Evaluation Of Performance Characteristics Of Engine With Variable Compression Ratio

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Abstract

This Due to stricter emission laws, automotive companies strive towards achieving lower emission to stay ahead of the competition. Variable Compression Ratio Engine technology is a long recognized technology to increase the efficiency of combustion engines and decrease the fuel consumption by providing varying compression ratios to deal with varying load while on the road. This paper presents various methods of achieving variable compression ratios and its effects on the output of the internal combustion engine particularly on diesel engine test rig.

Keywords— *Variable Compression Ratio, emission, efficiency*

I. INTRODUCTION

The static compression ratio of an internal combustion engine or external combustion engine is a value that represents the ratio of the volume of its combustion chamber from its largest capacity to its smallest capacity. It is a fundamental specification for many common combustion engines.

A high compression ratio is desirable because it allows an engine to extract more mechanical energy from a given mass of air-fuel mixture due to its higher thermal efficiency. This occurs because internal combustion engines are heat engines, and higher efficiency is created because higher compression ratios permit the same combustion temperature to be reached with less fuel, while giving a longer expansion cycle, creating more mechanical power output and lowering the exhaust temperature.

The compression ratio in a gasoline (petrol)-powered engine will usually not be much higher than 10:1 due to potential engine knocking (detonation) and not lower than 6:1. There is no spark plug in an auto-ignition diesel engine; the heat of compression raises the temperature of the air in the cylinder sufficiently to ignite the diesel when this is injected into the cylinder; after the compression stroke. The CR will customarily exceed 14:1 and ratios over 22:1 are common. The appropriate compression ratio depends on the design of the cylinder head. The figure is usually between 14:1 and 23:1 for direct injection engines, and between 18:1 and 23:1 for indirect injection, and also in CRDI injection.

The Variable Compression Ratio means that the compression ratio can be controlled at each operating condition of the engine. If more power is needed the compression can be increased and if higher efficiency is needed the compression can be decreased. The Variable Compression Ratio Engine (referred to as VCR henceforth), helps in adapting the engine to different load conditions and reduce knock tendency, vibrations, etc. and help achieve maximum efficiency at all load conditions.

The VCR operates at high compression ratios when the power output requirements are low to achieve maximum fuel efficiency, and it operates at lower compression ratio for higher power outputs to reduce the risk of knocking. The compression ratio is determined by various engine parameters like the inlet and exhaust gas temperatures, tendency of engine knock, fuel type, etc.

The operating conditions of engines vary widely, be it the stop and go driving in the city or the smooth cruising on the highways. General engines have fixed size of the cylinder blocks and hence fixed compression ratio. This leads to lower efficiencies and high fuel consumption. Tests suggest that raising the compression ratios raise the efficiencies level from 50 to 65%. This helps in reducing the fuel consumption and contributes towards the preservation of our environment.

II. METHODS OF CHANGING THE COMPRESSION RATIO

A. MOVING THE CYLINDER HEAD

The moving head concept combines head and liners into a monoblock construction which pivots with respect to the remainder of the engine. SAAB has enabled a tilting motion to adjust the effective height of the piston crown at TDC. The linkage serves to tilt the A monohead relative to the crankcase in order to vary the TDC position of the piston. By means of actuator and linkage mechanism the compression ratio can be varied from 8 to 14.

B. VARIATION OF COMBUSTION CHAMBER VOLUME

In order to vary the combustion chamber volume a secondary piston or valve is used .The piston could be maintained at an Intermediate position, corresponding to the optimum compression ratio for a particular condition .The combustion chamber volume is increased to reduce the compression ratio by moving a small secondary piston or valve which communicates with the Chamber.

C. VARIATION OF PISTON DECK HEIGHT

The Daimler-Benz VCR piston design shows variation in compression height of the piston and offers potentially the most attractive route to a production VCR engine, since it requires relatively minor changes to the base engine architecture when compared to other options.

D.MOVING THE CRANKSHAFT AXIS

In this method a crankshaft bearings are carried in an eccentrically mounted carrier that can rotate to raise or lower the top dead centre (TDC) positions of the pistons in the cylinders. The compression ratio is adjustable by varying the rotation of the eccentric carrier.

