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Performance of CI engine blended with Plastic oil

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Abstract :
In recent years pollution has been significantly associated with air but at the same time due to unmonitored dumping of solid waste contributed to both land and air pollution, in some cases water pollution as well. The major component of these solid wastes is plastic. The intent of this paper is to evaluate the plastic oil extraction and the influence of plastic oils on the emission characteristics of a four-stroke experimental diesel engine.

Keywords –Bio fuels, Cotton seed oil, Emission analysis, Injection events, Plastic oil, Performance.

1. Introduction

Most of the emission issues are caused by the transportation sector and in turn heavily contributed by the diesel-based power system. These power systems have a unique problem which initiates the process of generating excess emissions i.e. ignition delay. Fuel needs to be immediately ignited to release the best possible thermal energy from the molecule at peak pressures but this is not the case with diesel engines. The fuel's molecular properties need to be well balanced with the auto ignition and knock prevention parameters within the molecular structure. Plastic oils which can be extracted by the pyrolysis process are a suitable option to blend with diesel because of their energy content that is close to diesel. This approach of blending is also classified into the sustainable approach as they interfere with the global plastic waste [4].

2. Methodology

2.1 Oil extraction

The experiment is segregated in to two stages where the first one is pyrolysis of plastic waste. The reactor is an electrically heated metal tank and the outer surface covered with thermal insulation fabric, the outlet for the vapours is connected to a condensation tube and a spherical flask where the condensed oil was collected. The condensation was supported by running water into the condensation pipe. The plastics that were chosen for the experiment are of daily use domestic waste. The materials were procured form a waste plastic vendor and cleaned to remove dirt and other contaminants.Initially2 kilograms of the waste plastic is fed into the pyrolysis unit. The time taken for the extortion of the oil was 90 minutes approximately after reaching 300 degrees Celsius. Gas yield can be increased by maintaining higher pyrolysis temperatures and for longer reaction times, this typically reduces the char content in the residue. Pyrolysis reaction time of 60-120 minutes yields good quantities of fuel whereas more than 120 minutes will reduce the yield [5].

Waste plastic oil properties are [6].

Table 1 Plastic oil properties

Property	Value
Density (kg/m3)	835
Kinematic Viscosity at 40˚ (cST)	3.11
Calorific Value (MJ/kg)	37.13
Calculated Cetane number	45
Flash point (˚C)	36.5

2.2 Oil blending

The blending percentages were orderly fashioned to check for the variations in emissions and power characteristics. The blending percentages are,

Table 2 Blending Percentages

S.No.	Plastic oil (%)	Diesel (%)
1.	5	95
2.	10	90
3.	15	85
4.	20	80
5	25	75

2.3 Engine testing

The experimental setup used for the testing was a Kirloskar make single cylinder CI engine. The engine is coupled to an Eddy current dynamometer with a strain gauge load cell. The test rig has different loading and injection pressure parameters. The injection pressure of 180, 200, 220 bar while the injection timings can be set to 18˚, 22 ˚, 26 ˚and 30 ˚ BTDC.

Table 3 Engine Specifications

Make	Kirloskar Oil Engines Ltd.
Rated Power Output	7.5 kW @ 1500RPM, 10BHP
Stroke / Bore Ratio	116 mm / 102 mm
Stroke Volume :	948 CC
Compression Ratio	17.5:1
Loading	Eddy Current Dynamometer
Starting	By Hand Cracking

Figure 1 Experimental Rig

2.4 The emission analyser

The emissions were analysed using a QROTECH-401 which is five type gas analyser for monitoring CO, CO2, HC, O2 and NOX. this machine is capable of sensing gases in the of 0-10 percent in Volume of CO, 0-10 percent in volume of CO2, 0-9999 ppm of HC, 0-22 percent in volume of oxygen and 0-5000 ppm of NOX .

2 Gas Analyzer

3. Experimentation

The fuel was blended using an Ana-matrix magnetic stirrer. Each sample was measure in beaker and the appropriate percentages were stirred for 10 minutes at constant stirrer speed.

Figure 3 Magnetic Stirrer

The test was carried out with five loading conditions all with wide open throttle. The gas analyzer probes are placed in the engines exhaust systems after the 1 min of run. This ensured that there won't be any deviation in data due to start up or lubrication deficiency issues.

The dynamometer was loaded for the next testing parameter electrically once the data was logged in the computer. In this way all the blends were tested on the engine.

4. Results and Discussion

The performance and emissions of the experimental fuel with various blend percentages are discussed in detail in this section. The observed factors are Ignition delay ,brake thermal efficiency, hydro-carbon emissions, NOX , carbon monoxide and carbon dioxide.

