Study of Six Stroke Internal Combustion Engine

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Abstract: ***The most difficult challenge in engine is to increase its thermal efficiency. A conventional four stroke internal combustion engine has very low thermal efficiency because high amount of energy is lost in exhaust and also in cooling of the engine. It is found that about 35% of fuel is lost in exhaust of engine and 30% in its cooling. Out of the remaining 35% of energy, almost 50% of energy is converted into the work. Two additional strokes have to be added to enhance the thermal efficiency which led to development of six stroke engine. In six strokes the engine captures the exhausted heat from the four stroke cycle and uses it to get an additional power stroke and exhaust stroke of the piston in the same cylinder. The main advantages of six stroke engine include a reduction in fuel consumption by 40%, two power strokes in the six stroke cycle, a considerable reduction in pollution and multi-fuel operation. After adopting six stroke engine technology by the automobile industry, it will have a massive impact on the environment and world economy.***

Keywords: Internal combustion engine, Six stroke engine, Otto cycle, Efficiency

1. Introduction

In 1862 a Frenchman Alphouse Beau de Rochas gave his theory regarding the ideal cycle of the internal combustion engine. This theory was applied by a German engineer named Nikolaus A. Otto, who firstly built a successful four stroke SI engine in 1876. The four stroke combustion cycle later became known as the "Otto cycle". In four stroke engine the inlet valve opens and the air-fuel mixture enters into the cylinder. Then the inlet and exhaust valves are closed, and the piston is at its lowest position i.e. Bottom Dead Centre (B.D.C). During the compression stroke, the piston moves in upward direction and the air-fuel mixture is compressed. But before the piston reaches its highest position i.e. Top Dead Centre (T.D.C), the spark plug injects the air-fuel mixture and the mixture ignites, increasing the pressure and temperature of the cylinder. The piston is forced down by the high pressure gases, which in turn tends the crankshaft to rotate, producing a work output during the power stroke. At the end of power stroke, the piston is at B.D.C, and the cylinder is filled with the combustion products. The piston moves upward again and removes the exhaust gases through the exhaust valve and in next cycle, sucks in fresh air-fuel mixture through the inlet valve. Thus the piston completes the four stroke cycle which gives two complete revolutions to the crankshaft.

Whereas six stroke engine, is a cycle of six strokes out of which two are power strokes. It is a type of internal combustion engine with complications added to make it more efficient and reduce emissions. The internal combustion engines that operates on different cycles have one common feature, combustion occurring in the cylinder after each compression results in gas expansion that acts directly on the piston and is limited to 180 degrees of crankshaft angle.

According to its mechanical design, the six stroke engine with external and internal combustion and double flow is similar to the actual internal reciprocating combustion engine. However, it differentiates itself completely due to its thermodynamic cycle and a modified cylinder head with two supplementary chambers: combustion chamber and an air heating chamber, both independent from the cylinder.

2. Literature Survey

The six stroke engine is a concept that has been around for more than 100 years, but has only recently been reconsidered as a feasible alternative to the conventional four stroke engine due to advancement in automotive and material technologies. In 1883, engineer Samuel Griffin developed the first six stroke steam and gas engine mainly used for electric power generation. According to the literature survey done, Leonard Dyer invented the first six stroke internal combustion water-injection engine in 1915.

The first approach to the six stroke engine uses steam or air as the working fluid for the additional power stroke having single piston design in the same cylinder. The additional stroke also cools the engine and removes the need for a cooling system making the engine lighter and giving 40% increased efficiency over the normal Otto and Diesel Cycle. The currently notable six stroke engine designs in this category are a six stroke internal combustion water-injection engine invented by Leonard Dyer; the Crower's six stroke engine, invented by Bruce Crower of the U.S.A; the Bajulaz engine by the Bajulaz S A Company, of Switzerland; and the Velozeta's six stroke engine built by the students of an engineering college of Trivendrum.

The second approach to the six stroke engine uses a second opposed piston in each cylinder which moves at half the cyclical rate of the main piston, thus giving six piston movements per cycle. Functionally, the second piston replaces the valve mechanism of a conventional engine and also increases the compression ratio. The currently notable six stroke engine designs in this category include the Beare Head engine, invented by Australian farmer Malcolm Beare, and the German Charge pump, invented by Helmut Kottmann. Beare was the most successful inventor of six stroke engines.

