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Effect Of Compression Ratio On The Performance Of Diesel Engine At Different Loads.

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ABSTRACT
Variable compression ratio (VCR) technology has long been recognized as a method for improving the automobile engine performance, efficiency, fuel economy with reduced emission. The main feature of the VCR engine is to operate at different compression ratio, by changing the combustion chamber volume, depending on the vehicle performance needs .The need to improve the performance characteristics of the IC Engine has necessitated the present research. Increasing the compression ratio to improve on the performance is an option. The compression ratio is a factor that influences the performance characteristics of internal combustion engines. This work is an experimental investigation of the influence of the compression ratio on the brake power, brake thermal efficiency, brake mean effective pressure and specific fuel consumption of the Kirloskar variable compression ratio duel fuel engine. Compression Ratios of 14, 15, 16 and 18 and engine loads of 3kg to 12 kg, in increments of 3kg, were utilized for Diesel.
Keywords: Variable Compression Ratio (VCR), Diesel, Gasoline, Kirloskar Engine, Loads.

I. INTRODUCTION

Improving Internal Combustion (IC) engine efficiency is a prime concern today. A lot of engineering research has gone into the improvement of the thermal efficiency of the (IC) engines, so as to get more work from the same amount of fuel burnt. Most of the energy produced by these engines is wasted as heat. In addition to friction losses and losses to the exhaust, there are other operating performance parameters that affect the thermal efficiency. These include the fuel lower calorific value, QLV, compression ratio, and ratio of specific heats, γ.

The concept of variable compression ratio (VCR) promises improved engine performance, efficiency and reduced emissions. The higher cylinder pressures and temperatures during the early part of combustion and small residual gas fraction owing to higher compression ratio give faster laminar flame speed. Therefore, the ignition delay period is shorter. As a result, at low loads, the greater the compression ratio, the shorter is the combustion time. Time loss is subsequently reduced. Therefore, it seems reasonable that fuel consumption rate is lower with high compression ratios at part load.

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 14 to 18 for diesel engine. The present study focuses on investigating the better compression ratio for the variable compression ratio diesel engine at variable loads.

1.1 Compression Ratio (r_c)

Compression ratio is the ratio of the total volume of the combustion chamber when the piston is at the bottom dead centre to the total volume of the combustion chamber when piston is at the top dead centre.

$r_c =$ Total volume at BDC/ Total volume at TDC

1.2 Why VCR?

Theoretically, increasing the compression ratio of an engine can improve the thermal efficiency of the engine by producing more power output. The ideal theoretical air standard cycle has a thermal efficiency which increases with compression ratio (r_c)

$$\eta_T = \left(1 - \frac{1}{r_C^{\gamma-1}}\right)$$

1.3 Moving Head VCR Engine

In The moving head concept (Saab Automobile AB) combines a cylinder head with cylinder liners into a mono head construction, which pivots with respect to the remainder of the engine. The lower half of the block includes the crankcase and engine mounts, and carries the crankshaft, gear box, oil cooler, and auxiliaries. The upper half includes the cylinders, their Liners, camshafts, and an integrally cast cylinder head (Fig. 1).This part is referred to as the mono head. Saab has enabled a tilting motion to adjust the effective height of the piston crown at TDC. The linkage serves to tilt the mono head relative to the crankcase in order to vary the TDC position of the piston. By means of actuator and linkage mechanism the compression ratio can be varied from 14 to 18. A screw type supercharger provides a 2:1 boost pressure when open throttle conditions occur. This system-wide fuel flexibility, with reduced CO_2 emissions is proportional to fuel consumption. Saab recognized that the fuel efficiency of the VCR engine would be low without high-pressure supercharging.

