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Influence of compression ratio on the performance characteristics of a spark ignition engine

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ABSTRACT

The need to improve the performance characteristics of the gasoline engine has necessitated the present research. Increasing the compression ratio below detonating values 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 and theoretical 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 Ricardo variable compression ratio spark ignition engine. Compression ratios of 5, 6, 7, 8 and 9, and engine speeds of 1100 to 1600 rpm, in increments of 100 rpm, were utilised. The results show that as the compression ratio increases, the actual fuel consumption decreases averagely by 7.75%, brake thermal efficiency improves by 8.49 % and brake power also improves by 1.34%. The maximum compression ratio corresponding to maximum brake power, brake thermal efficiency, brake mean effective pressure and lowest specific fuel consumption is 9.The theoretical values were compared with experimental values. The grand averages of the percentage errors between the theoretical and experimental values for all the parameters were evaluated. The small values of the percentage errors between the theoretical and experimental values show that there is agreement between the theoretical and experimental performance characteristics of the engine.

Keywords: Compression ratio, brake power, brake thermal efficiency, specific fuel consumption, brake mean effective pressure.

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. Of the energy present in the combustion chamber only a portion gets converted to useful output power. 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, Q_{LV}, compression ratio,$r_c$and ratio of specific heats,γ [7].

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 center. Theoretically, increasing the compression ratio of an engine can improve the thermal efficiency of the engine by producing more power output. The ideal theoretical cycle, the Otto cycle, upon which spark ignition (SI) engines are based, has a thermal efficiency, η_T, which increases with compression ratio,$\boldsymbol{r_c}$and is given by [5].

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

where, γ is ratio of specific heats (for air γ = 1.4)

However, changing the compression ratio has effects on the actual engine for example, the combustion rate. Also over the load and speed range, the relative impact on brake power and thermal efficiency varies. Therefore, only testing on real engines can show the overall effect of the compression ratio. Knocking, however, is a limitation for increasing the compression ratio [5].

Yuh and Tohru (2005) conducted a research on the effect of higher compression ratios in two-stroke engines. The results show that the actual fuel consumption improved by 1-3% for each unit increase in the compression ratio range of 6.6 to 13.6. It was concluded that the rate of improvement was smaller as compared to the theoretical values. The discrepancies were mainly due to increased mechanical and cooling losses, short-circuiting at low loads and increased time losses at heavy loads. Power output also improved, but the maximum compression ratio was limited due to knock and the increase in thermal load. In addition, the investigation covered the implementation of higher compression ratio in practical engines by retarding the full-load ignition timing.

Asif *et at.* (2008) conducted a research on performance evaluation of a single cylinder four stroke petrol engine. In the research, the actual size of the engine parameters like the bore, stroke, swept volume, clearance volume, compression ratio and engine speed were recorded and computed. Based on the actual size of the engine parameters, the indicated horse power, brake power, and friction horse power were determined and were found to be 1.54, 1.29 and 0.25 respectively. The mechanical efficiency and the thermal efficiency were also calculated and were found to be 83% and 20.5% respectively. The fuel consumption per hour was found to be 0.8 litre/hour while the fuel consumption per distance traveled was found to be 60 km/litre.

This paper investigates for a four stroke spark ignition engine (The Ricardo variable compression ratio engine), the influence of compression ratio on the brake power, brake thermal efficiency, specific fuel consumption, brake mean effective pressure. The theoretical performance characteristics for the engine, obtained from derived equations, were also presented.

i) **Basic Theory**:
The engine torque, T is given by [4]

$$T = WR, \quad (2)$$

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

$$B_P = \frac{\pi NT}{30} \quad (3)$$

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 [4]

$$BMEP = \frac{2B_P}{V_S Nn} \quad (4)$$

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

$$\eta_T = \frac{B_p}{Q_{in}} \quad (5)$$

And

$$Q_{in} = m_f Q_{LV} \qquad (6)$$

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 [4]

$$SFC = \frac{3600\, m_f}{B_P} \qquad (7)$$

ii)**Torque Gain:**
Increase in compression ratio induces greater turning effect on the cylinder crank [6]. That means that the engine is getting more push on the piston, and hence more torque is generated. The torque gain due to compression ratio increase can be given as the ratio of a new compression ratio($newr_C$) to the old compression ratio ($old\ r_C$)given by [8]

