Performance characteristics of a spark ignited variable compression ratio engine at erratic loads

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Abstract: - Never ending demand for efficient and less polluting engines have always inspired newer technologies. Extensive study has been done on variable compression ratio, a promising in-cylinder technology, in the recent past. The present work is an experimental investigation to examine the variation of different parameters such as brake thermal efficiency, exhaust gas temperature and emissions with respect to change in compression ratio in a single-cylinder carbureted SI engine at different loads with two different fuels. Experiments were conducted at three different compression ratios (CR = 7.6:1, 7.8:1 and 8:1). The fuels used in this study are pure gasoline. The results showed that brake thermal efficiency increases with CR at all loads. Further, the experimental results showed the scope of improving the part-load efficiency of SI engine by adopting the concept of variable compression ratio (VCR) technology, especially when fuels with better anti-knock characteristics are used. The uncertainty analysis of the experiments based on the specifications of the equipment used is also tabulated.

Key-Words: - Performance characteristics; spark ignition; VCR

1 Introduction

Thomas et al. (2016) [1] in an experimental evaluation proposed that the concept of variable compression ratio (VCR) at different loading conditions is a viable alternative for better engine performance as well as emission characteristics. The experiment done also shows that the use of alcoholic fuels like n-butanol has indeed improved the engine performance at higher compression ratios and also suggested that a proper emission control systems can be designed for higher compression ratios to regulate the percentages of unburnt percentages HC and NO in check. Alahmer et al. (2015) [2] found in his research on Fuels for SI engines that using gasoline with octane grades higher than the requirement will decrease the engine performance. Volumetric efficiency of octane 95 is more 5% than octane 90 due to higher latent heat. NOx and CO emission concentration of octane 95 is lower than octane 90 by 11% and 17% respectively. Increase of divergence between the two values of SPL at higher speed for both octane gasoline fuels. Using octane ratings higher than the requirement is nosier disturbing than of octane fuel required. The experimental results showed that the using gasoline with octane grades higher than the requirement of an engine will decrease the engine performance.

Çinar et al. (2016) [3] performed an experiment on gasoline and LPG fuels in a SI engine, single-cylinder, four-stroke, single overhead camshaft (SOHC), spark ignition (SI) gasoline engine, modified to run with liquefied petroleum gas (LPG) fuel shows the variations of engine brake torque, power, BSFC, HC, CO and NOx emissions and exhaust gas temperature with unleaded gasoline and LPG fuels for two different valve lifts (7 and 8 mm) and observed that engine torque and power decreased and BSFC increased when the engine was converted to LPG fueling and 7 mm valve lift. Furthermore, improvements on the HC and CO emissions were observed with LPG fuel while NOx emissions increased. Experimental study performed by Nithyanandan et al. (2016) [4] on Improved SI engine efficiency using Acetone–Butanol–Ethanol (ABE) highlighted that Acetone– Butanol Ethanol (ABE) (6:3:1, 3:6:1 and 5:14:1 vol.% ratio) blends were combusted in an SI engine. ABE (6:3:1) showed combustion phasing closest to gasoline, accompanied by an improved brake thermal efficiency. Increasing n-butanol content increased HC emissions and CO emissions, due to incomplete combustion. On the other hand, ABE (6:3:1) showed reduced HC emissions. Under the tested conditions, fermentation products with higher acetone content, such as ABE (6:3:1) would be much better suited as alternative fuels for SI engines. During the research, pure ABE fuels with different component volumetric ratio, (A: B: E of 3:6:1, 6:3:1 and 5:14:1), were combusted in a naturally aspirated, port-fuel injected spark ignited engine. The Results were compared with pure gasoline and neat n-butanol. The tests were conducted at an engine speed of 1200 RPM and loads of 3 and 5 bar brake mean effective pressure (BMEP) under different equivalence ratios. Study concluded that The BSFC increased steadily with the ABE blends, due to the lower energy content of the blends and thus more fuel was required to match the power output of gasoline and increasing n-butanol showed increased HC emissions and increased CO emissions.

