INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
www.ijprems.com
editor@ijprems.com
Vol. 04, Issue 01, January 2024, pp : 363-370
e-ISSN : 2583-1062
Impact Factor : 5.725

DESIGN AND ANALYSIS OF PISTON MADE OF DIFFERENT MATERIALS

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DOI: https://www.doi.org/10.58257/IJPREMS32538

ABSTRACT

The goal of this task is to determine the temperature and thermal pressure distributions in piston and piston rings to improve the thermal performance of a engine. Temperature and thermal stress distributions are investigated in piston and piston rings through static and thermal analysis and design with Catia and ansys software. The most important objective of the piston is to check out and examine the thermal strain distribution of the piston in the real engine circumstances for the duration of the combustion method. In this procedure, we carried out temperature and convection as well as determining the general temperature at the body, general warmth flux, and warmness flux in the x, y, and z instructions, respectively. And this piston also has much less strain (174 MPa) and an appropriate safety element of 1.6. And the thermal warmth flux is additionally less different between cast iron and solid metallic. Piston and piston earrings: the use of thermal analysis and static analysis implemented the temperature, stress distinction cloth like al alloy, solid iron, and cast steel.

Keywords: Thermal stress, thermal strain CATIA, ANSYS

1. INTRODUCTION

1.1 Background of Piston

Engine pistons are one of the most complex and important part of an engine. The function of the piston is bearing the gas pressure and making the crankshaft rotation through the piston pin. Piston works in high temperature, high pressure, high speed and poor lubrication conditions. Piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head cracks and so on.

Piston in an IC engine must possess the following characteristics: 1) Strength to resist gas pressure 2) Must have minimum weight 3) Must be able to reciprocate with minimum noise 4) Must have sufficient bearing area to prevent wear 5) Must seal the gas from top and oil from the bottom 6) Must disperse the heat generated during combustion 7) Must have good resistance to distortion under heavy forces and heavy temperature.

1.2 Design and Analysis

The main requirement of piston design is to predict the temperature distribution on the surface of piston which enables us to optimize the thermal aspects for design of piston. Most of the motorbike pistons are made of an aluminium alloy which has thermal expansion coefficient 80% higher than the cylinder bore material (cast iron). Also, to improve mechanical efficiency and reduce inertia force in high-speed machines, the weight of the piston also plays a major role.

Finite Element Analysis Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow and other physical effects. The Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called Finite Element Method (FEM). It is used to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products, faster. Finite element analysis shows whether a product will break, wear out or work the way it was designed. In the product development process, it is used to predict what's going to happen when the product is used. FEA works by breaking down a real object into a large number (thousands to hundreds of thousands) of finite elements. FEA helps predict the behaviour of products affected by many physical

2. LITERATURE REVIEW

Vibhandik et. al . (2014), studied that Design analysis and optimization of piston and deformation of its thermal stresses using CAE tools, he had selected I.C. engine piston from TATA motors of diesel engine vehicle. He had performed thermal analysis on conventional diesel piston and secondly on optimized piston made of aluminum alloy and titanium alloy material. Conventional diesel piston made of structural steel. The main objective of this analysis is to reduce the stress concentration on the upper end of the piston so as to increase life of piston. After the analysis he conclude that titanium has better thermal property, it also help us to improve piston qualities but it is expensive for large scale applications, due to which it can be used in some special cases.

Ch. Venkata Rajam et. al . (2013), focused on Design analysis and optimization of piston using CATIA and ANSYS. He had optimized with all parameters are within consideration. Target of optimization was to reach a mass reduction of piston. In this analysis a ceramic coating on crown is made. In an optimization of piston, the length is constant because heat flow is not affected the length, diameter is also made constant due to same reason. The volume varied after applying temperature and pressure loads over piston as volume is not only depending on length and diameter but also on thickness which is more affected. The material is removed to reduce the weight of the piston with reduced material. The results obtained by this analysis shows that, by reducing the volume of the piston, thickness of barrel and width of other ring lands, Von mises stress is increased by and Deflection is increased after optimization. But all the parameters are with in design consideration.

