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STATIC AND THERMAL ANALYSIS OF STRAIGHT AND V-SHAPED FINS CYLINDER HEAD USING FEM METHOD

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Abstract - A cylinder head is multi-dimensional container having considerable depth to house ports of air and gas passages, it shelters the inlet and exhaust poppet-valves, houses the spark-plug or injector location holes, forms the upper face of the combustion chamber, and takes the combustion-pressure reaction. It is bolted to the top of the cylinder block, in which the piston reciprocates inside the cylinder. The aim of the project is to design 2-cylinder heads (straight fins and V-shape fins) and analysis is done by using different materials. Cylinder heads are modelled by using SOLID-WORKS software. SOLID-WORKS is a 3d modelling software widely used in the design process. SOLID-WORKS is used by the automotive and aerospace industries for automobile and aircraft product and tooling design. Analysis is done on the models by using different materials. Comparison between materials is done by observing the results of displacement and stress with respect to tables and graphs. Thermal analysis is also done. Analysis is done by using software ANSYS. Here existing material is steel and new materials are (al-6061, cast iron, and monel-400) by comparing all static thermal results we conclude which material is more optimum in both static and thermal loading conditions.

Key Words: Cylinder head, Straight fins, V-shape fins, 3d Modelling, ANSYS, al-6061, cast, iron, monel-400.

1. INTRODUCTION

In IC engines, combustion of air and fuel takes place inside of the engine cylinder and hot gases are produced. The temperature of gases will be around 2290-2520°C. This is a massive temperature and may result into burning of oil film between the moving parts. So, this temperature has to be decreased to about 145-205°C at which the engine will work most efficiently. Too much cooling is also not suggested because it reduces the thermal efficacy. So, that object of cooling system has to be maintain the engine performance at its most effective operating temperature. It was noted that the engine is quite unproductive when it is cold and so the cooling system is designed in such manner that it avoids cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. Heat engines generate mechanical power by observing energy from heat flows, water wheel abstracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is surplus heat which must be removed. Internal combustion engines remove unused heat through cool intake air, hot exhaust gases, and explicit engine cooling.

1.1 A typical distribution for the fuel energy

- Useful work at the crank shaft = 25 per cent
- Loss to the cylinder's walls = 30 per cent
- Loss in exhaust gases = 35 per cent
- Loss in friction = 10 per cent

1.2 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 Attocycle and use it to Power 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.

Internal combustion engine has been modified with the goal of higher efficiency. It is increasing the efficiency through the extra power stroke or fifth stroke. The big advantages are that we have got in six stroke engines, the waste of heat created the power in fifth stroke, and power has to be generated in the fifth stroke Due to the waste foretaste 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 consisted 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 above (Figure 1)

