

## Experimental Analysis of Piston and Piston Ring of S.I Engine Using Ansys Software

<sup>1</sup>M. Prabhu, <sup>1</sup>P.L. Ramalingam, <sup>1</sup>L. Ganesh and <sup>2</sup>R. Vigithra

<sup>1</sup>Department of Mechanical, Panimalar Institute of Technology, Chennai, India

<sup>2</sup>Department of Mechanical Engineering, Panimalar Institute of Technology, India

**Abstract:** A piston and piston ring are designed for a single cylinder four stroke petrol engine using CATIA V5R20 software. The design is being analysed by using ANSYS 14.5 software for three different materials. The structural and thermal analysis of piston for the different materials are analysed. Two different materials are selected for the piston ring. The structural and thermal analysis is performed using ANSYS 14.5 software. Results are shown and a comparison is made to find the most suited design based on the data obtained from the analysis.

### Key words:

### INTRODUCTION

The modern trend is to develop IC Engine of increased power capacity. One of the design criteria is the endeavour to reduce the structures weight and thus to reduce fuel consumption. This has been made possible by improved engine design. These improvements include increased use of light-weight materials, such as advanced ultra-high tensile strength steels, aluminium and magnesium alloys, polymers and carbon-fibre reinforced composite materials. The engine can be called the heart of an automobile and the piston may be considered the most important part of an engine. The present work has been undertaken with the following objective [1].

- To design an IC engine (piston and piston ring) by using CATIA V5 R20 software
- To perform the structural and thermal analysis (of piston and piston ring) using ANSYS 14.5 software.

Three different materials have been selected for piston and two different materials for piston rings [2].

**Design of the Components:** The piston and piston rings are designed according to procedures and specifications given in machine design and design data book. Dimensions are calculated and these are used for modelling the piston and piston ring in CATIA V5R20 as shown in Fig. 1 and Fig. 2.

These were then imported to ANSYS 14.5 for structural and thermal analysis. Structural analysis of piston is performed on ANSYS 14.5 Mechanical APDL and thermal analysis is performed on ANSYS 14.5 workbench. Structural and thermal analysis of piston ring is performed on the ANSYS 14.5 workbench [3].

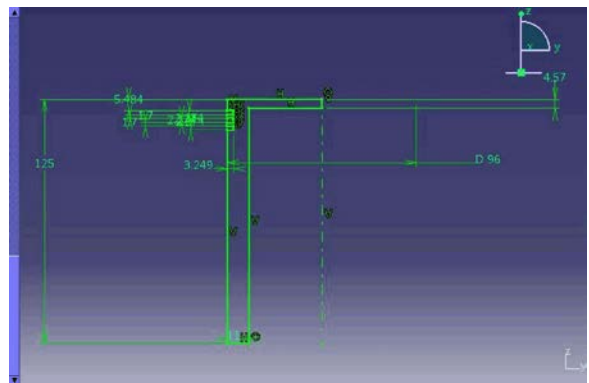


Fig. 1: Piston Drawing and Dimensions

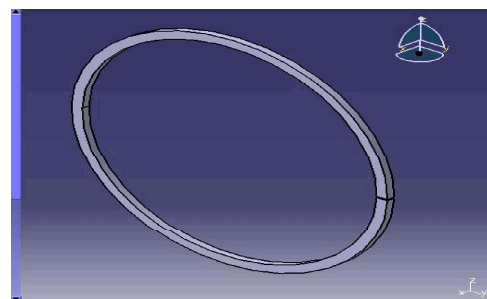


Fig. 2: Three D piston ring

## MATERIALS AND METHODS

Table 1: Material for piston

	Al alloy 4032	AISI4340 Alloy Steel	Titanium Ti-6Al-4V
Poisson ratio	0.35	0.28	0.342
Modulus of elasticity(GPa)	79	210	113.8
Thermal conductivity (w/m k)	155	44.5	6.7
Ultimate tensile strength MPa	380	745	950
Yield tensile strength MPa	315	470	880
Density g/cc	2.68	7.8	4.43

Table 2: Material or piston ring:

	Ductile Nodular Spheroidal cast iron	ASTM grade 50 (ISO grade 350, EN – JL 1060) Grey cast iron
Poisson ratio	0.275	0.26
Modulus of elasticity (GPa)	176	157
Thermal conductivity (w/m k)	33	46
Ultimate tensile strength MPa	414-827	362
Yield tensile strength (MPa)	240-621	228
DENSITY g/c.c	7.2	7.1