V. V. Mukkawar et. al . (2015), describes the stress distribution of two different Al alloys by using CAE tools. The piston used for this analysis belongs to four stroke single cylinder engine of Bajaj Pulsar 220 cc motorcycle. He had concluded that deformation is low in AL-GHY 1250 piston as compare to conventional piston. Mass reduction is possible with this alloy. Factor of safety increased up to 27% at same working condition. He used Al-GHY 1250 and conventional material Al-2618 and results were compared, he found that Al-GHY 1250 is better than conventional alloy piston

3. METHODOLOGY

1) Analytical design of pistons based on design formulae and empirical relations. 2)3-D piston models are created in CATIA V5.3) Meshing and analysis of piston is done in ANSYS Workbench 16.0. 4) Various stresses are determined by individually performing structural analysis, thermal analysis and thermomechanical analysis. 5) Various zones or regions where chances of damage in piston are possible are analyzed. 6)Comparison is made between the three materials in terms of stresses, deformation, strain, volume, weight, inertia force and factor of safety.

3.1 Design of Piston Engine: Bajaj Pulsar 220 cc petrol engine.

Table-1: Engine Specifications

PARAMETERS	VALUES
Engine type	Four stroke, petrol engine
Induction	Air cooled type
No. of cylinders	Single cylinder
Bore (D)	67 mm
Stroke (L)	62.4 mm
Length of connecting rod	124.8 mm
Displacement volume	220 cm³
Compression ratio	9.5+/-0.5:1
Maximum power	15.51 kW at 8500 rpm
Maximum torque (T)	19.12 N-m at 7000 rpm (N)
No. of revolutions/cycle	2

Mechanical efficiency of the engine (η) = 80 %. η = Brake power (B.P.)/Indicating power (I.P.) B.P. = 2πNT/60 = 2π*7000*19.12/(60*1000) = 14.015 kW

Therefore, I.P. = B.P./η = 14.015/0.8 = 17.518 kW

Also, I.P. = P*A*L*N/2 = P*π/4*D2*L*N/2 17.518*1000 = P*π/4*(0.067)2*(0.0624)*(7000)/(2*60)

So, P = 13.65*105 N/m2 or P = 1.365 MPa

Maximum Pressure (pmax) = 10*P = 10*1.365 = 13.65 MPa

3.2 Analytical Design Calculations

For Aluminium alloy

Thickness of the Piston Head According to Grashoff's formula the thickness of the piston head is given by: th = D√(3pmax/16σt) where σt = σut/2.5 = 480/2.5 = 192 MPa and D = cylinder bore diameter Therefore th = 67*√((3*13.65)/(16*192)) = 7.735 mm Empirical formula: th = 0.032 D + 1.5 = 3.644 mm The maximum thickness from the above formula (th) is 7.735 mm.

Piston Rings The radial width of the ring is given by: b = D√(3*pw/σp) = 67*√(3*0.025/100) = 1.834 mm

Axial thickness of the piston ring is given by: h = (0.7 b to b) = 0.7*1.834 = 1.284 mm

Width of Top Land and Ring Lands Width of top land: h1 = (th to 1.2 th) = 7.735 mm

Width of ring land: h2 = (0.75 h to h) = 0.75*1.284 = 0.963 mm

Piston Barrel Thickness of piston barrel at the top end: t1 = 0.03 D + b + 4.9 Therefore t1 = 0.03*67 + 1.834 + 4.9 = 8.744 mm

Thickness of piston barrel at the open end: t2 = (0.25 t1 to 0.35 t1) Therefore t2 = 0.25*8.744 = 2.186 mm Length of the skirt Ls = (0.6 D to 0.8 D) = 0.6*67 = 40.2 mm

Length of piston pin in the connecting rod bushing L1 = 45% of the piston diameter = 0.45*67 = 30.15 mm

Piston pin diameter do = (0.28 D to 0.38 D) = 0.3*67 = 20.1 mm

The centre of piston pin should be 0.02 D to 0.04 D above center of the skirt = 0.03*67 = 2.01 mm above skirt centre