$$Torque\ gain/loss = \left(\frac{newr_C}{oldr_C}\right)^{0.4} \qquad (8)$$

MATERIALS AND METHODS

i) **The Test Engine:**
The Ricardo variable compression ratio engine with direct current electric dynamometer is a four stroke water-cooled single cylinder petrol engine. It has a 76.2mm cylinder bore and 111.1mm stroke, giving a swept volume of 506,399mm^3. Variation of the compression ratio was achieved by raising the cylinder head up in order to decrease the compression ratio and by lowering it down to increase the compression ratio.

ii)**Theoretical Determination of Performance Characteristics:**
In the cylinders the combustion process takes place, and converts the chemical energy in the fuel to mechanical power. Ideally, all the heat stored in the fuel may be converted to power; in that case the delivered power is given by taking the product of the heating value of the fuel, Q_{LV}, and the fuel mass flow, m_f, through the cylinders. However there will be losses during the energy conversion, thus it will be multiplied with the brake thermal efficiency, η_{BT} [2]. Thus,

$$B_P = \eta_{BT} Q_{LV} m_f \qquad (9)$$

If equations (3) and (9) are equated, an equation for the relation between the engine torque and mass flow rate of the fuel is developed as

$$T = \eta_{BT} \frac{30\, Q_{LV}\, m_f}{\pi N} \qquad (10)$$

If the whole process is approximated to an Otto cycle multiplied by a constant, the brake thermal efficiency can be calculated by [2]

$$\eta_{BT} = k\left(1 - \frac{1}{r_C^{\gamma-1}}\right) \qquad (11)$$

K in equation (11) is a constant and it is introduced because in equation (1), energy losses due to incomplete combustion, heat transfer from gas to cylinder walls and timing losses have been neglected. Thus, equation (10) then becomes

$$T = \frac{K}{2\pi}\left(1 - \frac{1}{r_C^{\gamma-1}}\right) \frac{30\, Q_{LV} m_f}{N} \qquad (12)$$

The values for K (from 1100 to 1600rpm in increment of 100rpm) were determined experimentally for a reference compression ratio of 7 using equation (12). The theoretical torque gain for compression ratios 5, 6, 7, 8 and 9 were calculated by means of equation (8). The theoretical brake power, brake mean effective pressure, brake thermal efficiency and specific fuel consumption were calculated by means of equations (3), (4), (5) and (7) respectively.

iii) **Experimental Determination of Performance Characteristics:**
The brake load was measured through a dynamometer by the following procedure:
The engine was motor-started when the transformer was switched on by a switch gear (lever). The motor at this point becomes the load to the engine and it absorbs the engines power (as a dynamometer). The torque arm was measured; the brake load and time taken for 50ml of the fuel to be consumed were taken and recorded. The experimental values for the engine torque, brake power, brake mean effective pressure, brake thermal efficiency and specific fuel consumption were similarly calculated by equations (2), (3), (4), (5) and (7) respectively.

iv) **Error Analysis:**
The percentage errors in the performance characteristics were calculated by the following equation [2]

$$Error = \frac{Theoretical\ value - Experimental\ value}{Experimental\ value} \times 100\% \qquad (13)$$

RESULTS AND DISCUSSION

Figures 1 to 4 are the experimentally obtained graphs for the brake power, brake thermal efficiency, brake mean effective pressure and specific fuel consumption from the Ricardo variable compression ratio engine test. Comparisons between the theoretical and experimental values are also shown graphically in figures 5 to 8 for the various compression ratios of 5, 6, 7, 8 and 9 for each of the performance characteristics. The graphs presented for the comparisons are for an engine speed of 1500 rpm.

From figure1, it is seen that the engine brake power increases as the compression ratio increases. This is due to the increase in brake torque at high compression ratios. Increase in compression ratio induces greater turning effect on the cylinder crank. That means that the engine is giving more push on the piston, and more torque is generated. Equation (3) shows that the engine torque is directly related to the brake power.

