Performance Improvement of Single Cylinder Diesel Engine using Variable Compression Ratio

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Abstract - *As seen by the title, performance improvement is our main goal here. To fulfill this goal, we took the "Variable Compression Ratio Engine" as our topic to study and research. Our research provides higher Efficiency, Better Fuel economy, Emission control & increased power output for the engine. As Compression ratio can be varied in VCR engine, to find out optimum compression ratio experiments were carried out on a single cylinder four stroke variable compression ratio diesel engine. Tests were carried out at compression ratios of 12.38, 13.69, 15.55, and 17.5 at different loads of 3kg, 4kg, 5kg, 6kg, 7kg, and 8kg. The performance characteristics of engine like Brake power, Brake mean effective pressure, volumetric efficiency, A/F ratio, mechanical Efficiency Brake thermal efficiency, brake specific fuel consumption. As per our tests, the best performance of the engine is obtained at 13.69.*

1. INTRODUCTION

Now a days due to continuous rise in fuel costs and considering increasing demands of fuel , as fuel is non-renewable so it is our first priority to increase fuel efficiency. Since heat losses are major part of losses so thermal efficiency should be increased to improve parameters like CV, QLV, Specific heat.

1.1 Why VCR ?

Now to achieve our goal as per research , theoretically variable compression ratio offers number of benefits for Diesel Engine such as reduced time losses (at lower loads , greater CR , the shorter is the combustion time) , increased fuel efficiency , thermal efficiency , emission control (as it lower down NOx ,SOx ,CO_2) , power output, allows tolerance to piston at head,

Now there are various methods to achieve variable compression ratio such as By varying length of connecting rod or by adjustment of cylinder head in order to achieve VCR. due to various advantages Moving Head VCR engine is used.

1.2 OBJECTIVES:

1. To obtain optimum compression ratio (ratio for which the engine will perform its best) for VCR by testing the engine for different loads.

2. To obtain maximum possible efficiency for the engine such as mechanical efficiency and thermal efficiency

3. To minimize the losses

4. To achieve the goal of emission control.

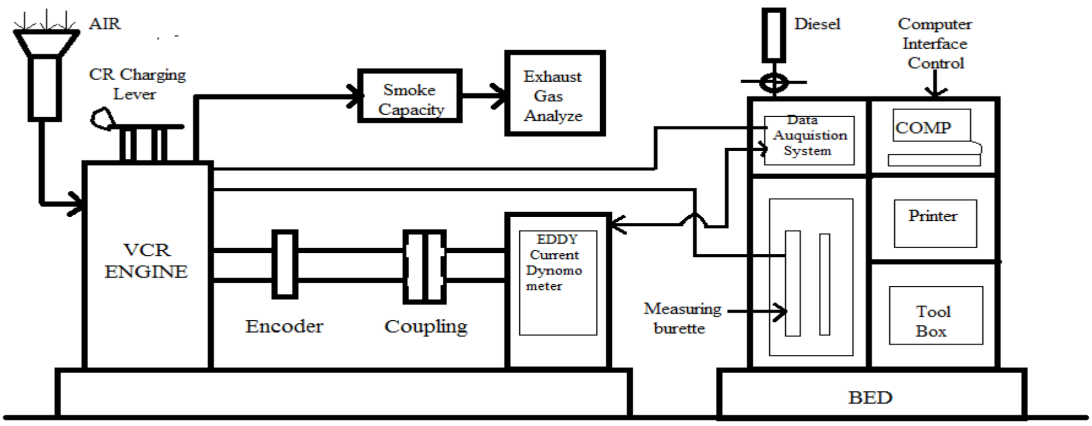
2. EXPERIMENTAL SETUP:

This setup consist of single cylinder four stroke VCR head diesel engine connected to eddy current type dynamometer for loading purpose. As shown in fig.

Parts of VCR Head:

1. Base Plate
2. Pressure bolts
3. Compression ratio adjuster with lock nuts
4. Support plate
5. Compression ratio indicator
6. Bearings

This setup is used to study performance parameter of VCR engine such as brake power, indicating power, mechanical efficiency, specific fuel consumption, A/F ratio, brake thermal efficiency.



3. EXPERIMENTAL PROCEDURE:

The experiment is started by turning ON the water jacket cooling system. This is followed by the adjustment of compression ratio which can be calibrated by tweaking the power screw arrangement.

The initial adjustment for compression ratio is done by uplifting the Variable Compression Head installed on the engine by 1mm and creating an offset. While the offset is to be created, initially all the fasteners are loosened to allow the free adjustment for VCR head. After the adjustment all the fasteners are again fastened to fix the setup properly. After all this adjustment the engine is started and readings are obtained through a computerized system for that particular CR for different loads. All the graphs are software generated using **LABVIEW 14.0** developed **by National Institute Banglore**. This procedure is repeated for adjustment for CR each time it has to be changed.

