Performance and Emission Characterization of Adjustable Cylinder Head Type Variable Compression Ratio in Two-Stroke SI Engine

R Gowtham¹, A Hakeem Meeran Bathusha², R Sankara Ganapathy³, K Mohanraj¹ and N Venkatasubramanian¹

¹Assistant Professor, Rajalakshmi Engineering College, Department of Automobile Engineering, Chennai, Tamilnadu, India.
²Student, Rajalakshmi Engineering College, Department of Automobile Engineering, Chennai, Tamilnadu, India.
³Student, Rajalakshmi Engineering College, Department of Mechanical Engineering, Chennai, Tamilnadu, India.

gowtham.r@rajalakshmi.edu.in, hakeemmeeranbathusha.a.auto.2017@rajalakshmi.edu.in, sankaraganapathy.r.mech.2017@rajalakshmi.edu.in.

Abstract. A lot of technologies have been introduced to retain the petrol engines which exhibit a lot of drawbacks based on emissions and knocking. Variable compression ratio (VCR) technology is applied in the line of SI engines for a long period to give back the standards. This paper is going to analyze and experiment on a commercially available type of VCR technologies. The investigation can provide a great method of varying the compression ratio that is put forth, practically analyzed, and previewed with a change from the previous paper and taken to an account to restrict the compression ratio of +/-1.5. In this analysis, we use the same technology as commercially used two-stroke engines but the clearance volume is changed and introduces a metallic bung on the burning chamber. We have performed the test by varying the compression ratios to more or less than two from the original compression ratio. At lesser weight conditions, a low compression ratio is maintained throughout the experiment to boost up the turbocharger to get a better amount of volumetric efficiency without any trouble. The engine is tested at various compression ratios for the performance study and emissions from the power source at various load conditions. While adopting this method in commercial, we can achieve a potentially higher fuel economy, more power, lower emission compared to other available technologies in ongoing research.

Keywords: Fuel economy, two stroke Engine, Variable compression ratio.
1. Introduction