4. METHODS FOR DESIGN & ANALYSIS TO DEVELOP THE WORK

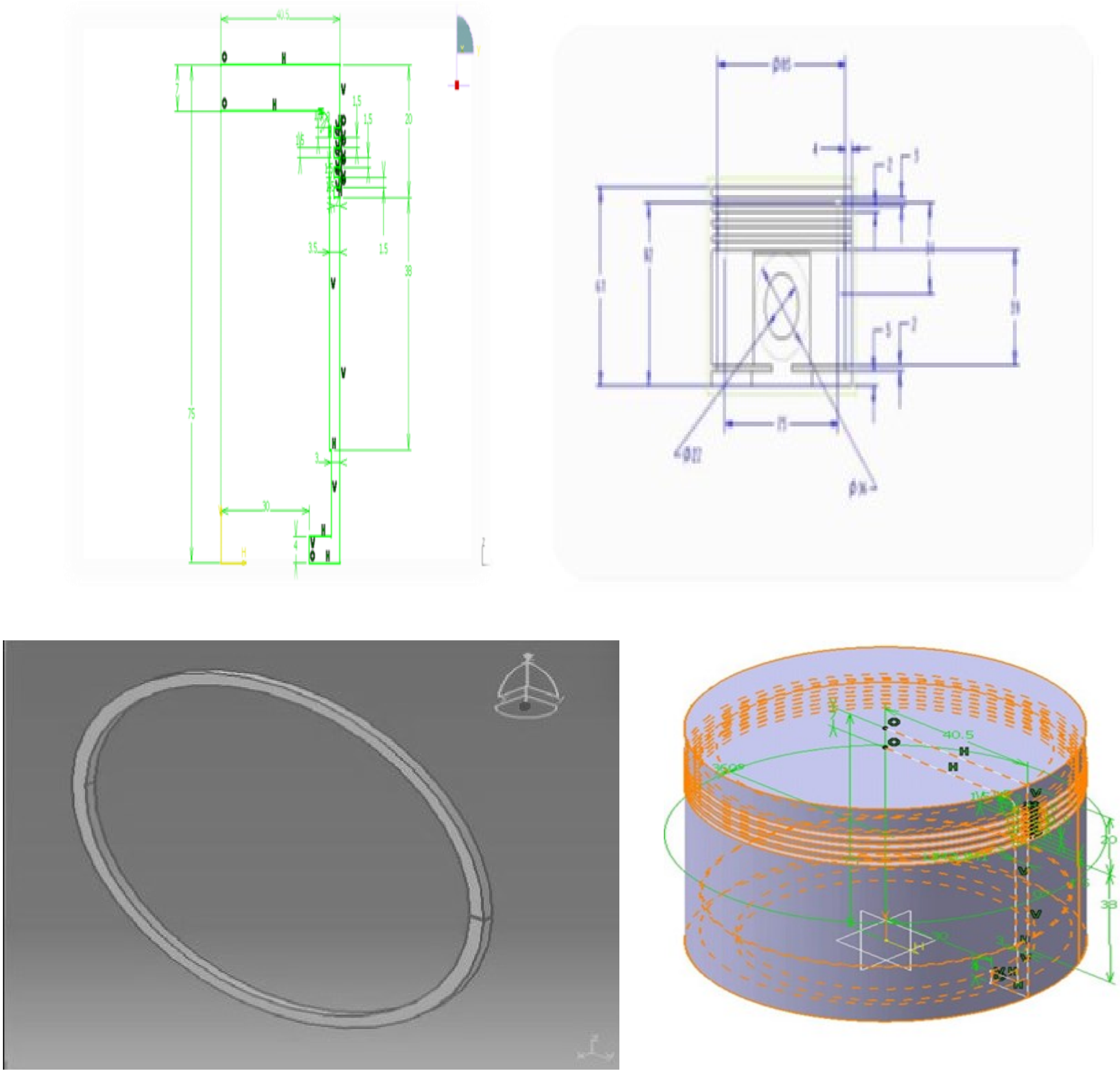
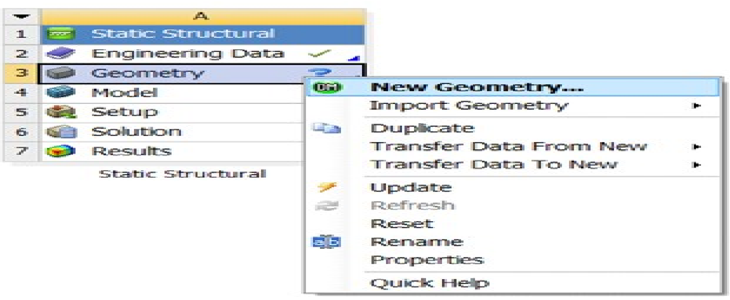


Figure 1 :Modelling of Piston in CATIA

Analysis of Piston

4.1 The first step indicates the type of analysis The second step is indicates the engineering the data means material properties adding from the library For modification select the engineering data and click two times the above window can appear after selecting the material /modifying the material physical properties In that window select the top at window update project and return project



