HEAT TRANSFER ENHANCEMENT FOR MULTI CYLINDER ENGINE PISTON AND PISTON RINGS

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ABSTRACT: A cylinder is a component of motors, pumps, and fuel compressors that react to commands. The purpose of a cylinder bar and also an associating bar in a motor is to shift the constraint from expanding gasoline within the chamber to the crankshaft. The materials used to make a cylinder determine not just its life and wear ability, but also its warm extension properties. It is contained inside a cylinder and is made gas-tight to piston rings. The majority of automobile engines have aluminum cylinders that are housed in an iron barrel. The normal temperature of a cylinder crown in a gas Engine during normal operation is approximately 300°C (573K), while the coolant that circulates through the Engine square is usually around 90°C (363K)

In this paper, the piston's thermal expansion characteristics are determined with the various materials, such as aluminum alloys 6061-T6, 7075-T6, and cast iron. Using Catia software, we designed two models of pistons flat head and piston rings, which were then thermally analyzed using solid works simulation. The total heat flux as well as the directional heat flux for both piston and piston ring were determined. And we need to figure out which material has the highest heat flux among cast iron, aluminum alloy steels 6061-T6, and 7075-T6 by comparing the respective outcomes of flat head piston and piston rings. To increase the heat transfer rate for piston and piston rings, the material with the highest total heat flux and directional heat flux should be chosen.

1. INTRODUCTION

a radiance Any engine or device that gets heat control from the ignition of gas or another source and transforms it into mechanical works of art is referred to as an engine.
A. External Combustion Engines are one kind of heat engine.
Internal Combustion Engines (I.C.E.) (I.C.E.)
In the External Combustion Engines scenario, gas combustion takes place outside of the chamber, much as it would in a steam engine, where the heat of ignition is utilized to generate steam, which is then used to drive a cylinder in a barrel.

Internal Combustion Engines (I.C.E.) (I.C.E.)

Inside the Engine's barrel, the gas is ignited with oxygen from the air. Inward ignition Engines include those that utilize mixes of burnable gases and air, called as gas Engines, those that use lighter fluid gas or soul, known as oil Engines, and those that use heavier fluid powers, known as oil pressure or diesel Engines. Despite the fact that inward ignition engines seem to be simple, they are very complicated machines. In order to offer yield vitality, many components must elegantly fulfil their capabilities.

2. LITERATURE REVIEW

[1] Ekrem Buyukkaya, Muhammet Cerit (2007) and colleagues evaluated a conventional (uncoated) diesel piston made of aluminum silicon alloy and steel in a study of the literature on increasing the heat transfer rate for multi-cylinder pistons and piston rings. To perform thermal tests on pistons coated with MgO– ZrO2 material, he utilized a commercial programmer called ANSYS. Finally, the results of four different pistons are compared. The effect of coatings on piston thermal behaviour is investigated.

[2] K. Bala Showry, Dr. A. V. S. Raju, Dr. P. Ravinder Reddy (2012) et al. presented a research on using Ansys to evaluate the stress distribution in various parts of the piston to identify the stresses caused by variations in gas pressure and temperature. The gasoline engine piston was subjected to a three-dimensional definite element analysis utilising the definite-element analysis software. Using the thermal boundary condition, the stress and deformation distribution conditions of the piston under the coupling impact of the thermal load and explosion pressure were calculated, providing a reference for design improvement. The findings show that temperature is the main cause of

piston safety, deformation, and excessive stress, and that by optimising the piston structure, the piston temperature may be lowered even further.

[3] U. I. Sjodin, U.L. O. Olofsson (2003) et al investigated early sliding wear on a piston ring in a radial piston hydraulic motor. The mass change and surface roughness of the initial sliding wear of a piston ring during run-in were investigated. The down motion test rig was developed. The two types of wear are mild wear and severe wear, with mild wear having a softer, smoother surface than the original and severe wear having a more forceful surface than the original. The piston ring wears the most at the asymmetric topmost at the outside surface contacting the cylinder bore. As a result, the roughness amplitude decreases rapidly at initially, and after a 10-meter sliding distance, it has decreased by one-third. The mass loss increased as the sliding distance grew, as seen in the graph. By adding material hardness data to the model, it may be utilized in the piston ring/cylinder bore system. The experiment resulted in the creation of a three-body abrasive wear model based on a laboratory simulator for simulating the wear development of the piston ring/cylinder bore system during steady state operation.

