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Thermal analysis of Aluminum alloy Piston

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ABSTRACT
In this study, Work is carried out to find out the thermal distribution on different Piston Materials used. In IC engine Piston is one of the most important and complex part, so it is important to maintain Piston in good condition in order to maintain the proper functioning of the engine. Piston mainly fails due to thermal Conditions. So as to search out proper thermal distribution different Piston Materials are considered.

Key words:. *:* IC engine, Piston, ANSYS, Piston Materials, WB-Modeller, aluminium alloys.

1. INTRODUCTION

Function of the piston

The piston as an element of power transmission

In the cylinder of an engine , the energy bounded up in the fuel is rapidly converted into heat and pressure during the combustion cycle. The heat and pressure values increase greatly within a very short period of time. The piston as the moving part of the combustion chamber has the task of converting this released energy into mechanical work.

The basic structure of the piston is a hallow cylinder, closed on one side, with the segments piston crown with ring belt, pin bass and skirt. The piston crown transfers the gas forces resulting from the combustion of the fuel air mixture via pin boss, the piston pin, and the connecting rod to the crankshaft.

The gas pressure against the piston crown and the oscillating initial forces, reflected to in the following as the inertia force, of the piston and connecting rod constitute the piston force. Due to the redirection of the piston force in the direction of the connecting rod (rod force) an additional component arises, following the force parallelogram namely the lateral force also known as the normal force. This force pressure the piston skirt against the cylinder bore. During a combustion cycle, the lateral force changes direction several times, which pressures the piston from one side of the cylinder bore to other, due to the existing piston clearance.

The most important tasks that the piston must fulfill are

- Transmission of force form and to the working gas.
- Variable bounding of the working chamber (cylinder)
- Sealing off the working chamber
- Linear guiding of the conrod (trunk piston engines)
- Heat dissipation
- Support charge exchange by drawing and discharging (four-stroke engine)
- Support mixture formation (by means of suitable shape of the piston surface on the combustion chamber side)
- Controlling charge exchange(in two-stroke engine)
- Guiding the sealing elements (piston)
- Guiding the conrod (for top guided conrode)

As the specific engine output increase, so do the requirements on the piston at the same time.

2. MATERIAL PROPERTIES

Table 1: AlSi Material properties

S No	Properties	Value
1	Young’s modulus	2.3×10^5Mpa
2	Poisons ratio	0.24
3	Density	2937 kg/m^3
4	Thermal conductivity	197 W/m^{0}C
5	Specific heat	894 J/kg^{0}C

Table 2: Al-Mg-Si Material properties

S No	Properties	Value
1	Young’s modulus	0.7×10^5 Mpa
2	Poisons ratio	0.33
3	Density	2700 kg/m^3
4	Thermal conductivity	200 W/m^{0}C
5	Specific heat	898 J/kg^{0}C

Table 3: AlSiC-10 Material properties

S No	properties	Value
1	Young’s modulus	1.67×10^5 Mpa
2	Poisons ratio	0.251
3	Density	2960 kg/m^3
4	Thermal conductivity	190 W/m^{0}C
5	Specific heat	786 J/kg^{0}C

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Table 4: AlSiC-12 Material properties

S No	properties	Value
1	Young's modulus	1.67×10^5 Mpa
2	Poisons ratio	0.21
3	Density	2890 kg/m^3
4	Thermal conductivity	170 W/m^0C
5	Specific heat	808 J/kg^0C

3. THEORITICAL CALCULATION

Maximum Heat flux of the piston crown

$$q = -k \frac{dT}{dx} \text{……………………..From Fourier's law}$$

K= Thermal conductivity of piston material
dT=Temperature gradient (T_2-T_1)
dx=Thickness of the top land of the piston (t)

$$q = -k \frac{(T_2 - T_1)}{t}$$

T_2= Temperature of the top surface of the piston crown.
T_1=Temperature of the Bottom surface of the piston crown.
t = Thickness of the top land of the piston

