Design And Thermal Analysis of Various Types of Piston With Different Aluminium Alloys

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Abstract- *Piston as one of the most important component in an engine, its thermal load always causes fatigue failure. A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings Piston that transfer the combustive gases power to the connecting rod. Failure of piston due to various thermal and mechanical stresses. This paper describes the thermal distribution of the single cylinder engine piston by using FEA. Creo Computer Aided Design (CAD) software was used to design the existing piston. The main objectives is to investigate and analyze the temperature distribution of piston at the real engine condition during combustion process. The Aluminium Alloy Al(6063) and Al(4032) have been selected for thermal analysis of piston and piston rings. We applied temperature 262ºC on piston crown. Finally choosing which one is the bestalloythat can be used as the piston material to improve the efficiency. Design of the piston is carried out using creo software, thermal analysis is performed using Finite Element Analysis Method in Ansys Software.*

Keywords- Piston, Aluminium Alloy, Al6063, Al4032, I.C. Engine, Types Of Pistons, etc.

I. INTRODUCTION

For proper functioning of the internal combustion engine, accurate piston temperature distribution is required because piston temperature has an important influence on ignition process of engine, ignition time delay, rate of burning, thermal efficiency, and production of pollutants. Knowledge of heat transfer in internal combustion engines is important to understand such systems. It contributes to engine development and design, processes simulation, and emissions reduction. In engine piston experiences high forces due to combustion chamber pressure and thermal load, which come from combustion process and from the huge temperature gradient between intake and exhaust gas flows so, it is important to guarantee the durability of engine components like piston, piston rings, valves, and cylinder wall, to avoid engine body distortions and to improve engine design related to weight and auxiliary energy consumption. In the case of the engine piston and cylinder, such knowledge is indispensable to have a thorough understanding of heat flux, temperature, and the distribution of these parameters. A common procedure used by some authors is to approximate the mean temperature of the distribution with one or more (very few) local measurements obtained by thermocouples.

Reciprocating Engine

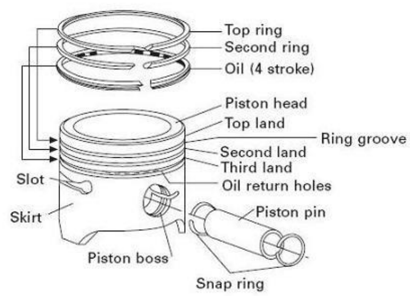

Figure1: Parts Of Piston

The piston of an internal combustion engine is acted upon by the pressure of the expanding combustion gases in the combustion chamber space at the top of the cylinder. This force then acts downwards through the connecting rod and onto the crankshaft.

Types of Piston

Square Bowl Piston Design

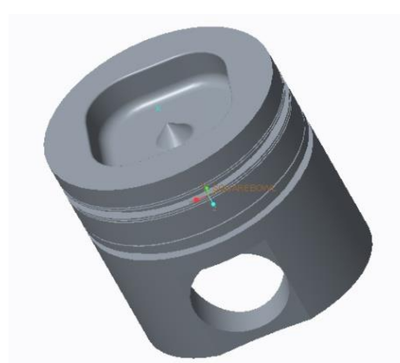

Figure 2: Square Bowl Piston

It has a square bowl space on its top as shown in Figure. This shape has a direct influence on the rate of heat released, especially with engines. The use of a bowl-shaped combustion chamber decreases rate of heat release by about 50% compared with a disc-shaped combustion chamber.

