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Design and Analysis of Piston Using Composite Material

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ABSTRACT

In an engine, the piston is used for transfer force from expanding gas in the cylinder to the crankshaft via a piston rod. Piston has to endure the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of the piston such as piston side wear, piston head cracks and so on. Usually tons are made of Aluminium for lightweight, thermal conductivity. But it has poor hot strength and high coefficient of expansion makes it less suitable for high temperature applications. In this project, Aluminium Silicon Carbide (AlSiC),an Aluminium matrix composite used as an alternative for Aluminium. A 3D model was made using ANSYS 15 and thermal analysis was done on ANSYS 15.Compared to aluminium,AlSiC has better abrasion resistance ,creep resistance, dimensional stability, exceptionally good stiffness-to-weight and strength-to-weight ratios and better high temperature performance. Fabrication of piston using AlSiC is also easier than using Aluminium.
Keywords: AlSiC Composite, Piston, ANSYS 15

I. INTRODUCTION

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. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via piston rod and or connecting rod.

Piston has to endure the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of the piston such as piston side wear, piston head cracks and so on. Usually the pistons are made of Aluminium because of lightweight and thermal conductivity. However, it has poor hot strength and high coefficient of expansion makes it less suitable for high temperature applications.

In this project, Aluminium Silicon Carbide (AlSiC), an Aluminium composite is used as an alternative for Aluminium. A 3D model was made using ANSYS 15 and the thermal analysis also was done on it.Compared to Aluminium AlSiC has better abrasion resistance, creep resistance, dimensional stability, exceptionally good stiffness to-weight ratios and better high temperature performance. Fabrication of piston using AlSiC is also easier than Aluminium. The effect of high temperature on mechanical properties of silicon carbide particulate reinforced cast Aluminium alloy composite is analysed. In addition, an extensive literature survey has been done to collect the material properties of AlSiC.

II. METHODS AND MATERIAL

A. Problem Formulation:

The objective of the present work is to design and analysis of pistons made of Aluminium alloy, Titanium alloy, AlSiC composite, and Grey cast iron. In this paper the materials(Aluminium alloy, Grey cast iron and Titanium alloy) are replaced with AlSiC.Piston models are created in ANSYS 15.After analysis a comparison is made between existing Aluminium alloy , Titanium alloy and Grey cast iron pistons viz AlSiC in terms of thermal conductivity, coefficient of heat transfer and high temperature distribution.

B. Methodology:

- Analytical design of pistons using specifications of four-stroke diesel engine.
- Creation of 3D models of piston using ANSYS
- Meshing of 3D models using ANSYS.
- Analysis of pistons using Transient thermal analysis method.
- Comparative performance of four materials piston under transient thermal analysis method.
- Comparative performance of the four materials (Titanium and Aluminium alloys, Grey cast iron and AlSiC) pistons under thermal analysis i.e. the pistons are subjected to a uniform gas pressure and constant temperature distribution.
- Select the best-suited material.
- Optimize the model and under Transient thermal analysis.

2.1 Engine specification:

The engine used for this work is a single cylinder four stroke water-cooled type vertical diesel engine. The engine specifications are given in Table 2.1

PARAMETERS	VALUES
Engine Type	Fourstroke,Vertical Diesel engine
Induction	Water cooling
Number of cylinders	Single cylinder
Bore	114.3mm
Stroke	139.7mm
Brake Power	6HP
Speed	650 rpm

Table 2.1 Engine Specifications

2.2 Analytical Design

Let

B.P = brake power (W)

ɳ = mechanical efficiency=74.64%

n = number of working stroke per minute = N/2(for four-stroke engine)

N = engine speed (rpm)

L = stroke length (mm)

t_h = thickness of the piston head(mm)

D = cylinder bore (mm)

P_{max} = maximum gas pressure or explosion Pressure (N/mm^2)

n_r = no of rings= 4

σ_b = allowable tensile strength (N/mm^2)

t_1 = radial width of ring (mm)

b_1 = width of top land (mm)

b_2 = width of other ring lands (mm)

t_3 = maximum thickness of barrel (mm)

Ls = length of skirt (mm)

d_o = piston pin outside diameter (mm)

Brake power of the engine=6HP=6*736=4416W

Bore diameter, D = 114.3mm

Stroke length, L = 139.7mm

Speed, N= 650 rpm

Indicative power IP= B.P+F.P=4416+1500=5916W

Where, F.P= 1500W

ɳ = 4416/5916=74.64%

IP = P_m*(π*D^2)/4*L*N/2

P_m = (5.916*60*4*2)/ (0.1397* π*0.1143*650)

