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Multifuel based Six Stroke Internal Combustion Engine

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***Abstract*:- Six Stroke engine, the name itself indicates a cycle of six strokes out of which two are useful power strokes. 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 entirely, due to its thermodynamic cycle and a modified cylinder head with two supplementary chambers: combustion and an air heating chamber, both independent from the cylinder. In this the cylinder and the combustion chamber are separated which gives more freedom for design analysis. Several advantages result from this, one very important being the increase in thermal efficiency.**

The Six Stroke is thermodynamically more efficient because the change in volume of the power stroke is greater than the intake stroke and the compression stroke. The main advantages of six stroke engine includes reduction in fuel consumption by 40%, two power strokes in the six stroke cycle, dramatic reduction in pollution, adaptability to multi fuel operation. Six stroke engine's adoption by the automobile industry would have a tremendous impact on the environment and world economy.

INTRODUCTION TO 6 STROKE IC ENGINE

The 6 stroke IC Engine is advancement over the existing 4 stroke IC Engine which employs the same principle as that of the 4 stroke IC 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 anytime better than a 4 stroke IC Engine where fuel is injected once in 2 complete cycles of the crankshaft. It should be noted that efficiency of the 6 stroke IC Engine is more than the existing 4 stroke IC Engine. 2 major type of secondary fuels used in the 5th stroke are air and water. Many types of 6- IC Engine have now been designed on these 2 fuels of which few important types will be discussed.

TYPES OF SIX STROKE ENGINES.

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

1. *Crower six stroke engine.*

In a six-stroke engine patented in the U.S. by Bruce Crower, after the exhaust stroke, fresh water is injected into the cylinder, and is quickly turned to superheated steam, which causes the water to expand to 1600 times its volume and forces the piston down for an additional stroke. This design also claims to reduce fuel consumption by 40%.

Crower's six stroke engine features:-

- No cooling system required
- Improves a typical engine’s fuel consumption
- Requires a supply of distilled water to act as the medium for the second power stroke.

2. *Beare Head Six Stroke engine.*

Figure 1: Beare Head Six Stroke engine.

This engine simply replaces the conventional Four Stroke Engines Cylinder Head. The manufacturers Four Stroke bottom end remains unchanged. The Engine utilises an overhead short stroke Crankshaft and Piston arrangement which opens and closes Inlet and Exhaust Ports leading through the Upper Cylinder Liner. The Beare Head Technology can be fitted to new production engines or retro-fitted via aftermarket replacement.

The top and bottom Crankshaft are connected via a drive chain or toothed belt. The top Crankshaft and Piston become positive power contributors to the overall power output, thus increasing the amount of power/torque generated by up to a possible 35%, in essence, The Engine results in having Two Pistons Operating and producing power within each cylinder. The absence of valves, springs, retainers and guides, mean that the Engines bottom end has been freed up from labouring and is allowed to spin up producing more power. The additional torque and power further generated by the Top Piston/Crank of the Cylinder Head is then channelled via the connecting drive chain to the Bottom Crank. The net result of the Engine is Tractor type pulling torque never before realised from a Four Stroke Internal Engine, the sort of steady locomotive type performance gained can only be likened to Steam Locomotives or Diesel Engines.

The net result is:

- Power/torque increases of 35% (conservative).
- Simpler and less expensive manufacturing and tooling.
- Reduction of cylinder head reciprocating parts.
- Lower maintenance costs due to less wearing parts (cylinder head).
- Longer servIC Engine intervals possible due to lower operating temperatures recorded.
- Increased economy due to the ability to operate and produce full operating power of much higher AIR to FUEL ratios.
- Reduction of exhaust emissions due to less fuel being consumed and the real prospect of meeting EURO-4 emissions standards, doing away with the catalytic converter.
- Possible one piece engine block and head casting, saving more manufacturing costs.
- Usable torque at as low as idle means suitability for lower RPM operation and adaptation to CVT (Constantly Variable Transmission).

3. *Bajulaz six stroke engine.*

The Bajulaz six stroke engine is similar to a regular combustion engine in design. But however there are some modifications to the cylinder head, with two supplementary fixed capacity chambers, a combustion chamber and an air preheating chamber above each cylinder.

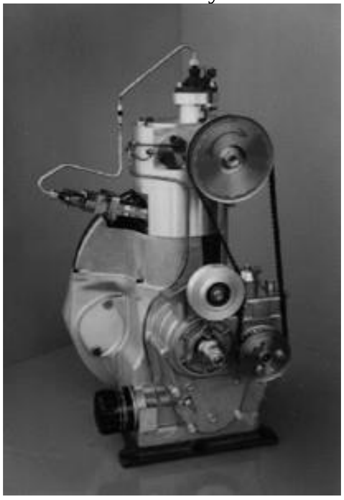

Figure 2: Bajulaz six stroke engine.

The combustion chamber receives a charge of heated air from the cylinder and the injection of fuel begins an isochoric burn which has increased thermal efficiency compared to a burn in the cylinder. The high pressure achieved is then released into the cylinder to work the power stroke. Meanwhile a second chamber which blankets the combustion chamber has had its air contents heated to a high degree by heat passing through the walls from the burn. This heated and pressurized air is then used to power another stroke of the piston in the cylinder. The advantages of the engine include reduction in fuel consumption by at least 40%, two expansion strokes (work) in six strokes, multi-fuel usage capability, and a dramatic reduction in pollution.