Altın et al. (2017) [5] proposed in a research paper that Equivalence ratio and spark plug configurations are more effective parameters on the total combustion duration than spark timing. Centrally-located single-plug configuration for equivalence ratio of 1.0 gives minimum combustion duration. Wu et al. (2016) [6] in his study concluded that the cold start performance of this SI dual-fuel engine under pure hydrogen injection and hydrogen/gasoline combined injection is better than that of pure gasoline port injection. Pure hydrogen direct injection and hydrogen/gasoline combined injection can realize the first effective firing cycle easily. Hydrogen addition contributes to the increased heat release rate and the increased incylinder pressure and cylinder temperature. This demonstrates that the addition of hydrogen is capable of enhancing the ignition reliability and the combustion stability during engine cold start. Lal et al. (2017) [7] in his experiment concluded that maximum diesel saving attained was 8.7%, 31.82%, 57.14% and 64.3% at compression ratio 12, 14, 16 and 18 respectively. The input parameters with values of maximum average cylinder pressure 37.74, 40.23, 43.72 and 47.19 bars for diesel mode and 32.26, 39.94, 45.29 and 54.49 bars for dual fuel mode at compression ratio 12, 14, 16 and 18 respectively were taken. At 2.4–3.2 kW brake power in both modes of operation lowest CO emission was observed. In dual fuel mode, the emission of CO was 81–84% higher than diesel mode. Hence, CO emission decreases with increase in compression ratio. In diesel HC emission was lower mode than in dual fuel mode. As compression ratio increases from 12 to 18 at 3.2 kW brake power the average reduction of 63.62% in HC emission was achieved. In dual fuel mode NOx emission was 35.29–56.09% lower, CO2 emission was 6.0–33.72% higher than diesel mode. CO2 emission increases with increase in load in both modes. The SOX emission in dual fuel mode was 54.54% lesser as compared to the diesel fuel mode, under condition of 3.2 kW load and compression ratio 18. The effect of compression ratio on noise emission in dual fuel mode was lower as compared to diesel mode.

The authors have performed an experimental analysis on a spark ignited engine using gasoline as main fuel, with variable compression and varying loads. An uncertainty analysis was also performed to estimate the errors during the course of the study.

2 Materials and methods

The experimental set-up is located on the premises of NIT Manipur. Figure 1 shows the arrangement of the experiment, from which the analysis was made. The set up consists of: Main frame, Engine Assembly, Data Acquisition systems. Table 1 and 2 shows the specification of the engine and the fuel respectively.

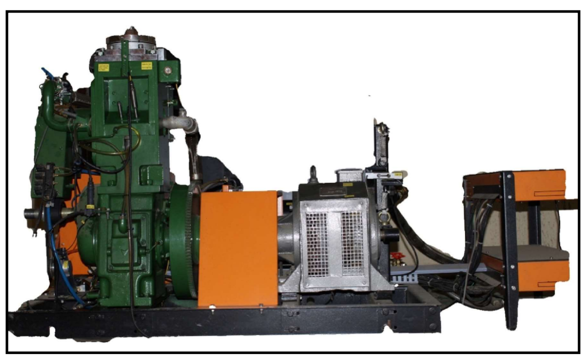

Figure. 1 Variable compression ratio engine along with dynamometer and ECU

Table.1 Specification of the test engine

Particulars	Value
Number of cylinders	1
Bore (m)	0.08
Piston offset (m)	0.00002

Stroke (m)	0.11
Connecting rod length (m)	0.235
Piston head ratio	1
Compression ratio	16.5

Table.2 Properties of test fuel

Particulars	Value
Sp. Gravity	0.85-0.87
Gross calorific value (k Cal/Kg)	10,700
Sulphur content (%)	0.5 – 1.8
Flash point(°C)	66
Pour point (°C)	18
Water content (%)	0.25
Ash content (%)	0.02

The total uncertainty of the equipments was found to be ±1.78, which can be taken as an acceptable range for experimental work [8, 9].

3 Results and discussion

The experiments were conducted using the test engine at various load and compression ratio.

3.1 Rate of heat release

The heat release rate at various compression ratios of 7.6, 7.8 and 8.0 were shown in the Figure 2, at different loads: 0kg, 1.5kg and 2.0 kg. It can be seen that the maximum heat release rate is maximum for CR 8.0 at all loads.

3.2 Pressure and volume

It can be observed from the Figure 3, that most of the part of the graph for CR 7.8 and 8.0 for each load (0 kg, 1.5 kg and 2.0 kg) are almost equal whereas the change in average cylinder pressure during expansion stroke at CR 7.6 is more.

3.3 Temperature of cylinder

The average cylinder pressures versus Crank angle plots are almost same for all the CRs. Here the Average cylinder temperature at the end of combustion stroke is maximum for CR7.8 which is unexpected observation as it is maximum for CR7.6 for all other loads. See figure 4.

3.4 Average pressure of cylinder

The plots between Temperature of cylinder versus Crank angle almost overlaps, whereas the peaks can be clearly seen in the graph above. The peak average cylinder pressure is at CR 8.0 for all the loads (0kg, 1.5kg and 2.0kg). See figure 5.

