Variable compression ratio

CHAPTER 1

BACKGROUND THEORY OF ENGINES

1. 1 VARIABLE COMPRESSION RATIO (VCR) ENGINE

1. 1. 1 INTRODUCTION TO VARIABLE COMPRESSION RATIO ENGINE

Variable Compression Ratio (VCR) is a system which is used to adjust the compression ratios of the internal combustion engine. In simple terms, it changes the combustion chamber size of the cylinder according to various different operating conditions such as speed, load, acceleration and torque. Car emissions and fuel economy are two challenges for the automotive sector in which VCR engine is a very decent technology approaching low fuel consumption and pollutant emission reduction. The car manufacturers have to look forward for more thermally efficient and less polluting engine. In present world the automotive sector spends over millions of dollars for approaching low emission as well as low fuel consumption cars. Various different ways are been discovered such as hybrid cars, fuel cell cars, solar cars and many more as future development. VCR engine would practically prove to be boon for automotive sector (Evolution Perspectives).

The Fixed Compression Ratio (FCR) engine has a fixed compression ratio without any kind of change in the size of the combustion chamber in cylinder. The FCR engines have high emissions due to the fact that when it comes to high speed or load, FCR use more fuel which produces more emissions but VCR engine provides increase in the fuel efficiency under varying loads and speed. Most of the cars used recently are Spark plug (SI) or diesel Ignition engines. The different ways the SI engine can increase its efficiency is by higher compression ratio, reducing throttle losses, low friction, variable timing valve and down-sizing. The concept of VCR engine

significantly contributes its benefits to thermo-dynamic efficiency. The concept of the VCR is that it continuously operates at different compression ratio as per the need of the performance. The change in the combustion chamber volume continuously takes place with the varying in the compression ratio. Therefore the thermodynamic advantages are been encountered through the engine map. At low level of power, VCR engine drives at higher compression ratio which can capture high fuel efficiency and at the high power levels the VCR engine runs at low compression ratio to prevent knocking. Unlikely as FCR engine, the VCR engine keeps the engine temperature more or less at the optimum with high combustion efficiency. It tends to keep high power at the same engine dimensions (Amjad Shaik, 2007).

1. 1. 2 ADVANTAGES OF VCR ENGINE

Today the " environmental safety" is a very big issue which is been concerned by many industries throughout the world. When it comes to the automobile sector, due to high ethical measures they have high amount of responsibility towards environment. All car manufacturing industry are targeting eco-friendly vehicles and down-sizing engine which can lead to the better living environment. In this case VCR engine has many improvements and benefits over FCR engine. All that is possible by the VCR is not been possible by FCR engine in terms of power output as well as overall efficiency. Some remarkable evaluation perspectives of VCR engine:

- Compression ratio adjustment does not allow " knocking", and allows extreme torque and specific power with great driving conditions.

- At part loads the VCR engine functions under high compression ratio (up to 16: 1 or 17: 1) which provides better fuel efficiency compared to FCR engine.
- By retaining in best combination between Ignition advance and compression ratio, VCR engine reduces emission pollutant even under extreme supercharging pressure.
- VCR engine tends to keep the thermodynamic temperature of the engine low compared to FCR by working under preferable compression ratio range and avoid engine heating.
- It permits increasing load-speed range which can result to effectiveness in lean-mixtures. The temperature and pressure controls which can permit combustions under ultra-lean mixtures and to set the auto-ignition timing precisely.
- The overall efficiency of the vehicle increases with pleasant driving conditions.

1. 1. 3 EXISTING VCR ENGINE CARS

Today, in automobile sector there are various different companies who are spending billions of dollars on the green car. The aim to keep the environment clean need the cars to lower down their emission and the car manufacturers are spending major of their finance on the research and development. The company are developing no. of different ways that can help them to minimise the car emissions and hence make an eco-friendly car.

Honda Company Ltd; has shown some documents to the World Congress unfolding their development in the recent times when it comes to variable

compression ratio engine. They are developing a compact VCR model which will use inertia force of the piston to switch the compression ratio between high and low stages (Concept: Honda R&D Developing Variable Compression Ratio Engine with Dual Piston Mechanism, 2009). Secondly SAAB has approached to make a very innovative and efficient VCR engine. At Geneva Motor Show, SAAB had reviled its VCR model which is called as the SVC (Saab Variable Compression) engine. The new innovative concept was more fuel efficient and the concept was totally new. The performance of the engine was far better than before with combination of reduced engine displacement and unique system of variable compression ratio enabling the engine to be more powerful and efficient than before. The fuel consumption of the car is reduced by 30% while the carbon emissions reduced as well. The CO, NOx and HC emission will meet all the future regulations (Saab Variable, 2008). The SVC engine system would not allow any kind of external or internal friction to the engine under operation which can tend to increase losses. The engine combustion chamber would not be detoriate by any kind of system interference (Miller, 2001).

