Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-5, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

A Review on Six Stroke CI Engine

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*Abstract***:.** *Six Stroke engine, the name itself directs a cycle of six strokes out of which two are useful power strokes. Conferring to its mechanical design, the six-stroke engine having external and internal combustion and dual flow is like the real internal reciprocating combustion ignition engine. However, it differentiates itself entirely, due to its thermodynamic cycle and a improved cylinder head with two additional chambers: combustion and an air heating chamber, both free from the cylinder. In this engine the cylinder and the combustion chamber are separated which gives more freedom for design analysis. Many advantages result from this, one very important is the increase in thermal efficiency. It contains two cycles of operations i.e. external combustion cycle and internal combustion cycle, each cycle having four events. Besides the two valves in the four stroke engine two extra valves are incorporated which are run by a piston arrangement. The Six Stroke is thermodynamically more proficient because the variation in volume of the power stroke or expansion stroke is more than the intake stroke and the compression stroke. The central advantages of six stroke engine includes decrease in fuel intake by 40%, due to two power strokes in the six stroke cycle, dramatic reduction in pollution, flexibility to multi fuel operation. The use of Six stroke engine by the automobile industry would have a remarkable impact on the environment and world economy [1].*

Key words: six-stroke engine, combustion, efficiency, cycle.

1. Introduction

The 6 stroke ICE is advanced version of the existing 4 stroke ICE which employs the same principle as that of the 4 stroke IC Engine. The 5^{th} stroke or the second power stroke uses the heat developed in the exhaust stroke (directly or indirectly) as heat needed for the rapid expansion of the secondary fuel (air or water) which pushes the piston downward (towards BDC) for the 2^{nd} power stroke in this manner rotating the crankshaft for another half cycle. As heat produced in the 4^{th} stroke is not wasted, so there is no requirement for a cooling system [2].

Here fuel is injected once in every three complete cycles of the crankshaft which is always better than a four stroke IC Engine where fuel is injected once in two complete cycles of the crankshaft. It is considerable that efficiency of the six stroke ICE is more than the existing four stroke ICE. Two major type of secondary fuels used in the 5^{th} stroke are air and water. Many types of six stroke IC Engines have now been designed on these two fuels of which one important type will be discussed.

2. Types of Six Stroke Engines

1) Crower six stroke engine.
2) Beare Head Six Stroke engine.
3) Bajulaz six stroke engine. [3]

3. Brief Overview of Bajulaz Six Stroke Engine

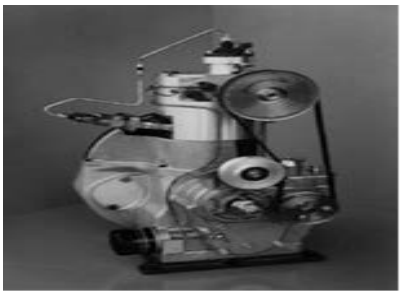

Fig-Bajulaz Six Stroke Engine

The Bajulaz six stroke engine is like a regular combustion engine in design. But however there are some alterations to the cylinder head, with two additional fixed capacity chambers, a combustion chamber and an air heating chamber directly above each cylinder. The combustion chamber takes a charge of heated air from the cylinder and the injection of fuel begins an isochoric combustion which has increased thermal efficiency related to combustion in the cylinder. The high pressure attained is then released into the cylinder to make the power stroke. Temporarily a second chamber which covers the combustion chamber has its air contents heated to a high degree by heat transferring through the walls from the burn. This high temperature and high pressure air is then used to push another stroke of the piston in the cylinder. [4]

The advantages of the engine include reduction in fuel intake by at least 40%, two expansion strokes

(power stroke) in six strokes, multi-fuel usage ability, and a vivid reduction in pollution.
Bajulaz Six Stroke Engine was developed in 1989 by the Bajulaz S A.

