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Performance Investigation of Diesel Engine Using Waste Plastic Pyrolysis Oil and Diesel Blends

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Abstract:
The consumption of energy in the form of fossile fuels has been increasing day by day. Modern world uses many components with plastic as a primary source due to its light weight, easy carrying, low cost. Consumption of plastics increasing drastically year by year there is a problem with plastics. Dumping of waste plastics into the land fields, municipal waste produces pollution problems. Waste to energy is the recent trend to convert waste into quality fuel. This paper presents the use of waste plastic pyrolysis oil as alternative fuel in testing the single cylinder four stroke kirloskar (5HP) diesel engine. Performance parameters of waste plastic pyrolysis oil with diesel blends with, different blending ratios like WPO15, WPO20, WPO30, WPO40, and WPO50, used in single cylinder diesel engine at constant speed 1500 rpm with no load to full load conditions at rated brake power. WPO20 blend gives good results when compared to pure diesel. Brake thermal efficiency of WPO20 gives (26.24%) higher than that of diesel (24.85%).specific fuel consumption was decreased at full load for all blends and exhaust gas temperature was increased for all blends compared wth pure diesel.

Key words: alternative fuel, Diesel engine, waste plastic oil, Pyrolysis process, Performance parameters

I. INTRODUCTION

Plastic consumption is increasing day to day life Due to its less weight, easy carrying low manufacturing cost. The increase in the rate of plastic consumption throughout the world has led to the creation of more and more amounts of waste, and this in turn poses greater difficulties for disposal. Plastic utilization is expanding drastically consistently because of the relative ease of generation in contrast with different materials and accommodation being used and application. In 2015, plastic creation achieved the 322 million tones worldwide and the 59 million tons in the European Union. Plastic is major commodity used in recent years, significant growth in the consumption of plastic globally has been due to the introduction of plastics into newer application areas such as in automotive field, rail, transport, aerospace, medical and healthcare, electrical and electronics, telecommunication, building and infrastructure, and furniture. Waste to energy is the new concept in recent years all over the world researchers are looking for alternative fuel to reduce depend on fossile fuels (2,3,4). Ashish Y. Pund et al (1) studied on Experimental Investigation of Performance Characteristics for CI Engine using Waste Plastic Oil and Ethanol blends as substitute fuel for diesel engine results shows that D-90 WPO 10,D-90 E-10 blends are better than pure diesel. Rajesh Guntur et al (2) reported on Experimental Investigations on the Performance and Emission Characteristics of a Diesel Engine Fuelled with Plastic Pyrolysis Oil Diesel Blends The present investigation was to study the performance and emission characteristics of a single cylinder, four-stroke, air-cooled diesel engine run with waste plastic pyrolysis oil-diesel blends. At full load Brake thermal efficiency of the engine is less than the diesel fuel operation and higher at part loads. Unburned hydrocarbon and Carbon dioxides were marginally higher than that of the diesel baseline. The toxic gas carbon monoxide emission of waste plastic pyrolysis oil was higher than diesel. Kintesh D Patel et al (3) studied on Performance and Emission Analysis of Diesel Engine using Waste Plastic Pyrolysis Oil and Diesel Blend: A Review Change of waste to energy is one of the recent trends in minimizing the waste transfer as well as could be utilized as a substitute fuel for internal combustion engines As an option, non-biodegradable, and renewable fuel, waste plastic oil is accepting expanding consideration. Ioannis Kalargaris et al (4) experimented on the utilization of oils produced from plastic waste at different pyrolysis temperatures in a DI diesel engine. Pyrolysis is a chemical recycling process that can convert plastics into high quality oil, which can then be utilized in internal combustion engines for power and heat generation. The aim of this work is to evaluate the potential of using oils that have been derived from the pyrolysis of plastics at different temperatures in diesel engines. The plastic pyrolysis oils were then tested in a four-cylinder direct injection diesel engine, and their combustion, performance and emission characteristics analyzed and compared to mineral diesel. The engine was found to perform better on the pyrolysis oils at higher loads. The pyrolysis temperature had a significant effect, as the oil produced at a lower temperature presented higher brake thermal efficiency and shorter ignition delay period at all loads. Ioannis Kalargaris (5) et al studied on Combustion, performance and emission analysis of a DI diesel engine using plastic pyrolysis oil. The plastic pyrolysis oil was tested on a four-cylinder direct injection diesel engine running at various blends of plastic pyrolysis oil and diesel fuel from 0% to 100% at different engine loads from