=761933 N/m^2 = 0.7619 N/mm^2

P_{max}= 10*0.76=7.6N/mm^2

Thickness of the Piston Head

According to Grashoff's formula the thickness of piston head is given by

$$t_h = D\sqrt{(3P_{max}/16\ \sigma_b)}$$

Where, σ_b = 60N/ mm^2

Therefore t_h = 114.3*√ ((3*7.6)/16*60)=27.60mm

Piston Rings

The radial width of the ring is given by:

$$t_1 = D\sqrt{(3*P_w/P_b)} = 114.3*0.02886 = 3.3mm$$

Axial thickness of the piston ring is given by:

$$t_2 = (0.7\ t_1 \text{ to } t_1) = 0.7*3.3 \text{ to } 3.3 \approx 3mm$$

Width of Top land and Ring lands

Width of top land:

$$b_1 = (t_h \text{ to } 1.2\ t_h) = 27.60mm$$

Width of ring land:

$$b_2 = (0.75\ t_2 \text{ to } t_2) = 0.75*3 = 2.25mm$$

Piston Barrel

Thickness of piston barrel at the top end:

$$t_3 = 0.03D + t_g + 4.5 \text{ mm}$$
$$= 0.03*114.3+3.3+4.5 = 11.63mm$$

Thickness of piston barrel at the open end:

$$t_4 = (0.25\ t_3 \text{ to } 0.35\ t_3)$$
$$= 0.25*11.63 \text{ or } 0.35*11.63 = 2.9 \text{ or } 4.07$$
$$\approx 3.8mm$$

Length of the skirt

Ls = (0.6D to 0.8D) =0.6*114.3 mm

Length of piston pin in the connecting rod bushing

L_1 = 45% of the piston diameter

= 0.45 * 114.3= 51.435 mm

Piston pin diameter

d_o = (0.28 D to 0.38D)=0.28*114.3

= 32mm

The centre of the piston pin should be 0.02D to 0.04D above the centre of the skirt, adopt 0.02D=4.572mm

2.3 Creation of 3D models of piston using ANSYS

Following are the sequence of steps in which the piston is modelled:

- Firstly, key points are generated.
- A straight line is drawn through the key points to form a half portion of the piston.
- Fillets are applied.
- Area command is applied and revolve option is given according to symmetry.
- Finally, the hole is made.

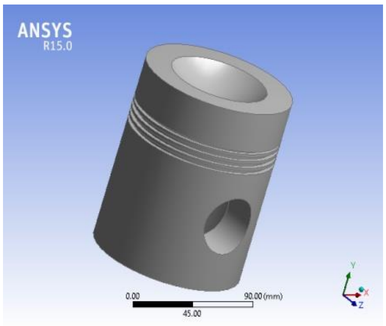


Figure 2.1 Model of the piston

2.4 Meshing of 3D model of Piston

For Transient thermal analysis, the element used is 43919-node tetrahedron shape meshing with 26675 elements. Element size is 12 mm.

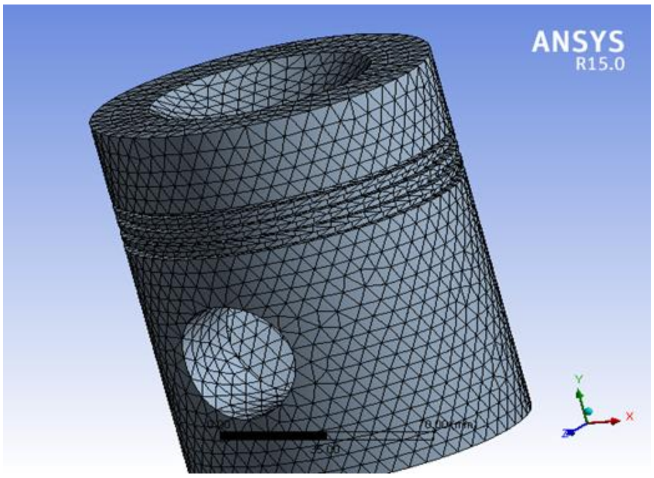


Figure 2.4 Meshing of Piston

2.5 Analysis of piston using Transient thermal analysis method

- Frictionless support at pin bore area is considered
- Downward pressure(7.6 N/mm^2) to gas load acting on piston head
- Temperature and heat transfer coefficients are applied to the piston