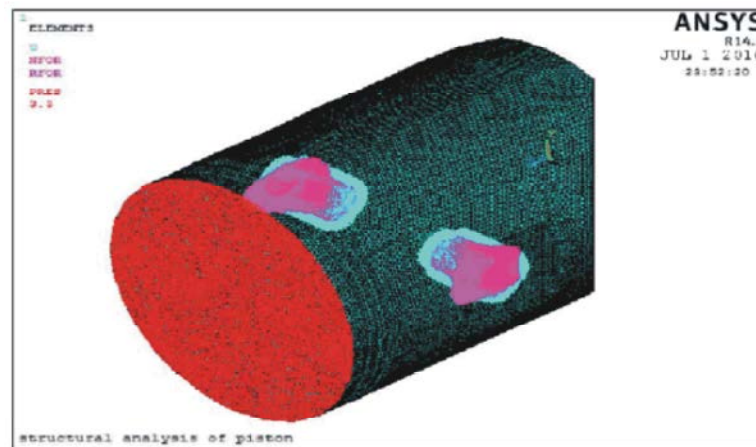


Fig. 3: Boundary Condition Of Structural Analysis

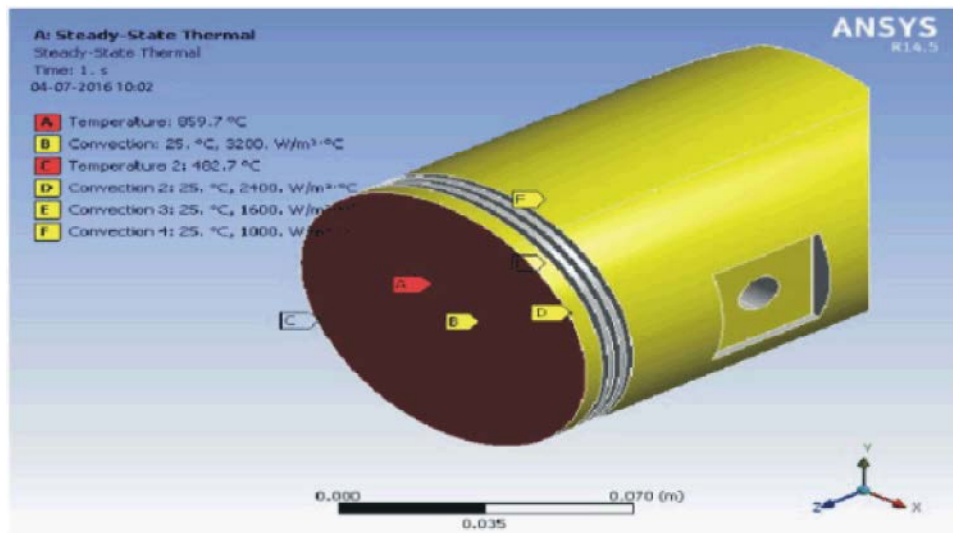


Fig. 4: Boundary Condition For Thermal Analysis

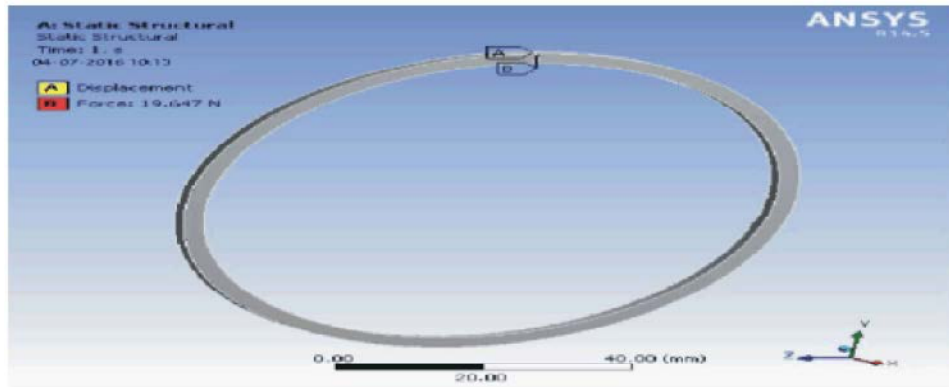


Fig. 5: Boundary Condition For Structural Analysis

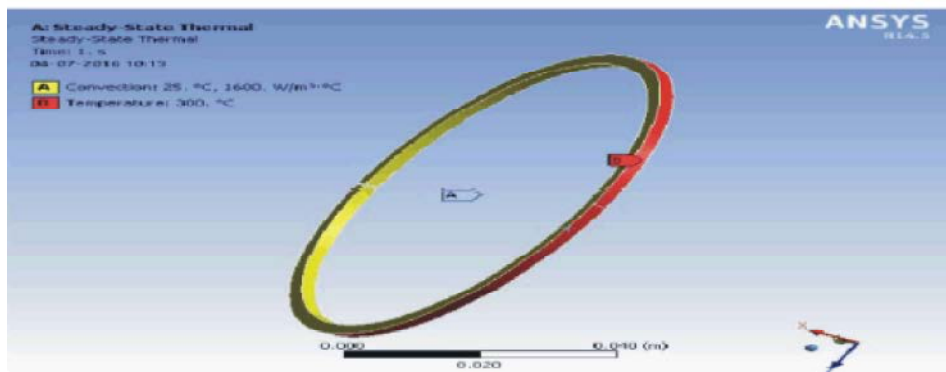


Fig. 6: Boundary Condition For Thermal Analysis

**Boundary Condition for Thermal Analysis of Piston:** The thermal boundary conditions consist of applying a convection heat transfer coefficient and the bulk temperature and they are applied to the piston crown, land sides, piston skirt shown in Fig. 4.

