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Thermal Analysis of a Piston

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Abstract: 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 Piston that transfer the combustive gases power to the connecting rod. To improve the efficiency of the engine there is a need to study about the piston. Pistons that are usually made up with alloy steels that show the grate resistant against thermal loads and structural loads. In the project we design a piston by using solid works 2016 design software and thermal analysis by applying various materials such as composites on piston in ansys workbench software
Keywords: Thermal ansys fem fea

I. INTRODUCTION

A. 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 a piston rod and/or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall.

B. PISTON RINGS.A ring groove is a recessed area located around the perimeter of the piston that is used to retain a piston ring. Ring lands are the two parallel surfaces of the ring groove which function as the sealing surface for the piston ring. A piston ring is an expandable split ring used to provide a seal between the piston an the cylinder wall. Piston rings are commonly made from cast iron. Cast iron retains the integrity of its original shape under heat, load, and other dynamic forces. Piston rings seal the combustion chamber, conduct heat from the piston to the cylinder wall, and return oil to the crankcase. Piston ring size and configuration vary depending on engine design and cylinder material.

II. MATERIALS

1) The most commonly used materials for pistons of I.C. engines are cast iron, aluminum alloy (cast aluminum, forged aluminum), cast steel and forged steel.
a) For a cast iron piston, the temperature at the centre of the piston head (TC) is about 425°C to 450°C under full load conditions and the temperature at the edges of the piston head (TE) is about 200°C to 225°C.
b) For aluminum alloy pistons, TC is about 260°C to 290°C and TE is about 185°C to 215°C.

A. *Composite Materials*

Introduction to composites: Composite materials have been widely used to improve the performance of various types of structures. Compared to conventional materials, the main advantages of composites are their superior stiffness to mass ratio as well as high strength to weight ratio. Because of these advantages, composites have been increasingly incorporated in structural components in various industrial fields. Some examples are helicopter rotor blades, aircraft wings in aerospace engineering, and bridge structures in civil engineering applications. Some of the basic concepts of composite materials are discussed in the following section to better acquaint ourselves with the behaviour of composites.

B. *Theoretical Analysis*

The function of the piston is to absorb the energy released after the Air/Fuel mixture is ignited by the high temperature .The piston then accelerates producing useful mechanical energy . To accomplish this, the piston must be sealed so that it can compress the mixture of air and fuel and does not allow gases out of the combustion chamber . This can be accomplished by the piston rings which also help to prevent oil from entering the combustion chamber from underneath the piston . Another function of the rings is to keep the piston from contacting the cylinder wall . Less contact area between the cylinder and piston reduces friction , thereby increasing efficiency. In the previous works a paper analyzed thermally pistons made from cast iron and aluminum alloy . Their results are indicated that the thermal flux is very high in the center of piston crown and it is low at the piston skirt . The temperature of the cast iron piston is higher than the temperatures of aluminum alloy piston by a value about to 40-80 ºC.

C. *Forces*

The major forces acting on the piston are as follows:
Inertia force caused by the high frequency of reciprocating motion of piston
Friction between the cylinder walls and the piston rings
Forces due to expansion of gases
Forces acting due to the compression of gases
Friction at gudgeon pin hole

D. *Objective*

Designing the piston for 150 cc petrol engine taking reference to the existing piston.
Design is modified to get better results
Creating of 3D model in Solid works and then by using CAE tools Simulation Xpress Study
Meshing of 3D model in Simulation Xpress Study
Material Aluminium 2024-T361 is selected for the study

E. *Modeling Of A Piston Requires*

It should In designing a piston for an engine, the following points should be taken into consideration: It should have enormous strength to withstand the high pressure.

It should have minimum weight to withstand the inertia forces.

1) It should form effective oil sealing in the cylinder.
2) It should provide sufficient bearing area to prevent undue wear.
3) It should have high speed reciprocation without noise.
4) It should be of sufficient rigid construction to withstand thermal and mechanical distortions.
5) It should have sufficient support for the piston pin.

F. *Introduction To Solid Works*

Solid works mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows TM graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent.