Bowl Piston Design

Bowl pistons are applied to minimise compression ratios due to the additional bowl combustion volume. They can be used on supercharged or turbocharged engines to eliminate detonation (that is the spark knock) under the boosted conditions of the two designs

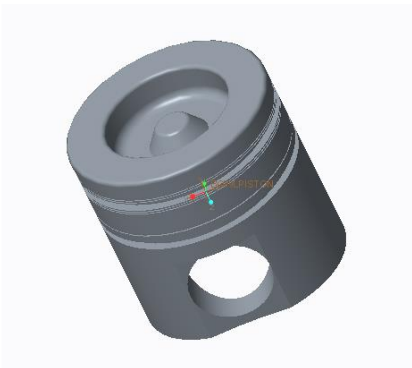

Figure 3: Bowl Piston

Dome Piston Design

The dome piston has additional volume on the top compared to flat pistons, whose tops are flat as shown in Figure. The extra volume is for improving the compression ratio of the piston and, consequently, improving performance. However, inefficiency in the in-cylinder surface design and highly domed pistons cause inefficient combustion and slow burning rates of the air-fuel mixture.

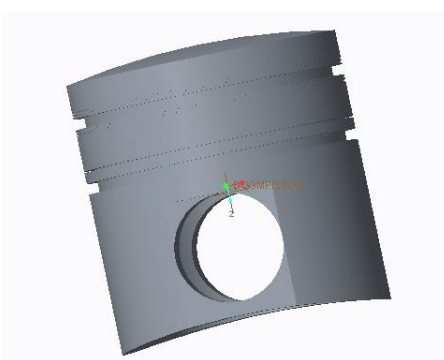

Figure 4: Dome Piston

Flat-Top Piston Design

This piston is commonly used in mass-produced engines. They are easy to develop, which keeps the cost of the engines low. Some flat-top pistons have material extracted from the top to ensure the valves do not hit the pistons during the opening and closing of the intake and exhaust valves. This improves their compression ratios by allowing the pistons to rise higher into the head of the cylinders. The last decade has seen advancements in piston technology.

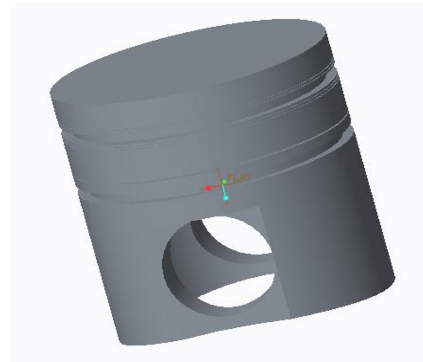

Figure 5: Flat top piston

II. MATERIAL AND METHOD

I. Material Selection

AL6063

Aluminium Alloy 6063 Aluminium alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodised. Most commonly available as T6 temper, in the T4 condition it has good formability.

AL4032

Aluminium/Aluminum alloys are known for strong corrosion resistance. These alloys are sensitive to high temperatures ranging between 200 and 250°C (392 and 482°F), and tend to lose some of its strength. However, the strength of Aluminium/Aluminum alloys can be enhanced at subzero temperatures, making them ideal low-temperature alloys.

Element	% Present
Magnesium (Mg)	0.45 - 0.90
Silicon (Si)	0.20 - 0.60
Iron (Fe)	0.0 - 0.35
Others (Total)	0.0 - 0.15
Chromium (Cr)	0.0 - 0.10
Copper (Cu)	0.0 - 0.10
Titanium (Ti)	0.0 - 0.10
Manganese (Mn)	0.0 - 0.10
Zinc (Zn)	0.0 - 0.10
Other (Each)	0.0 - 0.05
Aluminium (Al)	Balance

Table 1: Properties of Al 6063

Element	Weight %
Al	85.0
Si	12.20
Cu	0.90
Mg	1.0
Ni	0.9

Table 2: Properties of Al 4032

II. Mechanical Properties

Materials	Youngs Modules	Poissons Ratio	Density	Thermal Conductivity
Al alloy 6063	69.5 GPa	0.3	2.70 g/cm³	200 W/m.K
Al alloy 4032	72 GPa	0.33	2.69 g/cm³	155 W/m.K

Table 3: Mechanical Properties Of Alloys

III. Comparison Based On Rigidity Qualities

The weight reduction of mass of an automobile will improve the riding quality. The leaf contributes 10% - 20% of the mass. The weight of the composite piston is 3.75 times less than steel piston. Hence the riding comfort of an automobile is increased due to the replacement of the steel piston by composite piston. No one to the best of knowledge has worked but qualitatively on how much improvement in mileage/lit of passenger vehicle occurs and how much riding comfort improves. Only qualitative information is available on riding comfort of vehicle with respect to its mass. Steel piston is a multi-piston and its inter-leaf fabrication reduces its riding quality. But composite piston is a mono-piston and more conductive to riding qualities. The cost estimation of composite piston provides a clear economic viability of the product in comparison to that of a convectional piston.