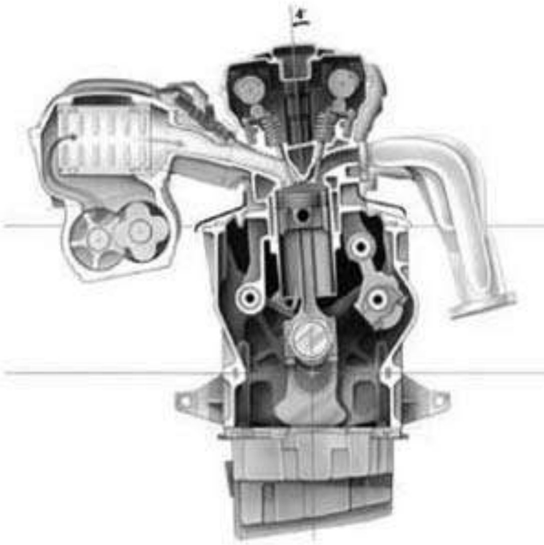


FIG. 1

1.4 Brake Mean Effective Pressure (BMEP), Efficiency and Specific Fuel consumption (SFC)

The engine torque, *T* is given by

$$T = WR,$$

Where W is the brake load in Newton and *R* is the torque arm in metres.

The actual power available at the crank shaft is the brake power, B_p, given by

$$B_P = \frac{\pi N T}{30}$$

Where, *N* is the engine speed in revolution per minute.

The brake mean effective pressure (*BMEP*) is the mean effective pressure which would have developed power equivalent to the brake power if the engine were frictionless, and for a four stroke engine is given by

$$BMEP = \frac{2B_P}{V_S N n}$$

Where, *n* is the number of cylinders and V_S is the swept volume.

The brake thermal efficiency, η_{BT} is the ratio of the brake power to the power supplied by the fuel, Q_{in} and is given by

$$\eta_T = \frac{B_P}{Q_{in}}$$

And

$Q_{in} = m_f Q_{LV}$

Where, m_f is the mass flow rate of the fuel and Q_{LV} is the lower calorific value of the fuel.

The specific fuel consumption (SFC) is the total fuel consumed per kilowatt power developed and it is given by

$$SFC = \frac{3600\, m_f}{B_P}$$

II. Experimental Setup

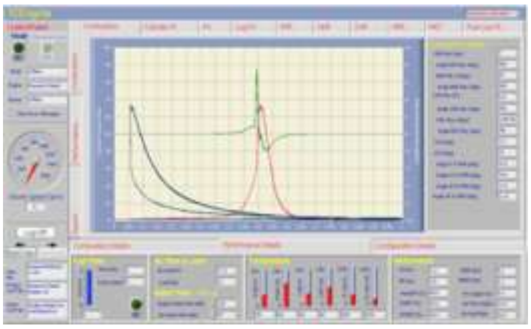
2.1 Engine Setup:

Single cylinder four stroke, water cooled, Kirloskar engine modified to VCR Diesel. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement.

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer. It is provided with necessary instruments for combustion pressure, crank-angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data acquisition device. The setup has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rotameters are provided for cooling water and calorimeter water flow measurement. In petrol mode engine works with programmable Open ECU, Throttle position sensor (TPS), fuel pump, ignition coil, fuel spray nozzle, trigger sensor etc. The setup enables study of VCR engine performance for both Diesel and Petrol mode and study of ECU programming. The Engine performance study includes brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis

2.1.1. Diesel Mode:

2.2 Software:



Engine Soft is Labview based software package developed by Apex Innovations Pvt. Ltd. for engine performance monitoring system. Engine Soft can serve most of the engine testing application needs including monitoring, reporting, data entry, data logging. The software evaluates power, efficiencies, fuel consumption and heat release. Various graphs are obtained at different operating condition. While on line testing of the engine in RUN mode necessary signals are scanned, stored and presented in graph. Stored data file is accessed to view the data graphical and tabular formats

III. Observations

3.1. Diesel Engine:

3.1.1 Engine Detail:

IC Engine set up under test is Research Diesel having power 3.50 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine Cylinder Bore 87.50 (mm), Stroke Length 110 (mm), Connecting Rod length 234(mm), Compression Ratio 14, Swept volume 661.45 (cc)

