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Research Article

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Combustion characteristics of waste pyrolytic plastic oil at full load operation in a direct injection compression ignition engine

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ABSTRACT

The use of alternate fuels in diesel engines has become very significant due to the fast depletion of conventional fossil fuels. Solid wastes like plastics cause several environmental problems and hindrances to existence of plant and animal life. This paper focuses on use of waste plastic oil as fuel. The combustion characteristics of a diesel engine fueled with plastic oil as fuel derived from the pyrolysis process. The blends of 15% waste plastic oil and 25% waste plastic oil with diesel are prepared on volume basis and tested on a single cylinder CI engine. The properties of WPO blends are found to be similar to that of diesel and within the ASTM standards. The combustion characteristics like In-cylinder pressure, Rate of pressure rise and Net heat release rate of the WPO blends exhibited characteristics competent with that of straight diesel. The curves indicating the ignition delay and maximum cylinder pressure are also presented for the blends. The ignition delay increased with increase in blend percentage and the peak pressure reduced with higher blends. The heat release rate of the WPO blends is slightly lower compared to diesel.

Keywords: Combustion, Waste plastic oil, Cylinder pressure, Heat release rate.

INTRODUCTION

Plastics are widely used in our day to day life on various applications and disposal of discarded and used plastics pose a major problem threatening the fragile environment of our living planet earth. The decomposition of plastics always was a big problem to environment. Conversion of used plastics into fuel is an intelligent idea to resolve the harmful threats caused by plastic usage. The oil produced from waste plastics have the expected fuel characteristics like flash point, calorific value and cetane index and are found competent to that of diesel fuel [1-3].The performance and emission analysis was carried out by Mani *et al*. [4] using waste plastic oil blends on CI engine at varying engine loads. The plastic oil was obtained by pyrolysis process of high density polyethylene. The experimental analysis revealed the lower values of BTE over the entire performance range and increase in EGT compared to diesel fuel. The brake specific fuel consumption reduced on increasing engine load conditions and it increased steadily with increasing of blend ratios. Increase in mechanical efficiency was observed at increase in engine loading conditions. The increase in blend composition resulted in increase of NO_x and CO emissions. But, the NO_x emission increased and CO emission reduced with the increase of engine load. The increase in UBHC emission with increase in blend proportion was observed. The emission of carbon di oxide was lower compared to diesel [4]. Subsequently, Mani *et al.* [5] carried out study on combustion characteristics using waste plastic oil and its blends. 100% waste plastic oil was used as a fuel and the engine was run without any modifications.

Straight waste plastic oil was used as a fuel in diesel engine which was operated with cooled EGR system. The oxides of nitrogen emissions were reduced when operated with the EGR system as compared to non EGR system. Minimal level of smoke, CO and HC emissions were obtained with reduced NO_x emissions using 20% EGR level. Combustion characteristics were found to be good by using EGR. The peak pressure reduced by five percent with 20% EGR compared to the engine operated without EGR. The use of EGR resulted in NOx emissions by using WPO [6].Mani and Nagarajan [7] carried out experimental investigations using 100% WPO. They found a longer ignition delay of 2.5° for waste plastic oil compared to diesel. High NO_x emissions by about more than 25% and reduction in CO emissions by about 5% was observed. Higher BTE was observed for WPO till 75% of the rated load. The experimental investigations were carried out on varying the injection timings using the waste plastic oil. The retarded injection timings decreased the oxides of nitrogen, carbon monoxide and UBHC emissions and increase of brake thermal efficiency at all test conditions [8, 9].

The present study involves the evaluation of combustion characteristics of waste plastic oil blended with diesel fuel at 15% (WPO15) and 25% (WPO25) blend ratios. Combustion parameters like In-cylinder pressure, Rate of pressure rise, Net heat release and cumulative heat release are evaluated for WPO blends and compared with diesel fuel.

2. Experimentation and Engine Details

The waste plastic oil is produced by the pyrolysis process using batch reactor. This WPO are blended with diesel on volume basis.15% blend (WPO15) and 25% blend (WPO25) of WPO with diesel fuel is prepared and their properties are tabulated in Table 1. The density and viscosity of the blended fuel increases with increase in percentage of WPO. The calorific value of WPO blends are found to be lesser compared to diesel fuel. The cetane index of the WPO blends are found to be slightly lower in than with that of diesel fuel. The properties are found to be within ASTM specifications. The specification details of the experimental engine set up is shown in Table 2. The standard compression ratio of the engine is 17.5:1 with injection timing of 23°bTDC. Loads are applied on the engine by using eddy current dynamometer. The cylinder pressure are measured by the PCB make SM111A22 piezoelectric sensor which converts the mechanical pressure into digital signals and the range of the piezo electric sensor is around 5000 psi. The net heat release rate is found by applying the first law of thermodynamics. The rate of pressure rise is evaluated with pressure and crank angle values. The calibration of the combustion measuring transducers is carried out and the uncertainty level is found to be ± 2.5%.

