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A Review-A Feasibility Study of Six Stroke Engine by Analysis through Available Research Design

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***Abstract*—The modern four stroke internal combustion engine has been widely applied due to excellent power to weight ratio and reliability. However, the major downside of the even most efficient modern 4 stroke engine is the production of significant amounts of excess heat energy, dissipated though the cylinder walls of the engine and expelled as waste energy during the exhaust stroke of the cycle. The development of a more efficient six stroke internal combustion engine for increasing the efficiency of four stroke engine for that the final two strokes designed to used of exhaust and convert it into power stroke and finally six stroke working as exhaust stroke and also batter scavenging. Some of basic modifications are done in four stroke engine and made a six stroke engine we can increase the brake thermal efficiency of the engine. Also the dramatic reduction in pollution and batter scavenging is occurs.**

***Keywords*— Analysis of six stroke engine, Design of six stroke engine**

I. Introduction

The 6 stroke internal combustion engine is advancement over the existing 4 stroke internal combustion engine which employs the same principle as that of the 4 stroke internal combustion engine.

The 5th stroke or the second power stroke uses the heat evolved in the exhaust stroke (directly or indirectly) as heat required for the sudden expansion of the secondary fuel (air or water) which pushes the piston downward for the 2nd power stroke thereby rotating the crankshaft for another half cycle.

As heat evolved in the 4th stroke is not wasted, the requirement for a cooling system is eliminated.

Here fuel is injected once in every 3 complete cycles of the crankshaft which is any time better than a 4 stroke internal combustion engine where fuel is injected once in 2 complete cycles of the crankshaft.

It should be noted that efficiency of the 6 stroke internal combustion engine is more than the existing 4 stroke internal combustion engine. Major type of secondary fuels used in the 5th stroke is air and water.

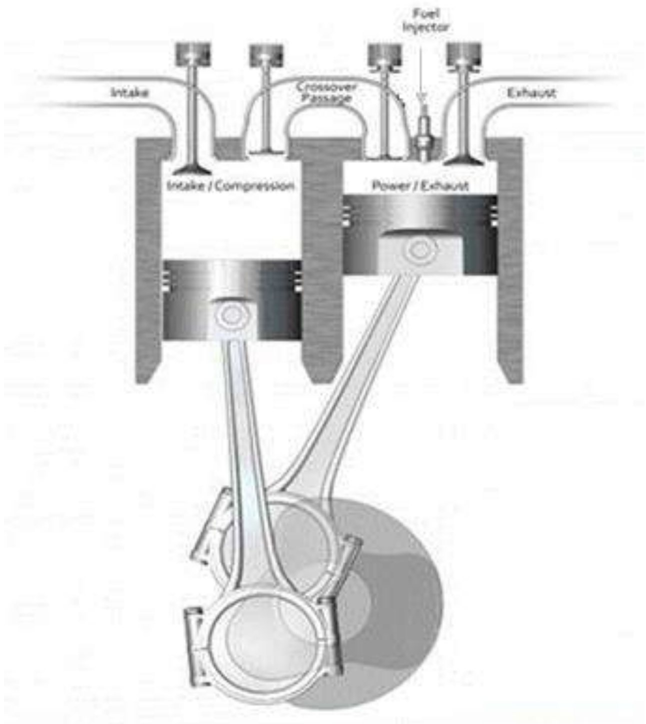

Fig. 1.1: Concept of six srroke engine

II. Working of six stroke engine

The working of all strokes in this engine are as below:

First Stroke (Suction Stroke): During the first stroke, the inlet valve opens and air-fuel mixture from carburettor is sucked into the cylinder through the inlet manifold.

Second Stroke (Compression Stroke): During the second stroke, piston moves from Bottom Dead Centre to Top Dead Center, both the inlet valve and exhaust valves are closed and air-fuel mixture is compressed.

Third Stroke (Fuel Power Stroke): During the third stroke, power is obtained from the engine by igniting the air-fuel mixture using a spark plug. Both valves remain closed. Piston moves from Top Dead Center to Bottom Dead Center.