[4] A. Mohammadi, M. Yaghoubi, M. Rashidi (2007) and colleagues published a study on heat transmission and combustion in a four-stroke single cylinder engine with a pent roof combustion chamber geometry and two intake and two exhaust valves. With regard to crank angle position, heat flux and heat transfer coefficient on the cylinder head, cylinder wall, piston, intake and exhaust valves are calculated. The total heat transfer coefficient of the cylinder engine is compared to the available correlation provided by experimental measurement in the literature for a given situation, and close agreement is observed. The local value of the heat transfer coefficient was discovered to vary significantly in various sections of the cylinder, although they follow a similar pattern with crank angle. New correlations are proposed based on the findings to estimate the maximum and lowest convective heat transfer coefficient in a SI engine's combustion chamber.

3. DESIGN:

The design calculations are given as below

3.1 Piston:

Once the thickness of piston is 100 mm, and fabric is forged iron piston. For 15 kw and 2200 rpm velocity. Created on power care, the thickness of piston head is given finished:

$$t_1 = \sqrt{\frac{(3 P_{in} \mathrm{n}\, D^2)}{(16\, S_{tp})}}$$

Where,

P_{in} = Extreme fuel strain, in (N/mm^2) = 5 Mpa

D = Width of piston or Tube bore, in (mm) = 100 mm

S_{tp} = Acceptable tensile weight of piston cloth,

= 37.5 N/mm^2 for Cast Iron

$$t_1 = \sqrt{\frac{(3\times5\times100^2)}{(16\times37.5)}} = 16\text{mm}$$

Founded on Heat debauchery the top thickness is strong-minded as:

$$t_1 = \frac{(1000\text{H})}{(12.56\text{K}\,(\text{Tc}-\text{Te}))} = \frac{(1000\times5421.8)}{(12.50\ 6\times40\ 6.69\times10^{-2}\times(205))} = 14.78\text{mm}$$

Where,

H = Temperature graceful finished the head (KW)

= C×m×C_v×Pb=0.05 x 0.15 x 44 x 10^3 x 17.278 = 5421.8 KJ/h

C = Constant = 0.05

m = mass of the gas used (i.e., Fuel intake), in (Kg/KW/s) = 0.15 Kg/Kw/h

C_v = Advanced Fattening value of the Fuel = 44 x 10^3 KJ/Kg for Diesel

P_b = Brake vigour of the Engine in custody with cylinder (KW)

$= \frac{(\text{PLAn})}{(60\text{x}10^3)}$ = (0.5 x 10020 x 10¯3 x 0.00785 x 2200) / (60 x 10^3) =17.278KW

P = Footbrake mean effective heaviness = 0.5 Mpa

L = Blow length =100 to 20 mm

A = Area of the piston at its top side, in (mm^2) = $\frac{\Pi}{4}$x 100^2=4.00785mm^2

n = Quantity of control strokes in possession with miniature = 1

T_c = Hotness on the middle of piston skull (˚C)

T_e = Hotness at the edge of piston cranium (˚C) = 205˚C

a. Struts:

No of ribs = 6 ribs

The breadth of rib as:

t_2 = (0.3 to 0.5) x 16= 8 mm

b. Piston Rings:

Solidity hoops = 3 motionless

Lowest earrings = 1

Pc = trace pressure in N/mm^2 = 0.103 N/mm^2.

Now, the radial width:

$$t_3 = 100\sqrt{\frac{(3x0.103)}{90}} = 6 \text{ mm}$$

And the axial thickness,

t_4 = (0.7 to 1) x 6 = 5mm

S_{br} = allowable meandering stress for circle material (N/mm^2) = 90 N/mm^2 for CI

The first ring groove distance = t_1 to 1.2t_1 =16 from the pinnacle.