25% to 100%. The engine combustion characteristics, performance and exhaust emissions were analyzed and compared with diesel fuel operation. The results showed that the engine is able to run on plastic pyrolysis oil at high loads presenting similar performance to diesel while at lower loads the longer ignition delay period causes stability issues. D. K. Ramesha et al (6) Experimental Investigation on Combustion, Performance and Emission characteristics of blends of Plastic oil and Biodiesel as a substitute fuels in Diesel Engine. Waste plastic oil is suitable for compression ignition engines and more attention is focused in India because of its potential to generate large-scale employment and relatively lower scale degradation. The present investigation was to study the effect of plastic oil blend with B20 rubber biodiesel and B20 honge biodiesel on four strokes, single cylinder direct Injection diesel engine. Results show that performance characteristics were found to be comparable with diesel. The emission characteristics shows that NOx emission levels are slightly higher and other emissions like CO, HC are compatible with diesel modes of operation. Hence plastic oil can be used as substitute fuel in place of conventional diesel fuel. Sanjeev et al (8) Experimental Investigation on Performance of Direct Injection Diesel Engine Fuelled with Jatropha Methyl Ester, Waste Plastic Oil and Diesel Oil. For this experiment we used four stroke, single cylinder, and water cooled, direct injection (DI) diesel engine. Four different blends of varying WPO, JME and diesel from 10% to 50% at steps of 10% on a volume basis, were considered for the investigation. Performance parameters are evaluated at different blend ratios and are compared with those of diesel. 20% blend with equal ratio of WPO and JME in diesel shows nearly same results as compared to diesel. From the literature review the present investigation was on single cylinder Four stroke Diesel engine with waste plastic pyrolysis oil and diesel blends with different mixing ratios likewise WPPO15, WPPO20, WPPO30, WPPO40 and WPPO50 at constant speed and different load conditions.

II. PRODUCTION OF WASTE PLASTIC PYROLYSIS OIL

Waste plastic oil was prepared by the pyrolysis process. Pyrolysis technology is thermal degradation process in the absence of oxygen. Plastic waste is treated in a cylindrical reactor at temperature of 300ºC – 350ºC. The plastic waste is gently cracked by adding catalyst and the gases are condensed in a series of condensers to give a low sulphur content distillate. All this happens continuously to convert the waste plastics into fuel that can be used for generators.

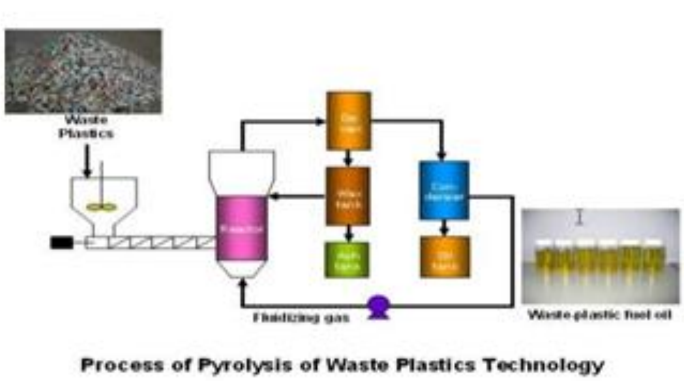


Figure.1. platic pyrolysis process

III. FRACTIONAL DISTILLATION OF WASTE PLASTIC PYROLYSIS OIL

Produced plastic oil was heated on electric heater above 100 ^{o} c to remove dust particles and impurities present in the oil .Heated oil vapour was collected and cooled by water to produce distilled plastic oil. This distilled oil was used in single cylinder 4-stroke Kirloskar Diesel engine (HMTO4) to find out performance emission parameters. Waste plastic pyrolysis oil collected from the plant. Collected WPPO Heated above 100 ^{0} c and then cooled by fresh water to produce distilled plastic oil.