Nissan has been developing a kind of piston-crank mechanism by the help of which the system to enable the variable compression ratio of the engine, unlike the static compression ratio which was taking place as the other cars. The system optimises the engine rpm with the compression ratio and can easily vary with the car driving speed which results in optimum combustion all time and raising output and fuel economy (Nissan). This all information really conveys that the automotive sector is keenly looking forward for

various ways and innovative mechanism which can prove to be boon for the future car market as well as eco-friendly environment.

1. 2 FIXED COMPRESSION RATIO (FCR) ENGINE

1. 2. 1 INTRODUCTION TO FIXED COMPRESSION RATIO ENGINE

A fixed compression ratio engine is a normal engine which recent cars have. The compression ratio of the combustion chamber remains the same throughout the operation. Particularly they do not have any disadvantages but when we compare it with the VCR engine than they have high fuel consumption as well as emissions. An engine is the main component of the car on which the major amount of car efficiency is depended. The major number of cars on the road is fuel cars, gasoline or diesel cars. The function of car engine is to convert the fuel (gasoline) into motion by which the car moves. The car is running through fuel combustion, so the engines are known as Internal Combustion Engines. It is known as Internal Combustion Engine because it consists of a combustion chamber in which the combustion of fuel occur using oxidiser, usually air. (Brain, 2010).

1. 2. 2 FOUR-STROKE INTERNAL COMBUSTION (I. C) ENGINE

The four stroke engine consists of four different strokes-

- Intake stroke
- Compression stroke
- Combustion stroke
- Exhaust stroke

The Piston moves downwards form the top dead centre (TDC) to the bottom dead centre (BDC) reducing the pressure inside the cylinder. Suction

phenomenon takes place where the mixture of fuel and air is forced to get in to the cylinder through the intake port for future combustion process. The intake valve is open in intake stroke where the exhaust valve is closed. As soon as intake stroke completes the intake valve closes down.

2. COMPRESSION STROKE

Compression stroke is the second stroke of the combustion process. In combustion process the inlet and the exhaust both the valves remain close. The piston is moves upwards to the top dead centre of the cylinder to compress the air-fuel mixture. This makes an explosion in the cylinder and helps the combustion to take place. This complete stroke is known as the compression stroke.

3. EXPANSION STROKE

Expansion stroke is also known as the power stroke. In this stroke both intake and exhaust valve remain close. When the piston is at the top dead centre, the ignition takes place in the combustion chamber usually with the help of spark plug. The air-fuel mixture ignites and results in to massive pressure and this pressure drives the piston back to the bottom dead centre with a huge force. This complete stroke is called the power stroke because at this stroke of the whole cycle the power erupts and engine's torque is able to drive the car. Power stroke is the most important stroke of the complete cycle in which the ignition takes place leading to power to the engine.

4. EXHAUST STROKE

Exhaust Stroke is the final stroke of the cycle. In this stroke the inlet valve remains closed and the exhaust valve opens. The piston which is at the bottom dead centre once again goes to the top dead centre position while

the valve is open. The action helps to though out the product of the combustion from the cylinder outside through help of the exhaust pipe. With the completion of the exhaust valve the completion of the combustion cycle takes place.

(Brain, 2010)

1. 3 COMPRESSION RATIO

The Compression Ratio of an internal combustion engine is the ratio of the volume of the combustion chamber when the piston is at the bottom dead centre position divided by the volume of the combustion chamber when piston is at the full compression position. In simple terms it is also known as the swept volume (Compression ratio, 2010).

