ABSTRACT

The quest for an engine which having the same or more power with higher fuel efficiency than the existing ones has started before many years. As a result of all these researches a new engine concept is formed, which is a six stroke engine. Lot of research works are conducting on this topic nowadays and already six types of six stroke engines were discovered yet. Of these the resent developed three six stroke engines, i.e., Beare head, Bruce crowers and Velozeta's are undergoing tremendous research works.

During every cycle in a typical four stroke engine, piston moves up and down twice in the chamber, resulting in four total strokes and one of which is the power stroke that provides the torque to move the vehicle. But in a six stroke engine there are six strokes and out of these there are two power strokes. The automotive industry may soon be revolutionized by a new six-stroke design which adds a second power stroke, resulting in much more efficiency with less amount of pollution.

CONTENTS

INTRODUCTION

The term **six stroke engine** describes two different approaches in the internal combustion engine, developed since the 1990s, to improve its efficiency and reduce emissions

In the first approach, the engine captures the waste heat from the four stroke Otto cycle or Diesel cycle and uses it to get an additional power and exhaust stroke of the piston in the same cylinder. Designs either use steam or air as the working fluid for the additional power stroke. As well as extracting power, the additional stroke cools the engine and removes the need for a cooling system making the engine lighter and giving 40% increased efficiency over the normal Otto or Diesel Cycle. The pistons in this six stroke engine go up and down six times for each injection of fuel. These six stroke engines have 2 power strokes: one by fuel, one by steam or air. The currently notable six stroke engine designs in this class are 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 College of Engineering, at Trivandrum in India.

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 it increases the compression ratio. The currently notable six stroke engine designs in this class include two designs developed independently: the Beare Head engine, invented by Australian farmer Malcolm Beare, and the German Charge pump, invented by Helmut Kottmann.

SYMBOLS USED

1. TFC :- Total fuel consumption in Kg/Hr
2. SFC :- Specific fuel consumption in Kg/Kwhr
3. BP :- Brake power in Kw
4. TDC :- Top dead center
5. BDC :- Bottom dead center
6. IVO :- Inlet valve opening
7. IVC :- Inlet valve closing
8. EVO :- Exhaust valve opening
9. EVC :- Exhaust valve closing
10. N :- Engine speed at final drive shaft to the wheel in rpm
11. P :- Load in Kg
12. T :- Time for 10 cc fuel consumption

HISTORY OF SIX STROKE ENGINES

As mentioned earlier there are two approaches to study about six stroke engines, i.e., first and second. There are four types of engine comes under the first category of six stroke engines and two types of engine come under the second category.

First Category:-

The engines coming under this category are

Griffin six stroke engine:-

Griffin engine was the first six stroke engine developed in the world. It is developed by the engineer Samuel Griffin in 1883. In 1886 Scottish steam locomotive makers found a future in Griffin's engine and they licensed the Griffin patents also marketed the engine under the name 'Kilmarnock'. They used this engine mainly for electric power generation. Only two known examples of a Griffin six-stroke engines survive today. One is in the **Anson engine museum**. The other was built in 1885 and for some years was in the **Birmingham Museum of Science and Technology**, but in 2007 it returned to Bath and the **Museum of Bath at Work**

Bajulaz six stroke engine:-

The Bajulaz Six Stroke Engine was invented in 1989 by the Bajulaz S A company, based in Geneva, Switzerland**.** The Bajulaz six stroke engine is similar to a regular combustion engine in design. There was 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, at the same time it burns 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.

The advantages of the engine include reduction in fuel consumption by 40%, multi-fuel usage capability, and a dramatic reduction in pollution

Crower six stroke engine:-

This engine is invented by Bruce crower of California in USA in the year 2004. Bruce Crower is actually a race car mechanic with his own workshop. In his six-stroke engine, power is obtained in the third and sixth strokes. First four strokes of this engine are similar to a normal four stroke engine and power is delivered in the third stroke. Just prior to the fifth stroke, water is injected directly into the heated **cylinder** via the converted diesel engine's fuel injector pump. The injected water absorbs the heat produced in the cylinder and converts into superheated **steam**, which causes the water to expand to 1600 times its volume and forces the piston down for an additional stroke i.e. the second power stroke. The phase change from liquid to steam removes the excess heat of the engine.

As a substantial portion of engine heat now leaves the cylinder in the form of steam, no cooling system radiator is required. Energy that is dissipated in conventional arrangements by the radiation cooling system has been converted into additional power strokes. In Crower's prototype, the water for the steam cycle is consumed at a rate approximately equal to that of the fuel, but in production models, the steam will be recaptured in a condenser for re-use.

