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Design Evaluation of Diesel Engine Piston Using Materials CI and Aluminum Alloy

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Abstract: ***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. The piston transforms the energy of the expanding gasses into mechanical energy. The piston rides in the cylinder liner or sleeve. Pistons are commonly made of aluminum or cast iron alloys. The main aim of the project is to design a piston for 1300cc diesel engine for two materials Cast Iron and Aluminum Alloy. The designs of the piston are modeled using Creo software. The designs are evaluated by structural and thermal analysis by applying pressures and temperatures respectively. The result is evaluated by checking the stress, displacement, thermal gradient and thermal flux to decide the best design of the piston. Structural and Thermal analysis are done in ANSYS software.***

Keywords: Reciprocating engines, reciprocating pumps, piston, aluminum or cast iron alloys, stress, displacement, thermal gradient and thermal flux, Thermal analysis, ANSYS software

1. Introduction

The piston transforms the energy of the expanding gasses into mechanical energy. The piston rides in the cylinder liner or sleeve. Pistons are commonly made of aluminum alloys or cast iron. To prevent the combustion gasses from bypassing the piston and to keep friction to a minimum, each piston has several metal rings around it. These rings function as the seal between the piston and the cylinder wall and also act to reduce friction by minimizing the contact usually 2 to 5, with each ring performing a distinct function. The top ring(s) acts primarily as the pressure seal. The intermediate ring(s) acts as a wiper ring to remove and control the amount of oil film on the cylinder walls. The bottom ring(s) is an oiler ring and ensures that a supply of lubricating oil is evenly deposited on the cylinder walls. Area between the piston and the cylinder wall. The rings are usually made of cast iron and coated with chrome or molybdenum. Most diesel engine pistons have several rings. Pistons move up and down in the cylinders which exert a force on a fluid inside the cylinder. Pistons have rings which serve to keep the oil out of the combustion chamber and the fuel and air out of the oil. Most pistons fitted in a cylinder have piston rings. Usually there are two spring-compression rings that act as a seal between the piston and the cylinder wall, and one or more oil control ring s below the compression rings. The head of the piston can be flat, bulged or otherwise shaped. Pistons can be forged or cast. The shape of the piston is normally rounded but can be different. A special type of cast piston is the hypereutectic piston. The piston is an important component of a piston engine and of hydraulic pneumatic systems. Piston heads form one wall of an expansion chamber inside the cylinder. The opposite wall, called the cylinder head, contains inlet and exhaust valves for gases. As the piston moves inside the cylinder, it transforms the energy from the expansion of a burning gas usually a mixture of petrol or diesel and air into mechanical power in the form of a reciprocating linear motion. From there the power is conveyed through a connecting rod to a crankshaft, which transforms it into a rotary motion, which usually drives a gearbox through a clutch. Components of a typical, four stroke cycle, DOHC piston engine. (E) Exhaust camshaft, (I) Intake camshaft, (S) Spark plug, (V) Valves, (P) Piston, (R) Connecting rod, (C) Crankshaft, (W) Water jacket for coolant flow.

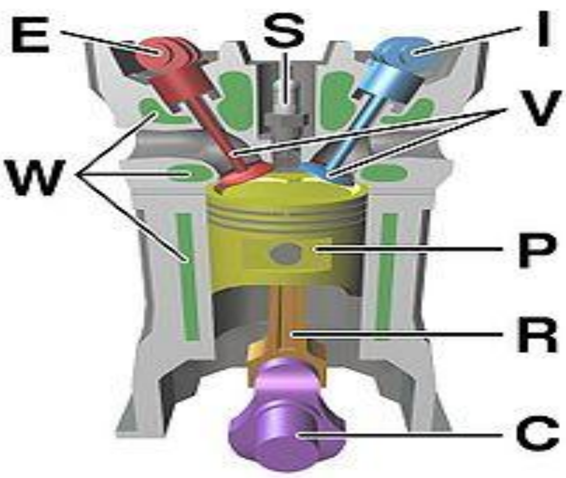


Figure 1: Piston Description

1.1 Parts inside the Piston

1.1.1. Piston head or crown

The piston head or crown may be that convex or concave depending upon the design of combustion chamber.

a) It with stands the pressure of gas in the cylinder.
b) The selection of piston crown primarily depends upon the requirement of values for the combustion chamber.