Based on the working condition of the engine, an engine having a varying compression ratio can be referred to as the variable compression engine. The compression ratio is reduced during higher loading conditions for more power. The compression ratio is kept higher at lesser load conditions for higher output performance. To reduce the knock occurrence, an engine with compression ratio which fits to demands of the load is needed under full load conditions. At lower capacity, the VCR engine works at a better compression ratio to realize the efficiency advantages of fuel, so at high power levels the engine works at a lesser compression ratio to avoid knocking. The ideal compression ratio is the working of vehicle working factors as air inlet factor and temperature of coolant in engine, outlet gas temperature, knocking, fuel octane rating, etc. In a VCR engine, the working temperature is mostly kept at appropriate temperature, where combustion efficiency is higher. Using a two-step compression ratio is to produce a mass engine practically and able to switch to a low compression ratio in 1 second. The variable compression ratio has slight friction in the essential engine [1]. In this study 100% petrol and 20% n-butane alcohol mixture in gasoline is utilized. As a result of which, at low load brake thermal efficiency increases with compression ratio. We can see that the adoption of VCR technology the part load efficiency of gasoline engine is increased and also with fuels having good anti knocking are used[2]. Performance and Emissions of pinnae oil-based bio-fuel are analyzed. The fuel mixes up to 1/4th are tested with four variable compression ratios. Fuels which are blended gives great results compared to diesel. At high compression ratio the emissions are low in VCR engine [3]. Effects of Compression ratio and lambda on CNG SI ICE 1st and 2nd law are practically analysed. With its methane decreasing, CNG shows more irreversible in combustion [4]. Tests were done with diesel and its works of a 4- stroke engine for proportional study with an injection force of 220 bar and compression ratio of 19:1[5]. The two-stroke engine was simple in working and in construction and had more advantages such as power, efficiency, and pickup. The engine needs two strokes of the piston for a cycle. The exhaust gases are escaped as the cylinder walls are not closed by the piston and the pressure inside the cylinder is reduced. The fuel-air mixture moves to the combustion chamber and pressurizes in the crankcase to a higher pressure than atmospheric [6-7]. The two stroke engine produces more power than a four stroke engine based on single piston movement. In Two Stroke Spark Ignition engines the thermal efficiency increases with a compression ratio rise. Under half speeding conditions, the fuel consumption shall be improvised with a higher rate of compression ratio. Anyhow, this is frequently accompanied with issues of roughness and knocking. This paper describes a type of new cylinder head design which lets operation at higher compression ratio under half weight circumstances and at low compression ratios under full speed condition. The reviews of all the design approaches and answers used to get VCR with its unique features consider the results of previous research and its corresponding commercial barriers. The gradually more stringent emission norms and to achieve a better economy of fuel have long prolonged difficulties for research in the automobile sector for advancements towards thermal efficiency and less polluting engines. VCR technology has been considered for a long time as a way for increasing the engine performance, mileage and output characteristics as possible for emission reduction. The most important thing about the VCR engine is to work as possible for various loads of compression, by varying the volume of the combustion chamber, together with the performance. The design and results towards achieving VCR with its unique features, consider the results of previous research and its corresponding commercial barriers [8-11]. The comparatively investigated the properties of En19 Steel and En41B Steel employed in Camshaft of diesel engine. The motive of the paper is to review the residual stress of the cylindrical specimen at surface. The engine camshaft is one of the most important parts within the automobile engines. Due to the rotational effect loading on the touching surfaces in the follower and cam it gives a wear in the component and causes a constant working of the gear valve (speed), displacement of valve, and therefore the torque [12]. To review experimentally the residual stresses of cylindrical objects at the surface layer. The camshafts from diesel engines are generally made by the EN19 Steel material. Replacing EN19 steel with EN41B. The outcome was taken from the hardness test rig shows that the
hardness of the Nitride steel EN 41B is 31 percent more than EN19 Steel and therefore the hardness of the Nitride steel EN41B is 45 percent greater than EN19 steel after hardening. The impact test shows that the toughness of EN41B is 38 percent greater than EN19. They all developed an idea of a Variable Compression Ratio Engine using a metal plug. Traditionally two stroke petrol engines discover a wide variety of uses in the manufacturing of two-wheelers universally, due to environmental laws these engines are decreasing in numbers. Despite these packed norms, these engines are still used in agriculture, generators, etc. During this present analysing, a great method of adjusting the compression ratio is researched and analysed. By introducing a metal plug on the combustion chamber the clearance volume is changed. This modification acceptable to possess four different values of clearance value has been brought out as two sections. The primary part deals with basic planning and fabricating of engine, and testing at various compression ratios for the study of the performance of the engine. The subsequent part deals with the combustion in the engine by means of FLUENT and the examination of the exhaust system. An increase in the compression ratio improvises fuel efficiency and output. The greatness of this project is to allow the 2 wheel drive to change the compression ratio. They have a new proposed design to increase or decrease the compression ratio by modifying the connecting rod at two stages. By this method, we can get high fuel economy savings in comparison to other systems. \(^{13-14}\). They introduced the knowledge about the progress in the inquiry and acknowledged his expertise concerning the dynamometer and flow bench applications. They perform an experimental and theoretical investigation on BT efficiency by varying the effect of CR. The effect of compression ratio on brake thermal efficiency, CO & NO\(_X\) are analyzed using Greaves MK20 SI Engine.\(^{15}\). The thermal efficiency is influenced mainly by compression ratio. A Higher compression ratio gives higher thermal efficiency and a lower compression ratio gives lower thermal efficiency in the engine. The operating conditions of a vehicle differ variably, as in traffic, frequent stopping and crowded roads, in freeway highway driving, and constant-speed highway driving, also driver condition depends. In a common SI engine, the maximum compression ratio is set by the state in the cylinder at high load. If the compression ratio is higher than the predetermined limit, the fuel will pre-ignite causing knocking. When the load is increased temperature increases at the end thermal efficiency is dropped which influences the compression ratio and air-fuel mixture. The fuel-air cycle Efficiency decreases so that a high compression ratio could be induced without the risk of knocking in power engines. Increasing the compression ratio from 8 to 14 gives efficiency again from 55 to 70 percent (15%), whereas going from the ratio from 16 to 20 produces a gain from 62 to 65 percent (3%). The figure 1 given below explains the effects of the compression ratio based on thermal efficiency.