IV. Strength Comparison

Static test has been conducted on steel and composite piston. The characteristics of these two are given below. Since, the composite piston is able to with stand the static load as well as the fatigue load, it is concluded that there is no objection from strength point of view also, in the process of replacing convectional piston by composite piston. To establish the consistency of test results, extensive trail on a large scale has to carried out. This requires large time and infrastructure, which are beyond the scope of the present study. Since, the composite piston is designed for same stiffness as that of steel piston, both the pistons are considered to be almost equal in car stability. The major disadvantage of composite pistons is cost and resistance. In this study, the cost factor has been proved to be ineffective. However the matrix material is likely to chip off when it is subjected to poor road environment (i.e. if some stone hit the composite piston then it may produce chipping), which may sometimes break the fibers in the lower portion of the piston. This may result in a loss of capability to share flexural stiffness. But this depends on the condition of the road. In normal road condition, this type of problems will not occur.

V. Analysis Of Pistons

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.

Analysis Procedure

→ Launch ANSYS, by going to the start-up menu and double clicking on workbench file in the ANSYS 17.1 folder.

→ Next Double click on the Geometry. This stage is for getting the required geometry read into the software; note that there is a blue question mark icon beside the geometry text. Looking at the bottom of the window you will see two windows one having the title of Messages, this title confirms that the imported geometry has no problems with it, the next window has the title Progress and that is necessary to prove that state of the progress and if there is a problem it will state the problem.

- → Once ANSYS Workbench window is active you will get a window asking to specify working units for the model dimension chose meters and press ok. For the user this step might seem secondary in importance but as a matter of fact it's of great importance, because at later stages you will have to specify the box size (discrete element dimension). Box size dimension leads to finer mesh, the finer the used mesh is the more accurate is the captured data. The captured data term refers to the fluid flow structures. Depending on case the selection of serial or parallel is taken, also depending on the hardware provided in the computer lab dual core or quad core etc.
- → A window having a title open will be visible to the user, choose File type Para solid(*x_t;*xmt_txt;*x_b;*xmt_bin) then go to the folder that has the required file .There are lots of software that are used to generate meshes, depending on the software used the file extension text would be, to generate the mesh and then exporting it in Para solid format. A question comes to the mind of the student why do I have to specify the file extension. The answer is that each mesh generation software has its own structure in its generated data sets
- → Looking at the Design Modeller window, we can't see the imported geometry yet, what is required next is to press on the generate icon that is represented by a yellow thunder icon. The Design Modeller will read in the imported data file, and will construct the required mesh. The imported Geometry Domain should look something like this, still that doesn't give any hints to the user, relating to the inner structure of the domain. The geometry domain is viewed in the shaded exterior style.
- → go to view and chose wireframe. This step is necessary to view the inner structure of the domain.
- → Once the student gets to this stage, that means he has finished from the Design Modeller and has to proceed to the Meshing part. Rotate the view and check that the Geometry satisfies the design requirements.
- → Go to the workbench and check that there is a green tick sign beside the Geometry and then double click on the Mesh Icon. After finished from Design Modeller and now have started with the Meshing part.
- → The Meshing part of the project has started, notice that beside the Mesh there is a yellow thunder icon. The scale shown at the bottom helps you make the right decision on the box sizing, so that we can see that the largest value on the scale is 0.200(m) which means we have to choose a value less than 0.050(m).
- → Right click on Mesh and chose Insert and then chose Method at this stage we come to the point where we have to choose what kind of mesh are we going to use wither regular or irregular or etc.
- → Click on the positive sign beside the Mesh you should get a tree sub branch have automatic Method using the left button click on the grey box domain, as a result it should by highlighted in green, then you see that the geometry text is highlighted in blue press the apply. Choose the parallel option in the projection mode, which will come handy later on, when you want to use the measure command or choosing the appropriate slice plane for your study.
- → Go to method and choose Tetrahedrons. This prepares the view for later wanted operations.
- → Go to algorithms and choose Patch Independent.

