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Effect of variable compression ratio on performance and emission for a diesel engine fuelled with waste plastic pyrolysis oil blended with diethyl ether

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ABSTRACT

This work investigates the effect of variable compression ratio on the performance and emission characteristics of a single cylinder, direct injection diesel engine powered by waste plastic pyrolysis oil blended with diethyl ether. Experiments were conducted with different compression ratios of 15, 16, 16.5 and 17 at various load conditions with a constant speed of 1500 rpm. Two blends of WD05 and WD10 on volume basis have been tested and compared with respect to waste plastic pyrolysis oil and diesel fuel. Brake thermal efficiency was slightly higher with respect to diesel fuel. It was observed that the exhaust emissions are significantly decreased with increase in diethyl ether waste plastic pyrolysis oil (DEE –WPPO) at full load conditions. By increasing the compression ratio from 15 to 17, produces lower smoke opacity, hydro carbon (HC), Oxides of nitrogen (NO_x) and carbon monoxide (CO) respectively.

Key words: Waste plastic pyrolysis oil, variable compression ratio, diesel engine, diethyl ether, emission, performance.

INTRODUCTION

The search of alternative fuels for diesel engines from the non-conventional energy sources are continuously growing owing to rising price of petroleum fuel, the threat to the environment from engine exhaust emissions, the depletion of fossil fuels, the global warming effect and so on Plastics waste management has become a problem world over because of their non-degradable property. A majority of landfills, allotted for plastic waste disposal, are approaching their full capacity. Thus recycling is becoming increasingly necessary.

Among the oxygenated alternatives which could work as ignition improvers are dimethyl ether (DME) and diethyl ether (DEE) with advantages of high cetane number and oxygen content. DI ethyl ester is a liquid at ambient conditions, is produced from ethanol by dehydration process which makes it attractive for fuel storage and handling. It can also assist to improve engine performance and reduce the cold starting problem and emissions when using as a pure or an additive in diesel fuel. The performance and emission characteristics of a diesel engine using fuels like DME and DEE offered promising alternatives. Diethyl ether is also a renewable fuel as it is produced from ethanol by dehydration process. It has several favorable properties such as higher cetane number, high oxygen content, low auto-ignition temperature and high volatility. Therefore it can assist in improving engine performance and reducing the cold starting problem and emission when used as a pure or additive in diesel fuel.

The objective of the present investigation is to study the effect of variable compression ratio on the performance and emission of a waste plastic pyrolysis oil fuelled diesel engine, with addition of 05% and 10% diethyl ether (DEE) at various load conditions and the results were compared with diesel

EXPERIMENTAL SETUP AND PROCEDURE

The engine used in the present study was a Legion brother's engine, single cylinder, air cooled, and vertical direct injection variable compression ratio multi-fuel engine with the specification given in Table 3. The experimental setup is shown in Figure 1. The engine was coupled to an eddy current dynamometer. The exhaust side of the engine consists of exhaust gas temperature indicator, exhaust gas analyzer (AVL Digas 444) and smoke meter (AVL 437). The operating ranges with accuracy for gas analyzer and smoke meter were given in Table 2. The standard compression ratio of the engine was 16.5. The engine was run at four different compression ratios (15, 16, 16.5 and17). All tested fuels were conducted at five different engine loads (2, 4, 6, 8 and 10) at constant engine speed of 1500 rpm. Samples were prepared, namely WD05 and WD10 blends on a volume basis and the experiments were conducted over the same range of loads

RESULTS AND DISCUSSION

Brake Thermal Efficiency: Brake thermal efficiency (BTE) is one of the important performance parameters which indicate the percentage of energy present in the fuel that is converted into useful work. Figure 2 explains the variation of brake thermal efficiency with compression ratio at max load for WD05 and WD10 blends. The increasing trend in efficiency with increasing the concentration of diethyl ether may be due to the lower heating value of waste plastic pyrolysis oil compared to that of diesel. At higher concentration of DEE, the increase in BTE may be due to the ability of DEE to reduce the surface tension or interfacial tension between two or more interacting immiscible liquids helped the better atomization of fuel, which improves the combustion. Also the lower fuel consumption may be one of the reasons for increased brake thermal efficiency. A slight decrease is observed in the BTE for WD05 as compared to diesel fuel. The increasing trend in efficiency with increasing the compression ratio was observed.