The compression ratio of an engine should be higher. Higher the compression ratio, the engine is able to extract more energy form the given mass of the air-fuel mixture because of the higher amount of thermal efficiency. The increase in the power takes place at the moment of ignition and more net work can be achieved by expanding the hot gases at a greater degree. There is major disadvantage while keeping the compression ratio higher is that make the gasoline engine subjected to engine knocking. In technical terms it is also known as detonation. It is mainly caused by using poor quality fuel. Detonation can cause the engine to reduce its overall efficiency, damage the engine parts and even can result to engine failure. CR = compression ratio

Vd = displacement volume

Vcv = clearance volume

CR = Displacement Volume+Clearance VolumeClearance Volume

Compression Ratio = Vd+ VcvVcv

CHAPTER 2

DESCRIPTION OF VCR PROTOTYPE MODEL

2. 1 DESCRIPTION OF EXISTING VCR PROTOTYPE

The variable compression ratio prototype is already been made by the previous student working. The driving mechanism is well made and is practically operational. The mechanism is very simple. The driving mechanism of the prototype is just an understanding of the overall system and helps to analyse different moving parts. The modifications been done are on the way the system has to be driven. The mechanism was been driven manually or by using an electric motor. The system has to be modified and designed to be driven pneumatically. The complete prototype helps to demonstrate the complete system visually. The theoretical part of the VCR is a bit more complicated, so the visual model really focuses and gives a very clear idea about the whole mechanism as well individual parts. The mechanism shows the rotating shaft motion conversion to the linear motion of the piston-cylinder mechanism driven manually, electrically or pneumatic sources. The variable compression mechanism is been attached to the system by which the angles of connecting rod lever can be changed which helps to change the travel length of the piston in the cylinder. The change in piston travel length tends to change the swept volume which is technically known as the compression ratio. The mechanism is designed is a way that the compression ratio can be changed easily any time even when

the system is running. The angle of eccentric adjustment is given a range from 0° to 60° where it can change compression ratio to certain extends.

2. 2 WORKING PRINCIPLE OF VCR PROTOTYPE

The working of the prototype is very simple. The working principle is that the angular motion of the shaft is been converted in to the linear motion of the piston-cylinder. A simple mechanism of the variable compression ratio is adjoined to the overall system. The variable compression ratio mechanism in the system allows the driving mechanism to change various angles by help of which the length of the stroke of piston changes which can change the overall swept volume. Hence the change in swept volume results in the variation in compression ratio.

NOTE: The figure shows the working principle of the prototype by giving more knowledge about the moving parts and their connection. Detailed drawing is been given further in the report.

The driving mechanism consists of various different moving parts as described in the part list. The extension shaft rotates at an angle of 360° which results to one to and fro motion of the piston. Once the extension shaft rotates, the motion is been transferred to the Crank shaft. The crank shaft transfers the motion to the eccentric journal bearing through the help of connecting rod and lever. At that position the angle of the eccentric mechanism decided the length of stroke of piston. This motion hence results into linear motion of the piston-cylinder mechanism by help of sliding mechanism connection. The piston than moves and completes a two stroke cycle by one revolution of shaft.

2. 3 MOTION TRANSFER STUDY

A simple overview of the motion transfer from one part of mechanism to the other is been shown.

DRIVING SOURCE

ROTATING SHAFT

CONNECTING ROD MOTION

ECCENTRIC JOURNAL BEARING MOTION

SLIDING MECHANISM CONNECTION

LINEAR MOTION OF PISTON-CYLINDER

2. 4 PART LIST OF PROTOTYPE MODEL

PART LIST OF VCR

DRIVING MECHANISM

Part No.	Part Name	Quantity
1	Cylinder Head	1
2	Cylinder Block	1
3	Piston	1
4	Roller Bearing	3

5	Sliding Mechanism Connection	1
6	Eccentric Journal Bearing	2
7	Connection Rod Lever	1
8	Connection Rod	1
9	Crank Shaft	1
10	Crank Shaft Mounting	1
11	Extension Shaft	1
12	Nut - Bolt	12

NOTE: The above part list is made on the basis of the system without any sort of driving mechanism modifications. The source of driving is manually which helps us to analyse the movement of prototype parts and is simple understanding of the mechanism.

2. 5 COMPONENT MATERIAL SELECTION

The variable compression ratio prototype is overall well designed. The completely prototype is a compact model and has an appropriate function. The mechanism of VCR is well managed when it comes to design part. The design is kept simple and easy to understand. The assembly of all components is done in a way that it is easy to disassemble and individual moving parts can be analysed. It is clear that the system is a complete assembly of many working parts. There are lots of parts which are been assembled using welding, or by using nuts and bolts. Some of the parts are been manufactured in the laboratory and some are been obtained from the suppliers due to time and material constraints.

