Reviewof Six Stroke Engineand Proposal for Alternative Fuels

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Abstract

This paper primarily concerns with review of Six Stroke Engine, its architecture, working along with its advantages. The six stroke engine is a combustion engine with six strokes i.e., two additional strokes to the conventional four stroke engines. In additional two strokes, the engine captures the exhausted heat from the four stroke cycle and uses it to get an additional power and exhaust stroke of the piston in the same cylinder. Thereby giving 2/3 Power strokes per revolution as compared to ½ in a Four Stoke Engine Six Stroke Engine has greater thermal efficiency, greater performance and compatibility to various fuels. Further proposals are made for alternate fuels that can be used in the engine to increase its efficiency and reduce emissions. The constant demand for decrease in emissions without any compromise in performance and efficiency is the driving motivation for this paper. Two fuels, Hydrogen and Brown's Gas are suggested as alternative fuels. The properties of each is explained in brief along with their mechanisms with the help of block diagrams.

Keywords: *Alternative Fuels, Brown's Gas Hydrogen, Oxyhydrogen (HHO), Six Stroke Engines,*

I. INTRODUCTION [1][2][3]

As the name suggests, a six stroke engine consists of six strokes in comparison with the 4 strokes of 4-stroke Internal Combustion engines. These engines consist of similar components as that of the conventional four stroke engine with addition of two more valves. The six stroke engine has the same basic mechanism of transmitting power as the traditional Internal Combustion Engine i.e., by reciprocating motion of the piston which is converted into the rotary motion of the crankshaft. The six stroke engines are mostly preferred in heavy vehicles where the prime focus is on load carrying capacity rather than fuel economy. It consists of six strokes which are due to the radical hybridization of 2 strokes and 4 strokes engines, i.e. the piston in each stroke goes up and down six times for the injection of fuel. The six stroke engine consists of 2 chambers having internal combustion and external combustion wherein, the unused or waste heat from the 4 stroke Otto cycle is then used to carry out further two strokes. These two additional strokes increase the work extracted per unit input of energy, and will include preferably a multiple of five non-uniform cylinders, and will have an energy efficiency of up to 30% higher than that of a 4-stroke internal combustion engine.

II. ARCHITECTURE OF SIX-STROKE ENGINE

A. *Major Components of Six-Stroke Engine [2]*

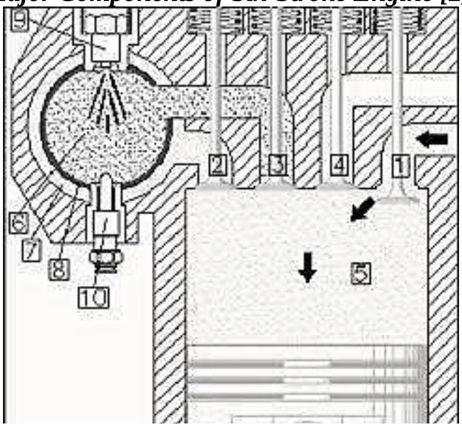

Fig 1: Components of Six Stroke Engine

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. Spark Ignition System

B. *Working of Six-Stroke Engine [3] [4]*

The six strokes of the six stroke cycles are as follows:

1. Intake stroke
2. Compression stroke
3. Ignition stroke
4. Recompression stroke
5. Steam expansion stroke and
6. Exhaust stroke

In a general six stroke engine, the first 4 strokesare similar to those in 4-stroke Otto cycle engine. In the first stroke i.e. the Intake stroke, air-fuel mixture, by the carburettor is supplied in the intake valve, whereas the exhaust valve is closed and the piston is said to move from TDC (Top Dead Center) to BDC (Bottom Dead Center). The second stroke is of Compression, wherein the intake as well as the exhaust valves is closed, consists of compression of the air fuel mixture and the piston moves from BDC to TDC. In the third stroke, Ignition takes place as a spark plug is used to ignite the compressed mixture and thereby begins the second revolution wherein the piston again moves from TDC to BDC. In the fourth stroke, these burnt gases are led out from the cylinder through exhaust valve and reed valve which then completes the second revolution and the fourth stroke as the piston moves from BDC to TDC.