Bajulaz six stroke engine features:-

- Reduction in fuel consumption by at least 40%
- Two expansions (work) in six strokes
- Multifuel
- Dramatic reduction in pollution
- Liquefied Petroleum Gas
- Costs comparable to those of a four-stroke engine.

Bajulaz six stroke engine

Design and construction:

- 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 flow of the fluids in the cycle
- Engine consists of a combustion chamber for burning of fuel air mixture(6) which is completely isolated from the cylinder and the burning of the fuel has no direct effect on the piston as in the case of a 4 stroke IC Engine.
- An air heating chamber surrounds the combustion chamber which holds pure air under high pressure. Heat passes from the combustion chamber to the air heating chamber
- The wall of the combustion chamber allows transfer of heat to the air heating chamber which heats the air under high pressure which is eventually used in the 5th stroke.
- The burning of the fuel does not have any direct influence on the piston.the energy released by the combustion passes through valve which enters the cylinder and hence work is done on the piston.

Working

The working of the 6 stroke IC Engine is very similar to the 4 stroke IC Engine. The first four strokes remain the same with the addition of 2 more strokes discussed below:

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

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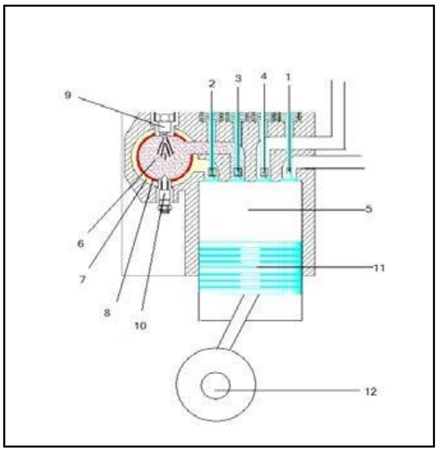

Figure 3: Bajulaz six stroke engine

1st stroke: The inlet valve(1) is kept open. Due to cranking, the piston moves downward which results in the formation of a pressure difference due to which pure air enters the cylinder (5). The crankshaft completes rotates for half cycle.

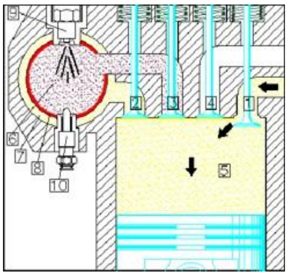

Figure 4: 1st stroke (Suction Stroke).

2nd stroke: The inlet valve closes and the heating chamber valve (2) opens. The piston moves upwards due to cranking forcing the pure air into heating chamber (7). The air at this stage is converted to high pressure. The fuel is injected in the combustion chamber and the fuel is ignited as shown the figure (initially compressed air is present in the combustion chamber which results in the formation of fuel air mixture). Part of the heat evolved will pass through the wall of the combustion chamber (8) and it heats up the compressed air present in the air heating chamber. The crankshaft completes another half cycle rotation in the 2nd stroke. **At the end of 2 strokes the crankshaft will complete one cycle.**

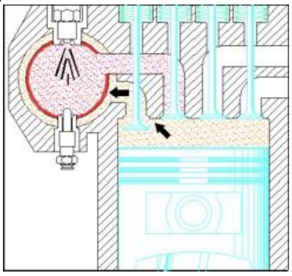

Figure 5: 2nd stroke (compression stroke)

3rd stroke (1st power stroke): The combustion chamber valve (3) opens and the gases of combustion enter the cylinder (5). This pusher the piston downward and hence is known as the power stroke. The crankshaft rotates for a half cycle. It should be noted that the air in the heating chamber is continuously heated and this results in further increase of pressure.

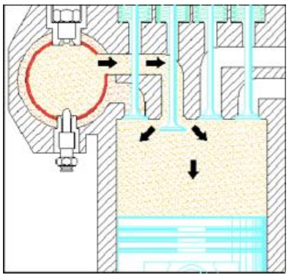

Figure 6:3rd stroke (1st power stroke).

4th stroke (exhaust stroke): The exhaust valve (4) opens. The piston moves upwards and the exhaust gases are removed via this valve. The crankshaft rotates another half cycle. At this stage the crankshaft completes 2 full cycles.

In this stroke, less amount of heat energy is expelled out when compared to the 4 stroke IC ENGINE as this heat has already been used to heat the air at high pressure in the air heating chamber (7).

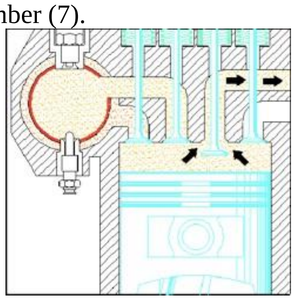

Figure 7: 4th stroke (exhaust stroke)

5th stroke (2nd power stroke): The heating chamber valve opens and the pure air now at high pressure and high temperature enters the cylinder as shown in the figure which does work on the piston and hence it moves downwards resulting in the 2nd power stroke. The crankshaft completes another half cycle.

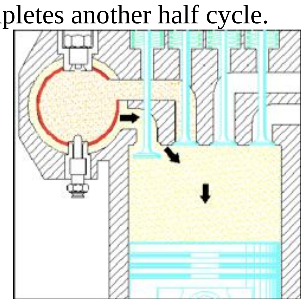

Figure 8: 5th stroke (2nd power stroke).

