ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 19, April 2017

Performance, Emission and Fabrication of Variable compression ratio in SI Engine

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ABSTRACT

The worldwide pressure to reduce the automotive fuel consumption and exhaust emission is leading to the introduction of various new technologies for the petrol engines as it fight for market share with the diesel engine. Variable compression ratio (VCR) technology has long been recognized as a method for improving the fuel economy of SI engines. Several designs of variable compression ratio two stroke engines are commercially available for analysis purpose. In this present investigation a novel method of changing the compression ratio is proposed, applied, studied and analyzed. The clearance volume of the engine is altered by introducing a metal plug into the combustion chamber. Low compression ratio is employed at full load allowing the turbocharger to work without problem of detonation. The novelty in this work is to permit the two wheeler driver to change the compression ratio. The study with the design, modification, engine fabrication and testing at different compression ratios are for the study of performance of the engine. Then the engine is tested at different compression for the study of emission on the engines. In this method we can able to get a high share of the potential fuel savings in comparison to other variable system.

INTRODUCTION

The variable compression engine means that the compression ratio of the engine can be controlled at each engine operation condition. When the more power of engine is needed during high load, the compression ratio is decreased, and when the higher efficiency is needed during low load, the compression ratio is increased. Under full load conditions, the performance and efficiency of an engine with a compression ratio that is adapted to load demands is capable of reducing knock susceptibility. The variable compression engine means that the compression ratio of the engine can be controlled at each engine operation condition. When the more power of engine is needed during high load, the compression ratio is decreased, and when the higher efficiency is needed during low load, the compression ratio is increased. Under full load conditions, the performance and efficiency of an engine with a compression ratio that is adapted to load demands is capable of reducing knock susceptibility. At low power levels, the VCR engine operates at a higher compression ratio to achieve high fuel efficiency benefits, while at high power levels the engine operates at low compression ratio to prevent knock. The optimum compression ratio is determined as a function of one or more vehicle operating parameters such as inlet air temperature, engine coolant temperature, exhaust gas temperature, engine knock, fuel type, octane rating of fuel, etc. In a VCR engine, the operating temperature is more or less maintained at optimum, where combustion efficiency is high.

1.1 What is compression ratio?

$$\text{Compression ratio} = \frac{\text{Maximum volume (Total volume)}}{\text{Minimum volume (clearance volume)}}$$

Compression ratio is defines as the ratio of total volume (Maximum volume) (i.e. Swept volume+ Clearance volume) to the clearance volume (Minimum volume).

1.2 Why two stroke engines?

The two stroke engine is simple to construct. The engine requires two piston strokes or one complete revolution for each cycle. Exhaust ports in the cylinder walls are uncovered by the piston, permitting the escape of exhaust of gases and reducing the pressure in the cylinder. The charge now flows into the cylinder and is compressed in a separate crank case compartment to a pressure greater than atmosphere pressure. Intake ports are uncovered by the piston and the compressed charge flows into the cylinder, expelling most of the exhaust products, however some charge do escape with the exhaust Comparing four stroke engines, two stroke engines can delivers 50 to 80 % greater power per one piston displacement, high power to weight ratio (twice as many power impulses per cylinder revolutions) piston pin & crank pin experience force in one direction and finally, low cost due to valueless design.

In Two Stroke Spark Ignition engines the thermal efficiency increases with increase in compression ratio. Also, with higher compression ratios the burning limit increases because of the reduction in initial combustion period. Under part throttle conditions the fuel economy can be improved with higher compression ratios. However, this is often associated with problems of knocking and roughness. The paper describes a new type of cylinder head design which allows operating at high compression ratios under part load conditions and at lower compression ratios under full throttle condition

DEMAND FOR VCR ENGINE

The present challenge in automotive engine technology is the improvement of thermal efficiency and fuel economy will lower emission levels. Compression ratio is the key features which influence thermal efficiency of engine. Higher compression ratio results in higher thermal efficiency in the engine. Generally, the operating conditions vary widely, such as stop and go city traffic,