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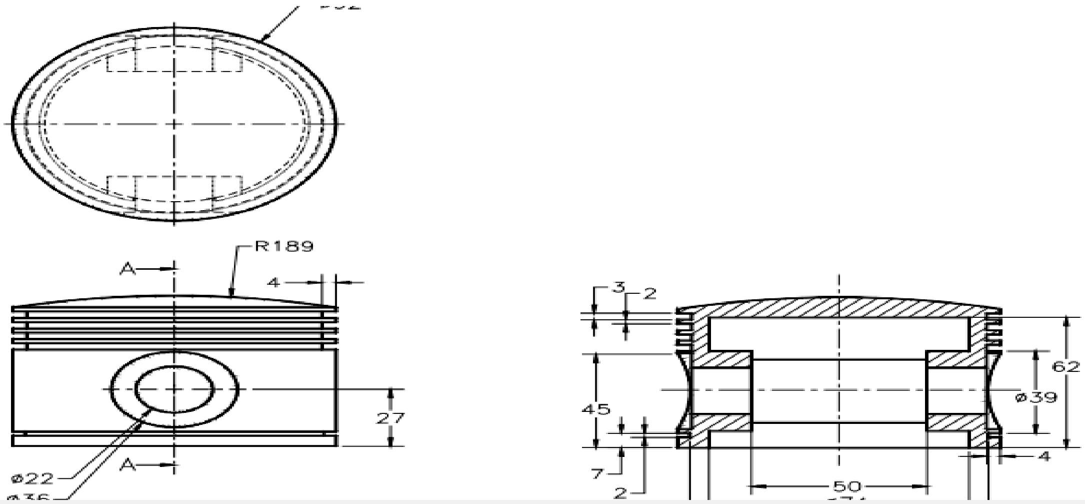
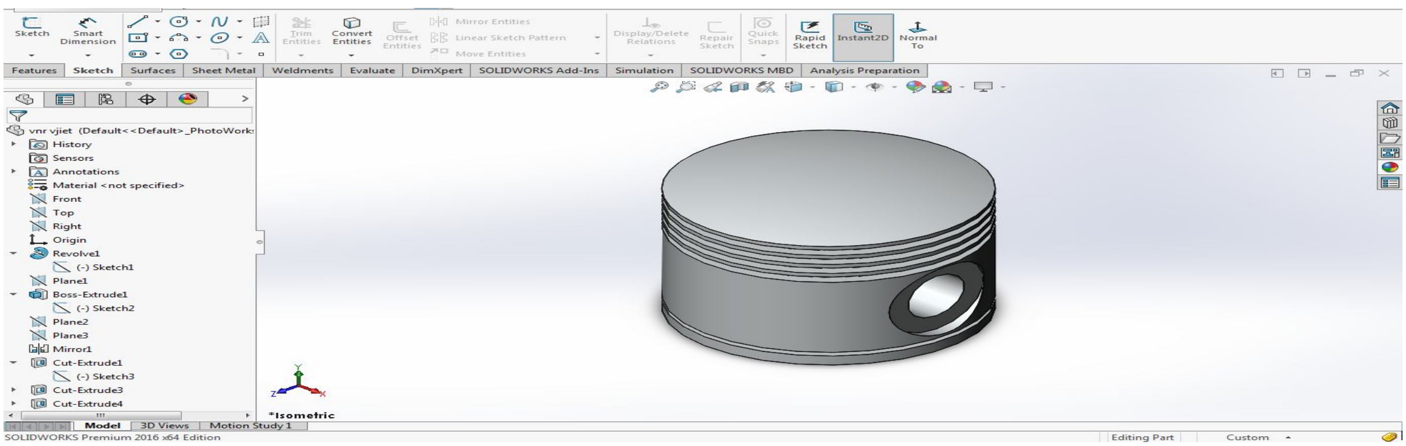
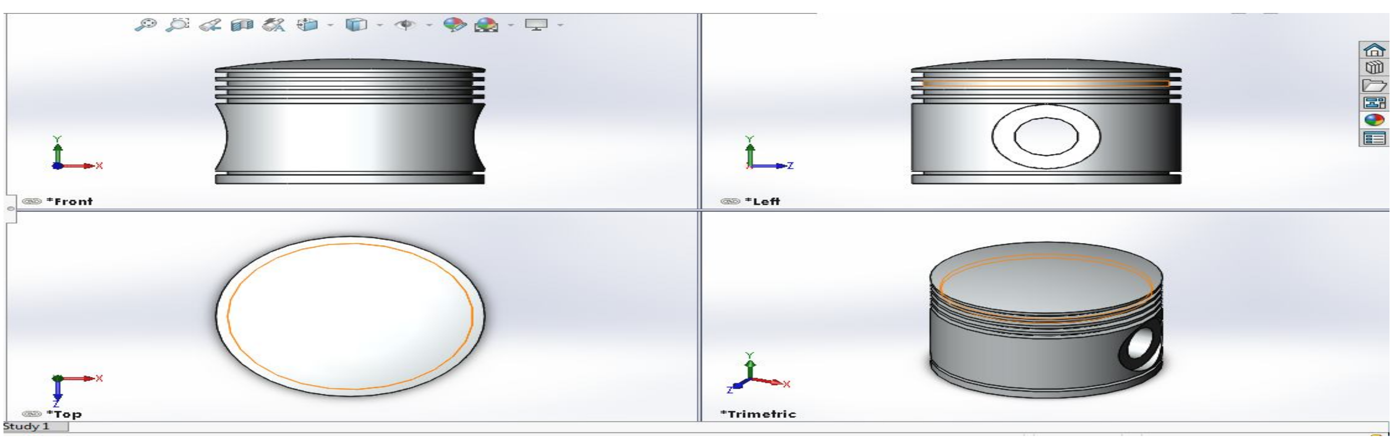
G. Modeling Of Piston







H. *Introduction To Ansys Analysis*

Basic Concepts of Analysis:

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.