6th stroke: Finally the combustion chamber valve

(3) opens the piston moves upwards forcing the pure air into the combustion chamber which will be used as air for the fuel-air mixture in the 3rd stroke or the first power stroke.The crankshaft will complete 3 full cycles at the end of the 6th stroke. Hence fuel is injected once every in 3 cycles of the crankshaft whereas in a 4 stroke IC ENGINE fuel is injected once in every 2 cycles.

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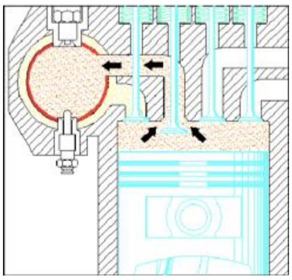


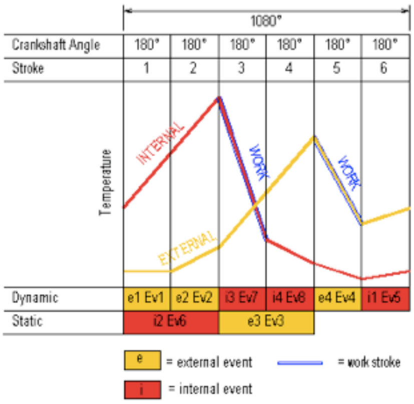
Figure 9: 6th stroke.

Graphical representation.

- Cycle of six stroke engine

Following is the graphical representation of the six strokes in a cycle. The crankshaft rotates a total of 1080° in 1 complete cycle. The six strokes are divided into 8 events which are intern classified into 2 categories ie:

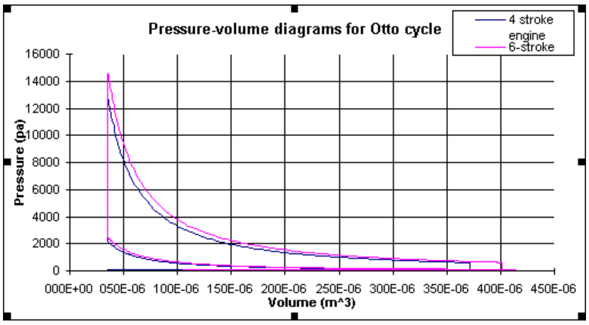
1. Static event: event occurs without the movement of piston
2. Dynamic event: event which occurs with the movement of piston



Graph 1: Graphical representation of six stroke engine.

Comparison of six stroke engine and four stroke engine.

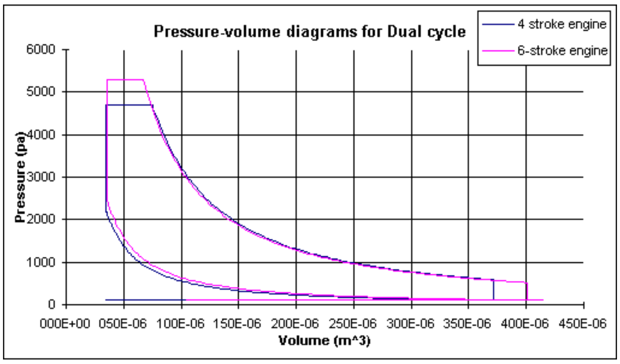
➢ **Otto Cycle.**



Graph 2: Otto cycle.

It is clear from the first graph that the work done by the 6 stroke engine is greater than the 4 stroke engine. Graph 2 is in reference with a Petrol engine.

➢ Dual Cycle



Graph 3: Dual cycle.

Graph 3 refers to a diesel engine. The work done by six stroke engine is greater than a 4 stroke engine for the same amount of fuel used.

Factors contributing to increased thermal efficiency, reduced fuel consumption and pollutant emission.

- ➢ The heat that is evacuated during the cooling of a conventional engine's cylinder head is recovered in the six- stroke engine by the air-heating chamber surrounding the combustion chamber. As a result of this less heat is wasted, which increases the thermal efficiency.
- ➢ After intake, air is compressed in the heating chamber and heated through 720° of crankshaft angle, 360° of which in closed chamber (external combustion).
- ➢ The transfer of heat from the very thin walls of the combustion chamber to the air heating chambers lowers the temperature and pressure of the gases on expansion and exhaust (internal combustion).
- ➢ Better combustion and expansion of gases that take place over 540° of crankshaft rotation, 360° of which is in closed combustion chamber, and 180° for expansion.
- ➢ The glowing combustion chamber allows the optimal burning of any fuel and calculates the residues.
- ➢ Better filling of the cylinder on the intake due to the lower temperature of the cylinder walls and the piston head.
- ➢ Elimination of the exhaust gases crossing with fresh air on intake. In the six stroke- engine, intake takes place on the first stroke and exhaust on the fourth stroke.
- ➢ Large reduction in cooling power. The water pump and fan outputs are reduced. Possibility to suppress the water cooler.
- ➢ Less inertia due to the lightness of the moving parts.
- ➢ Friction losses, theoretically higher in the six-stroke engine, are balanced by a better distribution of pressure on the moving parts due to the work being spread over two strokes and the elimination of the direct combustion.