In Figure 2, the maximum thermal efficiency occurred at compression ratio of 9. By compressing the available air and fuel mixture into a smaller space, with the heat of compression, causes better mixing and evaporation of the fuel. Greater combustion efficiency from increase in compression ratio means that the combustion of the fuel pays greater dividends by more energy release from the fuel. The net result is that the increase in energy available is greater.

As the compression ratio increases, the fuel mixture is sufficiently compressed thereby increasing the thermal efficiency, so that less fuel is required to produce the same amount of energy. Fuel consumption is reduced at higher compression ratios between 8 and 9.

Table 1.Grand averages of the percentage error

r_C	B_P (%)	η_{BT} (%)	*SFC* (%)	*BMEP* (%)
5	0.75	2.13	2.57	0.75
6	1.64	1.36	1.38	1.63
7	0.18	0.43	0.69	0.21
8	2.29	3.67	3.86	2.30
9	1.85	9.89	11.17	1.85

As the compression ratio increases (up to 8 and 9), the theoretical brake power increases beyond the experimental values (figure 5), which is understandable due to practical losses. In figure6, as the compression ratio increases, the theoretical thermal efficiency decreases below the experimental value. It means that the theoretical thermal efficiency was underestimated for compression ratio beyond 7. Similar trends are obtained for the specific fuel consumption and the brake mean effective pressure (figures 7 and 8). Increase in the compression ratio up to 8 and 9, increases the fuel consumption and brake mean effective pressure increases beyond the experimental values.

The errors in the theoretical performance characteristics of the engine were evaluated and are shown in table 1.

Table1 shows that the percentage discrepancy between the theoretical and experimental values ranged from 0.18 to 2.29% for the brake power, 0.43 to 9.89% for the brake thermal efficiency, 0.69 to 11.17 % for the specific fuel consumption and 0.21 to 2.3% for the brake mean effective pressure.

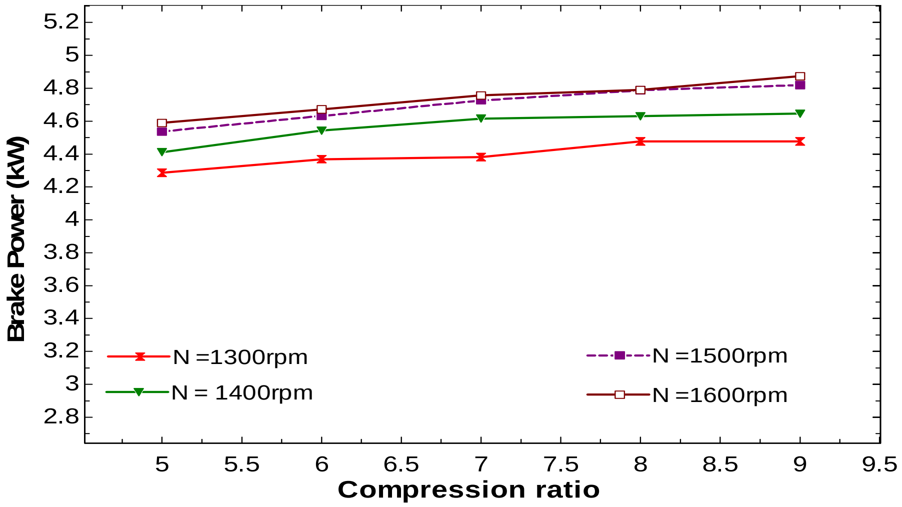

Figure 1. Variation of brake power with compression ratio for different engine speeds.