Above procedure are to be repeated for different loads at different CR.

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Figure 1: VCR head assembly.

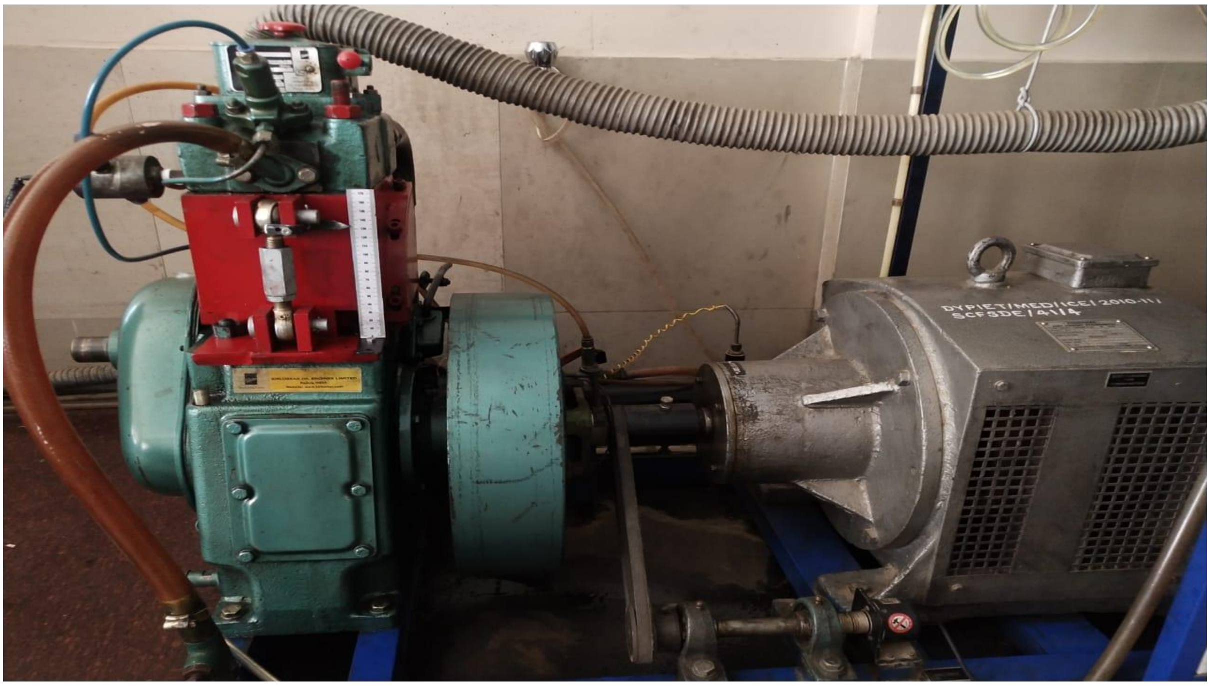

Figure 2:Single cylinder VCR Engine

TABLE 1: VCR ENGINE SPECIFICATION:

Sr.no.	Features	Specifications
1	Manufacturer	Kirloskar diesel Engine
2	Type	Four stroke, water cooled diesel engine
3	No. of cylinder	single
4	Load	Eddy current dynamometer
5	Stroke length	110mm
6	Cylinder diameter	87.5mm
7	Max. speed	1500RPM
8	Max. Power	3.5kw
9	Compression ratio	17.5:1
10	Compression Principle	Compression ignition
11	Max. Load	8kg

4. THEROTICAL CALCULATIONS:

The engine performance is indicated by the efficiency. Various efficiencies & power used in I.C engines practices are defined below.

- Compression ratio: Compression Ratio can be defined as the ratio of sum of swept volume & clearance volume to that of clearance volume.

$$\text{Compression ratio} = \{VS+VC\}/VC$$

- Indicating power(IP) : The rate of energy developed on the piston head by combustion of fuel to push the piston is called Indicating power.
- Brake Power (BP) : The rate of energy developed on the output shaft of the engine is called Brake Power (BP)
- Mechanical efficiency : mechanical efficiency is gives the effectiveness of the engine & transforming its input energy to output energy.

M.E.= B.P./I.P.

1. Thermal efficiency : Thermal efficiency of an engine is the indicator of conversion of heat supplied into work energy .it is either based on I.P. or on B.P. we have two types of thermal efficiencies :

1) Indicated thermal efficiency = I.P./ (m*C.V.)