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Modifications made

➢ ***Electrolysis***

The main commercial advantages of hydrogen production by electrolysis are its scalability and the emission-free production of hydrogen (when produced via renewable energy). Conventional electrolysis is the most common method used to produce renewable hydrogen. Electrolysis involves the separation of water into hydrogen and oxygen, using an electric current. Although some electrolyses use chemicals or intense heat to help the separation, conventional electrolysis uses no chemicals, and works at room temperature.

Electrolysis separates water into its constituent elements--hydrogen and oxygen-- by charging water with an electrical current. The charge, coming from two poles in the water, breaks the chemical bond between the hydrogen and oxygen and splits apart the atomic components, creating oppositely charged particles (see diagram). Because opposite charges attract, the negative pole (cathode) attracts the positive particle (with the hydrogen molecules), and the positive pole (anode) attracts the negative particle (with the oxygen molecules). As the particles reach the poles, the hydrogen and oxygen gases rise and are collected separately.

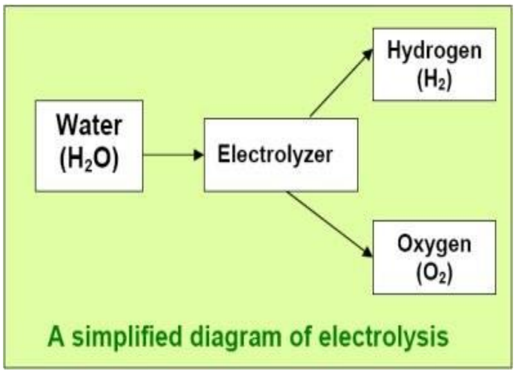


Fig 10: A Simplified diagram of electrolysis

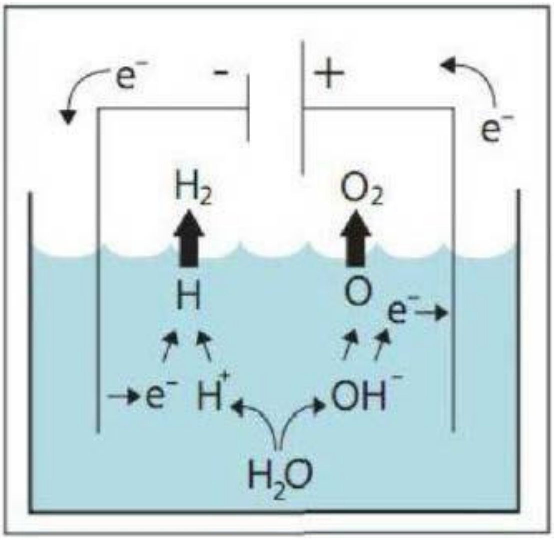
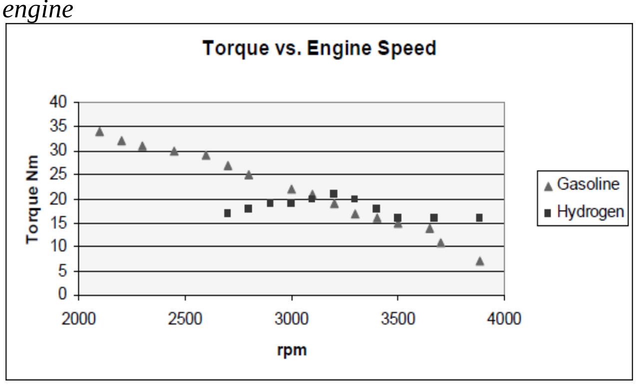


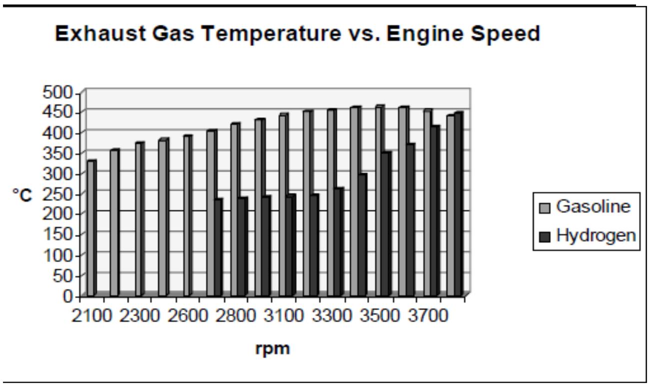
Fig 11: Process of conventional electrolysis

Comparison of Gasoline and Hydrogen

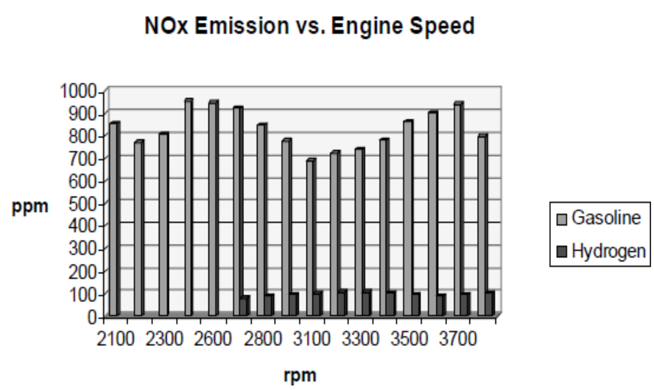
➢ Torque comparison between gasoline and hydrogen