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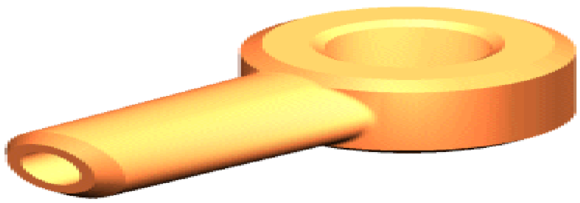
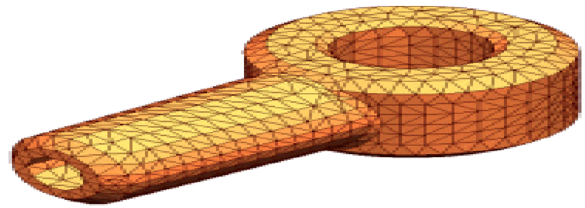


CAD model of a part



Model subdivided into small pieces (elements

I. Thermal Analysis

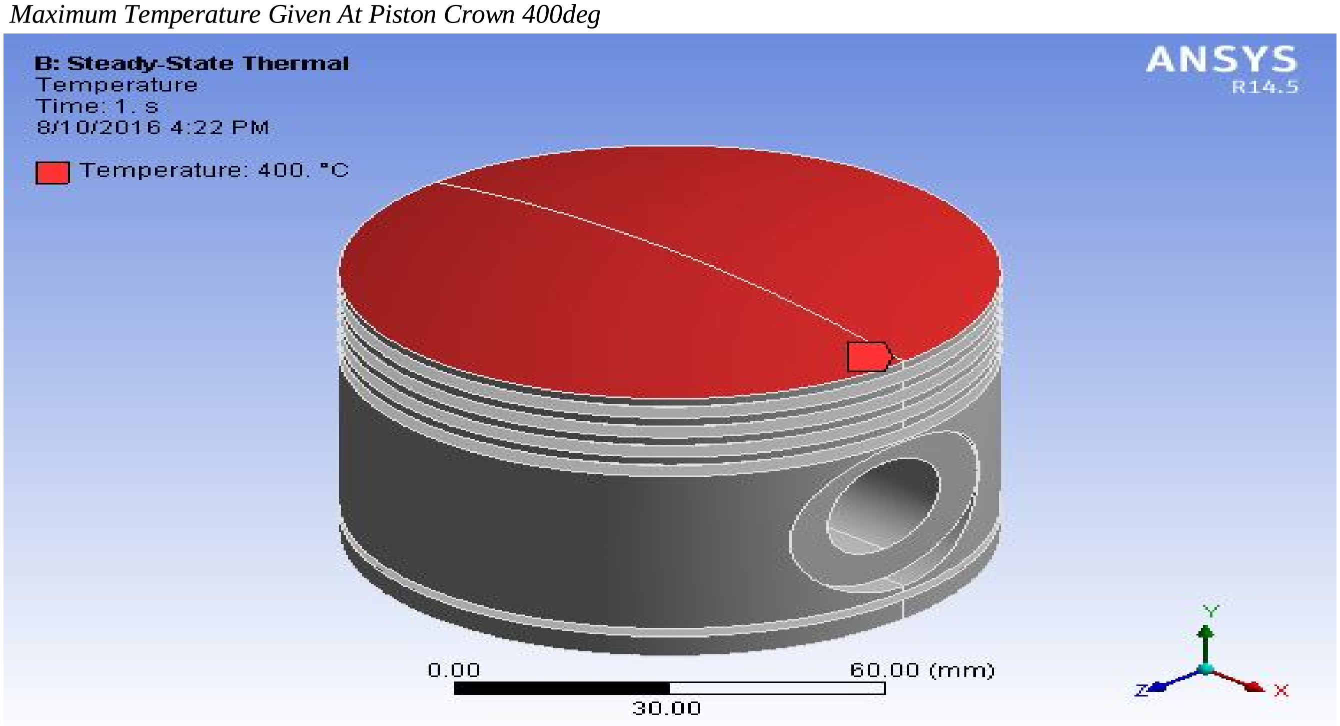
Thermal Stress Analysis:

1) Changes in temperature can induce substantial deformations, strains, and stresses. Thermal stress analysis refers to static analysis that includes the effect of temperature.
2) Perform thermal stress analysis using one of the following options:
3) Using a uniform rise or drop in temperature for the whole model.
4) Using a temperature profile resulting from a steady state or transient thermal analysis.
5) Using a temperature profile from Flow Simulation.