Brake thermal efficiency and ignition delay

Brake thermal efficiency (BTE) is a direct measure of how well the fuel is releasing the energy and that even depends at what point it is releasing. The following figure shows the efficiencies of all the five blend ratios and their performance at different injection timing. The maximum and minimum efficiencies achieved with these fuels are 36.5 % being the maximum while 17.6 % was the lowest. The efficiency of the engines when operated at full loads are comparable with diesel fuels as their thermal efficiency values are similar to diesel but simultaneously researchers also found out that there are considerable increase in HC and CO emissions when operated with Diesel fuel blends[6,7,8].

Figure 4 Brake thermal Efficiency

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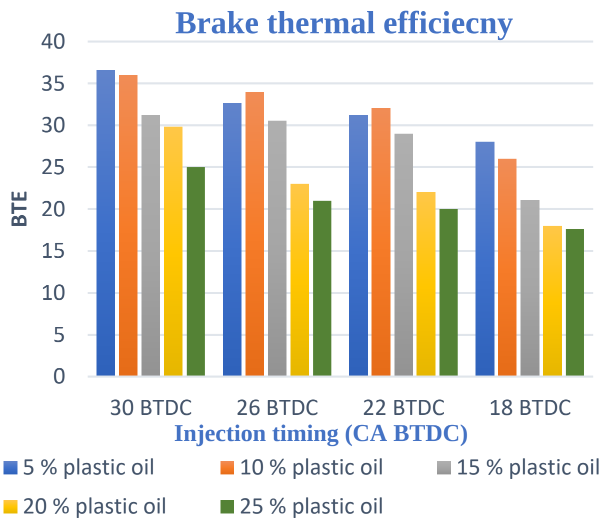
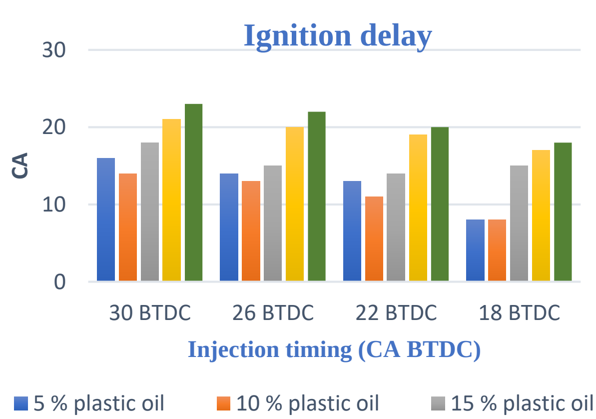


As the content of plastic oil increased in the diesel, the BTE started to drop but at injection timing of 26˚ and 22˚ BTDC the ten percent plastic oil fuel sample showed better efficiencies compared to the five percent plastic oil samples. This is primarily because plastic oil in the fuel sample aids in better initial ignition characteristics due to its calorific values being close to diesel fuels. On the other hand, the mixing characteristics were significantly affected by the increasing fuel blend as the plastic cannot be easily atomised unlike diesel fuels. The ignition delay has direct effect on the BTE, as the ignition delay reduced the time for mixing was less for the test done at retarded injection timings than the advanced ones. The test done at 18 ˚ BTDC has least efficiency compared to all other samples runs because of the ignition delay being less. But the least ignition delay depicted for the 18 ˚ BTDC event has better efficiency than the long delay of the same event. This is primarily because of the better atomisation, distribution and uniformity of combustible diesel within the combustion chamber. For these reasons, the advanced injection events have better BTE than all other categories.

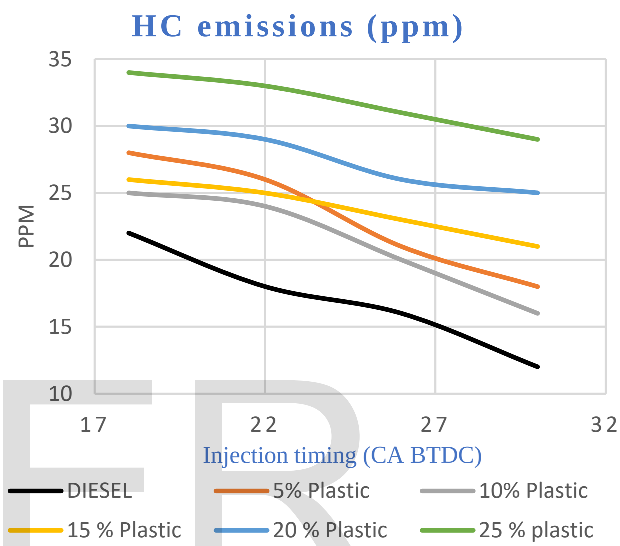
Figure 5 Ignition delay



4.2 Hydro-carbons (HC)

Improper or incomplete combustion of fuels within the combustion chamber leads to the un burnt fuel emissions which are known as hydrocarbon emissions. Factors that influence the HC emissions are the oxygen content in the combustion chamber, cetane number of the fuels and the latent heat of vaporization. It can be seen from the graph, that the emissions were higher at injection events close to TDC because of the ignition delay effect which is partially due to the lower cetane number of the plastic oil.