➢ *Exhaust gas temperature of gasoline and hydrogen engine*

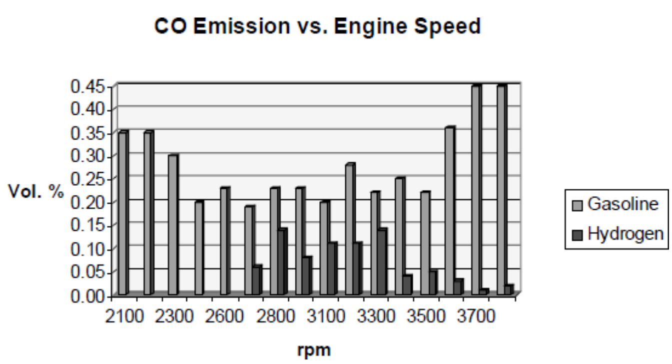




➢ NOx levels comparison between gasoline and hydrogen



➢ Carbon monoxide emissions comparison between gasoline and hydrogen



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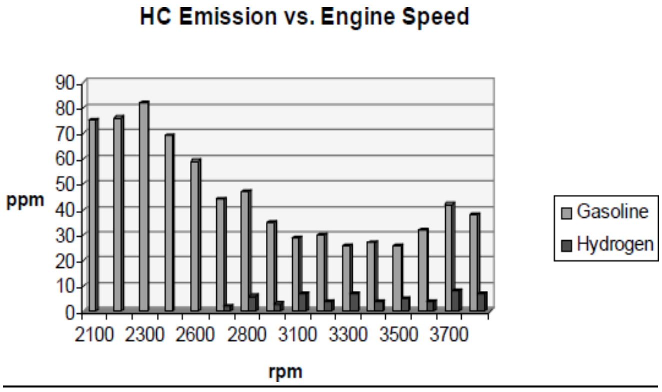

Main Advantages and Disadvantage of six stroke engine.

- Two expansions (work) in six strokes:

Since the work cycles occur on two strokes or 8% more than in a four-stroke engine the torque is much more even. This leads to very smooth operation at low speed without any significant effects on consumption and the emission of pollutants, the combustion not being affected by the engine speed. These advantages are very important in improving the performance of car in town traffic.

- Multifuel:

Multifuel par excellence, it can use the most varied fuels, of any origin (fossil or vegetable), from diesel to L.P.G. or animal grease. The difference in inflammability or antiknock rating does not present any problem in combustion. It's light, standard petrol engine construction, and the low compression ratio of the combustion chamber, do not exclude the use of diesel fuel. Methanol- petrol mixture is also recommended.

- Dramatic reduction in pollution:

Chemical, noise and thermal pollution are reduced, on the one hand, in proportion to the reduction in specific consumption, and on the other, through the engine's own characteristics which will help to considerably lower HC, CO and NOX emissions. Furthermore, it's ability to run with fuels of vegetable origin and weakly pollutant gases under optimum conditions, gives it qualities which will allow it to match up to the strictest standards

- Liquefied Petroleum Gas:

The great reduction in specific consumption should make the use of L.P.G. in mono fuel attractive, due to the lower cost and much lower pollution emissions than those of petrol. In addition, with the same operating range, the volume occupied by the tanks will be equivalent to that of present tanks.

- Cost comparable to those of a four-stroke engine:

The six-stroke engine does not require any basic modification to the existing engines. All technological experience and production methods remain unaltered. The cost of the modification to the cylinder head (combustion chamber and heating chamber) is balanced by the simplification of several elements, particularly by the lightening of the moving parts, the reduction of the cooling system, the simplification of direct injection with no spark plug, etc .The reduction in the dimensions of the tank and it's housing in a vehicle are also to be taken into consideration.

- It reduces the weight and complexity of the engines head by as much as 50%. Instead of using energy to drive the head, the head actually develops energy for conversion to power back through the timing chains of an engine.
- Torque is increased by 35% and efficiency increased by the same. This can be achieved by simply unbolting an existing head of a four-stroke engine and then bolting on a Beare Head.

Improvements needed in the six stroke engine.

- The six stroke engine, though very efficient and advantageous has not been practically implemented on a large scale.
- The engine turns out to be bulky when compared to the conventional four stroke engine .Thus it hasn't been used in automobiles yet.
- The six stroke engine is quiet complex and thus it is difficult to mass produce it.
- The perfect coordination between the four valves is quiet difficult to achieve.
- This type of engine should be modified to use fuels of high octane which may give higher efficiencies.

CONCLUSION.

Billions of explosion engines are running worldwide at this time, and this era is not about to end. It is commercially obvious that the big market is for automobile, heavy goods, construction-site and farm vehicles. This is a priority for the six-stroke engine.

- Drastically reducing fuel consumption and pollution without radically affecting performances would allow the current concept of the automobile to be reassessed.
- There is, at this day, no wonder solution for the replacement of the internal combustion engine. Only improvements of the current technology can help it progress within reasonable time and financial limits.
- The six-stroke engine fits perfectly into this view. Its adoption 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% to 90% in polluting emissions, depending on the type of fuel being used.

- Fuel consumption for mid-sized engines should be within 4 and 5 litres per 100km. and 3 to 4 litres for the small-sized engines.
- Automobiles equipped with the six-stroke engine could appear in the market within 3 to 5 years.

