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Research note

# Evaluation of Performance Characteristics and Exhaust Gas Analysis of VCR Engine at Different Compression Ratio and Loads

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*A B S T R A C T*

This paper deals with the systematic study of performance evalaution and exhaust emission characteristics of VCR (variable compression ratio) engine at different compression ratio and loads using diesel as fuel. Experimental analysis was done to find the optimal value of compression ratio and load at which the engine can produce higher thermal efficiency, lower specific fuel consumption and low exhaust emission. Performance parameters such as brake mean effective pressure (BMEP), brake thermal efficiency ($\eta_{bth}$), brake Specific fuel consumption (BSFC), and exhaust gas emissions like hydrocarbon, carbon monoxide and nitrogen monoxide are considered.

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## NOMENCLATURE

CR = Compression Ratio
Power in kW = (Pm LAN/n 100)/60 in bar
L = length of the stroke in m
A = area of the piston in $m^2$
N = Rotational speed of engine RPM
n= number of revolutions required to complete one engine cycle
n= 1 (for two stroke engine)
n= 2 (for four stroke engine)

## INTRODUCTION

Environmental pollution has increasig trend due to contineous use conventional fuels such as petrol and diesel. Petrolem fuels are limited and may be depleted soon. Therefore, it is required to optimise the performance of engine to improve fuel efficiency, fuel economy as well as reduction in exhaust emission level. Compresion igition (CI) engine is a type of internal combustion engine which works on diesel cycle. Diesel Engines are more in use because of having reliable operation and fuel economy. The combustion process in diesel engine takes place when atomised droplets of fuel get mixed with compressed air which is already reached to self igition temperature. In fact compression ratio plays an important role in compression of air to increase the pressure as well as temperature of combustable air. Along with compression ratio, performance of diesel engine also was affected by the engine load. Therefore, it is necessary to carry out analysis of CI engine for various engine parameters at different compression ratio and loads to optimize the engine performance.

The variable compression ratio of engine should be optimised for the diesel enegine performance as compression ratio as well as load can be varied to investigate the engine perforamance characteristics and exhasut emission level. Conventional diesel engines operate at a fixed compression ratio [2,3], and variable load, thus engine may run at low efficiency. The performance of CI engine can be improved with reduced level of exhaust emission by varying compression ratio per load. This paper deals with the evaluation of performance characterisctics and exhaust emission of CI engine by varying the compression ratio and loads for high performance.

## MATERIAL AND METHODS

Fig 1. Shows the experimental setup to conduct the experimantal tests on VCR engine. In present work, a (5 HP) variable compression ratio diesel engine is considered in which compression ratio can be varied

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from 12 to 17. Fig 2. Shows the procedure of changing the compression ratio of the engine. The air flow rate and fuel consumption are measured by mass flow sensor and burette method, respectively. Load on the engine can be applied by eddy current dynamometer. Tables 1, 2 and 3 summarized the specification of engine, dynamometer and gas analyzer.

**TABLE 1**. Engine Specification

| | |
|---|---|
| Manufacturer | Kirloskar Oil Engines Ltd, India. |
| No Of Cylinders | 1 |
| No Of Strokes | 4 |
| Fuel | Diesel |
| Rated Power | 3.5 kW at 1500 rpm |
| Cylinder Diameter | 87.5 mm |
| Stroke Length | 110 mm |
| Connecting Rod Length | 234 mm |
| Compression Ratio Range | 12 to 18.1 |

**TABLE 2**. Dynamometer Specification

| | |
|---|---|
| Manufacturer | Saj Test Plant Pvt Ltd, India. |
| Type | Eddy Current |
| Rated Power | 7.5 Kw @1500 Rpm |

**TABLE 3**. Gas Analyzer Specification.

| | |
|---|---|
| Manufacturer | Avl India Pvt Ltd.Mode |
| Type | Digas 444 |
| Model | 5 Gas Analyzer |

**Figure 1**. Experimental Setup

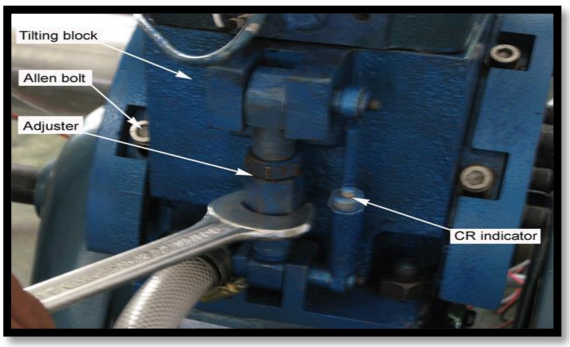


**Figure 2**. Setting to Change the Compression Ratio

**Important definations and formula**

Brake Power (BP): The brake power of an internal combustion engine engine is the power available at output shaft or crankshaft. It can be evaluated by the following expression:

Brake Power = $\frac{2\times\pi\times N\times T}{60{,}000}$

Brake thermal efficiency ($\eta_{bth}$): a measurement of overall efficiency of the engine is given by the brake thermal efficiency. Brake thermal efficiency is the ratio of energy in the brake power to the fuel energy which is defined by following relation:

$$\text{Brake Thermal Efficiency } (\eta_{bth}) = \frac{\text{BP}\times 3600}{\text{Fuel Flow}\times\text{Calorific Value}}\times 100$$

Brake Mean Effective Pressure : If the mean effective pressure is based on brake power it is called Brake Mean Effective Pressure (BMEP) stated as follows:

$$\text{Brake Mean Effective Pressure} = \frac{(\text{Brake Power}\times 60)}{\text{L}\times\text{A}\times\left(\frac{\text{N}}{\text{n}}\right)\times\text{No.of cylinder}\times 100}$$

Mechanical Efficiency ($\eta m$): Mechanical efficiency is the ratio of brake horse power (delivered power) to the indicated horsepower (power provided to the piston) given below:

Mechanical Efficiency ($\eta m$) = $\frac{\text{Brake Power}}{\text{Indicated Power}}$

Brake Specific Fuel Consumption (BSFC): BSFC is defined as fuel consumption (grams/second) per unit of thrust (kilo Newton, or kN).

Brake Specific Fuel Consumption = $\frac{\text{M}}{\text{BP}}$

## RESULTS AND DISCUSSION

Fig. 3 shows the variation of brake power plotted against the load. It is observed that the brake power is increasing as the load increases. From these data, it is observed that maximum brake power is developed at load 66% and at compression ratio of 17.Fig. 4 shows the variation of brake mean effective pressure plotted against the load. It is observed that the brake mean effective pressure is increasing as the load increases. From this plot it is observed that maximum brake mean effective pressure is developed at load 66% and at compression ratio of 17. Fig. 5 shows the variation of brake specific fuel consumption plotted against the load. It is observed that the brake specific fuel consumption is decreasing as the load increases. The data for of compression ratio of 13 shows high brake specific fuel consumption as compared to data given for other compression ratios. Fig. 6 depicts the variation of percentage of Carbon Monoxide (CO) in the exhaust plotted against the load. It is observed that the