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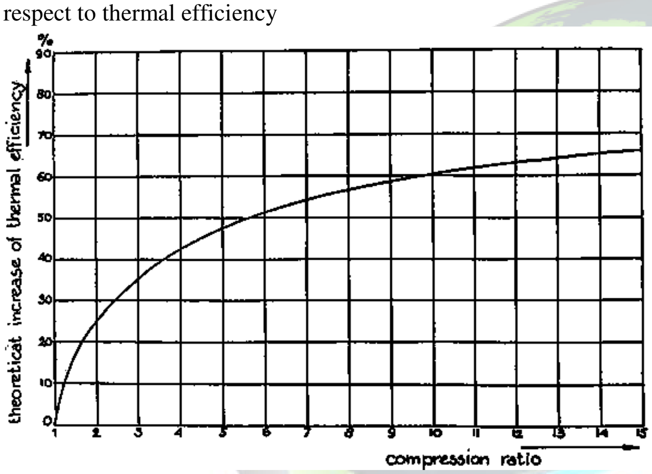
highway motoring at constant speed, or high-speed freeway driving. In a conventional SI, the maximum compression ratio is set by the conditions in the cylinder at high load, when the fuel and air consumption are at maximum levels. If the compression ratio is higher than the designed limit, the fuel will pre-ignite causing knocking, which could damage the engine. Unfortunately, most of the time SI engines in city driving conditions operate at relatively low power levels under slow accelerations, low speeds, or light loads, which lead to low thermal efficiency and hence higher fuel consumption. When load is increased temperature increases at the end thermal efficiency is dropped which influence compression ratio and air-fuel strength. The fuel–air cycle Efficiency gas drops, so that high compression ratio could be employed without the risk of knocking in naturally aspirated or boosted engines. Raising the compression ratio from 8 to 14 produces an efficiency gain from 50 to 65 per cent (15%), whereas going from 16 to 20 produces a gain from 67 to 70 %.Figure below shows the effects of Compression ratio with respect to thermal efficiency



A SUMMARY OF VARIOUS VCR CONCEPTS

- Moving the cylinder head
- variation of combustion chamber volume
- variation of piston deck height
- modification of connecting rod geometry
- moving the crankpin within the crankshaft
- Moving the crank shaft axis

1. Moving Head:

By combining head and liners into a semi monoblock construction which pivots with respect to the remainder of the engine, this enables tilting motion to adjust the effective height of the piston crown at TDC. The rotary eccentric can be used to alter the relative position of the two halves of the engine has to overcome the combined inertia of head, liners, supercharger, intercooler and manifolds.

2. Variation of combustion chamber volume:

The volume of the combustion chamber is changed to obtain the variable compression ratio by moving a small secondary piston which communicates with the chamber. The compression ratio is adjusted by using a secondary piston or valve. The device is presented primarily as a means of controlling knock as its dormant state is the high CR condition. It is suggested that the piston could be maintained at an intermediate position, corresponding to the optimum CR for a particular condition, however this would require a finite length bore in which the piston could travel which raises further questions of sealing, packaging and durability. In another design secondary piston moves continuously at half crankshaft speed and could, potentially, share drive with a camshaft. Phase variation between the secondary pistons and the crankshaft assembly enables the required variation in CR. Introduction of additional elements may affect the ideal geometry and layout of the valves and ports, hydrocarbon emissions increases due to additional crevice volumes.

3. Variable height piston:

Variation in compression height of the piston offers potentially the most attractive route to the production of VCR engine since it requires relatively minor changes to the basic engine architecture when compared to other options. Unfortunately, it requires a significant increase in reciprocating mass and, more importantly, a means to activate the height variation within a high speed reciprocating assembly. This is typically proposed by means of hydraulics using the engine lubricating oil, however reliable control of the necessary oil flow becomes a major problem.

4. Movement of the crankshaft or crankpins:

Several systems have been proposed which either carry the crankshaft main bearings in an eccentric assembly or move the crankpins eccentrically to affect a stroke change at TDC.

5. Modification of connecting rod geometry:

A popular approach has been to replace the connecting rod with a two piece design in which an upper member connects with the piston while a lower member connects with the crankshaft. By constraining the freedom of the point at which the two members join, the effective height of the connecting rod can be controlled and, hence, the compression volume.

All the above mentioned methods require additional mechanism to vary the compression ratio and make the engine operation complicated. They also results in increased reciprocating masses and cost of the engine. Hence in the present work a simple and cheaper method without using additional mechanism is proposed.