Case-I Maximum Heat flux in AlSi Alloy Piston

$$q = -k \frac{(T_2 - T_1)}{t}$$

$$q = -197 \times \frac{(400-150)}{13 \times 10^{-3}}$$

$$= 3.788 \times 10^6 \ W/m^2$$

Case-II Maximum Heat flux in Al-Mg-Si Alloy Piston

$$q = -k \frac{(T_2 - T_1)}{t}$$

$$q = -200 \times \frac{(400-150)}{13 \times 10^{-3}}$$

$$= 3.846 \times 10^6 \ W/m^2$$

Case-II Maximum Heat flux in AlSiC-10 Alloy Piston

$$q = -k \frac{(T_2 - T_1)}{t}$$

$$q = -190 \times \frac{(400-150)}{13 \times 10^{-3}}$$

$$= 3.653 \times 10^6 \ W/m^2$$

Case-II Maximum Heat flux in AlSiC-12 Alloy Piston

$$q = -k \frac{(T_2 - T_1)}{t}$$

$$q = -170 \times \frac{(400-150)}{13 \times 10^{-3}}$$

$$= 3.269 \times 10^6 \ W/m^2$$

4. PISTON DESIGN

The piston is designed according to the procedure and specification which are given in machine design and data hand books. The dimensions are calculated in terms of SI Units. length, diameter of piston and hole, thicknesses, etc., parameters are taken into consideration.

Table 4: Geometrical values

S NO.	Dimensions	Size Ranges (mm)	Preferable Size (mm)
1	Cylinder Bore, D	---	140
2	Width of the land	7 to 14	13
3	Height of the piston, H	112to182	150
4	Distance from the top to the axis of piston pin, h_1	63to 65.8	64
5	Diameter of thickness of piston pin, d	42 to 70	50
6	Distance from the front to the first channel, e	8.4to16.8	12
7	Wall thickness between channels, h_n	4.2 to 7	5
8	Radial thickness of the piston ring t_r	4.48to6.3	5
9	Axial thickness of the piston ring t_a	4.48to6.3	5

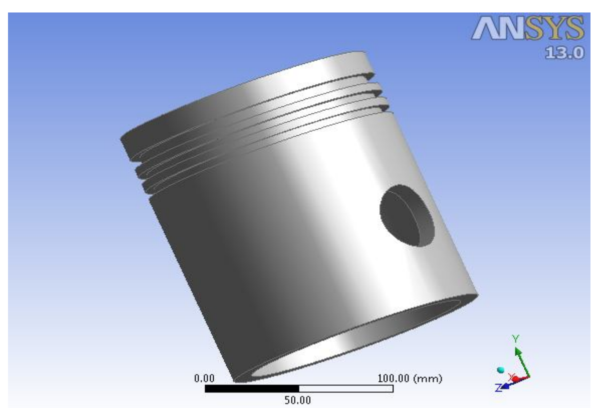

Figure 1:Modeling of the Piston

5. MESHING OF PISTON

The piston shape is irregular, especially in the presence of various curved surfaces of inner cavity. Firstly, Automatic

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meshing method is used to mesh the model. Element used is 20 node Tetrahedron named soilid90 . The element size is taken as 5, then total number elements were 11475 and nodes were 19591 found in meshed model.

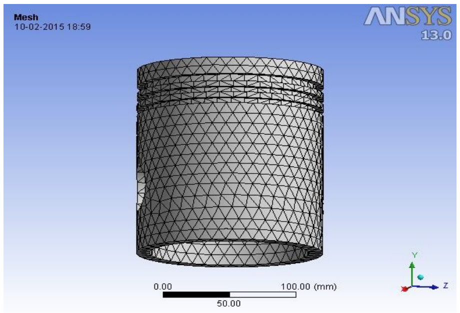

Figure 2:Meshing of the Piston

6. BONDARY CONDITIONS AND LOADS

- Maximum gas pressure at top surface of the piston 5MPa
- Temperature at Top surface of the piston 400°C
- Piston pin holes are fixed $D_x = D_y = D_z = 0$

7. RESULTS AND DISCUSSIONS

AlSi

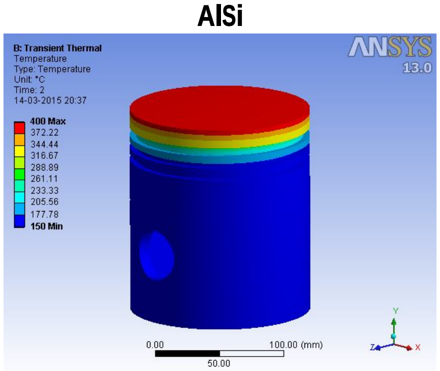

Figure 3; Temperature distribution for AlSi piston

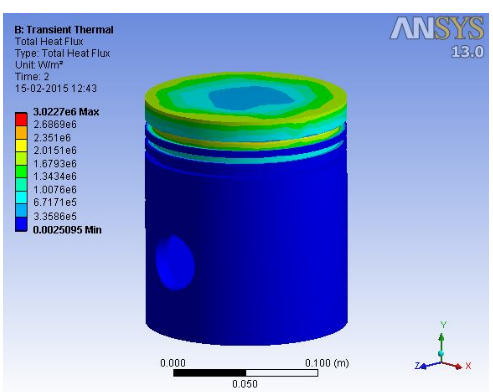

Figure 4: Total heat flux for AlSi piston

Fig (2) show the distribution of Temperature induced within the piston body. The maximum values of Temperature observed at top surface of the piston crown .