1.1.2 Piston rings

These are used to seal the cylinder in order to prevent hatiage of the gas past the piston.

a) To act as passage of heat flow from piston crown to the wall of the cylinder.

b) To act as a lubricating oil controller on the cylinder wall so as to minimize wear.
c) To absorb some part of the piston due to side thrust.
d) The material for piston rings is usually cast iron & alloy cast iron due to their good wearing qualities & also they retain the spring characteristics ever at high temperatures.

Piston Rings are two types:
a) Compression rings- A sealing of the combustion gas.
b) Heat transfer from piston crown to the Cylinder wall.
c) Oil control rings: to prevent excessive oil from Passing

Through the end gap of rings and between the cylinder wall & the ring face.

2. Literature Survey

The cast iron pistons were superseded by aluminum al-loy piston around the year 1920 (Sarkar 1975). Cole G.S. and Sherman A.M.(1995) explained that a considerable interest had been grown in replacing cast iron and steel in automotive component like piston with light weight aluminum alloy casting to improve the performance and efficiency. Haque M.M and Young J.M. (2001) referred the low expansion group of aluminum–silicon alloy as piston alloy, since this group of alloy provides the best overall balance of properties. Near eutectic aluminum silicon pis-ton alloy exhibit complex fatigue behavior due to their multi component microstructure (Moffat et al 2005)

A ceramic insert is adapted on the head portion of the piston and connected to the same by mechanical locking. The ceramic insert is provided with pores at least on the portion engaging the piston head. The pores have sizes which enable them to be filled with the light alloy during the manufacture of the piston by the squeeze casting method (Mahrus 1988). Piston can be formed in two parts. The main part is formed by gravity die casting from aluminum or aluminum alloy and a second part of the piston is formed by a squeeze casting process to produce a material which is stronger and more resistant than the gravity die cast aluminum or aluminum alloy. The two parts are then electron beam welded together to form the complete piston. The squeeze cast portion may be reinforced with whiskers or fibers to further improve its properties. This method of construction has the benefit that only a smaller portion of piston is formed by the more expensive and time-consuming squeeze casting process. This is the benefit in large diesel pistons (Avezou 1987). David. J (1985) worked on the provision of a wear resistant insert for pistons of light weight alloys. The insert comprises an annular ring of wear resistant material which has a cylindrical peripheral edge. The annular ring has at least one projection or A ceramic insert is adapted on the head portion of the piston and connected to the same by mechanical locking. The ceramic insert is provided with pores at least on the portion engaging the piston head. The pores have sizes which enable them to be filled with the light alloy during the manufacture of the piston by the squeeze casting method (Mahrus 1988).

3. Design Calculations

Density of diesel = 820 to 950 kg/cm at 15˚c
= 0.00095 kg/cm³
Density = 0.00000095 kg/mm³
Diesel $C_{10}H_{22}$ to $C_{15}H_{28}$ = $C_{15}H_{28}$
Molecular weight of $C_{15}H_{28}$ =208g/mole
Mass =density × volume
m = 0.00000095× 130000
m =1.235
R = 8.3143 J/mol K
PV = m R T
P = (m R T)/V = (1.235× 8.3143× 288)/(0.208× 0.001300)
= 10936107.69 J /m³
P = 10.936 N/mm

3.1. Piston Head

Gas pressure p = 10.936 N/mm²
Outside diameter of piston = 72.5
σt = bending tensile stress = 35-40MPa
Temperature at the centre of the piston head Tc = 425˚c to 450˚c
Temperature at the edge of the piston head Te = 200˚c to 225˚c
Tc – Te = 220˚c th= $\sqrt{((3p \times D^2))/(16\ \sigma_t)}$
= $\sqrt{(3\times10.936\times[72.5]^2)/(16\times40)}$
= 16.41mm

