formed with plastic blend in the combustion chamber leading to a more uniform fuel-air mixture during combustion. an effective combustion by making use of the rich oxygen content within the ester (FOME) and plastic molecules leading to higher pressure[10,11].

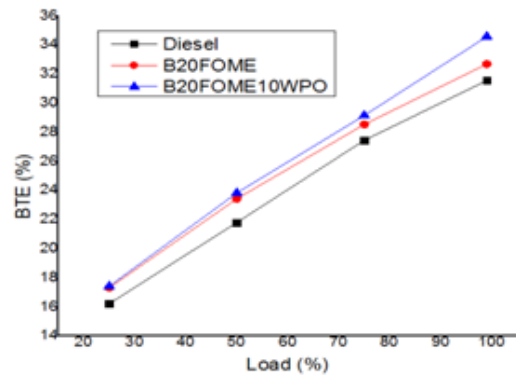


Fig.1 Variation of BTE with Load

## 3.2. Combustion Analysis

### 3.2.1 Peak Cylinder Pressure

The comparison of peak cylinder pressure with load has been shown in Fig. 5. The peak pressure increases steadily with the load. It is seen from the Figure that the peak pressure of B20FOME10WPO is higher than that of diesel at all loading conditions. The maximum Peak Pressure was shown by B20FOME10WPO at 65.52 bar whereas B20FOME and Diesel showed at 64.93 bar and 63.62 bar respectively. At full load B20FOME10WPO and B20FOME showed a greater Peak Pressure than Diesel by 2.98% and 2.06%, respectively. At full load condition the B20FOME10WPO blend shows an increase in peak pressure due to its higher ignition delay which arises due to premixed combustion as it has higher viscosity it takes more time to mix with air and get ignited than other fuels. Thus the combustion is more abrupt so peak pressure is higher and concentrated at a smaller Crank Angle Range.

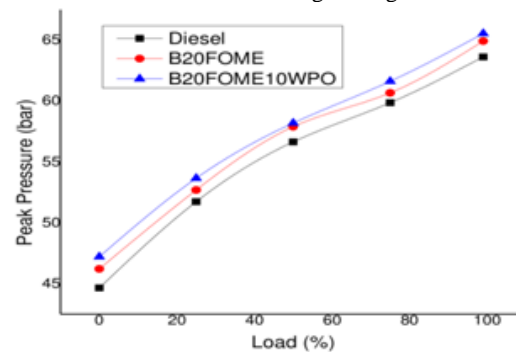


Fig. 2 Variation of Peak Pressure with load

## 3.3 Emission Analysis

### 3.3.1 Exhaust Gas Temperature

The Fig.6 depicts the variation of EGT with load for all the fuels tested. It was observed that EGT increases with increase in load for all the fuels, because of more amount of fuel being consumed. It can be seen that B20FOME10WPO shows slight increase in EGT as that of other fuels. This is due to higher HRR and poor volatility which leads to late burning that causes increase in temperature [15]. It may also be due to a higher Oxygen content in the plastic fuel so burning gets more complete. At the full load B20FOME10WPO showed the highest EGT at 360.790C whereas B20FOME and Diesel showed 340.262 0 C and 340.8850C respectively. 20FOME and Diesel showed similar values. This is due to nearly same quantity of both fuels being consumed per hour. Since heat loss to the exhaust on percentage basis was approximately constant throughout the loadrange, therefore same quantity of fuel consumed implies same heat was rejected resulting in marginal variation in EGT for Diesel and B20FOME.