3.1.2. Combustion Parameters:

Specific Gas Constant (kJ/kg-K): 1.00, Air Density (kg/m^3): 1.17, Adiabatic Index: 1.41, Polytrophic Index : 1.28, Number Of Cycles : 10, Cylinder Pressure Reference: 4, Smoothing 2, TDC Reference : 0

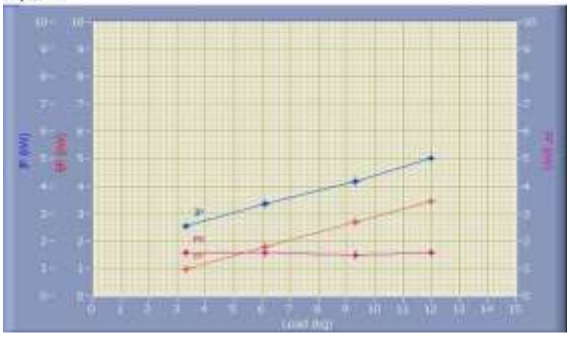
3.1.3. Performance Parameters:

Orifice Diameter (mm): 20.00, Orifice Coefficient. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia. (mm): 12.40, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m^3): 830, Calorific Value Of Fuel (kJ/kg) : 42000

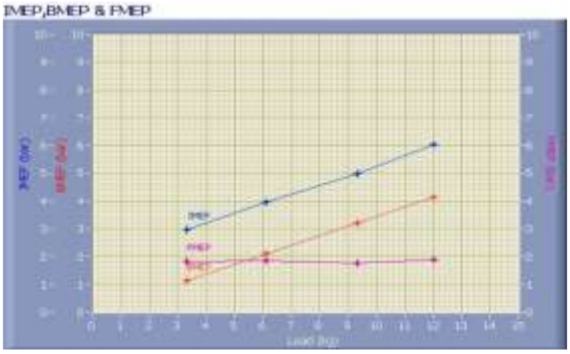
3.1.4. Graphs:

For Compression Ratio = 14:

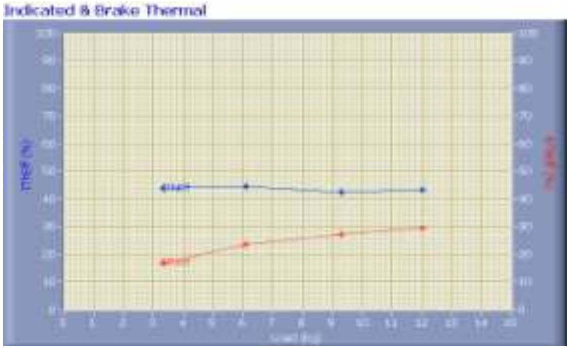
IP, BP &



IMEP,BMEP & FMEP

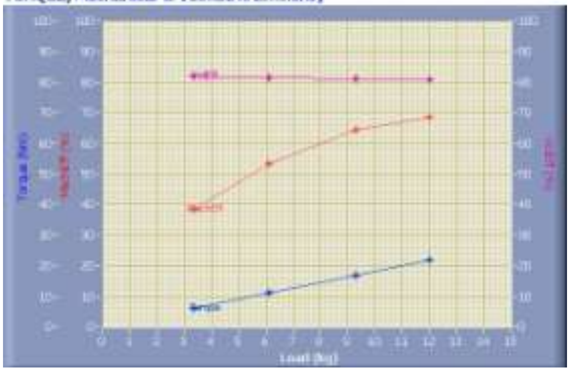


Indicated & Brake Thermal



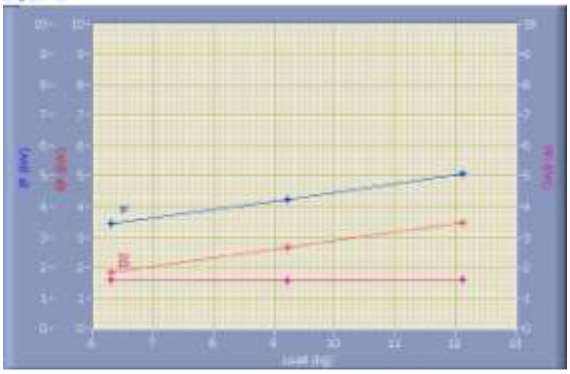
SFC & Fuel Consumption

TORQUE, Mechanical & Volumetric Efficiency

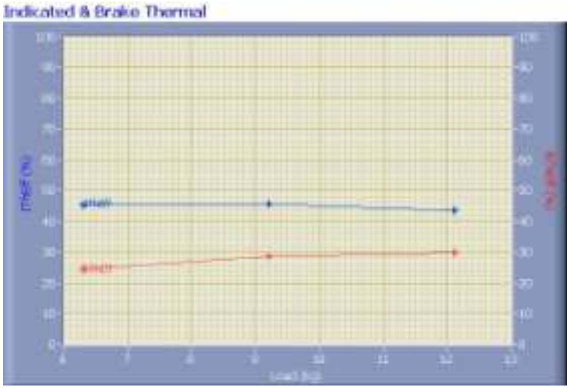


For Compression Ratio = 15:

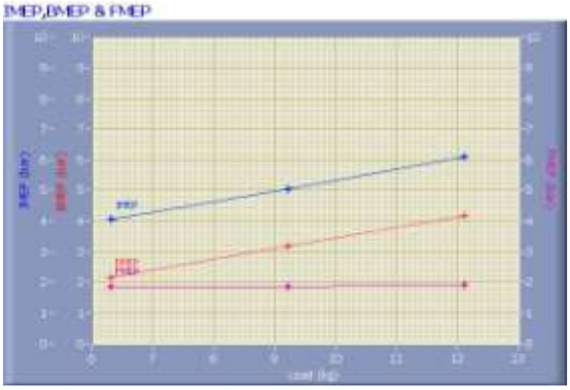
IP, BP &



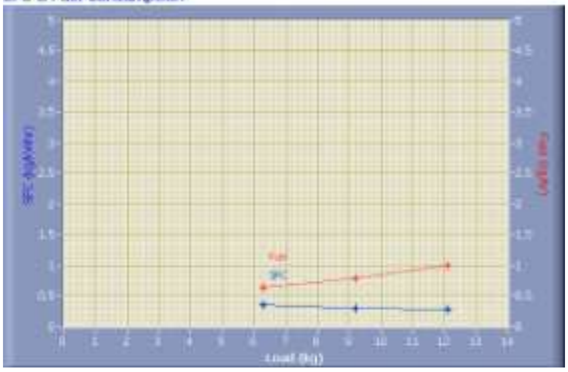
Indicated & Brake Thermal



IMEP,BMEP & FMEP



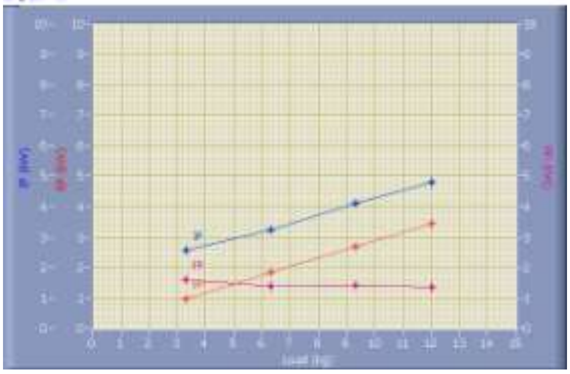
SFC & Fuel Consumption



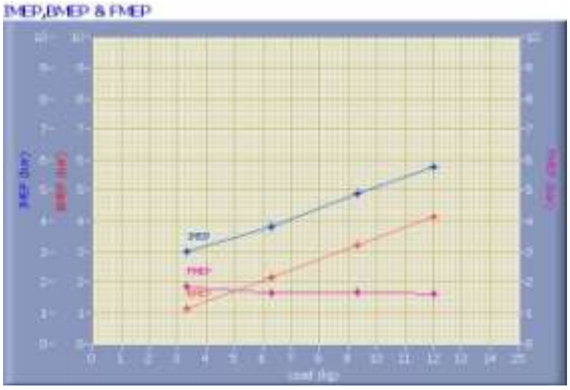
TORQUE, Mechanical & Volumetric Efficiency

