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Design of Piston Using Hybrid Materials

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***Abstract*-From very beginning days piston has been made up of cast iron or Aluminium for their high heat transfer rate. After some days cast iron expands much more on heating that it overcomes the clearance level that comes to seize the engine. This paper aims to design a piston using composite material that will differ from traditional engine piston which will be partially reinforced like Al-Si or Al-Mg as it produces a layer between reinforced and unreinforced layer. In this paper Al-Si-Mg composite has been tested for manufacturing of piston. Design calculations of piston is prepared from Al-Si-Mg properties and model is prepared by using Pro-E , finally analysed on ANSYS. The modified piston model has been successfully designed in this paper which posses the benefits of mass and cost reduction compared to the traditional piston..**

1. INTRODUCTION

Composite material refers when it consists of more than two or more metals. That does not matter having similar physical and chemical properties. For any specific carbon and glass fibre based composite materials often referred as 'composite' like polymer matrix, metal-matrix and ceramic composites. Subsidiarily some reports indicate importance of inter metallic matrix composites and especially for AMC (Aluminium Matrix Composites). In AMC generally the content is aluminium or Aluminium Alloys, matrix which serve as reinforcement that is usually not metallic and most commonly used ceramic for these days are Sillicon Carbide and Aluminium Oxide.

Piston is used in combustion engine. It is supposed to expand due to gas inside the cylinder to crank shaft or connecting rod. Basically it reduces gas pressure and this work may cause fatigue to piston. This states that greater stress is developed at the top part of the piston and high stress developed here. This is the main reason for failure in it. Basically engines has 2 kinds of its own.

1. External Combustion Engine:

When working fluid inside the engine is heated outside by an external source. The working fluid is heated by external source in an automobile

2. Internal Combustion Engine:.

This is a kind of engine where kindling of fuel is held in the interior part by an oxidiser (generally air).

In Internal combustion engines, temperature and pressure applied on it is very high due to direct force applied in it. Application of Force is done by piston. Hence this is mandatory to keep an eye to the material of piston.

From previous days Piston is generally made up of Cast iron then with successful research, as Al-Si alloys give greater efficiency with less material cost and it got a revolutionary change in manufacturing of piston. Automobiles are in distinguished appetite because of its improved efficiency with reduced cost. Scientists are still developing critical components with shortest possible optimization and quick absorption in progress of advanced products. Here material preferred is Al-Si-Mg because of some major advantages of AMCs compared to unreinforced materials are as follows:

1) Improved strength
2) Greater stiffness
3) Reduced weight i.e. Density
4) Sustain at elevated temperatures
5) Higher thermal expansion coefficient
6) Enhanced electrical performance
7) Higher abrasion and wear resistance

[**TABLE 1**]
[Properties of Al – Si – Mg][12]

Property	**Value**
Bulk Modulus	67GPa
Density	2.7g/cm^3
Young’s Modulus	69GPa
Elongation at Break	9 – 25%
Electrical Conductivity	40-58% IACS
Fatigue Strength	55-97 Mpa
Hardness	25-95
Shear Modulus	34GPa
Shear Strength	70-207MPa
Specific Heat Capacity	2400 kJ/m^3-K
Ultimate Strength	310MPa
Yield tensile strength	276 MPa
Thermal Conductivity	188 W/m-K

2. PROCEDURE FOR PISTON DESIGN

Design of piston has been initiated by taking dimension of piston as

Diameter of bore = 138mm
Length of Piston = 150mm

Taking properties from TABLE I following piston parameters have been derived.

- Thickness of piston head (T_h)
- Heat flows through the piston head (H)
- Radial thickness of the ring (t1)
- Axial thickness of the ring (t2)
- Width of the top land (b1)
- Width of other ring lands (b2)

According to Grashoff’s formula

$T_h = \sqrt{\frac{3PD^2}{16\sigma}}$ in mm

Where

P = maximum pressure due to fuel in N/mm²

D = cylinder bore / outside dia of the piston in mm.