The lands amongst the trinkets = (0.75 to at 1) t_4 = 4mm

The gap amongst the moveable ends of the ring is occupied as C = (3.5 to 4) t_3 = 22mm

Piston barrel:

The supreme thickness of barrel faster to piston head is assumed by incomes of,

t_5 = 0.03D+b+0.5 = 0.03(100) + 6 +0.5 = 6.4mm

Where b = Circular depth of ring channel

= t_3 +0.4= 6+.4 =6.4mm

Depth of barrel at the unspoilt stop of piston is,

t_6 = (0.25 to 0.35) t_5 = 4 mm

c. Piston Skirt:

The facet thrust strain must no longer exceed 0.28 N/mm^2 for gradual velocity engines and 0.5 N/mm^2 for high pace machines.

Heaviness is given by way of F_s = μ F_g

Anywhere μ = co. Effectual of friction amongst lines and lies 0.03 to 0.1

F_g = gasoline pressure = $\frac{\Pi}{4}$ D^2 P_m = 70mm

The side thrust force = Side thrust weight / Projected Area = 100 to 150mm

Length of Skirt = L_s = $\frac{F_s}{(P_s \text{ x } D)}$

Where D = Bore width

Distance of Piston:

The period of piston, L_p = L_s + length of ring stage + highpoint land= 120mm

Empirically, L_p = D to 1.5D =100 to 150mm

gudgeon pin:

L=period of piston pin

D = diameter of piston jot

P_n = Permissible bearing density of piston =25N/mm^2

Being energy of piston pin

F_b = bearing stress x projected place = P_b x ℓ x d

By associating this being weight to fuel force

$P \times \ell \times d = F_g ; \frac{39270}{45} \times 25 = dp$

Where $F_g = \frac{\Pi}{4} \times D^2 \times Pm$

Usually, $\frac{\ell}{d} = 1.5$ to 2

The piston is checked for winding, as the activated Winding draining,

M = meandering instant = $\frac{(F_g \times D)}{8} = \frac{39270 * 100}{8} = 490875$ N-mm

S_b = permissible winding pressure

= 40 N/mm^2 for balminess dealt with blend metal

$S_b = \frac{(32\ M)}{\Pi d^3} < [S_b] = \frac{490875 \times 32}{\Pi \times 35^3} = 116.62$ N/mm^2<140 Mpa.
So, the plan is secure.

d. Design of piston in CATIA

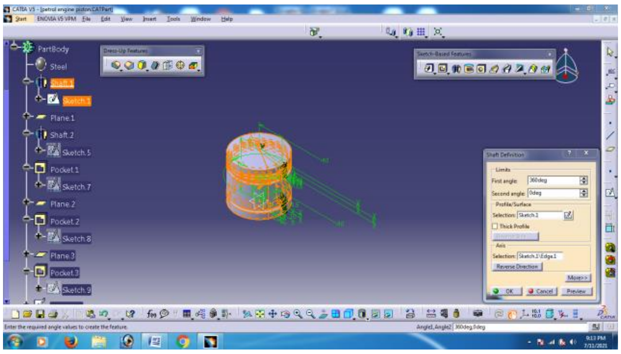

Fig: 3.1 piston sleeting file

Fig: 3.2 piston side view

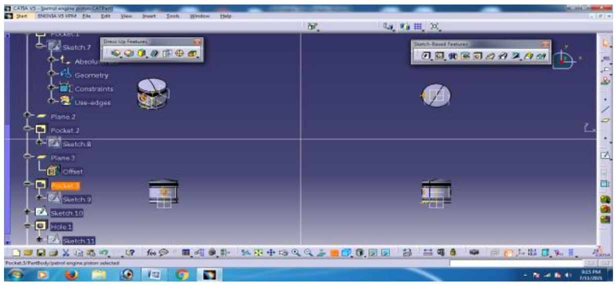

Fig: 3.3 Piston all view's

e. Design Of Piston Ring in Catia:

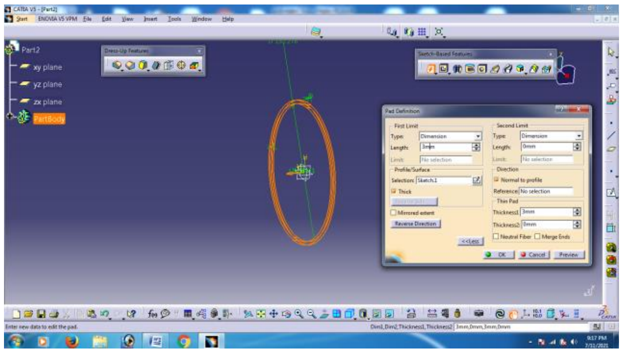

Fig: 3.4 piston ring

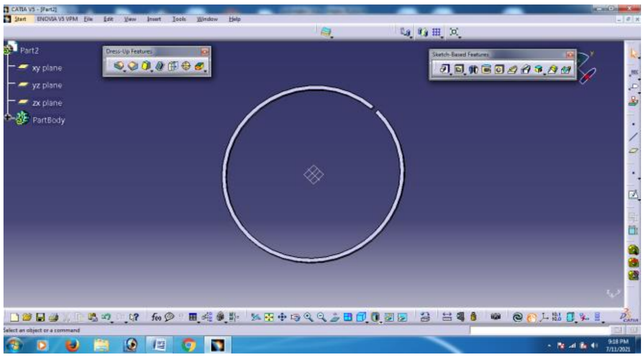

Fig: 3.5 piston ring

4. ANALYSIS AND RESULTS

4.1 Thermal analysis of a level head piston using 6061-T6 aluminum alloy

The thermal evaluation of flat head piston is done by way of applying 6061-T6 alloy and applying a temperature of 400℃ on the flat face of piston and bulk ambient temperature of 30℃. The following properties has been taken into consideration to conduct the thermal analysis.

TABLE 1
Aluminium alloy 6061-T6 Constants

Density	7.85e-006 kg mm^{-3}
Coefficient of Thermal Expansion	1.2e-005 C^{-1}
Specific Heat	4.34e+005 mJ kg^{-1}C^{-1}
Thermal Conductivity	6.05e-002 W mm^{-1} C^{-1}
Resistivity	1.7e-004-ohm mm

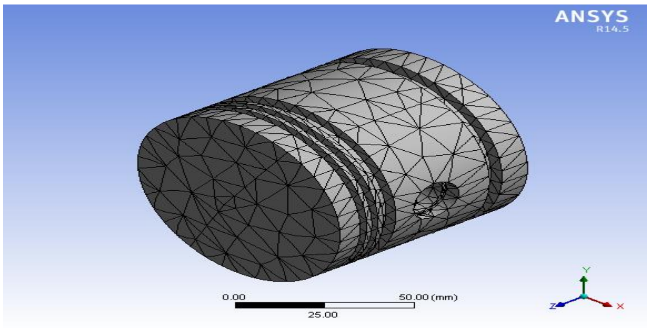

Fig: 4.1 piston

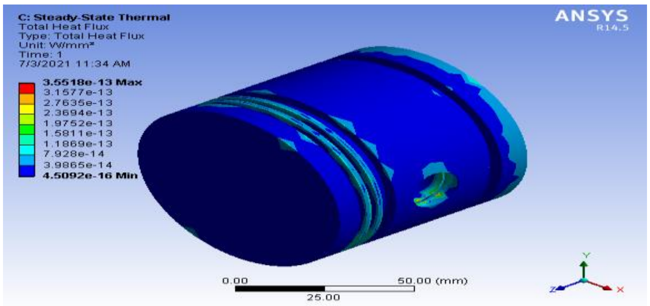

Fig: 4.2 total heat flux

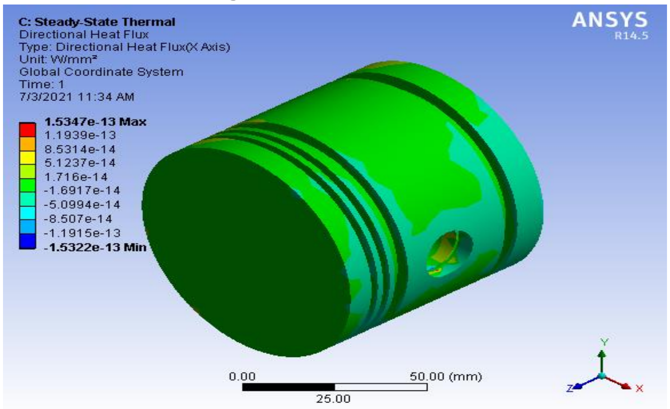

Fig: 4.3 directional heat flux

a. Application of Cast Iron to the thermal analysis of a level head piston

Now the thermal evaluation of flat head piston is done by way of applying Cast Iron alloy and applying a temperature of 400℃ on the flat face of piston and bulk ambient temperature of 30℃. The following properties has been taken into consideration to conduct the thermal analysis.