Fourth Stroke (Re-Compression Stroke): During the third stroke, piston moves from Bottom Dead Center to Top Dead Center. Both the inlet and the exhaust valves are closed. By the time piston reaches Top Dead Center, water injector injects water which is then converted to steam.

Fifth Stroke (Steam Power Stroke): During the fifth stroke, the steam initiates the second power stroke. Both valves remain closed. Piston moves from Top Dead Center to Bottom Dead Center.

Sixth Stroke (Exhaust Stroke): During the sixth stroke, piston moves from Bottom Dead Center to Top Dead Center. The inlet valve remains closed. The exhaust valve opens and the exhaust gases are released.

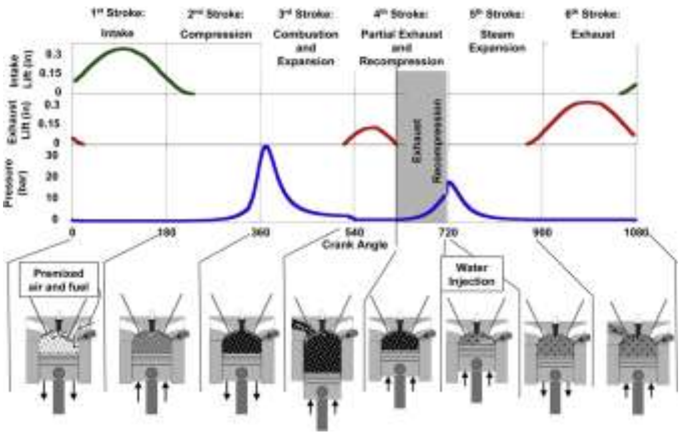

Figure 1.2: Working of six stroke engine

III: Literature review:

[1] **A. Kéromnès, B. Delaporte , G. Schmitz , L. Le Moyne,"** "Development and validation of a 5 stroke engine for range extenders Application", **DRIVE – ID Motion Laboratory, University of Burgundy, 49 rue Mlle Bourgeois, 58027 Nevers, France-2014**

Current trends in engine development are governed by more and more stringent emission regulations and aim at lowering consumption and emissions in order to obtain ever cleaner engines. The efficiency of a reciprocating internal combustion engine is strongly linked to its expansion ratio since increasing the expansion ratio allows an increase of the fuel conversion efficiency. However, in traditional internal combustion engines, the compression ratio is limited due to mechanical stress and combustion issues.

Power losses from the engine are mainly due to thermal losses. For most engines, either spark ignition engines or compressed ignition engines, around one third of the energy available in the fuel is lost inside the cylinder due to heat losses through the wall. Another third of the energy is lost in the exhaust gases . However, reducing heat losses to the wall thanks to insulation of the cylinder leads to a higher temperature of the exhaust gases. This results in increased energy losses in the exhaust gases Design and Analysis of Six Stroke Internal Combustion Engine.

This paper presents the development and the validation of a novel design for internal combustion engines, the 5 stroke engine which allows an increase in efficiency. This design is based on an in-line, three-cylinder, turbo-charged, port-injection spark ignition engine.

[2] **James C. Conklin, James P. Szybist, "**A highly efficient six-stroke internal combustion engine cycle with water injection for in-cylinder exhaust heat recovery" **Oak Ridge National Laboratory, 2360 Cherahala Blvd, Knoxville, TN 37932, USA-2010.**

In internal combustion engines, a significant amount of the fuel energy exits the engine in the form of thermal energy in the exhaust. The exhaust temperature range of naturally aspirated gasoline engine is higher, typically from 450˚C to 800 ˚C. A much larger portion of fuel energy, 27.7%, exits the vehicle in the form of thermal energy in the exhaust, while the remaining 61.9% of the energy balance consists of energy losses to friction, coolant, and other.