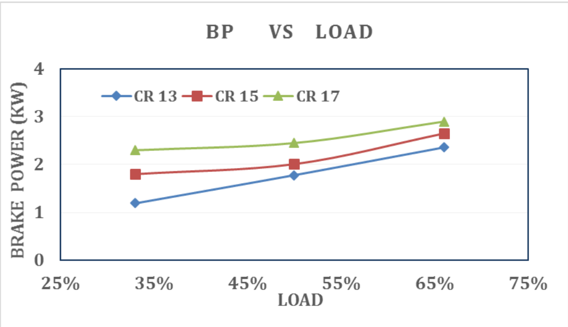


**Figure 3**. Variation of Brake Power against Load

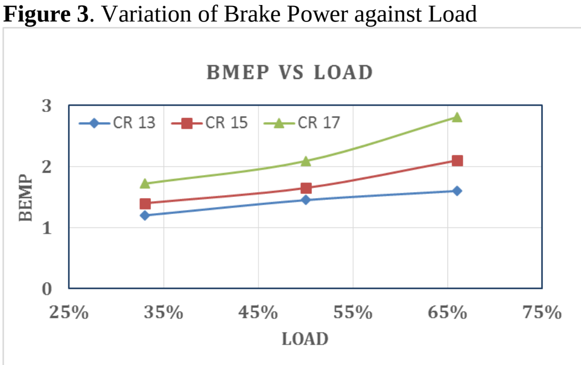


**Figure 4**. Variation of Brake Mean Effective Pressure against Load

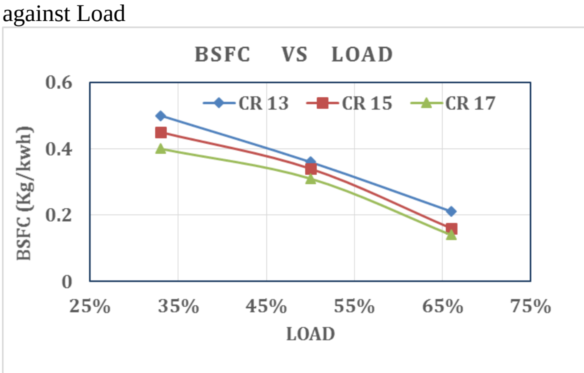


**Figure 5**. Brake Spectific Fuel Consumption against Load Graph

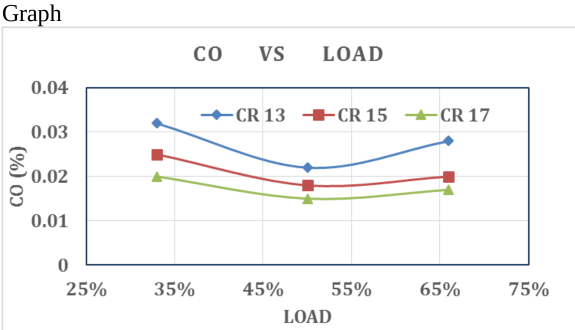


**Figure 6**. Variation of Carbon Monoxide against the Load

Carbon Monoxide (CO) decreases up to 50 % of load. After this, there is slight increment. The line of CR13 emits maximum amount of CO compared to other blends. Fig. 7 illustrates the variation of percentage of Nitrogen oxide ($NO_x$) in the exhaust plotted against the load. It is observed that the nitrogen oxide increases up to 50 % of load. After this point, small decrement was observed. The trend line of compression ratio of 17 emits maximum amount of $NO_x$ compared to line of other compression ratio.

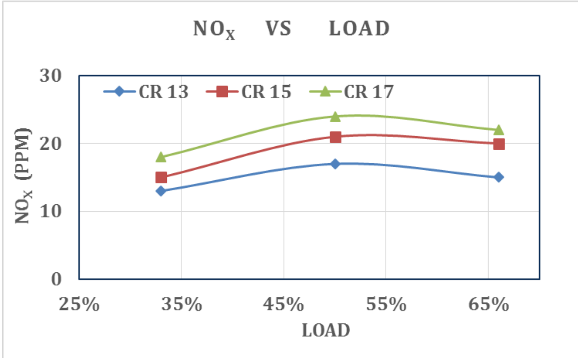


**Figure 7**. Variation of Nitrogen Oxide emmision against Load

## CONCLUSION

Following conclusions are drawn from the experimental work carried out,

1. Brake power of the engine increased by 60 % and 93% as compression ratio increased from 13 to 15 and 17, respectively. The brake power increased by 27 % when compression ratio increased from 15 to 17.
2. When CR is increased from 13 to 15 and 17, the brake mean effective pressure of the engine also was increased by 17 % and 42 %, respectively.
3. Brake mean effective pressure of the engine increased by 22 % as the CR is increased from 15 to 17.
4. Brake specific fuel consumption of the engine decreased by 10 % as the CR is increased from 13 to 15 and 17.
5. Brake specific fuel consumption of the engine decreased by 5 % as the CR is increased from 15 to 17.
6. Carbon Monoxide (CO) emission of the engine decreased by 21 % and 38% as the CR is increased from 13 to 15 and 17%, respectively. After 50 % of load, as the CR is increased from 15 to 17, the CO emission decreased by 20 %.
7. Nitrogen oxide ($NO_x$) of the engine increased by 15 % and 38% as the CR is increased from 13 to 15 and 17, respectively.
8. Nitrogen oxide ($NO_x$) of the engine increased by 20 % as the CR was increased from 15 to 17.

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**Persian Abstract**

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**چکیده**

این مقاله به مطالعه سیستماتیک از ویژگی های اندازه گیری عملکرد و انتشار خروجی VCR (نسبت فشرده سازی متغیر) در نسبت فشرده سازی مختلف و بارهای با استفاده از سوخت دیزل می پردازد. تجزیه و تحلیل تجربی برای به دست آوردن ارزش مطلوب نسبت فشرده سازی و بار است که در آن موتور می تواند راندمان حرارتی بالاتر، مصرف سوخت پایین تر و انتشار کم اگزوز را تولید کند. پارامترهای عملکرد مانند فشار متوسط اثر ترمز (BMEP)، بازده حرارتی حرارتی (тчиbth)، ترمز مصرف سوخت مخصوص (BSFC) و انتشار گازهای خروجی مانند هیدروکربن، مونوکسید کربن و مونوکسید نیت در نظر گرفته شده است.