3.5 Variation of load and engine performance

The S.F.C. at various loads remains almost constant for every compression ratios, whereas the brake thermal efficiency first increases linearly from 0 – 1.5 kg load and then becomes almost constant till 3kg load as shown in the figure 5.5.1, 2, 3. It is quite evident from the graphs above that the average volumetric efficiency is about 50% with some minute fluctuations with load. See the figure 6 having resultant graphs of Load vs performance.

4 Conclusion

In this study, performance characteristics of VCR engine with single cylinder, four strokes fueled with pure gasoline is analyzed while the loading conditions were varied from no load to a value of 2.0 kg (0, 1.5 and 2.0,). The experiment was performed on the compression ratio with the range from 7.6 to 8.0. The results produced from the engine test (v15) were thoroughly analyzed. The following conclusions can be drawn from it

- The values of the output parameters are almost equal and therefore the performance characteristics will also be same. There is negligible difference between the graphs drawn corresponding to CR 7.6. 7.8 and 8.0.
- It can be observed that a slight change in the CR doesn't change the performance of the engine whereas change in the load applied changes the performance characteristics significantly. So, load is the governing factor for the performance characteristics.
- It can be clearly seen that the maximum Average cylinder temperature increases with the increase in CR from 7.6 to 8.0 corresponding to increasing loads (0 to 2.0 kg).
- The rate of heat release at exhaust is maximum for CR 8.0. The average cylinder temperature at the end of combustion stroke is maximum for CR7.8 which is unexpected observation as it is maximum for CR7.6 for all other loads.
- SFC, BTE remains almost constant with increase of load with different CR, while the volumetric efficiency shows increase with the increment in loading conditions.

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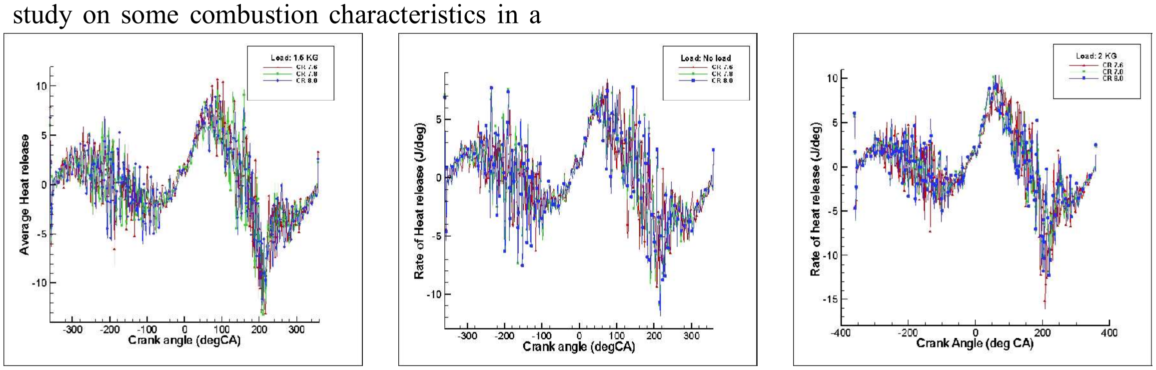