Features of Bajulaz six stroke engine:-

- Reduction in fuel intake by at least 40%
- Two expansions (work) in six strokes
- Multifuel (svo or biofuels)
- Intense reduction in pollution
- Liquefied Petroleum Gas (LPG)
- Costs comparable to the four-stroke engine.
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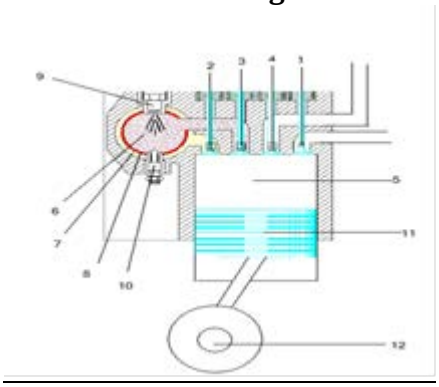
3.1 Parts of Six Stroke Engine



1) Intake valve
2) Heating chamber valve
3) Combustion chamber valve
4) Exhaust valve
5) Cylinder
6) Combustion chamber
7) Air heating chamber
8) Wall of combustion chamber
9) Fuel injector
10) Heating plug
11) Piston
12) Crankshaft [6]

4. Design and Construction

I. The engine consists of 4 valves: intake valve (1), heating chamber valve (2), combustion chamber valve (3) and the exhaust valve (4) which control the fluids flow in the cycle.

II. Engine contains a combustion chamber for burning of fuel air mixture (6) which is totally isolated (no heat or mass transfer) from the cylinder and the burning of the fuel has no direct effect on the piston as in case of a four stroke IC Engine.

III. An air heating chamber surrounds the combustion chamber which has pure air under high pressure. Heat goes from the combustion chamber to the air heating chamber

IV. Heat transfer occurs from wall of combustion chamber to the heating chamber which heats the air under high pressure which is eventually used in the 5th stroke.

V. The burning of the fuel does not have any direct effect on the piston. The energy produced by the combustion passes through valve (3) and enters the cylinder (5) and hence work is done on the piston (11). [7]

4. **Working:** The working of the six stroke IC Engine is very similar to the four stroke IC Engine. The first four strokes remain the same with two more additional strokes discussed below [8].

1st stroke: Intake of pure air in cylinder

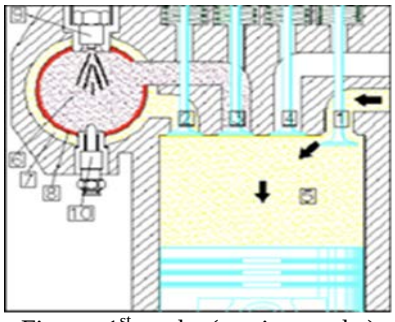


Figure- 1st stroke (suction stroke)

2nd stroke: Compression of Pure air in heating chamber

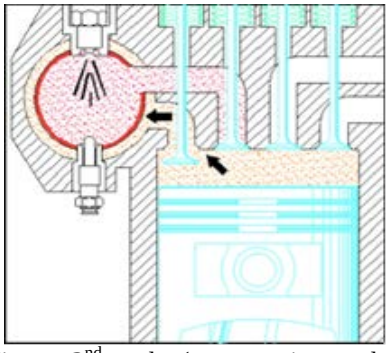


Figure- 2nd stroke (compression stroke)

3rd stroke: Release of combustion gases in the cylinder

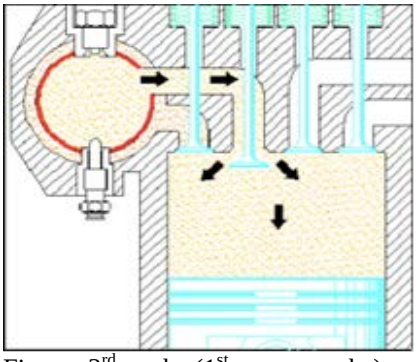


Figure- 3rd stroke (1st power stroke)

4th stroke: Exhaust of combustion gases

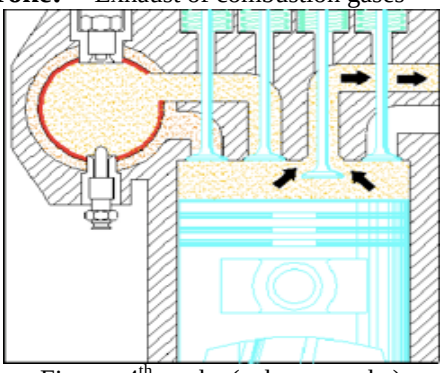


Figure- 4th stroke (exhaust stroke)