VARIABLE COMBUSTION CHAMBER VOLUME:

Design of variable combustion chamber volume:

Selection of engine:

- A center oriented spark plug cylinder head is chosen to avoid the contact of piston and metal plug
- If the normal compression ratio is less, the clearance volume will be large and it will have space for modifications like introduction of an auxiliary chamber

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- Service and other facilities for the purchased engine should be available immediately.

With all the above in mind, TVS CHAMP engine with the following specifications is chosen

- MAKE = TVS CHAMP
- TYPE = Centre oriented spark plug
- POWER = 3.5kW
- SPEED = 3500rpm
- BORE =39 mm
- STROKE = 40mm
- DISPLACEMENT =59.99 cc
- COMPRESSION RATIO = 6.84
- FUELS PROPOSED = Petrol

DESIGN OF CYLINDER HEAD FOR VARIABLE OPERATION OF COMPRESSION RATIO:

The swept volume of the engine is kept constant at 48.97cc and the Compression ratio is varied by varying the clearance volume by the introduction of an auxiliary chamber. As this will only reduce the compression ratio, the cylinder head is drilled with a diameter of 10mm and it is threaded with a standard threading diameter of M10 so that the metal plug can be threaded easily. The threaded hole in the cylinder head is drilled at 45^0 so that the metal plug can be inserted to a maximum length of 7 cm without disturbing the piston and the spark plug. The fins are grinded so that the metal is perfectly seated in the cylinder head which reduces leak of gases from the combustion chamber. [5] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

DESIGN OF METAL PLUG:

The metal plug is made from EN19 material which can withstand higher temperature up to 950^0C. The chemical composition of EN19 material has been described below

SELECTION OF MATERIAL:

- It should have a Low wear resistance
- The material should have High quality and high tensile steel
- It must have a tempered hardness of 28-34HR
- The Shape of the material should be metric round bar
- It should have a Thermal processing temperature of $850\text{-}950^0$C

CHEMICAL	COMPOSITION
Fe	96.86%
C	0.38%
Si	0.21%
Mn	0.91%
P	0.01%
S	0.01%
Cr	1.04%
Mo	0.23%
Ni	0.23%
Al	4.21%

The machined metal plug is shown in figure. The machined tool must be precisely made with less tolerance to manufacture the metal plug error free.

OVERALL FABRICATION:

The machined metal plug is screwed inside the cylinder head and the cylinder head is fixed in the cylinder block. Appropriate care must be taken that the metal plug must not knock with the piston while running. In this work, the metal plug of length 7mm is inserted inside the cylinder head which is going to reduce the clearance volume of the cylinder where the compression ratio of the engine is being altered. The metal plug inserted must not disturb the spark plug position which may result in incomplete combustion, leads to the failure of the novelty in this work. The overall fabricated cylinder head is shown in figure

CYLINDER HEAD AT LOW COMPRESSION RATIO

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CYLINDER HEAD AT HIGH COMPRESSION RATIO

THEORITICAL CALCULATION OF COMPRESSION RATIO:

STOCK COMPRESSION RATIO:

To find compression ratio

$$C.R = \frac{\text{swept volume} + \text{clearance volume}}{\text{Clearance volume}}$$

Swept volume= 3.1416 x (radius of bore)^2 x stroke
= 3.1416 x 1.95^2 x 4.1
= 48.97cc

Clearance volume= 3.1416 x (radius of bore)^2 x clearance height
= 3.1416x 1.95^2 x 0.7
= 8.56cc

Stock compression ratio:

$$C.R = \frac{48.97+8.56}{8.56} = 6.7$$

ALTERED COMPRESSION RATIO:

- **Calculation of metal plug**:

Section -1

Volume of metal plug
= (pi/4) x (diameter of metal plug)^2 x length
= 0.7854 x (0.5^2) x 0.425
= 0.5337cc

Section -2

Volume of metal plug
=0.1721 (from the model)

Total volume of metal plug:

$$= 0.5337 + \frac{0.1721}{2} = 0.761421cc$$

- **Varied compression ratio**:

Change in clearance volume
= original clearance – metal plug volume
= 8.36- 0.71875 = 7.6125cc

