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Optimization of Compression Ratio of a Diesel Engine Fueled with Tyre pyrolysis oil and diesel Blends

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Abstract: *In this paper the performance and emission characteristics of single cylinder Variable Compression Ratio (VCR) engine test rig are determined and the results were optimized using Response surface methodology technique. Input parameters were load, fuel blend and the compression ratio. During experimentation the variation of the various blends of tyre pyrolysis oil like TPO 10, TPO 25,TPO 50 and TPO 75 were used and tested in the engine. Load was varied on the engine in the range of 25%, 50% 75% and full load. Compression ratio was varied as 12,14,16 and 18. Trial was conducted to evaluate engine performance parameters like BTE, BSFC, HC and emission characteristics like CO and NOx which were recorded for every set of experiment. Interaction effects between input parameters and various fuel blends on responses are studied with the help of plots and commented in the paper. Then optimization of input parameters is carried out with respect to plots drawn for variable tests. It is observed that BTE increases and BSFC decreases with increase in load and compression ratio. Optimization analysis shows that the increase in compression ration increases NOx emission with the decrement in CO emissions. It is also found that reducing the Compression ratio to 12 reduces NOx significantly.*

Keywords: *Variable compression ratio (VCR), Brake thermal efficiency (BTE), Brake specific fuel consumption (BSFC), Response surface methodology (RSM), Brake mean effective pressure (BMEP)*

I. Introduction

Research on the alternative fuel has been the major area on which numbers of researchers are concentrating. In this regard the effect of compression ratio on the various performance parameters of the engine is of greater interest. K Murlidharan et al [1] worked on the performance, emission and combustion characteristics of diesel engine working at variable compression ratios of 18:1, 19:1, 20:1 and 22:1 for blends of methyl esters of cooking oil derived from waste of 20%, 40%, 60% and 80% by volume basis. They concluded that the brake thermal efficiency for B40 is somewhat higher that of pure diesel at higher compression ratios. The mean effective pressure found to be higher for B40 at lower compression ratios. They also commented that longer ignition delay, maximum rate of pressure rise, lower heat release rate and higher mass fraction was found at higher compression ratio for waste cooking oil methyl ester as compared with pure diesel. S.Kurre et al [2] worked on effect of Compression Ratio on diesel Engine emission and performance with Diesel- Ethanol Blends. They concluded that HC decreases and NOx increases with the increase in compression ratio. NOx also reduces as the ethanol increases in the blend. They found the comparable NOx reduction of 65% with E20 blend at compression ratio 17, as compared with the neat diesel. Carbon dioxide and smoke also found to be decreased with increase in the compression ratio. Brake specific fuel consumption decreases Brake thermal efficiency increase with the increase in compression ratio.

N. Mohite et al[3] Investigated the performance of diesel engine at variable compression ratio for different blends of ethanol- diesel like 5%, 10%, 15% and 20% ethanol. They observed slight variation of BMEP of different blends as compared to pure diesel. They found slight reduction in brake power at CR 18 with change in the compression ratio.

A Reddy et al [4] experimentally evaluated the effect of Compression Ratio on the performance of Diesel engine at various Loads. They concluded that as the compression ratio of the engine is increased, BSFC reduces. They found the maximum fuel consumption at CR 14. and maximum brake thermal efficiency at a compression ratio of 18 due to the superior combustion and better intermixing of the fuel. The least brake thermal efficiency was found at a compression ratio of 14.M.Kassaby et al [5] worked on the effect of compression ratio on an engine fueled with waste oil produced biodiesel/diesel fuel. They found that the engine torque for all blends increases as the compression ratio increases. The BSFC for all blends decreases as the compression ratio increases and at all compression ratios BSFC was higher for the higher blends as the biodiesel percent increase. The change of compression ratio from 14 to 18 resulted in the increase in brake thermal efficiency with increase the proportion of biodiesel in the blend.