5th stroke: Release of pure air into cylinder

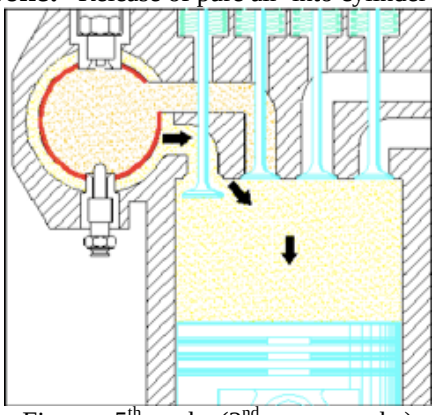


Figure - 5th stroke (2nd power stroke)

6th stroke: Recompression of pure air in the combustion chamber

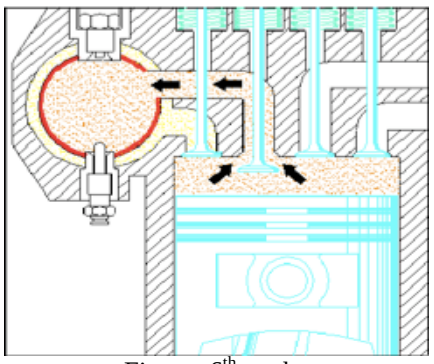


Figure- 6th stroke

6. Graphical representation:

Following are the graphical depiction of the six strokes in a cycle. The crankshaft rotates a total of 1080° in one complete cycle. The six strokes are separated into 8 events which are further classified into 2 categories i.e.:

Static event: This event occurs without the movement of piston.

Dynamic event: This event which occurs with the movement of piston.[9]

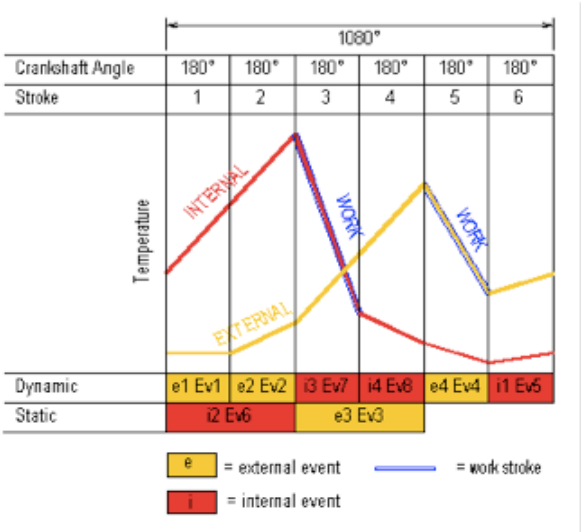
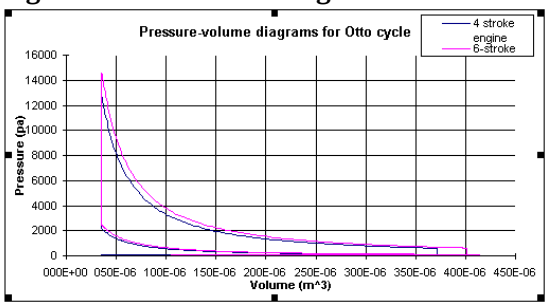


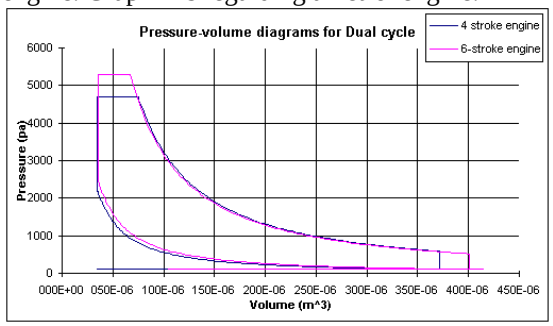
Figure-7 Graphical representation of six strokes