2) Brake thermal efficiency = B.P./ (m*C.V)

2. Volumetric efficiency : It is measures of the degree to which the engine fills to its swept volume.

   It is defined as the ratio of actual mass of change inducted during suction stroke to the mass of charge corresponding to swept volume of the engine at atmospheric pressure and temperature

3. Specific fuel consumption :

   Specific fuel consumption is defined as the amount of fuel required to be supplied to an engine to develop 1KW power per hours.

$$B.S.F.C = (m_f/B.P)*3600$$

4. Air fuel ratio : It is defined as the ratio of relative mass of air and fuel in engine.

$$(A/F)\ ratio = m_a/m_f$$

5. CALCULATIONS:

Given Data:

Bore Diameter=87.5mm =0.0875m

Stroke length =0.11m

Compression Ratio at normal position= 17.5:1

We know that

Compression ratio,

$$CR = \frac{Vs + Vc}{Vc} = \frac{Vs}{Vc} + 1$$

Where,

b = Cylinder bore

s = Piston stroke length

Vc = Clearance Volume

Now,

I. Swept Volume, $Vs=\left(\frac{\pi}{4}\right)(b^2 * s)$

$$Vs=\left(\frac{\pi}{4}\right)(87.5 * 10^{-3})^2 * (110 * 10^{-3})$$

$$Vs= 6.61 * 10^{-4}\ m^3 \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Now put the (1) value in equation of CR

$$CR = \frac{Vs}{Vc} + 1$$

$$17.5 = \frac{6.61 * 10^{-4}}{Vc} + 1$$

Therefore $\quad Vc = 4.006 * 10^{-5}\ m^3$

Now, Clearance Volume, $Vc = \left(\frac{\pi}{4}\right)(b^2 * lc)$

$$4.006 * 10^{-5} = \left(\frac{\pi}{4}\right)((87.5 * 10^{-3})^2 * lc)$$

Therefore, $\quad lc = 6.66*10^{-3}$ m

I. For 1mm offset:

Swept Volume, $V_s = \left(\frac{\pi}{4}\right)(b^2 * s)$

$$V_s = \left(\frac{\pi}{4}\right)(87.5 * 10^{-3})^2 * (110 * 10^{-3})$$

$$V_s = 6.61 * 10^{-4}\ m^3 \ldots\ldots\ldots\ldots(1)$$

We know that,

For normal position,, $\quad l_c = 6.66*10^{-3}$ m

Therefore, For 1mm Offset Add $1 * 10^{-3}$ in l_c

Now, $\quad l_c = (6.66*10^{-3}) + (1 * 10^{-3})$

$$L_c = 7.66*10^{-3}\ m$$

Now, Clearance Volume, $V_c = \left(\frac{\pi}{4}\right)(b^2 * lc)$

$$V_c = \left(\frac{\pi}{4}\right)((87.5 * 10^{-3})^2 * (7.66 * 10^{-3}))$$

Therefore, $\quad V_c = 4.61*10^{-5}$ m

$$CR = \frac{Vs}{Vc} + 1$$

$$CR = \frac{6.61*10^{-4}}{4.61*10^{-5}} + 1$$

Therefore, CR=15.55

II. For 2mm offset:

Swept Volume, $V_s = \left(\frac{\pi}{4}\right)(b^2 * s)$

$$V_s = \left(\frac{\pi}{4}\right)(87.5 * 10^{-3})^2 * (110 * 10^{-3})$$

$$V_s = 6.61 * 10^{-4}\ m^3 \ldots\ldots\ldots\ldots(1)$$

We know that,

For normal position,, l_c=6.66*10^{-3} m

Therefore, For 2mm Offset Add 2* 10^{-3} in lc

Now, l_c= (6.66*10^{-3}) +(2* 10^{-3})

l_c= 8.66*10^{-3} m

Now, Clearance Volume, $V_c = \left(\frac{\pi}{4}\right)(b^2 * lc)$

$$V_c = \left(\frac{\pi}{4}\right)((87.5 * 10^{-3})^2 * (8.66 * 10^{-3}))$$

Therefore, V_c = 5.207*10^{-5} m

$$CR = \frac{Vs}{Vc} + 1$$

$$CR = \frac{6.61*10^{-4}}{5.207*10^{-5}} + 1$$

Therefore, CR=13.69

III. For 3mm offset:

Swept Volume, $V_s = \left(\frac{\pi}{4}\right)(b^2 * s)$

$V_s = \left(\frac{\pi}{4}\right)(87.5 * 10^{-3})^2 * (110 * 10^{-3})$

$V_s = 6.61 * 10^{-4}\ m^3$ ……………………..(1)