TABLE 2
Cast Iron Constants

Density	7.2e-006 kg mm^{-3}
Coefficient of Thermal Expansion	1.1e-005 C^{-1}
Specific Heat	4.47e+005 mJ kg^{-1} C^{-1}
Thermal Conductivity	5.2e-002 W mm^{-1} C^{-1}
Resistivity	9.6e-005-ohm mm

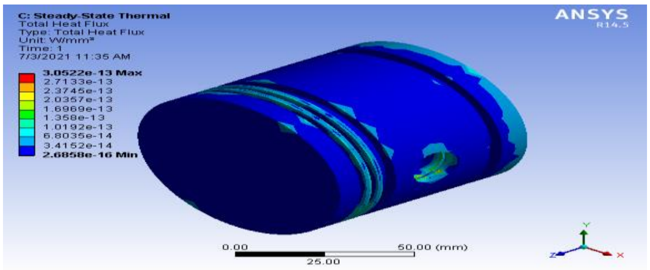

Fig: 4.4 total heat flux

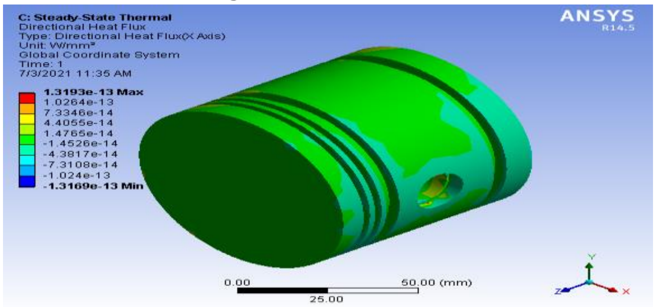

Fig: 4.5 directional heat flux

b. Application of Aluminum alloy 7075-T6 to the thermal study of a level head piston

Now the thermal evaluation of flat head piston is done by way of applying 7075-T6 alloy and applying a temperature of 400℃ on the flat face of piston and bulk ambient temperature of 30℃. The following properties has been taken into consideration to conduct the thermal analysis.

TABLE 3
Aluminium alloy 7075-T6 Constants

Density	1.8e-006 kg mm^{-3}
Coefficient of Thermal Expansion	2.6e-005 C^{-1}
Specific Heat	1.024e+006 mJ kg^{-1} C^-1
Thermal Conductivity	0.156 W mm^{-1} C^{-1}
Resistivity	7.7e-004-ohm mm

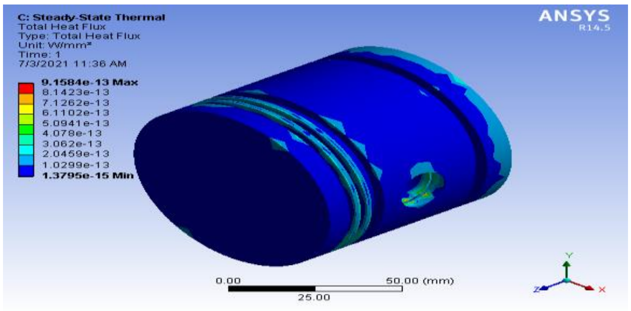

Fig: 4.6 total heat flux

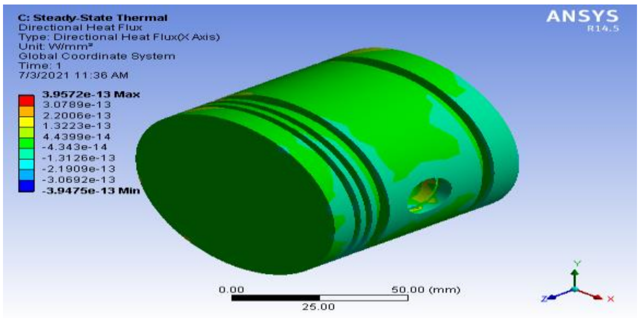

Fig: 4.7 directional heat flux

c. Thermal analysis of a piston ring using 6061-T6 aluminum alloy

Now the thermal evaluation of piston ring is done by way of applying 6061-T6 alloy and applying a maximum temperature of 400℃ and min/ambient temperature of 30℃. The following properties of Aluminium alloy 6061-T6 has been taken into consideration to conduct the thermal analysis

