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Modifications for Conversion of Conventional Four Stroke Engine to a Six Stroke Engine

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ABSTRACT
Considering the climate change and the shortage of non-renewable energy resources, the interests in the waste heat recovery from internal combustion engines is one of the opportunities for economizing of energy consumption. In an internal combustion engine, a great amount of fuel energy is wasted in the form of heat due to thermal limitations. Roughly one-third of fuel energy is converted to mechanical power and the rest is released to the ambience in the form of heat. To save the non-renewable energy resources, the interest in waste heat recovery has been growing. A six-stroke internal combustion engine will increase the fuel efficiency and reduce the heat dissipation of the engine. There are additional two strokes, namely steam power and steam exhaust strokes in six-stroke engine. Some of the basic modifications are done in the four stroke engine to convert six-stroke engine. There are crank shaft modification, cam shaft modification and an injector & ECU which must be required for water injection once per cycle. Major modifications of conventional internal combustion engine must be done. In this paper the modifications of the conventional four stroke internal combustion engine are illustrated to convert it into six stroke engine.

Keywords: Internal Combustion Engine, Water Injection, Cam Shaft, Steam Power, Waste Heat.

1. INTRODUCTION

Combustion of fuel is the fundamental driving force of an internal combustion engine. Oil being a non-renewable source of energy is bound to get exhaust over time. The oil & Gas Journal, in 2010 estimated that around 1,354 billion barrels of oil reserves were left on the planet. Approximately 90 billion barrels of oil is used every year. There are extremely infinitesimal changes of discovering any new oil reserves. Only 15 year worth of oil is left for future consumption [1]. The efficiency of internal combustion engine is low due to energy losses in exhaust and engine cooling system. The difficult challenges in engine technology are the urgent need of increase in engine thermal management strategies and the combustion process which are expected to play crucial roles in the development of high efficiency engines for the 21st century.

The six-stroke engine is a modification of the conventional four stroke engine in order to add two additional strokes. In the case of a two valve per cylinder engine this is achieved by incorporating an electronic water injector and extra valve on the head of the engine for the injection and exhaustion of water. The first four strokes are same as conventional engine but the final two strokes are obtained by dedicating two existing valves, replacing one with an injector and using the other for the exhaustion of water. Increasing the diameters of the air intake and exhaust valves may also be necessary. The six strokes in the engine cycle are;

(a) Intake
(b) Combustion
(c) Compression
(d) Exhaust
(e) Water injection/ expansion
(f) Steam exhaust

In a six-stroke engine, the fifth stroke starts at the end of the exhaust stroke, when the piston is at TDC; the electronic injector will spray water in the cylinder. The water that enters the combustion chamber uses the heat of combustion and turns to steam. This steam expands and exerts pressure on the piston combined with the rotational inertia of the engine, causing extra power stroke without using fuel. When the piston reaches BDC, the exhaust valve opens and the steam is pushed out of the combustion chamber by the upward motion of the piston. Heat is generally dissipated through the radiator is utilized to increase the work of the engine. The amount of work obtained from the same quantity of fuel increase, thus improving thermal efficiency. Bruce Crower managed to develop the first six-stroke using a modified single cylinder diesel engine in 2006. After the exhaust stroke, water is injected into the cylinder and a steam form forcing the piston back down and in turn cools the engine. The result is normal level of power using much less fuel and no need for an external cooling system [2].According to Crower's design, water is injected only after the exhaust stroke is completely finished. In order to recover the waste heat, a new idea has been proposed by J.C.Conklin and J.P.Szybist in 2009. The idea is to trap and recompress the exhaust gas from fourth piston stroke followed by a water injection and expansion of the resulting steam exhaust mixture [3]. Improving the efficiency of internal combustion engine is an ongoing area of active research. Numerous designs have been proposed on the traditional Otto and Diesel cycle. Fig.1 shows a schematic of typical four stroke sequence for an Otto cycle and Fig.3 illustrates the corresponding pressure volume trace. The modified cycle proposed here adds two additional strokes that increase the work extracted per one time input of fuel energy. Fig 2 illustrates six stroke sequence and Fig 4 illustrates the corresponding pressure volume trace.