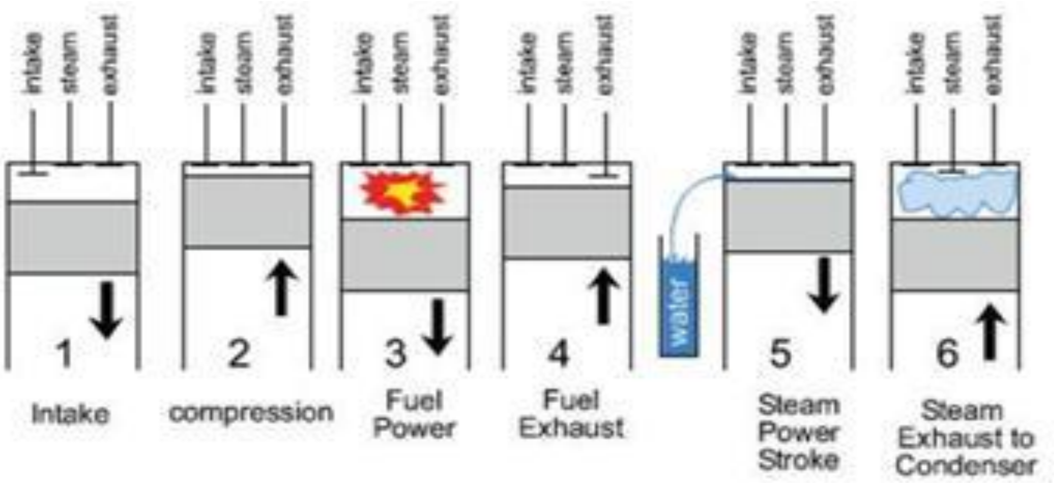


Figure1

1.3 Basic Engine Design Metrics

Design Parameters	Calculated Value
D	78mm
L	78mm
Bmep	11.76 bar
Imep	13.85 bar
Pmax	13.85 bar
Volume	1500cc
Indicated Power	141.176 HP
Friction Power	21.176 HP
Mechanical Efficiency (assumed)	85%
Break Power	120 HP

Thickness of Cylinder is 5 mm.

Cylinder Head Design = 9mm

Design Parameters	Calculated Value
Cylinder wall thickness	5 mm
Cylinder head thickness	9 mm

Root thickness of the fin = 3mm

Space between two fins = 6.8mm

No of fins 11

2. LITERATURE OVERVIEW

Arnold E. Biermann and Benjamin Pinkel - Obtained heat transfer coefficient over a range of air speeds from 30 to 150 miles per hour from tests in a wind tunnel of a series of electrically heated finned steel cylinder, which covered a range of fin pitches from 0.10 to 0.60-inch, average fin thickness from 0.04 to 0.27 inch, and fin width from 0.37 to 1.47 inch. They concluded that the value of surface heat transfer coefficient varies mainly with air velocity and the space between fins. The effect of the other fin dimensions is small.

J.C. Sanders - To carried out the cooling tests on two cylinders, one with original steel fins and one with 1-inch spiral copper fins brazed on the barrel. The copper fins improved the overall heat transfer coefficient from the barrel to the air 115 percent. They also concluded that in the range of practical fins dimensions, copper fins having the same weight as the original steel fins will give at least 1.8 times the overall heat transfer of the original steel fins.

Denpong Soodphakdee - To compared the heat transfer performance of various fin geometries. These consist of plate fins or pin fins, which can be round, elliptical, or square. The plate fins can be continuous (parallel plates) or staggered. The basis of comparison was chosen to be a circular array of 1mm diameter pin fins with a 2mm pitch. The ratio of solid to fluid thermal conductivity for aluminum and air is quite high, around 7000, permitting the fins to be modelled as isothermal surfaces rather than conjugate solids. The CFD simulations were carried out on a two-dimensional computational domain bounded by planes of symmetry parallel to the flow. The air approach velocity was in the range of 0.5 to 5m/s. the staggered plate fin geometry showed the highest heat transfer for a given combination of pressure gradient and flow rate.

Fernando Illan - To simulated the heat transfer from cylinder to air of a two-stroke internal combustion finned engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analyzed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition.

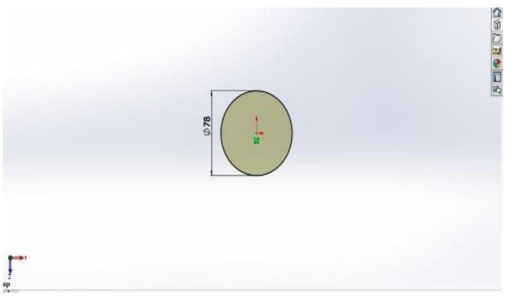
3. SOLIDWORKS

Solid Works is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systems. According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also, according to the company, fiscal year 2011–12 revenue for SolidWorks totaled $483 million

3.1 Developing models by using solid works

Select solid works -> open

New -> enter name -> ok



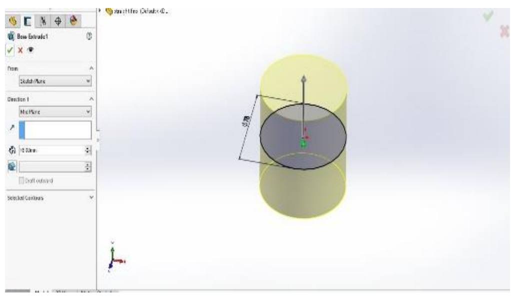
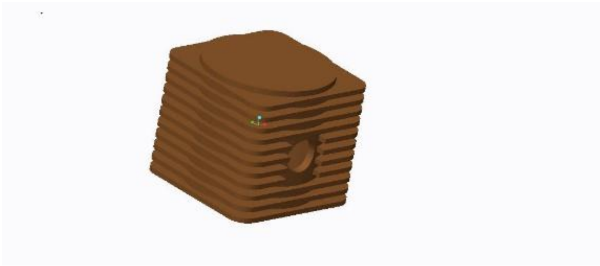


