International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Modeling and Analysis of Piston using Various Piston Crown Geometries

Mohd Abdul Rahman, P. Ravi Chander, M. Prasad

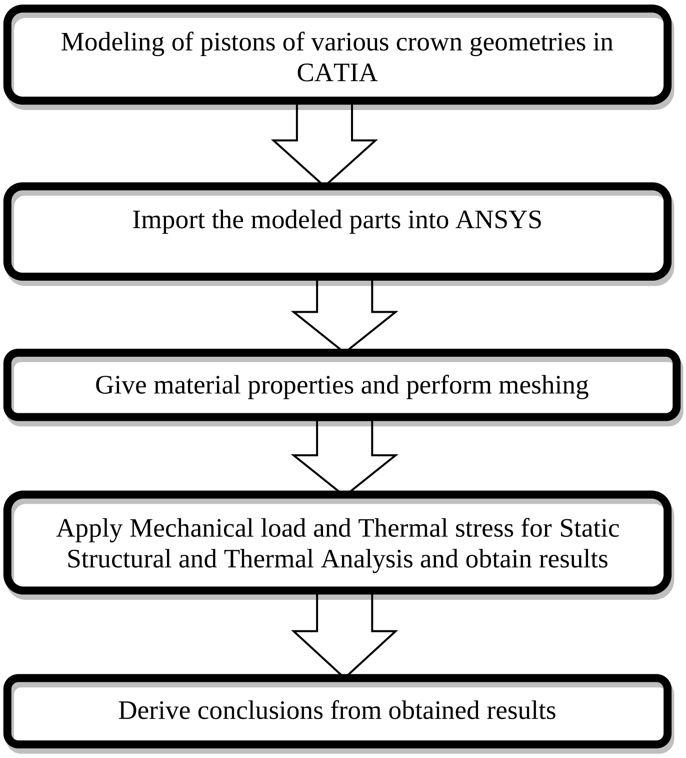
Abstract*: Piston is the essential part of an IC engine and due to increase in manufacturing of automobiles of various types based on performance and power, the piston of an IC engine is under significant stress which causes wear of the piston. Piston is under mechanical and thermal loads due to combustion of the fuel and generation of high pressure gases. To reduce the damage incurred on an IC piston by the combustion of fuel the crown geometry of the piston can be modified. This reduces the wear incurred on an IC engine piston and increases the life of the IC engine piston. To understand the impact of mechanical loads on the piston static structural analysis has to be performed and to understand the impact of thermal loads, thermal analysis has to be performed. In this paper we have modeled three dimensional pistons with four different crown geometries using CATIA and performed static structural and thermal analysis in ANSYS to find total deformation, equivalent (von-misses) stress, maximum shear stress, temperature and heat flux. So we can find the best crown geometry for the manufacturing of IC engine piston.

Keywords: ANSYS/CATIA, IC engine Piston, Static Structural and Thermal analysis, Various Piston Crown Geometries.

I. INTRODUCTION

IC engine is the main component of automobiles, motorcycles which converts the chemical energy into mechanical energy in the combustion chamber. In combustion chamber due to combustion of fuel with an oxidizer, high temperature and high pressure gases are produced which impacts the piston of the engine. These high pressure and temperature gases apply force on the piston causing it to move over a distance and this is how chemical energy is converted into work. The piston is the most important component of the IC engine and forms crank mechanism together with crank shaft and connecting rod. Piston has to transmit the force, dissipate the heat and guide the movement of connecting rod. The piston is the first component which gets damaged due to high temperature and pressure of the gases in IC engine. Various researches have been conducted by varying the material of the piston and applying mechanical and thermal loads to find the best material which doesn't undergo much deformation under the loads [1]. Other attempts have been made to overcome the problems in the engine like knocking, presence of residual exhaust gases by changing the shape of the combustion chamber and using F-head type engine with a tapered piston[2]. Convex piston can be used for light weight daily motoring vehicles and concave piston can be used for diesel engine[3]. When compared to conventional piston design parameters of the piston can be changed like reducing skirt length and it reduces the temperature on the piston due to thermal load [4]. Computational results of analysis is close to theoretical calculations and structural deformation is maximum at the piston crown[5]. The stress is concentrated at the centre of the piston crown[6]. CFD analysis on various piston heads show varying results and the best crown geometry can be used in the manufacturing[8]. Various parameters of the piston like volume, mass length and bore diameter of the piston are changed to optimize the piston and compare it with conventional piston and the results suggest that optimized piston is better[9]. In this paper we have tried to optimize the IC engine piston by changing the crown geometry of the piston and considered four different crown geometries out of which crown-a piston is the conventional piston crown. Our aim here is to perform Static Structural and Thermal analysis and analyze the results obtained to find the best crown geometry which can be used for manufacturing of the piston.

