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VARIABLE COMPRESSION RATIO ENGINE: A FUTURE POWER PLANT FOR AUTOMOBILES

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ABSTRACT

Increasingly stringent emissions and fuel economy standards have long remained a source of challenges for research in automobile engine technology development towards the more thermally efficient and less polluting engine. Spark ignition (SI) engines have lower part-load efficiency when compared with the diesel engines. The greatest opportunity for improving SI engine efficiency is by way of higher compression ratio, variable valve timing, low friction, reducing throttling losses, boosting, and down-sizing.

Variable compression ratio (VCR) technology has long been recognized as a method for improving the fuel economy of SI engines. In order to vary the compression ratio, some method of varying the geometric compression ratio through changing the clearance volume is required. There are several ways of doing this; various patents have been filed and designs presented, including modification of the compression ratio by moving the cylinder head, variation of combustion chamber volume using a secondary piston or valve, variation of piston deck height, modification of connecting rod geometry, moving the crankpin within the crankshaft, and moving the crankshaft axis.

The potential of these technologies needs to be evaluated by a trade-off between cost and consumption benefit. This paper reviews the geometric approaches and solutions used to achieve VCR, consider the results of prior research, and forecasts what benefits, if any, a VCR would bring to present engine design.

KEYWORDS: spark ignition (SI) engines, variable compression ratio (VCR), thermal efficiency, fuel economy, clearance volume, knock.

1. INTRODUCTION

The concept of variable compression ratio promises improved engine performance efficiency and reduced emissions. The higher cylinder pressures and temperatures during the earth part of combustion and small residual gas fraction owing to higher compression ratio gives faster laminar flame speed. Therefore the ignition delay period is shorter .as a result at low loads the greater the compression ratio the shorter is the combustion time. Time loss is subsequently reduced. Therefore it seems reasonable that fuel consumption rate is lower with higher compression ratio at part load.

The VCR or more correctly variable expansion ratio can make a significant contribution to thermodynamic efficiency. The main feature of VCR engine is to operate at different compression ratio depending on the vehicle performance need. A VCR engine can continuously vary the compression ratio by changing the combustion chamber volume. In a VCR engine the thermodynamic benefits appear throughout engine map. At low power level the VCR engine operates at a higher compression ratio to capture high fuel efficiency benefits, while at a higher power level the engine operates at low compression ratio to prevent knock. The optimum compression ratio is determined as a function of one or more vehicle operating parameters such as inlet air temperature, engine coolant temperature, exhaust gas temperature, engine knock, fuel type, octane rating of fuel etc. In a VCR engine the operating temperature is more or less maintained at optimum where combustion efficiency is high. It has been proven that a VCR engine develop much more for the same engine dimensions i.e. it very

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compact and has a high power to weight ratio without any penalty on specific fuel consumptions. In other words reducing the engine capacity at the same power leads to reduction in fuel consumption owing to reduced pumping friction and heat losses.

2. NEED FOR VCR:

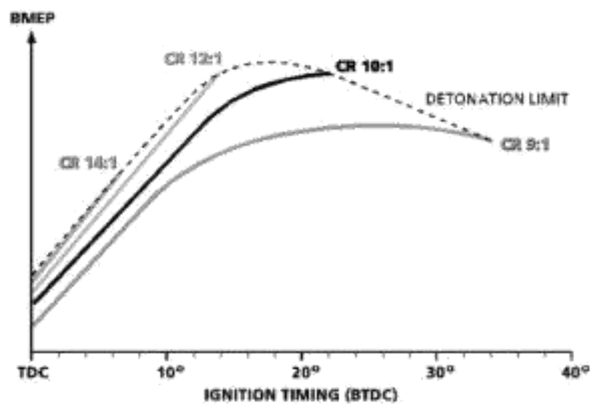
The present challenge in automotive engine technology is the improvement of thermal efficiency and hence the fuel economy and lower emission levels. One of the key features affecting thermal efficiency is the compression ratio, which is always a compromise in fixed compression ratio spark ignition engine.

