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Design and Analysis of Cylinder and Cylinder Head of 6-Stroke Si Engine for Weight Reduction

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Abstract: **The present paper deals with design of cylinder & cylinder head with air cooling system for 6 strokes 6 cylinder SI engine. The main objective of design is to reduce weight to power ratio & will result in producing high specific power. The authors have proposed preliminary design cylinder & cylinder head of a horizontally opposed SI engine, which develops 120 BHP and possess the maximum rotational speed of 6000rpm. Four stroke opposed engine is inherently well balanced due to opposite location of moving masses and also it provides efficient air cooling. For the requirement of weight reduction the material selected for design of cylinder and cylinder head is Aluminum alloy that is LM-13. The cylinder bore coating using NIKASIL coating was done to improve strength of cylinder with minimum weight.**

I. INTRODUCTION

The six-stroke engine is a type of internal combustion engine with an advance feature of more power generation some complexity intended to make it more efficient and utilize the fuel. Two more additional strokes are the fifth stroke, which called water injection stroke while the last stroke is called exhaust stroke. Besides, the stroke engine also known as engine two-stroke, four-stroke and also six-stroke which are new things for us. The specific power of the six-stroke engine will not be less than that of a four-stroke petrol engine, the increase in thermal efficiency compensating for the issue due to the two additional strokes. Chemical, noise and thermal pollution are reduced.

These engines almost consist of similar components as that of the four stroke engine with addition of two more valves. The six-stroke engine is a radical hybridization of two and four stroke engine that the top portion of two stroke engines and the bottom rather the middle section of a four stroke engine. In six-stroke cycle, two parallel functions occur in two chambers which result in eight event cycle: four events internal combustion cycle and four event external Combustion cycles. 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.

Fig.1 Prototype of six stroke engine

i. Need to Develop Six Stroke Engine

The necessity to developed six stroke engine is to increase the efficiency of the internal combustion engine. The disadvantage of the four-stroke cycle is that only half as many power strokes are 2 completed per revolution of the crankshaft as in the two-stroke cycle and only half as much power would be expected from an engine of given size at a given operating speed. The four-stroke cycle, however, provides more positive scavenging and charging of the cylinders with less loss of fresh charge to the exhaust than the two-stroke cycle. However we want to developed the six stoke engine that can be free us from the entire problem of two stroke & four stroke engine.

ii. Principle of Six Stroke Engine

A six stroke engine describes a number of different approaches in the internal combustion engine to capture the waste heat from the four stroke Otto cycle and use it toPower an additional power and exhaust stroke of the piston. The six stroke engine has 2 power strokes, one fuel, one steam or air. The rapid vaporization of the water during the fifth stroke is similar to the combustion of the gasoline. The combustion converts chemical energy into usable power, and likewise, the vaporization of water converts waste heat energy into usable power. By harnessing waste heat, the added strokes effectively reduce fuel consumption, and therefore emissions, without significantly compromising on power.

iii. About the Six Stroke Engine

Internal combustion engine has been modified with the goal of higher efficiency. It is increases the efficiency through the extra power stroke or fifth stroke. The big advantages is that, we have got in six stroke engine, the waste of heat created the power in fifth stroke, and power has to be generated in the fifth stroke Due to the waste of heat.

The heat is used to generate the steam from the water which is further used as a 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.

`The six stroke engine has consist of the six processes in a complete cycle such as four stroke engines consist only four process in a complete cycle. These four processes are as

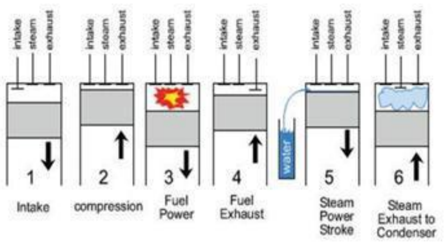

Fig.2 Schematic diagram of the six stroke engine

A. First Stroke (Suction Stroke)

During the first stroke the Inlet valves opens and air- fuel mixture from carburetor is sucked into the cylinder through the inlet valve and piston moves from TDC to BDC which results in the formation of a pressure difference due to which pure air enters the cylinder.

B. Second Stroke (Compression Stroke)

During the second stroke, the inlet valve closes and the heating chamber valve Opens and piston moves upward due to cranking forcing air into heating chamber. The air at this stage is converted to high pressure.