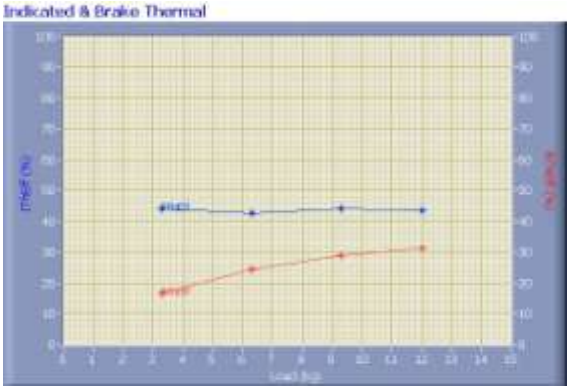
For Compression Ratio = 16:

IP, BP &

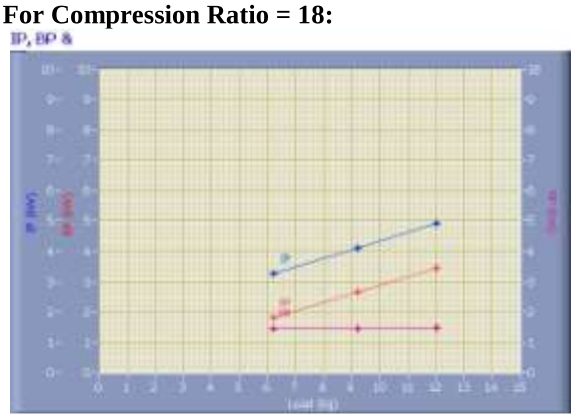


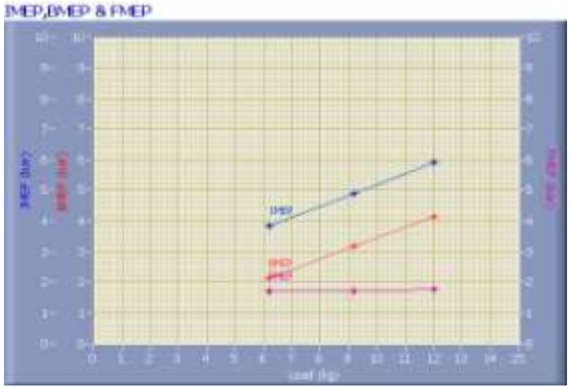
IMEP,BMEP & FMEP

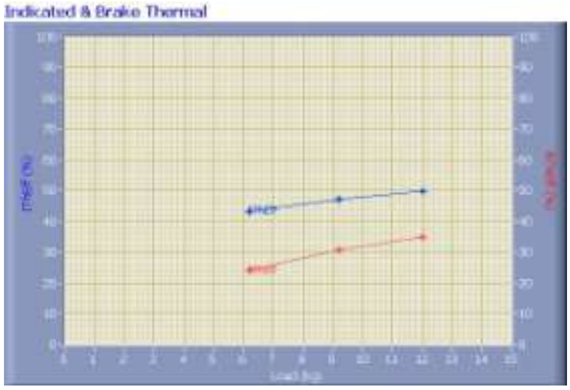




For Compression Ratio = 18:





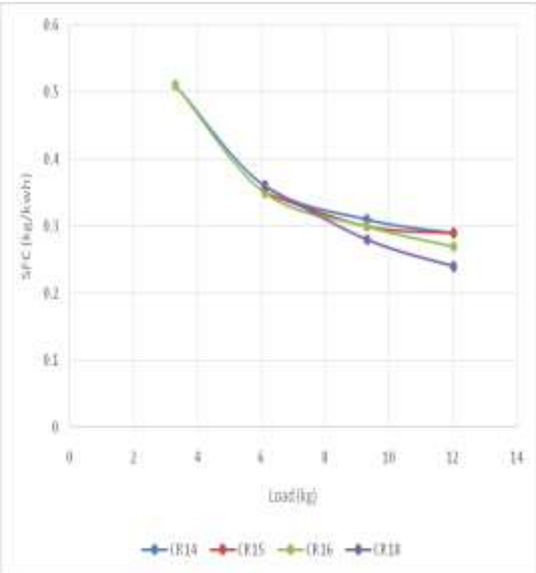


IV. Results

In order to determine optimum compression ratio for variable compression diesel engine fuelled with diesel fuel, tests were carried out at entire load range and compression ratios of 14, 15, 16 and 18 while maintaining speed at 1500 rev/min.

4.1. The comparison of brake specific fuel consumption with varying load:

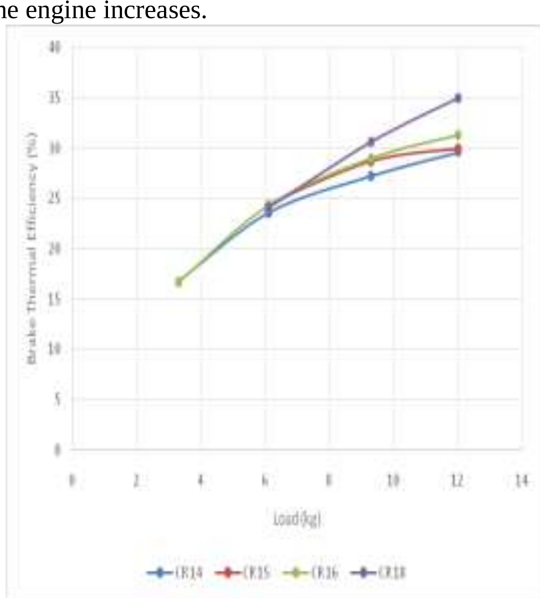
The comparison is presented in following Graph at 1500 rev/min. The least fuel consumption is obtained at compression ratio of 18. The lower compression ratios than 18 has resulted in high fuel consumptions. At the lower sides of the compression ratios, fuel consumption is high due to incomplete combustion of fuel. The maximum fuel consumption is measured at CR 14.It is observed that, as the compression ratio of the engine is increased, BSFC decreases (improves). Out of the four compression ratios selected for the study, CR-18 gives lowest BSFC. This is because at higher compression ratio, brake power increases. The Graph shows that when we increase the load at any particular compression ratio then the specific fuel consumption decreases from 0.51 kg/kwh at 3.31 kg load and we get lowest SFC 0.29, 0.29, 0.27, 0.24 for compression ratios 14, 15, 16 and 18 respectively at load (12 kg). And as the compression ratio is increased we get the decrement in the SFC and it is observed that lowest value of SFC occurs at compression ratio 18 and at 12 kg load.



4.2. Comparison of Brake Thermal Efficiency with load:

The following graph shows the variations of brake thermal efficiency with respect to load at different compression ratios for diesel fuel engine operation. The thermal efficiency increases with increase in load. 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.As the graph Load vs the Brake Thermal Efficiency (%) at different compression ratio shows that as we increase the load at any particular compression ratio then brake thermal efficiency increases and statistical data shows that it increases from 16.75 % at 3.31 kg load to 29.63, 29.95, 31.29 and 34.99 % for compression ratio 14, 15, 16 and 18 respectively at 12 kg load.