TABLE 4
Aluminium alloy 6061-T6 Constants

Density	7.85e-006 kg mm^{-3}
Coefficient of Thermal Expansion	1.2e-005 C^{-1}
Specific Heat	4.34e+005 mJ kg^{-1}C^{-1}
Thermal Conductivity	6.05e-002 W mm^{-1} C^{-1}
Resistivity	1.7e-004-ohm mm

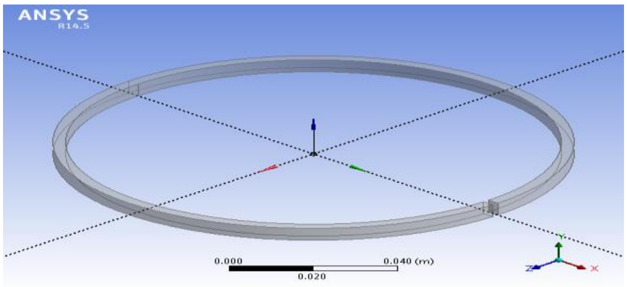

Fig: 4.8 Piston ring

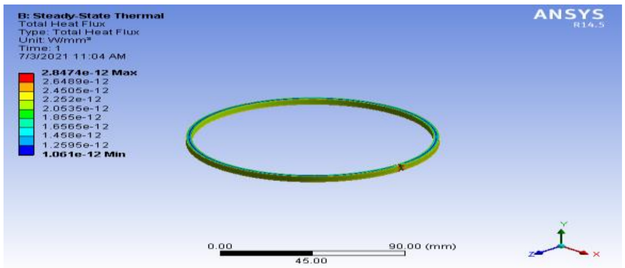

Fig:4.9 total heat flux

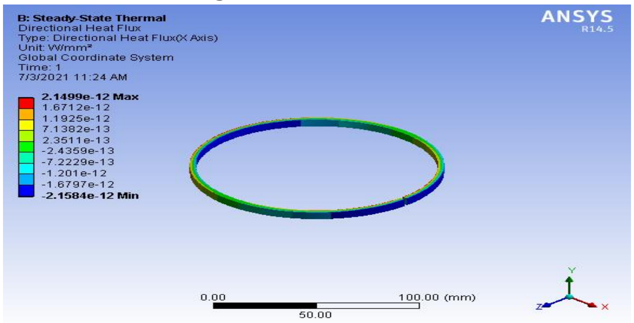

Fig: 4.10 directional heat flux

d. Application of Cast Iron to Piston Ring Thermal Analysis

The thermal evaluation of piston ring is done by way of applying Cast Iron alloy and applying a maximum temperature of 400℃ and min/ambient temperature of

30℃. The following properties of Cast Iron has been taken into consideration to conduct the thermal analysis.

TABLE 5
Cast Iron Constants

Density	7.2e-006 kg mm^{-3}
Coefficient of Thermal Expansion	1.1e-005 C^{-1}
Specific Heat	4.47e+005 mJ kg^{-1} C^{-1}
Thermal Conductivity	5.2e-002 W mm^{-1} C^{-1}
Resistivity	9.6e-005-ohm mm

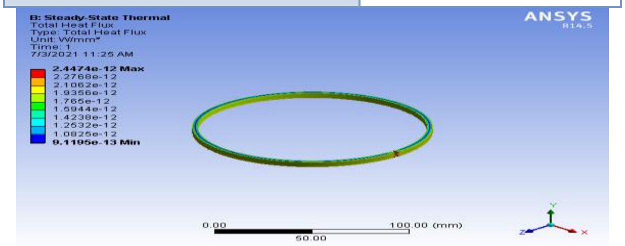

Fig:4.11 total heat flux

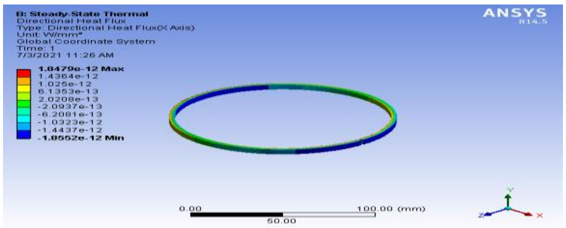

Fig: 4.12 Directional heat flux

e. Thermal analysis of piston ring by applying Aluminium alloy 7075-T6

The thermal evaluation of piston ring is done by way of applying 7075-T6 alloy and applying a maximum temperature of 400℃ and min/ambient temperature of 30℃. The following properties of Aluminium alloy 7075-T6 has been taken into consideration to conduct the thermal analysis