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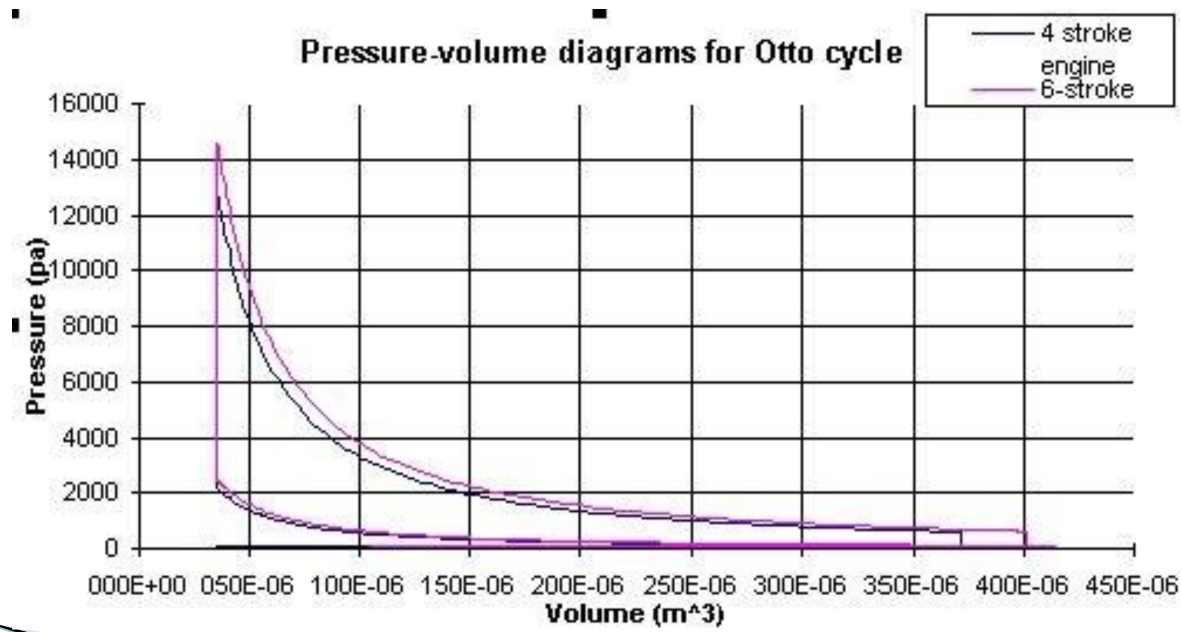

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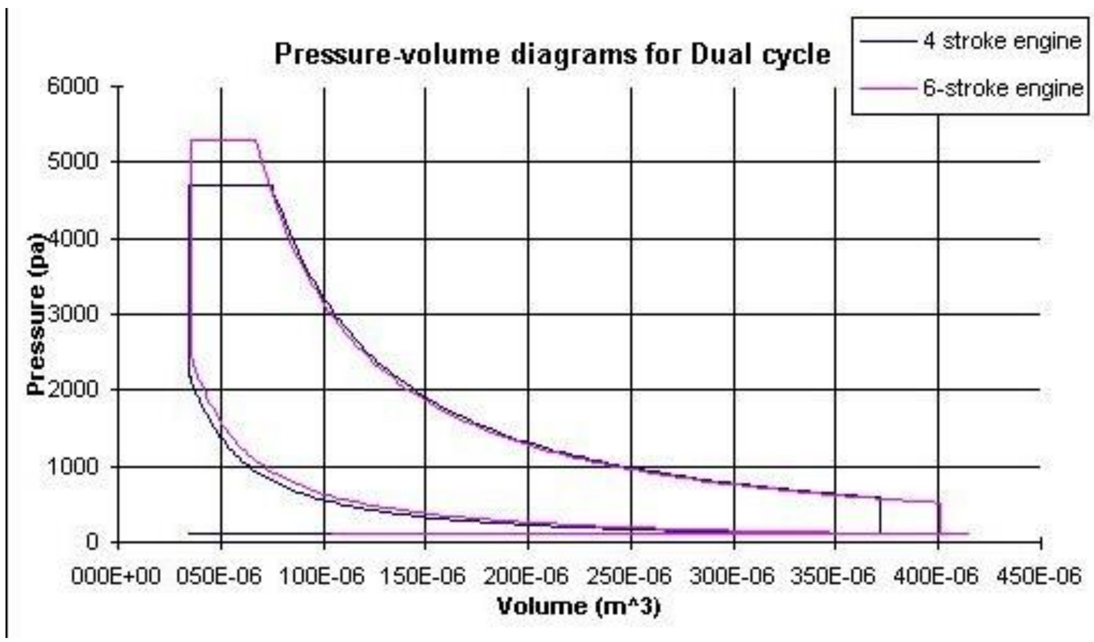

