ISSN: 0975-833X

*Available online at http://www.journalcra.com*

*International Journal of Current Research*
*Vol. 9, Issue, 01, pp.44640-44642, January, 2017*

**INTERNATIONAL JOURNAL OF CURRENT RESEARCH**

**RESEARCH ARTICLE**

# 5 STROKE ENGINE-A REVOLUTIONARY PATHWAY FOR EFFICIENT ENGINE PERFORMANCE

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**ARTICLE INFO**

***Article History:***
Received 25th October, 2016
Received in revised form
15th November, 2016
Accepted 14th December, 2016
Published online 31st January, 2017

***Key words:***

Engine, 5 stroke, Mechanical, Dynamics.

**ABSTRACT**

During the past three centuries, there has always been an emphasis on development of a kind of engine that has superior efficiency is less polluting and has good power generation. This review paper describes the new advancement in the four stroke Internal Combustion Engine (ICE) which has enormous advantage. For further improvement in IC engines, a Belgium Engineer name Gerhard Schmitz presented a new innovation called five stroke Engine. This concept gained momentum and its prototype was put in reality by Ilmor Engineering. After considering research, it was developed with the idea of generating expansion ratio significantly higher than compression ratio. This engine has a similar torque generation and high power density but low fuel consumption when compared with the Four-stroke engines. The total efficiency is improved in the certain range.



**Citation: Sidharath Joshi, 2017.** "5 stroke engine-a revolutionary pathway for efficient engine performance", *International Journal of Current Research*, 9, (01), 44640-44642.

## INTRODUCTION

The internal combustion engine is a heat engine that converts one form of energy (chemical energy) into mechanical energy. Inside the cylinder of the engine, due to combustion or oxidation with air the chemical energy of fuel is converted into thermal energy. The temperature and pressure of gases are raised by this thermal energy within the combustion chamber and high-pressure expands against the mechanical mechanisms of the engine (Pulkrabek, 1997). The Four-stroke engine played has an integral role and is well known throughout the entire population. During this period of time, there were a lot of improvement and modification which subjected to dynamic development. But many designers failed to increase efficiency greater than 35% by reducing fuel consumption in a wide range of engine load and speed (Alten *et al*., 1999). With the passage of time, many innovative designs have come into consideration which are a revolution in IC Engine industry. Out of these innovative designs, Ilmor 5 stroke engine came into existence which was designed in 2007 by Ilmor Engineering (Alten *et al*., 1999). In 2003, Belgium engineer Gerhard Schmitz patented the five stroke engine prototype (Schmitz, 2003). It was earlier impossible to increase expansion ratio as it is always equal to compression ratio. So, this concept gains a lot of curiosity by increasing the expansion ratio with the same torque acquired by 4 stroke Engines. In this review, an effort has been done to highlight various aspects of five stroke Engines.

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### Historical Aspects

Natural resources are on the verge of extinction leading to need of increasing the efficiency of an internal combustion engines and accordingly various aspects in the field. From the humble beginning it was in 16th century when the work started. In 1673, Christian Huygens introduced the concept and design of one of the earliest Internal Combustion engines. In the same century, Newcomen came up by with invention of a stream engine and in advancement, J.J.E Lenoir in the beginning of 19th century practically introduced first working engine with the power generation of 4.5 kW and mechanical efficiency of 5% (Basshuysen *et al*., 2004). In,1867, Otto- Langen worked together and improved the efficiency to 11% by designing a type of atmospheric engine with the power stroke propelled by atmospheric pressure acting against the vacuum (Ralph Stein, 1967). In 1870's, there was big emphasis based on development of four stroke IC (Internal combustion) engine which lead Nikolaus August Otto and Langen to develop first internal combustion engine that compressed the fuel mixture prior to combustion for far higher efficiency than any other engine developed that time (Ralph Stein, 1967). Later on, a new concept of five stroke engine but forward by Gerhard Schmitz which lead of a discovery of engine with numerous advantages.

### Five stroke Engine

Presently a lot of engines run in a four stroke thermodynamic cycle. In four stroke engine, when the fuel is pumped into the cylinder, piston moves from Top Dead Centre (TDC) to the

Bottom Dead Centre (BDC) the process is called induction or suction stroke (for petrol engine its air-fuel mixture). In the second stroke, due to cranking effect (caused by flywheel), the piston rises from BDC to TDC due to which compression of charge take place leading to increase in high temperature and pressure gain. When the piston reaches the TDC a spark takes place in petrol engines generating a power stroke which lead to ignition bringing out combustion creating enormous increase in temperature and pressure. Similarly, piston moves from TDC to BDC, allowing gases of combustion to expand and giving a superior torque of the working of engine. When the piston reaches BDC:, the gases are under heavy pressure and need a space to escape hence exhaust stroke take place making a pathway for the burnt gases to escape out of the engine taking the piston from BDC to TDC (Rajput, 2008). Basically, in a four stroke engine the crankshaft rotates two time in 360° by achieving piston movement due to induction, compression, expansion and exhaust strokes hence completing a cycle. Thus, all four-strokes repeatedly undergo creating engine to perform. Instead of using these four stroke, a new concept was built by Gerhard Schmitz that is changing the current process by adding a new stroke for power increasing the expansion ratio (Schmitz, 2003).