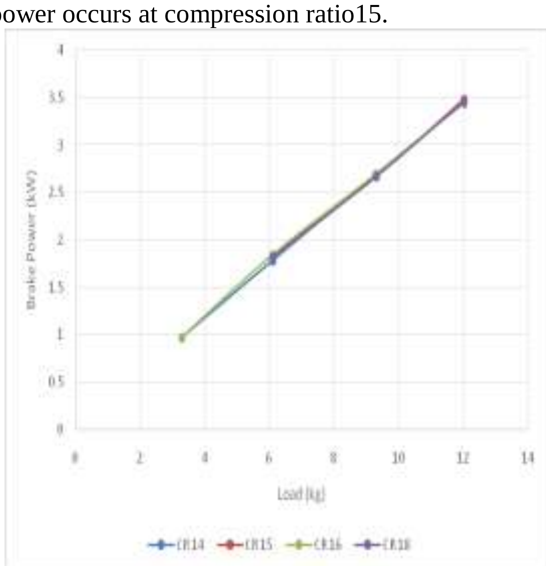
It is also observed that as compression ratio is increased at any load then brake thermal efficiency of the engine increases.



4.3. Comparison of brake power with load:

As the graph Load vs Brake Power at different compression ratio shows that as we increase the load at any particular compression ratio then brake power increases and statistical data shows that brake power increases from 0.97KW at 3.31 kg load to 3.44, 3.48, 3.45, 3.46 KW for compression ratio 14, 15, 16 and 18 respectively at 12 kg load.

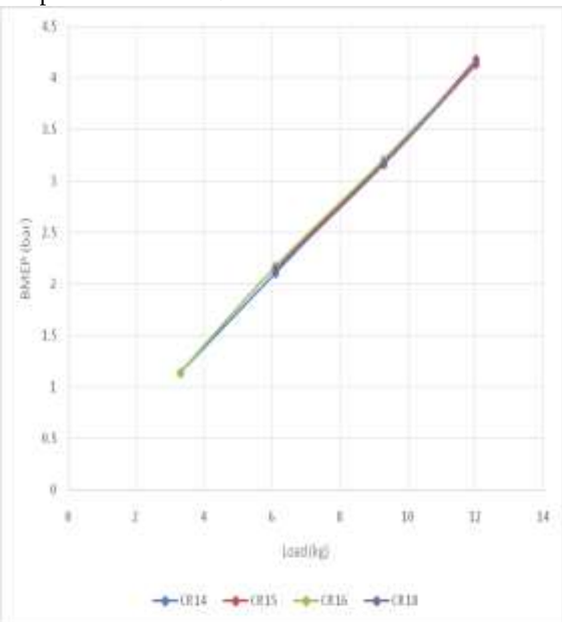
It is also observed that optimal value of brake power occurs at compression ratio15.



4.4. Comparison of brake mean effective pressure with load:

The below graph Load vs Brake Mean Effective Pressure (bar) at different compression ratio shows that as we increase the load at any particular compression ratio then Brake Mean Effective Pressure increases and statistical data shows that it increases from 1.14 bar at 3.31 kg load to 4.14, 4.18, 4.14, 4.14 for compression ratio 14, 15, 16 and 18 respectively at 12 kg load.

It is also observed that as compression ratio is increased at any load then Brake Mean Effective Pressure first increases then optimal value occurs at compression ratio 15.



V. Conclusion:

The general conclusions drawn from the results of this work for Diesel Engine are as follows:

1) As the compression ratio of the engine is increased, BSFC decreases (improves). At the lower sides of the compression ratios, the fuel consumption is high due to incomplete combustion of the fuel. The maximum fuel consumption is measured at CR 14.

2) 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.

VI. Nomenclature

CR = Compression Ratio
VCR= Variable Compression Ratio
BP = Brake Power
IP = Indicated Power
BMEP = Brake Mean Effective Pressure
IMEP = Indicated Mean Effective Pressure
FMEP = Friction Mean Effective Pressure
SFC = Specific Fuel Consumption

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