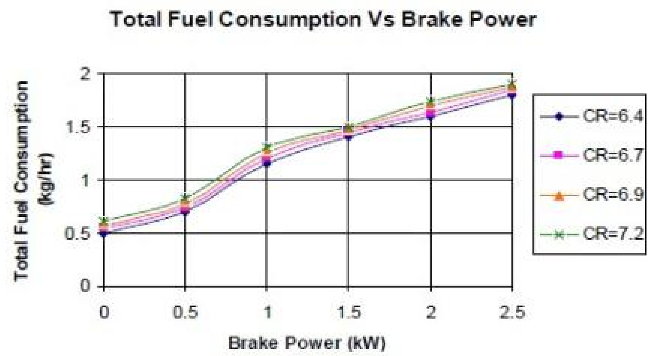
Total varied compression ratio

$$= \frac{\text{swept volume} + \text{varied clearance volume}}{\text{Varied clearance volume}}$$

$$= \frac{48.17+7.6125}{7.6125} = 7.309$$

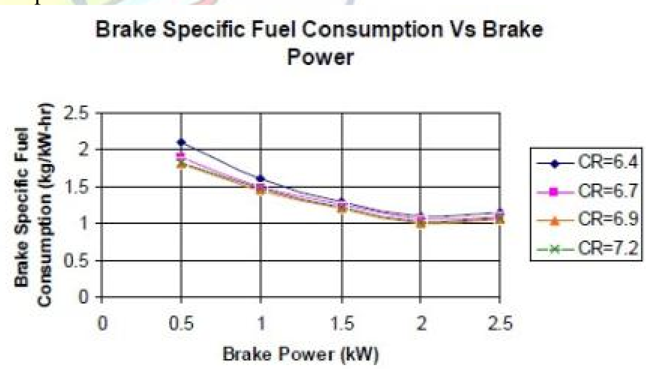
Results and Discussions:

The variation of total fuel consumption with brake power at different compression ratios is shown in the fig.. The total fuel consumption increased with the brake power at all the compression ratios. The total fuel consumption increased up to a compression ratio of 6.9. The improvement in the fuel consumption is considered to be a result of the reduced specific heat ratio of the working gases and increased mechanical loss, cooling loss and time loss.



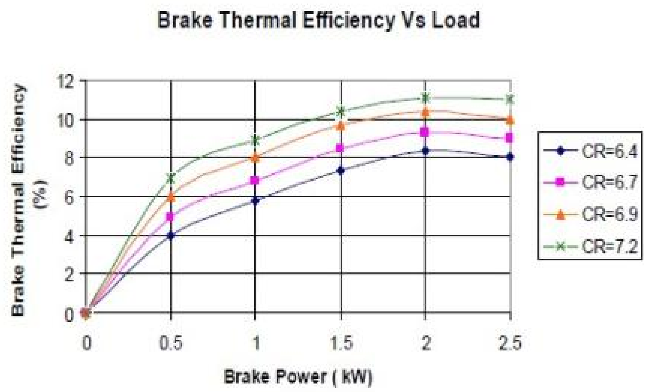
Variation of total fuel consumption with BP at different compression ratios.

The variation of brake specific fuel consumption with brake power at different compression ratios is shown in the fig.. The BSFC reduced with BP at all compression ratios. The BSFC reduced up to the compression ratio 6.9 but slightly increased with the compression ratio of 7.2.



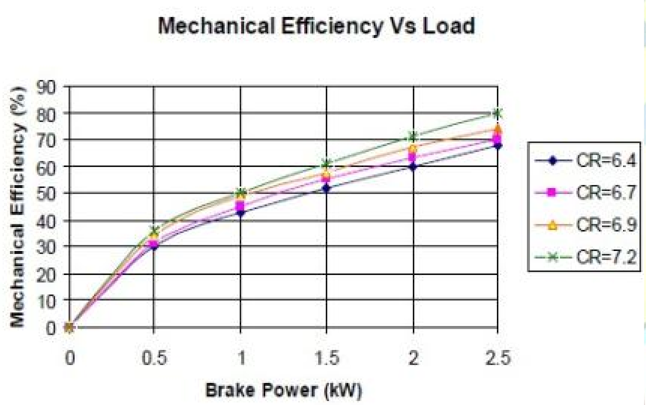
Variation of brake specific fuel consumption with BP

The variation of brake thermal efficiency with brake power at different compression ratios is shown in the fig. The results show that the BTE increases with compression ratio. It is due to the working gas temperature affected by an increase in compression ratio. Variation of the working gas specific heat ratio does not prevent the effect of compression ratios.