## Design and Configuration

As described by Schmitz, a typical five stroke engine with three cylinders shown is in Fig 1. Here charge i.e., Air fuel mixture for petrol and Air for diesel is pumped into the cylinder which is turbo charged earlier to increase the turbulence. 3 cylinders are placed in which cylinder 1 and 3 are having high pressure expansion while the other cylinder i.e., cylinder 2 have low pressure expansion.

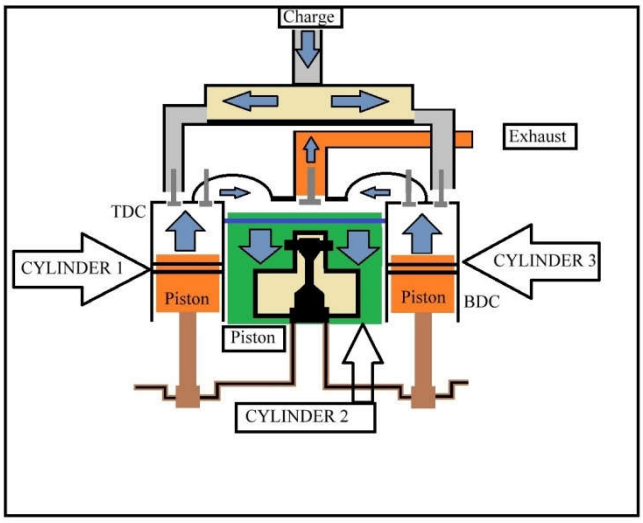


**Figure 1. Five stroke engine with three cylinders**
**Source: Schmitz, 2003**

A simple piston arrangement with the connecting rod to the crankshaft for the delivery of power to the wheels are used five-stroke engine. The directions in Fig 1 is describing the pathway of the charge in the different stroke of the engine from the induction stroke to the exhaust stroke.

## Working of the engine

Schmitz's 5 stroke Engine gains torque by firing two high pressure cylinders i.e., cylinder 1 and cylinder 3 which operates on convectional four stroke Otto cycle. The main feature of this engine with a simpler 4 stroke engine is instead of sending exhaust to the cylinder into atmosphere, this engine gives an induction of exhaust into the cylinder 2 (shown in Fig. 1) that creates an extra expansion stroke for the same compression by this it receives high expansion. This 2nd cylinder is a low-pressure cylinder which decouples the expansion and compression and provide heavy expansion ratio.

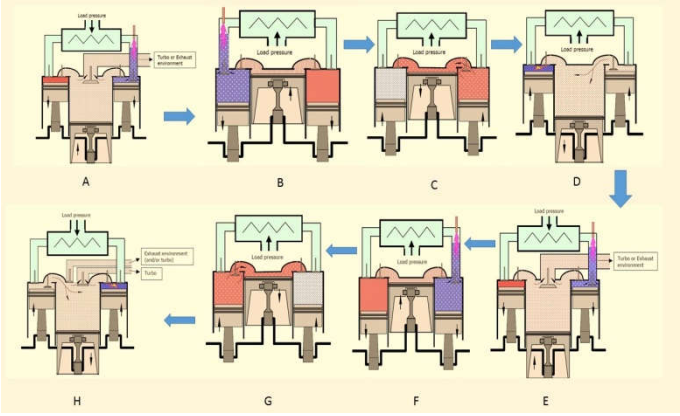


**Figure 2. Working cycle of 5 stroke engine**
**Source: Schmitz, 2003**

Above Figure 2 describes the working cycle of five stroke engine with 3 cylinders. This engine has 8 Stages from induction to exhaust followed by first strokes. Considering A stage, the piston of cylinder 1 moves from Top dead centre (TDC) to Bottom dead centre (BDC) due to the charge pumped into the cylinder. In cylinder 2 there is exhaust making movement of piston from BDC to TDC simultaneously there is a spark in the third cylinder and as the piston is touching TDC. B Stage represents induction expansion in cylinder 1 reaching BDC, in cylinder 2 exhaust stroke is completed as piston reaches TDC and from TDC to BDC power stroke is achieved making heavy expansion of gases due to combustion in the cylinder 3. On reaching stage C, in cylinder 1 from BDC to TDC compression stroke take place. Cylinder 3 is in high pressure and needs exhaust stroke, so here comes the main feature of five stroke engine that is instead of releasing into the atmosphere it transfers the exhaust into the cylinder 2 creating a new power stroke and making high expansion ratio. On coming into stage D as cylinder 1 is in TDC spark generates simultaneously full expansion of gases in cylinder 2 to BDC and exhaust to TDC takes place. E stages refers to movement of piston from TDC to BDC due to combustion leading to power stroke in cylinder 1, the exhaust in the cylinder 2 will start its exhaust stroke which is released into the atmosphere and in cylinder 3 the fresh charge is pumped making piston to move from TDC to BDC. Considering stage F expansion reaches BDC in cylinder 1 and exhaust stroke completes in cylinder 2 simultaneously reaches its BDC position completing its induction stroke. In the 7thstage i.e., G stage, exhaust from cylinder 1 start transferring to the low-pressure cylinder 2 making the piston movement from TDC to BDC and compression stroke in the cylinder 3 takes place. In the last stage cylinder 1 reaches TDC completing its exhaust stroke leading to the power stroke of the cylinder 2 creating expansion and makes the piston to move from TDC to BDC. At the same time the piston touches TDC of the cylinder 3 which generates spark. Hence these stages repeatedly take place to let the engine run further under different loads and condition.