Fig (4) show the maximum total heat flux in the piston geometry due to the application of gas temperature is **3.0227 MW/m^2**, which is observed at the edge portion of the piston crown.

Al-Mg-Si

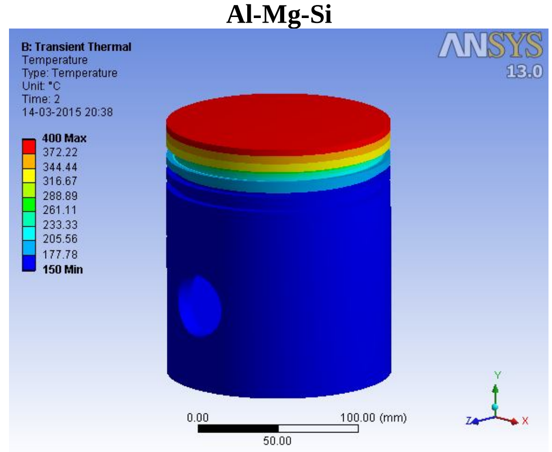

Figure 5: Temperature distribution for Al-Mg-Si piston

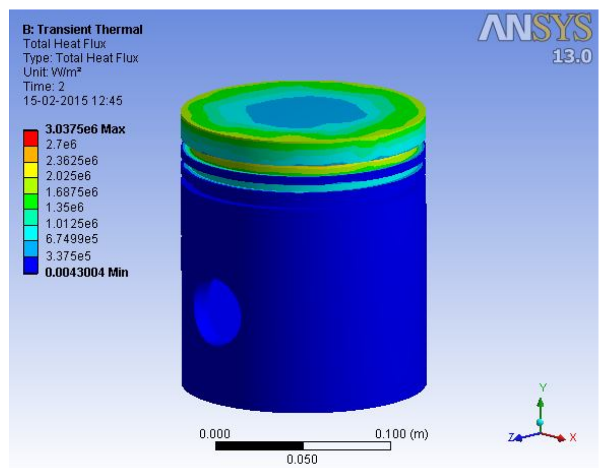

Figure 6: Total heat flux for Al-Mg-Si piston

Fig (5) show the distribution of Temperature induced within the piston body. The maximum values of Temperature observed at top surface of the piston crown.

Fig (6) show the maximum total heat flux in the piston geometry due to the application of gas temperature is **3.0375 MW/m^2**, which is observed at the edge portion of the piston crown.

AlSic-10

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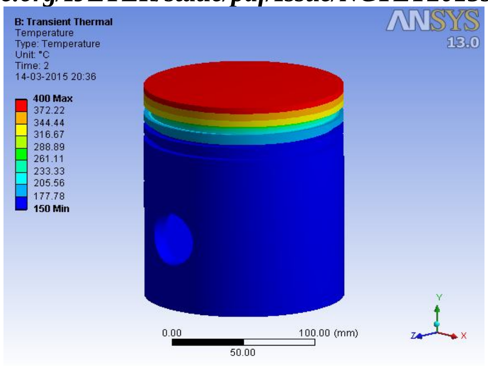


Figure7: Temperature distribution for AlSiC -10piston

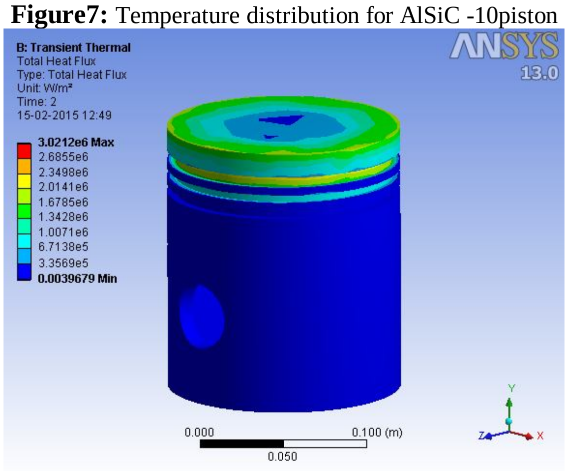


Figure 8: Total heat flux for AlSiC-10 piston

Fig (7) show the distribution of Temperature induced within the piston body. The maximum values of Temperature observed at top surface of the piston crown.