Second category:-

The engines coming under this category are

1. **Beare Head six stroke engine:-**

Malcolm Beare 47 year old Australian wheat farmer is the inventor of this six stroke engine. Actually the name six stroke engines was introduced by Malcolm Beare. Beare created an innovative hybrid engine, combining two-strokes in the top end with a four-stroke above the middle portion. So by adding this four plus two equals six, he derived the name six 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. But the cylinder head and its poppet valves get thrown away in this design. To replace the camshaft and valves, 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. Much higher compression ratios can be obtained in this engine. Malcolm used on his first six-stroke, based on a Honda XL125 farm bike. Malcolm Beare claims his engine is 35% more economical at low revs/throttle openings than an equivalent conventional engine and 13% less thirsty at high rpm/full throttle.

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. 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. 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. Good for hybrid technology and stationary engines. The engine is claimed to be suited to alternative fuels since there is no corrosion or deposits left on valves. The six strokes are: aspiration, pre-compression, gas transfer, compression, ignition and ejection.

VELOZETA’S SIX STROKE ENGINE

Mechanical Engineering students of the college of Engineering in Trivandrum, in the year 2006 made this six stroke engine as a part of their B.Tech project. After the completion of the course they formed the company Velozeta with the help of state and central government. They have got the patent of this engine also.

In Velozeta's six stroke engine, a four-stroke Honda engine was experimentally altered to build the six stroke engine.The first four strokes of this engine are just like a conventional four stroke engine. The additional two strokes are for better scavenging and cooling of the engine which is provided by a secondary air induction system.

Theory:-

There is only a slight difference between Crower's six stroke engine and Velozeta's six stroke engine. In the Crower's six stroke engine and this engine, the first four stokes are the same as a conventional four stroke engine. In Crowers engine during the fifth stroke water is injected into the cylinder and converted to steam which is used for expansion and the sixth stroke eliminates the expanded vapors through the exhaust manifold. But here the difference is that in the fifth stroke, instead of water, air from an air filter is sucked into the cylinder through a secondary air line provided at the exhaust manifold. In the sixth stroke, a mixture of this air and unburned gases are pushed out through the exhaust valve.

Engine parts modified:-

1) Camshaft / Crankshaft Sprockets

In the six stroke engine the crankshaft has 1080 degrees of rotation for 360 degree rotation of the camshaft per cycle. Hence their corresponding sprockets are having teeth in the ratio 3:1.In the original four stroke engine the teeth of the sprockets of the crankshaft and the camshaft were in 2:1 ratio. The 34 teeth sprocket of the four stroke engine camshaft was replaced by a 42 teeth sprocket in the six stroke engine. The camshaft sprockets were also replaced from 17 teeth to 14 teeth to convert the four stroke engine into six stroke engine.

2) Cam lobes

In the six stroke engine the 360 degrees of the cam has been divided into 60 degrees among the six strokes. The valve provided at the exhaust has to be kept open during the fourth, fifth and the sixth stroke. The cam has been made double lobed in order to avoid the hitting of the exhaust valve with the piston head. The profiles of the exhaust and the inlet cams have been shown in the figure 1.

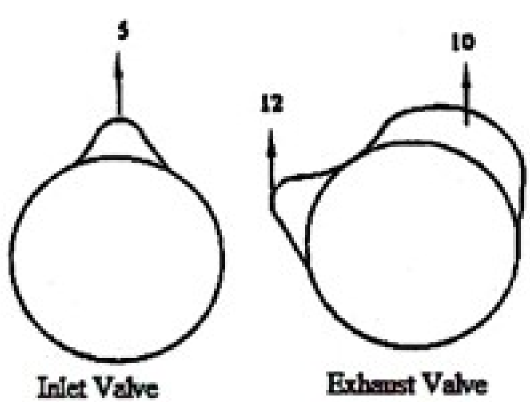


Figure 1: cam lobes

3) Valve Timing

The valve timing of the four stroke Honda engine has been changed. The inlet valve opening (IVO) is 0° at TDC, same as that of the four stroke Honda activa engine. Inlet valve Closes (IVC) at 25° after BDC, same as that of the four stroke engine. Exhaust valve opens (EVO) 0° at BDC, which in the original engine was 25° before BDC. Velozeta reduced this 25° advanced opening of exhaust valve to extract maximum work per cycle. Exhaust valve closes 10 degree before TDC in order to prevent the loss of air fuel mixture through the exhaust valve. Two reed valves have been provided for the proper working of the engine.