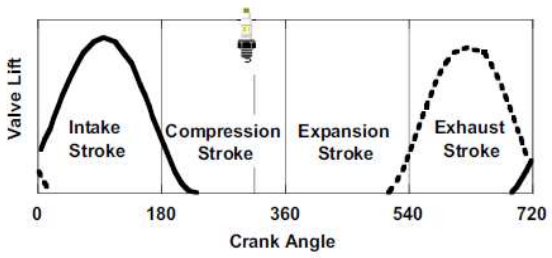
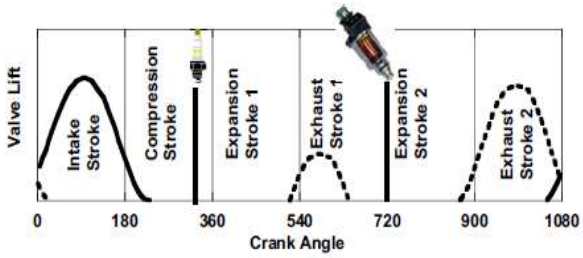


Fig.1. Schematic of typical intake and exhaust valve events for a gasoline engine. [4]



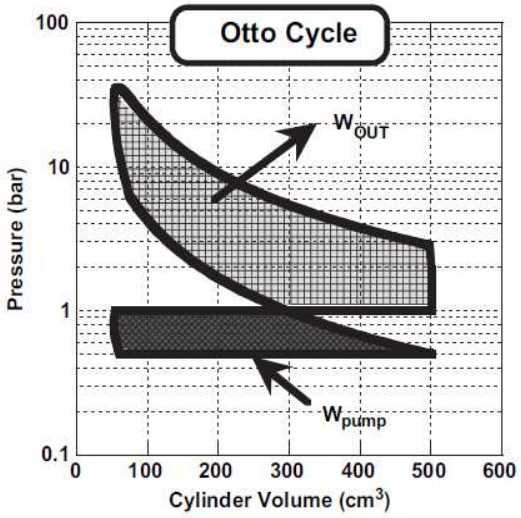


Fig.3. Schematic of pressure vs. volume for a typical gasoline engine Otto cycle. [4]

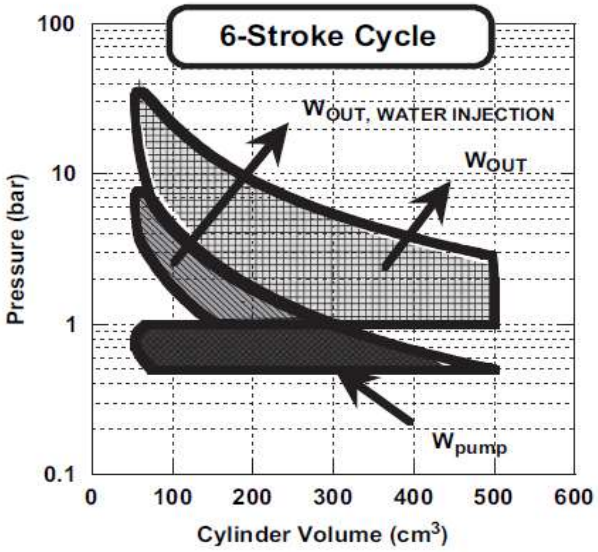


Fig.4. Schematic of pressure vs. volume for a six-stroke engine cycle. [4]

II. ENGINE MODIFICATIONS

To convert six-stroke engine from conventional four-stroke engine, a few modification must be done to be sure that the new engine with six-stroke will run successfully.

A. Crank Shaft to Cam Shaft Ratio Modification

In conventional four-stroke engine, the crank shaft must rotate 2 revolution while the cam shaft rotate

one revolution for one complete cycle. However, the crank shaft must rotate 3 revolution for one revolution of camshaft. The crankshaft to cam shaft gear ratio must be changed to 3:1 as shown in Fig 5.

Fig 5 Crank Shaft and Cam Shaft gear mesh

B. **Cam Shaft Modification**

The original camshaft has two lobes, one for the intake valve and one for the exhaust valve. The camshaft is shown in Fig 6. Each lobe is contact with a flat follower pushrod which move a rocker arm inside of the head. The other side of the rocker arm pushes the valve inside of the cylinder. A valve spring returns the valve inside of the cylinder. A valve spring returns the valve back to the original position.

For camshaft modification, a steel shaft is used as the base and machined down to fix the existing bearing in the crankcase. The lobes have been cut from steel slightly over size and ground down for more accuracy. The lobes are then welded onto the shaft at the proper angle. The gear is placed on a shaft and uses a key to lock it into position. The lobe for inlet valve is not changed but the lobes for exhaust valve is changed as shown in Fig 7.

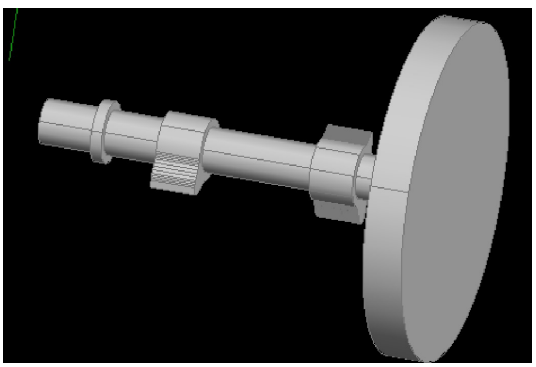


Fig 6 Camshaft for six-stroke engine

Fig.7. Cam lobes for inlet and exhaust valves of six-stroke engine

C. **Change Head Design**

The fifth stroke of six-stroke engine requires wafter injection which requires additional hardware to be added to the head. Remove some cooling fin from original head and drill a hole for injector. Fig 8 shows the modified cylinder head.