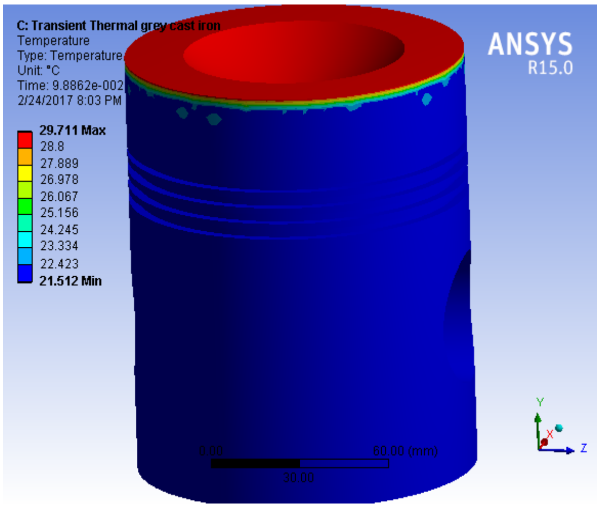
The different thermal properties of materials for analysis are shown in the table below:

Material	Maximum temperature given (°C)	Thermal conductivity (W/m°C)	Specific heat capacity (J/kg°C)
Aluminium alloy	600	175.24	875
Grey cast iron	600	52	447
Titanium alloy	600	21.9	522
AlSiC	600	197	894

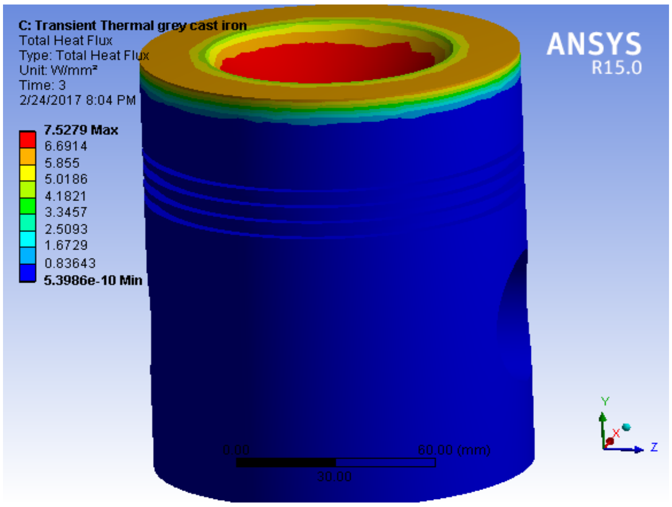
Table 2.2 Temperature given and thermal Conductivity of the materials

III. RESULTS AND DISCUSSION

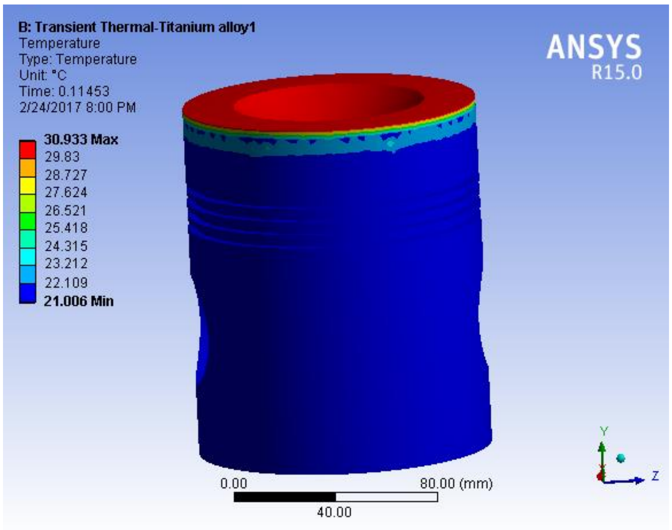
The results obtained are shown below:



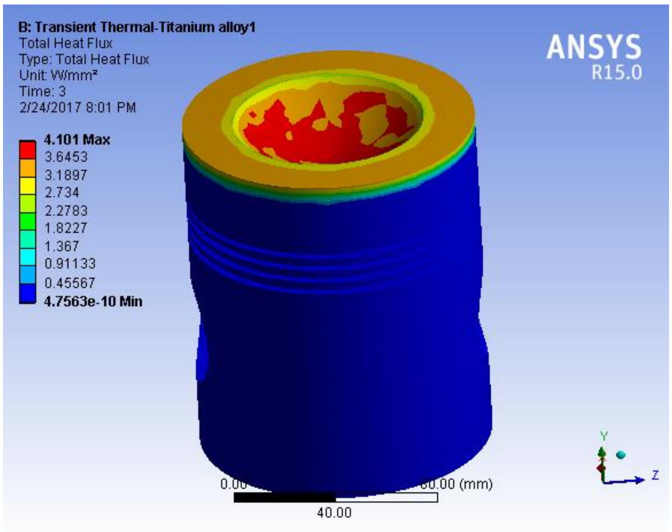
a) Grey cast iron temperature distribution



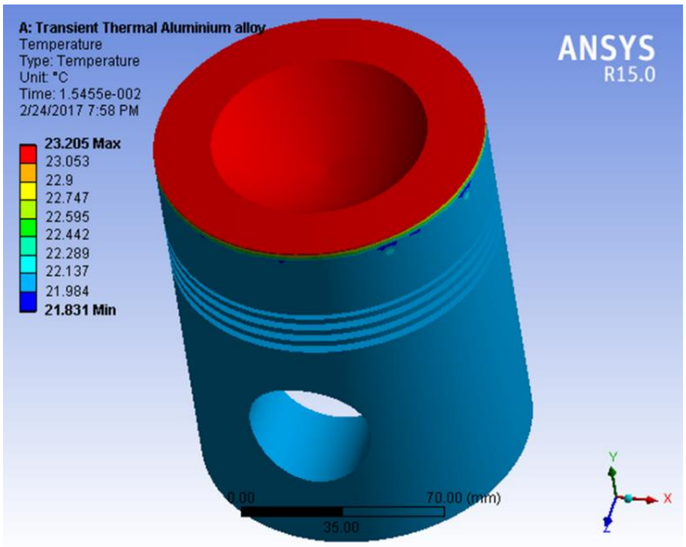
b) Grey cast iron total heat flux distribution



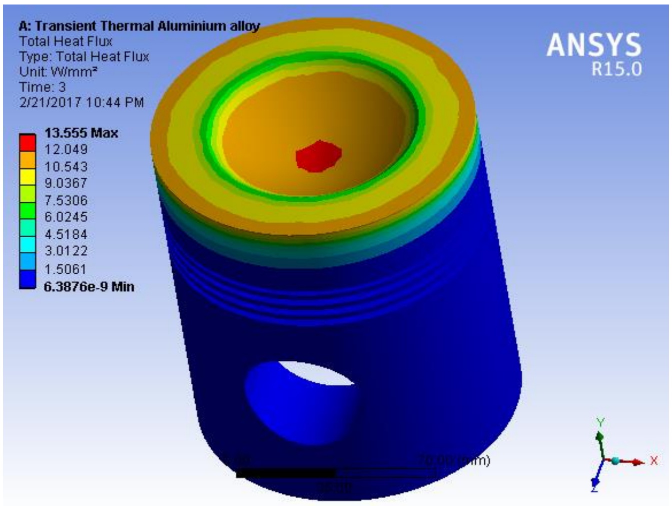
c) Titanium alloy temperature distribution



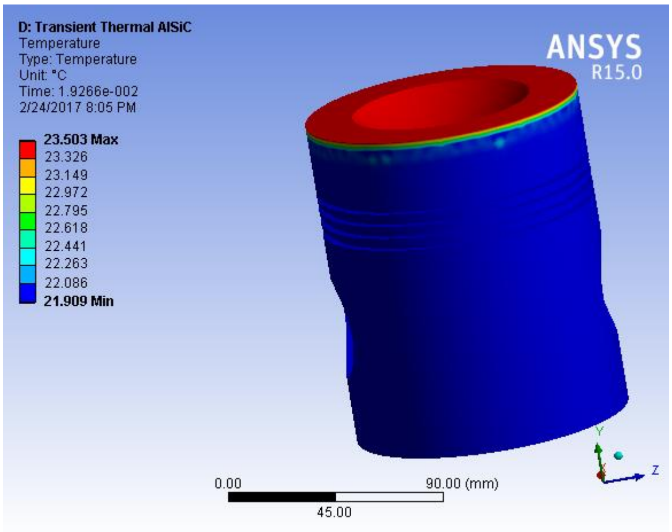
d) Titanium alloy total heat flux distribution