The formula for air standard cycle efficiency is $g=1-(1/r)k-1$

Higher compression ratio results in higher thermal efficiency and improved fuel economy in the in SI internal combustion engine. If the compression ratio is higher than the design limit , the fuel will pre-ignite causing knocking, which could damage engine.

Raising the compression ratio from 8 to 14 produces an efficiency gain from 50 to 65, whereas going from 16 to 20 produces a gain from 67 to 70 percentages.

The maximum output is obtained when the air fuel capacity of the engine is utilized, when the maximum amount of fuel can be burnt efficiently. The maximum brake mean effective pressure In SI engine is 12 bar where as in diesel engines it is 18 bar. A higher compression ratio increases the pressure and temperature of the working air-fuel mixture, which increase the tendency of engine to knock.



Variation of b.m.e.p. with ignition timing for different compression ratios (wide open throttle condition)

3. VARIOUS VCR APPROACHES

- Moving the crankshaft axis.
- Modification of the connecting rod geometry .
- Moving the cylinder head.
- Variation of combustion chamber volume using a secondary piston.
- Variation of piston deck height.
- Moving the crankpins

Moving the crankshaft axis

FEV, Germany has chosen to alter the position of the crankshaft. In their engine, 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.

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. The compression ratio is adjustable by varying the rotation of the eccentric carrier. Mounting the crankshaft on eccentric bearings is simple in that the reciprocating assembly itself is unchanged.

Fact, the engine requires an offset fixed-position output shaft, a coupling is required between the movable crankshaft end and the fixed output shaft. The compression ratio is adaptable from 8 to 14 approximately by varying the rotation of the eccentric carriers through 55°.

Modification of the connecting rod geometry

The Nissan project uses a multi-link system to achieve VCR by inserting a control linkage system between the connecting rod and the crankshaft, and connecting this to an actuator shaft, so that the compression ratio can be varied.

This project was incorporated in a four-cylinder engine without major modification of the engine block. The shorter crank throw allowed room for the link system, which was anchored by an eccentric rotary actuator. Comthe pression was varied from 10 to 15 approximately by a 70° rotation of the actuator, while at TDC, the piston position was changed by 3.1 mm .

Examining the details of multi-link system operation reveals some advantages. The most striking advantage is that of maximum piston accelerations. Tension forces acting through the connecting rod and piston at TDC represent one of the factors limiting piston speed, so a geometry that reduces the peak piston acceleration would allow either an increase in sustainable engine speed or an increasing stroke, either of which is useful in terms of increasing power output.

Moving the cylinder head

The moving head concept (Saab Automobile AB) combines a cylinder head with cylinder liners into a monohead construction, which pivots with respect to the remainder of the engine. The lower half of the block includes the crankcase and engine mounts, and carries the crankshaft, gear box, oil cooler, and auxiliaries. The upper half includes the cylinders, their liners, camshafts, and an integrally cast cylinder head.This part is referred to as the monohead . Saab has enabled a tilting motion to adjust the effective height of the piston crown at TDC. The linkage serves to tilt the 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. A screw type super charger provides a 2 : 1 boost pressure when wide open throttle conditions occur . This system gives wide fuel flexibility, with reduced CO_2 emissions proportional to fuel consumption. Saab recognized that the fuel efficiency of the VCR engine would be low without high-pressure supercharging.

Variation of combustion chamber volume using a secondary piston

Ford have patented a means to vary combustion chamber volume by using a secondary piston or valve. The piston could be maintained at an intermediate position, corresponding to the optimum compression ratio for a particular condition. The volume of the combustion chamber is increased to reduce the compression ratio by moving a small secondary piston which communicates with the chamber. However, this would require a finite length bore in which the piston could travel, which raises questions of sealing, packaging, and durability. Varying combustion chamber geometry compromises the area available for intake and exhaust valves, while moving the cylinder head and barrel is feasible in a research engine but harder to accomplish in a production vehicle. The cylinder head cooling needs to be improved by an efficient cooling system and the auxiliary piston needs proper lubrication for efficient functioning of the VCR engine.