### Usefulness of Engine

From day to day development of the engines lead to a discovery of enormous advantages. This 5 stroke Engine stands in good ranking as compared with similar the 4 four stroke engines under different conditions. Schmitz mentioned that the fuel consumption of this engine is reduced from 16% (at maximum load) up to 30% (at minimum load). The extra cylinder provided in this engine gives additional expansion process by which more work can be extracted, therefore increase the thermodynamic efficiency. The compression ratio supplied is nearly 7.0:1 but the effective expansion ratio obtained is 14.5:1, hence converting the maximum thermal energy into work. The chamber provided in the engine is compact which reduces its volume variation during combustion due to which an excessive temperature drop of the flame is obtained in the end of combustion (Schmitz, 2003). Apart from this a high-power density and lower consumption during the working range can be archive by providing heavy turbocharging. Due to high expansion ratio, higher mileage is archived due to which this engine is many times more economical than 4 stroke engines. The total piston displacement of this engine is reduced by 37% (Schmitz, 2003).

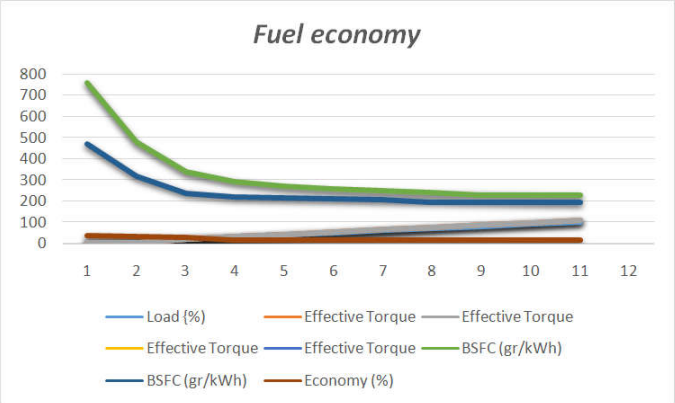


**Figure 3. Fuel Economy of 5 stroke Engine Vs 4 stroke Engine Source: Adopted from Schmitz, 2003**

Schmitz compared the fuel efficiency of the 5 Stroke engine with the 4 Stroke Engine with various aspects as summarized in Fig 3. The results shown in Fig 3 shows the effective torque, Brake specific Fuel consumption (BSFC). It has been found that the effective torque achieved by 5 stroke engine and 4 stroke engine is same and at the same load BSFC obtained by 5 stroke engine is less than BFSC obtained by the 4 stroke engine hence the fuel economy of 5 stroke Engine is higher.

### Limitations and Future modifications

Engines other than this is having even number of strokes and the cylinder are of same masses due to which their equilibrium is perfect but this engine utilizes cylinders of different masses which requires to be critically designed otherwise torque generation will not be in equilibrium. Also, this engine has 2 cylinders of high pressure and other of low pressure which creates irregularity in heat density hence suitable cooling should be provided to withstand the efficient working of engine. Nowadays global warming biggest concern is pollution which can be decreased in this engine by providing extra time combustion period of extra power stroke. In addition to this concept a new hybrid steam system can be added. This steam can be pumped to the Low-pressure cylinder when the High-pressure cylinder transfer its exhaust to low pressure cylinder which can further increase the pressure, due to which an extra force will act on the piston which will lead to high temperature generation. Due to this there will be less production of pollution as all unburnt hydrocarbons will be combusted. Further, pollution can be reduced by the addition of diesel oxidation catalyst (DOC) in the exhaust of the engine as platinum-palladium based DOC is cost effective and provides the benefit of passive regenerations through $NO_2$ and soot reactions (Dou Danan, 2012).

### Conclusion

Overall features of five Stroke Engine have been reported to be more advantageous as compared than modern conventional engines when we evaluate in terms of part or full load fuel performance, design aspects and economy. It has been found that the piston displacement is reduced and a high expansion ratio is achieved under low fuel consumption. Addition of practical use of this engine in large scale will change the different parameters like fuel efficiency, pollution, etc., hence the operation of this engine leads to a better living standard instead of a simple polluting internal combustion that are in use nowadays.

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