We know that,

For normal position,, $l_c=6.66*10^{-3}$ m

Therefore, For 3mm Offset Add $3*10^{-3}$ in lc

Now, $l_c= (6.66*10^{-3}) +(3*10^{-3})$

$L_c= 9.66*10^{-3}$ m

Now, Clearance Volume, $V_c = \left(\frac{\pi}{4}\right)(b^2 * lc)$

$V_c = \left(\frac{\pi}{4}\right)((87.5 * 10^{-3})^2 * (9.66 * 10^{-3}))$

Therefore, $V_c = 5.808*10^{-5}$ m

$$CR = \frac{Vs}{Vc} + 1$$

$$CR = \frac{6.61*10^{-4}}{5.808*10^{-5}} + 1$$

Therefore, *CR=12.38*

TABLE 2: CALCULATIONS OF CR:

Sr.No.	V_s (m^3)	Clearance length(l_c)	V_C(m^3)	CR
1	0.000662591	0.00666	$4.006*10^{-5}$	17.5
2	0.000662591	0.00766	$4.61*10^{-5}$	15.55
3	0.000662591	0.00866	$5.207*10^{-5}$	13.69
4	0.000662591	0.00966	$5.808*10^{-5}$	12.38

6. Result and performance analysis :

- COMPAIRE THE GRAPH OF COMPRESSION RATIO OF **17.5 :1** TO **15.5:1** THEN FOLLOWING RESULT ARE OBTAINED :

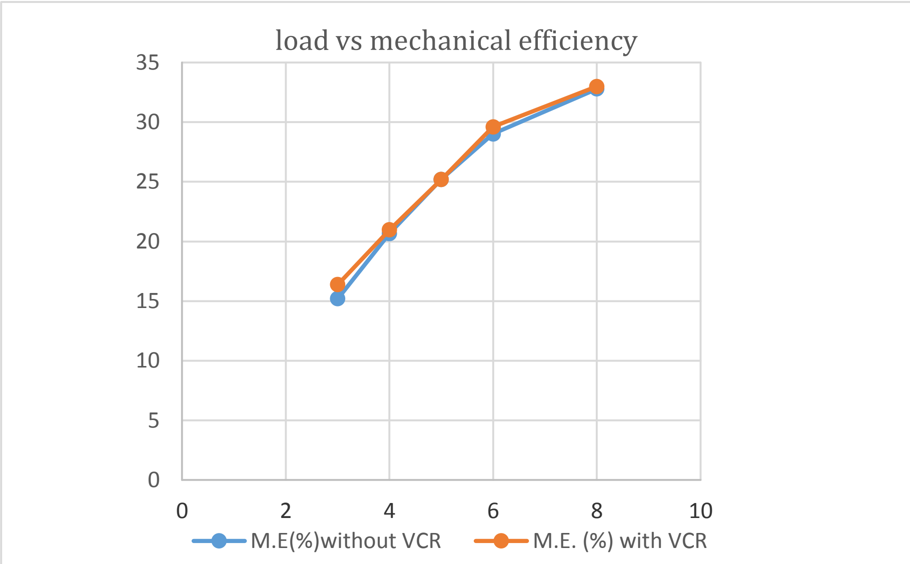

Chart-1 : Load vs mechanical efficiency

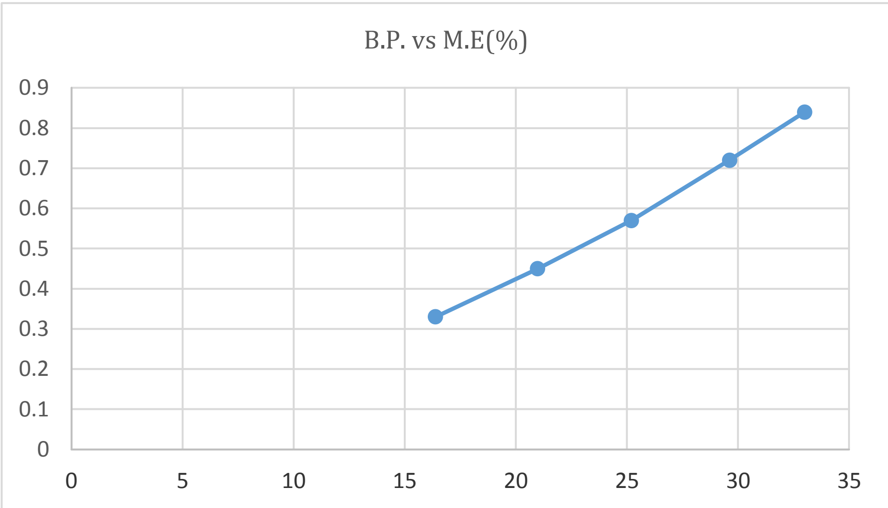

Chart -2 : Brake power vs M.E.(%)