Thickness of the ribs =$t_h/3$ to $t_h/2$
= 5.47 (or) 8.20 mm

3.2. Piston Ring

Radial thickness of the ring
$t_1 = D \times \sqrt{(3 \times Pw)/\sigma_t}$
Pw = pressure of gas on the cylinder wall
Pw = 0.025 to 0.042 N/mm²
σt = 85 MPa to 110MPa for CI rings
t1 =72.5 × $\sqrt{(3\times .042)/110}$ = 2.45mm
axial thickness t2 = D/10nR
nR = no. of rings = 3
t2 =72.5/(10× 3) =2.41mm
Width of top land b1 = th to 1.2 th =16.41 to 19.692 mm

The width of other ring land (distance between the ring grooves)
b2 = 0.75t2 to t2 =1.8075 to 2.41 mm

The gap between the free ends of the ring
= 3.5t1 to 4t1
=8.575to9.8 mm

3.3. Piston Barrel (Cylindrical Portion of The Piston)

Thickness of piston barrel
t3 = radial depth of piston ring groove
b= t1+0.4 =2.85mm
t3 = 0.03× 69.6+2.75+4.5 = 9.525mm
The piston wall thickness towards the open end
t4 =0.25t3 to 0.35t3
t4 = 3.33mm

3.4. Piston Skirt

Maximum gas load on the piston
$P = p \times \pi D^2/4$
P= maximum gas pressure
$P = 10.936 \times [\pi \times 72.5]^2/4$
P= 45226.79866 N
Maximum side thrust on the cylinder
R= p/10= 4522.67N
Length of the piston skirt
L= 0.65D to 0.8D = 58 mm
Length of ring section = 7× b2=16.87
Total length of the piston
L = length of the skirt +length of the ring section +top land
=58+16.84+19.692
= 94.532mm

3.5. Piston Pin (Gudgeon Pin or Wrist Pin)

d_0 = outside diameter of the piston pin
l_1 =length of the piston pin in the bush of the small end of the connecting rod
= 0.45D = 0.45× 69.6
l_1= 32.625mm
Load on the piston due to gas pressure
p = 45226.79866N
Load on the piston pin due to bearing pressure or bearing load = bearing pressure × bearing area
$P = p_{b1} \times d_0 \times l_1$
p_{b1} = bearing pressure at the small end of the connecting rod bushing
$d_0 = p/(p_{b1} \times l_1)$
Bearing pressure of tin bronze =50MPa
$d_0 = 45226.79866/(50\times 32.625) = 27.725$mm
$d_i = 0.6 d_0 = 16.635$mm
Length between the supports
$l_2 = (l_1+D)/2 = (32.625+72.5)/2$
l_2 = 52.56mm
The mean diameter of the piston bosses = 1.4 d_0
= 38.815mm

