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Experimental Investigations of Performance and Emission Characteristics of CI Diesel Engine Using Plastic Oil Blends

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Abstract: In India the fossil fuel reserves are exhaustive in nature due to the increase in the consumption. With this the environment pollution is also a serious problem, which should be addressed immediately. Even today in major sectors like Agriculture, Industries, Power etc., the diesel fuel is a major source of energy. There is a need to search for a substitute fuel which will reduce the dependency on the diesel fuel. From the previous researchers, it is learnt that the plastic oil is one of the prominent substitute fuel for the diesel fuel. However, some of the properties pertaining to the plastic oil are inferior to the diesel. Therefore, in this work an attempt is made for better combustion of plastic pyrolysis oil derived from the pyrolysis of waste plastic and is blended with diesel fuel. The experiments are carried out on a single cylinder, four stroke, vertical, water cooled, direct injection, CI engine using diesel and plastic oil blends. The performance and emission characteristics like brake thermal efficiency, brake power, brake mean effective pressure, specific fuel consumption, mechanical efficiency are computed. Further in this work the emissions CO, HC, NO_X and smoke opacity are evaluated. The performance and emission rates are measured at different loads for pure diesel and plastic oil blends. The test results indicate that the plastic oil blends can be used directly in the diesel engine without any modifications to the engine.
Keywords: Biodiesel, Blends, Plastic Oil, Pyrolysis**.**

I. Introduction

Transportation is one of the major sector for the day-to-day functioning of the world. The entire world would literally come to a standstill without transportation. Without transportation it is really impractical to imagine our life. The transportation by means of air, road and water are all a part of our daily routine life. The Department of transportation makes sure that the public transportation services like buses, trains and subways etc., are able to properly serve the society where infrastructures like roads and bridges are properly maintained. The major issue with the use of the fossil fuels is that it is a finite resource. This means that once all the resources are depleted, it will be the end for the usage of the fossil fuels. At this point of time with the current rate of usage, it is estimated that approximately left with 35 to 40 years to completely use up the total fossil fuels. This is an alarming fact that at this juncture one has to acknowledge and to act upon accordingly.

Diesel engines are the most efficient prime movers. In view of protecting the environment and concerns for the long term energy security, it becomes necessary to develop alternative fuels with properties closure to petroleum based fuels. India's demand for the diesel fuels is approximately ten times that of the gasoline unlike rest of the world. Without compromising engine's operational performance, alternative fuels should be easily available at low cost, fulfill energy security needs and be environmentally friendly. For twin crises of the fossil fuel depletion and environmental degradation the alternative fuels like bio-oil or plastic pyrolysis oil can be a feasible solution to the developing countries. These fuels are getting revived attention because of the global stress on the reduction of the greenhouse gases and clean development mechanism.

The performance and emissions of plastic pyrolysis oil with various blends B20, B40 and B60 and diesel are evaluated. The performance related parameters like specific fuel consumption is lesser for diesel when compared to the blends. Whereas the brake thermal efficiency and total fuel consumption is higher for the diesel when compared with the blends. However the emission parameters like CO and NO_x emissions are more for the diesel fuel than for blends [8].

The experimental investigations are carried out on performance and emission characteristics of blends of plastic pyrolysis oil like B10, B30, B50 and diesel. The mechanical efficiency and brake specific fuel consumption increases with increase in the blend ratio. However with increase in the blend ratio the brake thermal efficiency reduces. The increased exhaust gas temperature increases the hydrocarbon and carbon monoxide emissions. The unburnt oxygen is greatly reduced due to the increased combustion [2].

The emission and combustion characteristics of various blends of plastic pyrolysis oil and diesel as such as B10, B20 are determined. When compared to the blends the brake thermal efficiency is higher for diesel. The combustion parameters like peak cylinder pressure and heat release rate are higher for the blends because of the presence of oxygen in blends which may contribute to complete combustion. The emission parameters like CO, hydrocarbon and NO_x are less for the blends [10].

The experimental investigation on the various blends of plastic pyrolysis oil and diesel shows that brake thermal efficiency increased with all blends when compared to the conventional diesel fuel. Further the brake specific fuel consumption is decreased with the blends when compared to diesel. By using the blends CO, CO_2 and HC emissions are decreased significantly when compared with diesel. Among all the blend B20 reveals better performance compared to other blends [5].