![Figure 1: Compression ratio Vs. theoretical increase of thermal efficiency](image-url)
2. Materials and Methods

2.1 Experimental Design
The variable compression ratio is gained by modification of volume of the cylinder by dislocating the periphery piston, which is small and meets with the combustion chamber. The compression ratio is altered with the use of a periphery piston. For a particular condition, it is advised to keep the piston at median point near to the best compression ratio, anyhow it needs the cylinder bore at finite length for the piston to move freely. The variation in the piston's compression height gives a correct way to form a variable compression ratio engine. To activate the change of height with high speed reciprocating assembly, the VCR system needs to increase the reciprocating mass. All the pointed concepts above need extra devices to make the engine operation difficult and change the compression ratio. Thus in this work, a change in the later model is made to get a higher difference in the compression ratio and analyze the difference in data.

2.2 Variable Compression ratio
Selection of engine: A center placed spark plug cylinder head is chosen to prevent the contact of the piston and metal plug. With all the above in mind, the YAMAHA RX100 engine with the following specifications was chosen. The scrub capacity of the engine sustained at 96.97cc and the burning ratio changed while changing consent capacity while introducing an additional chamber. By using this only decreased compression ratio, cylinder head drilled with a diameter 9.5mm along with it is threaded with a standard threading diameter of M9 so that the metal plug can be threaded without difficulty. The threaded hole in the cylinder head is drilled at 350 so that the metal plug can be inserted to a Maximum length of 8.5 cm without disturbing the piston and the spark plug. The fins are grinded such that the metal plug is seated perfectly in the cylinder head which prevents leak of gases from the burning chamber. The tabular column 1 is Engine Specification and Tabular column 2 Chemical composition of metal plug.

Table 1: Two-Stroke Engine Specification

| MAKE        | YAMAHA RX100                        |
|-------------|-------------------------------------|
| ENGINE TYPE | Petrol Engine with Centered spark plug |
| POWER       | 11kW                                |
| SPEED       | 7500rpm                             |
| BORE        | 50.8 mm                             |
| STROKE      | 50.8 mm                             |
| DISPLACEMENT| 98 cc                               |
| COMPRESSION RATIO | 6.7:1                          |
### Table 2: Chemical Composition of Metal Plug

| Material          | COMPOSITION   |
|-------------------|---------------|
| Ferrous           | 97 – 97.79%   |
| Carbon            | 0.36 – 0.44%  |
| Silicon           | 0.21%         |
| Manganese         | 0.7 - 1%      |
| Phosphorus & Sulfur | 0.01%        |
| Aluminum & Nickel | 4.21% & 0.23% |
| Chromium          | 0.9 – 1.2%    |
| molybdenum        | 0.25 – 0.36%  |

#### 2.3 Design of Metal Plug

The metal plug is made from 709M40 material, low alloy steel which can withstand higher temperatures up to 1000°C. The chemical composition of 709M40 material has been described below. The selection based on low wear resistance, high quality, high tensile strength and metric round bar. They have a tempered hardness of 201-375HB. It should have a Thermal processing temperature of 850-950°C.

The machined metal plug is shown in figure 2 and Figure 3 is 3D modelling. The machined tool must be precisely made with less tolerance to manufacture the metal plug error-free. Mechanical properties of the metal are: Tensile strength – 700 to 1225 MPa; Yields strength – 445 to 940 MPa; Hardness, Brinell – 201 to 175 HB.