Improving the efficiency of internal combustion engines is an on going area of active research. Numerous designs have been proposed based on the traditional Otto or Diesel cycles, and all of these include four sequential thermodynamic processes or strokes of the piston. These are the following strokes: 1) air–fuel intake, 2) air–fuel compression, 3) post-combustion expansion, and 4) exhaust gas discharge.

The modified cycle proposed here adds two additional strokes that increase the work extracted per unit input of fuel energy. These additional strokes involve trapping and recompression of some of the exhaust from the fourth piston stroke, followed by a water injection and expansion of the resulting steam/exhaust mixture. The residual exhaust gas is trapped in the cylinder by closing the exhaust valve earlier than usual. Energy from the trapped recompressed exhaust gases is transferred to the liquid water, causing it to vaporize and increase the pressure. This added pressure then produces more work from another expansion process.

There is an advantage in delaying the early exhaust valve closing in order to increase MEPsteam for any given value of water injection.

The value of this exhaust valve closing for maximum MEPsteam depends on the limiting conditions of 1 bar or the dew point temperature of the expansion gas/moisture mixture. Although the thermodynamic modeling presented here wasperformed for one set of engine conditions, similar increases in engine output are expected for a wide variety of engine geometries and operating conditions.

An ideal thermodynamics model of the exhaust gas compression, water injection at top center, and expansion was used to investigate a modification to recover energy from two waste streams that effectively add two strokes to a common four-stroke internal combustion engine. The additional two strokes require substantial modifications to the exhaust valve operation as well as a manner to inject water directly into the combustion chamber.

[3] **Kiran P**, "A Feasibility Study on Waste Heat Recovery in Six Stroke IC Engine" **International Journal on Mechanical Engineering and Robotics (IJMER), Volume-1, Issue-1, 2013.**

Waste heat recovery from internal combustion engines (ICE) is one of the opportunities for economizing of energy consumption. In an ICE, a great amount of fuel energy is wasted in the form of heat due to thermal limitations. To recover the waste heat, various methods are being adopted.

During every cycle in a typical four stroke engine, piston moves up and down twice in the chamber, resulting in four total strokes and one of which is the power stroke that provides the torque to move the vehicle.

But in a six stroke engine there are six strokes and out of these, there are two power strokes. The automotive industry may soon be revolutionized by a new six-stroke design which adds a second power stroke, resulting in much more efficiency with less amount of pollution.

In a six stroke engine, when the combustion chamber temperature reaches approx. 400 oF (200oC), just before the fifth stroke fresh water is injected directly into the hot combustion chamber through the engine's fuel injector pump, which is quickly turned into a superheated steam, which causes the water to expand to 1600 times its volume and forces the piston down for an additional power stroke.
By the utilization of the waste heat, the performance of the internal combustion engine is considerably increased. With the utilization of the waste heat of internal combustion engine the world energy demand on the depleting fossil fuel reserves would be reduced . The fuel efficiency would be increased by the development of six stroke engine with the same amount of fuel the internal combustion engine would give more mileage and it would relief growing demand.

[4] **R. Saidur , M.Rezaei ,W.K.Muzammil , M.H.Hassan, S.Paria M.Hasanuzzaman**," Technologies to recover exhaust heat from internal combustion engines" **Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603KualaLumpur, Malaysia-2012.**

From the study, it has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies. Waste heat recovery entails capturing and reusing the waste heat from internal combustion engine and using it for heating or generating mechanical or electrical work.

It would also help to recognize the improvement in performance and emissions of the engine if these technologies were adopted by the automotive manufacturers. The study also identified the potentials of the technologies when incorporated with other devices to maximize potential energy efficiency of the vehicles.

Recovering engine waste heat can be achieved via numerous methods. The heat can either be ''reused'' within the same process or transferred to another thermal, electrical, or mechanical process.

The common technologies used for waste heat recovery from engine include thermo- electrical devices, organic Rankine cycle or turbocharger system. By maximizing the potential energy of exhaust gases, engine efficiency and net power may be improved.