2.1 Single piston designs

These designs use a single piston per cylinder, like a conventional two or four stroke engine. A secondary, non-detonating fluid is injected into the chamber, and the leftover heat from combustion causes it to expand for a second power stroke followed by a second exhaust stroke. The six stroke engine designs in this category are:

- **Griffin six stroke engine:** Heated exhaust-jacketed external vaporizer, into which fuel was sprayed, was the main principle of working of griffin six stroke engines. The temperature was held around 550 °F, sufficient to vaporize the oil but not to break it down chemically. This fractional distillation supported the use of heavy oil fuels, the unusable tars and asphalts separating out in the vaporizer.

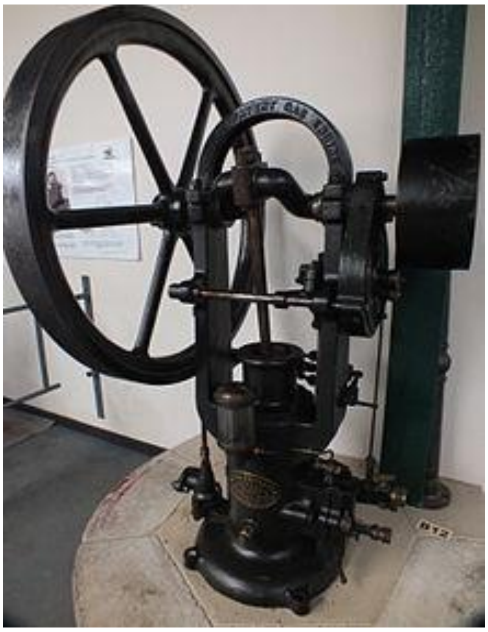

Figure 1: Griffin six stroke engine

- **Bajulaz six stroke engine:** The Bajulaz six-stroke engine is similar to a regular combustion engine in design. There are, however, modifications to the cylinder head, with two supplementary fixed capacity chambers: a combustion chamber and an air preheating chamber above each cylinder. The combustion chamber receives a charge of heated air from the cylinder; the injection of fuel begins an isochoric (constant-volume) burn which increases the thermal efficiency compared to a burn in the cylinder.

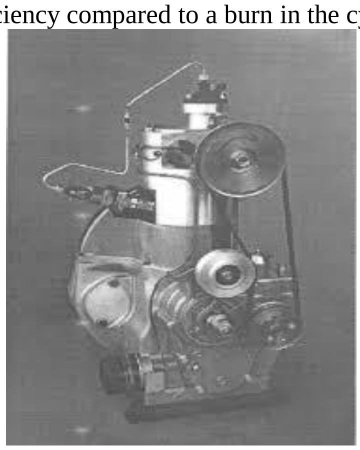

Figure 2: Bajulaz six stroke engine

- **Velozeta six stroke engine:** In a Velozeta engine, fresh air is injected into the cylinder during the exhaust stroke, which expands by heat and therefore forces the piston down for an additional stroke. The valve overlaps have been removed and the two additional strokes using air injection provide for better gas scavenging.

Figure 3: Velozeta six stroke engine

- **Niykado six stroke engine:** This is the only engine that is categorized as a fully working prototype. The first prototype was developed in 2004, which used only two valves. The second prototype, developed in 2007, was an improved design using four valves.

Figure 4: Niykado six stroke engine

- **Crower six stroke engine:** In a six-stroke engine prototyped in the United States by Bruce Crower, water is injected into the cylinder after the exhaust stroke and is instantly turned to steam, which expands and forces the piston down for an additional power stroke. Thus, waste heat that requires an air or water cooling system to discharge in most engines is captured and put to use driving the piston.

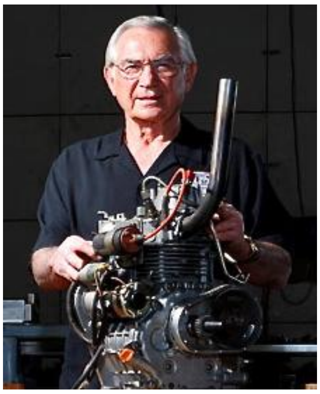

Figure 5: Crower six stroke engine

2.2 Opposed piston designs

These designs use two pistons per cylinder operating at different rates, with detonation occurring between the pistons. The six stroke engine designs in this category are:

- **Beare Head six stroke engine:** The term "Six Stroke" was coined by the inventor of the Beare Head, Malcolm Beare. The technology combines a four stroke engine bottom end with an opposed piston in the cylinder head working at half the cyclical rate of the bottom piston. Functionally, the second piston replaces the valve mechanism of a conventional engine.

Figure 6: Beare Head six stroke engine

- **M4+2:** The M4+2 engines have much in common with the Beare Head engines, combining two opposed pistons in the same cylinder. One piston works at half the cyclical rate of the other, but while the main function of the second piston in a Beare Head engine is to replace the valve mechanism of a conventional four stroke engine, the M4+2 takes the principle one step further.