Maximum on piston head temperature = 859.7°C, Bulk temperature = 25°C, Heat transfer coefficient on piston surface = 3200 W/m²K, Maximum temperature at edges piston = 482.7°C, Heat transfer coefficient on edge piston = 2400 W/m²K, Heat transfer coefficient on lands rings = 1600 W/m²K, Heat transfer coefficient on piston skirt = 1000 W/m²K.

## RESULTS

It is clear from Fig. 7, 9 and 11 that the maximum displacement is observed in the piston made of Al alloy 4032 and minimum in AISI 4340 alloy steel. As it is expected maximum displacement is observed at the top of the centre of the piston. It is shown in the Fig. 8, 10 & 12 that the maximum stress intensity is observed in AISI 4340 with 301.903 MPa and minimum in Al alloy 4032 with 295.69 MPa [4]. It is observed that the maximum stress intensity is on the bottom surface of the all piston

crown and along the edges [5]. Again in piston made of titanium alloy moderate stress intensity is found. Whereas the yield strength of the piston is very high in Titanium alloy piston followed by AISI 4340 steel and Al alloy 4032 [6].

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 Al alloy [7]. This is due to thermal conductivity of the materials. Minimum temperature is in the skirt of the piston is observed as shown in Figure 13, 15 & 17.

Figure 14, 16 & 18 shows that max total heat flux is observed in piston of Al alloy and piston of titanium alloy shows the lowest value of max total heat flux along the edges [8].

Piston rings are made of Nodular Spheroidal Cast Iron & Grey Cast Iron. GCI Piston Rings show more deformation than in NSCI. Stress intensity is equal in both. Maximum temperature is equal in both materials, where minimum temperature is higher in GCI, which is 222.8°C. Here, maximum total heat flux is observed in GCI piston rings & minimum value in NSCI piston rings [9].