J. Material Properties

Material	Density (Kg/M^3)	Thermal Conductivity (W/m^0C)
Grey Cast Iron	7200	52
Aluminium Alloy	2770	175
Alsic	2711	250
Al203	3720	248

1) *Maximum Temperature Given At Piston Crown 400deg*



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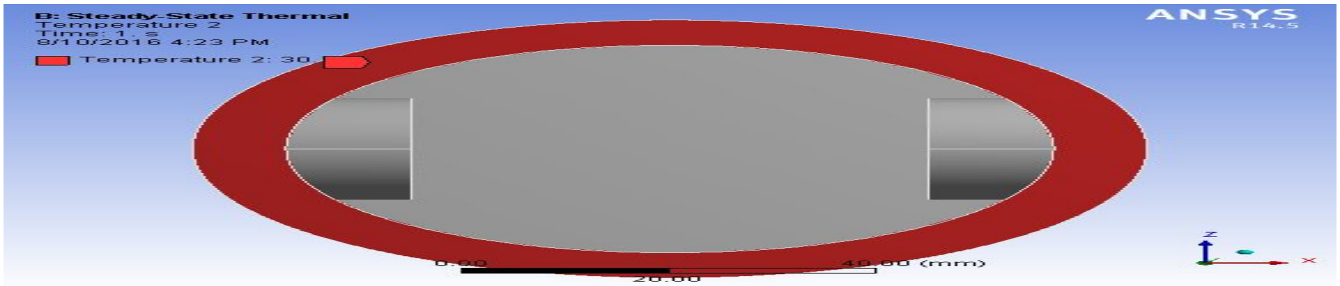
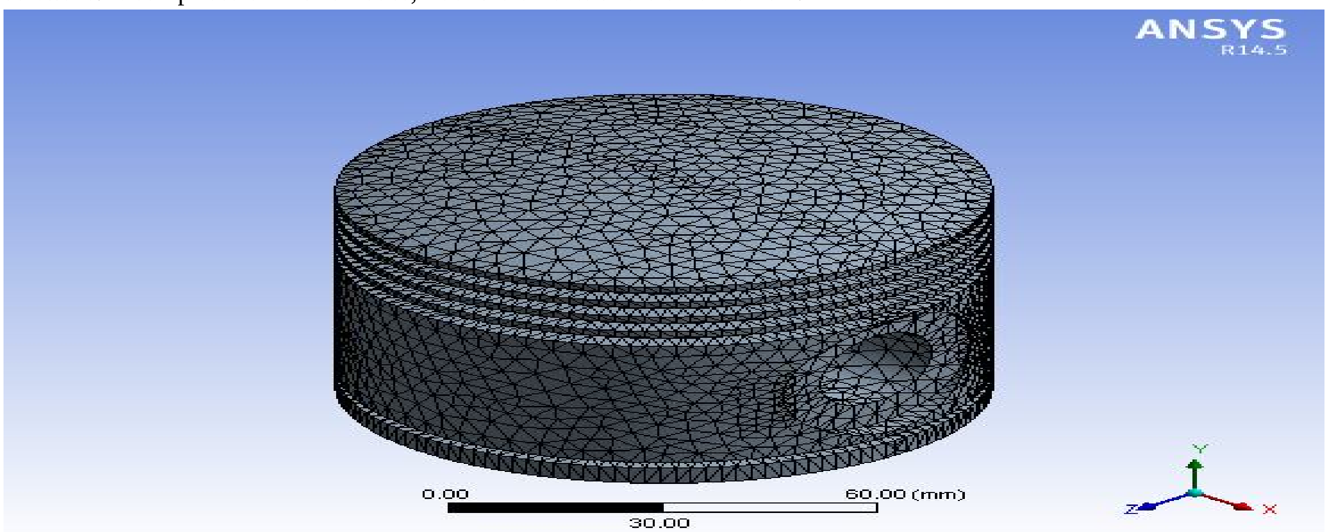
2) Minimum Temperature Given At Bottom Face 30deg