4) Secondary Air Induction System

The secondary air induction system, supplies the air which is used during the fifth and sixth stroke. During the fifth stroke air from the air filter (fig24) is sucked into the cylinder through the secondary air induction line. The reed valve (fig22) opens to permit the air flow. During the sixth stroke, the air is removed through the exhaust manifold (fig 13). The reed valve (fig 23) opens and the reed valve (fig 22) closes during this stroke. The inlet valve remains closed during these strokes.

Working of velozeta six stroke engine:-

The detailed working of the six stroke engine has been explained by using figures 2-7, which give explanations regarding the each stroke. A detailed label of the engine parts has been given in page (4). The working of the engine is as follows. Also the detailed label of engine parts in the figures is given allow.

Detailed Label of Engine Parts:-

1. Rings
2. Inlet Manifold
3. Cylinder Head
4. Cam shaft
5. Cam Lob No.1
6. Inlet valve
7. Sprocket 42T
8. Rocker Arm
    8.1. Inlet Rocker arm
    8.2. Exhaust Rocker arm
9. Head Cover
10. Cam Lob no.3
11. Exhaust valve
12. Cam Lob No.2
13. Exhaust Manifold
14. Spark plug
15. Cylinder
16. Piston
17. Connecting rod
18. Timing Chain
19. Sprocket 14T
20. Crank
21. Secondary air induction unit
22. Reed valve (One way valve)
23. Reed valve (One way valve in Exhaust manifold)
24. Air filter
25. 42T sprocket holder
26. Bearing

First stroke (Figure 2):-

During the first stroke the inlet valve (6) opens and air-fuel mixture from carburetor is sucked into the cylinder through the inlet manifold (2).

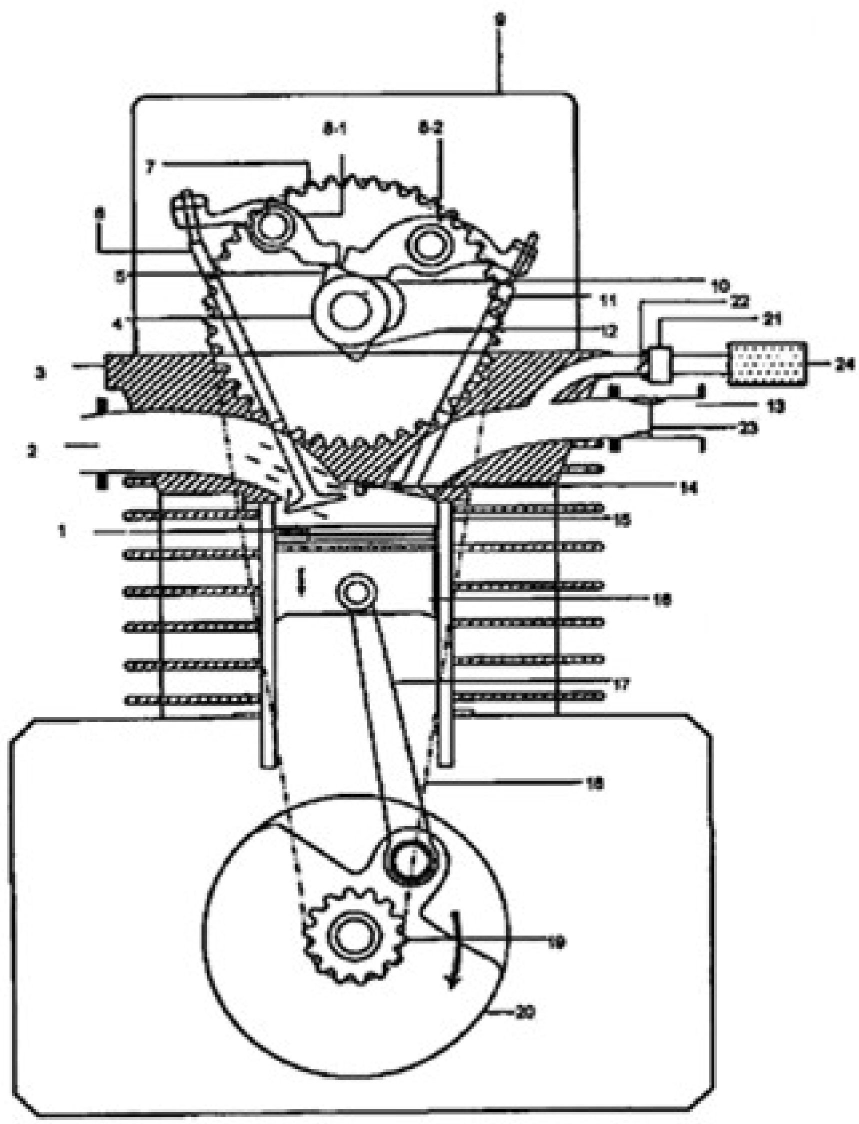


Figure 2: First Stroke

Second stroke (Figure 3):-

During the second stroke, piston moves from BDC to TDC, both the inlet valve (6) and exhaust valve (11) are closed and the air-fuel mixture is compressed. The compression ratio of the modified engine is same as that of the original four stroke Honda engine 9:1.