The experimental checking and the suitability of the plastic pyrolysis oil as a fuel in the diesel engine and performance characteristics are investigated by using blends of plastic pyrolysis oil and diesel such as B10, B30, B50 and B70. The total fuel consumption, brake thermal efficiency and brake mean effective pressure increases with increased blend ratio and is more than that of diesel. With increase in the blend ratio the specific fuel consumption decreases and is lower than that of diesel fuel [4].

The experimental work with various blends of plastic pyrolysis oil such as B25, B50, B75 presented that the torque and power developed is reduced in the case of the blends of plastic pyrolysis oil and diesel when compared to diesel. This is due to the increase in the combustion temperatures and increase in friction loss. Because of the same reason with an increase in the blend ratio the thermal efficiency also reduces. As the blend ratio increases the ignition delay also increases because of the low cetane number of the plastic pyrolysis oil when compared to the diesel [7].

Several blends of plastic pyrolysis oil and diesel like B25, B50 and B75 are investigated on diesel engine. The performance parameter like specific fuel consumption for waste plastic oil is higher than diesel fuel operation. Whereas the toque and power developed is higher for the diesel than in comparison with the blends. CO and CO_2 emission for waste plastic oil blends is higher than diesel operation. NO_X emission increased with an increase in the fuel blended ratio[6].

II. Experimental procedure

Plastic pyrolysis oil is a synthetic fuel and is a hydrocarbon liquid recovered through the de-polymerization of the plastic waste. The properties of the plastic pyrolysis oil are as shown below:

Sl. No	PROPERTIES	PLASTIC PYROLYSIS OIL	DIESEL OIL
1	Calorific Value, KJ/Kg	42,865.65	45,273.35
2	Kinematic Viscosity, CST	2.210	2.428
3	Density, Kg/m^3	760	824
4	Flash Point,^{0}C	26	43
5	Fire Point, ^{0}C	29	48

Table 2.1 – Properties of Plastic pyrolysis oil

2.1. Preparation of plastic pyrolysis oil

The production method for the conversion of plastics to liquid fuel is based on the pyrolysis of the plastics and the condensation of the resulting hydrocarbons. Pyrolysis refers to the thermo-chemical process for conversion of waste plastic by heating the feed stock at high temperature in absence of air which produces gaseous products and in turn condensed to give liquid fuels consisting of pyrolytic oil or liquid oil.

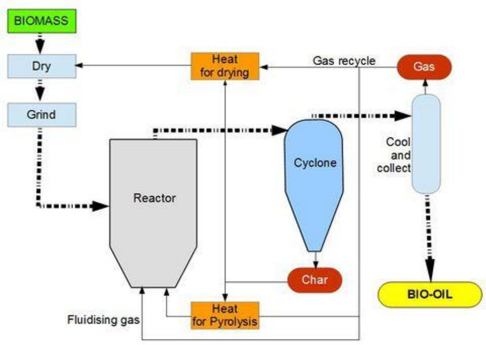

Fig 2.1 – Principle of Pyrolysis process

2 .2. Preparation of blends

The plastic pyrolysis oil can be blended with the diesel and can be used in many different concentrations. They include B100 (Pure Plastic pyrolysis oil), B20 (20% Plastic pyrolysis oil, 80% Diesel), B5 (5% Plastic pyrolysis oil, 95% Diesel), B10 (10% Plastic pyrolysis oil, 90% Diesel), and B15 (15% Plastic pyrolysis oil, 85% Diesel). The most common blend is B20 because of its better performance and lower emission characteristics. The blend is referred to as B20 because it contains 20% plastic pyrolysis oil by volume and 80% diesel by volume. Also B0 means pure Diesel.

Here, “B” factor is used to state the quantity of plastic pyrolysis oil present in any fuel mix. The blends we made are mentioned below:

I. B0 (100% Diesel),
II. B5 (5% Plastic pyrolysis oil, 95% Diesel),
III. B10 (10% Plastic pyrolysis oil, 90% Diesel),
IV. B15 (15% Plastic pyrolysis oil, 85% Diesel),
V. B20 (20% Plastic pyrolysis oil, 80% Diesel).