Variation of Brake Thermal Efficiency with compression ratio

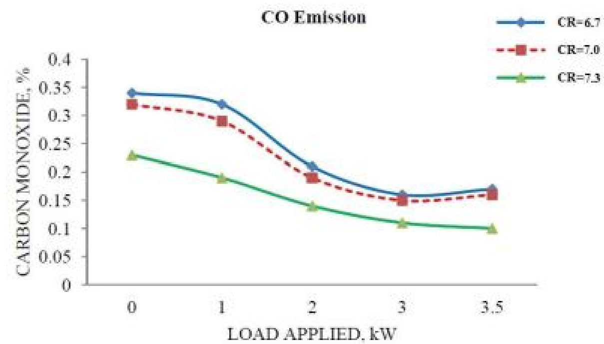
The variation of mechanical efficiency with brake power at different compression ratios is shown in the fig. The mechanical efficiency increases with compression ratio.
The maximum mechanical efficiency is observed with compression ratio of 7.2 at all loading conditions of the engine.

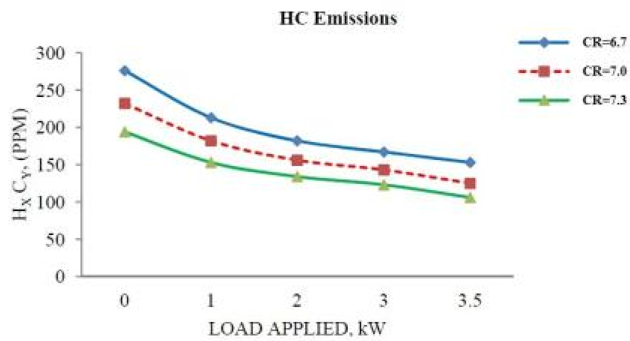


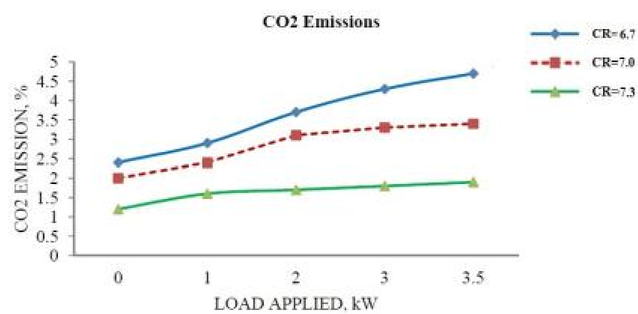
Variation of Mechanical Efficiency with compression ratio

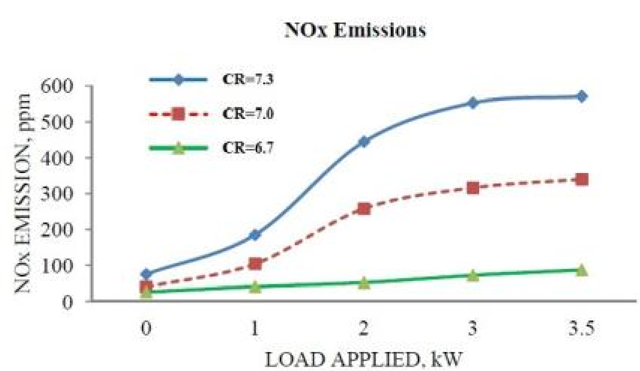
EMISSIONS:

For automotive engines, the great challenge is not only to confirm to future pollutant emissions standards: this is already possible under good conditions. The great challenge is to conform to pollutants emissions standards while responding to CO2 emissions reduction objectives.









Conclusions:
The significant conclusions from the present work are summarized as follows.
1. The compression ratio is varied by using a simple.
2. The total fuel consumption increased with the compression ratio.

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3. The specific fuel consumption reduced with compression ratio.
4. The brake thermal efficiency increased with compression ratio.
5. The mechanical efficiency increased with compression ratio
6. No elaborate setup is required to change the compression ratio and new design enables the driver to operate at compression ratio of his choice based on terrain he wishes to drive. A knurled head is provided to the pin for easy change.

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