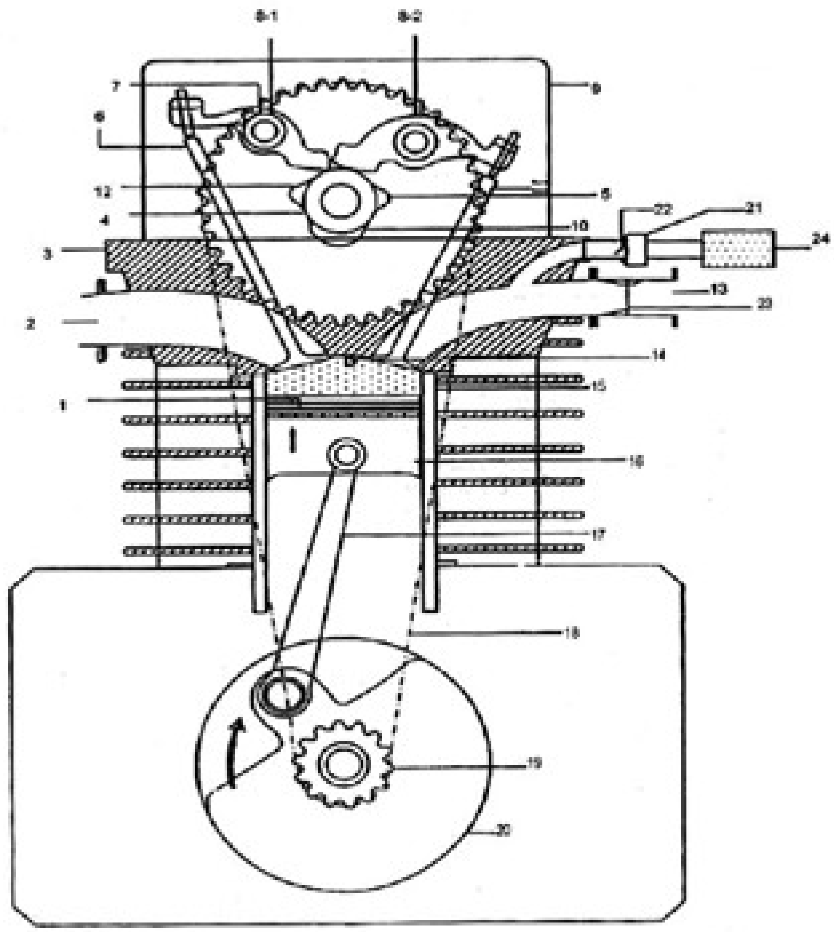


Figure 3: Second Stroke

Third stroke (Figure 4):-

During the third stroke, power is obtained from the engine by igniting the compressed air- fuel mixture using a spark plug (14). Both valves remain closed. Piston moves from TDC to BDC.