4. Structural Analysis of Piston

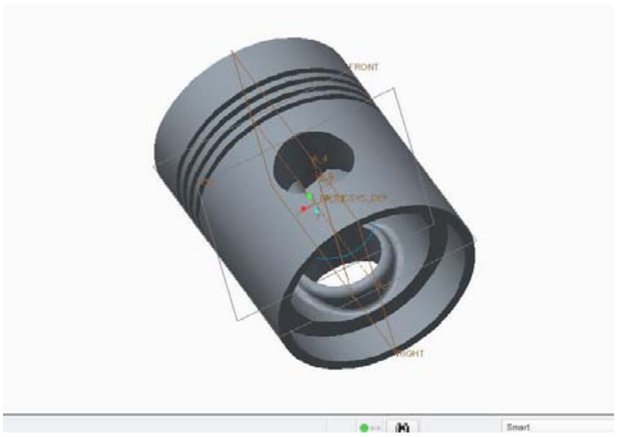


Figure 2: Part Model

4.1 Cast Iron

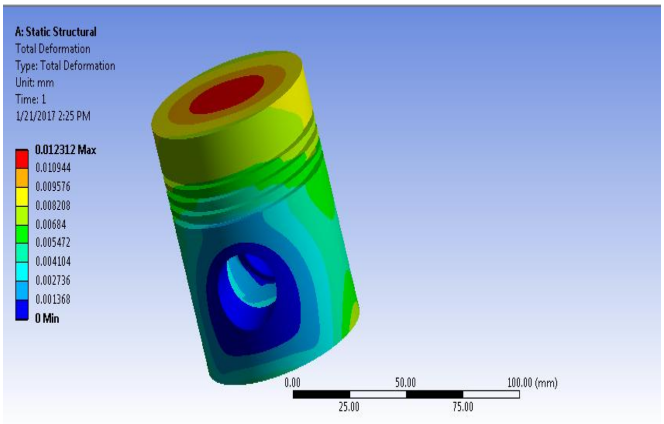


Figure 3: Total deformation for Cast Iron

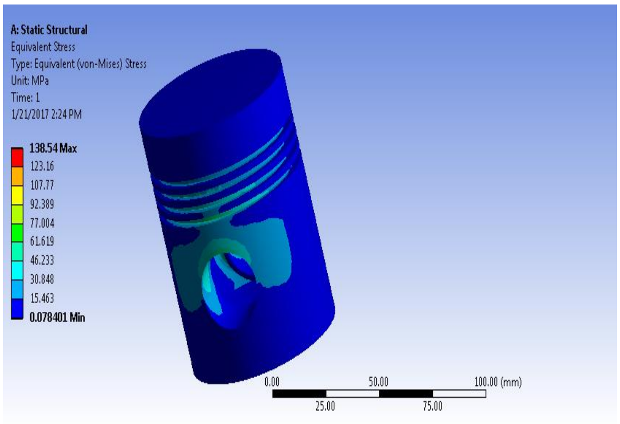


Figure 4: Stress For Cast Iron

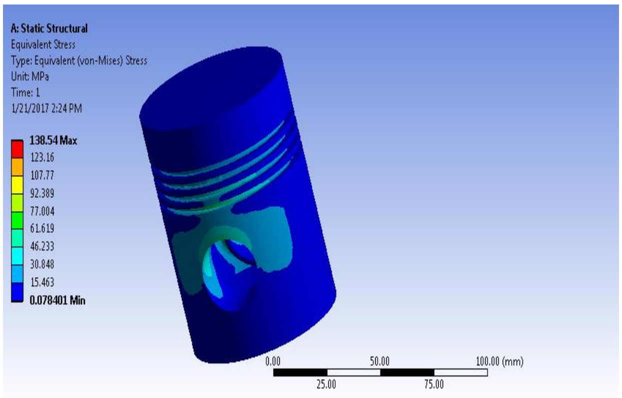


Figure 5: Strain For Cast Iron

4.2 Aluminum Alloy

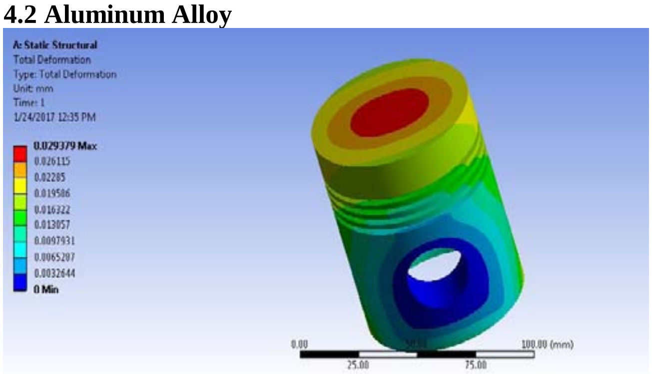


Figure 6: Total deformation For Aluminium Alloy

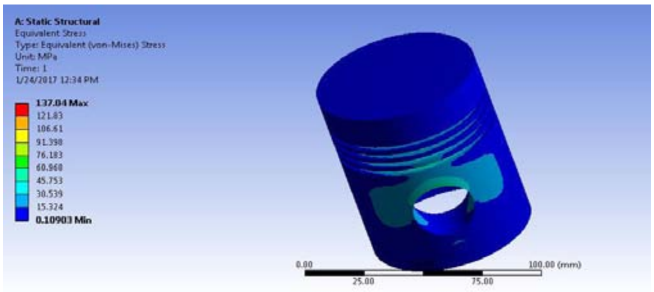


Figure7: Stress for Aluminium Alloy

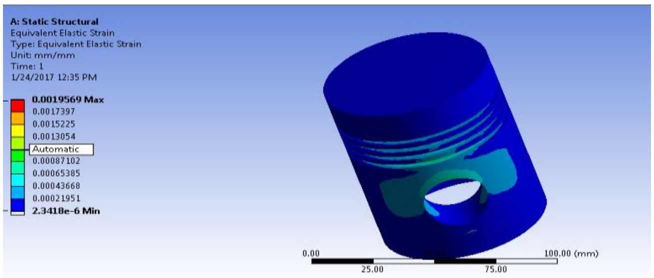


Figure 8: Strain for Aluminium Alloy

5. Thermal Analysis of Piston

5.1 Cast Iron

