Temperature, Heat Distribution and Performance Analysis in a Variable Compression Ratio Internal Combustion Engine

Dinesh Kumar Soni, Rajesh Gupta, Rahul Kumar Singh

Abstract: - The internal combustion engines are also known as heat engines because of the utilization of heat energy of the fuel to convert it in to mechanical energy of the engine which finally runs the vehicle. Therefore, it is necessary to examine the generation and utilization of heat inside and outside the engine. For the above mentioned purpose, a variable compression ratio engine was used to perform experiment. The heat distribution of the used engine was investigated to recognize the heat loss areas from the engine. The experiments were performed by changing compression ratio from 15 to 21 and an optimum compression ratio was found. The experiments are further extended to find an optimum load value at standard compression ratio of the engine. The analysis was performed by using various factor of heat utilization such as heat supplied by fuel, heat equivalent to brake power, heat loss to exhaust gases, heat loss to engine cooling water and heat unaccounted. The proposed research will be useful to overcome the challenges during selection of compression ratio for design of an engine in industries.

Keywords: Variable Compression Ratio Engine, Heat Balance Sheet, Compression Ratios.

I. INTRODUCTION

The search of a suitable engine to work with SI and CI engine is completed by using a variable compression ratio engine. This engine facilitates the use of gasoline and diesel fuel in the same engine by changing compression ratio. The compression ratio can be changed by means of an inbuilt mechanical system.

Compression ratio is high for CI engines (15-21) and low for SI engine (9-14). In case of CI engines, the high compression ratio increases fuel temperature sufficiently high at the end of compression stroke to self ignite combustible mixture. Whereas, in case of SI engines, a spark plug is use to burn the fuel inside combustion chamber. The variable compression ratio engine is used extensively in the field of IC engine research. Many researchers are focused on that engine due to its easiness of operation. The variable compression ratio engine is used extensively in the field of IC engine research. Many researchers are focused on that engine due to its easiness of operation. Some promising researches are present in the literature review.

Selvan et al [1] used cerium oxide nano particles and carbon nano tubes as fuel borne additives and analyze the effects on emission, performance and combustion characteristics of a variable compression ratio engine. Raheman et al [2] performed experimental analysis by using a biodiesel with diesel fuel at variable compression ratio and injection timings. Chintala et al [3] investigated dual fuel operation in a variable compression ratio engine for enhancement of hydrogen share in the fuel. Hariram et al.[4] investigated effects of variation in compression ratio on combustion and performance characteristics of direct injection compression ignition engine. Laguitton et al [5] examined the effect of variation in compression ratio on exhaust emission in a PCCI engine. Biplab et al [6] used palm oil methyl ester in diesel fuel to perform thermodynamic analysis of a variable compression ratio engine. Bora et al [7] performed experiments on a variable compression ratio engine by using raw gas as a fuel and analyze it,s effect on performance, combustion and emission parameters. Murlidharan et al [8] performed experiments by using blends of methyl ester of waste cooking oil and diesel fuel and analyze their effect on performance, combustion and emission parameters. In another research [9] they used blends of diesel and biodiesel for the same analysis. Liu et al [10] investigated the effect of air dilution and optimum compression ratio of a n-butanol fuelled homogeneous charged compression ignition engine. Gong et al [11] analyzed the effects of variable compression ratio in terms of emission and performance parameters in a methanol fuelled stratified charged engine. Bora et al [12] investigated dual fuel operation in rice bran – biogas fuelled variable compression ratio engine. Kassaby el al. [13] studying the effect of waste oil produced biodiesel/diesel fuel in a variable compression ratio engine. Ramalingam et al. [14] studied the effects of injection timings and compression ratio at a diesel engine fuelled with annona methyl esters. Jindal et al [15] investigated the effects of change in compression ratio compression ratio and injection pressure in a Jatropha methyl ester fuelled direct injection diesel engine.

Manuscript published on January 30, 2020.
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Bora et al [16] optimized diesel engine based on raw biogas working in dual fuel mode by varying compression ratio and injection timing. Ganamoorthi et al [17] performed experiments by changing compression ratio on blends of ethanol and diesel fuel, and analyze their effect on performance, combustion and emission parameters.