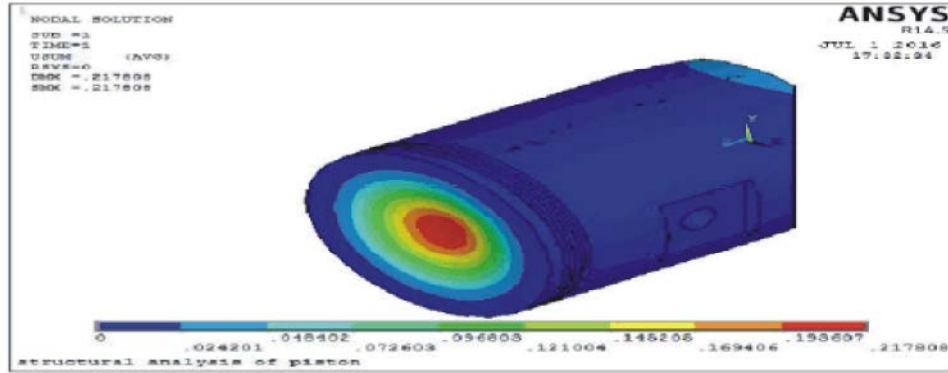


Fig. 7: Displacement vector sum for Al Alloy 4032

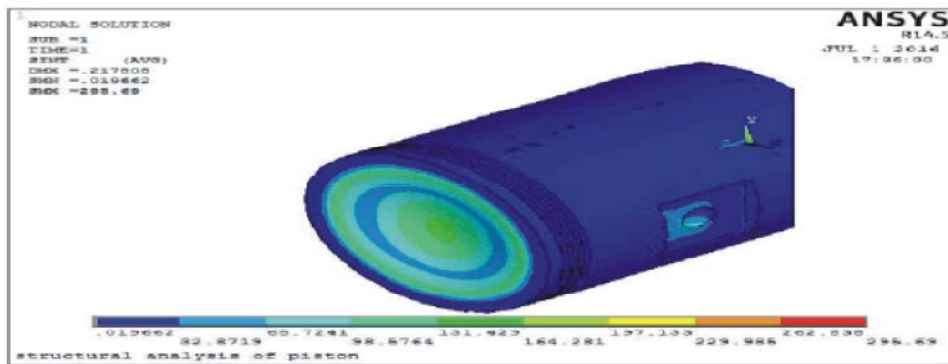


Fig. 8: Stress intensity for Al Alloy 4032

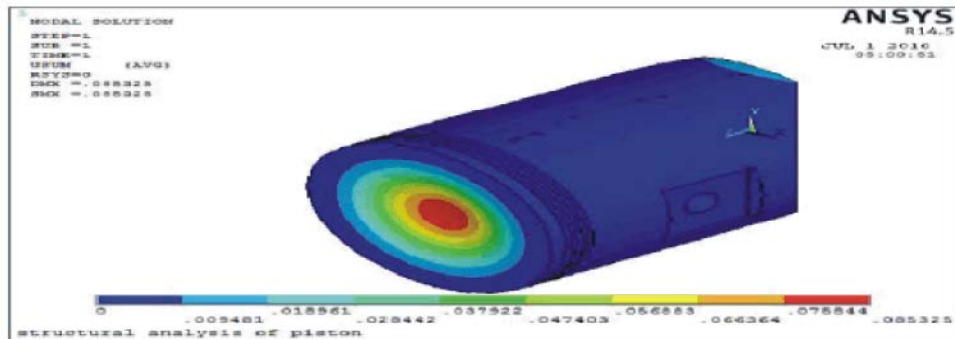


Fig. 9: Displacement vector sum for Alloy Steel 4340

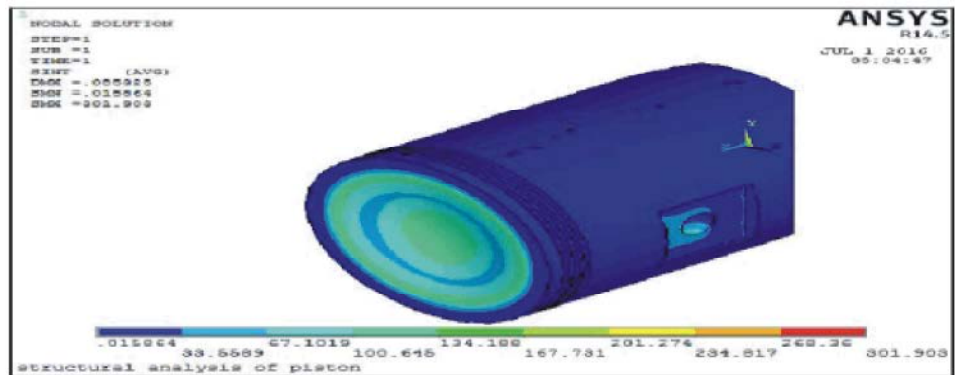


Fig. 10: Stress intensity for Alloy Steel 4340

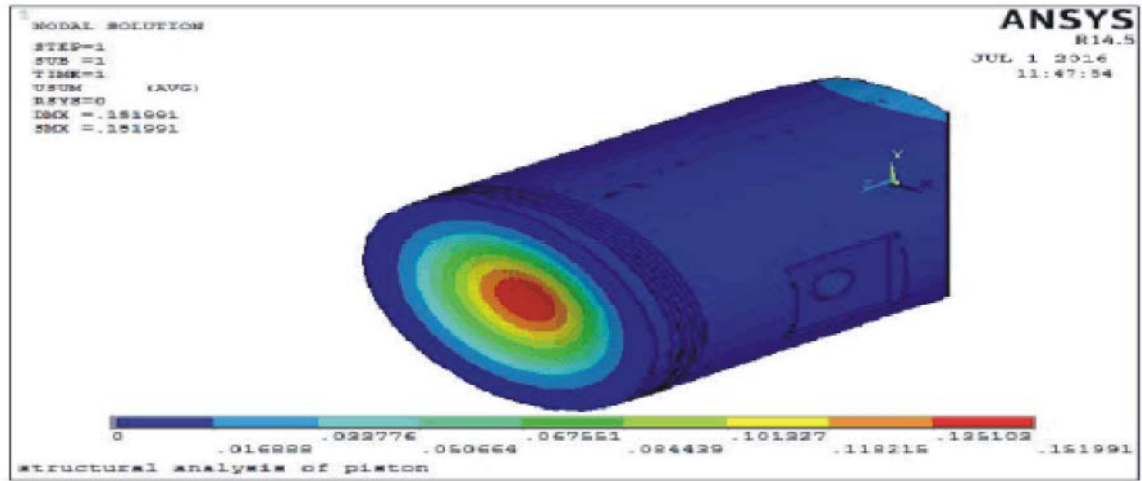


Fig. 11: Displacement vector sum for Titanium Ti-6Al-4V

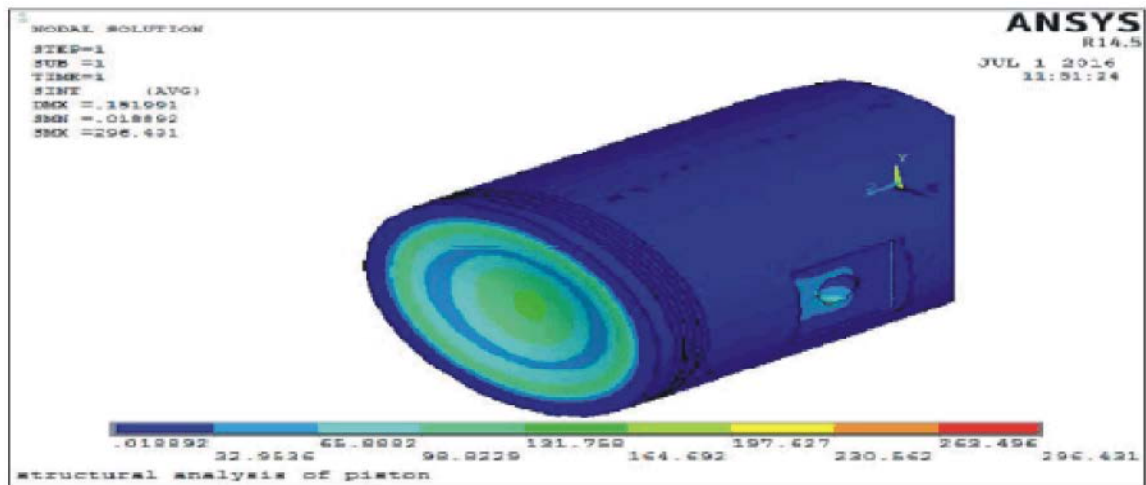


Fig. 12: Stress intensity for Titanium Ti-6Al-4V

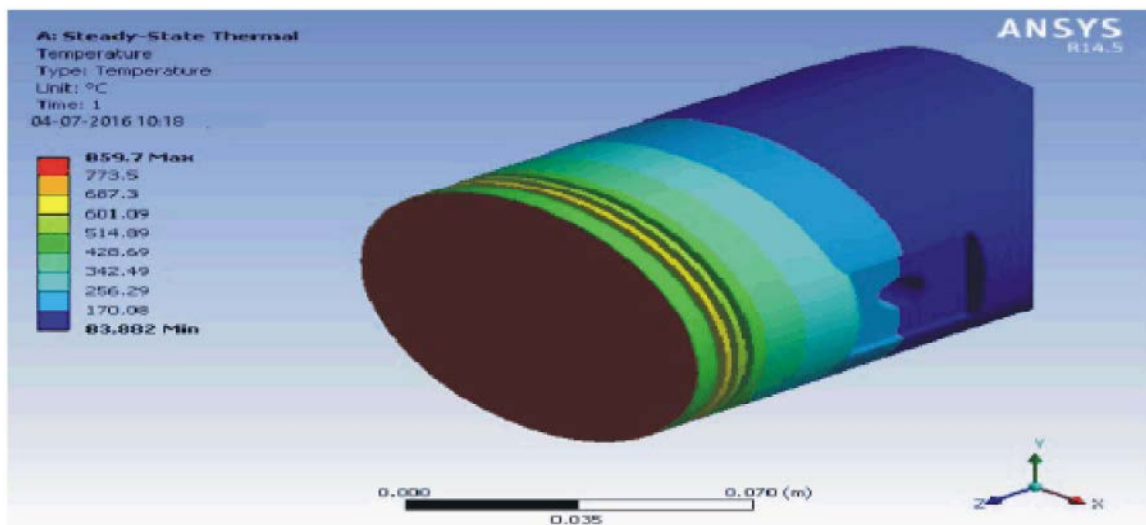