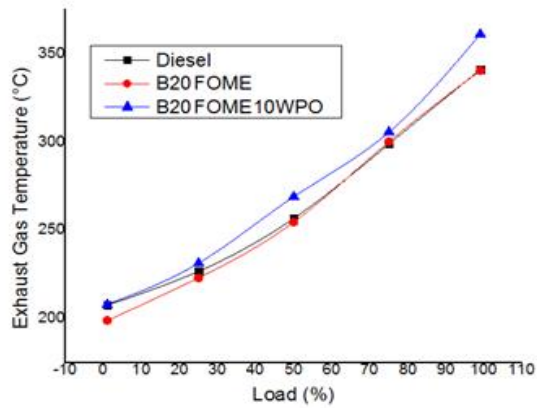


Fig. 3 Variation of EGT with Load

### 3.3.2 Oxides of Nitrogen

Fig.7 depicts the variation of NO<sub>x</sub> with load for all tested fuels. The nitrogen oxides result from the oxidation of atmospheric oxygen at high temperature inside the cylinder of an engine rather than just resulting from a contaminant present in the fuel. It is observed from the figure that the amount of NO<sub>x</sub> increased with increase in the load for all fuels, it happens because, with increase in the load the temperature of the combustion chamber increases, as NO<sub>x</sub> formation is strongly temperature dependent phenomenon [16]. The figure indicates that NO<sub>x</sub> emissions were found at full load to be 1110ppm for B20FOME10WPO, 1080ppm for B20FOME and 1050ppm for Straight diesel. NO<sub>x</sub> emission of B20FOME appears to increase marginally as compared to that of diesel. The plastic blend shows increased NO<sub>x</sub> emission as compared to other fuels. The reason for this trend is higher HRR in case of plastic blend. Due to higher HRR, the temperature inside cylinder will also increase thereby NO<sub>x</sub> emission will be more [17].

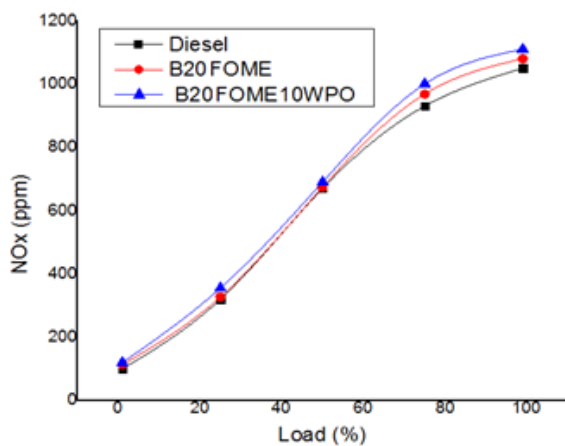


Fig. 4 Variation of NOx with load

### 3.3.3 Unburnt Hydrocarbons

Fig. 8 shows the variation of UBHC with load. From the Figure it is observed that UBHC emissions for all blends are lower than the diesel. At full load B20FOME and B20FOME10WPO showed lesser UBHC emission than diesel by approximately 14.2 % and 24.1 % respectively. The biodiesel is comprised of animal fat and vegetable oil methyl esters i.e., there are hydrocarbon chains whose one end of the chain is oxygenated. The presence of oxygen in the biodiesel and plastic oil promotes more complete combustion that leads to lowering the hydrocarbon emissions.

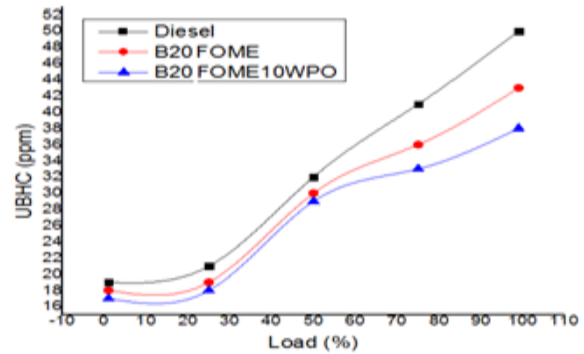


Fig.5 Variation of UBHC with load

### 3.3.4 Carbon Monoxide

The variation of CO with load is presented in the Fig. 9. The CO is a toxic by product of combustion of all hydrocarbons due to incomplete combustion. It is reduced by increasing the oxygen content of the fuel. From the Figure, it is found that the amount of CO at no load is higher than part load since no load corresponds to very lean mixture and equilibrium leads to CO formation. It is decreased at part load (0-60% loading condition) and again increased at full load condition for all tested fuels. This is due to a richer air- fuel mixture needed for maximum power condition corresponding to full load condition. It is observed that CO emissions for biodiesel and plastic blends are lower than straight diesel. Presence of oxygen content in methyl esters and plastic blend leads to the further decrease in the CO emissions compared to that of B20FOME and straight diesel. Carbon monoxide emission is mainly due to the lack of oxygen, poor air entrainment, mixture preparation and incomplete combustion process.