Nagaraja et al [18] investigated the Effect of Compression Ratio with Preheated Palm Oil - Diesel Blends to analyze Performance and Emission Characteristics of Variable Compression Ratio Engine.

After a detailed discussion, it can summarize that heat distribution analysis has not carried out by any researcher in a variable compression ratio engine in view of thermal efficiency and power. Now, it is very much essential to investigate heat balance due to its importance in the working of an engine. Thus, heat distribution analysis is carried out in the variable compression ratio engine at various compression ratios

II. MOTIVATION

The distribution of heat in a variable compression ratio engine is an interesting area for research. The heat is the governing factor which operates whole engine and produce power. Every fuel in the world is used to produce certain amount of heat by either mechanical or chemical process. The heat is produced by fuel is used to reciprocate piston inside combustion chamber and this reciprocating motion is converted to rotational power to flywheel by using crank and connecting rod mechanism. Therefore, it is necessary to investigate the distribution of heat at different compression ratio in the variable compression ratio engine.

III. RESEARCH OBJECTIVE AND SCOPE

Heat distribution analysis will be carried out for CI engine mode in a variable compression ratio engine. The compression ratio will be changed from 15 to 21 and an optimum compression ratio will be found by studying the heat distribution analysis, indicated thermal efficiency and indicated power. Mainly, the heat generated by fuel is distributed for four purposes in the engine. The first part of heat is utilized to produce power in the engine, second part is used to produce cooling effect in the engine by circulating water, third part is defined as the heat carried away by exhaust gases and last part is called as heat unaccounted. The heat unaccounted contains heat loss to heat up the engine at initial stage, heat taken away by lubricating oil, heat carried away by piston and connecting rod etc.

The motivation of present research is gained by keeping the mentioned aim in mind. The present paper illustrates the effect of variation in compression ratio on heat distribution in a variable compression ratio engine. The researchers all around the world are trying to reduce heat loss from the CI engine, thus it requires more attention to analyze the heat balance at variable compression ratio engines and to check there effects on thermal efficiency and power at various compression ratio. There is need to explore the optimum compression ratio which gives best result.

IV. PROPOSED METHODOLOGY

The present investigation will involve following two steps and work required against each step. Experimental Procedure: A variable compression ratio engine will be used to perform experimental analysis by changing compression ratio. Following steps will use to perform experimental analysis.

a) Change in compression ratio between 15 to 21at high load, and change in load in standard compression ratio of 17.5.
b) Finding the heat balance sheet for each compression ratio and temperature readings by the installed software. Repeated same for the procedure for change in load operating conditions.
c) Comparison of heat balance sheet at different compression ratio with indicated thermal efficiency and power.
d) Finding of optimum compression ratio as per analysis.

The investigation will be focused to explore the impact of change in compression ratio in terms of heat balance or distribution. Furthermore, these results get compared with the indicated power and thermal efficiency of the engine. In the view of above objective, a variable compression ratio engine is required for experimental procedure. The experimental setup is shown in following figure 1 and Specifications are listed in table 1.

Figure 1. Variable Compression Ratio Engine

Table 1

Engine Type	4 Stroke, 1 Cylinder, VCRE-Water Cooled
Engine Make & Model	ATE Make VCRE_MF
Bore(mm)	87.50
Stroke(mm)	110.00
Standard C.R.	17.50
Com. Rod Length(mm)	232.00
Swept Volume (C.C.)	662.00

Variable Compression Ratio Engine Specifications

V. RESULT AND DISCUSSION

Test was carried out at different compression ratios ranging from 15 to 21 at different loads or torque like 5.00, 10.40, 15.10, 20.30, 25.20 N-m.

The performance characteristics of engine, temperature distribution and heat balance analysis are categorized in two sections of the paper. The first section describes the analysis of different loads at fixed compression ratio of 17.5 and second section describes the analysis of different compression ratio at high load operating conditions.

