Effect of Compression Ratio on Performance and Emissions of a Single Cylinder Four Stroke Diesel Engine

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Abstract – Experimental work was conducted to evaluate the effect of compression ratio on performance and emission by using conventional diesel fuel on the single cylinder four stroke variable compression ratio (VCR) engine. The compression ratio is a factor that influences the performance characteristics of an internal combustion engines. This work is an experimental investigation of the influence of the compression ratio on brake thermal efficiency, specific fuel consumption, and Exhaust Gas Temperature (EGT) with emission HC, CO & NOx. of the Kirloskar variable compression ratio duel fuel engine. Compression Ratios of 16, 17, 18, 19 and 20 and engine loads of 0 kg to 10 kg, with increments of 2kg, were utilized for Diesel Engine. The tests were performed at 1500 rpm engine speed and emissions were measured by AVL emission 5 gas analyser.

Keywords— VCR Engine, CR, .NO_x, HC,CO

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1. INTRODUCTION

In the present research study, the effect of different compression ratios on engine performance and emission behaviour of diesel engine was studied and optimum compression ratio was determined. The compression ratios set for study were ranging from 16 to 20 for diesel engine. The present study focuses on investigating the better compression ratio for the variable compression ratio diesel engine at variable loads.

2.1. EXPERIMENTAL SETUP

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current dynamometer for loading. The schematic diagram of experimental setup is shown below in fig.1. The compression ratio can be changed by changing the clearance volume. Setup is provided with necessary instruments and provision for interfacing airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, and fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement.

Table1. Engine Specifications

S. no.	Description	Parts with specification
1	Variable Compression Ratio	Model: VCR, Single cylinder
	Engine	diesel, 4 stroke, water- cooled
		stroke 110 mm, bore 80 mm
		Manual Crank Start,

2	Power	2.237–3.728 kW
3	Speed	1450–1550 rpm
5	Maximum Load	10 kg
6	Injection pressure	200 bar
7	Compression ratio range	6:1–20:1
9	Lubrication oil	SAE 20W40
10	Dynamometer	Type: eddy current, air cooled
		with loading unit
11	Load measurement	Direct coupling, strain gauge,
		manual loading
12	Exhaust Gas Calorimeter	Type shell and tube, *K* type
		thermocouple, water cooling
13	Exhaust gas analyser	Model—AVL

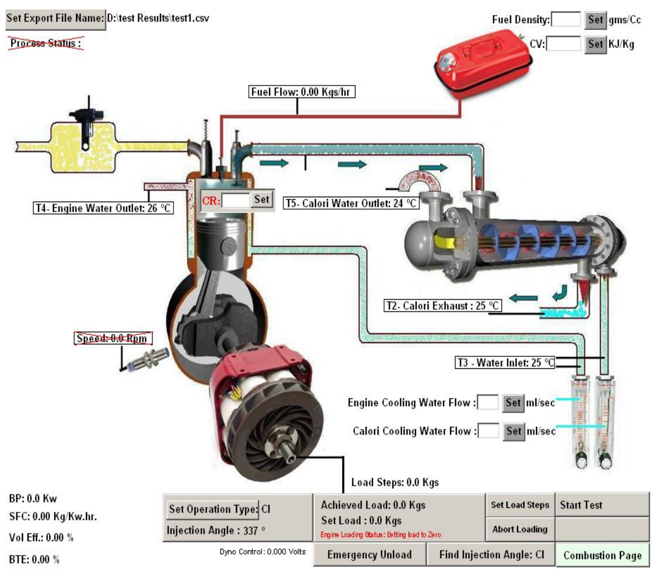

Fig.1. Schematic Diagram of Experimental Setup

OPERATING PROCEDURE

VCR engine was allowed to run with diesel for 15 minutes to precondition the experimental setup. The cooling water was allowed at constant rate of 80 ml/s. The compression ratio was changed from 16 to 20 by changing the clearance volume of the VCR engine. An eddy current dynamometer with a load cell was connected to load the engine.

In each test, the speed of the engine, manometer readings, exhaust gas emissions such as carbon monoxide, hydrocarbon, oxides of nitrogen, and carbon dioxide were recorded. From the observed measurements mass of fuel consumption, brake power, indicated power, brake thermal efficiency and specific fuel consumption were calculated. For each operating condition the performance and exhaust emission levels were measured.

RESULTS AND DISCUSSION

Brake Thermal Efficiency

Brake Thermal Efficiency curves were plotted for varying loads at different compression ratios from 16 to 20. From Fig. 1, it is seen that for the compression ratio 20, brake thermal efficiency is higher at all the loads.

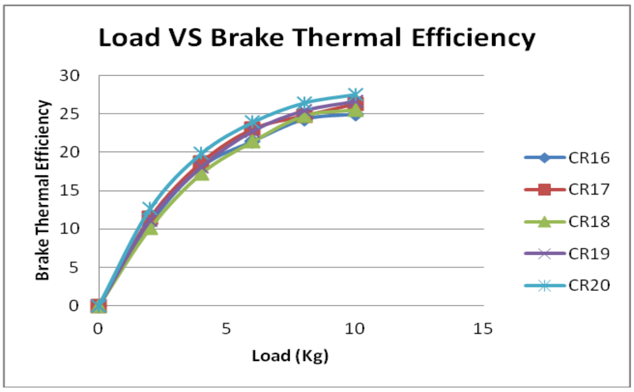

Fig.2 Variation of Brake Thermal Efficiency with compression ratio.