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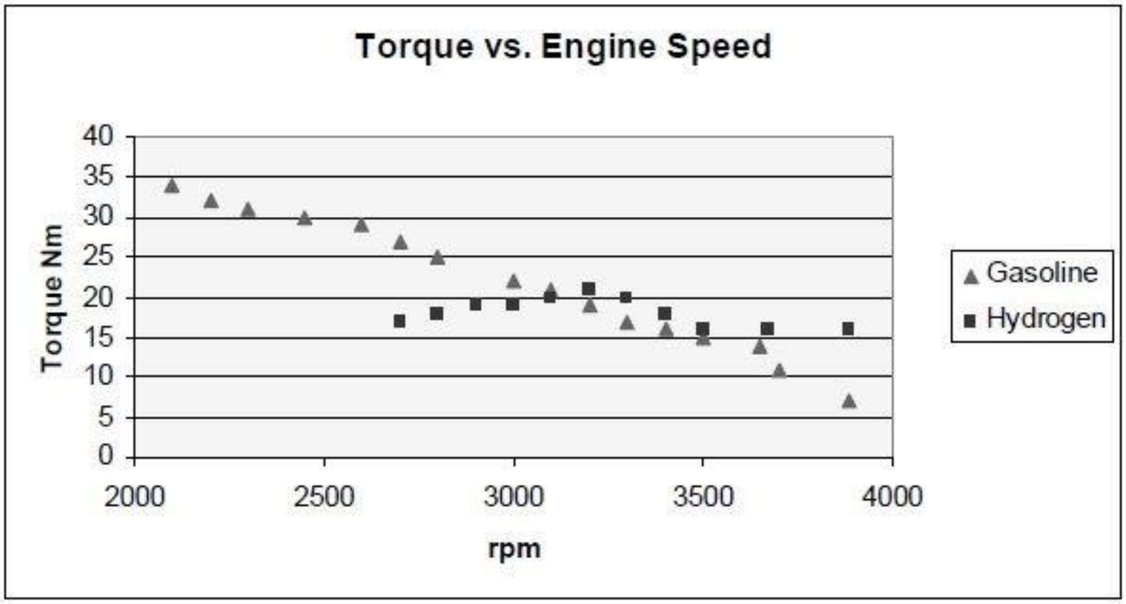
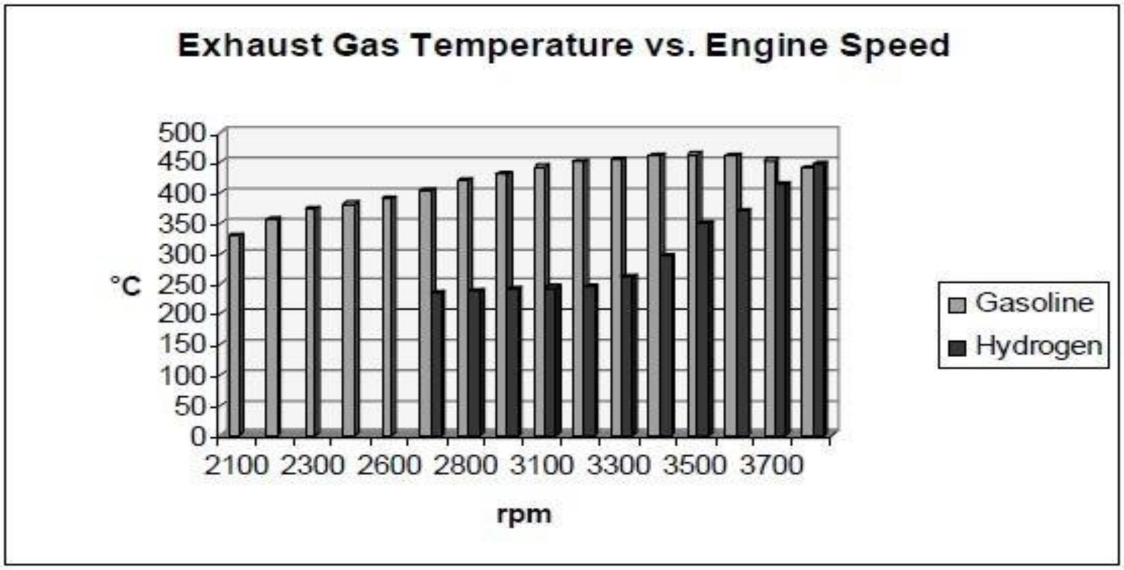
Results: Based on modified engine

Torque comparison between gasoline and hydrogen.