BLENDS	CALORIFIC VALUE (KJ/Kg)	KINEMATIC VISCOSITY (Centistokes)	DENSITY (Kg/m^3)	FLASH POINT (^{0}C)	FIRE POINT (^{0}C)
B0	45,273.35	2.428	824	43	48
B100	42,865.65	2.210	760	26	29
B5	44,495.03	2.419	822	42	47
B10	43,915.43	2.382	822	40	46
B15	43,378.43	2.357	821	39	44
B20	42,906.53	2.324	820	37	42

Table 2.2 – Properties of the blended fuels

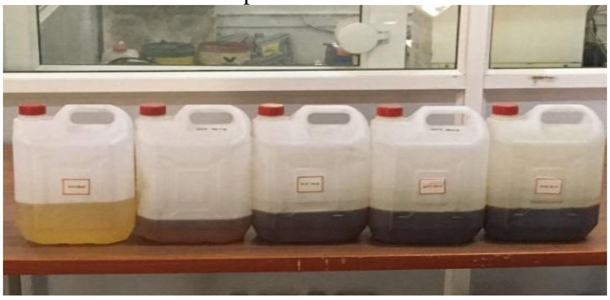

Fig 2.2 – Prepared Blends (B0, B5, B10, B15, B20)

III. Experimental set up

In this work experiments are conducted on a single cylinder, four stroke, direct injection, water cooled, compression ignition engine with a compression ratio of 17.5:1 and developing 5.2 KW power at 1500 rpm is used for this work. Fuels used in this experiment were diesel, and blends of diesel and plastic pyrolysis oil. The cylinder pressure and top dead centre (TDC) signals are acquired and stored in a high-speed computer based digital data acquisition system. The stored signals are processed with specially designed software to obtain the performance and combustion parameters.

Fig 3.1 –Engine Setup

An AVL DIGAS 444 exhaust gas analyzer is used to measure the Carbon Monoxide (CO), Hydro Carbon (HC), Carbon Dioxide (CO_2), Unburnt Oxygen (O_2) and Nitrogen Oxide (NO) levels. The analyzer is a fully microprocessor controlled system employing non-destructive infrared techniques. The smoke level is measured using a standard AVL 437C smoke meter.

Fig 3.2 – Gas Analyzer

The research engine setup has a 2 liters capacity variable compression ignition engine which is basically a single cylinder four stroke multi-fuel engine. It consists of a eddy current dynamometer as loading system, fuel supply system for both the diesel supply and petrol supply, water cooling system, lubrication system and various sensors , instruments integrated with the computerized data acquisition system for online measurement of load, air and fuel flow rate, instantaneous cylinder pressure, injection pressure etc. The engine has two flow meters to measure the flow to the engine and the calorimeter.

IV. Results and Discussion

The C.I engine test rig was first operated with the diesel fuel and then with the four blends of plastic pyrolysis oil and diesel B5, B10, B15, B20. The engines performance parameters like Brake Power, Brake Mean Effective Pressure, Brake Thermal Efficiency, Mechanical Efficiency, Specific Fuel Consumption, Air / Fuel ratio have been evaluated for diesel, B5, B10, B15 and B20. Even the emission parameters like CO emissions, CO_2 emission, HC emission, NO_x emission and smoke emissions also have been evaluated for diesel, B5, B10, B15, B20. The results are discussed below:

4.1. Brake mean effective pressure vs Brake power

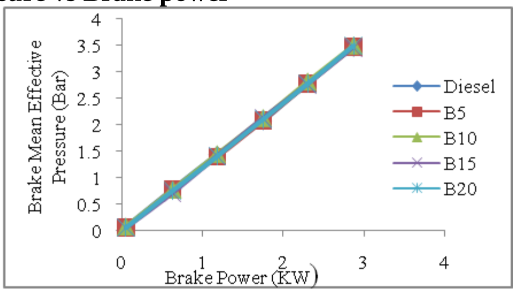

Fig 4.1 – Brake Mean Effective Pressure vs Brake Power

The BMEP of the plastic pyrolysis oil blends is almost nearer to that of the diesel at all the loads. The BMEP is linearly increasing with the increase in brake power as shown in fig.4.1.The reason for the same value of BMEP for the diesel and plastic pyrolysis oil blends is due to the higher oxygen content and higher combustion of the blends. Since the brake power and the torque values have no major variations from the values of diesel.