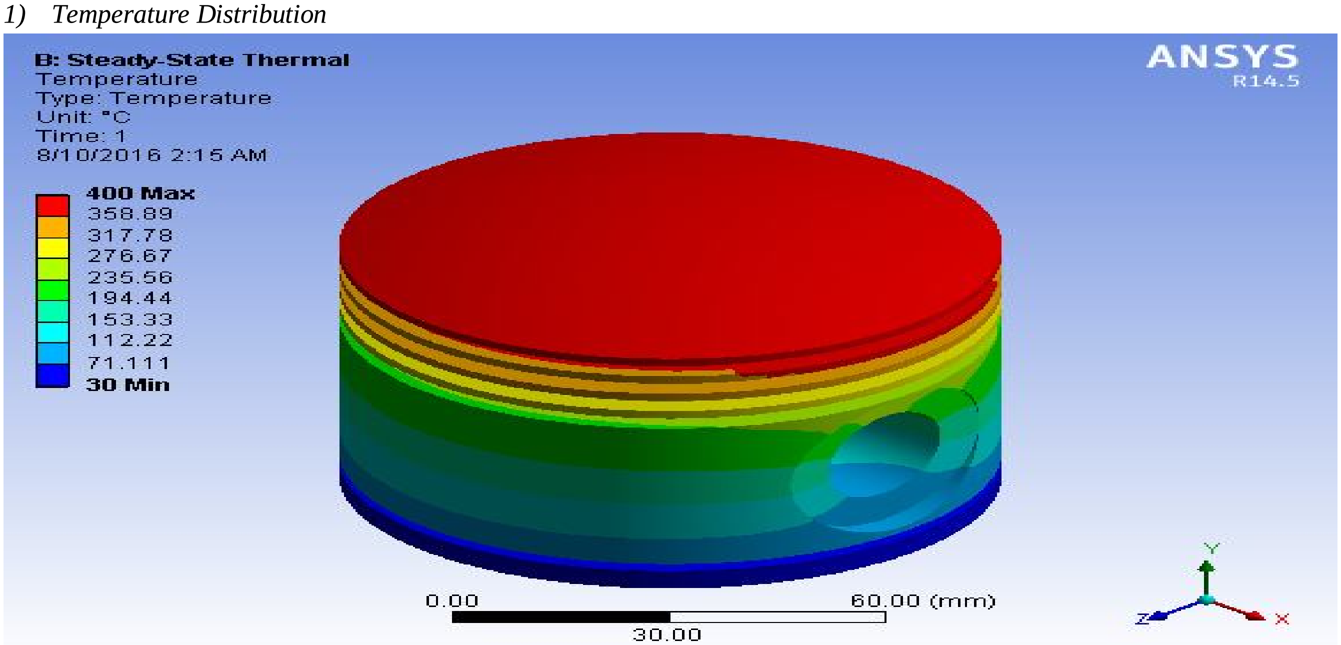
K. Meshing

Mesh type is tetrahedral The piston is meshed by using the hyper mesh software because of easy to mesh compared to ansys software. It comprises of 22970 nodes, 18845 elements and element size 4.



L. For Grey Cast Iron

1) Temperature Distribution



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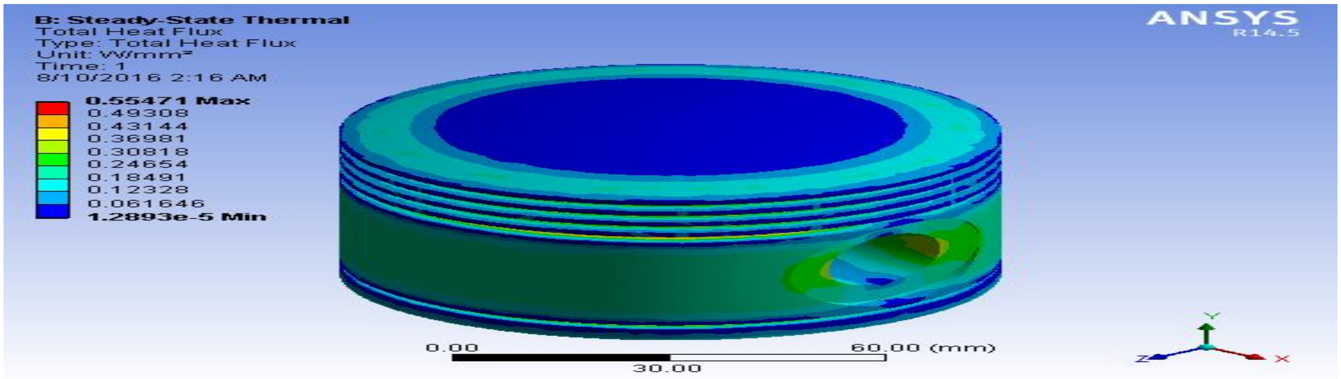
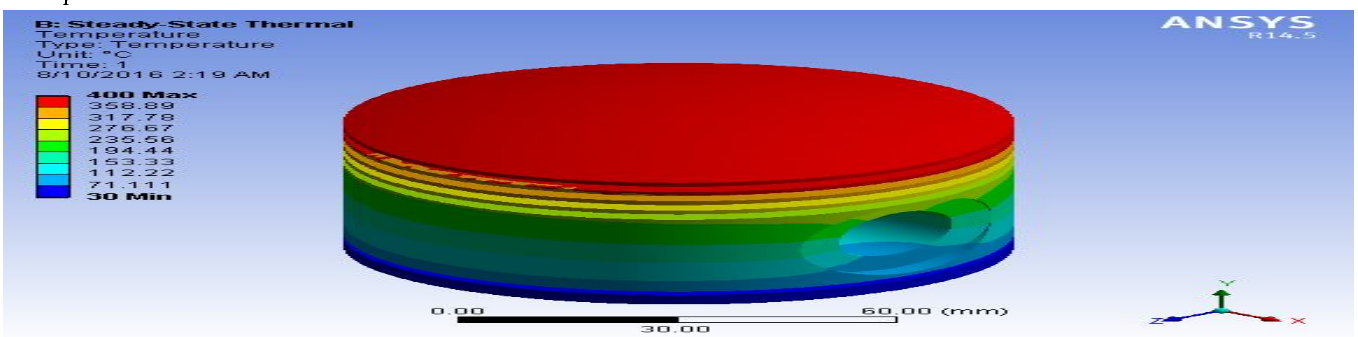
2) HEAT FLUX