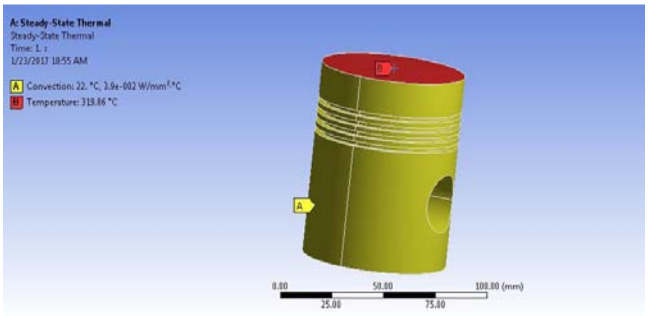


Figure 9: Convection

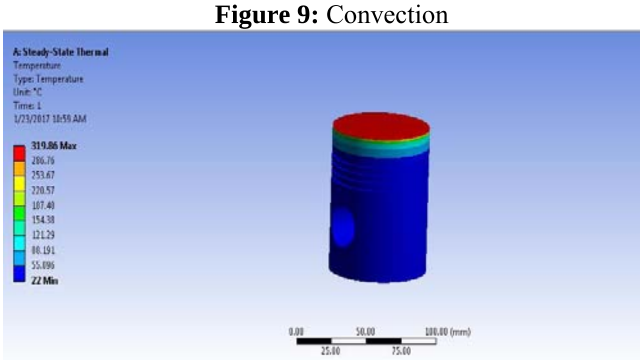


Figure 10: Temperature for Cast Iron

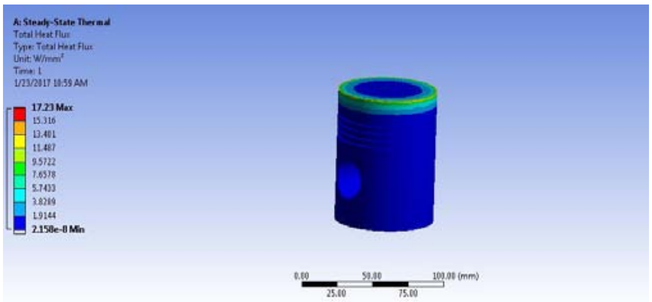


Figure 11: Total Heat Flux for Cast Iron

5.2 Aluminium Alloy

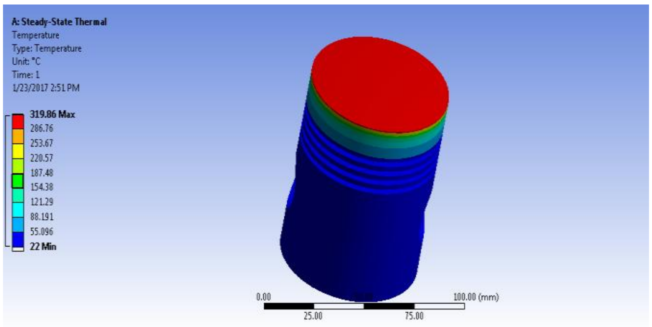


Figure 12: Temperature for Aluminium Alloy

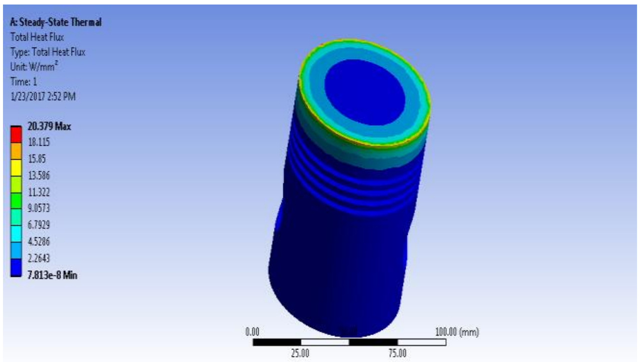


Figure 13: Total Heat flux For Aluminium Alloy

6. Tables & Graphs

Table 1: Structural Analysis

Materials	Deformation (mm)	Strain	Stress (MPa)
Cast iron	0.012312	0.00083046	138.54
Aluminium alloy	0.029379	0.0019569	137.04
Aluminium 6061	0.26491	0.0017645	137.49
Aluminium 7475	0.026146	0.0017415	137.42