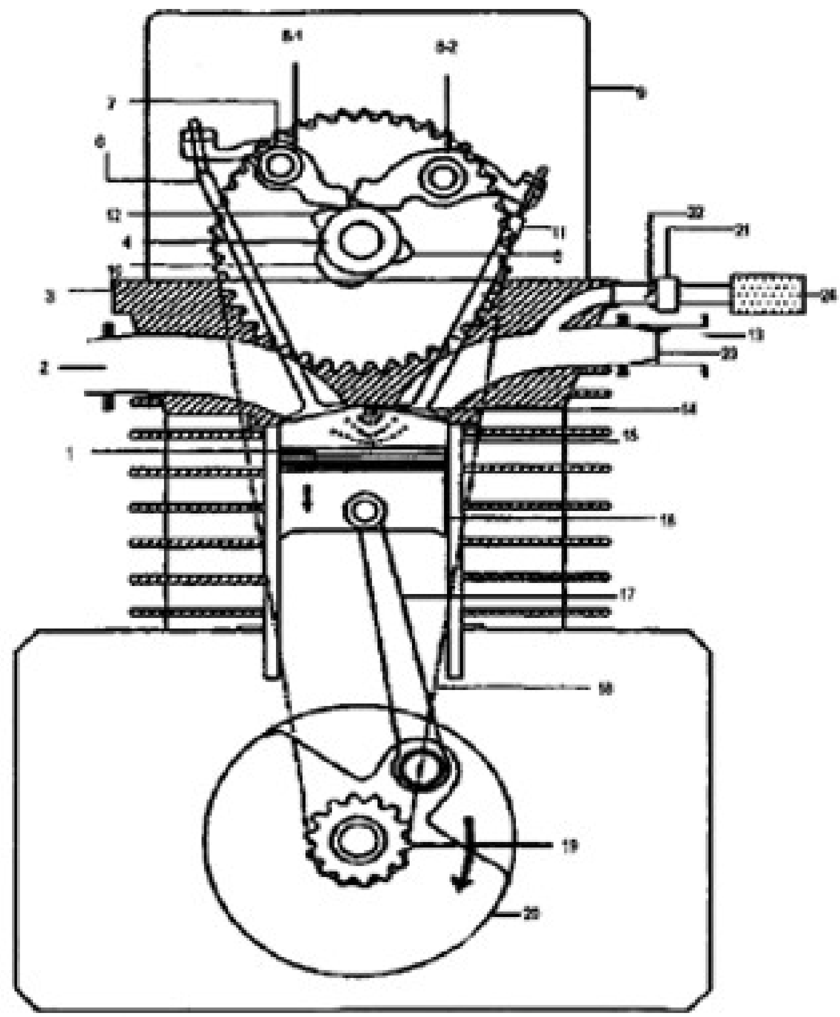


Figure4: Third Stroke

Fourth stroke (Figure 5):-

During the fourth stroke, the exhaust valve (11) and the reed valve (23) opens to remove the burned gases from the engine cylinder. Piston moves from BDC to TDC.

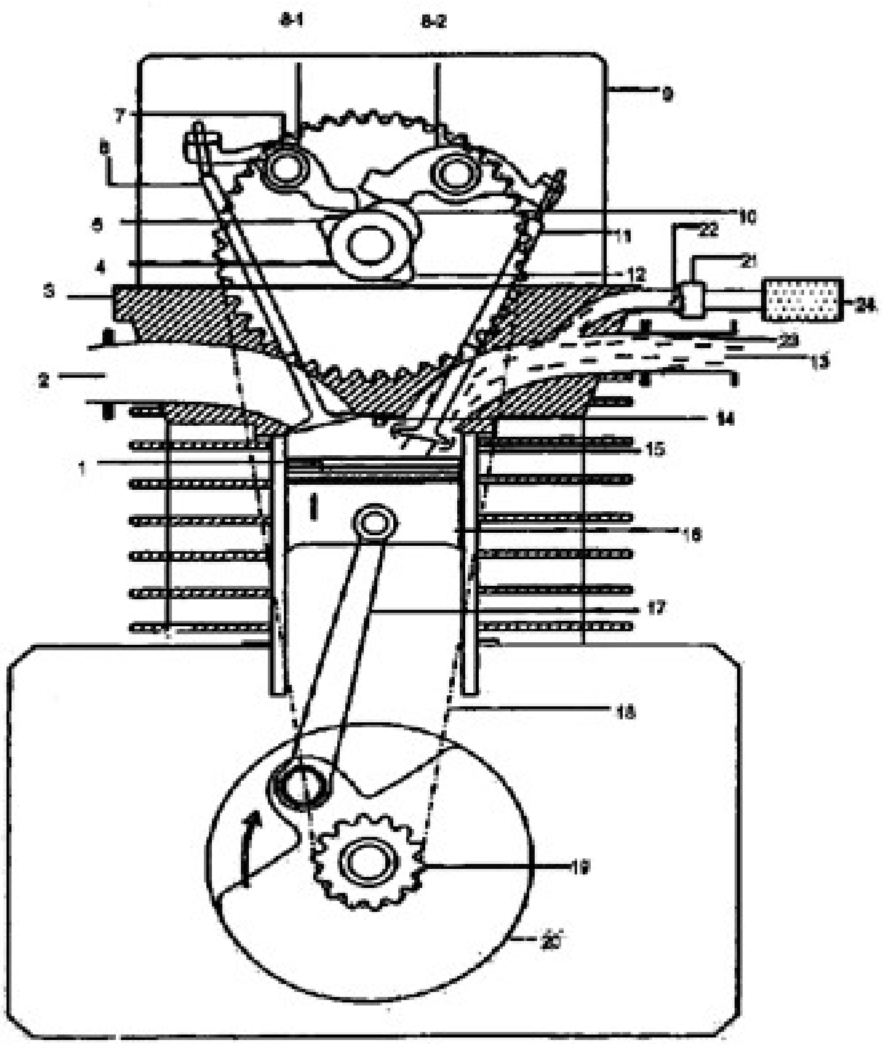


Figure 5: Fourth Stroke

Fifth stroke (Figure 6):-

During the fifth stroke, the exhaust valve (11) remains open and the reed valve (23) closes. Fresh air from the air filter (24) enters the cylinder through the secondary air induction line (21) provided at the exhaust manifold (13). The reed valve (22) opens.