TABLE 6
Aluminium alloy 7075-T6 Constants

Density	1.8e-006 kg mm^{-3}
Coefficient of Thermal Expansion	2.6e-005 C^{-1}
Specific Heat	1.024e+006 mJ kg^{-1} C^-1
Thermal Conductivity	0.156 W mm^{-1} C^{-1}
Resistivity	7.7e-004-ohm mm

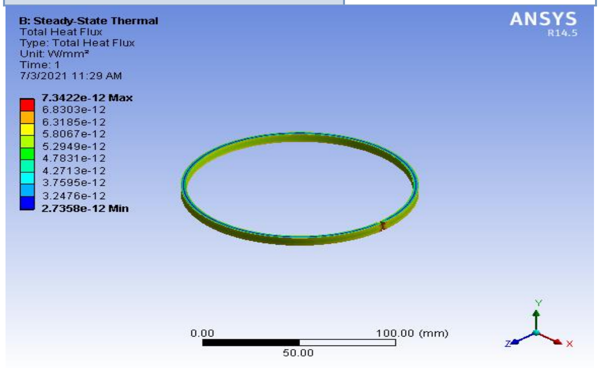

Fig:4.13 total heat flux

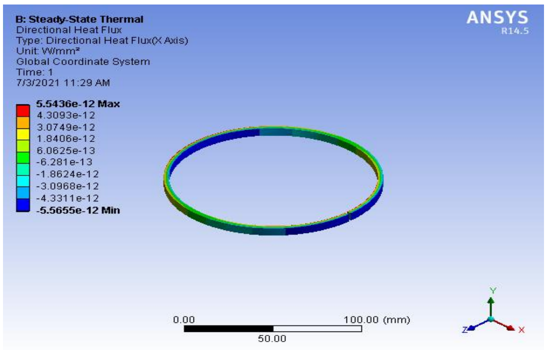

Fig: 4.14 directional heat flux

5. RESULTS AND DISCUSSIONS SYNOPSIS

A cylinder's warm extension properties are determined by the compound from which it is formed. More flaming engines need the use of more strong chemicals in order to maintain close resilience without scraping.

The following are the most important factors that influence cylinder performance:

1. Head thickness strength and concern

2. Circulation of heat through the cylinder material

3. Increasing the thickness of the cylinder head

4. Changing the material

The following table summarizes and tabulates the findings:

MODEL 1 PISTON

Material	Total Heat Flux in (W/mm^2)		Directional heat flux (W/mm^2)	
	Max.	Min.	Max.	Min.
Aluminium alloy 6061-T6	3.5518e-13	4.5092e-16	1.5347e-13	-1.5322e-13
Cast Iron	3.0522e-13	2.6858e-16	1.3169e-13	-1.3193e-13
Aluminium alloy 7075-T6	9.1584e-13	1.3795e-15	3.9572e-13	-3.9475e-13

MODEL 2 RING

Material	Total Heat Flux in (W/mm^2)		Directional heat flux (W/mm^2)	
	Max.	Min.	Max.	Min.
Aluminium alloy 6061-T6	2.8474e-12	1.061e-12	2.1499e-12	-2.1584e-12
Cast Iron	2.4474e-12	9.1195e-13	1.8479e-12	-1.855e-12
Aluminium alloy 7075-T6	7.3422e-12	2.7358e-12	5.5436e-12	-5.5655e-12

As shown in the flat head cylinder data, the total heat flux and directional heat flux for Aluminum Alloy 7075-T6 compound are greater than cast iron and Aluminum Alloy 6061-T6 compound. As a consequence, cylinder pistons made of Aluminum Alloy 7075-T6 are a suitable option.