II. METHODOLOGY



Revised Manuscript Received on March 30, 2020.

***** Correspondence Author
Mohd Abdul Rahman*, Post graduate student in the field of mechanical engineering at Methodist College of Engineering and Technology, Hyderabad, India. Email: mohd.rahman162@gmail.com
Dr.P.Ravi Chander, Assistant Professor, Department of mechanical engineering, Methodist college of engineering and technology, Hyderabad, India. Email: vira755@gmail.com
M.Prasad, Assistant Professor, Department of mechanical engineering, Methodist college of engineering and technology, Hyderabad, India., Email: prasadmatam@gmail.com

III. PISTON CROWN GEOMETRIES

We have considered four different crown geometries of the piston as shown in fig 1, 2, 3 and 4.

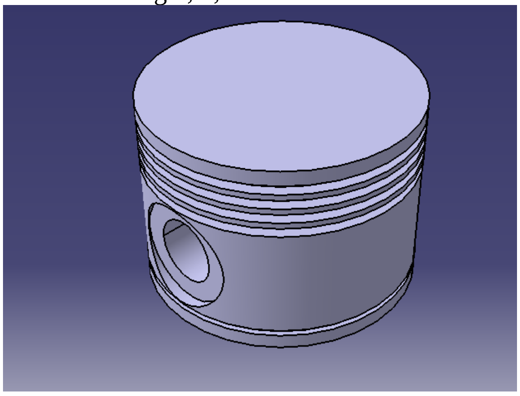


Fig1. Piston with Crown A

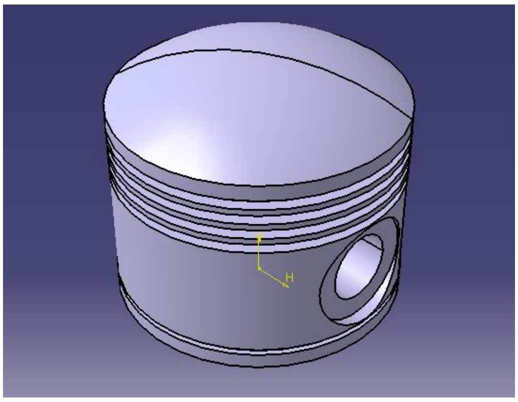


Fig2. Piston with Crown B

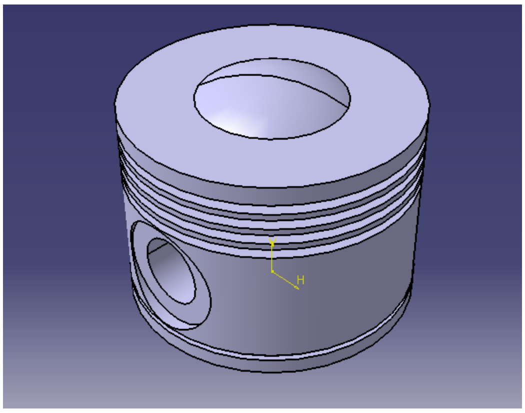


Fig3. Piston with Crown C

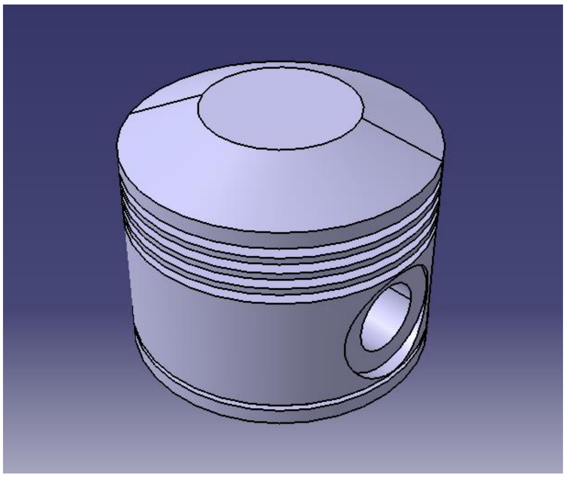


Fig4. Piston with Crown D

IV. MATERIAL PROPERTIES

S.No	Properties	AlSi10Mg (Aluminum alloy)
1	Young's Modulus in Pa	7.66e+10