Figure.2. Schematic layout of Fractional Distillation Setup

IV. BLENDING OF DIESEL WITH PLASTIC OIL

Plastic oil from the plant was collected. Distillation process was used to convert dust into pure plastic oil blend the diesel with plastic oil. Different blends was prepared with diesel likewise WPPO15,WPPO20, WPPO30,WPPO40, WPPO5 used in single cylinder 4-stroke Diesel Engine kirloskar 5HP to test engine with constant speed with varying load condition

Figure.3. Tested samples of plastic oil with Diesel blends

V. PROPERTIES OF DIESEL WASTE PLASTIC OIL AND DIESEL

Table.1. Properties of diesel waste plastic oil and diesel

Fuel	**Kinematic Viscosity at 40^0C (cst)**	**Density (kg/m3)**	**Calorific value (kJ/g)**	**Cetane number**	**Flash Point (0C)**	**Fire Point (0C)**
Diesel	3.5	850	42000	55	45	46
Waste plastic pyrolysis oil	2.78	793	41858	51	36	39

VI. THE ENGINE

The Engine chosen to carry out experimentation on a single cylinder, four stroke, vertical, water cooled, Kirloskar make CI Engine. This engine can withstand higher pressures encountered and also is used extensively in agriculture and industrial sectors. Therefore this engine is selected for carrying experiments. The specifications of the engine given Table 4.1. Fig. 4.1 shows the actual photos of the C.I. Engine and its attachments.

Figure.4. Experimental set up of C.I. Engine

VII. ENGINE SPECIFICATIONS

Table .2. Engine Specifications.

Engine	Four stroke, single cylinder, water cooled, diesel engine, Kirloskar engine (HMTO4)Ltd
Ignition System	Compression Ignition
Bore	0.0875m
Stroke	0.11m
Compression ratio	17.5:1
Speed	1500 rpm

The performance investigation of diesel blends with plastic oil (WPPO15, WPPO 20, WPPO 30, WPPO 40, and WPPO50) with Waste plastic oil have been studied and compared with diesel fuel at constant speed for different loads. The experiments were conducted at no load to full load condition. Operating Parameters, including fuel consumption, Brake power, brake specific fuel consumption, and brake thermal efficiency were computed waste plastic oil as alternative fuel.

VIII. RESULTS AND DISCUSSION

Engine Performance Brake thermal efficiency.

Variations in brake thermal efficiency (BTE), with respect to Load, for all of the fuels of diesel and its blends are shown in Figure 4.3. From the figure it is observed that the Plastic oil content increases, BTE decreases by increasing Brake power. BTE of all plastic oil blends are less than the Diesel. Maximum brake thermal efficiency was 26.24 % for WPO20, which was increase to that of diesel (24.85%) which was higher than that of diesel fuel more oxygen content in the WPO 20 blend higher BTE was obtained with WPO20.the oils lower BTE are largely attributable to their higher aromatic content. Aromatic bonds require more energy to break.

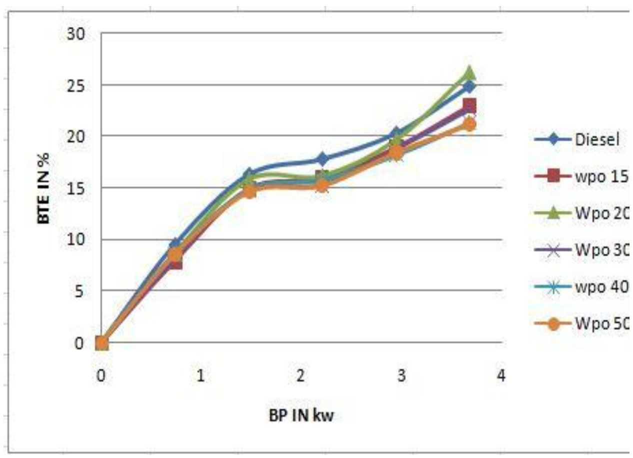


Figure.5. BP Vs BTE

Brake Specific fuel consumption.