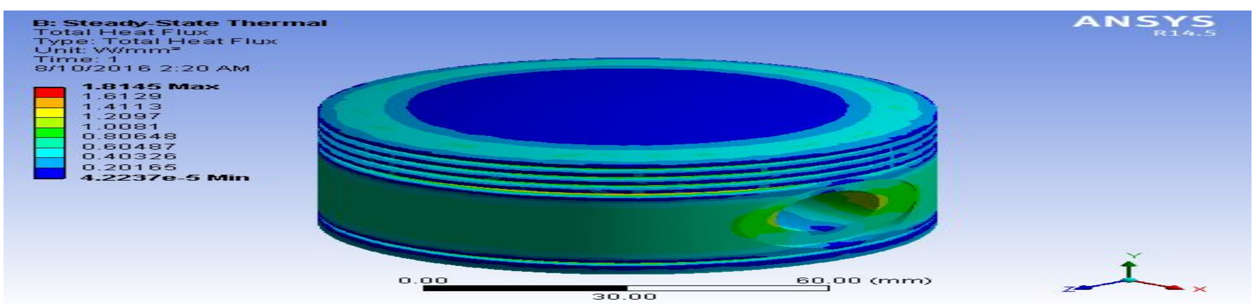


M. For Aluminium Alloy

1) Temperature Distribution

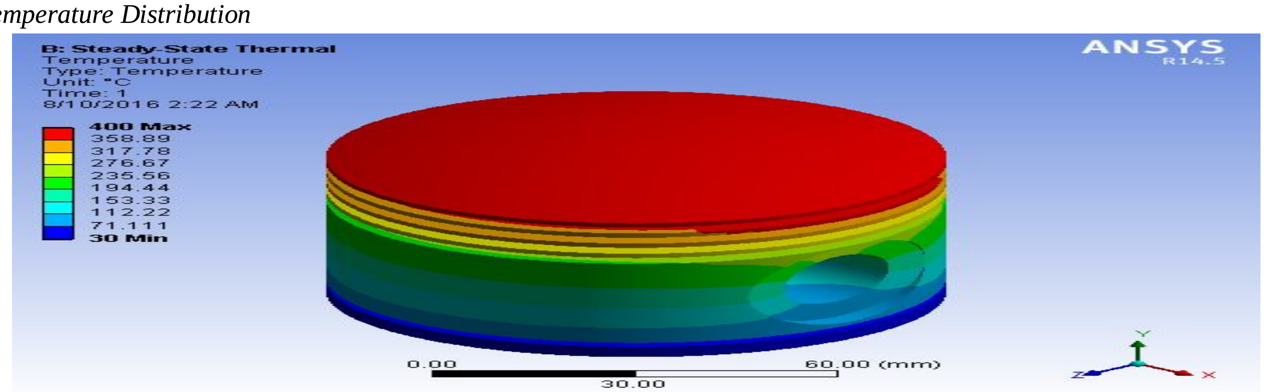


HEAT FLUX

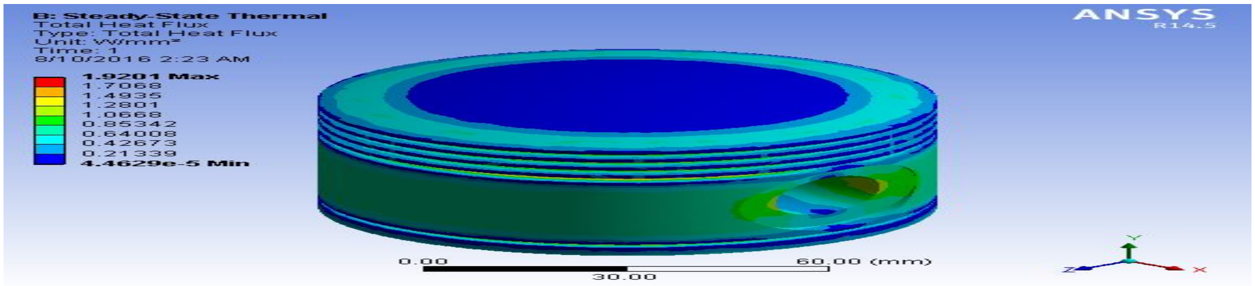


For AlSiC

2) Temperature Distribution

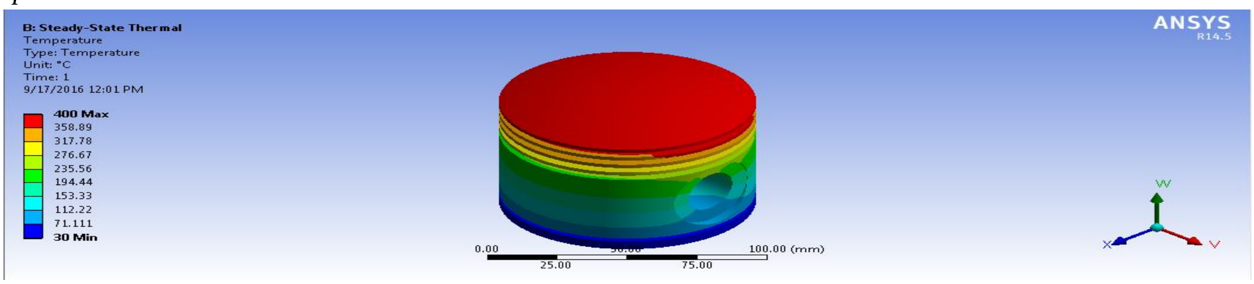


HEAT FLUX

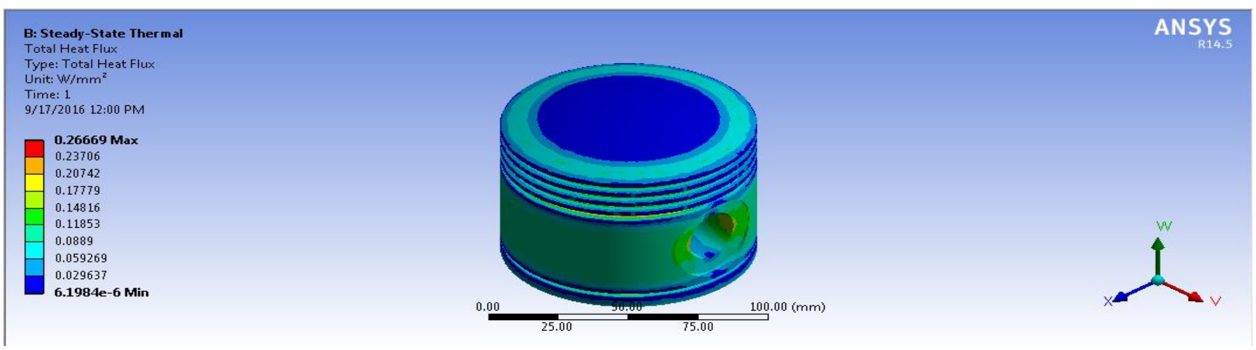


For Al2O3

3) Temperature Distribution



HEAT FLUX



N. Future scope of work

Piston Design models are simulated on iteration based and it requires more number of iterations to check whether design is safe or not and to validate the models with the allowable. Instead of the above process, DOE – Design of Experiments concept can be used to optimize the design within short time and to get better optimized parameters. DOE should be carried in Ansys workbench. In Ansys workbench modelling can be done from Catia or Design Modeller using parametric model options. DP stands for design points, optimization can be done in workbench based on the required outputs namely deformations and stress with in prescribed limits.