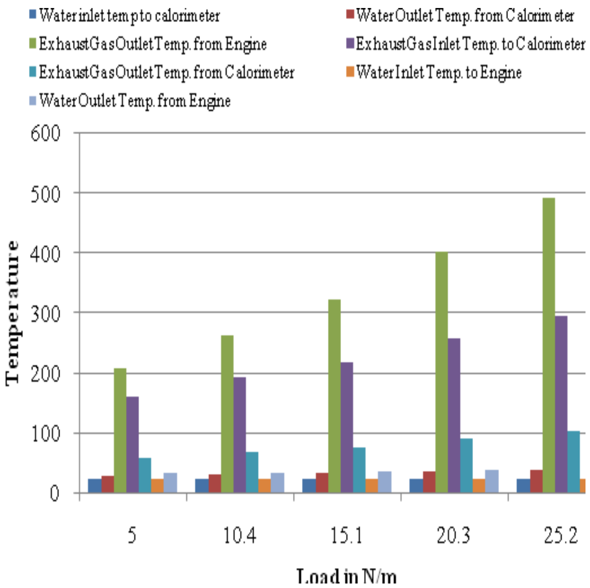

Figure 2. Temperature variation at different points

A. Different loads at a fixed compression ratio of 17.43

Different loads are get examined under a fix compression ratio of 17.43 operating condition. The temperature at the different points of the engine is recorded by the software of the engine and drawn in the figure 2.

In the above figure, it can be shown that the exhaust gas temperature is higher than other temperatures due to complete burning of the fuel, whereas water inlet temperature to engine is lowest. Fig. 3 shows the brake specific fuel consumption of the engine in g/kwh. Brake specific fuel consumption shows the amount of fuel used by engine to produce one kw power for one hour of continuous running.

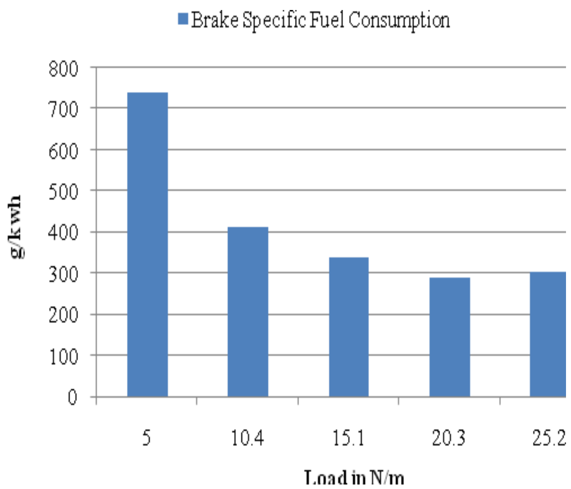

Figure 3. Brake specific fuel consumption at different load

Fig. 4 shows the brake thermal efficiency (BTE) and indicated thermal efficiency (ITE) at different loads of the engine. The indicated thermal efficiency is always higher than the brake thermal efficiency. The indicated thermal efficiency is calculated at the distribution of heat in engine (piston) whereas brake thermal efficiency is calculated at the delivery section of the engine (crankshaft).

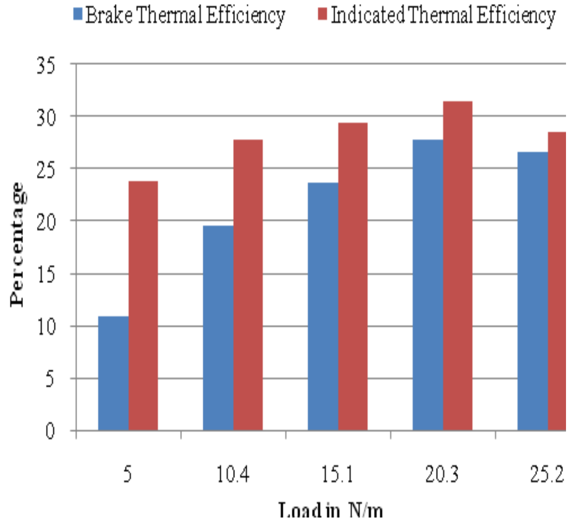

Figure 4. BTE and ITE at different load

Fig. 5 shows the heat distribution in percentage during running of the engine. The full heat of the fuel is distributes in the various section of the engine such as heat equivalent to brake power, heat loss to exhaust gases, heat loss to engine cooling water and heat unaccounted. It can be seen from fig that the heat loss to exhaust gas is higher in high load operating condition whereas, heat unaccounted is higher at low load operating condition.