[5] **Tejaskumar U Kothari, Mr.Devranjan Kumar, Mr.K.D.Tandel**, "Design and Analysis of Six Stroke Internal Combustion Engine" **Thermal Engineering department, SVMIT, Bharuch-392001, Gujarat, INDIA-2014.**

The engine captures the waste heat from the four stroke Otto cycle or Diesel cycle and uses it to get an additional power and exhaust stroke of the piston in the same cylinder. Designs either use steam or air as the working fluid for the additional power stroke.

As well as extracting power, the additional stroke cools the engine and removes the need for a cooling system making the engine lighter and giving 40% increased efficiency over the normal Otto or Diesel Cycle.

The pistons in this six stroke engine go up and down six times for each injection of fuel. These six stroke engines have 2 power strokes: one by fuel, one by steam or air.

The six stroke engine modification promises dramatic reduction in fuel consumption of an internal combustion engine. The fuel efficiency of the engine can be increased and also the valve timing can be effectively arranged to extract more work per cycle.

The brake thermal efficiency of four stroke two cylinder diesel engine can increases by modified its some component and convert into six stroke engine.

Better scavenging is possible because exhaust of first cylinder exhaust is become a inlet of second cylinder during the fifth stroke and its work as second power stroke the exhaust during the sixth stroke.

IV. BASIC PARTS MODIFICATION:

1.Crankshaft To Camshaft Speed Ratio:

The original angular speed of the camshaft is one-half that of the crankshaft, such that the camshaft rotates once for every two revolutions (or four strokes) of the crankshaft. The crankshaft pulley of the unmodified (4-stroke engine) engine has a 21 tooth and camshaft pulley of the engine has a 42 tooth.

In conventional four stroke engine ,the crankshaft must rotate720° while the camshaft rotates 360° to complete one cycle. For six-stroke engine, the crank shaft must rotate 1080°to rotate the cam shaft 360° and to complete one cycle.

Hence their corresponding speed ratio is 3:1. In modified engine a camshaft pulley has a 42 tooth which is same as that was in unmodified (4-stroke engine) engine and crankshaft pulley has a 14 tooth which is 1/3 of the camshaft pulley because the rotation ratio of crankshaft to camshaft is 3:1 in six stroke engine.

So it is necessary to keep camshaft pulley three time bigger than crank shaft pulley.

2.Modification In Inlet And Exhaust Manifold:

In given four stroke engine there is common inlet manifold through which required quantity of fresh charge from atmospheric air is sucked due to movement of piston and vacuum creation and mixed with the fuel for proper combustion.

Figure 1.3: Inlet and Exhaust Manifold of Four Stroke Engine

The common inlet manifold of four-stroke engine parted by welding a plate between the common inlet manifold as shown in figure 1.4.

The plate welded between the inlet manifold is of aluminium. Because manifold is made of aluminium.

The main benefit of this manifold is exhaust gases come out at high temperature so it will preheat the inlet air so increase the combustion rate.

Figure 1.4: Modified Inlet and Exhaust Manifold of Six Stroke Engine

3.Camshaft Modification:

In six stroke engine piston moves three times up and down so for that valve open two times in a one revolution of a complete cycle. So that in place of four stroke engine in six stroke engine two lobes are provided as shown in figure 1.4.

Figure 1.4: Modified camshaft

V. CONCLUSION

This injection water is heated by the engine coolant, this six-stroke concept presented here recovers energy from both the engine coolant and combustion exhaust gas.

Thus, this concept recovers energy from two waste heat sources of current engine designs and converts heat normally discarded to useable power and work.

Provisions may need to be made to keep the exhaust after treatment components hot enough to function properly. This concept has the potential of a substantial increase in fuel efficiency over existing conventional internal combustion engines while potentially not decreasing the power density significantly.

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[7] **Mojtaba TAHAN, Saeed JAVAN, Mojtaba BIGLARI**, " A comprehensive study on waste heat recovery from internal combustion engine using organic Rankine cycle ".