Now that you have specified the mesh properties, you can proceed to the next step.

- → Press the Update icon and then press on the Generate Mesh icon. For our case we will want to know the dimensions of the inflow section of the pipe.
- → Click on mesh, now it's visible to the user the generated mesh. Click on the middle button to rotate the view to inspect your mesh.

Go to work bench, you will see there is a green tick beside the mesh congratulations you can now proceed to the setup. Check the messages window if there are any errors you will have to go back in steps and check where you went wrong.

III. RESULTS AND DISCUSSION

I. Meshing

Meshing involves division of the entire of model into small pieces called elements. It is convenient to select the free mesh because the cooling fins have sharp curves, so that shape of the object will not alter. To mesh the cooling fins the element type must be decided first. Here, the element type is solid 45. The element edge length is taken as 5 mm. The numbers of elements are taken 2225 and the total numbers of nodes are 8099.

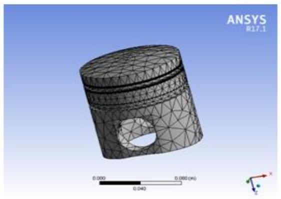

Fig. 6.a

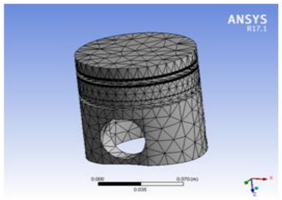

Fig. 6.b

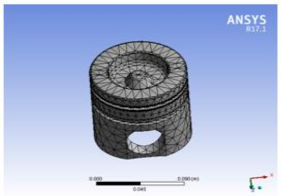

Fig. 6.c

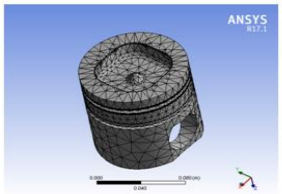

Fig. 6.d

Where,
Fig. 6.a - Meshing Of Dome Piston
Fig. 6.b - Meshing Of Flat Top Piston
Fig. 6.c - Meshing Of Bowl Piston
Fig. 6.d - Meshing Of Square Bowl Piston