The differentiating points are the latest two strokes i.e. the 5th and the 6th stroke. The fifth stroke initiates the power stroke, wherein instead of air- fuel mixture only air is sucked into the cylinder from the air filter through the secondary air induction line and the piston moves from TDC to BDC. In the sixth stroke, the exhaust air from the cylinder is led to the atmosphere by the exhaust valve. In some cases, the sixth stroke is also known as Scavenging Stroke.

III. LITERATURE REVIEW [5]

Following are the various approaches categorising the six stroke engine design:

1. The First Approach
2. The Second Approach

A. *The First Approach*

There are two additional strokes by the main piston as fifth and sixth stroke along with the conventional four strokes of Internal Combustion Engine. These engines have 2 power strokes: one by fuel, one by steam or air.

- Griffin Six Stroke Engine
- Bajulaz Six Stroke Engine
- Crower Six Stroke Engine
- Velozeta Six Stroke Engine
- NIYKADO Six Stroke Engine

1) Griffin Six Stroke

The key principle of the "Griffin Simplex" was a heated exhaust-jacketed external vaporiser, into which the fuel was sprayed. The temperature was held around 550 °F (288 °C), sufficient to physically vaporiser 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 vaporiser.

2) Bajulaz Six Stroke [6][7]

The first prototype of this type was patented in 1985 followed by the patent of an improved version in 1989. 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 burn which increases the thermal efficiency compared to a burn in the cylinder. The high pressure achieved is then released into the cylinder to work the power or expansion stroke. Meanwhile a second chamber which blankets the combustion chamber, has its air content heated to a high degree by heat passing through the cylinder wall. This heated and pressurized air is then used to power an additional stroke of the piston.

3) Crower Six Stroke:

In a six-stroke engine developed in the U.S. by Bruce Crower in 2004, fresh water is injected into the cylinder after the exhaust stroke, and is quickly turned to superheated steam by absorbing the cylinder heat, which causes the water to expand to 1600 times its volume and forces the piston down for an additional stroke. The phase change from liquid to steam removes the excess heat of the engine.

4) NIYKADO Six Stroke

The engine was developed, designed and patented by Chanayail Cleetus Anil from Kochi, India in 2012. This is the only engine that is categorised as a fully working prototype. The first prototype was developed in 2004 which used only 2 valves. The second prototype developed in 2007 which was an improved version using 4 valves.

5) Velozeta Six Stroke [8]

In a Velozeta engine, during the exhaust stroke, fresh air is injected into the cylinder 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.

B. *The Second Approach*

It uses a second opposed piston which moves at half the cyclical rate of the main piston, thus giving six piston movements per cycle and theoretically replacing the valve mechanism of a conventional engine and also increasing the compression ratio

- Beare head six stroke engine
- Charge pump engine

1) Beare Head Six Stroke

This engine combines the top portion of two stroke engine and the middle section of a four stroke engine. It is a radical hybridization of two and four stroke engines. Below the cylinder head gasket, everything is conventional, in his design. So one main advantage is that the Beare concept can be transplanted to existing engines without any redesigning or retooling the bottom end and cylinder. Beare used a short-stroke upper crankshaft complete with piston, which is driven at half engine speed through the chain drive from the engine. This piston moves against the main piston in the cylinder and if the bottom piston comes four times upwards, upper piston will come downwards twice. The compression of charge takes place in between these two pistons.

2) *Charge Pump Engine*

In this engine, similar in design to the Beare head, a 'piston charger' replaces the valve system. The piston charger charges the main cylinder and simultaneously regulates the inlet and the outlet aperture leading to no loss of air and fuel in the exhaust. It is also possible to charge two working cylinders with one piston charger. The combination of compact design for the combustion chamber together with no loss of air and fuel is claimed to give the engine more torque, more power and better fuel consumption. The benefit of less moving parts and design is claimed to lead to lower manufacturing costs.

C. *Advantages of Six-Stroke Engine [3][5]*

1) *No External Cooling Required*

In the two additional stokes, the exhaust heat energy present in the cylinders is used up by the air or water to do work. Thereby decreasing the engine temperature and ruling out the need for heavy external cooling systems& radiators.