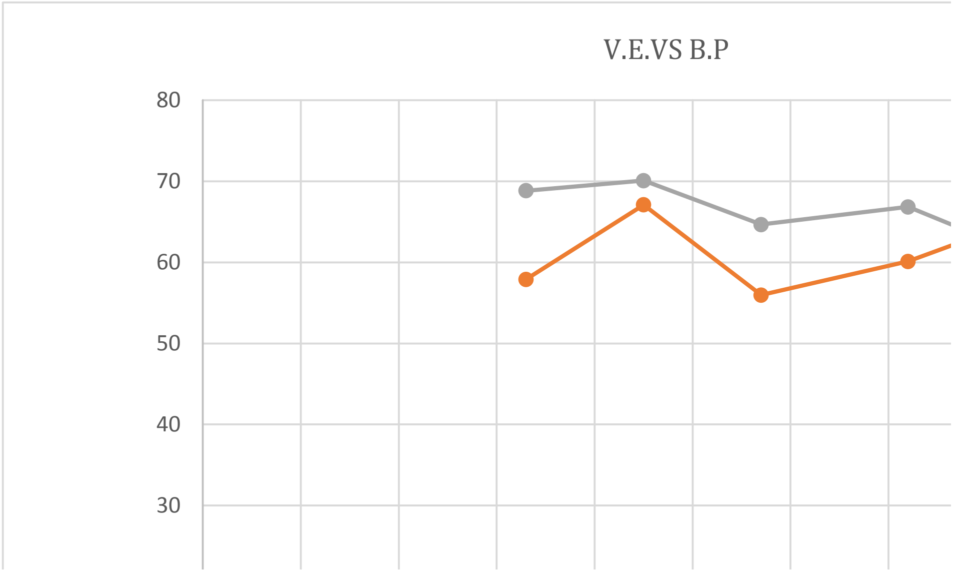

Chart -3: V.E vs B.P.

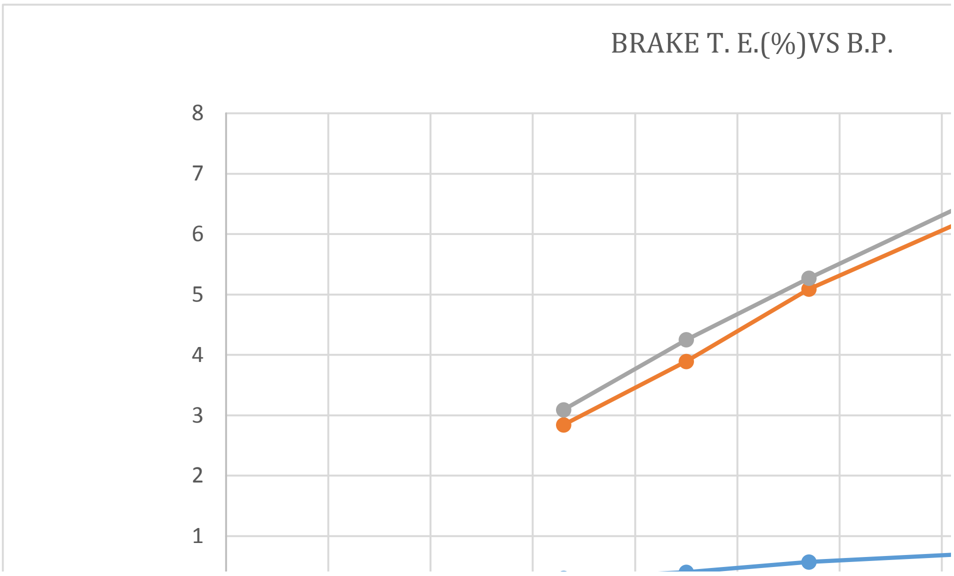

Chart -4: Brake thermal efficiency vs Brake power

Conclusions:

I. The optimum compression ratio for the given engine is 13.69. Maximum fuel efficiency obtained at the compression ratio of 13.69.
II. Rate of fuel consumed is highest at compression ratio 12.38.
III. Moderate temperatures of exhaust gas are obtained at compression ratio 17.5.
IV. For more power at high loads the engine should operate at compression ratio 13.69 due to less specific fuel consumption.
For lower power output at low loads the engine should operate at compression ratio 13.69 due to less fuel consumption

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