Fig (8) show the maximum total heat flux in the piston geometry due to the application of gas temperature is **3.0212 MW/m^2**, which is observed at the edge portion of the piston crown.

AlSiC-12

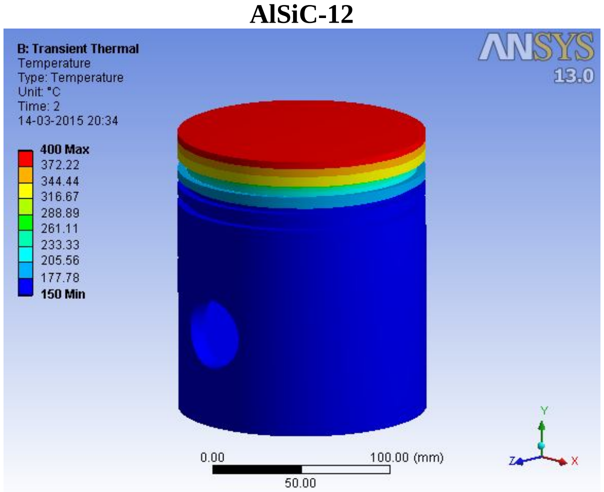


Figure 9: Temperature distribution for AlSiC -12piston

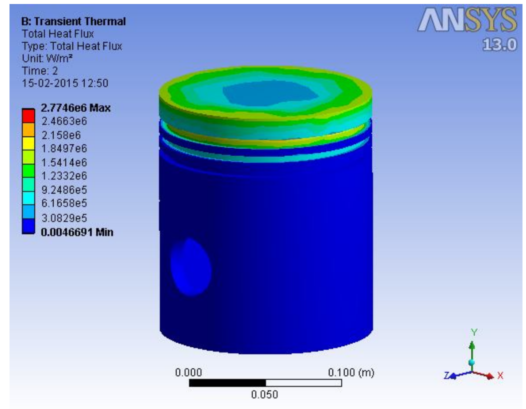


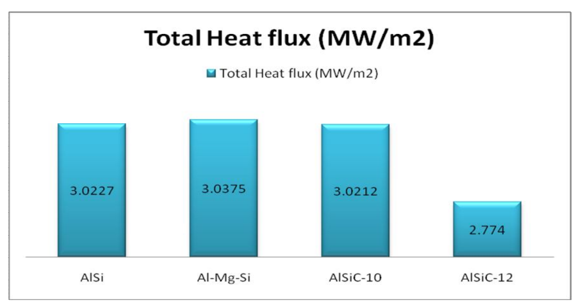
Figure 10: Total heat flux for AlSiC-12 piston

Fig (9) show the distribution of Temperature induced within the piston body. The maximum values of Temperature observed at top surface of the piston crown.

Fig (10) show the maximum total heat flux in the piston geometry due to the application of gas temperature is **2.774 MW/m^2**, which is observed at the edge portion of the piston crown.

Table 4: Results

SNo	Material	Total Heat flux (MW/m^2)
1	AlSi	3.0227
2	Al-Mg-Si	3.0375
3	AlSiC-10	3.0212
4	AlSiC-12	2.774



Graph 1: Total Heat Flux

Table 4: Comparison

S No	Material	Total heat Flux (MW/m^2)	
		Theoretical	Simulated
1	AlSi	3.788	3.0227
2	Al-MgSi	3.846	3.0375
3	AlSiC-10	3.653	3.0212
4	AlSic-12	3.269	2.774

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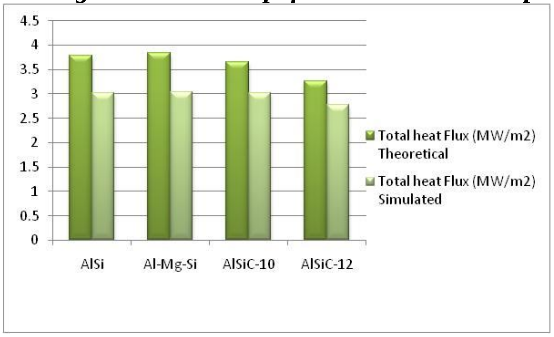

Graph 1: Total Heat Flux Comparison

5. CONCLUSION

1. From the analysis results of different material on piston is observed that total heat flux reduces in AlSiC composite compared to Al-Si, Al-Mg-Si, Alloy.
2. The maximum heat flux reduced by increases composition of carbides in AlSiC Alloy.
3. Results comparison between theoretical and analysis simulated done and found approximately same.

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