E. CONNECTING ROD LINKAGES

A popular approach has been developed to replace the conventional con rod with a 2 piece design in which an upper member connects with the piston while a lower member connects with the crankshaft. The shorter crank throw allowed room for the link system, which was anchored by an eccentric rotary actuator.

III. EXAMPLES OF VCR

A. Infiniti VC Turbo

Infiniti’s variable compression engine is called the VC-Turbo. It’s a turbocharged 2.0-liter inline-4 with direct fuel injection, and will initially deliver a peak 268 horsepower and 288 pound-feet of torque. Those numbers are substantially better than the 208 hp and 258 lb-ft from Infiniti’s current turbocharged 2.0-liter inline-4, and the new engine may offer better gas mileage too.

Infiniti calls its 2.0-liter four-cylinder engine the VC-Turbo, and its engineering layout is ingenious. An elliptic device attached to the crankshaft where the rods go changes the distance the pistons travel in the cylinder by as much as 6 mm, or about a quarter of an inch. That varies the compression from 8.1 to 14.1. The result is V-6-like performance with four-cylinder diesel-like fuel economy -- with none of the image baggage or cost of the diesel. The automaker also claims the specific layout of the engine’s internals and its reciprocating motion makes it smoother than conventional inline engines, even matching the lower noise and vibrations of some V-6 engines.

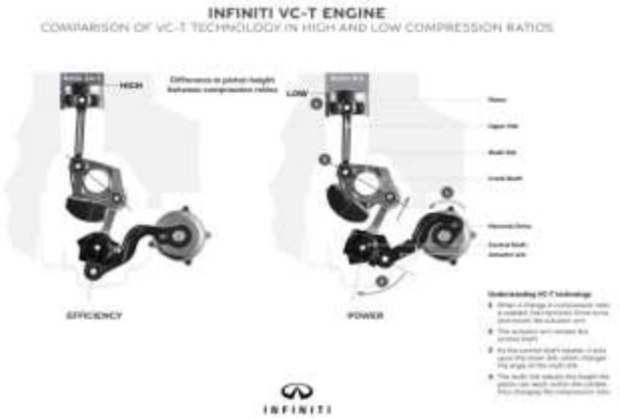

Figure 1 Infiniti VC Turbo Engine Linkages

B. Saab Variable Compression (SVC) engine, designed for the Saab 9-5

This engine uses a technique that dynamically alters the volume of the combustion chamber, thus changing the compression ratio.

To alter the combustion chamber volume, the SVC 'lowers' the cylinder head closer to the crankshaft. It does this by replacing the typical one-part engine block with a two-part block, with the crankshaft in the lower block and the cylinders in the upper portion. The two blocks are hinged together at one side. By pivoting the upper block around the hinge point, the volume of the combustion chamber can be modified. In practice, the SVC adjusts the upper block through a small range of motion, using a hydraulic actuator. This design was originally patented by Gregory J. Larsen of Lakeland, FL USA.

IV. VARIABLE COMPRESSION RATIO DIESEL ENGINE PERFORMANCE ANALYSIS

Variable Compression Test rig made Kirloskar was used by K.Satyanarayana Et Al. to determine various performance parameters of a VCR under different compression ratios. In order to find out optimum compression ratio, experiments were carried out on a single cylinder four stroke variable compression ratio diesel engine. Tests were carried out at compression ratios of 16.5, 17.0, 17.5, 18.0 and 19.0 at different loads the performance characteristics of engine like Brake power (BP), Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC). Results show a significant improved performance at a compression ratio 19.0.

VCR Test Rig Specifications:

1. Make: Kirloskar Diesel Engine
2. Type : Single Cylinder, Four Stroke Variable Compression Engine, Water Cooled
3. Max Speed: 1500 RPM
4. Crank Radius: 55mm
5. Connecting Rod Length: 300mm
6. Cylinder Diameter: 80mm
7. Stroke Length : 110mm
8. Compression Ratio: 14 to 20

Performance Analysis Graphs:

A. Brake Thermal Efficiency:

It is the ratio of the Brake Power to the heat input to the engine from the fuel. Graph (Brake Power vs Brake Thermal Efficiency) shows that the maximum brake thermal efficiency is obtained at a compression ratio of 19.0; the least brake thermal efficiency is obtained at a compression ratio 16.5. Hence, with respect to brake thermal efficiency, 19 can be treated as optimum power output. This can be attributed to the better combustion and better intermixing of the fuel and air at this compression ratio.\