Exhaust gas temperature: The variation of exhaust gas temperature (EGT) with change in compression ratios were shown in Figure 3 Exhaust gas temperature decreases with compression ratio for all blends when compared to the diesel fuel. This is due to fact that DEE has high latent heat of evaporation value and this leads to reduction in exhaust gas temperature.

Brake specific fuel consumption: The variation of brake specific fuel consumption (BSFC) with change in compression ratios were shown in Figure 4. From the graph it is seen that as the compression ratio increases the Brake specific fuel consumption decreases. This may be due to the increase in temperature and pressure leads to increase the rate of complete combustion and there by decreases the brake thermal efficiency because of increase in thermal efficiency.

CO Emissions: The variation of CO emission with change in compression ratios for diesel and waste plastic pyrolysis oil-diethyl ether blends at maximum loads were shown in Figure 5. It can be seen all blends are found to emit significantly lower CO concentration compared to that of pure diesel over all compression ratios. When the percentage of diethyl ether increases, CO emission decreases. The excess amount of oxygen content of results in complete combustion of the fuel and supplies the necessary oxygen to convert CO to CO_2. Both HC and CO emissions are low at higher percentage of diethyl ether.

NO_x Emissions: Figure 6 shows the variation of NO_x emissions with variation compression ratio for diesel and waste plastic pyrolysis oil-diethyl ether blends at maximum loads. It is seen from the graph that, increase in compression ratio increases the NO_x emission whereas the increase in DEE percentage decreases the formation of NO_x. This may be due to increase in temperature of the intake air at higher compression ratio and availability of oxygen in DEE leads to decrease in NO_x.

Smoke Opacity: Figure 7 presents the variation of smoke opacity with compression ratio for diesel and waste plastic pyrolysis oil diethyl ether blends. It is observed that smoke opacity of diesel and various blends of diethyl ether was lower at low loads, but increased at higher engine loads because more fuel is injected at higher load so less oxygen will be available for the reaction. Also it is noticed that smoke opacity for all diethyl ether percentages are lower than that of pure diesel. This is because smoke decreases with high oxygen content in the biodiesel that contributes to complete fuel oxidation.

HC Emissions: Figure 8 shows the variation of HC emission with compression ratio for waste plastic pyrolysis oil blended with diethyl ether. Hydrocarbon emission is an important parameter for evaluating emission behavior of the engine. The HC value continuously decreases with the increase in the percentage of diethyl ether for all compression ratios. The obvious reason for that is the complete combustion and higher inside temperature due to the availability of excess content of oxygen as compared to pure diesel fuel. At high compression ratio the temperature of the intake air increases which leads to complete combustion.

Table.1.Engine Specifications

Make	Legion
BHP	3-5
Number of cylinder	1
Bore	80
Stroke	110
Compression ratio	5:1 – 20:1
Method of loading	Eddy current dynamometer
Method of cooling	Water
Speed	1450-1600 rpm

Table.2.Properties of fuels

Properties	Standard test methods	Diesel	WPPO	DEE
Calorific Value J/Kg	ASTM D 445	46500	45216*	33900
Specific gravity	ASTM D 2217	0.840	0.798*	0.713
Flash point °C	ASTM D93	50	42*	45
Fire point °C	ASTM D93	56	45*	55
Chemical structure		$C_{12}H_{26}$	C_nH_{2n-1}	C_2H_5-O- C_2H_5
Cetane number		40-45	51	126