Table 1.Properties of WPO blends and Diesel

Properties	Units	Testing Methods	Diesel[5]	WPO15	WPO 25
Density @ 15°C	kg/m^3	IS:1448 P:16	835	846	851
Kinematic viscosity, @ 40°C	Cst	IS:1448 P:25	2.15	2.48	2.59
Flash point	°c	IS:1448 P:20	49	46	44
Fire point	°c	IS:1448 P:20	59	56	56
Gross calorific value	kJ/kg	IS:1448 P:6	44,000	43,238	42,698
Sulphur content	%	IS:1448 P:33	0.042	0.02	0.01
Carbon residue	%	IS:1448 P:122	0.38	0.04	0.07
Ash content	%	IS:1448 P:126	0.01	0.01	0.01
Cetane index		IS:1448 P:9	53	51	49

Table 2. Test Engine Specifications

Engine Parameters	Specifications
Make and model	Kirloskar TV1 oil engine
Type	Single cylinder, 4 stroke
Bore/Stroke	87.5mm/110mm
Rated power	3.5kW @1500 rpm
Compression ratio	17.5:1
Injection timing	23° bTDC
Loading type	Eddy current dynamometer
Piezo electric sensor	PCB make SM111A22
Piezo sensor range	5000 psi
Engine control unit	PE 3 series ECU

RESULTS AND DISCUSSION

3.1 Variation of Cylinder Pressure

The In-cylinder pressure of diesel and blends of WPO - 15% WPO (WPO15) and 25% WPO(WPO25) at standard setting are shown in Figure 1A at full load condition. The delay period is noticed to be 16° for diesel at full load conditions and for the WPO blends, the delay period increased steadily with increase in blend composition of WPO. The delay period is observed as 17°and 17.8° for the 15% and 25% WPO blends respectively. This increase in delay period is due to lower Cetane index which reduces with composition of WPO in the blend.

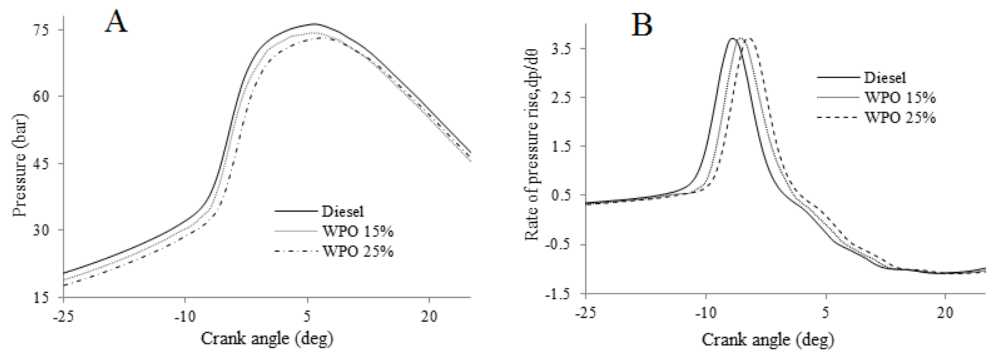

Figure 1. Variation of (A) In-cylinder pressure and (B) Rate of pressure rise at full load condition

The rate of pressure rise indicate the start of combustion as seen in Figure 1B. The ignition delay variation for the WPO blends and diesel at various loads is presented in Figure 2A. The delay period reduces with increase in engine load conditions. This is due to the increase in charge temperature within the combustion chamber where the mixture would be rich[9, 10]. This same phenomenon of reduction in delay period with increase in load are also observed for the WPO blends. The ignition delay at 50% loading was observed to be 18° and 18.6° for 15%WPO blend and 25%WPO blend [12].