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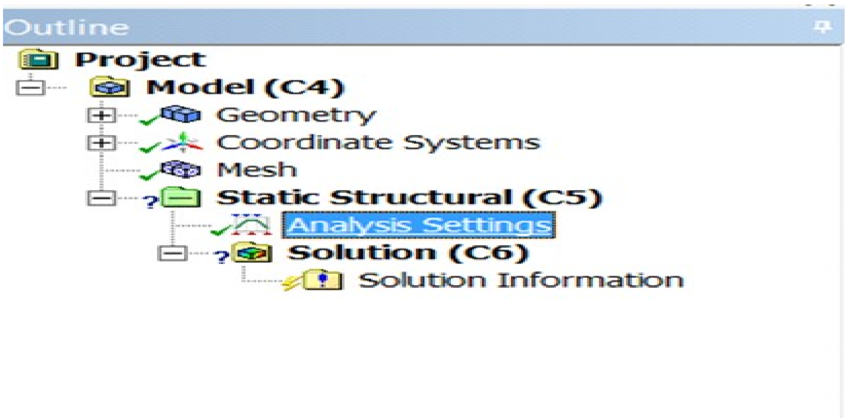
The right said of the window selects the geometry and right click it display new geometry /import Geometry. Select the import geometry go to browse the model In .igs /stp format Igs means (initial graphics exchange specifications) For mixing of two fields go to setup and right click transfer data from new /Transfer data to new

4.2 Material Assignment

For analysis of piston, the 3-D model prepared in CATIA V5 is converted in to IGES format so that it can be imported in ANSYS 16.0. After importing the model in ANSYS, material properties are assigned in engineering data

4.2 Meshing of Piston Model

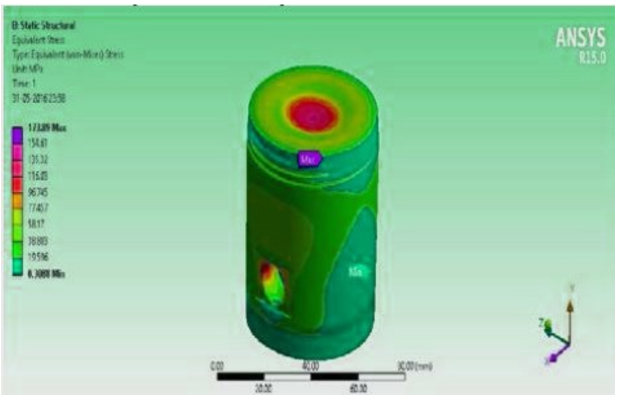
After assigning material properties, model is opened in mechanical. The whole body of the piston model is selected and meshing is performed. Tetrahedral elements are used and the element size is 2 mm.

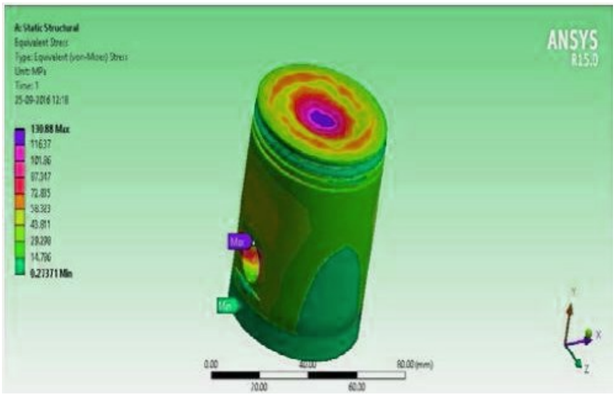


STATIC STRUCTURAL ANALYSIS

In static structural analysis, boundary conditions like pressure and supports are applied1) Pressure at the head of piston: 13.65 MPa 2) Frictionless support is applied at piston pin hole as pin can freely rotate inside hole. 3) Fixed supports are applied at edges of piston pin hole