6.1. Graphical comparison of six stroke engine and four stroke engine:



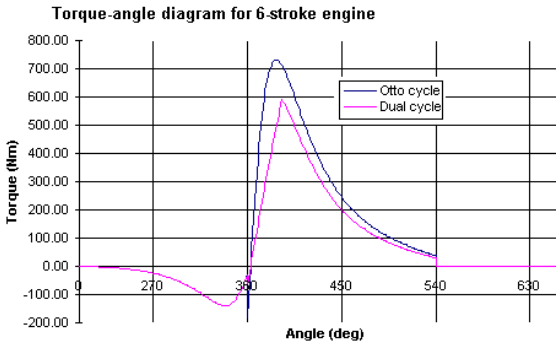
Graph 1: Otto cycle

It is obvious from the first graph that the work done by the 6 stroke engine is more than the four stroke engine. Graph 1 is regarding a Petrol engine.



Graph 2: Dual cycle

Graph 2 talks about to a diesel engine. The work done by six stroke engine is more than a four stroke engine for the same amount of fuel used



Graph-3 torque-angle diagram

7. Main Advantages and Disadvantages of Six Stroke Engine

Two expansion or power stroke in six strokes: The torque is much more even since the work or power cycles occur on every two strokes or 8% more than in a four-stroke engine. This leads to very smooth operation at low speed without any

major effects on consumption and the NOx emission, the combustion do not get affected by the engine

speed. These advantages are vital in improving the performance of car in massive traffic.[10]

Multifuel: It can use the most varied fuels, of any origin like fossil or vegetable, from diesel to L.P.G. or animal waste. The variance in inflammability or antiknock rating does not cause any problem in combustion.

Besides the six stroke petrol engine has low compression ratio but it do not eliminate the use of diesel fuel. Methanol-petrol mixture is also suggested.

Dramatic reduction in pollution: Chemical, noise and thermal pollution are minimized, first, in proportion to the reduction in specific fuel consumption, and on the other, through the engine's own features which will help to greatly lower HC, CO and NOX emissions. Moreover, its ability to run with fuels of vegetable origin (SVO) and weakly pollutant gases under optimal conditions, makes it able to match up to the strict standards.

Liquefied Petroleum Gas: Due to greater reduction in specific fuel consumption, it should make the use of L.P.G. in monofuel system, having lower cost and much lower pollution emission than the petroleum fuels. In addition, with the same operating range, the volume occupied by the tanks will be equal to that of present tanks.

Cost comparable to those of a four-stroke engine: The six-stroke engines do not need any major modification to the existing engines. All technical experience and production methods remain unchanged.

The cost of the modification to the cylinder head (combustion chamber and heating chamber) is managed by the simplification of several elements, mainly by the lightening of the moving parts, the elimination of the cooling system, the simplification of direct injection with no spark plug etc. The decrease in the dimensions of the tank and its housing in a vehicle are also to be taken into concern.

Improvements required in the six stroke engine:

I. The six stroke engine, though very efficient and advantageous has not been practically implemented on a large scale.
II. The engine seems to be bulky when compared to the conventional four stroke engine .Thus it has not been used in automobiles yet.
III. The six stroke engine is quiet complex and thus it is difficult to mass produce it.
IV. The perfect coordination between the four valves is quiet difficult to achieve

8. Conclusion: There are billions of explosion engines running worldwide at the present time, and this period is not about to end. It is commercially clear that the big market is for automobile, heavyweight goods, and construction-site and farm vehicles. This is an importance for the six-stroke engine.

1. Significantly reducing fuel consumption and pollution without drastically affecting performances would agree to the current concept of the automobile to be reevaluated.
2. In present time there is no replacement of the internal combustion engine. Only the current technology can be improved to help it progress within rational time and economical limits.
3. The six-stroke engine is best into this view. Its implementation by the automobile industry would have a fantastic impact on the environment and world economy, assuming up to 40% reduction in fuel intake and 60% to 90% in polluting emissions ($NOX_)$, depending on the type of fuel being used.
4. Fuel intake for medium size engines should be within 4 and 5 liters per 100km. and 3- 4 litres for the small-sized engines.
5. Automobiles running on the six-stroke engine could look in the market within 3 to 5 years.

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