Results: Based on modified engine

Exhaust gas temperature of gasoline and hydrogen engine



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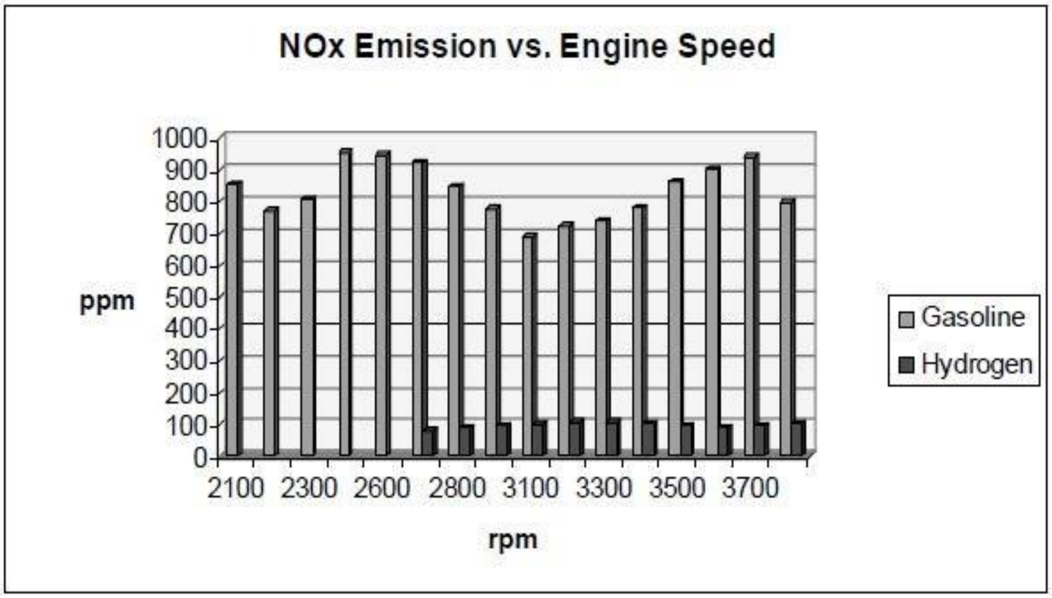
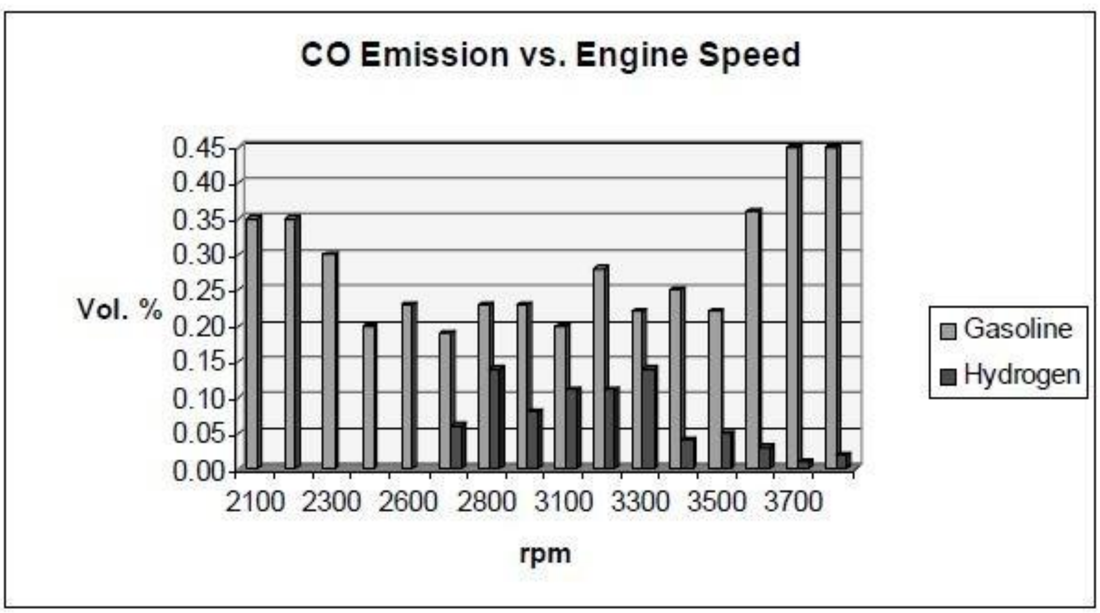


Results: Based on modified engine

Carbon monoxide emissions comparison between gasoline and hydrogen.



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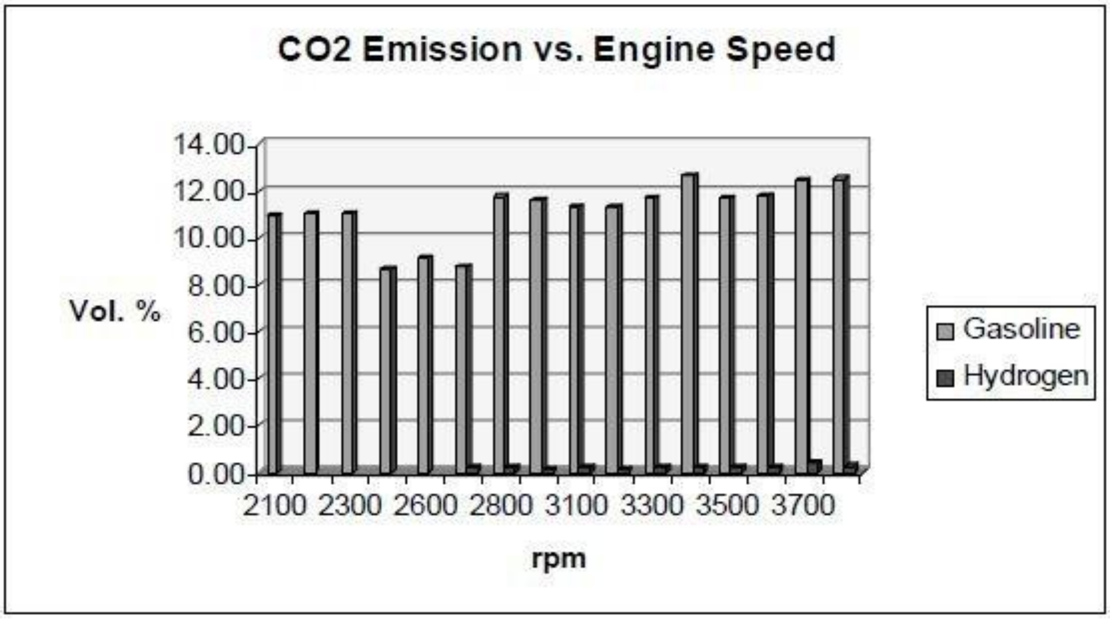
Results: Based on modified engine

Carbon dioxide emissions comparison between gasoline and hydrogen.



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