Δt = maximum allowable stress for the material of the piston. Here the material is a particular grade of Al-Si-Mg alloy whose permissible stress is 50 Mpa-90Mpa. For calculation of thickness of piston head, the diameter of the piston is to be specified as 138mm.

The heat flow through the piston head is deliberated as

$H = 12.56 * T_h * k * (t_c - t_e)$

Where

k = thermal conductivity of material which is 174.15W/mk for Al-Si-Mg alloy

t_c = temperature at center of piston head in °C.

t_e = temperature at edges of piston head in °C

2.1. Radial Thickness of Ring (t1)

$t1 = D\sqrt{\frac{3P_w}{\sigma_t}}$

Where D = cylinder bore in mm

Pw = pressure exerted by fuel on cylinder wall in N/mm². Its value ranges from 0.025N/mm² to 0.042N/mm².

For Al-Si-Mg material here Δt is considered as 90Mpa i.e. for maximum stress we are calculating design considerations.

2.2. Axial Thickness of Ring (t2)

The thickness of the rings can be calculated as

t2 = 0.7t1 to t1

Let assume t2 = t1

2.3. Width of the top land (b1)

The width of the top land varies from

b1 = tH to 1.2*tH

i.e. b1=32.544

2.4. Width of other lands (b2)

Width of other ring lands varies from

b2 = 0.75t2 to t2

i.e. b2=2.7105mm

2.5. Maximum Thickness of Barrel (t3)

t3 = 0.03*D + b + 4.5 mm

Where b = Radial depth of piston ring groove

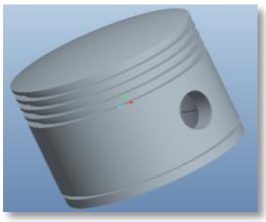
Here as per the calculated values these values are summarised as shown in Table 2.

[TABLE 2]
[Calculated values as per properties from Table 1]

Serial Number	Design Parameters	Size in mm
1	Length of the Piston (L)	150
2	Cylinder Bore dia OR Outside diameter of piston (D)	138
3	Thickness of piston Head (T_h)	32.544
4	Radial thickness of ring (t1)	2.78
5	Axial thickness of ring (t2)	1.946
6	Width of top land (b1)	39.0598
7	Width of other ring lands (b2)	1.4595

Piston during working exposes to high amount of gas pressure and subjected to a very high temperature value. At the mean time its another end is connected to small end of connecting rod with piston pin. So to make the piston withstand gas pressure considered as 18MPa applied at uniform pressure over top surface of piston i.e. crown all degrees of freedom will b restricted. For design consideration the fit is considered to be clearance fit.

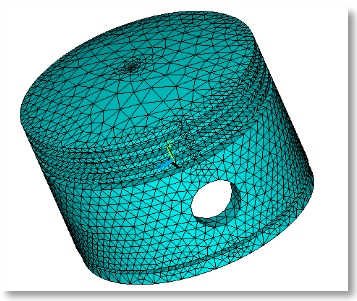
A piston model is prepared using TABLE 2 software Using TABLE 2 values piston model is prepared using Pro-e software as shown in Fig 1.



[Fig 1 ProE Model of piston]

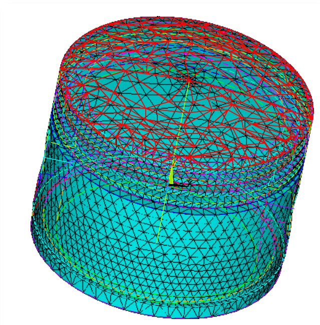
The Piston choosen here is solid187 tetrahedron shape which is a higher order tetrahedron element. This mesh counts for model containing 71910 number of nodes and 41587 elements. Following are the different types of results with the given boundary conditions as we need to fix the two rings in the piston and the pressure is applies on the upper part of the piston as about 18 Mpa. Based on the properties of Al we got the following results.