![Figure 2: The machined metal plug](image1)

![Figure 3: 3D Modeling of machined plug](image2)

#### 2.4 Experimental Fabrication

The machined metal plug is screwed within the plate and the plate is fitted into the engine block. Acceptable care ought to be taken that the metal plug shouldn't knock with the piston once running. During this paper, the metal plug of length 8.5cm is inserted within the plate that goes to reduce the clearance volume of the cylinder wherever the compression quantitative relation of the engine is altered. The metal plug inserted shouldn't disturb the plug position which could end in incomplete combustion, and fails the novelty during this work. The figure 4 and 5 shows the cylinder head at lower compression ratio and 3D Modeling. The figure 6 and 7 shows the cylinder head at higher compression ratio and 3D Modeling.
3 Results and Discussion
3.1 Performance characteristics

3.1.1 Total Fuel Consumption
The below graph represents the difference of complete combustible utilization with brake power at distinct compression ratio. The combustible utilization raised with capacity in least the compression ratios. The complete combustible utilization raised till compression ratio of 6.9. The progress within combustible utilization taken into account to be consequence of decreased heat capacity ratio of functioning gases and raised time loss, mechanical loss and cooling loss.
3.1.2 Brake Thermal Efficiency

The below graph shows that the change of brake thermal efficiency with brake thermal capacity at various compression ratios. The consequence exhibits that BTE increases with compression ratio. Due to the functioning gas centigrade high-flown by a rise in the compression ratio. Effect of the burning ratio cannot be prevented while changing the functioning gas particular heat ratio.

![Figure 8: Variation of total fuel consumption with BP at different compression ratio.](image)

![Figure 9: Variation of Brake Thermal Efficiency with compression ratios](image)

3.2 Emissions Characteristics

For internal combustion engines, the challenge is not only to confirm future emissions standards: which is already possible under good conditions as well as to check the CO and NOx emissions along with other products. There is an increase in compression ratio to increase the capacity ratio in the burning chamber. Due to a decreased surface to volume ratio, the hydrocarbon emissions and carbon monoxide are decreasing and will be visible in the graph. The thermal efficiency is lowered and as a result exhaust gas temperature is increased, inside the combustion chamber attaining a complete combustion increases the peak cycle temperature. The use of higher compression ratio results in more blaze gas centigrade and smaller remaining content. It may guide a larger NOx discharge on a capacity...
base. Although engine regulation rises with rise in compression ratio, brake specific particular oxides of nitrogen discharge reduce. The burning chamber consequence more surface to capacity ratio, a correlative more crack capacity and smaller fatigue vapor centigrade. Thus the capacity of blaze state regions rises resulting in more HC discharge. Due to this engine CR raises with a rise in hydrocarbon discharge. While raising particular CO discharge is reduced due to lower CR% fuel efficiency. The below graph shows hydrocarbon emission versus brake power at different compression ratios of two stroke engines. The diagram 11 shows the oxides of nitrogen versus brake power for different compression ratios. The figure 12 shows emission of Carbon monoxide and brake power at various burning ratios.

**Figure 10**: Hydrocarbon VS Brake Power

**Figure 11**: Oxides of nitrogen VS Brake Power
Conclusions
The experimental study of fabrication and performance of variable ratio engines is being performed using a chassis dynamometer. Lower the compression ratio increases the pulling capacity of the engine due to high torque being achieved. High compression ratio raises the NOx due to high brake thermal efficiency whereas it reduces the CO and HC emission due to complete. The burning ratio is diverse by employing easy metal plugs. The complete combustible utilization was increased with an increase in compression ratio. The particular combustible utilization was decreased with a compression ratio. The brake thermal efficiency raised with the increase in compression ratio for increase in specific CO emission. The mechanical efficiency and torque increased with a compression ratio because of the increase in stroke to bore ratio. No detailed report is needed to vary the compression ratio and new pattern authorize the driving force to work at the burning ratio of his alternative supported land he desires to guide.