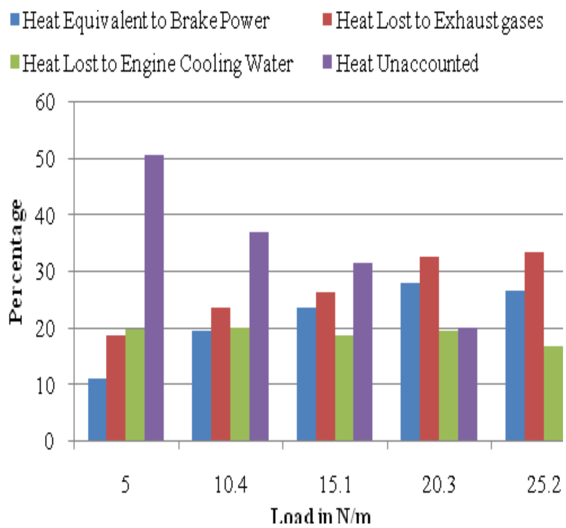

Figure 5 Heat distribution at different load

B. Different compression ratio at high load

Different compression ratios are examined under a fix high load of 25.2 N/m operating condition. The temperature at the different points of the engine is recorded by the software of the engine and drawn in the figure 6.

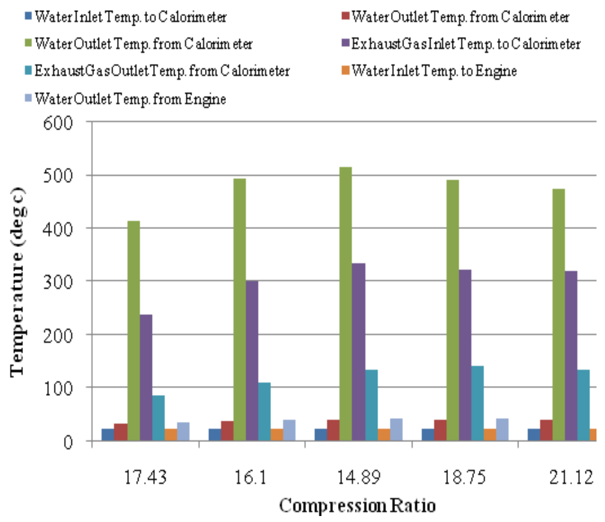

Figure 6. Temperature variation at different points

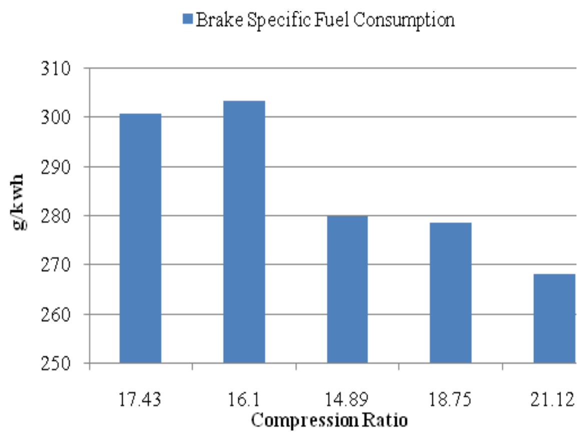

Figure 7. Brake specific fuel consumption at different Compression Ratio

In the above figure, it can be seen that the behavior of the temperature chart is same at that of the case of figure 2. Fig. 7 shows the brake specific fuel consumption of the engine in g/kwh. Fig. 8 shows the Brake thermal efficiency (BTE) and Indicated thermal efficiency (ITE) at different compression ratio of the engine during high load operating condition.