C. Third stroke (first power stroke)

During the third stroke, power is obtained from the engine by igniting the compressed air- fuel mixture using a spark plug. Both valves remain closed. Piston moves from TDC to BDC. Now we can simply says the combustion chamber valve opens and gases of combustion enter the cylinder.

D. Fourth Stroke (Exhaust Stroke)

During the fourth stroke, the exhaust valve opens to remove the burned gases and the exhaust gases are removed via this valve. From the engine cylinder Piston moves from BDC to TDC.

E. Fifth Stroke (Second Power Stroke)

During the fifth stroke, the exhaust valves remains close and the water Inlet valves open. Fresh water from the water Inlet valves enters the cylinders through the secondary water Induction system. Piston moves from TDC to BDC.

F. Sixth Stroke (Second Exhaust Stroke)

During the sixth stroke, the water exhaust valves remain open. The water sucked into the cylinder during the fifth stroke is removed to the atmosphere through the water exhaust valve. Piston moves from BDC to TDC and six strokes are completed.

II. MATERIAL SELECTION

As means for reducing weight, there are several methods available substituting lightweight materials for conventional materials, that is to decrease specific gravities, rationalization of structure (decrease the number of parts through integration), & downsizing (decrease the volume of each part).In the past, the engine performance has been compromised in order to improve emission. The methods presented here, however are fundamentally different from the past one.

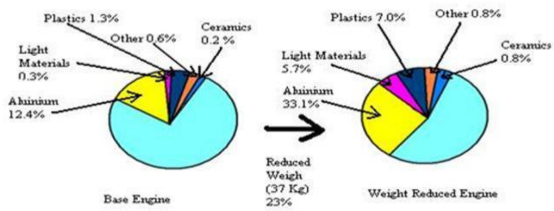

Fig 3. Material Composition of Weight-Reduced Engine & Base Engine

The engine weight has reduced by 37 Kg from a base one of 162 Kg (excluding engine oil) .This corresponds to 23% weight reduction. As shown in fig.3 the component weight ratio of the materials are 53% steel for the weight-reduced engine (86% in the base engine), 33% (13%) Aluminum alloys, 7% (1%) plastics & elastomers, 6% (0%) other light weight materials such as titanium alloys & magnesium alloy, & 1% (0%) ceramics. The materials substitutions applied for the engine structure component represented by a cylinder is no more than simple weight reduction. But, when applied this to several moving & functional components, it not only weight reduction method but also contributes to improve engines & emission performance.

i. Material Comparison

PARAMETER	LM12	LM13	LM14
Chemical composition (%)			
Si	2	0.85	0.6
Fe	0.5/1.5	0.8	0.6
Cu	9/10.5	0.5/1.3	3.5/4.5
Mg	0.15/0.35	0.8/1.5	1.2/1.7
Ni	0.5	0.7/2.5	1.8/2.3
Mn	0.6	0.5	0.6
Pb	0.1	0.1	0.05
Mechanical properties			
σ u (N/mm^2)	220 to 268	173 to 252	220 to 283
Brinell Hardness Number (BHN)	100	100	100
Characteristics	1) Good hardness at elevated temperature	1) Good fluidity	1) Excellent strength
	2) Good strength	2) High temperature strength	2) Excellent hardness at elevated temperature
	3) Good resistance to Wear	3) Low coefficient of thermal expansion	
		4) Good resistant to wear& low weight.	

Table.1: Material Comparison

From above it is clear that, the material suitable for given application is LM-13. Because it has a low thermal coefficient also for further processing of coating on cylinder bore of this material is well suited.

Material	Sfc (gm/kw-	Thermal conductivity	Weight
Cast iron	490	54	2.18
Aluminum barrel With cast iron	380	54-109	1.12
Aluminum barrel with NIKASIL	310	109	0.78

Table.2: Improvement of engine performance by cylinder block material

III. BASIC ENGINE DESIGN

i. Design of Cylinder:

Design parameters	Calculated value
D	78mm
L	78mm
Bmep	11.76 bar
Imep	13.85 bar
Pmax	138.5 bar
Volume	1500cc
Indicatedpower	141.176 HP
Friction Power	21.176 HP
Mechanical Efficiency(assumed)	85%
Break power	120 HP

Table.3: Cylinder Dimensions

ii. Cylinder Thickness Design:

Thickness of Cylinder is 5 mm.