4.2.Brake thermal efficiency vs Brake power

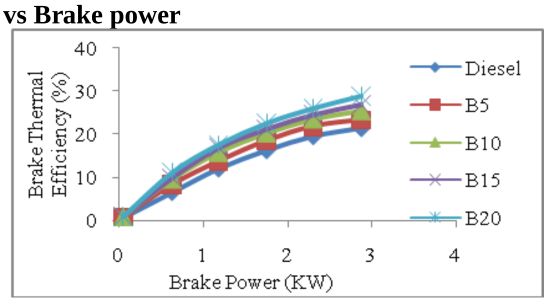

Fig 4.2 – Brake Thermal Efficiency vs Brake Power

From the Fig 4.2, it is observed that with increase in the engine load the brake thermal efficiency increases. The brake thermal efficiency of all the blends is initially equivalent to that of the diesel but as the load increases the BTE of the blends is higher than that of the diesel. As the load increases it can be concluded that the brake thermal efficiency of B20 is around 6% higher than that of the diesel. This may be due to the higher brake power of the engine when compared to its thermal input from the fuel.

4.3. Mechanical efficiency vs Brake power

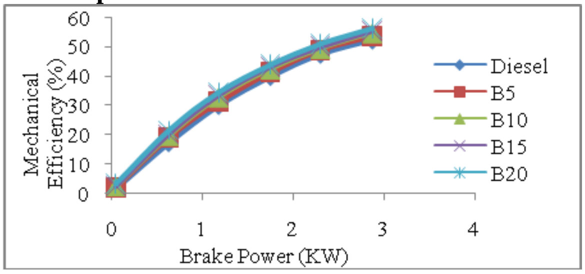

Fig 4.3 – Mechanical Efficiency vs Brake Power

It is found that the mechanical efficiency increases with an increase in the engine load shown in fig 4.3. The mechanical efficiency of the blends is almost equivalent to that of the diesel fuel but the mechanical efficiency of the blend B20 is slightly better when compared to that of the diesel. As the brake power is increased to 2.5 KW, it can be observed that the mechanical efficiency of the blend B20 is increased by 4% compared to diesel, but at all other loads the mechanical efficiency is similar to that of diesel.

4.4. Specific fuel consumption vs Brake power

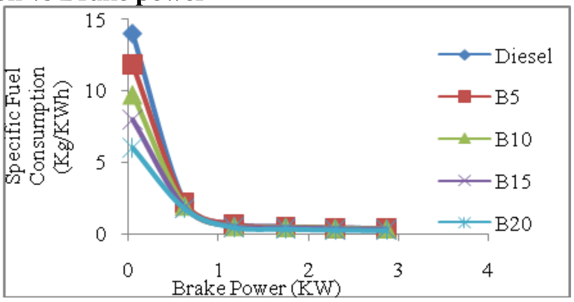

Fig 4.4 – Specific Fuel Consumption vs Brake Power

The SFC of the plastic pyrolysis oil blends is initially lower when compared to the diesel but as the load increases the SFC of the blends is equal to that of the diesel as shown in Fig 4.4. This may be due to the varying thrust output or because of the combined effects of the higher fuel flow rate and the lower heating value.

4.5. Air / fuel ratio vs Brake power

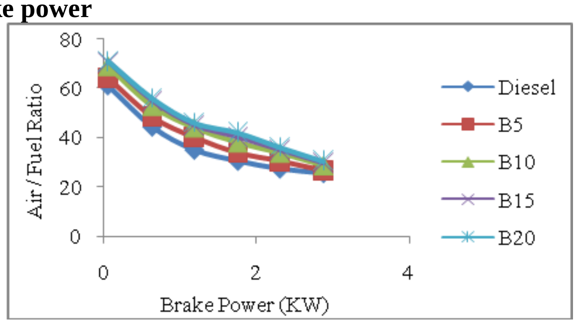

Fig 4.5 – Air / Fuel Ratio vs Brake Power

The A/F ratio of the plastic pyrolysis oil blends is initially higher than that of diesel. As the load increased to full load it is almost near to that of the diesel as shown in Fig 4.5. The A/F ratio of B15 and B20 are higher when compared to other blends. Also among these B20 is having slightly higher A/F ratio. It can be noticed that as the brake power increases the A/F ratio decreases. At the full load, the A/F ratio of the blend B15 and B20 is higher than diesel. This may be due to the higher oxygen content of the blends requiring less amount of diesel to run the engine at the provided loads.