2) *Increased Stroke Volume*

In six stroke engine the change in volume during the compression stroke is slightly higher than four stroke engine after the ports are closed. Also, the expansion stroke is much greater in six strokes than four strokes, both from T.D.C. to B.D.C. and from T.D.C. till the exhaust port is open. Therefore, large volume in the cylinder is obtained, thereby increasing power. Better filling of the cylinder on the intake due to the lower temperature of the cylinder walls and the piston head.

3) *Reduction in Fuel Consumption*

The operating efficiency of a 4-stroke petrol engine is approximately 30%. Whereas that of the six-stroke will be of order of 50%. For the same amount of fuel, we get additional two strokes (using air/water) thereby reducing the overall fuel consumption of six-stroke engines. The increase in thermal efficiency compensated for any reduction in specific power. It has less inertia due to the lightness of the moving parts which is another contributing factor.

4) *Two Work Cycles in Six Strokes*

As the work cycles occur on two strokes i.e., 8% more than in a 4-stroke engine, the fluctuations in torque is minimal. This lead to very smooth operation at low speed, thereby improving performance in stop and go situations as in heavy traffic in a city. Also there is increase in torque by 35% in six stroke engine.

5) *Reduction in Pollution*

Significant reduction in chemical, noise and thermal pollution are reduced. There occurs no problem in combustion due inflammability difference in six stroke engine. Also the emissions of HC, CO, NOx are reduced.

6) *Adaptability to various fuels:*

It can use the variety of fuels, of any origin which maybe fossil or vegetable, from diesel to L.P.G. or animal grease. It's light, standard petrol engine construction, and the low compression ration of the combustion chamber; do not exclude the possibility ofuse of diesel fuel.

The above advantage of adaptability to various fuels is the prime motivating behind the idea for using alternative fuels with higher calorific value in the two strokes other than water or air.

IV. ALTERNATIVE FUELS PROPOSAL

The first four strokes of the 6-stroke engines use conventional fossil fuels such as petrol, diesel. The next two strokes however use air or water as fuel. In case of air, compressed air is supplied through the inlet valve to the cylinder. As the cylinder temperature is still high due to the previous expansion stroke, the air as soon as it comes in contact it absorbs this heat and expands rapidly. Thereby pushing the piston head downwards for the next power stroke.

In case of water, water is sprayed in the cylinder in atomised form. The water is converted into steam on contact with the cylinder, thus pushing it downwards similar to earlier case.
The efficiency of six stroke engine can be further increased by using a fuel with higher calorific value than air or water and preferably with low flash point. Thereby reducing the fuel consumption for the same amount of power.

The various alternative fuels that can be incorporated are:

a) Hydrogen Fuel
b) Brown's Gas (HHO)

A. *Hydrogen Fuel [9] [10]*

A very simple method of producing the hydrogen gas is by electrolysis of water in which the liberation of hydrogen gas is done by splitting of the hydrogen molecules from the water molecules. Clean burning characteristics of hydrogen provides a strong incentive to study its utilization as a possible alternate fuel. Hydrogen can be used in Spark Ignition (S.I) as well as Compression Ignition Engine (C.I). Hydrogen is not an energy source, but an energy carrier because it takes a great deal of energy to extract it from water.

Hydrogen reduces the smoke, particulate and soot emissions to the considerable amount by the maximum replacement of 20% in C.I engine without sacrificing the engine power output. The problems like pre-ignition and backfire could be eliminated compared to S.I engine that make the usage of hydrogen to be safer in CI mode.

Hydrogen has a wide flammability range in comparison with all other fuels. As a result, hydrogen can be combusted in an internal combustion engine over a wide range of fuel-air mixture and can run on a lean mixture. It can burn in air at a very wide range of concentrations between 4% and 75% by volume.

Fuel economy is greater and the combustion reaction is more complete when a vehicle is run on a lean mixture. Additionally, the final combustion temperature is generally lower, reducing the amount of pollutants, such as nitrogen oxides, emitted in the exhaust.Hydrogen has very low ignition energy. The amount of energy needed to ignite hydrogen is about one order of magnitude less than that required for gasoline.

Hydrogen has a relative high auto ignition temperature. The hydrogen as an auto ignition temperature of spontaneous ignition in air is 500°C (932 °F). This has important implication when a hydrogen-air mixture is compressed. High peak flame temperature due to higher enthalpy of combustion, 286 kJ/mole energy density.