iii. Cylinder Head Design:

Deign Parameter	Calculated values
Cylinder wall thickness t	5 mm
Cylinder head thickness t'	9 mm

Table 4.0 Cylinder Head Dimensions.

iv. Valve Spacing On Cylinder Head

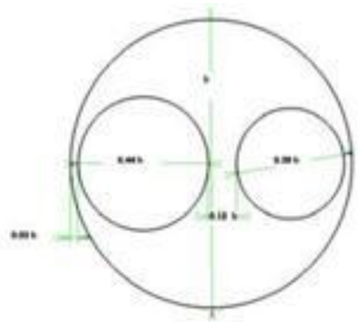

Fig.4: Valve spacing diagram

Figure shows the empirical relation for inlet & exhaust valve spacing. Clearance between valve & bore = 2.3 mm

Space between valves (inlet & exhaust) = 9.36 mm

v. Inlet and Exhaust Manifold Design:-

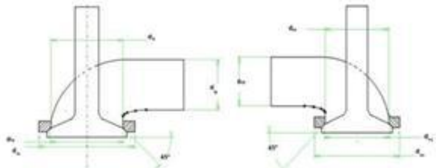

Fig. 5. Inlet Manifold. Fig.6. Exhaust Manifold.

vi. Valve Seat:

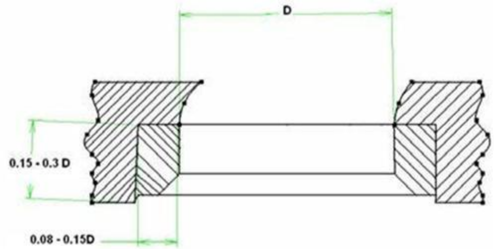

Fig 7: Valve Seat design

From figure we get the relation for valve seat outside diameter & height.

A. Inlet Valve Seat Design:-

Thickness of valve seat (t)i = 3.517 mm Height of valve seat (h)i 9.0558 mm

B. Exhaust Valve Seat Design:-

Diameter of valve seat (De):- 24.57 mm

Thickness of valve seat (t)e = 3.003 mm

Height of valve seat (h)e = 7.37 mm

PARAMETER (mm)	INLET VALVE SEAT	EXHAUST VALVE SEAT
D	30.186	24.57
t	3.517	3.003
h	9.0558	7.37

Table.5: Dimensions of valve seats

vii. Design of Cooling Fins

Material: - Aluminum alloy (Thermal conductivity =109 web/mK)

Required parameter	Calculated value
Root thickness of the fin,	3 mm
Space between two fins	3.96 mm
Number Of fins	24
length of fin	25 mm

Table.6: Dimensions of cooling fins

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IV. SOLID MODELING OF CYLINDER

Fig . 8. Model of cylinder

Fig. 9. Model of cylinder head

V. FEA ANALYSIS OF CYLINDER AND CYLINDER HEAD

PARAMETER	VALUE
Maximum pressure	1.38e+007 N/m2
Maximum temperatur	1032 K
Young's modulus	7e+010 N/m2
Poisons ratio	0.34
Density	2700 Kg/m3
Thermal expansion	2.968 e-004 (1/K)
Yield strength	346e+008 N/m2

Table.7: Input parameters for analysis

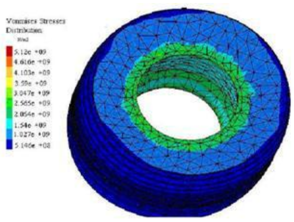

Fig. 10 Analysis of cylinder

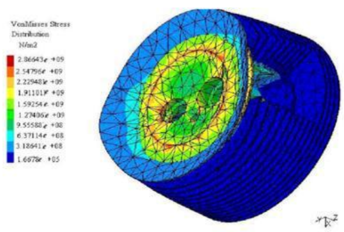

Fig. 11 Analysis of cylinder head

VI. CONCLUSION

From the analytical solution & the analysis result we get the values of stresses produced in cylinder and cylinder head due to application of temperature and pressure are within permissible limit. Hence we concluded that the basic design of cylinder and cylinder head is safe with reference of pressure and temperature basis. Due to use of light weight material i.e. LM-13 with NIKASIL cylinder bore coating, we can effectively reduce the weight of cylinder and cylinder head with improved strength. Also due to the use of air cooling system an efficient and faster cooling of engine achieved.

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