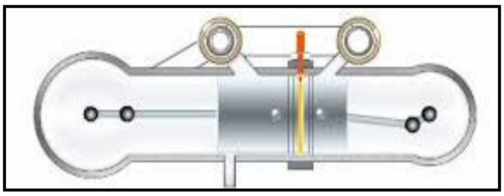

Figure 7: M4+2

- **Piston charger engine:** In this engine, similar in design to the Beare head, a "piston charger" replaces the valve system. Piston charger perform the work of charging the main cylinder and simultaneously it control the inlet and outlet opening which leads to no loss of air and fuel in the exhaust. In the main cylinder, combustion takes place every turn as in a two stroke engine and lubrication as in a four-stroke engine. Fuel injection can take place in the piston charger, in the gas transfer channel or in the combustion chamber [5].

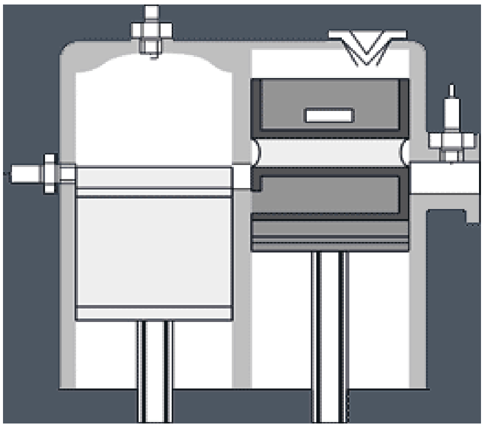

Figure 8: Piston charger engine

3. Proposed Methodology

In one cycle or three complete revolutions, there are six strokes present as follows:

- **Intake stroke:** The inlet valve open as the piston moves down from T.D.C to B.D.C which enters the air-fuel mixture into the chamber.
- **Compression stroke:** The inlet valve close as the piston moves B.D.C to T.D.C and compress the air-fuel mixture under pressure.
- **Expansion stroke:** The air/fuel mixture is then ignited, causing a small explosion which forces the piston back down which turns the crank and provides the torque.
- **Fuel exhaust stroke:** In this stroke the exhaust valve open as the piston moves back up once again, pushing the by products of the fuel explosion out of the chamber.
- **Steam expansion stroke:** After the exhaust stroke in six stroke engine, the water inside the extremely hot chamber the water immediately turns to steam (expanding to 1600 times its volume), which force the piston down for a second power stroke.
- **Steam exhaust stroke:** In this stroke all the remaining vapors and gases are thrown away from the chamber water vapors are collected by a condenser which is attached with the exhaust port so that water can be used again.