Figure 6 HC emissions

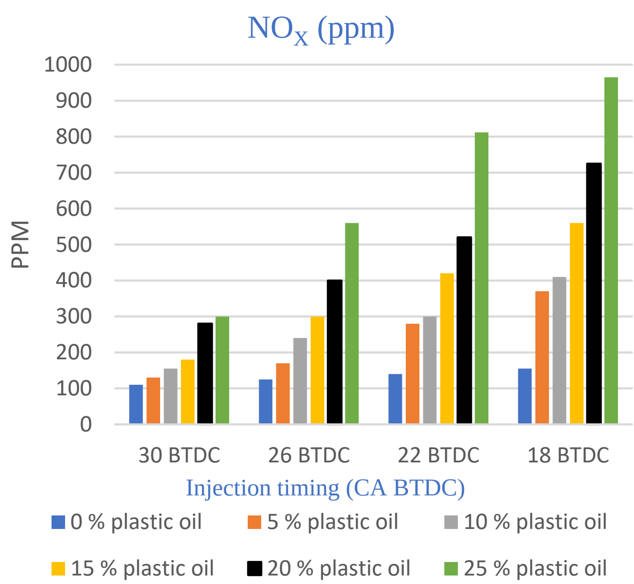


Samples of more than 10 percent concentration of plastic oil have higher emissions due to improper mixing which resulted in fuel pockets or deposits on the combustion chamber surface. This leads to oxygen deficient zones to combust the entire fuel. Studies reported that the HC and CO emissions are generally high in diesel with plastic oil blends due to the presence of heavier aromatic compounds and longer ignition delays[9,10].

4.3 Oxides of Nitrogen (NO_X)

The reason for NOx being the most influencing pollutant is because of its nature to react with UV rays which results in photochemical smog as well as it contributes to acid rains. The NOX emissions are very less for the injection event 30 BTDC but these emissions increased significantly and reach a maximum of 965 ppm at 18 BTDC. The fuel sample that has the most plastic oil content of 25 percent contributed for the highest emissions. This is primarily because of the abundantly available oxygen for the nitrogen to react at exhaust gas temperature inside the system.

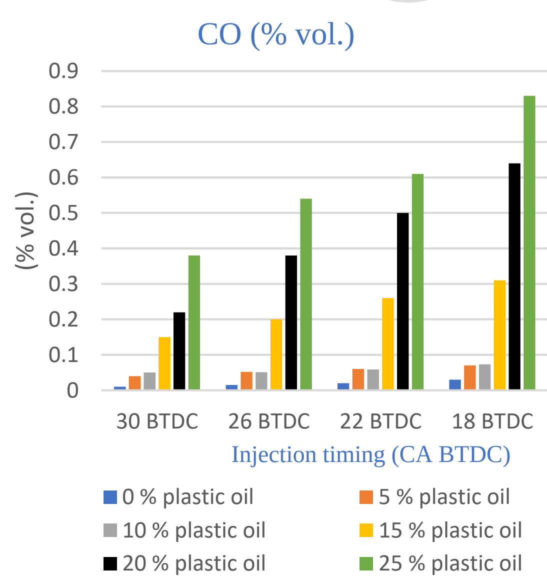
Figure 7 NOx Emissions



4.4 Carbon monoxide (CO)

Similar to the HC emission carbon monoxide requires the availability of oxygen and incomplete combustion of fuel. Thus, a similar pattern can be established between these two parameters. At retarded injection timings which are close to TDC show drastic increase in CO emissions, but the aggressive dilution of diesel with plastic oil (15 %, 20 %, 25%) shows that the combustion is incomplete as result which the part of the left-over oxygen forms CO.

Figure 8 Carbon monoxide emissions



5. Conclusions

From the experiment it is evident that thermal efficiency of the engine was not compromised by the addition of limited amounts of plastic oil. However, BTE is also highly influenced by the ignition delay setup by the injection timings. As the injection timings were advanced the emissions reduced significantly this is clearly seen between the 30 BTDC and 18 BTDC. The improper mixing of fuel leads to incomplete combustion and the rest of the pollutant formation mechanisms follow up. The same behaviour is observed when the plastic oil concentration increased, the increase in HC emissions is evident along with it the CO emissions follow up from the partially burned fuel.

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