4.6. CO Emission vs Brake Power

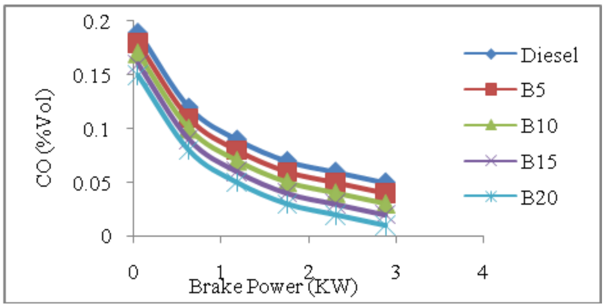

Fig 4.6 – CO emission vs Brake Power

As the load increases the CO emissions of the fuels are reduced as shown in Fig 4.6.The CO emissions of the blends initially were almost equivalent to that of the diesel but as the load is increased the CO emission of the blends are lesser than that of the diesel. It can be detected that at full load condition the CO emissions by % vol of B20 is approximately 40% lower when compared to that of the diesel. It is mainly formed due to the large size droplets of fuel or insufficient swirl or turbulence in the combustion chamber.

4.7. HC Emission vs Brake Power

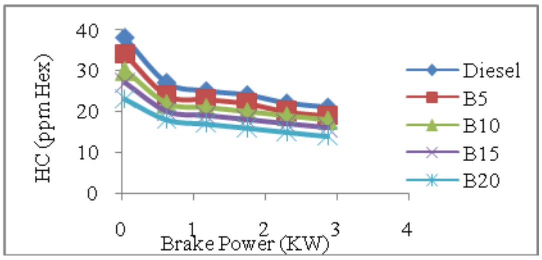

Fig 4.7 – HC emission vs Brake Power

From Fig 4.7, it can be determined that as the load is increasing the HC emissions of the fuels are decreasing. The HC emissions of the plastic pyrolysis oil blends are less when compared to that of diesel. The HC emissions of the diesel are higher than that of the blends. The unburned hydrocarbons are generally the products of the incomplete combustion and also because of the lean air-fuel mixture, the HC emissions increases in case of diesel fuel.

4.8. NOx Emissions vs Brake Power

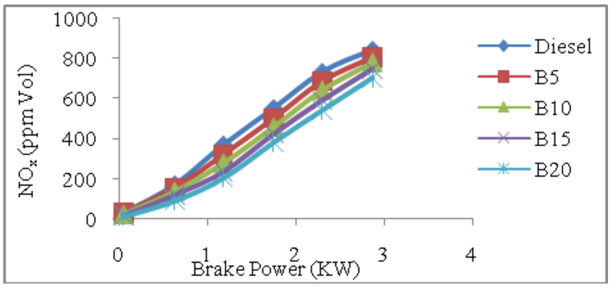

Fig 4.8 – NO_x emission vs Brake Power

From the Fig 4.8, it is recorded that with an increase in the engine load the NO_x emissions of the fuel increases. The NO_x emission of the plastic pyrolysis oil blends initially is equivalent to that of the diesel and as the load increases the NO_x emissions of the diesel increases. The increase in the density of fuel may increase the NO_x emissions because the fuel injector injects a constant volume, but a larger mass of more dense fuels which when burned, produces more NO_x emissions. Also, as the temperature of combustion increases the NO_x emissions increases.

4.9. Smoke Emission vs Brake Power

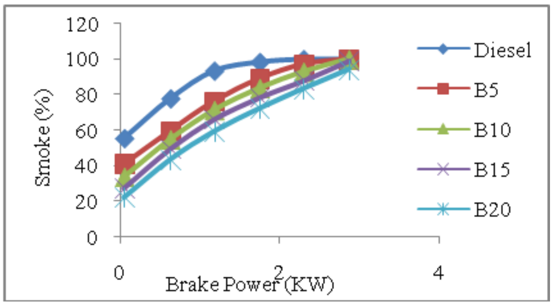

Fig 4.9– Smoke emission vs Brake Power

It is observed that the smoke emissions of the fuels are increasing with an increase in the engine load shown in fig 4.9. The smoke emissions of the plastic pyrolysis oil blends are lower than that of the diesel fuel. The reduction in the smoke emissions is due to the complete atomization and combustion of the blends when compared to that of the diesel.

V. Conclusion

In this work, the engine performance and emission characteristics are studied at differnt loads by using the blended fuels viz., B5, B10, B15 and B20. Performance parameters of the blends are almost similar and better than that of diesel. As the load increases it can be concluded that the brake thermal efficiency of B20 is around 6% higher than that of the diesel. The emissions like CO, HC, NO_x and smoke emissions of the blends are lower than that of the diesel. At full load condition the CO emissions of B20 is approximately 40% lower when compared to that of the diesel. Further it is concluded that with the higher order blends i.e., blends containing higher plastic pyrolysis oil percentage, a more effective reduction in the emission parameters can be expected when compared to the diesel.

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