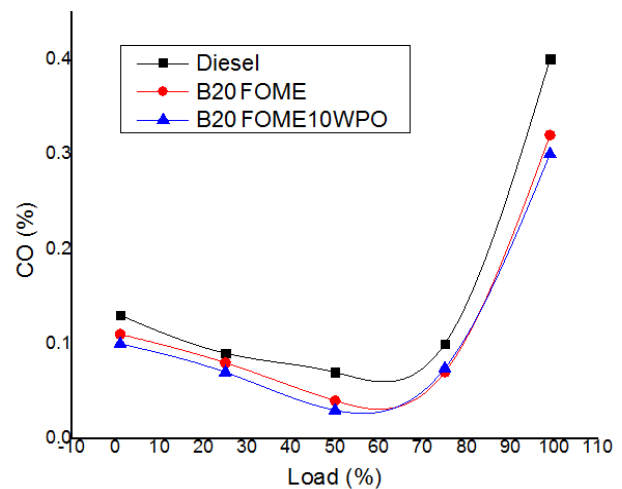


Fig.6 Variation of CO with load

### 3.3.5 Smoke Opacity

Fig.10 shows the variation of opacity with load. The amount of smoke present in the exhaust gas gives the measure of particulate matter present in exhaust gas. It is observed that the smoke opacity of exhaust gas with increase in load for all fuels. This is due to more amount of fuel being consumed at full load so more soot particles are encountered in the exhaust. It can be noticed that the smoke for the blends is higher than the diesel; this is due to poor volatility and mixing of the fuel droplets with air because of higher viscosity of the blends. The molecules of biodiesel and plastic oil being heavier also attributes to the increase in smoke emissions [19].

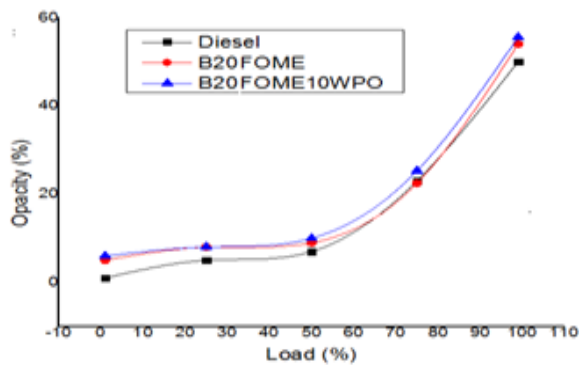


Fig.10 Variation of Opacity with load

#### 4. CONCLUSION

In this study engine tests were conducted with plastic oil and fish blends for no load to full load condition and the corresponding performance, combustion and emission characteristics were studied in comparison with Diesel fuel. All the tests were conducted under the same condition and repeated for three times to obtain consistent values. Waste plastic oil blended with biodiesel from Fish is determined to be suitable replacement to straight diesel. From the results, following features were noticed. Transesterification of the Fish oil leads to reduction in kinematic viscosity and density whereas the calorific value is increased. The B20FOME10WPO showed increased BTE with respect to diesel by 9.3% at full load. The cylinder pressure was found to be maximum for B20FOME10WPO. The oxygen content in B20FOME10WPO helps in the premixed combustion phase to progress in a better way which leads to better combustion. For B20FOME10WPO the emission of HC, CO decreases as compared to diesel signifying a near complete and an efficient combustion. It shows a slight increase in Smoke Opacity and NOx as compared to diesel. Thus these factors strongly support the fact that Plastic oil blended with Fish oil and diesel can be a promising fuel for diesel engines in future as they have good efficiency and reduced emissions. Using renewable and eco-friendly fuels like waste plastic oil and Fish oil, a significant percentage of the limited diesel can thus be eliminated. It also provides a novel method to recycle plastic.

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