Figure 2 **Figure 3**

After completion of that just click on ok then we will get below model. To create holes here we using extrude cut option and the sketch dimensions Is shown in below

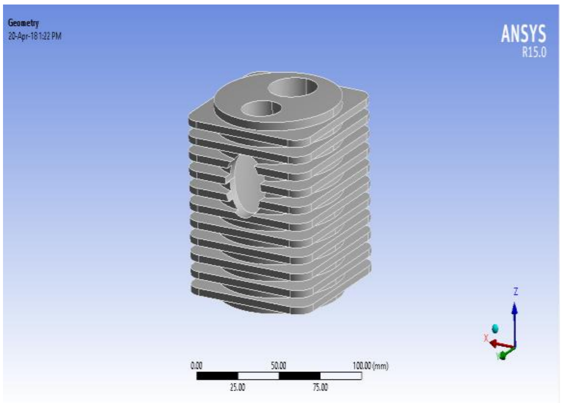


Final model straight fins cylinder
Figure 4

V-shape cylinder final model
Figure 5

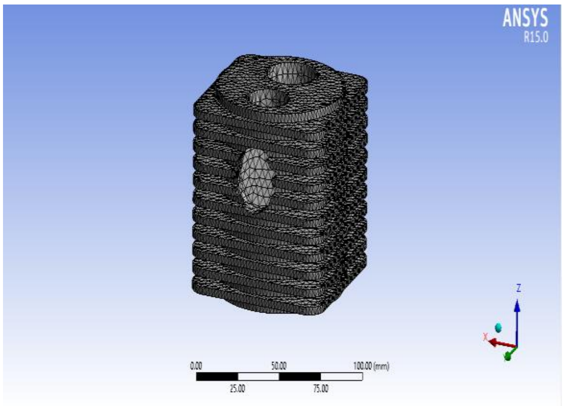
4. ANSYS PROCESS

4.1 STRUCTURAL ANALYSIS



Imported Model

Figure 6



Meshing

Figure 7

Boundary conditions – Straight Fins

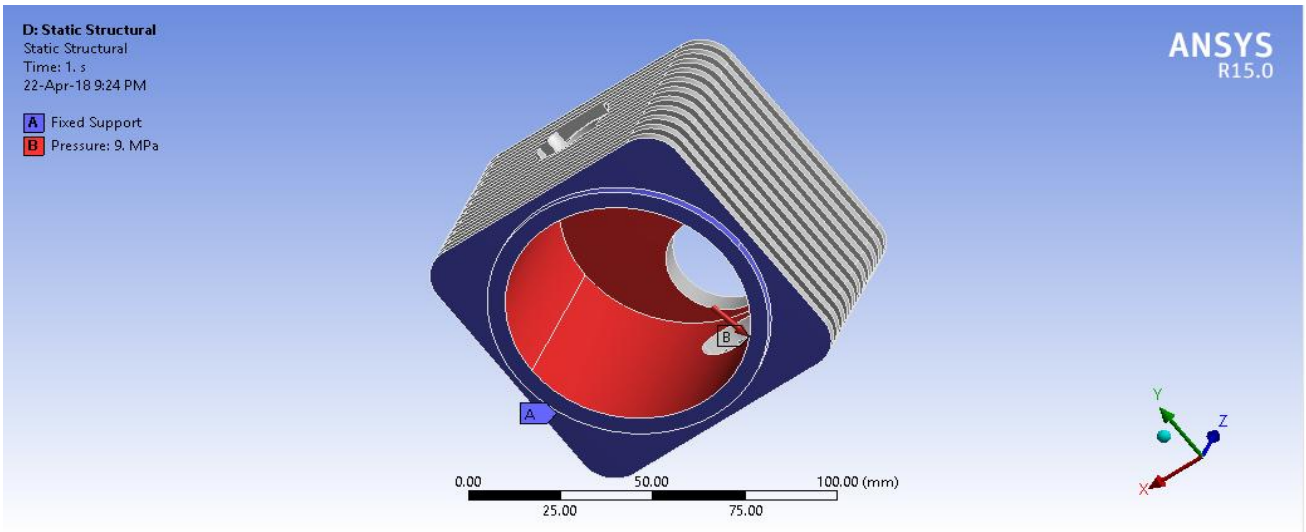


Figure 8

Static structural -> support -> fixed support -> select bottom area

Pressure -> 9Mpa

Table 3

Straight Fins Cylinder Static Results			
	Deformation (mm)	**Stress (Mpa)**	**Safety Factor**
Steel	0.038692	171.84	1.4548
Al-6061	0.11153	173.68	1.5892
Cast iron	0.070606	170.56	1.794
Monel-400	0.04304	173.08	1.9933