III. RESULTS

Material	Heat flux
Grey cast iron	0.55471
Aluminum alloy	1.8145
Al-sic graphite	1.9201
Aluminum oxide	0.26669

IV. CONCLUSION

Modeling and analysis of piston is done
Modeling of piston is done in solid works 2016 design software by using various commands
The solid works part file is converted into IGS file and imported to ansys workbench.
First Static structural analysis is carried out on piston at 1.5MPa pressure with four different materials, such as grey cast iron, aluminum alloy and al-sic graphite and aluminum oxide in ansys workbench.
Maximum stress, deformation, maximum strain and maximum shear stress are noted and tabulated
Then steady state thermal analysis is carried out at maximum temperature 400deg and minimum temperature 30deg for the above four various materials.
Temperature distribution and heat flux are noted for four different materials and tabulated.
From the tables it is concluded that the aluminum silicon carbide graphite (Al-SiC Graphite) is showing efficient results
Hence Al-SiC-Graphite is preferable among the four applied materials

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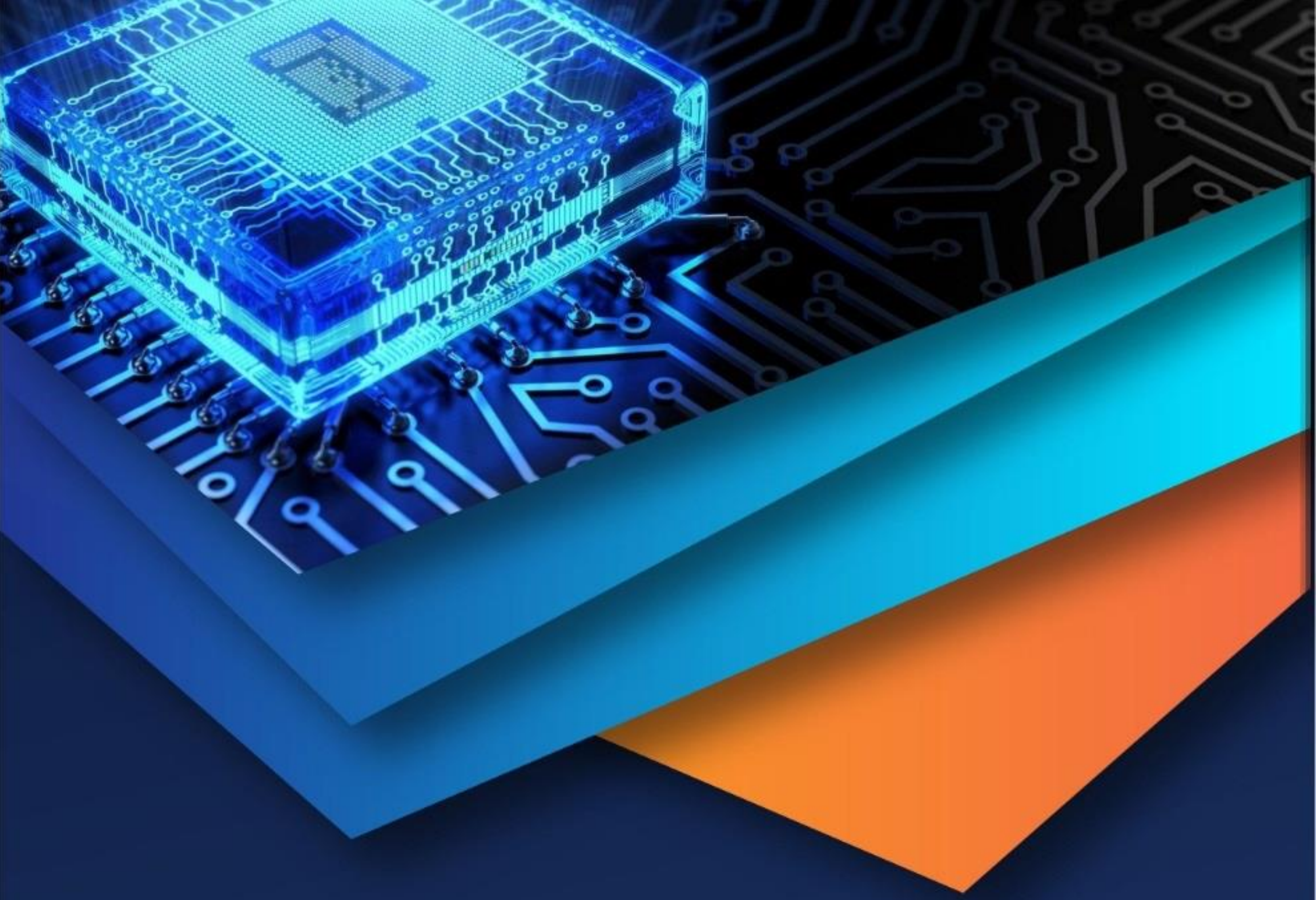

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