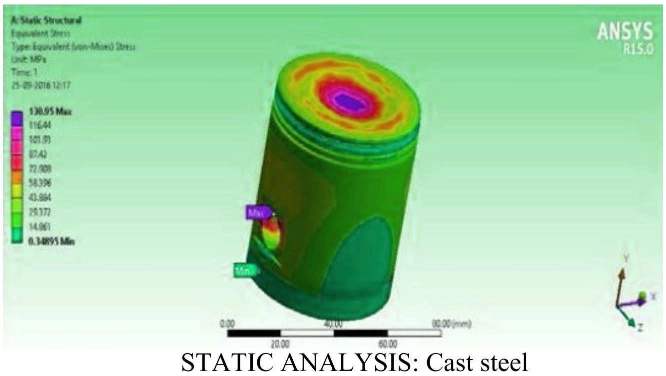
ANALYSIS





STATIC ANALYSIS : Al alloy

STATIC ANALYSIS : Cast iron



STATIC ANALYSIS: Cast steel

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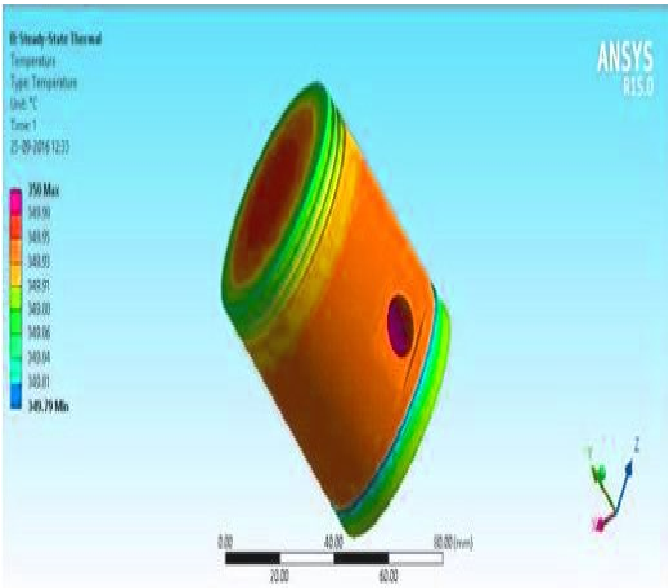
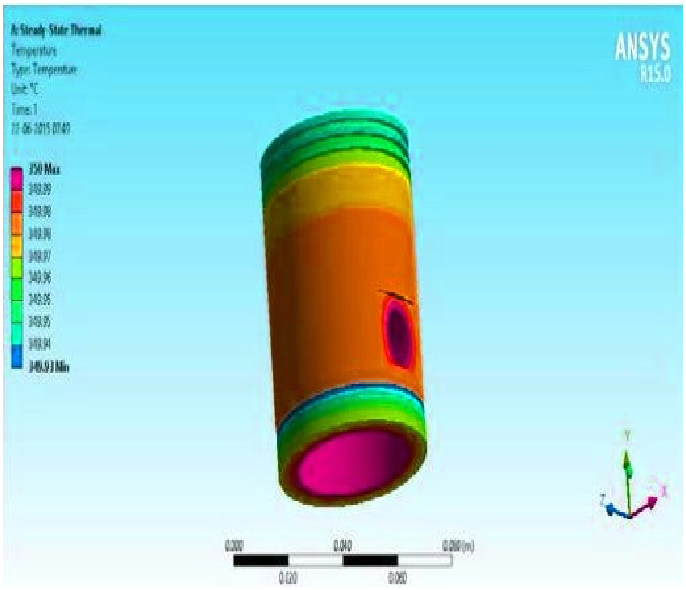
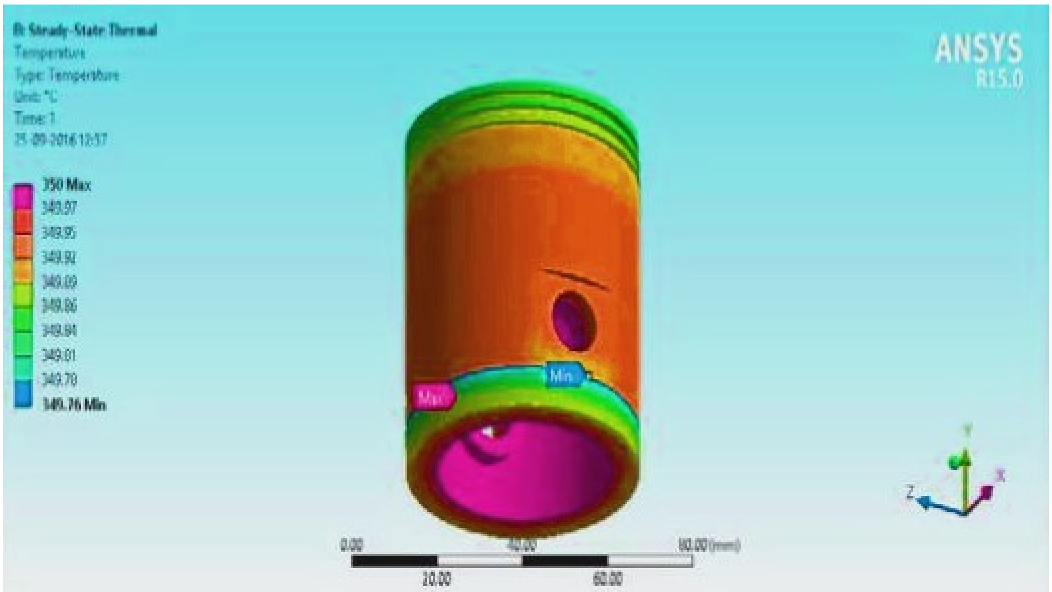