Based on the aforementioned piston ring data, the total heat flux and directional heat flux for Aluminium Alloy 7075-T6 compound are greater than cast iron and Aluminium Alloy 6061-T6 compound. As a consequence, Aluminum Alloy 7075-T6's fine texture is excellent for cylinder rings.

6. CONCLUSIONS

We built a piston and piston ring assembly for our project. Aluminum alloy 6061-T6, cast iron, and aluminium alloy 7075-T6 are the three materials examined.

1. For this project, CATIA software was used to build a 3D model of a flat head piston and piston ring.

2. The model is meshed and the Finite Element Analysis is performed using ANSYS.

3. The thermal analysis of the piston and piston rings was successful in estimating total heat flow, directional heat flux, and other parameters.

4. The steady state thermal study of the aforementioned three materials is carried out at a maximum temperature of 400°C and a minimum temperature of 30°C.

5. In order to identify the best material for flat head pistons and piston rings, the temperature distribution and heat flow of three different materials are measured and computed.

6. The Aluminum Alloy 7075-T6 delivers effective piston and piston ring results, based on the facts. As a consequence, aluminium 7075-T6 is the best material for engine pistons and piston rings.

REFERENCES

1. "Thermal analysis of a ceramic coated diesel engine piston using 3-D finite element method," Ekrem Buyukkaya and Muhammet Cerit, Surface and Coatings Technology, November 2007.

2."Multi-Dimensional Modelling of Direct Injection Diesel Engine and Split Injection Effects," International Journal of Scientific and Research Publications, Volume 2, Issue 1, January 2012. 2. K. Bala Showry, A.V.S. Raju, and P. Ravinder Reddy, "Multi-Dimensional Modelling of Direct Injection Diesel Engine and Split Injection Effects," International Journal of Scientific and Research Publications, Volume 2, Issue 1, January 2012.

3.Wear 254, pp. 1208-1251, 2003, Royal Institute of Technology, Sweden. 3. Initial sliding wear on piston rings in a radial piston hydraulic motor. Initial sliding wear on piston rings in a radial piston hydraulic motor, Royal Institute of Technology, Sweden, Wear 254, pp. 1208-1251, 2003. 7. U.I. Sjodin, U. I. O. Olofsson, Initial sliding wear on piston rings in a radial piston hydraulic motor, Royal

Institute of Technology, Sweden, Wear 254, pp. 1208-1251, 2003.

4. “Analysis of local convective heat transport in a spark ignition engine,” International Communications in Heat and Mass Transfer, August 2007.

5.“Design Analysis and Optimization of Piston Using CATIA and ANSYS,” Ch. Venkata Rajam, P. V. K. Murthy, M. V. S. Murali, Krishna, and G. M. Prasada Rao, ISSN 2319-5665, January 2013.Shuoguo Zhao, Shu (EMEIT-2012).

6.“Piston Strength Analysis Using FEM,” International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 2, March-April 2013, ISSN: 2248-9622. Swati S Chougule and Vinayak H Khatawat, “Piston Strength Analysis Using FEM,” International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 2, March-April 2013, ISSN: 2248-9622.

7. Piston friction and wear processes, pages 43-49, S. Singhal, P. C. Nautiyal, and J. P. Sharmat. M. Priest, D. Dowson, and C.M. Taylor, Predictive wear modelling of lubricated piston rings in a diesel engine, Wear 231, pp. 89-101, March 1999.

9. John J. Truhan, Jun Qu, and Peter J. Blau, The effect of lubricating oil condition on friction and wear in piston ring and cylinder liner materials in a reciprocating bench test, Wear 259, pp. 1048-1055, 2005.

9. Milwaukee, Wisconsin, USA, May 3–6, 2009. 10. ICES2009, Milwaukee, Wisconsin, USA, May 3–6, 2009. "Procedures of the ASME Internal Combustion Engine

10. Division 2009 Spring Technical Conference," ICES2009, Milwaukee, Wisconsin, USA, May 3–6, 2009. 16. Richard Mittler and Albin Mierbach, "Procedures of the ASME Internal Combustion Engine Division 2009 Spring Technical Conference," ICES2009, Milwaukee, Wisconsin, USA, May 3–6, 2009.