Boundary conditions – V Shape Fins

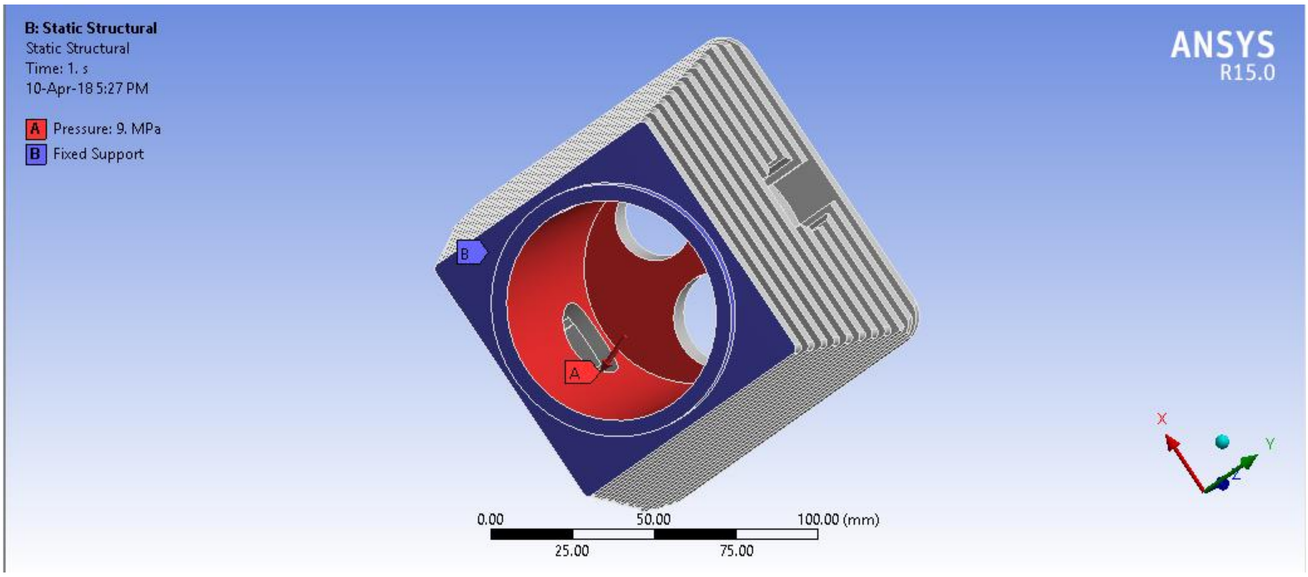


Figure 9

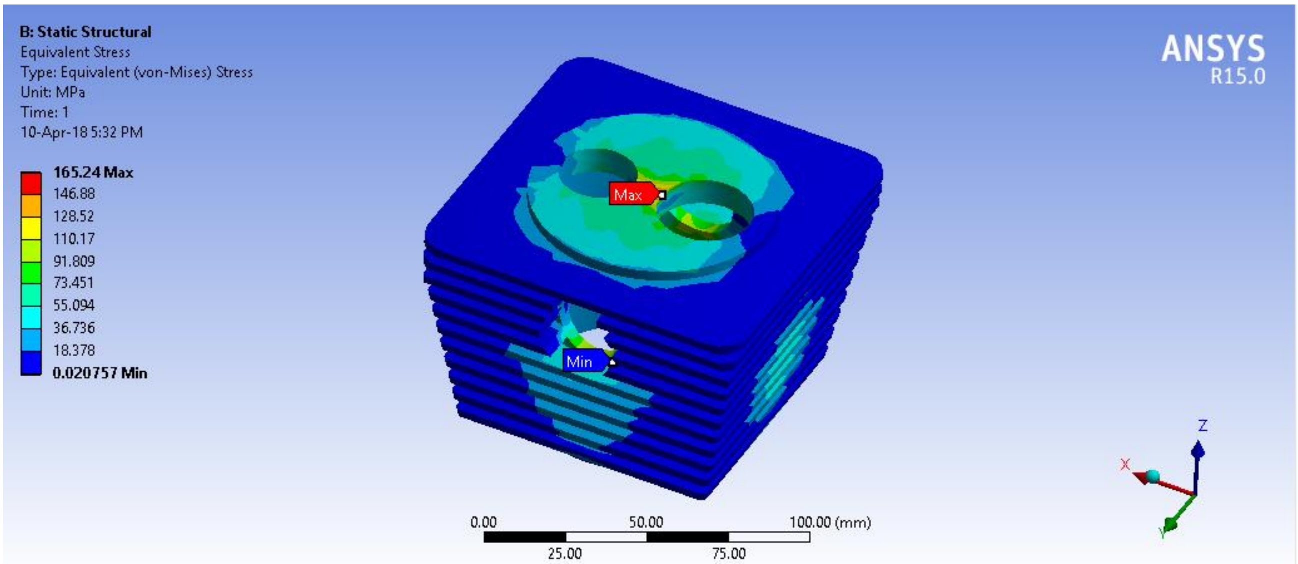


Figure 10

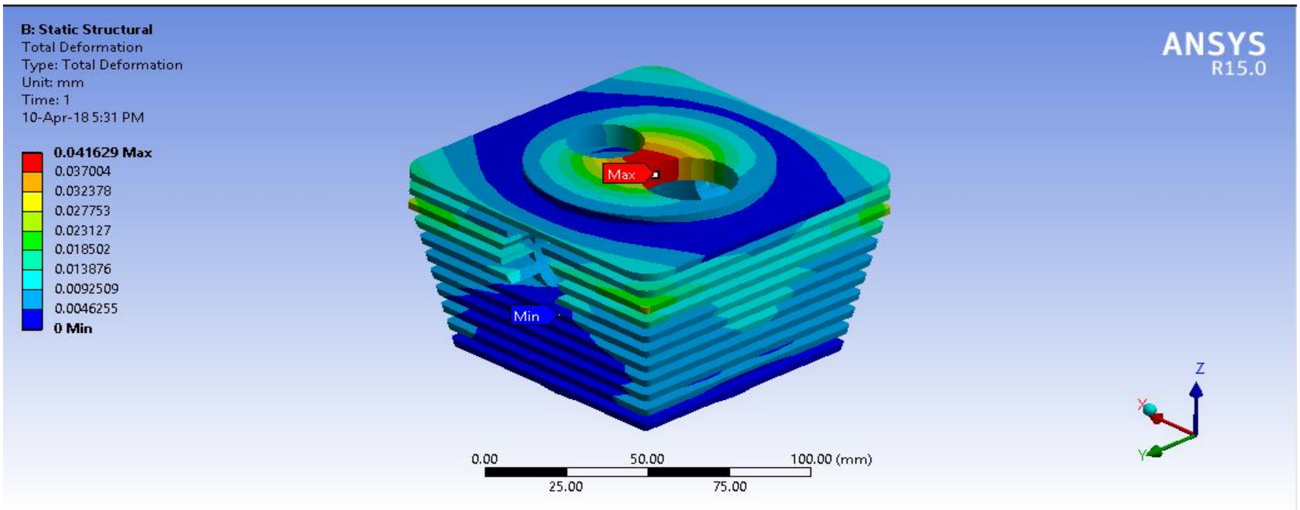


Figure 11

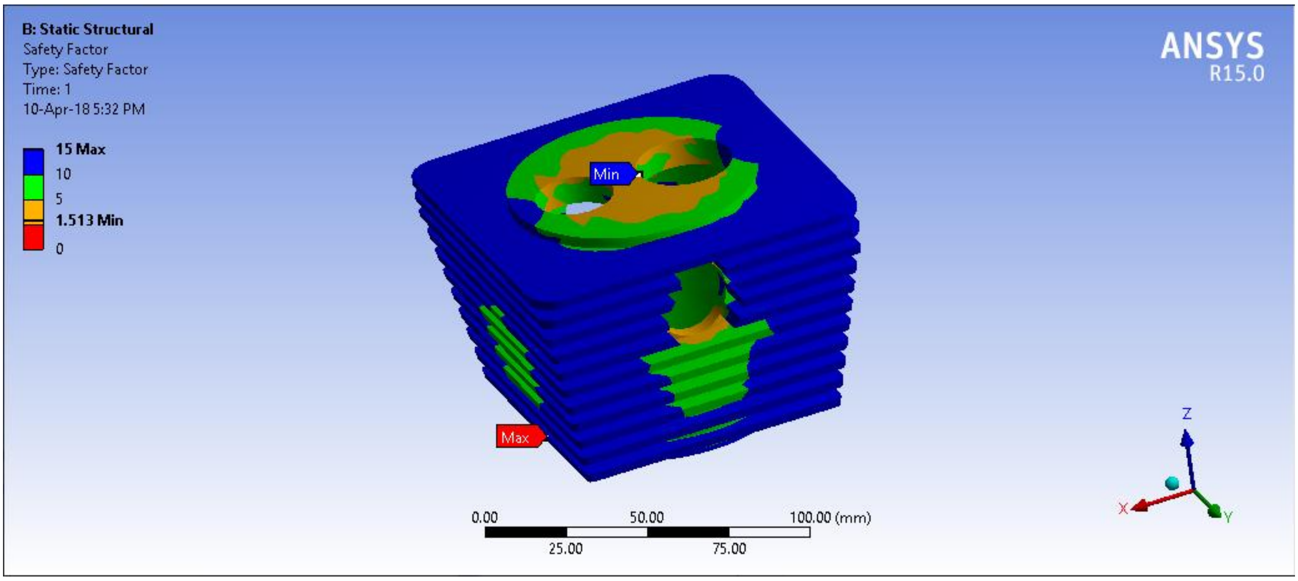


Figure 12

After completion of boundary conditions here we have to check results by solving. Just click on solve option and select results like deformation, stress and safety factor values for the object.

Table 4

V-Shape Fins Cylinder Static Results			
	Deformation (mm)	**Stress (Mpa)**	**Safety Factor**
Steel	0.041629	165.24	1.513
Al-6061	0.12018	165.24	1.6503
Cast iron	0.075893	163.85	1.8676
Monel-400	0.046353	166.59	2.071

From the above results here we can see here cast-iron material has least stress values compare to existing material and monel-400, cast iron material have strength values than steel. When compare both straight fins cylinder and V-shape cylinder values, here V-shape cylinder decreases stress values over the body and increases strength compare to straight fins model. From the above results here we can say V-shape model has better results than straight fins model, but we cannot decide V-shape model can replace the straight fins model by only static analysis, to finalize our model here we also applying thermal boundary conditions on it and the results shown in below