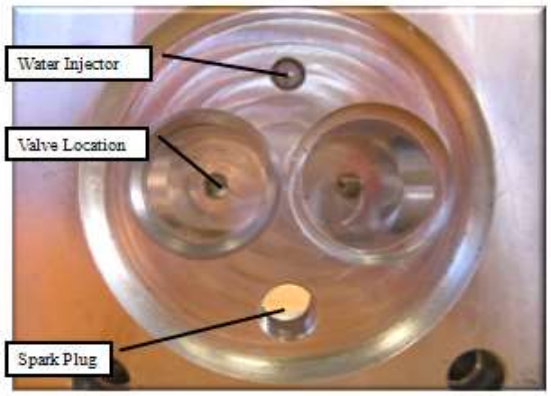


Fig .8.Modified engine head for six stroke

D. **Water Injector and ECU**

Since the water injection must be electronically controlled, the water injection system consists of three main components, the injector, the water pressuring system and electronic control system. Fig 9 shows an injector and water tank for water injection. A program for the ECU has been written and loaded onto micro controller. This code take the input from both the optical sensor and encoder to uses then to generate a timing cycle for the physical component as shown in fig 10.

Fig.9. Injector for water injection

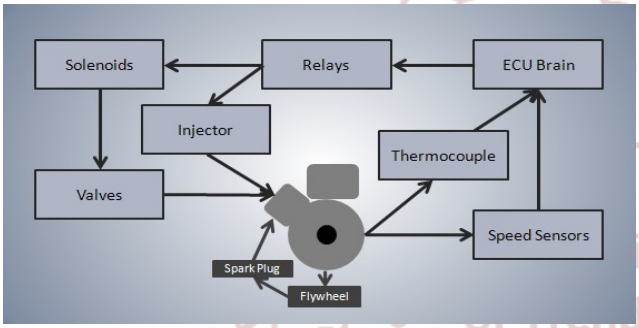


Fig .10. Arrangement diagram for six-stroke engine

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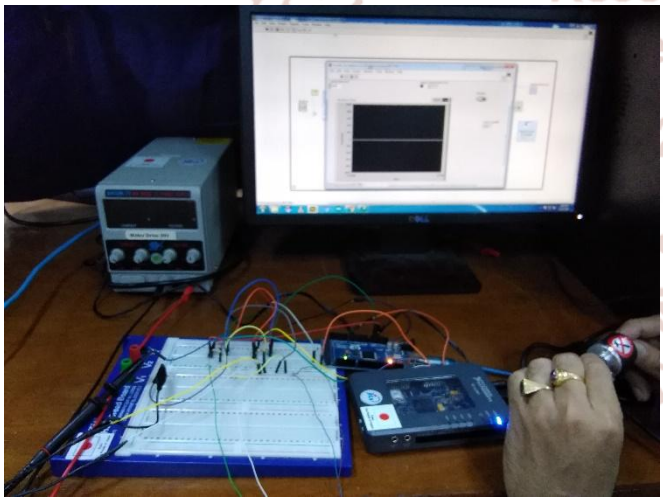

Fig 11. Testing encoder

III. ADVANTAGES AND DIS ADVANTAGES OF SIX STROKE ENGINE

The advantages of six stroke engine are;

1. Thermal efficiency will increase above 40% (30% for the conventional four stroke engine.)
2. Fuel consumption reduced by about 40% [5].
3. Reduction of chemical and thermal pollution.
4. Two expansion (work) through six stroke.
5. Eliminate the radiator and cooling system.

The disadvantage of six stroke engine are;

1. High initial cost due to change in gears, injector, ECU and camshaft modification.
2. High manufacturing cost in six stroke engine.
3. Engine head and crank case modifications

CONCLUSIONS

The six-stroke engine modification reduces the fuel consumption of an internal combustion engine. That will increase the fuel efficiency of the engine.

The injected water is heated by waste heat from the cylinder and the second power stroke is developed without fuel. It improves thermal efficiency of the engine by developing extra power from waste heat energy. The use of waste heat energy, the world energy demand on the fossil fuel reserves would be reduced.

In this paper the modifications required to convert the four stroke engine to six-stroke engine are illustrated. In spite of some balancing and vibration problems with multi cylinder engine the fuel efficiency would be increased by the development of six-stroke engine.

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