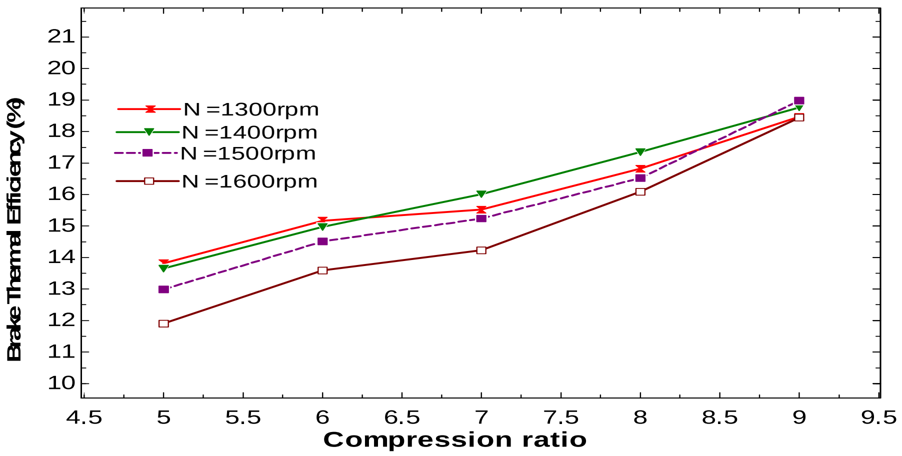

Figure 2. Variation of brake thermal efficiency with compression ratio for different engine speeds.

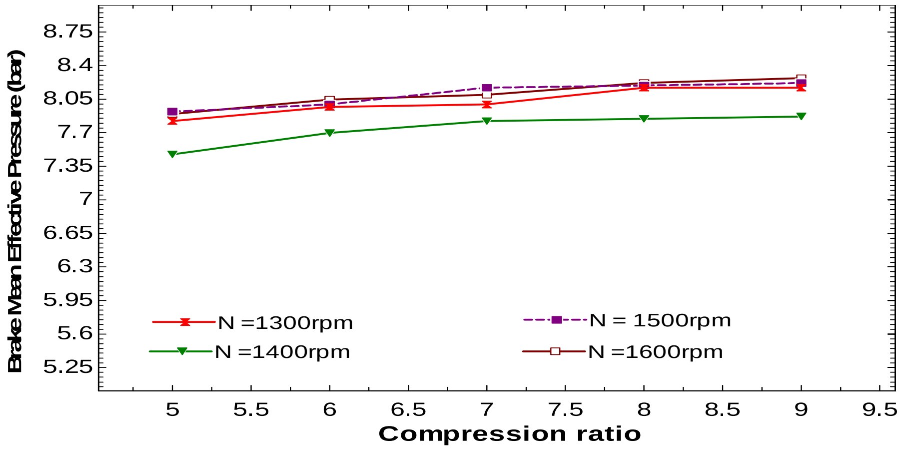

Figure 3. Variation of brake mean effective pressure with compression ratio for different engine speeds.

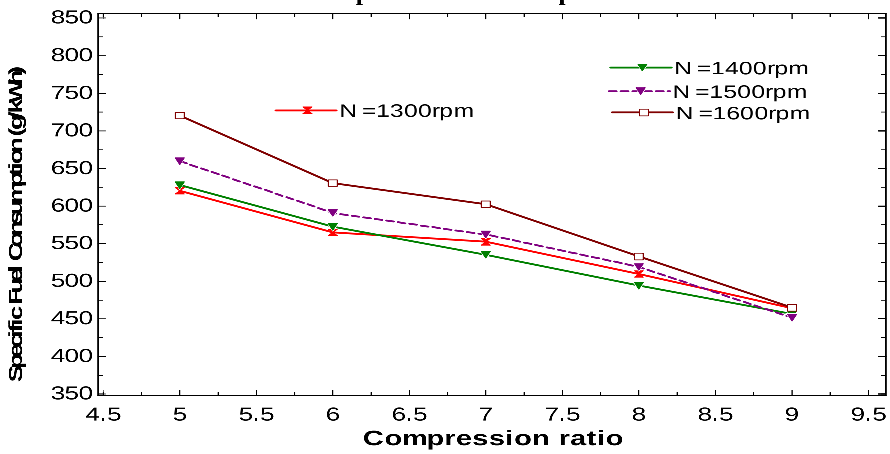

Figure 4. Variation of specific fuel consumption with compression ratio for different engine speeds.