Fig. 13: Temperature for Al Alloy 4032



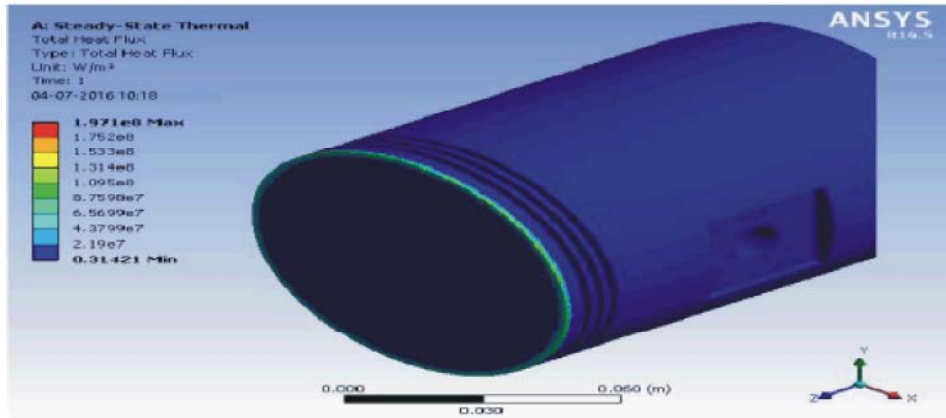


Fig. 14: Heat flux for Al Alloy 4032

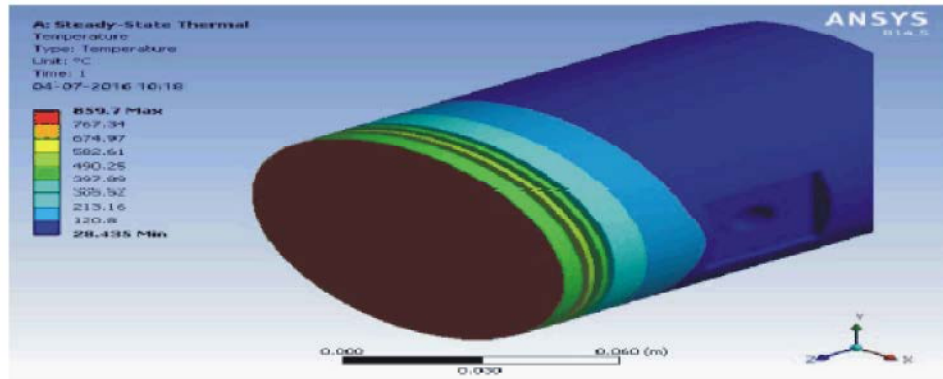


Fig. 15: Temperature for AISI Alloy Steel 4340

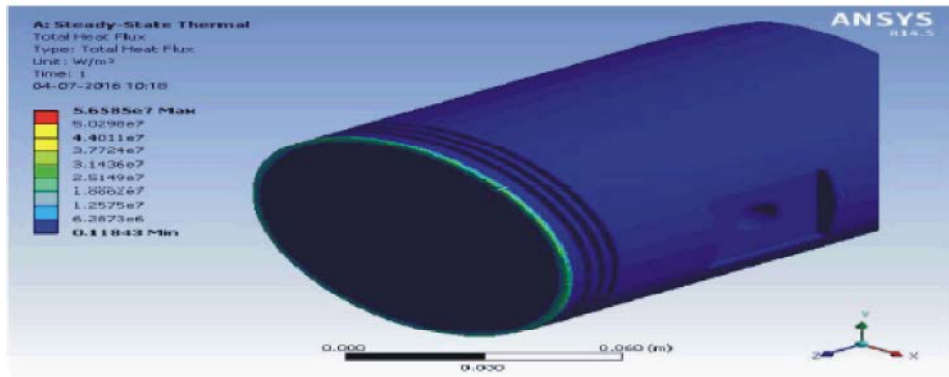


Fig. 16: Heat flux for AISI Alloy Steel 4340

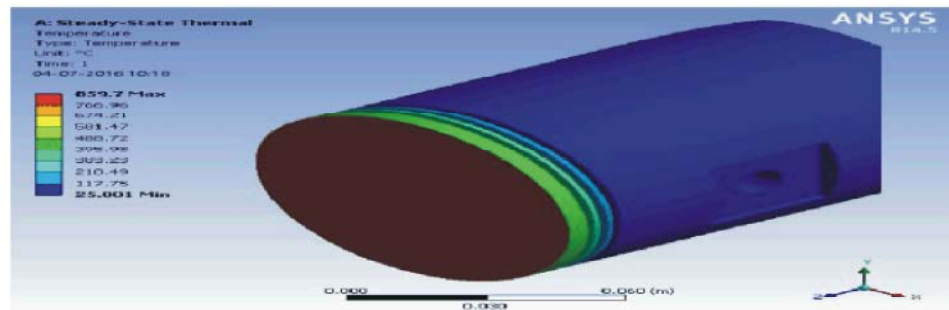


Fig. 17: Temperature for Titanium Ti-6Al-4V

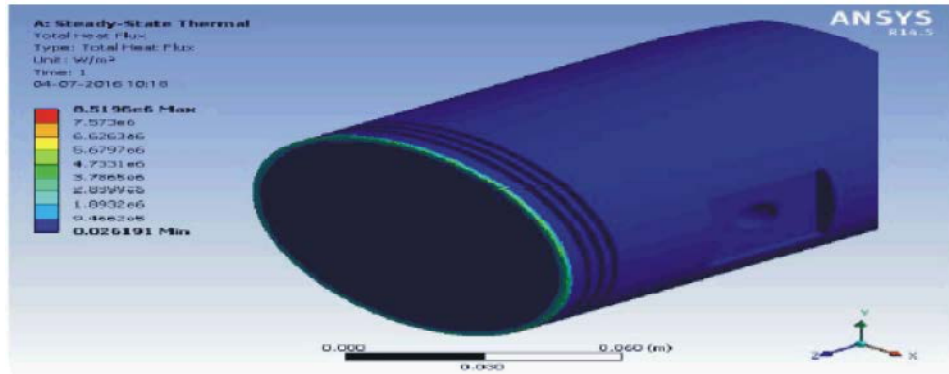


Fig. 18: Heat flux for Titanium Ti-6Al-4V

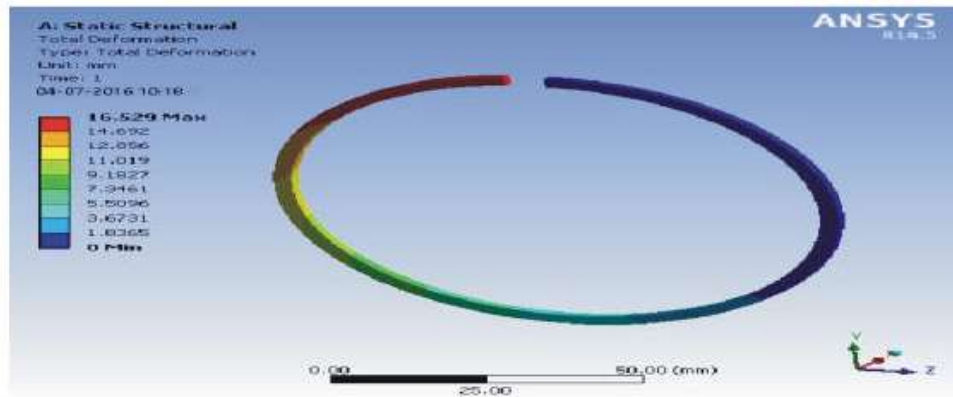


Fig. 19: Total deformation for Nodular pearoidal cast iron