Jincheng H.et al [6] worked on the performance of diesel engine with blend of diesel –ethanol fuel and compared with performance and emission of diesel. They concluded that due to lower heating value of ethanol there is a rise in fuel consumption. Thermal efficiency was comparable with diesel. The smoke emission was less than that of diesel. Carbon monoxide decreased for half load condition while increased for low load and speed. NOx and HC emissions were all higher for top loads at high speed. A Datta et al[7] worked on effect of compression ratio on the performance, combustion and emission from a diesel engine using palm biodiesel. They found that brake thermal efficiency decreases and brake specific fuel consumption increases with the use of palm biodiesel instead of diesel. The thermal efficiency increased and the brake specific fuel consumption decreased with the increase of compression ratio. The higher compression ratio results in higher in-cylinder pressure and higher heat release rate as well as lower ignition delay. The NO and CO emissions increase at higher compression ratio due to the higher pressure and temperature. On the other hand, the specific PM emission and smoke opacity are less at higher compression ratio. S. Nagaraja et al [8] investigated the effect of Compression Ratio on brake power, mechanical efficiency, indicated mean effective pressure and emission characteristics over the variable compression ratio engine fueled with preheated Palm Oil -Diesel Blends. They found that maximum mechanical efficiency at higher compression ratio and was higher than diesel. Also the brake power of blend O20 is found to be 6% higher and BMEP lower than pure diesel at higher compression ratio. They found that emission of CO, HC reduced with an increase in blending ratio and compression ratio of maximum load. But CO emission found to be higher than diesel. They suggested that the engine performance was optimum at O20 blend and at higher compression ratio of 20 at full load condition. G. Miraculas et al [9] worked on the effect of compression ratio on diesel engine fueled with tamanu oil methyl ester and its blends. They found that biodiesel can be blended with diesel at an optimum compression ratio of 20 to get the improved performance and reduced emissions. B. Bora et al [10] worked on the on the effect of compression ratio on performance, emission and combustion characteristics of a duel fuel diesel engine fueled with raw biogas. They found the reduction in CO and HC emissions but increase in the NOx emissions with increase in the compression ratio from 16 to 18.They suggested to operate the duel fuel engine at higher compression ratio.

From the above literature it is observed that compression ratio affects the performance and emission characteristics and should also be verified for TPO and diesel blends and to evaluate the optimum compression ratio for the improved performance of the engine.

Objective of this paper is to study the effect of compression ratio on the performance and emission of diesel engine fueled with tyre pyrolysis oil and diesel blends.

II. Engine Specification

Parameter	Details
Engine	VCR High speed Diesel
Bore diameter (cm)	8.75
Stroke length(cm)	11
Maximum power(kW)	3.5
Maximum speed(rpm)	1500
Connecting rod length (cm)	23.4
Swept volume (cc)	661.5
Stroke and cylinder	4 and 1
Speed type	Constant
C.R	12 to 18:1
Cooling type	Water
Orifice dia. (cm)	2.0
Dynamometer	Eddy current type, water cooled

III. Methodology

Initially engine was made to run on diesel from zero load to peak load conditions. Then the fuel tank was totally drained out and the different blends of diesel and tyre pyrolysis oil were inducted in the tank. During the test readings taken for variations in load, speed, air flow rate, fuel flow rate, engine temperature and exhaust gas temperature for four levels of loading conditions and four levels of TPO proportions like 10%,25% 50% and75% in the blend. Load was varied on the engine in the range of 25%, 50% 75% and full load. Compression ratio was varied as 12,14,16 and 18. BTE, BSFC, HC, CO and NOx were chosen as the output combustion parameters which were recorded for every set of experiment. All the readings were noted for all the blends. Then all results were computed and then compared with pure diesel.

IV. Results And Discussions

Various graphs were plotted for variable compression ratio which is taken on X axis and performance parameters on Y-axis. Performance parameters like BTE, BSFC, and exhaust emission parameters like CO, HC and NOx were analyzed.

V. Performance Analysis

5.1. Brake Thermal efficiency (BTE)

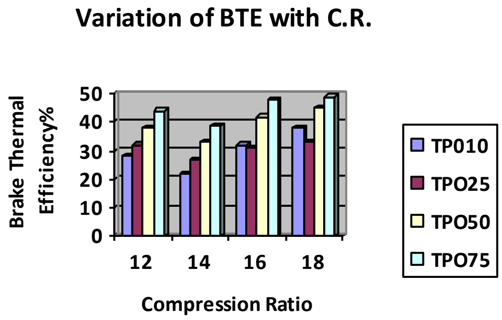

Figure1. Variation of BTE with C.R at full load

Variation of Brake thermal efficiency with compression ratio for different blends of TPO at full loading conditions is shown in figure 1.It is observed that increase with the compression ratio generally BTE increases. Lower BTE was observed at compression ratio 14 and thereafter it continuously increases. For lower compression ratio due to incomplete combustion of fuel BTE is less. Higher value of BTE was observed at compression ratio 18. This is because at higher compression ratio the rate of combustion ofTPO increases which result better thermal efficiency