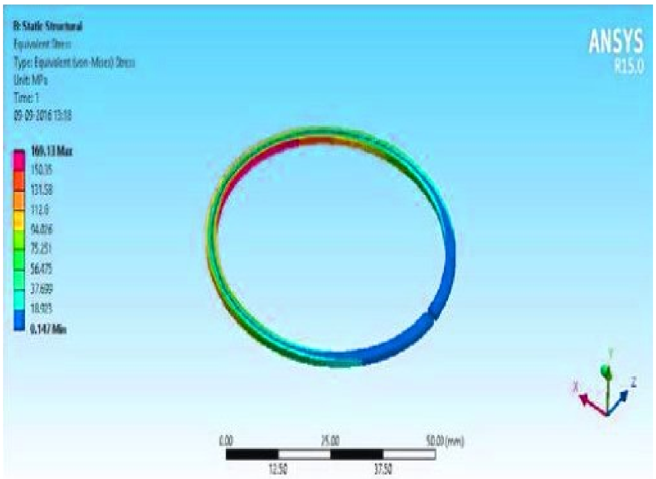
THERMAL ANALYSIS :: Al alloy



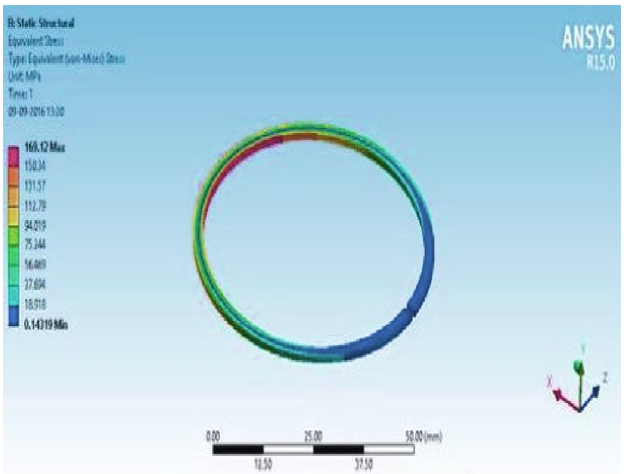
THERMAL ANALYSIS : Cast iron



THERMAL ANALYSIS : CAST STEEL



STATIC ANALYSIS: al alloy