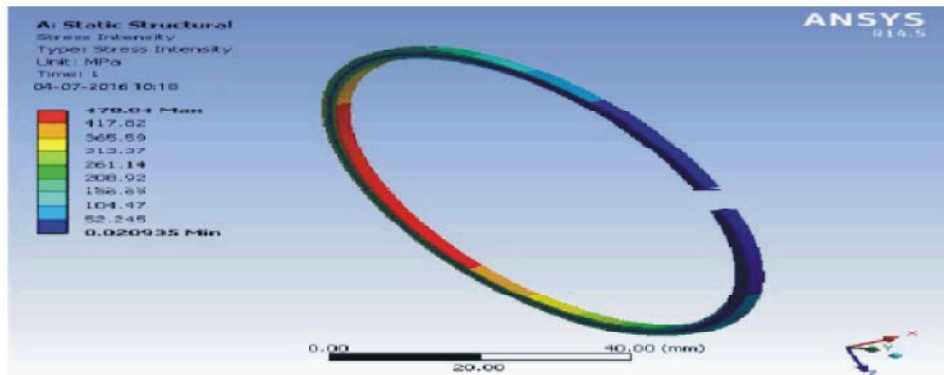


Fig. 20: Stress intensity for Nodular Spheroidal cast iron

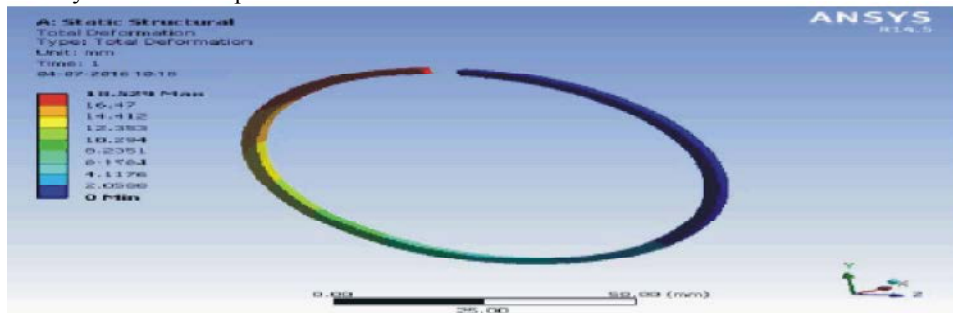


Fig. 21: Total deformation for grey cast iron

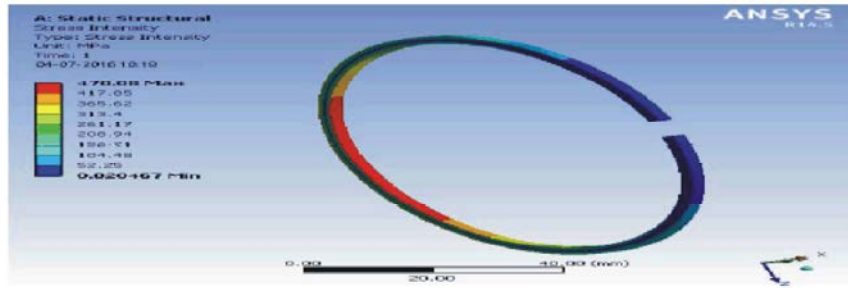


Fig. 22: Stress intensity for grey cast iron

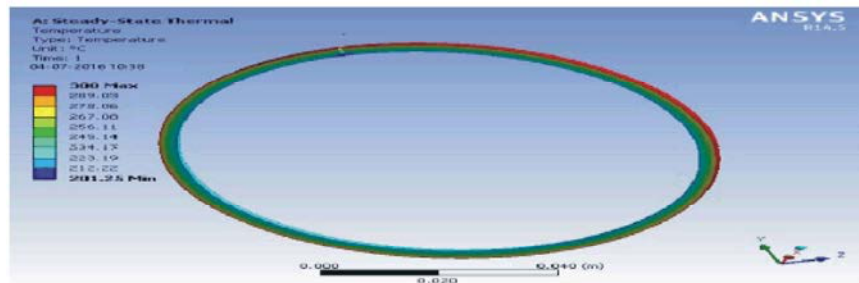


Fig. 23: Temperature for Nodular Spheroidal cast iron

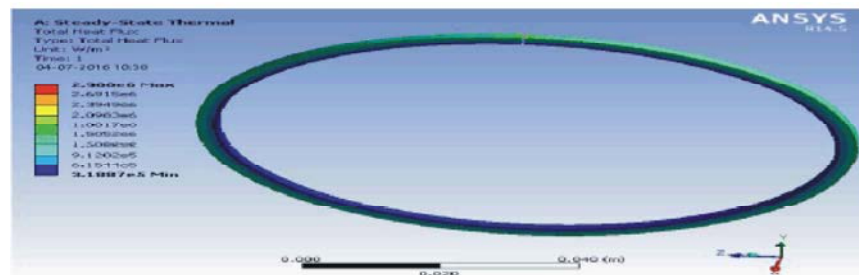


Fig. 24: Total heat flux for Nodular Spheroidal cast iron

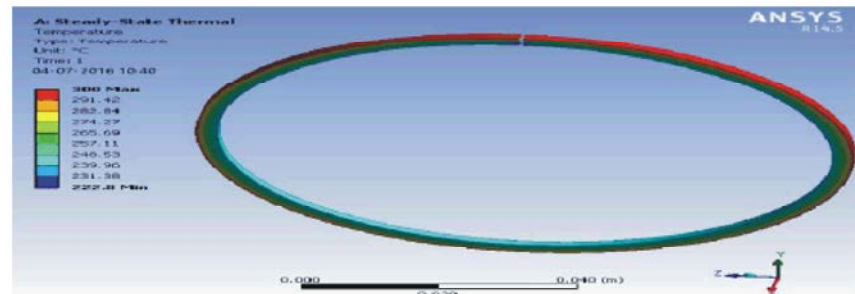


Fig. 25: Temperature for grey cast iron

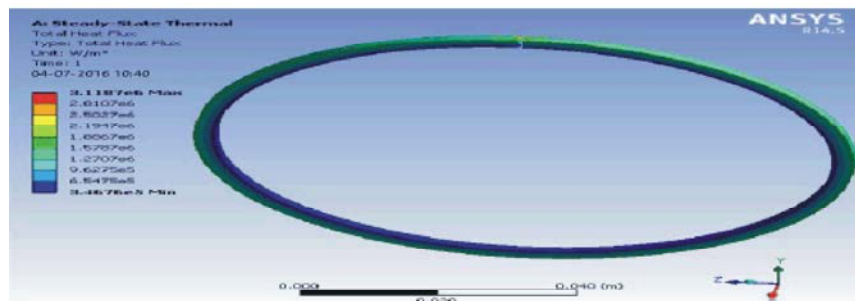


Fig. 26: Total heat flux for grey cast iron



## CONCLUSION

It is concluded from the above study that using CATIAV5R20 software design and modelling become easier. Only few steps are needed to make drawing in three dimensions. Same can be imported to ANSYS for analysis. Piston made of three different materials Al alloy 4032, AISI 4340 Alloy steel and Titanium Ti-6Al-4V (Grade 5) are analysed. Their structural analysis shows that the maximum stress intensity is on the bottom surface of the piston crown in all the materials, but stress intensity is close to the yield strength of Al alloy piston. 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 the materials, heat transfer rate is found maximum in Al alloy piston and minimum in Ti alloy piston. For the given loading conditions, Al alloy piston is found most suitable. But when the loading pattern changes, other materials can be considered. With the advancement in material science, very light weight materials with good thermal and mechanical properties can be used for fail safe design of the I.C.engine. This will reduce the fuel consumption and protect the environment.

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