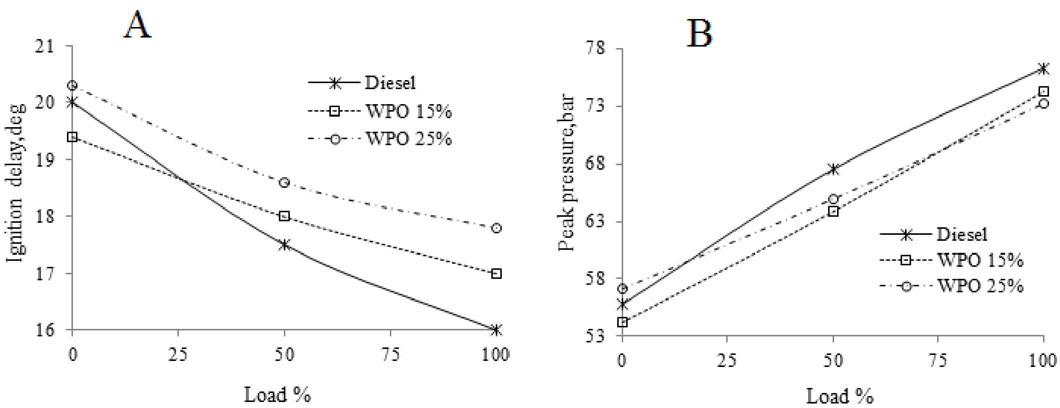

Figure 2. Variation of (A) Delay period and (B) Peak Cylinder pressure with load

Figure 2B shows the variation of peak cylinder pressure with load for diesl and WPO blends. The peak cylinder pressure of the WPO blends are observed to be slightly lower than that of diesel. The peak pressure of the diesel fuel is observed to be 76.3 bar and for 15% and 25%WPO blends, it is observed to be 74 bar and 72 bar respectively. This reduction of peak pressure for WPO blends could be due to the poor atomization characteristics affecting the premixed combustion stage at higher loading. The peak pressure variation of the WPO blends at various loads is seen in Figure 2B. As seen for diesel fuel, the general trend of increase in peak pressure with increase in engine loads is observed. The peak pressure is observed to be 67.5 bar, 64 bar and 65 bar for diesel, 15%WPO blend and 25% WPO blend at 50% engine loading.

3.2 Variation in Heat Release Rate

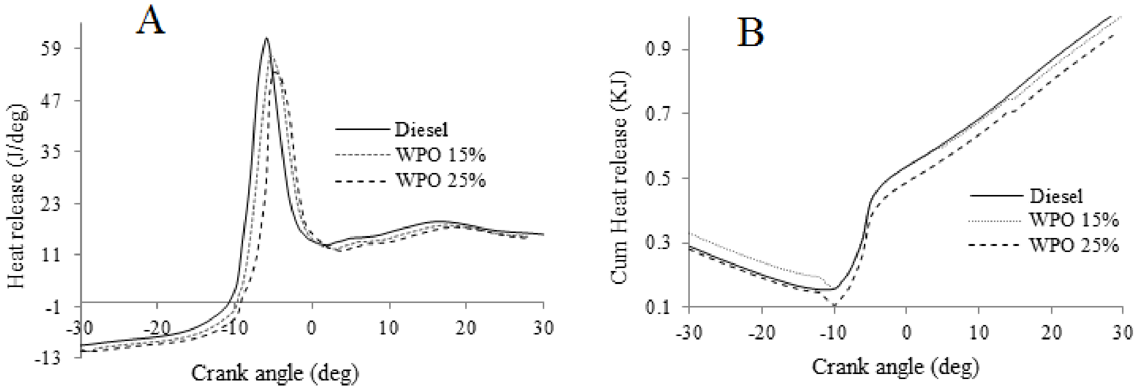

Figure 3. Variation in (A) Rate of heat release and (B) Cumulative heat release at full load operation

The variation in heat release rate is shown in Figure 3A for diesel, 15%WPO blend and 25% WPO blend at full load condition. The heat release rate reduces with increasing blend percentage of WPO. The lower heat release rate of the WPO blends indicate the reduced performance of the engine as the brake thermal efficiency reduces. The higher density as well as viscosity of the WPO blends results in improper mixture formation. This results in poor atomization of the fuel which results in reduced heat release rate of the WPO blends by combustion. The peak heat release rate is found to be 60J/CA, 57J/CA and 54J/CA for diesel, 15%WPO blend and 25%WPO blend respectively at full load condition. The peak heat release rate is found slightly away from TDC for WPO blends compared to diesel. The variation of cumulative heat release with crank angle is shown in Figure 3B. The cumulative heat release of 15%WPO blend and 25% WPO blend is found to be lesser by 1.2% and 2.3% respectively compared to diesel fuel.

CONCLUSION

The combustion characteristics were studied for WPO blends (WPO15 and WPO25) and compared with diesel fuel. The WPO blends exhibited good combustion characteristics but they are slightly inferior compared to straight diesel. The peak pressure of the WPO blends is lesser by 3% compared to straight diesel. The peak pressure increased with higher loads for all the fuels. The ignition delay of the WPO blends is found to increase in comparison with diesel and the ignition delay period is 17° and 17.8° for 15% and 25% WPO blends. Also, the delay period reduces with increase in engine load conditions. The heat release rate is found to be lesser with increase in composition of WPO blends and the heat release rate reduced by 6 to 8% for the WPO blends compared to diesel fuel. Moreover, the peak heat release rate moved away from TDC for the WPO blends. The cumulative heat release also reduced by 1.2% and 2.3% for the 15%WPO and 25% WPO blend..

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