STATIC ANALYSIS: Cast steel

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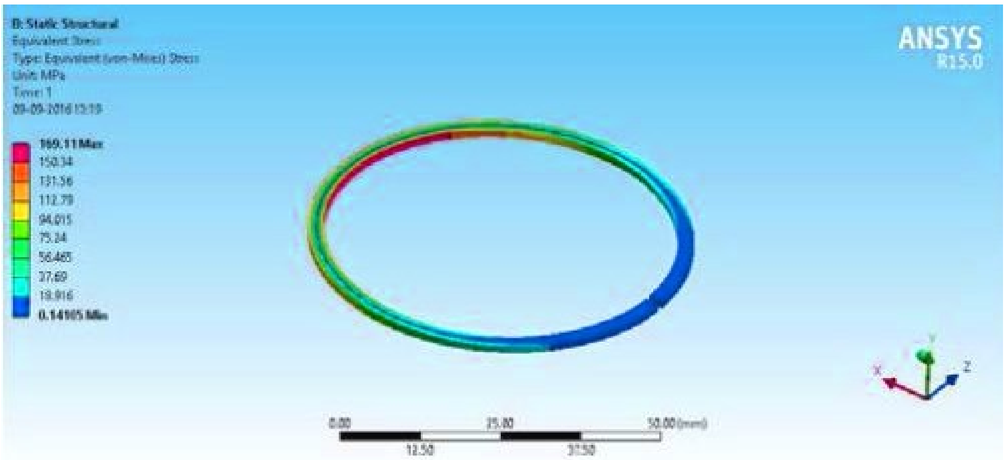
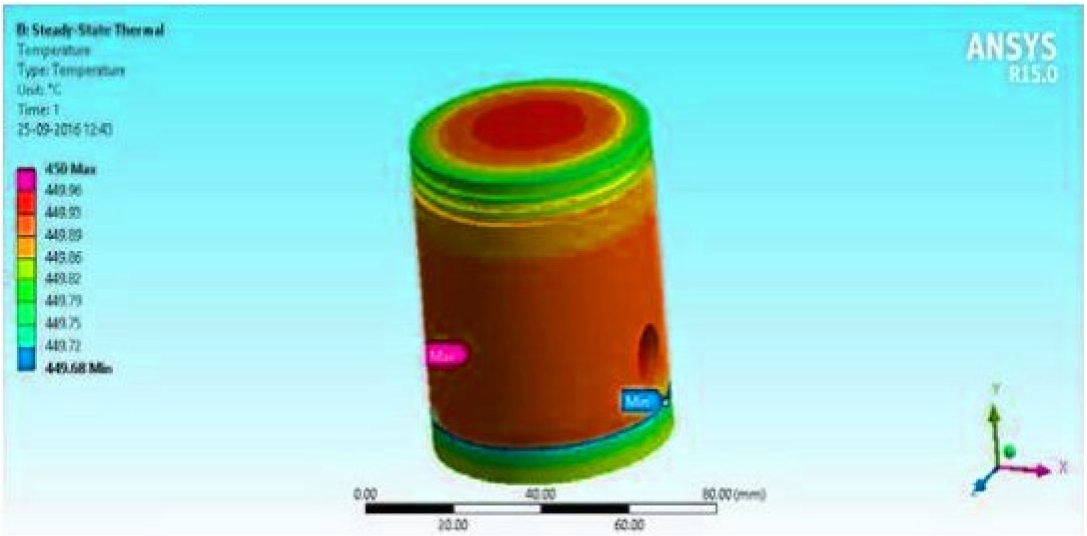
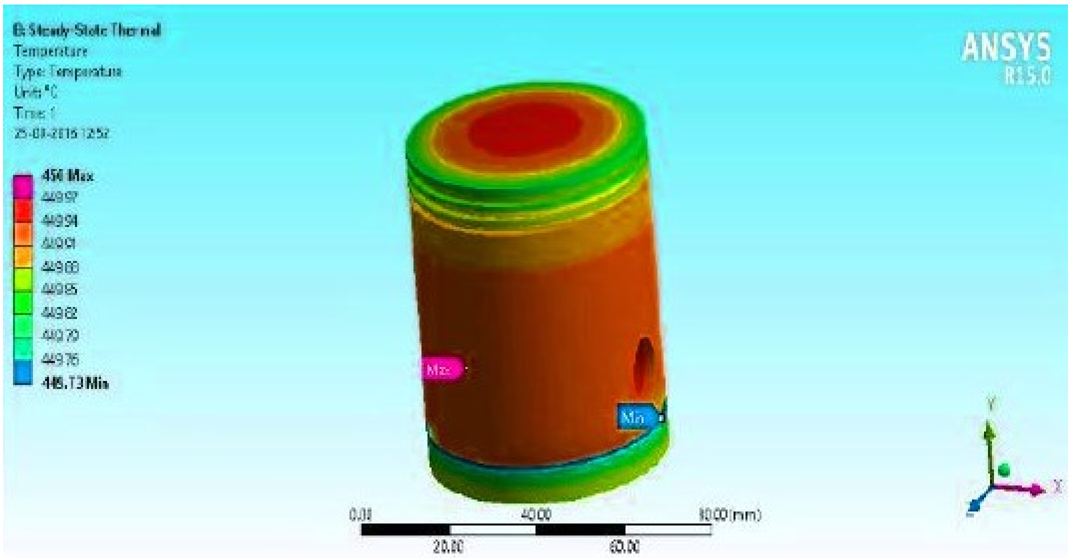