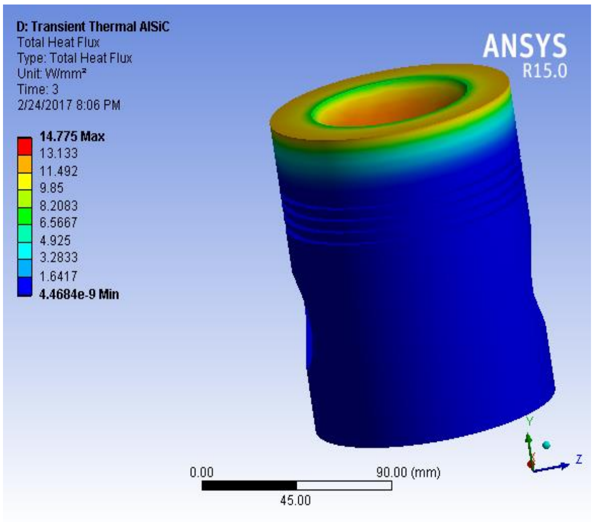
e) Aluminium alloy temperature distribution



f) Aluminium alloy total heat flux distribution



g) AlSiC composite temperature distribution



h) AlSiC composite total heat flux distribution

The comparison for the temperature distribution and Total Heat flux distributions of different materials are shown in the table below:

Material	Maximum temperature (°C)	Minimum temperature obtained (°C)	Total heat flux (W/mm²)
Grey cast iron	600	21.512	7.5279
Titanium alloy	600	21.006	4.101
Aluminium alloy	600	21.831	13.555
AlSiC Composite	600	21.909	14.775

Table 3.1 Results obtained after analysis

It is clear from figures and Table 3.1 Thermal analysis of piston shows that the value of maximum temperature is same for all the materials at the top surface of the piston crown, but minimum value of temperature in the piston made of Titanium alloy. The highest value of minimum temperature is found in the piston of AlSiC composite. This is due to thermal conductivity of materials. Minimum temperature is in the skirt of the piston is observed as shown in figures a, c, e& g.

Figures b, d, f, & h shows that max total heat flux is observed in piston of AlSiC composite and piston of Titanium alloy shows the lowest value of max total heat flux along the edges.

IV. CONCLUSION

It is conclude from the above study that using ANSYS 15 software design and modelling become easier. Only few steps are needed to make drawing in three dimensions. Same can be imported to analysis in ANSYS itself. Piston made of four different materials Grey cast iron, Titanium alloy, Aluminium alloy and AlSiC composite. Their Transient Thermal analysis shows that Maximum temperature is found at the centre of the top surface of the piston crown. This is equal for all materials .Depending on the thermal conductivity of materials, heat transfer rate is found maximum in AlSiC composite piston and minimum in Titanium alloy piston. The maximum total heat flux is different for the materials and shows maximum value for AlSiC composite material which show that this piston had high withstanding capacity at higher temperatures.i.e, it can with stand at higher temperature distributions than all other materials. For the given loading conditions AlSiC Composite is found most suitable. But when the loading pattern changes other materials may be considered. With the advancement in material science, very light weight materials with good thermal properties can be used for fail safe design of the I.C.engine. This will reduce the fuel consumption and protect the environ ment.

V. REFERENCES

[1]. Abino john, Jenson T Mathew, Vasdev Malhotra, & Nitin Dixit,"Design and Analysis of Piston by SiC Composite Material" IJIRST, volume 1, issue 12, May 2015
[2]. Isam Jasim Jaber and Ajeet Kumar Rai "Design and Analysis of I.C.Engine Piston and Piston ring using CATIA and ANSYS software" IJMET, ISSN 0976-6359, volume 5, Issue 2, February 2014, pp.64-73
[3]. DeovratVibhandi, AmeyaPradhan, SampadaMhaskar Nikita Sukthankar and Atul Dhale"Design Analysis And Optimization of Piston and Determination of its Thermal stresses using CAE Tools" IJESRT,ISSN: 2277-9655,May 2014
[4]. Ajay Raj Singh, Dr.Pushpendra Kumar Sharma "Design, Analysis and Optimization of Three Aluminium Piston Alloys using FEA" IJERA, ISSN: 2248-9622, vol.4,Issue1(version3,January 2014),pp. 94-102