

Review on Scuderi Split Cycle Engine

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Abstract: Internal combustion engines are the important prime movers on the earth. The study of I.C. engine is an active field of research for many automobile industries and from environmental point of view. I.C. engine has wide application such as in automobile industries, transportation in sea as well as in air and for industrial purpose. Many technologies have been invented to enhance performance and to reduce emissions from the IC engines, the Scuderi Split Cycle Engine is one of them. This paper review, a new IC engine developed by Scuderi Group called 'Scuderi Split Cycle Engine'. This engine is more efficient than a conventional engine and also has less emission.

Keywords: Scuderi Split cycle engine, Internal Combustion Engine, Miller cycle, Otto cycle.

I. Introduction

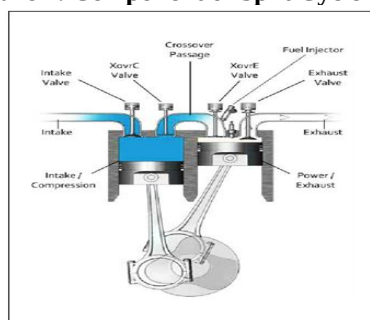
Scuderi Split-cycle engines divide the four strokes of conventional engine such as intake, compression, power, and exhaust into two separate but paired cylinders. The first cylinder called as compression cylinder, which is used for intake and compression of air. The compressed air is then transferred through a crossover passage from the compression cylinder into the expansion cylinder. In expansion cylinder fuel is injected and burned to undergo combustion and exhaust stroke. A Scuderi split-cycle engine is an air compressor on one side and a combustion chamber on the other. The Backus Water Motor Company of Newark, New Jersey produced an example of a split cycle engine as far back as 1891. Various scientists and engineers worked to explore the possibility of the split cycle engine. But, none has matched the results obtained by Late Carmelo J. Scuderi. The Scuderi Group, engineering and licensing company based in West Springfield, Massachusetts and founded by Carmelo Scuderi's children, completed the prototype and unveiled it to the public on April 20, 2009.

II. The Component of Scuderi Split Cycle Engine

1. Intake and Exhaust Valves

The intake and exhaust valves are inwardly opening, i.e., towards the piston. Intake valve controls the amount of air coming in the compression cylinder and exhaust valve rejects the exhaust gases from the power cylinder to the surrounding.

Figure 1: Component of Split Cycle Engine



2. Compression and Expansion Cylinder

The split-cycle engine design splits the four strokes and the processes of suction and compression take place in the compression cylinder, and the processes of expansion and exhaust take place in the power cylinder. The compression cylinder consists of the a piston, inlet valve and the crossover compression valve whereas a power cylinder consists of a piston, exhaust valve, crossover expansion valve and the spark plug. The efficiency of an internal combustion engine is increased if the gas is expanded more during the expansion stroke than it is compressed during the compression stroke. In Split Cycle Engine the design of compression cylinder is different from that of the expansion cylinder. The displacement volume of compression cylinder is less than that of the displacement volume of the power cylinder. This makes the expansion stroke greater than that of the compression stroke. Due to this arrangement more work is obtained in power stroke and less work has to be given in compression cylinder which is not possible in conventional IC engine.

3. Compression Piston and Expansion Piston

A compressor cylinder including a compression piston moves within the compression cylinder and it is connected to the crankshaft. Compression piston reciprocates through the suction stroke and the compression stroke during a

single rotation of the crankshaft. An expander cylinder includes an expansion piston which moves within an expansion cylinder and is connected to the crankshaft such that the expansion piston reciprocates through an expansion stroke and an exhaust stroke during a single rotation of the crankshaft.

4. Crossover Passage

A crossover passage interconnecting the compression and expansion cylinders, and it includes a crossover compression (XovrC) valve and a crossover Expansion (XovrE) valve. It also consists of a fuel injector. The crossover passage transfers the compressed air from the compression cylinder to the expansion cylinder and maintains the pressure in between the two cylinders. It consists of a fuel injector which injects the fuel in the passage.

5. Crossover Valve

Due to very high compression ratios an outwardly opening (opening outward away from the cylinder and piston) crossover compression (XovrC) valve at the crossover passage inlet is used to control flow from the compression cylinder into the crossover passage. Due to very high expansion ratios an outwardly opening crossover expansion (XovrE) valve at the outlet of the crossover passage controls flow from the crossover passage into the expansion cylinder.

6. Crank and the Crankshaft

The pistons of both the compression and power cylinder are connected to the crank by crankshaft. When the crank rotates it drives the piston in the power as well as in the compression cylinder. Generally the expansion piston leads the compression piston by 20 degrees.