STATIC ANALYSIS: cast steel



PISTON RING: cast iron



PISTON RING: Cast steel

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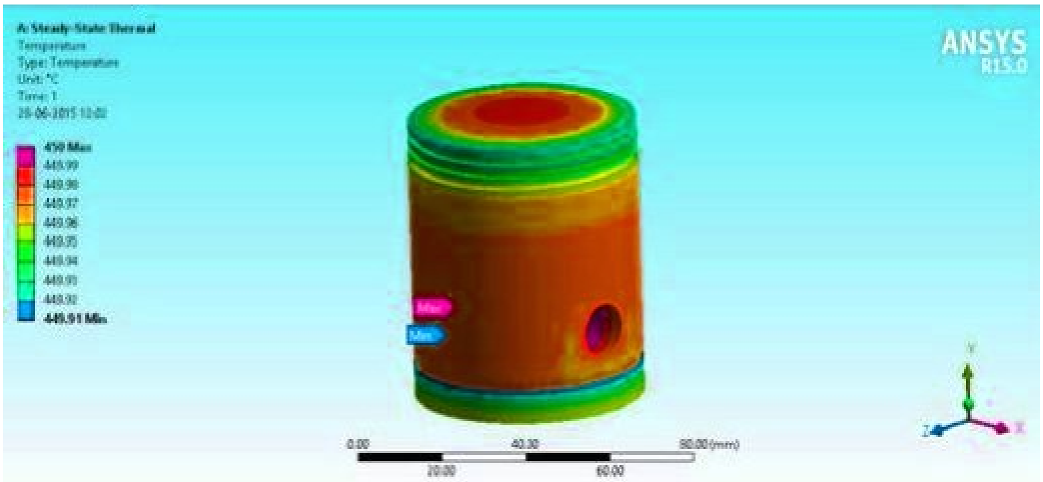

PISTON RING: Al alloy

5. RESULTS AND DISCUSSION

PISTON STATIC ANALYSIS

Materials	Al-alloy	Cast steel	Cast iron
Deformation (mm)	0.95969	0.036373	0.066456
Stress (Mpa)	174	140.95	136.88
Safety factor	1.6	1.9391	1.7637

PISTON RING STATIC ANALYSIS

Materials	Al-alloy	Cast steel	Cast iron
Deformation (mm)	7.4	2.6	4.7
Stress (Mpa)	168.13	169.12	169.11
Safety factor	0.0043823	0.000645	0.00353

PISTON THERMAL ANALYSIS BETWEEN AL ALLOY, CAST STEEL AND CAST IRON

Materials	Al-alloy	Cast steel	Cast iron
Total temperature (*c)	350(max)- 349.93 (min)	350(max)-349.7(min)	350(max)-349.76(min)
Heat flux (w/m^2)	2315.8	1758.1	1757.9
Heat flux in x (w/m^2)	1484.5	1313.1	1113
Heat flux in y (w/m^2)	1560.1	1753.8	1653.7
Heat flux in z (w/m^2)	1593.1	1312.4	1312.3

PISTON RING THERMAL ANALYSIS BETWEEN AL ALLOY, CAST STEEL AND CAST IRON

Materials	Al-alloy	Cast steel	Cast iron
Total temperature (*c)	450(max) -449.91 (min)	450(max)-449.73(min)	450(max)-449.68(min)
Heat flux (w/m^2)	2923.3	2224.5	2224.2
Heat flux in x (w/m^2)	2098.4	1483	1481.3
Heat flux in y (w/m^2)	2266.4	2519	2468.8
Heat flux in z (w/m^2)	2309.3	1482.1	1472

6. CONCLUSION

In this project we have done one piston model by using CATIA , ANSYS. To improve results here we selected another material Al-Alloy and existing material is steel only. And applied real time boundary conditions on it

but in this case we get good results for existing material only. So we decide to change the design.

- In our project we have designed a piston used in two wheeler and modeled in 3D modeling, software CATIA. and the we analyze the piston with different materials like Aluminum And cast steel and cast iron with help of fem
- In static conditions when we applied 15Mpa pressure on existing piston (steel) and piston ring produced 174 MPa by changing design and adding zirconium coating we reduced it al alloy,cast iron and cast steel 158.72Mpa nearly 160MPa stress have been reduced but in real time conditions these results are not enough so we have analyse these models with thermal loads also
- In this project we replace piston material cast iron to al-alloy to cast steel to cast iron by this change we are getting same results for both reduce our piston and piston ring weight nearly 35% of original piston And this piston also having less stress(174 MPa) and good safety factor 1.6. and the thermal heat flux also less (2316.8 w/m^2) compare
- the above we can say in thermal conditions cast steel,cast iron and al alloycombination produces better results compare with other. And it also has good static results
- Finally we conclude caste steel, al alloy and cast iron piston and piston ring will satisfy both static and thermal conditions. And it increases the piston and piston ring efficiency

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