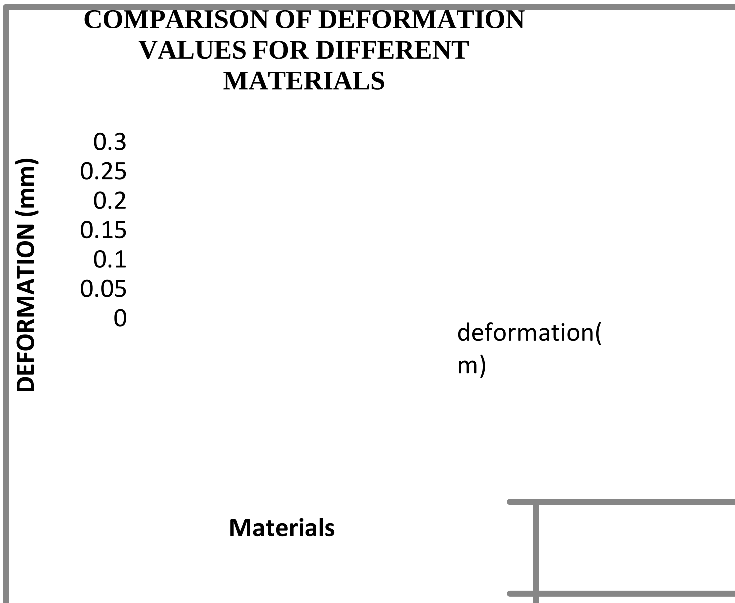


Figure: Comparison Of Deformation Values For Different Materials

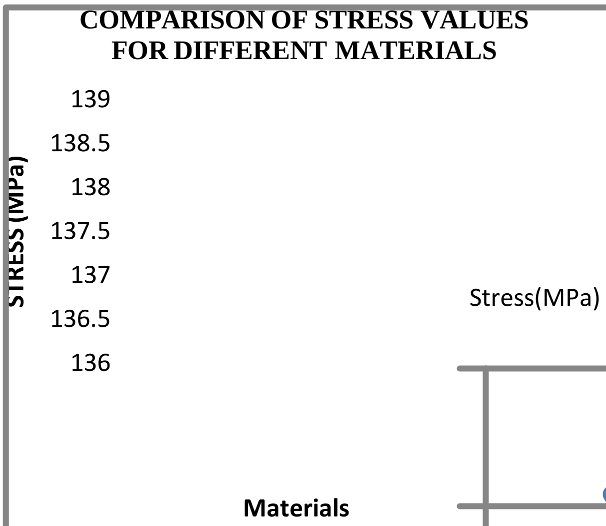


Figure: Comparison Of Stress Values For Different Materials

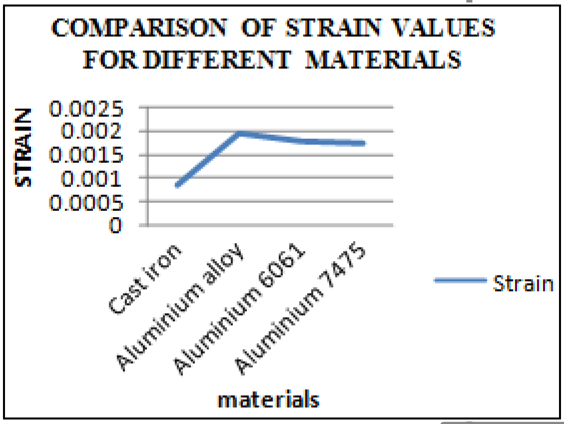


Figure: Comparison of Strain Values For Different Materials

Table 2: Thermal Analysis

Materials	Temperature	Heat flux(W/mm2)
Cast iron	319.86	17.23
Aluminium alloy	319.86	20.379
Aluminium 6061	319.86	18.663
Aluminium 7475	319.86	20.627

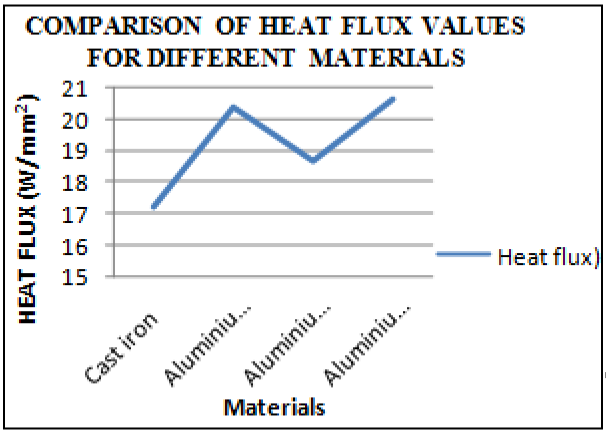


Figure: Comparison of Heat Flux Values For Different Materials

7. Conclusions

In this project designed of a piston in 1300cc petrol engine using theoretical calculations for material Cast Iron. A 2D drawing is drafted and 3D modeling of piston is done in Pro/Engineer. Structural and thermal analysis is done on piston to validate the strength and heat transfer rate of this designed model. Analysis is done for different materials Cast Iron and Aluminum Alloy, Aluminum alloy 7475 and Aluminum alloy 6061.By observing the analysis result, the obtained stress values are less than their respective permissible stress values. So it can say that design is safe under working conditions. When comparing the stress and deformation values for all materials, they are less for Aluminum Alloy 7475. When comparing the thermal property heat flux for all the materials, it is more for Aluminum Alloy 7475 (i.e) heat transfer rate is more. So from the above data, its conclude that for designed piston Aluminum Alloy 7475 is better