7. Fuel Injector

The main function of fuel injector is to inject the fuel and mixes it with air and it form homogeneous mixture of air and fuel which is necessary for the proper combustion of charge.

8. Spark Plug

It provides the spark which is required to ignite the fuel and start the combustion process. It gives energy to the charge and increases the temperature of fuel to its ignition temperature.

III. Scuderi Split Cycle Engine

The four strokes of the Otto cycle are “split” over the two cylinders such that the compression cylinder, it perform the intake and compression strokes, and the expansion cylinder, perform the expansion and exhaust strokes. The working of the engine is explained in four strokes:

Figure 2: Scuderi Split Cycle Engine



1. Suction Stroke

During the intake stroke, intake air is drawn into the compression cylinder through an intake manifold disposed in the cylinder head. An inwardly opening intake valve controls fluid communication between the intake manifold and the compression cylinder. The intake air is supercharged at 1.5 bar. A boosting device is connected to the intake manifold such as supercharger.

2. Compression Stroke

During the compression stroke, the compression piston pressurizes the air and, upon XovrC opening, drives the air to crossover passage. This means that the compression cylinder and compression piston are a source of high pressure gas to the crossover passage, which acts as the intake passage for the expansion cylinder. Fuel injector injects fuel into the pressurized air at the exit end of the crossover passage in correspondence with the XovrE valve opening, which occurs shortly before expansion piston reaches its top dead centre position. At this time, the pressure in the crossover passage is more than the pressure in the expansion cylinder. Fuel is injected in the Crossover valve.

3. Expansion Stroke

When XovrE valve opens, the pressure in crossover passage is substantially higher than the pressure in expansion cylinder. This high pressure ratio causes initial flow of the air or fuel charge to flow into expansion cylinder at high speeds. As piston begins its descent from its top dead centre position, the XovrC valve is still open, and the spark plug, which includes a spark plug tip which is fired to initiate combustion in that region. The high speed flow of the air/fuel charge is particularly advantageous to split-cycle engine because it causes a rapid combustion

event, which enables the split-cycle engine to maintain high combustion pressures even though ignition is initiated while the expansion piston is descending from its top dead centre position. The Xover valve is closed after combustion is initiated but before the resulting combustion event can enter the crossover passage. The combustion event drives the expansion piston downward in the power stroke.

4. Exhaust Stroke

During the exhaust stroke, exhaust gases are pumped out of the expansion cylinder through exhaust valve disposed in cylinder head. An inwardly opening poppet exhaust valve, controls fluid communication between the expansion cylinder and the exhaust valve.

IV. The Distinctive Element After Top Dead Centre Firing (ATDC Firing)

Unlike conventional engine which are fired before top dead centre split cycle engine are fired after top dead centre, i.e., spark is generated when the piston starts its downward travel. To fire BTDC in a split-cycle engine, the compressed air is expanded into the power cylinder as the power piston is in upward stroke. The pressure of the compressed air is released and the work done takes place. To fire BTDC the power piston recompresses the air. Therefore engine required to perform the work of compression twice. Although considered bad practice in conventional engine design, firing after top dead centre in a split-cycle arrangement eliminates the losses created by recompressing the gas. When the engine is fired before top dead centre position, maximum combustion pressure is obtained at TDC. However at this position the connecting rod and the crankshaft throw are nearly aligned with the cylinder axis. Thus the pressure generated acts vertically downwards in line with the connecting rod. Whereas if engine is fired after TDC adjustments can be made to coincide maximum combustion pressure with maximum torque generated thus increasing the thermal efficiency.

V. Air Standard Cycle

The conventional SI engine works on the Otto cycle in the same way there is an air standard cycle for the Scuderi d split cycle engine which is Miller Cycle.

A. Miller Cycle

It is an over-expanded cycle, i.e., a cycle which has expansion ratio higher than its compression ratio. Apart from this it also fulfils the Miller effect. The efficiency of an internal combustion engine is increased if the gas is expanded more during the expansion stroke than it is compressed during the compression stroke. In the Miller cycle, this is typically accomplished by early inlet valve closing and late inlet valve closing.