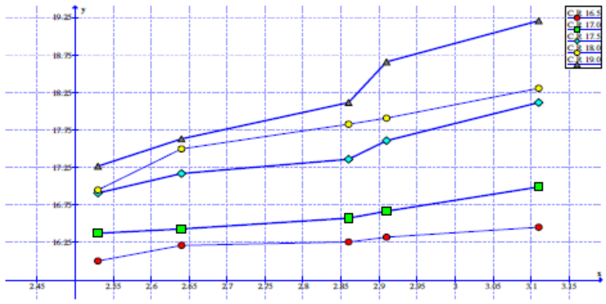

Figure 2 Brake Power vs. Brake Thermal Efficiency

B. Fuel Consumption:

The better fuel consumption was obtained at a compression ratio of 19 .The higher and lower compression ratios than 19 resulted in high fuel consumptions. The fuel consumption at a compression ratio of 17 and 17.5 was almost the same. The high fuel consumption at higher compression ratios can be attributed to the effect of charge dilution. At the lower sides of the compression ratios, the fuel consumption is high due to incomplete combustion of the fuel.

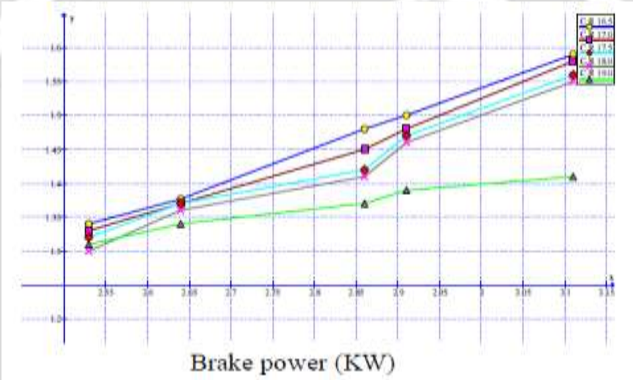

Figure 3 Brake Power vs. Fuel Consumption

C. Specific Fuel Consumption:

Brake Specific fuel consumption (BSFC) or sometimes
simply Specific fuel consumption, SFC, is an engineering term that is used to describe the fuel efficiency of an engine design with respect to thrust output. Brake Specific Fuel Consumption may also be thought of as fuel consumption (grams/second) per unit of thrust (kilo newtons, or kN).

The better specific fuel consumption was obtained at a compression ratio of 19.0 and lower compression ratios than 19.0 resulted in high specific fuel consumptions. The specific fuel consumption at a compression ratio of 18.0 and 17.5 was almost the same. At the lower sides of the compression ratios, the specific fuel consumption is high due to incomplete combustion of the fuel.

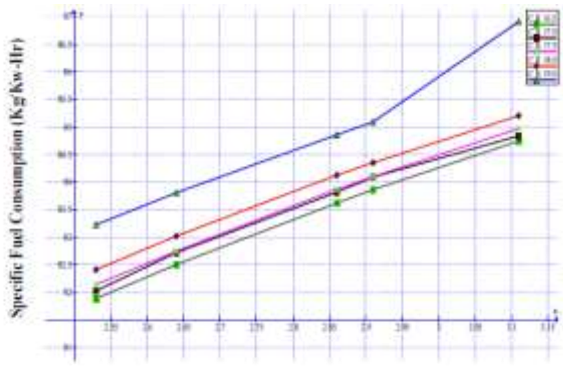

Figure 4 Brake Power vs. Brake Specific Fuel Consumption

D. Mechanical Efficiency:

Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is input to the device into an output force and movement. Efficiency is measured as a ratio of the measured performance to the performance of an ideal machine.The variation in mechanical efficiency at different loads for different compression ratios is shown in Fig. It is observed that mechanical efficiency increases with the increase in the load due to increase in the BP and IP. With the increase in compression ratio the mechanical efficiency also increases. And the mechanical efficiency at compression ratio of 16.5 and 17.0 was almost the same.