Brake thermal efficiency increases with load for the entire compression ratio. Due to higher compression ratio, the temperature and pressure of intake air increases which support better combustion of the fuels. Therefore efficiency of the engine is higher at the full load.

Specific Fuel Consumption

Specific fuel consumption is the amount of fuel consumed by the engine to produce unit power per hour. SFC is an important performance indicator for internal combustion engine.

SFC decreases with increase in load and compression ratio. Cylinder temperature increases while increment in the load due to which combustion temperature also increases resulting in better combustion at higher loads and compression ratio. The fuel requirement for developing unit brake power comes down at higher loads and compression ratios. This is evident from the SFC noted for compression ratios 16–20.

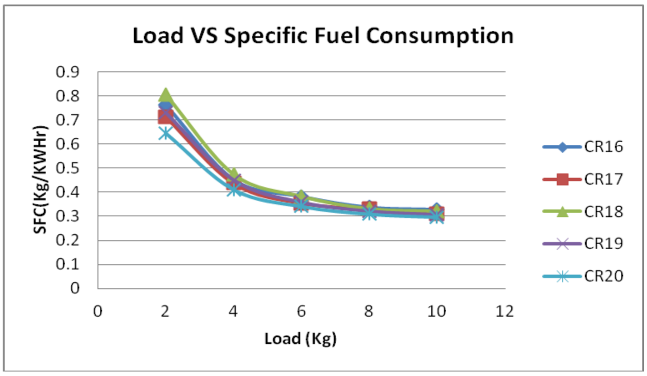

Fig.3 Variation of SFC with Compression Ratio.

Exhaust Gas Temperature

Exhaust gas temperature is also an important parameter as it provides some qualitative information about the combustion process .Exhaust gas temperature is an indicator of the heat release rate of the fuels tested during combustion and its effective utilization to produce power. It depends on the combustion characteristics of the fuel and also on the heat losses to exhaust. Figure 4 shows the variation of exhaust gas temperature (EGT) with load for diesel engine. It can be clearly seen from the figure that exhaust gas temperature increases with the increase in load for all compression ratios. This is due to the fact that temperature after combustion becomes more as more fuel is required to be burnt at higher load condition. It can also be noted from Fig. 4 that the exhaust gas temperature increases with the decrease in compression ratio.

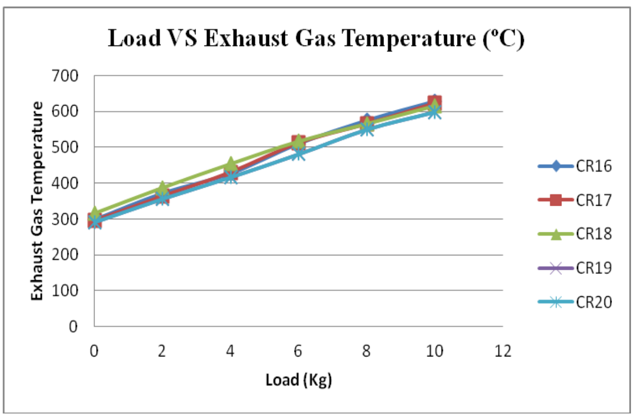

Fig.4 Variation of EGT with Compression Ratio

Unburned Hydrocarbon

Unburnt hydrocarbons are emitted from CI engine due to low combustion temperature and presence of lean or rich mixture. Fuel exhaust hydrocarbons are composed of original fuel molecules and partially oxidized hydrocarbons. The curves in Fig. 5 show that CI engine emits higher HC with increase in load. At higher loads CI engine requires rich mixture, due to poor atomization and due to local rich mixture formation incomplete combustion takes place.

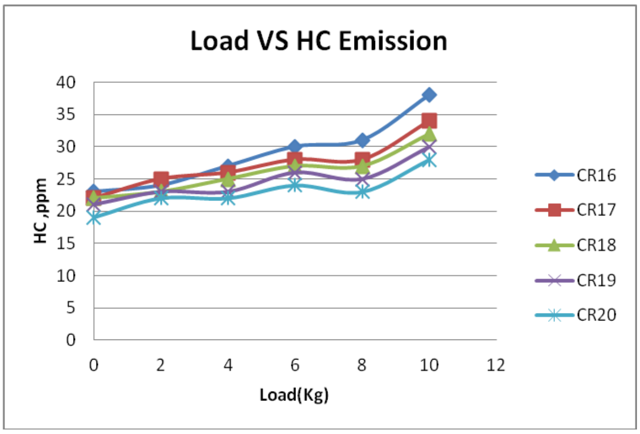

Fig.5 Variation of HC emmission with Compression Ratio

With increase in compression ratio, temperature and pressure of air in the combustion chember increases which enables complete combustion of fuel and lowers emmission of HC.