II. Ansys Results

Dome Piston

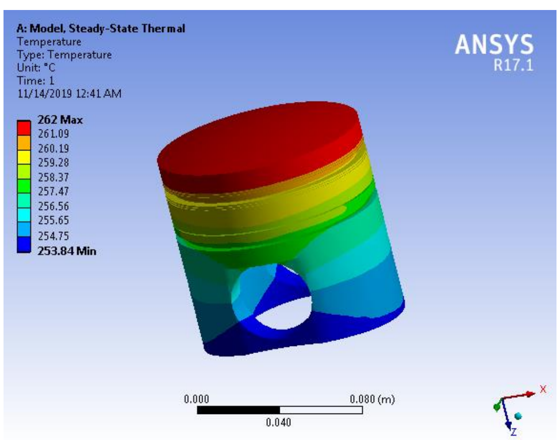

Fig. 7.1 Temperature Distribution Of Dome Piston In Al 6063

Maximum temperature achieved is 262 ºC
Minimum temperature achieved is 253.84 ºC

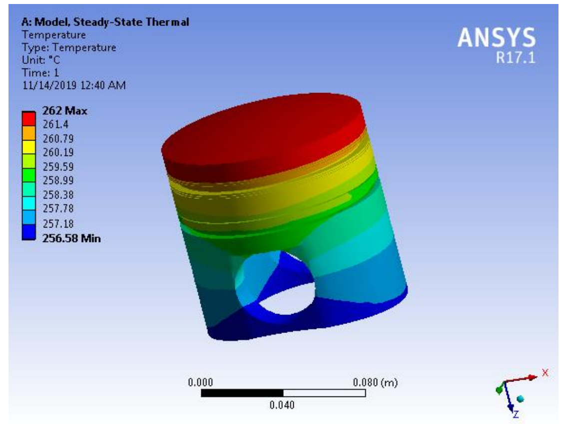

Fig. 7.2 Temperature Distribution Of Dome Piston In Al 4032

Temperature applied on the piston is 262ºC
Maximum heat distributed in the piston is 260ºC
Minimum heat distributed in the piston is 256.58ºC

Flat Top Piston

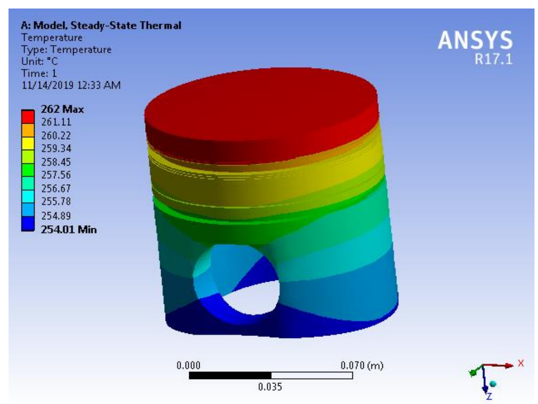

Fig. 7.3 Temperature Distribution Of Flat Piston In Al 6063

Maximum temperature distributed in the piston is 262ºC
Minimum temperature distributed in the piston is 254.01ºC

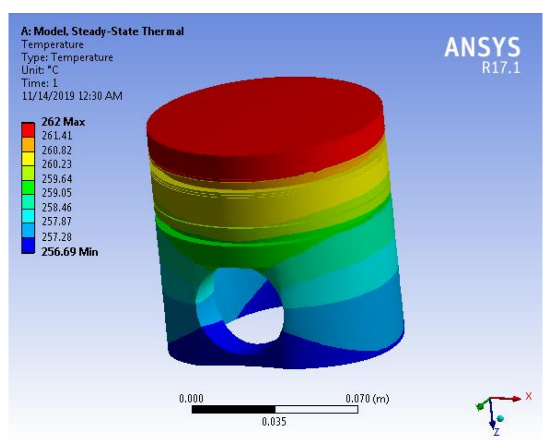

Fig. 7.4 Temperature Distribution Of Flat Top Piston In Al 4032

Maximum heat distributed in the piston is 262°C
Minimum heat distribution in the piston is 256.69°C

Square Bowl Piston

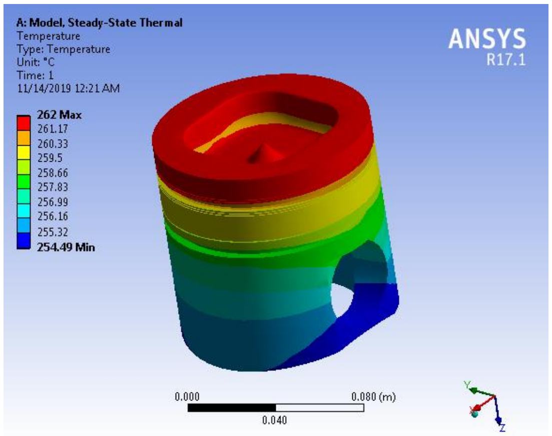

Fig. 7.5 Temperature Distribution Of Square Bowl Piston Piston In Al 6063

Maximum heat distributed in the piston is 262°C
Minimum heat distributed in the piston is 254.49°C