Table.3.Instrumentation and their accuracies

Instruments	Range	Accuracy	Measurement techniques	Percentage uncertainties
AVL Digas 444 Gas Analyzer	CO 0-10% CO_2 0-20% HC 0-10000 NOx 0-5000	±0.02% ±0.03% ±20ppm ±10ppm	NDIR NDIR Electro Chemical Sensor Electro Chemical Sensor	±0.2% ±0.15% ±0.2% ±0.2%
AVL 437 Smoke Meter smoke	Smoke-BSN 0-10 Absorption k m-10-99.99	±0.1 ±0.01		±1%
Tachometer ((Speed)	0-10,000 rpm	±10rpm	Magnetic Pick up type	±0.1%
Load	0-50 kg	±0.1 kg	Stain gauge type	±0.2%
Burette		±0.1 cc		±1%
Pressure Pickup	0-100bar	±0.1 kg		±1%
Crank angle Encoder		±1°	Magnetic Pick up type	±0.2%
Ignition delay				±0.3%

Figure.1.Experimental setup

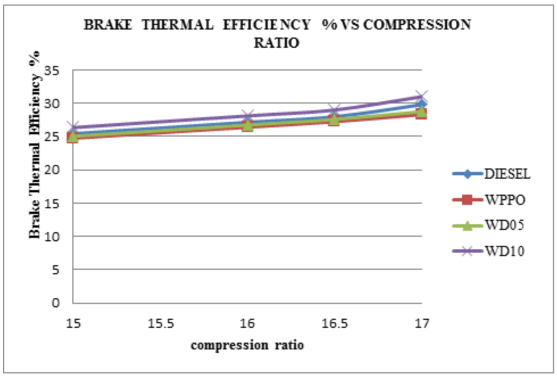

Figure.2.Brake Thermal Efficiency vs. Compression ratio

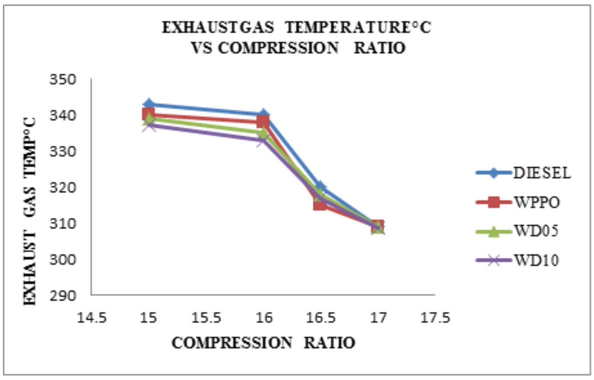

Figure.3.Exhaust gas temperatures vs. Compression ratio

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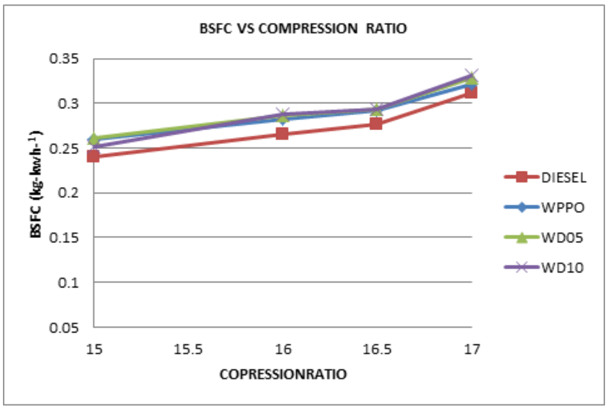