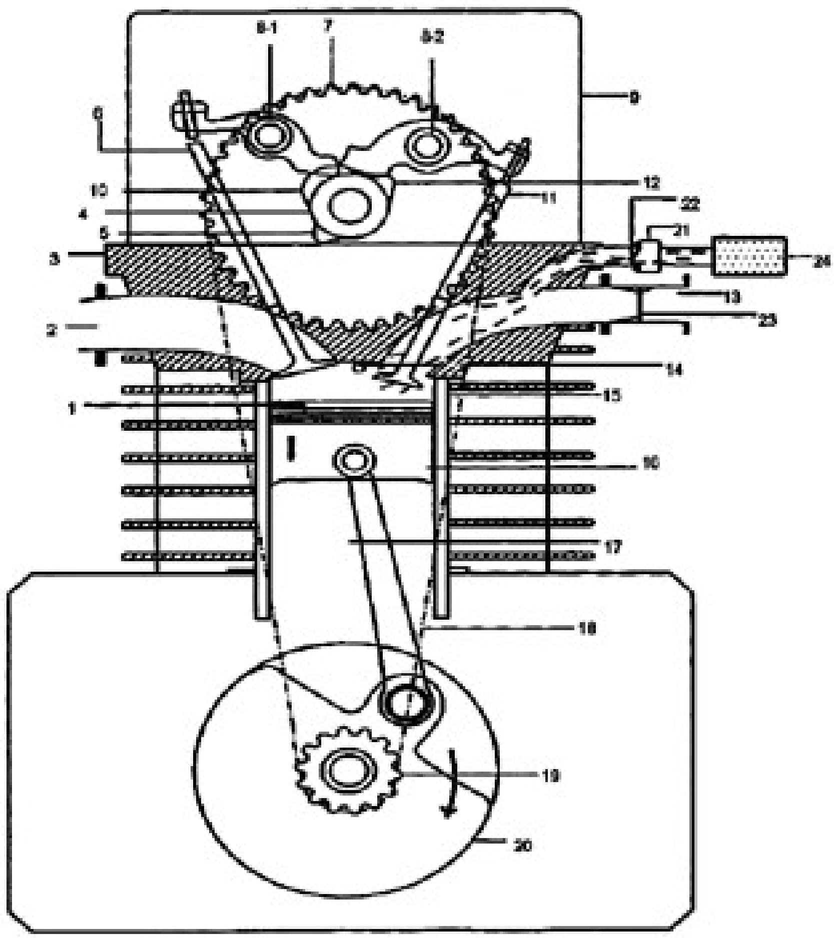


Figure 6: Fifth Stroke

Sixth stroke (Figure 7):-

During the sixth stroke, the exhaust valve (11) remains open. The air sucked into the cylinder during the fifth stroke is removed to the atmosphere through the exhaust manifold (13). The reed valve (23) opens and the reed valve (22) closes.