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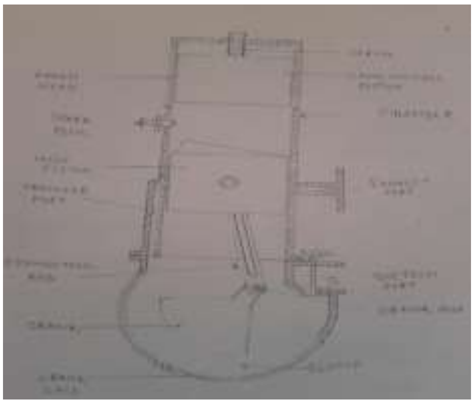

Benefits of VCR

The VCR engine constitutes a major solution for homogeneous lean-burn combustion as it permits an increase in compression pressure and temperature to restore favourable conditions for the combustion process (no misfiring and rapid flame propagation) even under high air–fuel ratio conditions. Thus VCR provides better control over pollutant generation and after-treatment than a conventional fixed compression ratio (FCR) engine. It also extends the life expectancy of a three-way catalytic converter. As the geometrical volumetric ratio is under control on VCR engines, the engine always operates below the knock limit, whatever the load. There should be a compromise between engine compression ratio and ignition advance to obtain the best indicated thermal efficiency. VCR reduces exhaust gas temperature at maximum power, which in turn decreases the engine thermal stresses and avoids charge enrichment high power. Hence the important benefits of the VCR engine can be summarized as follows:

- Optimum combustion efficiency in the whole load and speed range.
- Low fuel consumption and low exhaust emissions.
- High fuel flexibility with optimal combustion efficiency.
- Very smooth idle and full load acceleration are achieved.
- Reduction in low-frequency noise because of constant peak pressure.
- Smoother combustion because the rate of heat release in the same both at low and high compression ratios.
- Cold starting emission can be reduce greatly by early warm-up in the catalytic converter.
- Improvement in the low end torque of a petrol engine without the risk of detonation.
- Good idling performance at low ambient temperatures.
- Constant frictional losses owning to almost constant peak pressure

Commercial barriers

Variable compression ratio engines have not yet reached the market, despite patents and experiments dating back over decades. Indeed, several prototypes of VCR engines and vehicles have been tested. In many cases, the deviation from conventional production engine structure or layout represents a significant commercial barrier to widespread adoption of the technology. Some of the commercial barriers are listed below.

- The available methods requires major changes to the base engine architecture and represent significant commercial barriers to wide spread adoption of the technology.
- Introduction of additional elements within the crowded combustion chamber environment threatens to the compromise ideal geometry.
- There is a significant increase in reciprocating mass in the case of variable height piston.
- In some case, reworking of the entire engine structure is necessary.
- Engine out emissions performance is likely to be undermined by additional crevice volumes which obstruct complete burning.

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4. CONCLUSIONS

The VCR engine has great potential for improving part-load thermal efficiency and reducing greenhouse gas emissions. As VCR is a geometric approach to improve all existing engine strategies, it is potentially one of the profitable sources to investigate for the automotive industry. Variable compression ratio promises more efficient operation, the ability to down-size the engine, multi-fuel flexibility, and the potential to revise emission characteristics. The full potential of variable compression can only be realized when it is used in combination with reduced engine displacement and high supercharging pressure. The biggest challenge in adoption of the VCR is incompatibility with major components in current production. In short, VCR features will permit SI engines significantly to reduce fuel consumption and emissions. Purchasing fuel-efficient, clean vehicles would be greatly encouraged by tax breaks and subsidies by government.

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