4.2 THERMAL ANALYSIS

Boundary conditions – V Shape

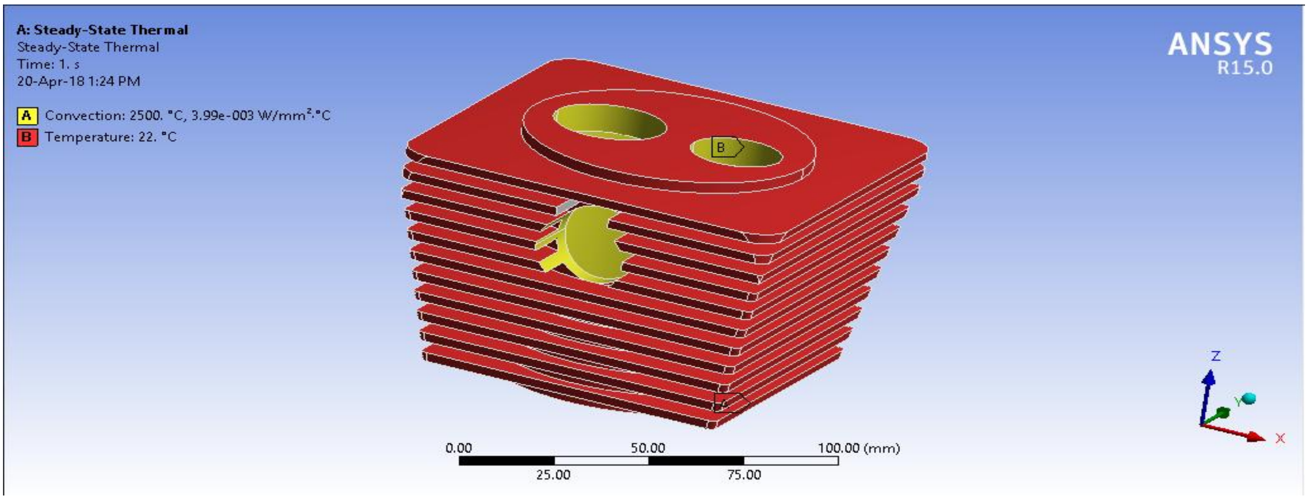


Figure 13

Convection→ select all inner areas→convection →2500*c

Coefficient of film→3.99e-3 w/mm^2, *c

Conduction→select all outer areas →22*c

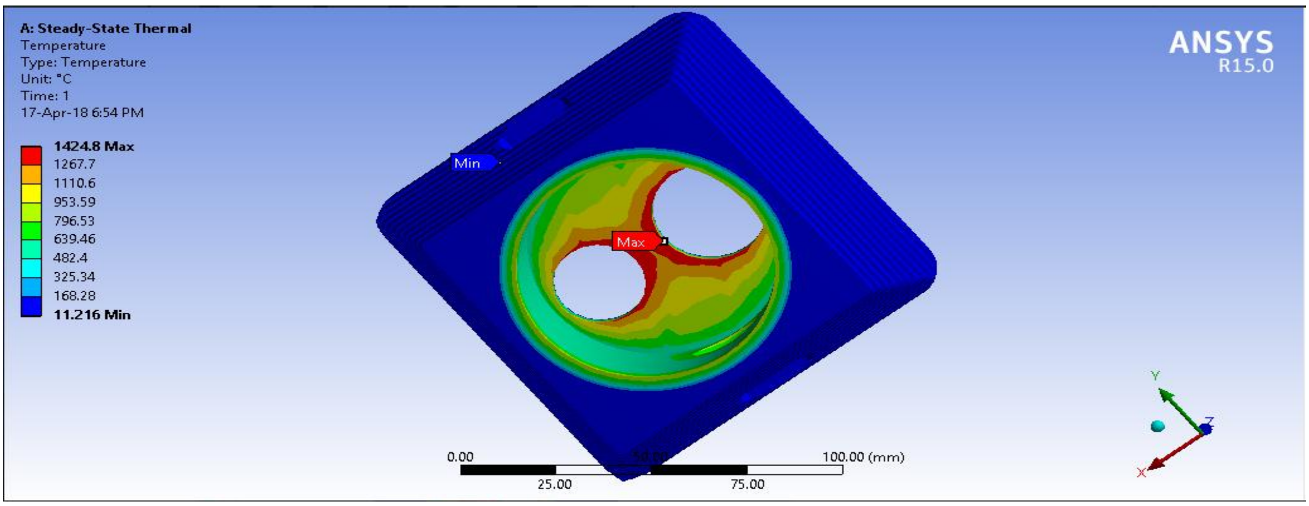


Figure 14

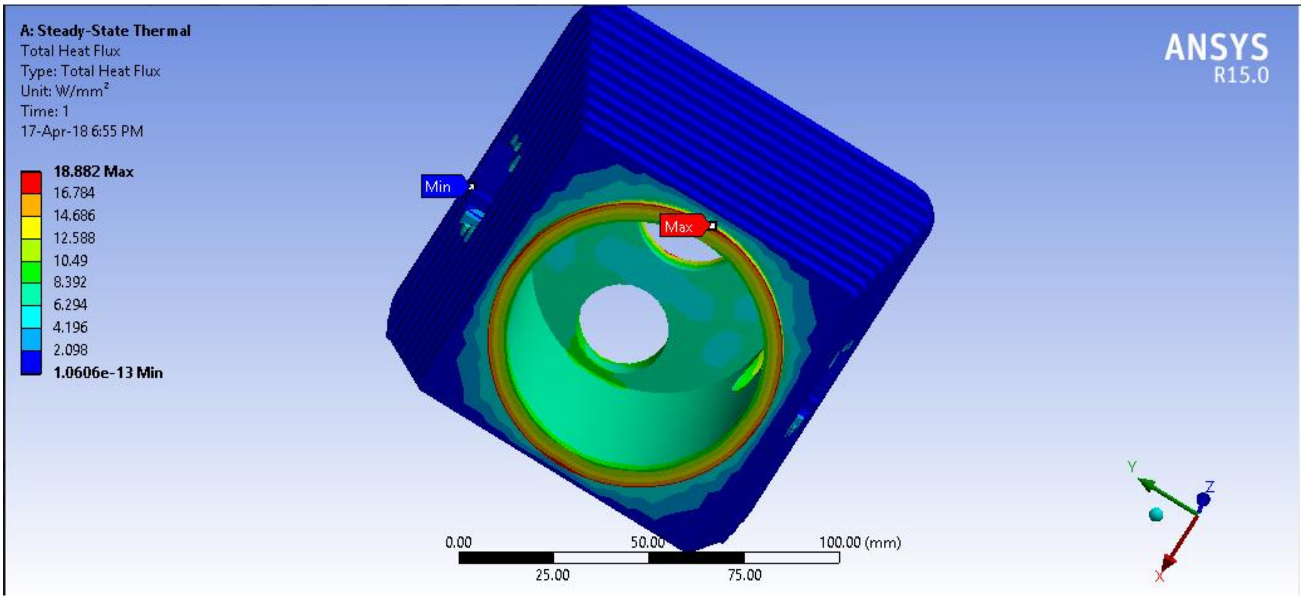


Figure 15

Table 5

V-Shape Thermal Results		
	Total temperature (*C)	**Total heat flux (W/mm^2)**
Steel	1424.8	18.882
Al-6061	753.27	24.346
Cast iron	1533.8	18.091
Monel-400	2165.2	13.46

Table 6

Straight Fins Cylinder Thermal Results		
	Total temperature (*C)	**Total heat flux (W/mm^2)**
Steel	1430.5	20.623
Al-6061	752.82	22.674
Cast iron	1546.8	20.189
Monel-400	2188.7	17.031

5. CONCLUSIONS

In this project we designed two-cylinder heads (straight and V-shape fins) by using cad tool solid-works and analyzed with cae tool Ansys workbench, here we took steel as an existing material for both models and to get more results here also we modified materials and we took 3 new materials (al-6061, cast iron, monel-400) while analyzing our models with static load conditions here we came to know that straight fins cylinder can with stand 9Mpa inside pressure only but other 3 materials are having good safety factor values than existing material, in this process V-shape cylinder (165.24Mpa) has less stress values than straight fins (171.84Mpa) model, by changing the shape of cylinder we can decreases over all stress values up to 5%, and we can increase the strength.

From the thermal results of straight fins cylinder here al-6061 has lowest temperature values but the difference between existing material and al-6061 is very high and we cannot replace this material with steel material even though it has good heat flux values. Other two materials are producing high temperature values and low heat flux values compare to existing material steel, so we cannot replace these materials even though these materials have good static analysis results. But we can reduce the temperature by changing design here we got less temperature values for V-shape cylinder compare to straight fins model. Finally, we can conclude V-shape cylinder head is satisfying both static and thermal load conditions with steel material.

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