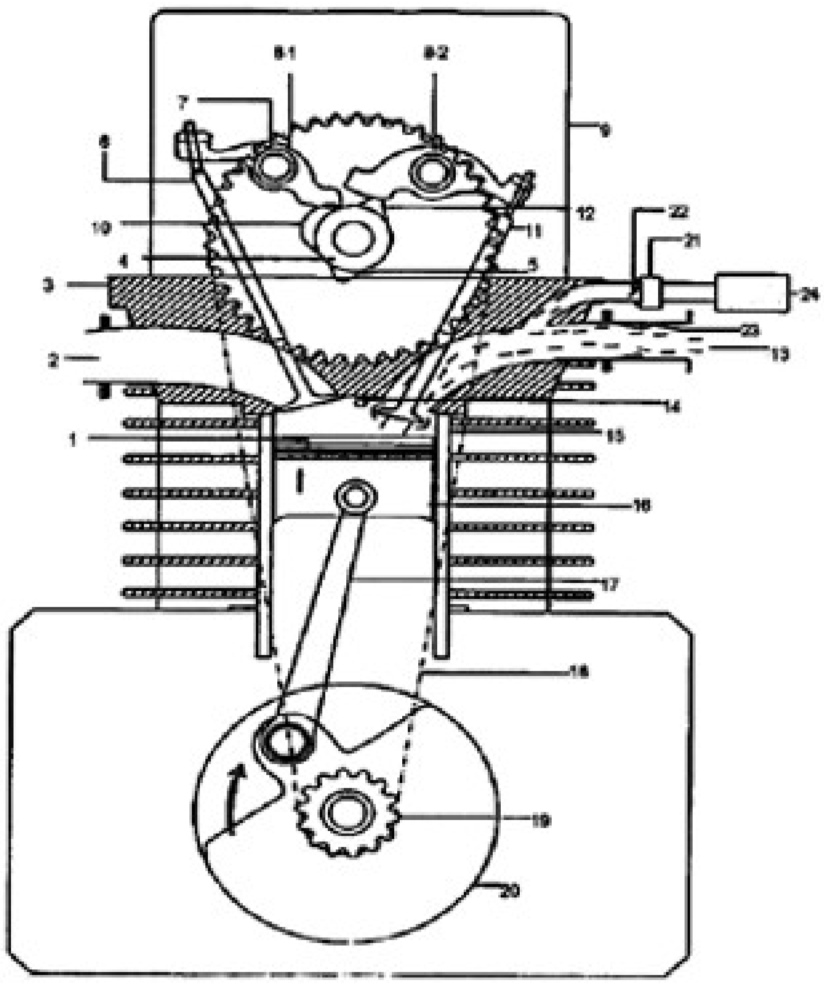


Figure 7: Sixth Stroke

Performance test results:-

Two tests i.e., Engine load test and Pollution, test was conducted on the six stroke engine and on the same four stroke engine from which the six stroke was developed.

Experimental Procedure:-

The same engine was altered as four stroke and six stroke to perform the experiments. Load test and pollution test were conducted. The load test was conducted using brake drum dynamometer. The final drive shaft from the engine to the wheel was used for loading during the experiment. The engines were tested for 320rpm and640rpm under the same loading conditions. The time for consumption of 10cc of the fuel was noted during the experiment. The % vol. of CO in exhaust gas during idling was tested to check the pollution level of the engines. The results of load test and pollution test have been tabulated in table (1) and table (2) respectively.

Load test results:-

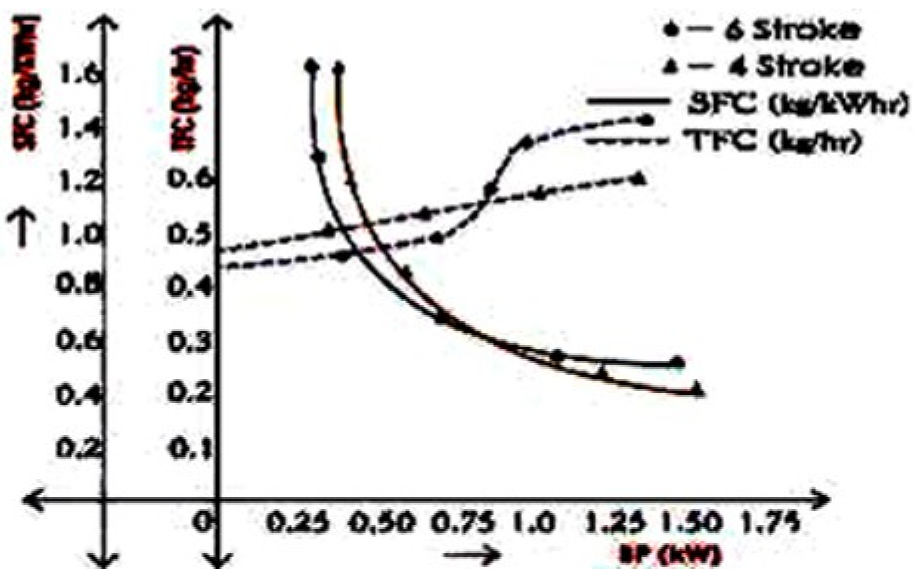
N (rpm)	P (kg)	t_4 (s)	t_6 (s)	TFC_4 (kg/hr)	TFC_6 (kg/hr)	TFC Redn. %
320	0	88	95	0.302	0.280	7.36
	4	83	92	0.321	0.289	9.81
	8	78	90	0.341	0.296	13.32
	10.5	75	84	0.355	0.317	10.72
	13.5	71	78	0.375	0.341	8.98
640	0	58	62	0.459	0.429	6.46
	4	52	54	0.512	0.493	3.70
	8	47	49	0.566	0.543	4.09
	10.5	44	39	0.605	0.683	-12.81
	13.5	42	35.5	0.634	0.750	-18.32