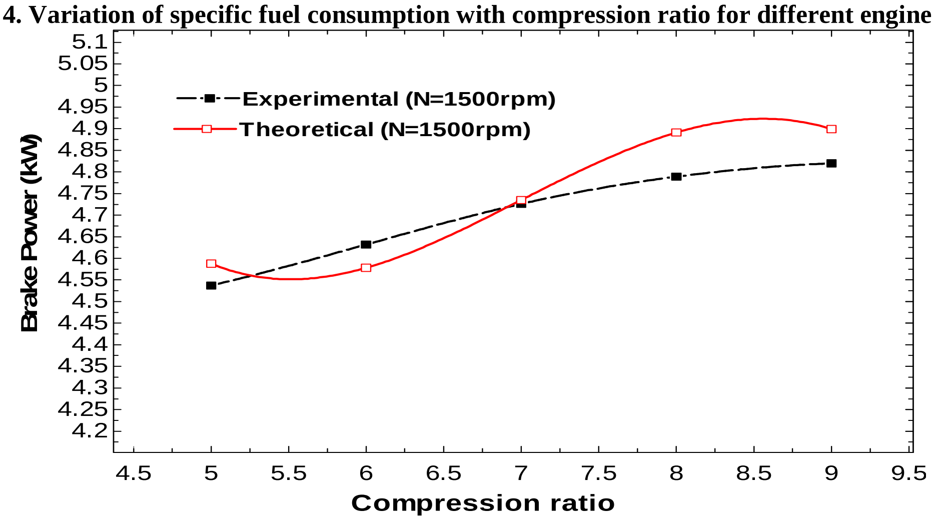

Figure 5. Variation of brake power with compression ratio at engine speed of 1500rpm

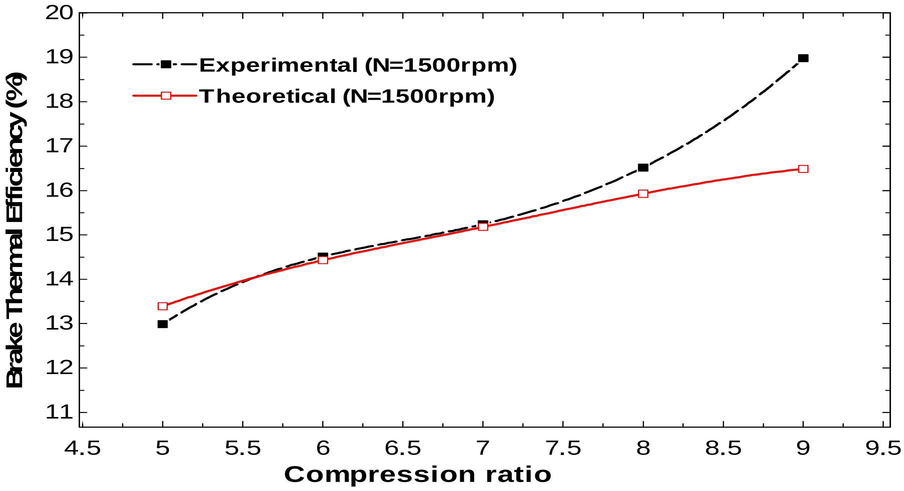

Figure 6.Variation of brake thermal efficiency with compression ratio at engine of 1500 rpm

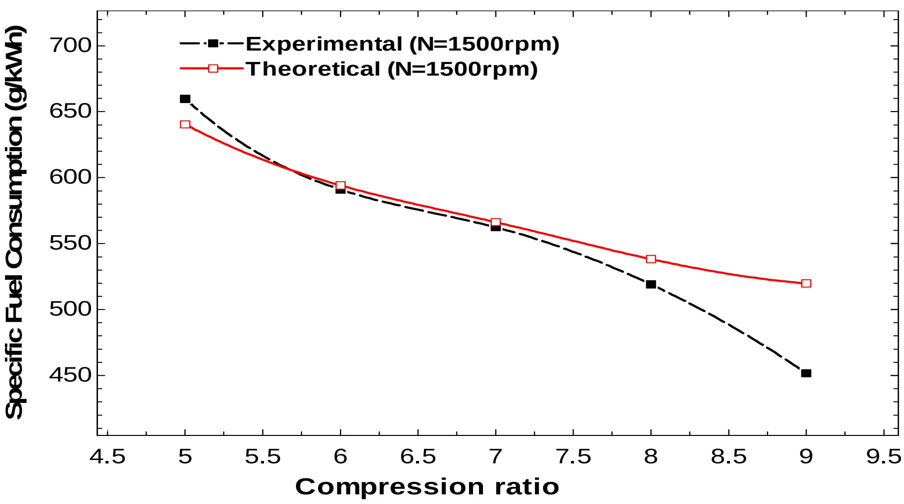

Figure 7. Variation of the specific fuel consumption with compression ratio at engine speed of 1500 rpm