Here is mesh view represented by Fig 2.



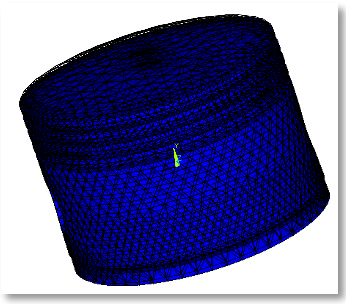
[Fig 2 Mesh View]

As mentioned above showing the loading and boundary conditions are taken for analysis. Uniform pressure of 18MPa applied over crown of piston and derived as Fig 3 below. Red colour shows effect after applying pressure on the piston



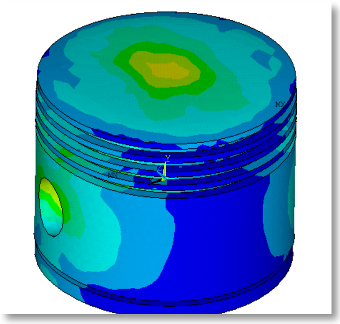
[Fig 3 After Application of pressure]

Then we get deformed shape as below in Fige 4
After this, for preparing FEM screenshot is attached below Fig 4. Here we got the displacement of 0.02721 after applying the pressure of 18 MPa.



[Fig 4 Deformed Shape]

After obtaining deformed shape we get Vonmisses Stress escribed in Fig 5



[Fig 5-Vonmisses Stress]

Factor of Safety
= Yield Strength / Max Stress
= 435 / 251.13
= 1.75

This design is Safe as it is more than 1.5

5. CONCLUSION

It has come to knowledge form this above that's fatigue is not prominent reason to get damage of pistons for this paper work, If we get to analysis from previous days maximum deflection is about 0.02721 which is reasonable for application 180 bar gas pressure over the crown of piston. So changing the material of piston to Al-Si-Mg is safe as well as economic. As design value is still safe even after getting shorten value of length and diameter we can think of giving tolerance to the piston so that it can identify the knock

6. SCOPE OF FUTURE WORK

Simulation can be done using MATLAB A provision of knock sensor with required tolerance and design calculations can be introduced in future work.

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REFRENCES

1. N. K. Chougule, *CAD/ CAM / CAE* by Scitech Publication , 2009
2. M.L. Mathur and R.P. Sharma , *Internal Combustion Engines*, Dhanpat Rai Publication
3. www.ansys.com
4. A.S. Khurmi , J.K. Gupta, *A Text Book of Machine Design*, EURASIA PUBLISHING HOUSE Private Limited .,3rd Edition
5. A.R.Bhagat ,"Thermal Analysis & Optimization of Internal Combution Engine Piston using Finite Element Method",
6. Ch.Venkata Rajam, *"Design Analysis and Optimization of Piston using CATIA and ANSYS"*, International Journal of Innovative Research in Engineering & Science, January 2013, issue 2 volume 1
7. Ghodake A. P. , *Piston Design and Analysis by CAE Tools,* 22 JULY 2002, IOSR Journal of Engineering (IOSRJEN), IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-3021 ISBN: 2878-8719 PP 33-36
8. Konstantinos G. Dassios , *"A. P Mechanical properties of alumina Nextel TM 720 fibres at room and elevated temperatures: tensile bundle testing*". IOSR Journal of Engineering (IOSRJEN)
9. Varuzan Kevorkizan, *"Development of AL MMC composite" ,Yugoslav Association of Metallurgy"* process,UDC:669.715/419.7:629.11=20
10. Wu Shenqing & Li Jun, "*Application of ceramic short fiber reinforced Al alloy matrix composite on piston forinternal combustion engine"*,China Foundry,Vol 7,No 4
11. Shigley, *A text book for design machine elements " Shigley's Mechanical Engineering Design*"
12. http://www.makeitfrom.com/material-data/?for=Aluminum-Magnesium-Silicon-Wrought-Alloy-6000-Series.