Variations in brake specific fuel consumption (BSFC), with respect to engine brake power are shown in Figure 4.3.2. For all of the fuels tested, BSFC had a tendency to decrease as engine brake power increased until it reached a minimum value. BSFC initially decreased slightly as Plastic oil content in the blends increased up to 20%, but increased as Plastic oil content increased further due to Plastic oil as lower calorific value and higher viscosity. For blends WPO15 and WPO20, BSFC were 0.44, 0.45kg/kW.hr, slightly more than diesel (0.41).

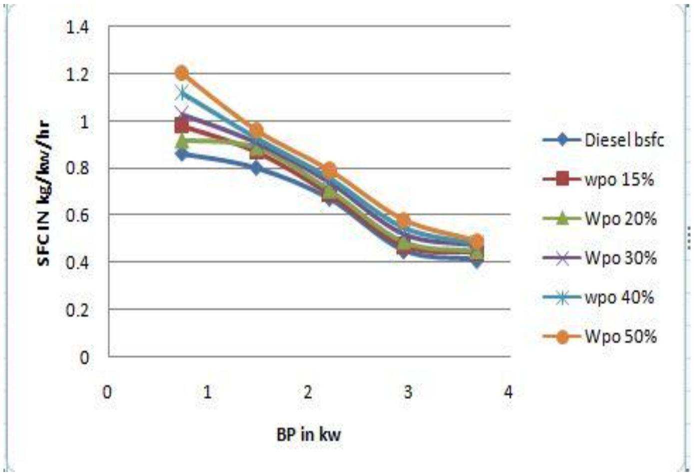


Figure.6. BP Vs SFC

Exhaust gas temperature.

Exhaust gas temperature (EGT) varied with load and the results for different fuels are presented in Figure 4.3.3 EGT of all the tested fuels increased with load. EGT of WPO15 and WPO20 was lower than that of diesel fuel at the highest load due to the blends' higher viscosities, lower calorific value which resulted in poorer atomization, poorer evaporation, and extended combustion during the exhaust stroke. When Plastic oil content increased, viscosity increased, calorific value decreased and, as a result, EGT of the blends were lower than that of diesel. Maximum EGT at peak load for Diesel, WPO15, WPO20, and WPO30 were 300 ^{0}C, 310^{o}C, 320^{o}C, and 325^{o}C respectively.

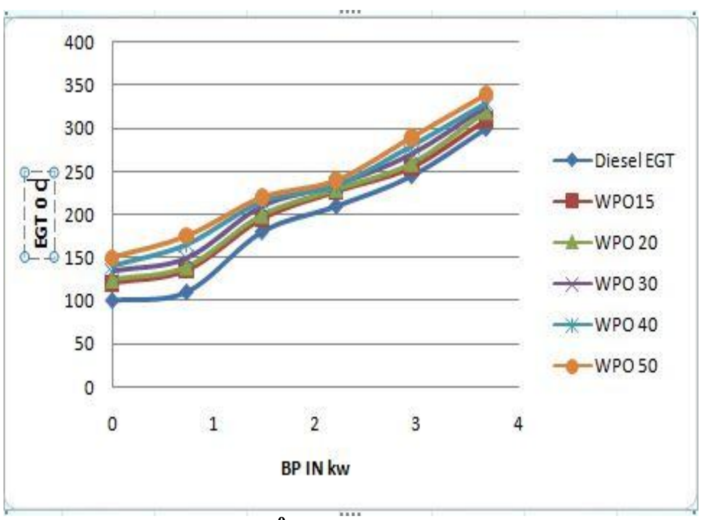


Figure.7. BP Vs EGT in ^{0} C

Engine Emissions

Carbon Monoxide (CO %).