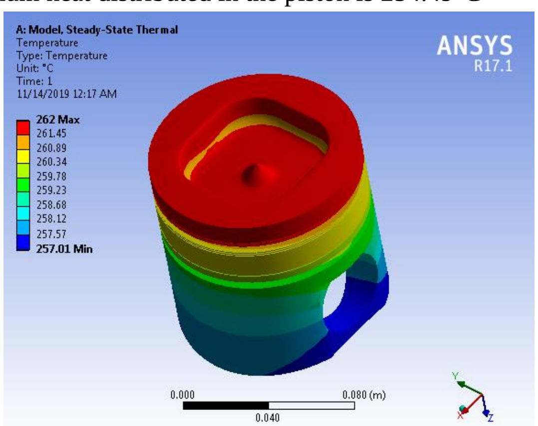

Fig. 7.6 Temperature Distribution Of Square Bowl Piston In Al 4032

Maximum temperature distributed in the piston is 262°C
Minimum temperature distributed in the piston is 257.01°C

Bowl Piston

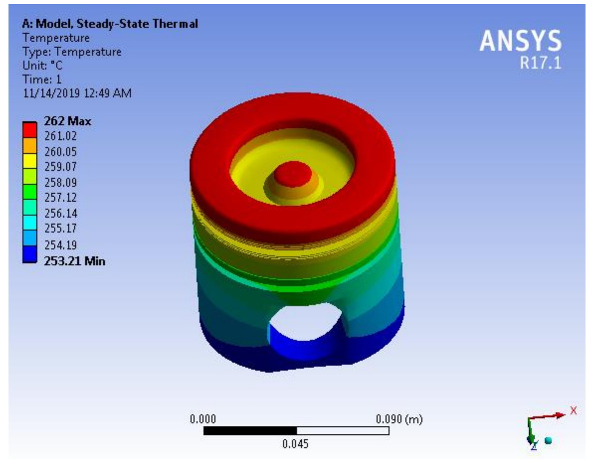

Fig. 7.7 Temperature Distribution Of Bowl Piston Piston In Al 6063

Maximum Temperature distributed in the piston is 262°C
Maximum Temperature distributed in the piston is 253.21°C

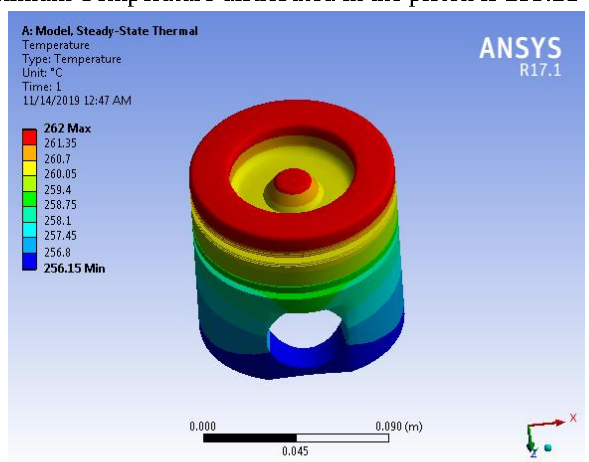

Fig. 7.8 Temperature Distribution Of Bowl Piston Piston In Al 4032

Maximum Temperature distributed in the piston is 262°C
Maximum Temperature distributed in the piston is 256.15°C

IV. CONCLUSION

An existing design of piston was modeled in four different types (Dome Piston, Flat Top piston, Square Bowl and Bowl Piston) and analysed for available boundary conditions. The Temperature of 262°C is applied to the pistons and the thermal performance of different pistons is obtained. The piston model was analyzed for different aluminium alloys (Al 6063 & Al 4032). From the results, it is found that the temperature, total heat flux and directional heat flux of the piston for Aluminium alloy Al 4032 is very low compared to that of Aluminium alloy Al 6063. From the above results it is clear that flat design have a high structural stability compared to others. It is also found that Al 4032 have high stability compared to Al 6063.

V. FUTURE SCOPE

By this brief analysis of four types of piston using Al 4032 and Al 6063 alloy Al4032 is obtained as a best material when compared to the other one. But there is no major difference in this alloy so in next phase the material combination of the Al4032 is changed and an new alloy is made and the real time thermal investigation is to be done and compared with the design analysis**.**

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