Oxides of Nitrogen

Oxides of Nitrogen are produced by oxidization inside the cylinder at a temperature of 2200 K. Nitrogen requires very high energy to break its triple bond. When the high combustion temperature favours oxidization NOx is produced.

The effect of compression ratio on NOx emission can be observed from Fig. 6. At higher compression ratio, NOx emission is higher. The higher temperature inside the cylinder creates suitable environment for NOx emission. It has also been reported that at lower compression ratio, the premixed combustion phase is lengthened due to the longer ignition delay and eventually decreases the NOx emission.

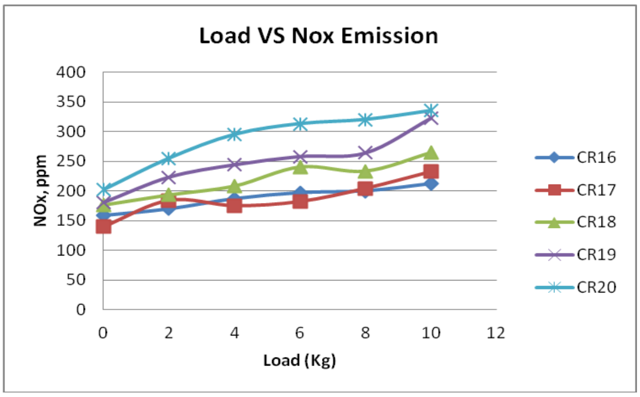

Fig.6 Variation of NOx with Copmpression Ratio.

Carbon Dioxide

One can note that CO_2 emission increases for all the loads with the increase in compression ratio. At higher compression ratio, the combustion is improved and it leads to more amount of CO_2 formation. On the other hand, poorer atomization of fuels at lower compression ratio reduces the amount of CO_2 emission.

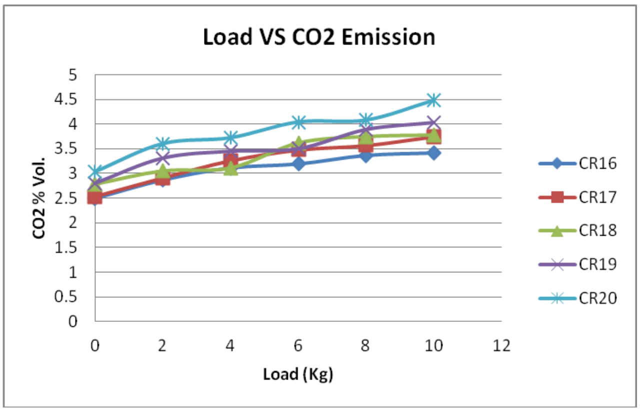

Fig.7 Variation of CO_2 Emission with compression Ratio

Carbon Monoxide

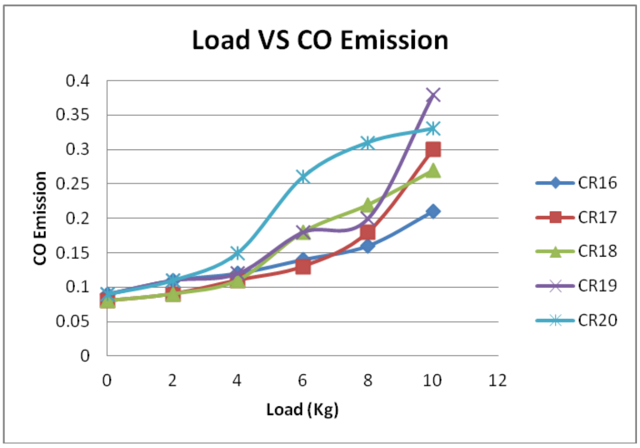

Fig. 8 Variation of CO Emission with Compression Ratio

From the graph it is found that CO emission increases with increase in compression ratio as well as load.With increase in load the CO emission increases because to meet maximum load condition, rich mixture is supplied to CI engine but same amount of oxygen is supplied for combustion of rich mixture resulting in higher CO emission.

CONCLUSIONS

It is observed from above graphs that the Brake Thermal Efficiency increases with increase in load as well as increase in compression ratio. At higher compression ratio the temperature of combustion chamber is higher so complete combustion of fuel takes place resulting in higher thermal efficiency and lower BSFC. So at CR 20 Engine performance is better.

EGT is again at higher side at CR17 at all the loads. It is seen from the graphs that with increase in CR, the EGT is reduced. Also at all the compression ratios EGT increases with load due to availability of more fuel at higher loads.

Fig. 5 show that CI engine emits higher HC with increase in load and emission decreases with increase in compression ratio. At higher loads, CI engine requires rich mixture, due to poor atomization and local rich mixture formation leads to incomplete combustion which further causes higher HC emission.

From Fig. 6 It is evident that at higher compression ratio and higher loads NOx emission is higher. This is because at higher temperature inside the cylinder creates suitable environment for NOx emission.

CO_2 increases at high compression ratio and higher loads. This is because at higher compression ratio, the combustion is improved resulting in more CO_2 emission. Also CO emission increases with increase in load as well as compression ratio.

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