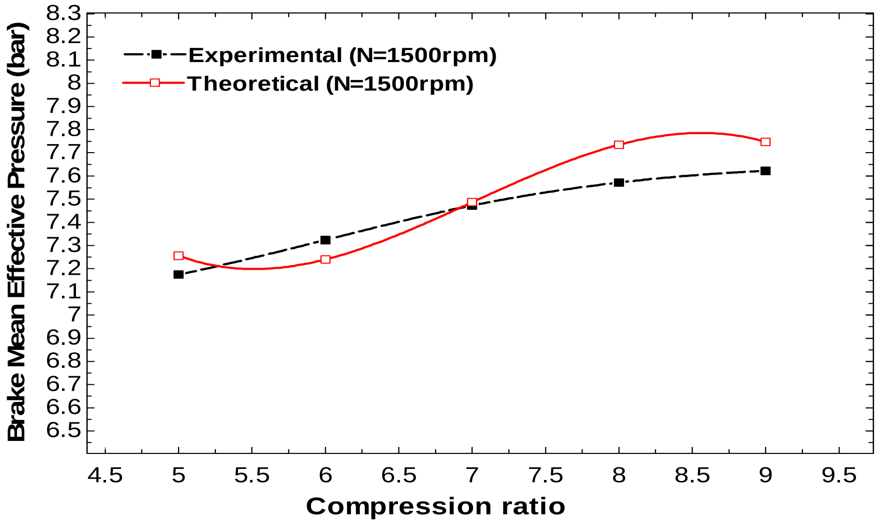

Figure 8.Variation of brake mean effective pressure with compression ratio at engine speed of 1500 rpm.

CONCLUSSION

The general conclusions drawn from the results of this research work are as follows:

- Increase in compression ratio on the Ricardo variable compression ratio engine increases the brake power, brake thermal efficiency, brake mean effective pressure and reduction in the specific fuel consumption. It means that higher compression ratios make it possible to improve the performance characteristics of spark ignition engines.
- The highest compression ratio corresponding to the maximum brake thermal efficiency and brake power is 9.
- The small values of the percentage errors between the theoretical and experimental values show that there is agreement between the theoretical and experimental performance characteristics of the engine.

REFERENCES

[1] Abdel Rahman, A.A. and Osman, M.M. *Experimental investigation of varying compression ratio of spark ignition engine working under different Ethanol-Gasoline fuel blends*. **1997**. Vol. 21, issue 1.
[2] Andreas, B., *Torque Modeling and Control of a Variable Compression Engine,* Performanced in Vehicular System, Dept. of Electrical Engineering at Linkopings University, Sweden. **2003.**
[3] Asif, A.M., Jandool, K., Saeed, A.S. and Ali, A.C., **2008**, *Performance Evaluation of a Single Cylinder Four Stroke Petrol Engine,* Farm machinery institute, National Agricultural Research Centre, Islamabad, Pakistan.
[4] Eastop, T.D. and McConkey, A. *Applied Thermodynamics for Engineering Technologists*, ELBS with Longman, 5th Edition, **1995**, pp 420-439.
[5] Chaiyot, D. and Somrat, K.., **2005**, *Experimental Influence of Compression Ratio on to Performance and Emission of Compressed Natural Gas Retrofit Engine*, King Mongkut's Institute of Technology North Bangkok.
[6] Heywood J. B., *Internal combustion Engines Fundamentals*. McGraw Hill Book Company, **1988**.
[7] Mohit, S. and Lamar S., **2010**, *Making more efficient combustion engines*, Bright Hub Publisher.
[8] Philip, H.S. and David, N.W., *The Design and Tuning of Competition Engines*. Bentley publisher, 6th edition, **1954.**
[9] Yuh, M. and Tohru, G., **2010,** *The Effect of Higher Compression Ratio in Two-Stroke Engines*, Yamaha Motor Co, Ltd. pp 355-362.