2	Poisons ratio	0.33
3	Density in Kg/m³	2670
4	Thermal Conductivity	110 W/(m°c)
5	Tensile Ultimate Strength in Pa	3.5e+8

V. MESHING

Meshing is performed on the piston which is done to create subdivision of continuous geometric space into discrete geometric and topological cells. Meshing is done because performing analysis on complex shaped geometries is difficult so we need small geometries which are also called as meshes to perform the analysis. These small geometries when considered together represent the complex geometry on which analysis has to be performed. So basically meshing facilitates the analysis process and helps us to get correct results. Sometimes the shapes on which analysis has to be performed are quite complex and performing analysis is difficult in such case meshing has to be done and then analysis can be carried out.

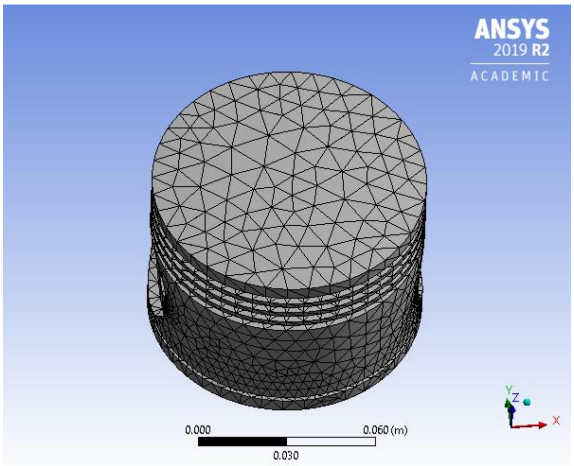


Fig5. Meshing of Crown-A Piston

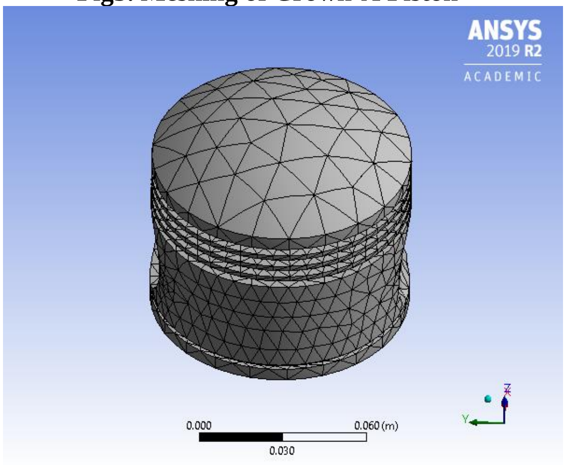


Fig6. Meshing of Crown-B Piston

Retrieval Number: E2751039520/2020©BEIESP
DOI: 10.35940/ijitee.E2751.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