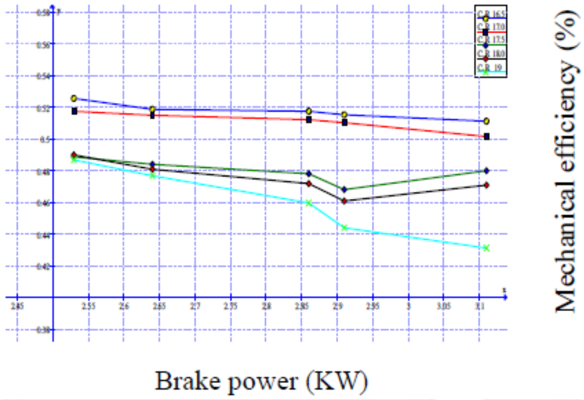

Figure 5 Brake Power vs. Mechanical Efficiency

E. Exhaust Gas Temperature:

Exhaust gas temperatures were found to be increasing with the increase in load and the compression ratio. The highest exhaust gas temperature was recorded for the compression ratio 19.0 while the least was for 16.5.

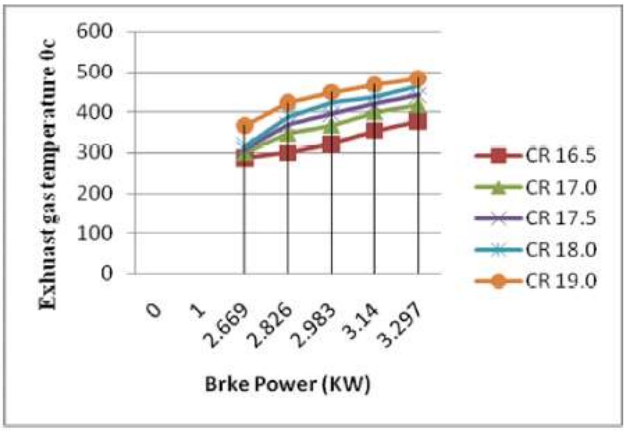

Figure 6 Brake Power vs. Exhaust Gas Temperature

F. Indicative Mean Effective Pressure:

When quoted as an indicated mean effective pressure or IMEP (defined below), it may be thought of as the average pressure acting on a piston during a power stroke of its cycle.

Indicative Mean Effective Pressures were found to be increasing with the increase in load and the compression ratio. The highest Indicative Mean Effective Pressures was recorded for the compression ratio 19.0 while the least was for 16.5.

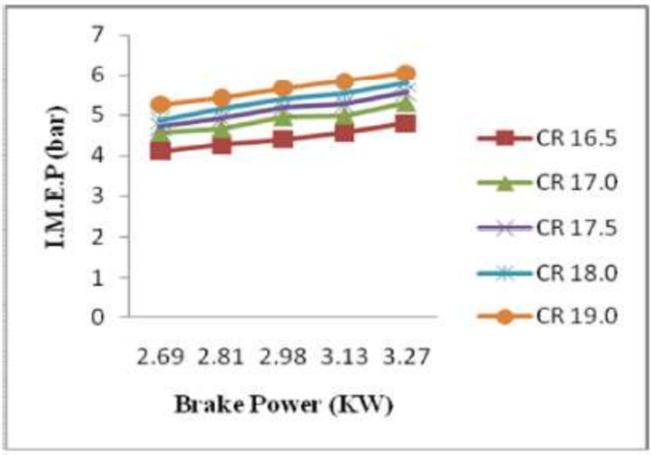

Figure 7 Brake Power vs I.M.E.P

V. CONCLUSION

1. Following conclusions can be drawn:
2. VCR technology has huge potential as it reduces and eliminates many major drawbacks g the conventional engines like knocking, thrust forces and emissions.
3. According to the experiment conducted by K. Satyanarayana:
4. The optimum compression ratio is 19 as operation for the given engine. Better fuel economy is obtained at thecompression ratio 19.
5. Fuel consumption is higher at compression ratio 16.5.
6. Smoke density is less at compression ratio 19.0.
7. Exhaust gas temperatures are moderate at compression ratio 16.5.
8. For more power at high loads the engine should operate at compression ratio 19 due to less specific fuel consumption.
9. For lower power output at light loads the engine should operate at compression ratio 16.5 due to less fuel consumption.

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