The parts which are been obtained directly from the dealer:

- Connecting Rod
- Roller Bearings
- Crank Shaft
- Connecting Rod Lever
- Eccentric Bearing
- Nuts and Bolts

The parts which are been manufactured in the laboratory:

- Piston

- Cylinder Block
- Prototype foundation (wooden base)
- Extension Shaft (Attached to electric motor)
- Supporting bars for assembly

COMPONENT AND THEIR MATERIAL

Part No.	Part Name	Material
1	Cylinder Head	Plastic
2	Cylinder Block	Plastic
3	Piston	Plastic
4	Roller Bearing	Plastic
5	Sliding Mechanism Connection	Steel
6	Eccentric	Steel

	Journal Bearing	
7	Connecti on Rod	Forged Steel
	Lever	
8	Connecti on Rod	Forged Steel
9	Crank Shaft	Forged Steel
10	Crank Shaft Mountin g	Aluminiu m
11	Extensio n Shaft	Cast Iron
12	Nut - Bolt	Mild Steel

Material Selection Criteria

As we can see the material been used in the prototype are metals and have high resistivity to high temperature and external or internal stresses. They do not have a tendency to deform under small loading conditions which really helps to keep the alignment and working of the prototype without any

problems. The components are directly available in the market and it save a lot of time as well as money which can be spending innovating miscellaneous ideas.

CHARACTERISTICS OF THE VCR PROTOTYPE

Every product or its prototype has some positive as well as negative aspects. The positive features are those which favour the users and the negative aspects are those which create some kind of errors or functional faults.

POSITIVE CHARACTERISTICS

DESIGN

The complete system is designed in a way that it is really appreciated. The design is compact, easy to analyse and low weight. Even though the material used in most of the parts is metals but even though the overall prototype does not exceed a lot. Looking at the individual design in detail:

The existing VCR prototype consist

INTRODUCTION TO PNEMATIC SYSTEM

Pneumatic is a branch of technology which enables the pressurised gas to affect mechanical motion. Pneumatic system is the system which helps to pressurise gas and convert the pressure of gas in to mechanical motion. There are many industry which use pneumatic systems for various purposes. The compressor is used to compress air and this force of air is used for the various purposes such as dentistry, construction, automobile, mining and many more.

Pneumatic system is basically a fixed system which is installed in factories that have application of compressed air for various purposes. Usually the moisture is been removed from the air and small quantity of oil is been

added in it as lubrication to the moving parts. The basic pneumatic system is most efficient when the theoretical calculation prove basic three things:

- Amount of force applied by the actuator
- Can that force be able to move the desired load
- The speed at which the load can be moved

Components of Basic Pneumatic System

Part A - Compressor:

The compressor is the main component of all. It is a pump which compresses air. It simply raises the pressure of compressed air and supplies it to the pneumatic system.

Part B - Check valve:

Check valve is simple one way valve. This valve allows the compressed air which is having high pressure to enter the pneumatic system. It does not allow the back flow of air again in to the compressor.

Part C - Accumulator:

Accumulator is known as the storage tank of the system. It stores the compressed air and hence helps to supply it to system as per the requirement and relieves the duty cycle of compressor.

Part D - Directional Valve:

The directional valve gives the direction to the compressed air and controls the flow of air from source to port selected. This can be done manually or might be used sensors or electrically to give better precision.

Part E - Actuator:

Actuator is the device which concerts the force (energy) of compressed air into the mechanical motion.

(Elements of Basic Pneumatic system, 2003)

Working of Pneumatic system

Atmospheric air is been drawn in to the air filter in which the air is been filter. The foreign material, duct particles are been removed and pure air is achieved. The air then passes to the compressor where it gets compressed to a certain required pressure. The vapour and humidity is been removed making air dry and pressurised. Then the air is passed to the reservoir where the pressured air is been stored and can be readily available when required. It is known as accumulator. Many companies tend to compress air in a huge compressor and then store it in different storage reservoirs at different places without any kind of pressure (energy) loss.

The pressure development is been depended on the size and capacity of the compressor. There are many safety devices used in the system like valves and sensors which readily help to ensure complete safety of the system. After it is stored in the reservoir it is been used whenever and wherever required using control valve which can help to control the flow of pressurised air and help to use the energy to convert to mechanical motion.