Figure 4.4.1 compares the carbon monoxide (CO) emissions, with respect to brake power. CO emissions of all the fuels had a tendency to increase with load. CO emissions were slightly increases with increasing plastic oil content. The CO emissions of all blends were more than that of Diesel for all loads. The percentage of CO emissions of Diesel, WPO15, WPO20, WPO30, WPO40 and WPO50 blends were 3.69, 3.72, 3.86, 3.96, 4.38 and 4.48 respectively. High CO emission from the diesel engine is sign of in complete combustion; Diesel produces the lowest CO emission.

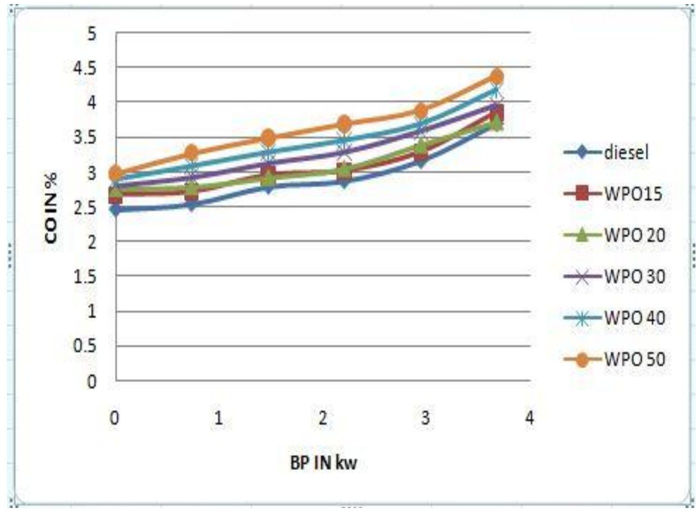


Figure.8. BP Vs CO in %

Carbon Dioxide (CO_2).

The Variation of carbon dioxide with plastic oil blends with different brake power is graphically represented in Fig 4.4.2. It was observed that the percentage of carbon dioxide in all the blends was found to be low at all loads as compare to Diesel. At the brake power of 3.73kW, the percentage Carbon dioxide of Diesel, WPO15, WPO20, WPO30 for were 7.1, 7.45, 7.53, and 7.64, respectively. For WPO15 and WPO20 the percentage of carbon dioxide is increased compared to 100% diesel were 0.35and 0.43 respectively. Co2 formed by the complete oxidation of carbon atoms contained in the fuel.

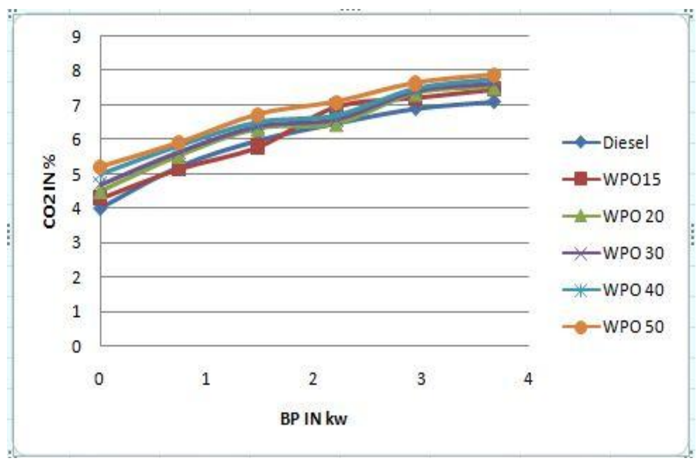


Figure. 9. BP Vs CO2 in %

HC Emission.