5.2. Brake Specific fuel consumption (BSFC)

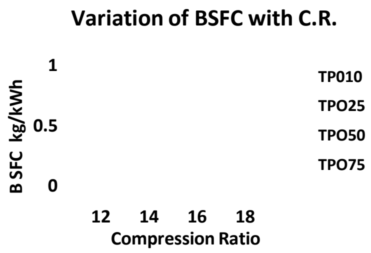

Figure2. Variation of BSFC with C.R at full load

Variation of Brake Specific Fuel Consumption with compression ratio for different blends of TPO at full loading conditions is shown in figure 2.It is observed that at lower compression ratios, fuel consumption is high due to incomplete combustion of fuel. The maximum fuel consumption is measured at CR 12.It is also found that as the compression ratio of the engine is increased, BSFC decreases. At higher compression ratio of 18 lowest BSFC was observed. This is because at higher compression ratio, brake power increases.

5.3. Carbon Monoxide emissions (CO)

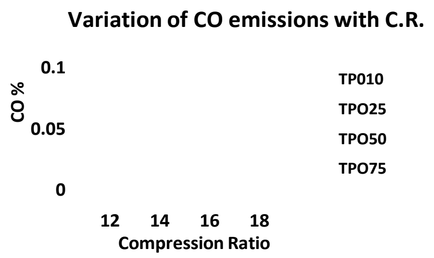

Figure3. Variation of CO emissions with C.R at full load

Variation of Carbon monoxide emissions with compression ratio for different blends of TPO at full loading conditions is shown in figure 3.It is found that with increase in the load CO emissions decreases. This is due to increase in the fuel requirement of engine with increase in the load. It is also observed that with increase in the compression ration CO emissions slightly decreases. This is because with increase in the compression ratio combustion improves causing burning of carbon particles forming CO_2 instead of CO.

5.4. Nitrogen oxides emissions (NOx)

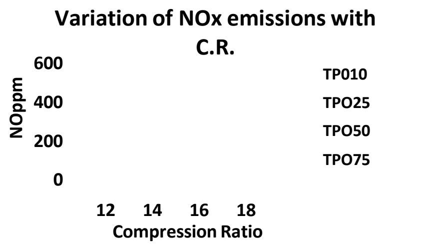

Figure4. Variation of NOx emissions with C.R at full load

Variation of nitrogen monoxide emissions with compression ratio for different blends of TPO at full loading conditions is shown in figure 4. It is observed that as the compression ratio increases the NOx emissions increases for all the TPO blends. Lower NOx was found at lower compression ratio. This is because of the lower cylinder temperatures due to incomplete combustion of fuel. With increase in the compression ratio combustion improves and complete combustion occurs which leads to the increase in the cylinder temperature and thus increasing NOx emissions Higher NOx was observed at higher compression ratio of 18 while lowest Nix emissions were observed at lower compression of 12.

VI. Conclusion

From the experimentation following conclusions were drawn

- For lower compression ratios, fuel consumption is high due to incomplete combustion of fuel. The maximum fuel consumption is found at CR 14.Further above CR14 when compression ratio is increased, BSFC decreases showing lowest BSFC at CR 18. This is due to increase in brake power.
- Brake thermal efficiency increases with increase in the compression ratio.The maximum brake thermal efficiency is obtained at a compression ratio of 18, due to the superior combustion and better intermixing of the fuel. The least brake thermal efficiency is obtained at a compression ratio of 14
- With increase in the load CO emissions decreases. This is due to increase in the fuel requirement of engine with increase in the load.
- It is also observed that with increase in the compression ratio,CO emissions slightly decrease. This is because with increase in the compression ratio combustion improves.

- As the compression ratio increases NOx emissions increases for all the TPO blends. Lower NOx was found at lower compression ratio. This is because of the lower cylinder temperatures due to incomplete combustion of fuel.
- Higher NOx was observed at higher compression ratio of 18 while lowest NOx emissions were observed at lower compression of 12.

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