Following is the block diagram illustrating the use of hydrogen in six stroke engine along with its details.

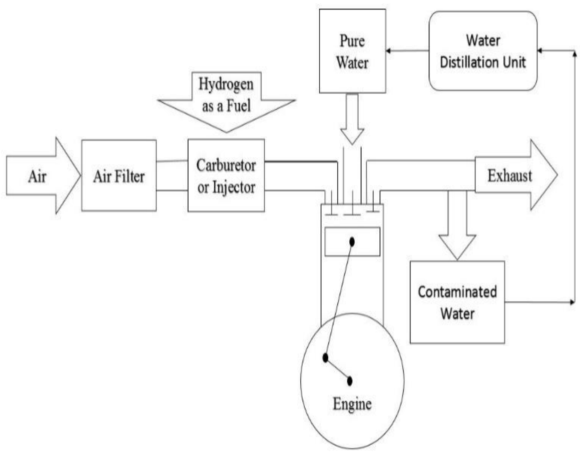

Fig 2: Block Diagram of Hydrogen Fuelled Six Stroke Engine

The above figure shows block diagram of the proposal for implementing hydrogen fuelling in six stroke engine. The airis injected through an air filter which is metered through the carburettor. In the 1^{th} stroke, hydrogen is supplied through the injector into the cylinder. Hydrogen is compressed & ignited in the 2^{nd} stroke,which on ignition forces the piston downwards to give the power stroke. In exhaust stroke, water is formed which is passed through the Distillation Unit, where it is condensed and distilled. This distilled water is then recirculated for use in the 5^{th}& 6^{th} stroke. Again in the exhaust stroke (6^{th} stroke) water is formed which can be again distilled for reuse. However, the number of cycles which the water can be reused is limited due to losses and contamination leading to wear of engine parts.

In hydrogen fuelled engine, the principal exhaust products are water vapour and NOx [11]. Emissions such as HC, CO, CO2, SOx and smoke are either not observed or are very much lower than those of diesel engine. Small amount of hydrogen peroxide may be found in the exhaust of the hydrogen-operated engine. Unburned hydrogen may also come out of the engine, but this is not a problem since hydrogen is non-toxic and does not involve in any smog producing reaction. NOx are the most significant emission of concern from a hydrogen engine. Researchers have been successful in the biological production of hydrogen from organic effluents and a large-scale bioreactor of 12.5 m3 capacity is being developed in India

B. Brown's Gas [12] [13] [14]

Brown Gas (HHO) is a mixture of 2/3 ofhydrogen and 1/3 of oxygen (O2) by volume and a special form of water called Electrically Expanded Water (EEW) or Santilli Magnecules. When water is introduced with electrical DC (Direct Current) it divides into its primary elements of Hydrogen and Oxygen. The Hydrogen and Oxygen rise from the liquid water as a gas. The gas is called HHO.

For a stoichiometric mixture, Oxyhydrogen(HHO) gets ignited at a temperature of about 570°C at normal atmosphericpressure.When ignited, the gas converts to water vapourand releases energy of about 241.8 kJ of energy for every mole of H_2 burned.The amount of energy released isindependent of the mode of combustion.It is implosive in nature. When burned in itspure mixture, the gases implode back into water.The flame is only about 300 degrees hot, but can produce 15,000 degrees of heat using electrical energy directly from the object it is burning.Brown Gas power potential is much greater than50,000 BTU/lb. (115 MJ/kg). Also, 1 litre of water makes 1850 litres of Browns Gas.

Following is the block diagram illustrating the use of hydrogen in six stroke engine along with its details.