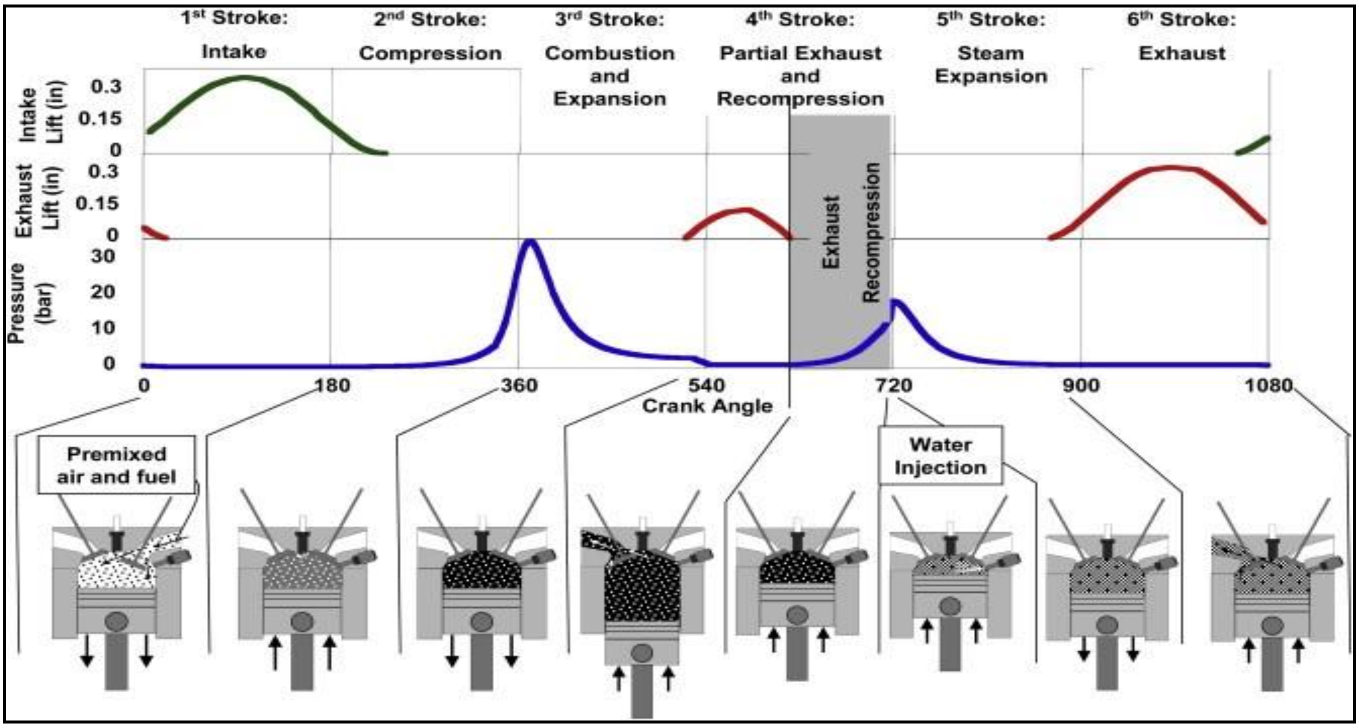

Figure 9: Variation of pressure (bar) and lift (inches) with respect to crank angle (degrees)

4. Results

The six stroke engine is a radical hybridization of two and four stroke engine that the top portion is of two stroke engine and the bottom rather the middle section is of a four stroke engine. In six stroke cycle, two parallel functions occur in two chambers which result in eight event cycle: four events internal combustion cycle and four event external combustion cycles. This results in less fuel consumption by at least 40% and dramatic reduction in pollution.

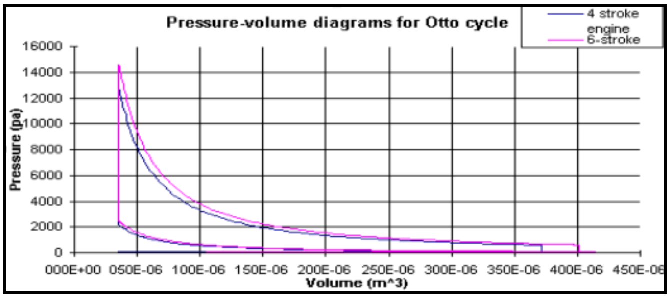

Figure 10: Pressure-volume diagrams for Otto cycle

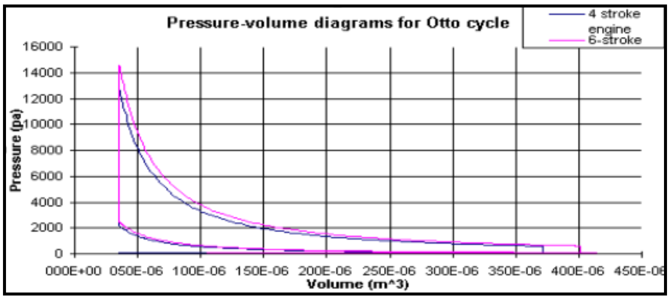

Figure 11: Pressure-volume diagrams for Dual cycle

Table 1: Comparison between 4-stroke and 6-stroke engine

Features	4-stroke engine	6-stroke engine
Number of cycles	4 cycles, • Suction • Compression • Ignition • Exhaust	6 cycles, • Suction • Compression • Ignition • Exhaust • Air Suction • Air Exhaust
Number of power strokes	One	Two
Output torque	Lower	Higher
Output Power	Lower	Higher
Efficiency	Low	High
Emission	High	Low
Air pollution	Higher	Lower
Fuel consumption	High	Low
Cooling System	Good	Better due to more air intake

5. Conclusion

It is commercially obvious that there is a big market for automobile, heavy goods, construction-site and farm vehicles. The efficiency of internal combustion engine is very low due to loss of energy in exhaust and cooling of an engine. There is a need of engine with greater efficiency. The six stroke engine is one of the alternate that today we can have. Reducing fuel consumption and pollution without any effect on performance will reassess the concept of automobile. Due to water injection, the cooling system is improved. It enables to lower the engine temperature and therefore increases its overall efficiency. At this moment, there is no wonder solution for the replacement of internal combustion engine. Only enhancements of the current technology can help it progress within reasonable time. The adoption of six stroke engine by the automobile industry would have a tremendous impact on the environment and world economy, assuming up to 40% reduction in fuel consumption and 60-90% in polluting emissions, depending on the type of fuel being used.

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