Table 1: Load Test

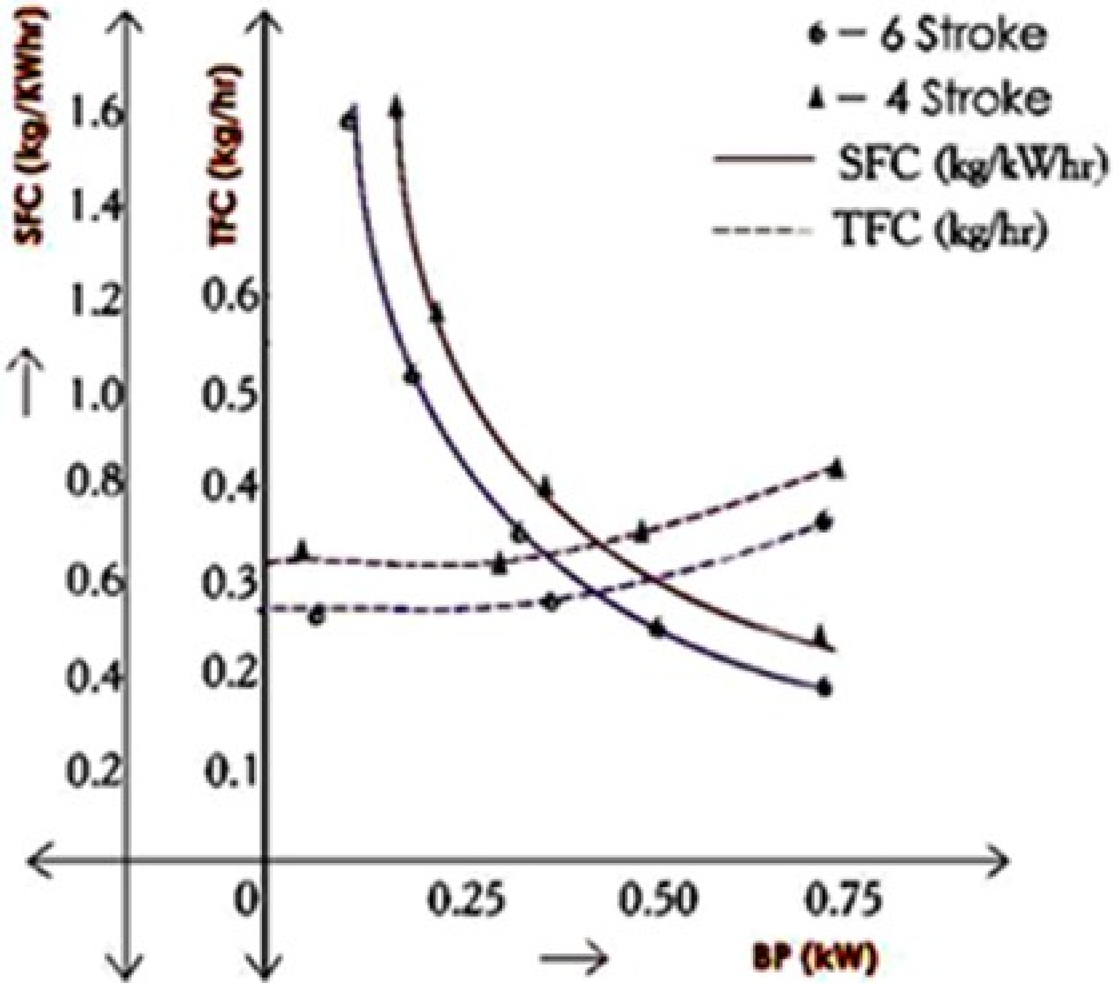
Pollution Test Results:-

4 stroke engine	6 stroke engine	% Pollution Redn.
0.92	**0.32**	**65.2**

Graphs:-



Graph-1: Bp Vs TFC & SFC at 320rpm



Graph-2: Bp Vs TFC & SFC at 640 rpm

Advantages of the Engine

- Reduction in fuel consumption
- Dramatic reduction in pollution normally up to 65%
- Better scavenging and more extraction of work per cycle
- Lower engine temperature - so , easy to maintain the optimum engine temperature level for better performance
- Less friction – so , less wear and tear
- The six-stroke engine does not require any basic modification to the existing engines. All technological experience and production methods remain unaltered
- Higher overall efficiency

CONCLUSION

The six stroke engine modification promises dramatic reduction of pollution and fuel consumption of an internal combustion engine. The fuel efficiency of the engine can be increased and also the valve timing can be effectively arranged to extract more work per cycle. Better scavenging is possible as air intake occurs during the fifth stroke and the exhaust during the sixth stroke. Due to more air intake, the cooling system is improved. It enables lower engine temperature and therefore increases in the overall efficiency.

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