References

[1] A. R. Bhagat and Y. M. Jibhakate, "Thermal Analysis and Optimization of I.C. Engine Piston using finite element method" International Journal of Modern Engineering Research Vol.2, Issue.4, July-Aug 2012, pp-2919-2921

[2] S. Srikanth Reddy, Dr. B. SudheerPrem Kumar "Thermal Analysis and Optimization of I.C. Engine Piston using finite element method" International journal of innovative research in science, engineering and technology. Vol. 2, Issue 12, December 2013, PP-7834-7843

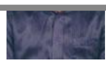
[3] Swati S Chougule, Vinayak H Khatawate "Piston Strength Analysis Using FEM" International Journal of Engineering Research and Applications Vol. 3, Issue 2, March -April 2013, pp.1724-1731

[4] Praful R. Sakharkar ,Avinash M. Wankhade "Thermal Analysis of IC Engine Piston Using FEA" International Journal of Engineering Science and Technology (IJEST), Vol. 5 No.05 May 2013, PP-75-77.

[5] VinodYadav and Dr.D.N.Mittal "Design and Analysis of Piston Design for 4 Stroke Hero Bike Engine" International Journal of Engineering Innovation &Research ,Volume 2, Issue 2, PP.148-150.

[6] Shuoguo Zhao" Design the Piston of Internal Combustion Engine by Pro\ENGEER" 2nd International Conference on Electronic & Mechanical Engineering and Information Technology (EMEIT-2012), Published by Atlantis Press, Paris, France. pp. 2163-2166.

Author Profile



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