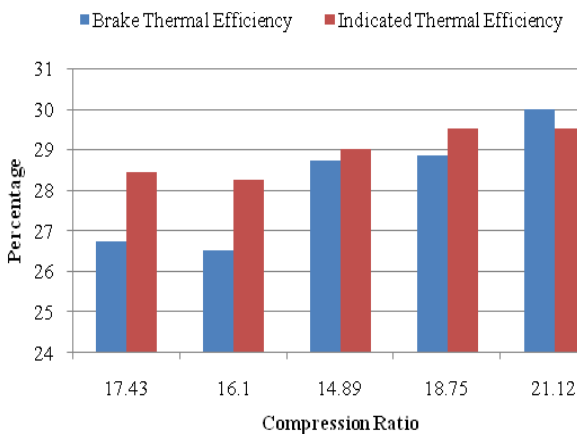

Figure 8. BTE and ITE at different compression Ratio

Fig. 9 shows the heat distribution in percentage during running of the engine. The full heat of the fuel is distributes in the various section of the engine such as heat equivalent to brake power, heat loss to exhaust gases, heat loss to engine cooling water and heat unaccounted. It can be seen from fig that the heat loss to exhaust gas is higher in high load operating condition whereas, heat unaccounted is higher at low load.

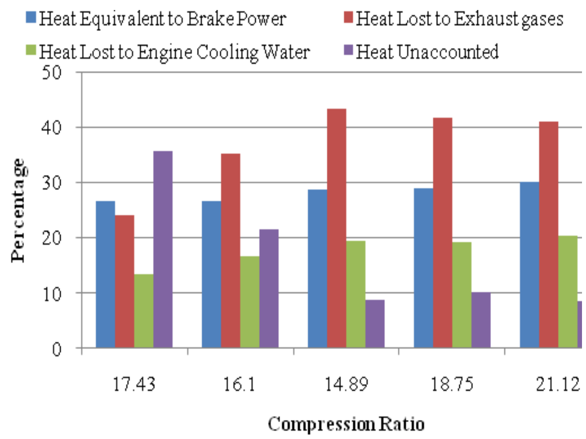

Figure 9. Heat distribution at different load

The above results are concluded in the following section to justify the experiments performed in the research.

VI. CONCLUSION

The heat distribution, performance and temperature characteristics of a variable compression ratio engine under various compression ratios and variable loads are investigated to understand the effect of compression ratio on heat distribution and performance. Based on the experimental investigations, the following major conclusions are arrived.

A. Optimum Compression ratio based on heat distribution

The heat distribution i.e. heat loss to exhaust gases and heat loss to engine cooling water by the engine is decreased on an average by 19.2%. When the compression ratio was increased from 14.89 to 17.43. The corresponding value for further increase of compression ratio from 17.43 to 21.12, the heat losses by engine is increases on an average 16.99%. At full load condition, an increase in compression ratio from 14.89 to 17.43 reduced the fuel consumption from 311.5 g/kWh to 300.67 gm/KW/h. This shows that increasing the compression ratio up to 17.43 has more benefits with full load condition than with other load conditions.

B. Optimum Compression Ratio on performance parameters

The optimum compression ratio is 21.12 as operation for the given engine. Better fuel economy is obtained at the compression ratio 21.12. Fuel consumption is higher at compression ratio 17.43. Exhaust gas temperatures are lowest at compression ratio 17.43. For more power at high loads the engine should operate at compression ratio 21.12 due to less specific fuel consumption.

C. Optimum load on performance parameters

Better fuel economy is obtained at 20.30 Nm with a fixed compression ratio of 17.43. Exhaust gas temperatures is moderate at 20.30 load operating condition.

For more power at high loads the engine should operate at compression ratio 17.43 at 20.30 Nm due to less specific fuel consumption.

Overall analysis shows that the operation of engine with a fixed compression ratio gives a better performance at 20.30 Nm load operating condition, however, the compression ratio of 21,12 shows better results compared to other compression ratio at high load operating conditions.

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