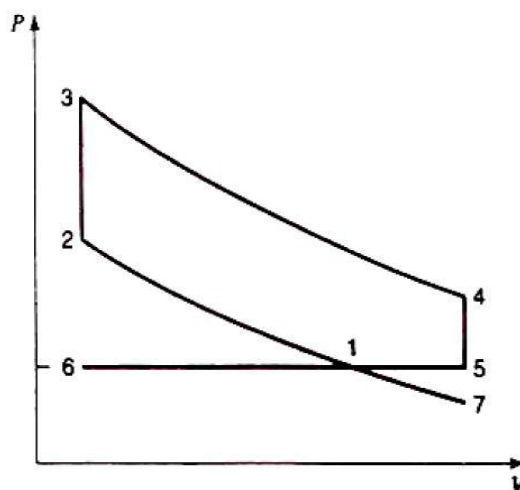
For example, if the inlet valve of a conventional engine is closed late a portion of the intake air that was drawn into the cylinder during the intake stroke is pushed back out of the cylinder from the intake port. The intake valve is kept open during about the first 20% to 30% of the compression stroke so the actual compression occurs only in about the last 80% to 90% of the compression stroke.

A1. Miller Cycle Utilizing Early Inlet Valve Closing

Referring to Fig No 3, the same effect can be achieved in the Miller cycle by early inlet valve closing.

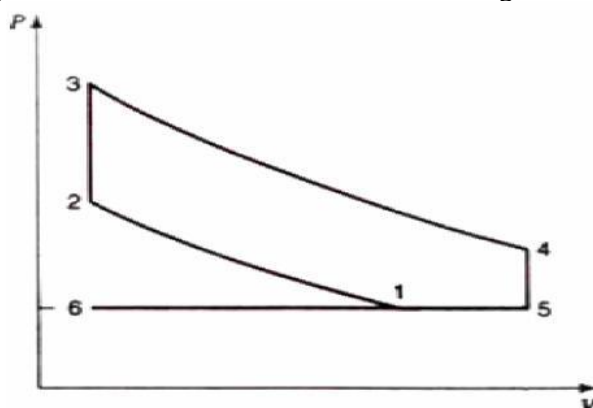
In such case, the pressure remains constant during the intake stroke from point 6 to point 1. Then at point 1 the intake valve closes, and the cylinder pressure decreases from point 1 to point 7. During the compression stroke, from point 7 to point 1 the pressure increases, replaces the previously traced path, and continues to point 2 during the remainder of the compression stroke. The net result of this is the same as late intake valve closing which is less than the entire piston stroke is effectively used for compression, decreasing the effective compression ratio.

Figure 3: PV Curve for Early Inlet Valve Closing



A2. Miller Cycle Utilizing Late Inlet Valve Closing

Figure 4: PV Curve for Late Inlet Valve Closing in Miller Cycle



From point 6-5-1 and 5-1, the intake stroke of the piston from top dead centre to bottom dead centre, the cylinder pressure follows a constant pressure line from point 6 through point 1 and finally to point 5. During the initial portion of the compression stroke, the cylinder pressure retraces the pressure line from point 5 back to point 1. At point 1 the intake valve closes and the cylinder pressure increases from point 1 to point 2 during the remainder of the compression stroke. The volume swept along the path 1-5 is cancelled by the path 5-1, and the effective compression ratio is the volume at point 1 divided by the volume at point 2 but for Otto cycle it is the volume at point 5 divided by the volume at point 2.

From point 1-2, The compression piston pressurizes the air and, upon XovrC opening, drives the air into the crossover passage. The XovrC valve opens in between the compression stroke. Fuel injector injects fuel into the pressurized air at the exit end of the crossover passage in correspondence with the XovrE valve opening, which occurs shortly before expansion piston reaches its top dead centre position. At this time the pressure in the crossover passage is more than that in the expansion cylinder.

From point 2-3, The charge usually enters the expansion cylinder shortly after expansion piston reaches its Top Dead Centre position (TDC), although it may begin entering slightly before TDC. As piston begins its descent from its top dead centre position, and while the XovrE valve is remain open, spark plug, which includes a spark plug tip that protrudes into cylinder is fired to initiate combustion in the region around the spark plug tip. From point 3-4, The XovrE valve is closed after combustion is initiated but in such a way that products of combustion doesn't enter the crossover passage. The combustion event drives the expansion piston downward in the power stroke. From point 4-5, during this process the exhaust valve opens and the gases are released from the power cylinder when piston moves from its BDC to TDC.

VI. Conclusion

It can be seen that this engine is more efficient than conventional engine due to its inherent features, from the literature review. The Scuderi Split Cycle Engine development is a result of the endeavour to increase the efficiency and reduce the emissions of the engine. The research in the development of this new engine is very unique attempt as compared to the researches going around world for two decades for improving the power output by installing additional accessories to the conventional engine. The research and development of Scuderi Split Cycle Engine is very essential because of high requirement of efficient engines with very less emissions are prevalent. The performance of Scuderi split cycle engines are more efficient than a conventional engine. Due to high performance and efficiency, conventional engines are replaced by Scuderi split cycle engines for the same applications in power generation, automobiles. Therefore they are future alternatives of the conventional engines.

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