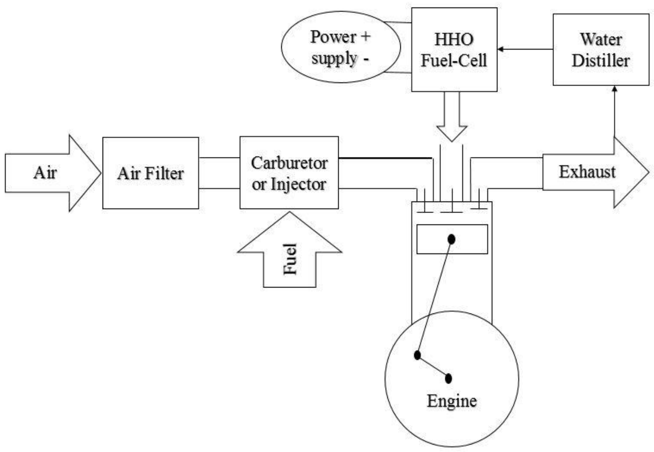

Fig 3: Block Diagram of Brown's Gas Fuelled Six Stroke Engine

The above figure shows block diagram of the proposal for implementing Brown's Gas fuelling in six stroke engine. The filtered air is mixed with the fuel and metered in the carburettor. This mixture is sent to the combustion chamber. Here HHO (Oxyhydrogen) can also be supplied along with the air-fuel mixture. It is found that the total fuel consumption for Brown's gas enriched operation at full load gives 6% lesser than conventional engine operation without Brown's Gas. In this proposal, Brown's Gas is also supplied in the 5th stroke of the six stroke engine.

Brown's Gas is generated in a portable HHO Fuel Cell. It consists of titanium electrodes, distilled water stirred with NaCl, Battery (9volts), Moisture filter and Back fire arrestor. Distilled water is poured into the electrolyser till the electrodes gets submerged. The electrodes are connected to positive and negative terminals so that DC current is flow into it. When the current passes into salted distilled water, molecular bonds get breaks up and HHO gas is formed.

It is passed into inlet manifold through nozzle of the HHO fuel system. Since HHO is lighter than water, it flows into cylinder along with air easily. HHO is supplied to the inlet manifold from the on board HHO fuel cell.

This HHO is injected in the 5th stroke which on combustion forms oxygen and water. This water can be again distilled in a similar manner as in hydrogen fuelled engine and can be reused. In HHO engine, oxygen is produced which reduces emissions up to 40%.

V. COMPARISON BETWEEN HYDROGEN AND OXYHYDROGEN

A. Hydrogen

This fuel is complete in itself. It does not need oxygen from the atmosphere to burn, which is an improvement over fossil fuels in saving the oxygen in our air supply. In fact, when hydrogen burns perfectly, nothing at all comes out of the tail pipe. If salt and metal alloy are used to create hydrogen, then there will be residues of that in the exhaust, but hydrogen fuel does not contribute oxygen to the atmosphere. The necessary modifications in engine, carburettor & spark plug need to be done for modifying a normal I.C engine vehicle to hydrogen powered vehicle. Also storage of Hydrogen poses a problem.

B. Brown's Gas

This is the most perfect fuel of all for running our vehicles. Like pure hydrogen, it is made from water, i.e., hydrogen and oxygen, but it burns in the combustion engine so that, depending on the setup, it may actually release oxygen into the atmosphere. In that case, what comes out of the tail pipe is oxygen and water vapour, just as with fuel cells; but the oxygen comes from the water that's being used to create the Brown's gas fuel. So burning Brown's gas as fuel can add oxygen to the air and thus increase the oxygen content of our atmosphere. The main thing is the removal of the carburettor and its replacement by a pressure reducer and throttle valve. The only other change needed to the engine itself us re-timing to allow for the fact that the hydrogen-oxygen mixture has a higher flame speed that the normal gasoline-air mixture. Brown's Gas however is produced real-time and need not be stored unlike Hydrogen.

From the above brief comparison, it is evident that Brown's Gas holds is easy to implement and more advantageous than Hydrogen. Hence Brown's Gas holds a more promising future in next generation alternative fuelling techniques.

VI. CONCLUSION

Today we are facing a huge energy crisis. For combating this situation, modern engineering technology and energy conservation techniques need to be implemented. The Six Stroke Engine along with the proposed alternative fuels is the key. The Six Stroke engine gives more power strokes per revolution, reduces cooling demands, 35% increase in torque, 40% reduced fuel consumption & 60% to 90% reduction in polluting emissions, depending on the type of the fuel being used. The use of proposed alternative fuels provides additional significant impact on engine brake thermal efficiency and brake power, also reducing emissions. Hence it is safe to say, that the technologies discussed in this paper will certainly contribute to reduction in dependency on fossil fuels.

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