Figure 2. Variation of heat release rate with crank angle at various CR and load

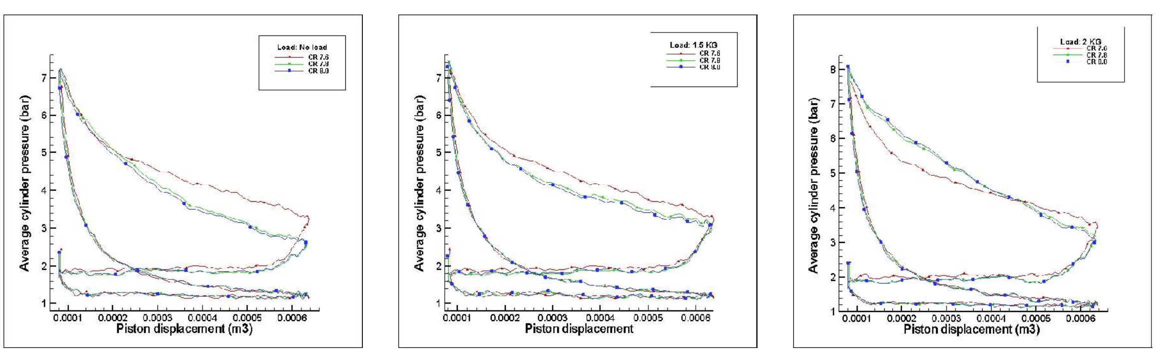

Figure 3. Variation of pressure with volume at various CR and load

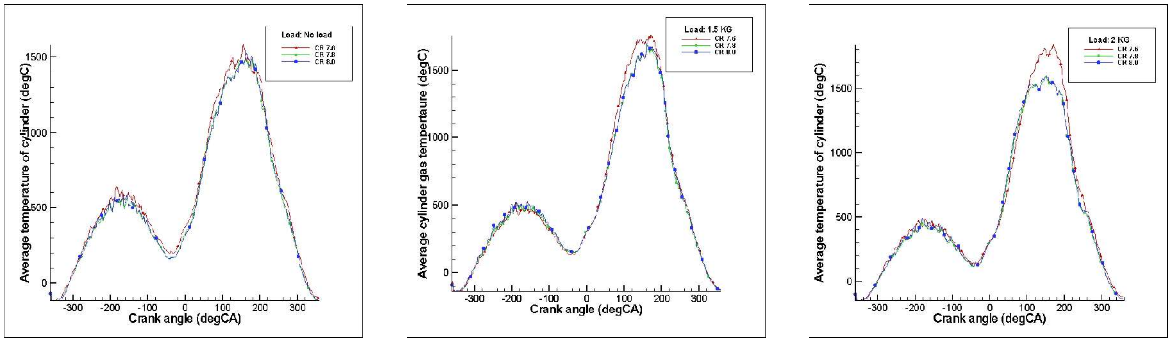

Figure 4. Variation of average temperature with crank angle at various CR and load

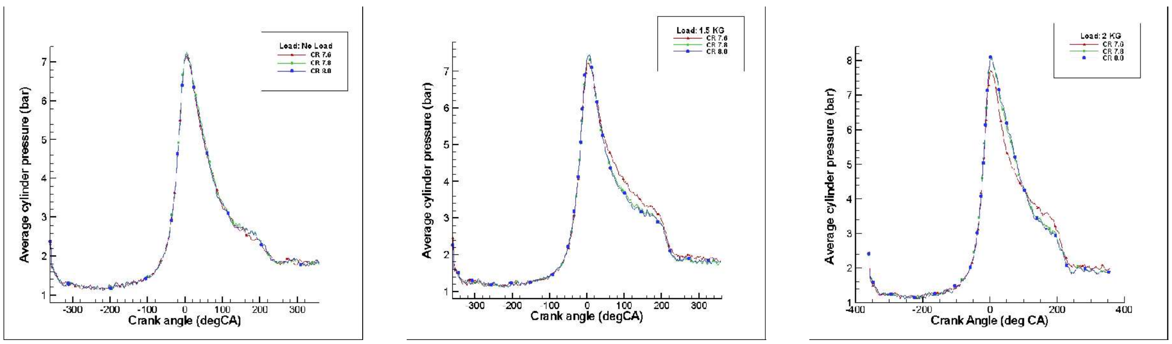

Figure 5. Variation of average pressure with crank angle at various CR and load

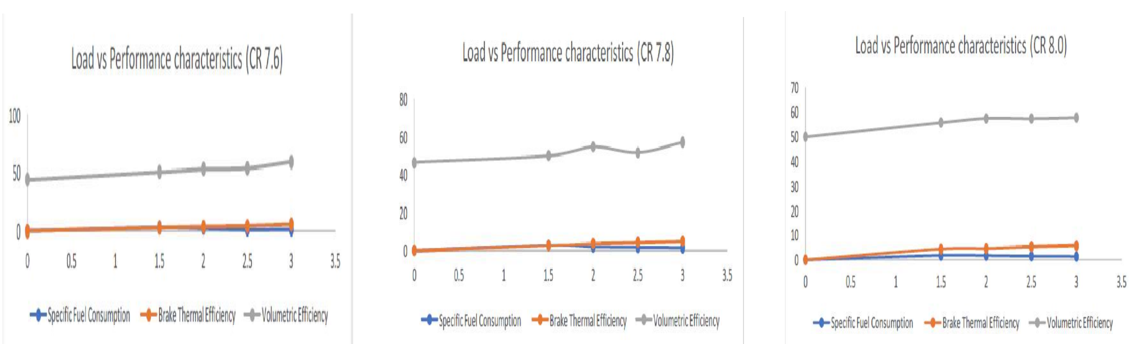

Figure 6. Load vs Performance characteristics