The Variation of unburned hydrocarbon with Biodiesel blends with different brake power is graphically represented in Fig.4.4.3 It was observed that the percentage of hydrocarbon in all the blends as compared to diesel was found to be high at all loads. At the brake power of 3.67kW, the hydrocarbon of about 1606 ppm for 100% diesel and 1610 ppm for WPO15. The 04 ppm of hydrocarbon is increased compared to 100% diesel and also it was observed that the proportion of plastic oil aromatic content increases the percentage of unburned hydrocarbon

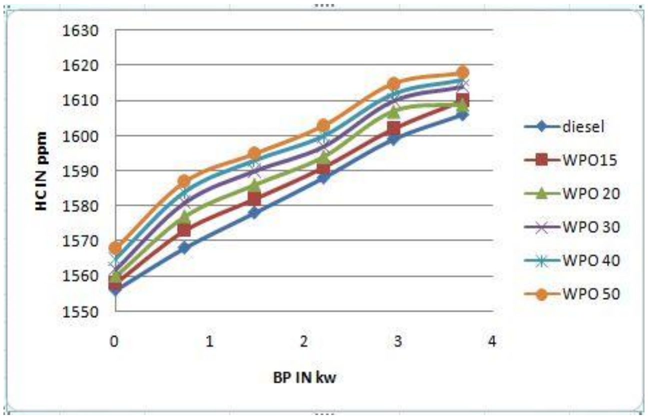
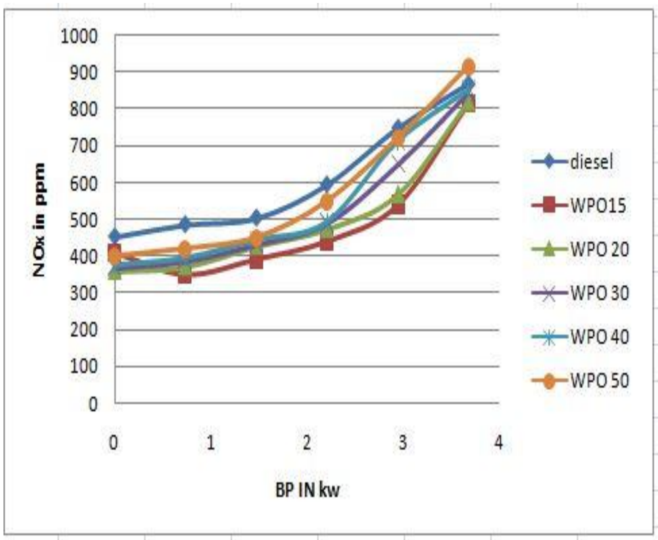


Figure.10. BP Vs HC in ppm

NOx Emission.

The Variation of NOx with plastic oil with diesel blends with different brake power is graphically represented in Fig 4.4.4 It was observed that the percentage of NOx in all the blends was found to be low at all load as compared to diesel. At the load 5 kg, the NOx reaches its maximum of 855 ppm for 100% Diesel and 869 ppm for WPO15. The 14 ppm of NOx increased compared to 100% diesel and also it was observed that the proportion of plastic oil blends increases the 14 ppm of NOx increases.



BP Vs NOx in ppm

IX. CONCLUSIONS

Performance investigation of single cylinder four stroke diesel engines was run with waste plastic oil and diesel blends as alternative fuel. Waste to energy is the recent trend which will focus new intrest on research. Brake thermal efficiency of waste plastic oil blend (WPO20) BTE 26.24% at 3.67 kw bp was more than that of diesel (24.85%). Specific fuel consumption of plastic oil with diesel blends was slightly higher than that of diesel. Exhaust gas temperature of plastic oil with diesel blends increasing due to longer ignition delay of plastic oil. Carbon monoxide emission increases with increasing brake power at load conditions at 3.67 kw the co emission for plastic oil blends WPO15,WPO20,WPO30,WPO40 and WPO50 3.69, 3.63 ,3.72, 3.96, 4.18 and 4.18%. Carbon dioxide emission of plastic oil blends with diesel increases slightly at WPO20 brake power 2.94 kw decreases less than that of diesel due to complete combustion of fuel. Hydro carbon emission plastic oil blends more than that of diesel at all brake powers. at 3.67 kw bp hc emission for diesel,WPO15,WPO20,WPO30,WPO40, and WP O50 were 1606, 1610, 1609, 1614, 1616 and 1618 ppm. Nitrogen oxide emission of all tested plastic oil blends was low at part loads and high at maximum load conitions. WPO15, WPO20, WPO30, WPO40, and WPO50 870, 815, 820, 845, 852 and 915 ppm.

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