References
[1] Karsten Wittek Frank Geiger Jakob Andert Mario Martins Vitor Cogo and Thompson Lanzanova 2019 Experimental investigation of a variable compression ratio system applied to a gasoline passenger car engine Energy conversion and management Vol. 183 Page number 753-763.
[2] Rinu Thomas M Sriessankaran Jeevan Jaidi Dileep M. Paul P. Manjunath 2016 Experimental evaluation of the effect of compression ratio on performance and emission of SI engine fuelled with gasoline and n-butanol blend at different loads Perspectives in Science Vol. 8 743–746.
[3] T Ashok Kumar R Chandramouli T Mohanraj 2015 A study on the performance and emission characteristics of esterified pinnai oil tested in VCR engine Ecotoxicology and Environmental Safety Volume 121 Pages 51–56.
[4] A Javaheri V Esfahanian A Salavati-Zadeh and M Darzi 2014 Energetic and Exegetic analyses of a variable compression ratio spark ignition gas engine Energy Conversion and Management Volume 88:739–748.
[5] Srinivas kommana Balu Naik Banoth Kalyani and Radha Kadavakollu 2016 Performance and Emission of VCR-CI Engine with palm kernel and eucalyptus blends Perspectives in Science Volume 8 Pages 195-197.
[6] M Ayaz Afsar Prafulla V. Pawar and Prathik Dahule S. Papinwar 2001 Experimental investigation of direct air injection scavenged two stroke engines International symposium on computing, communication and control (ISCCC). Proc. Of CSIT vol.1 (2001) PP. 21-24.
[7] Yuh Tohru G 2010 The effect of higher compression ratio in two-stroke engines Yamaha Motor Co Ltd SAE 931512 Page number 355-362.

[8] Amjad Shaik N Shenbaga Vinayaga Moorthi and R Rudramoorthy 2007 Variable compression ratio engine: A future power plant for automobiles- An overview Proceedings of the Institution of Mechanical Engineers Part D: Journal of Automobile Engineering vol. 221 no. 9. pp 1159-1168.

[9] N. Seshaiyah 2010 Efficiency and exhaust gas analysis of variable compression ratio spark ignition engine fuelled with alternative fuels International journal of energy and environment, Vol.1 Issue 5 pp 861-870.

[10] Lawankar, S 2013 Influence of Compression Ratio and Ignition Timing on the Performance of LPG Fuelled SI Engine SAE Technical Paper Page number 2013-01-2889.

[11] Mahesh P. Joshi and Aparna V. Kulkarni 2012 Variable Compression Ratio (VCR) Engine- a review of future power plant of automobile at International Journal of Mechanical Engineering Research and Development (IJMERD) Volume 2 Number 1 pp. 09-16.

[12] N.V Diwakar C. Bhagyanathan and J. David Rathnaraj 2014 Analysis of mechanical properties of EN 19 Steel and EN44B Steel used in Diesel Engine Camshaft at International Journal of Current Engineering and Technology Special Issue-2 page no: 162-167.

[13] Dr. A.Srinivas Dr. G.VenkataSubbaiah P.Venkateswar Rao and M. Penchal Reddy 2014 Some innovation in design of low cost variable compression ratio two stroke petrol engine International Journal of Mechanical Engineering Volume 2 Issue 5.

[14] Savita Tomar Reena Mishra Sarita Bisht Sanjeev Kumar Aman Balyan and Gaurav Saxena 2013 Optimisation of connecting design to achieve VCR Journal of Engineering Research and Applications ISSN : 2248-9622 Vol. 3 Issue 6 pp.281-286.

[15] Jai Preetham R , 2014 Performance and Emission characteristics of variable Compression ratio S.I engine at International Journal of Innovation and Applied Studies Vol. 6 No. pp. 172-186.