Figure.4.Brake Specific Fuel Consumption vs. Compression ratio

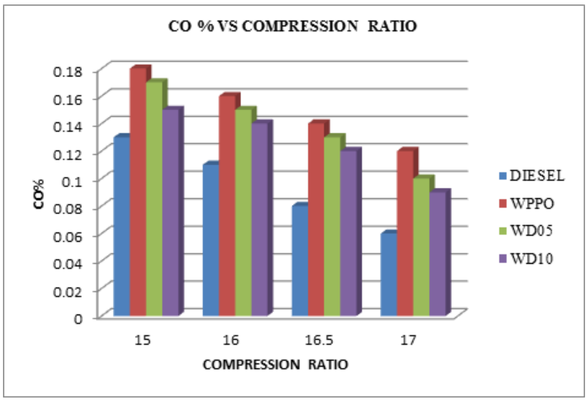

Figure.5.CO Emissions vs. Compression ratio

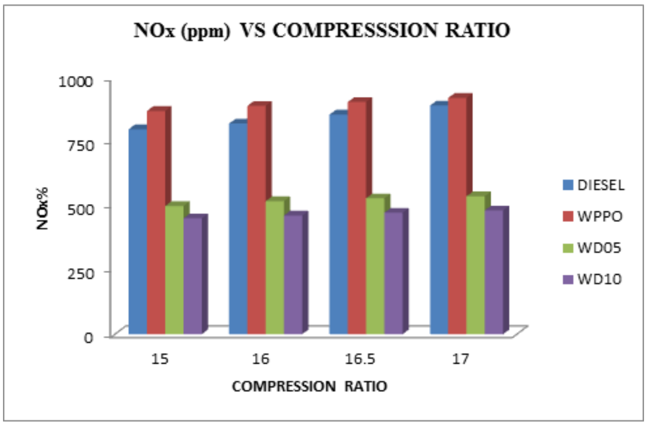

Figure.6.NO_x Emissions vs. Compression ratio

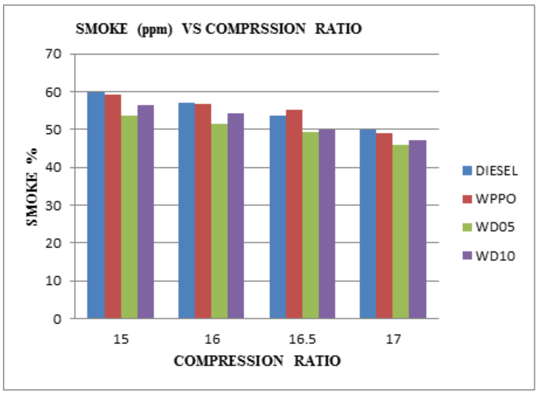

Figure.7.Smoke Opacity vs. Compression ratio

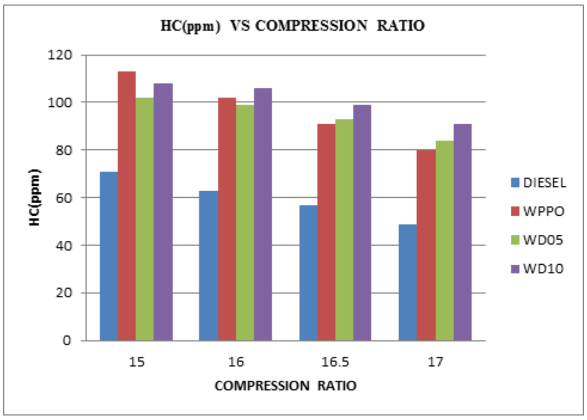

Figure.8.HC Emissions vs. Compression ratio

Abbreviations

DEE: Diethyl ether
WPPO: Waste plastic pyrolysis oil
WD05: Waste plastic pyrolysis oil+5%DEE
WD10: Waste plastic pyrolysis oil+10%DEE
CO: Carbon Monoxide
CO_2: Carbon Di-oxide
NO_X : Oxides of Nitrogen
HC: Unburned Hydro Carbon
VCR: Variable Compression Ratio

CONCLUSION

Increasing the percentage of diethyl ether and increase in compression ratio is increasing the brake thermal efficiency and BSFC slightly. Both NO_x and CO emissions decrease drastically with the increase in the blends of diethyl ether recorded maximum reduction with diethyl ether for all compression ratios. The measured HC for all blends of diethyl ether is higher than that of diesel. It is found to be higher with higher compression ratio and higher diethyl ether blends. Smoke opacity is reduced for all diethyl ether blends. It is observed to be lower with higher compression ratio. The best fuel combination is diethyl ether which has same combustion results with good reduction in the emissions as compared to base line diesel fuel; also less increase in the NOx emissions is noticed in diethyl ether as compared with diesel. As the cost of the DEE is less, so it can be used as a diesel fuel additive in engines.

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