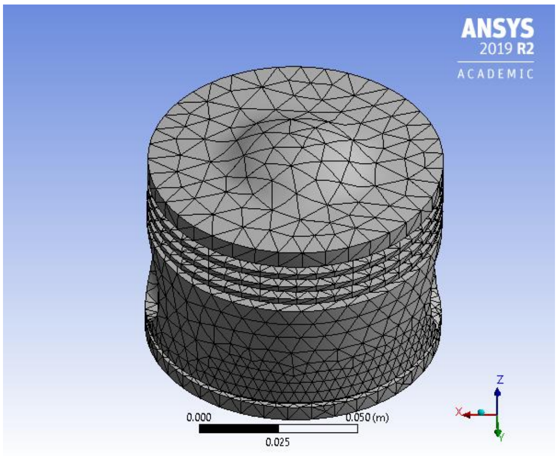


Fig7. Meshing of Crown-C Piston

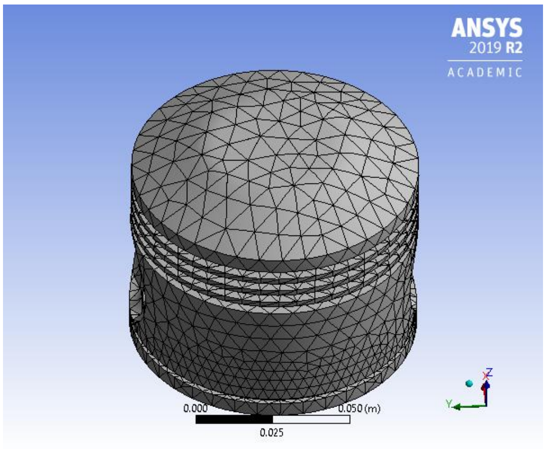


Fig8. Meshing of Crown-D Piston

VI. MECHANICAL LOADING

We need to apply mechanical load which is due to the pressure exerted by the gases due to combustion of the fuel and is considered to be 12MPa applied at the crown of the piston. We also need to give frictionless support to the piston.

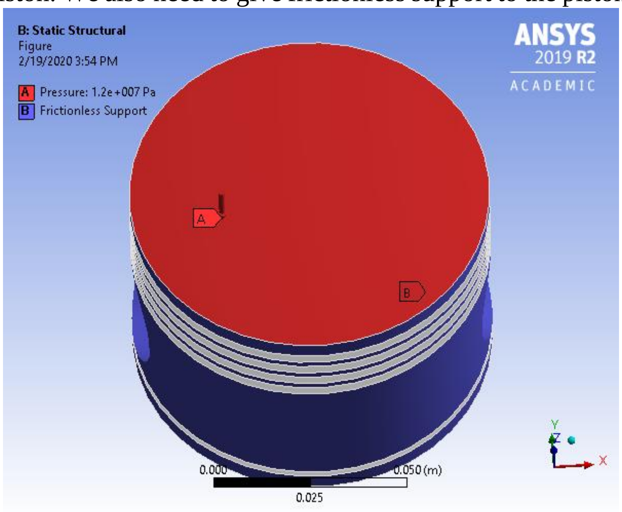


Fig9. Mechanical load and Frictionless Support on Crown-A Piston

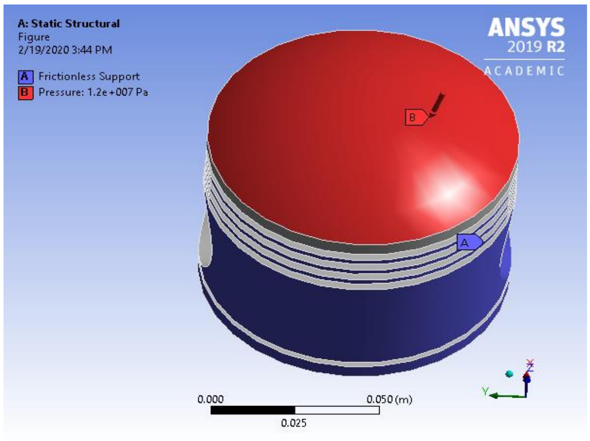


Fig10. Mechanical load and Frictionless Support on Crown-B Piston

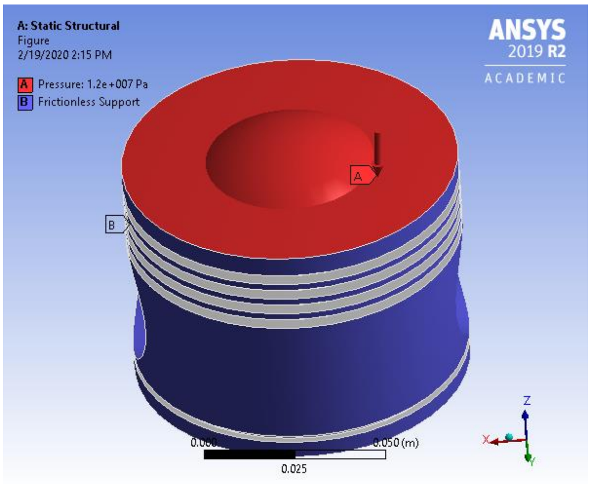


Fig11. Mechanical load and Frictionless Support on Crown-C Piston

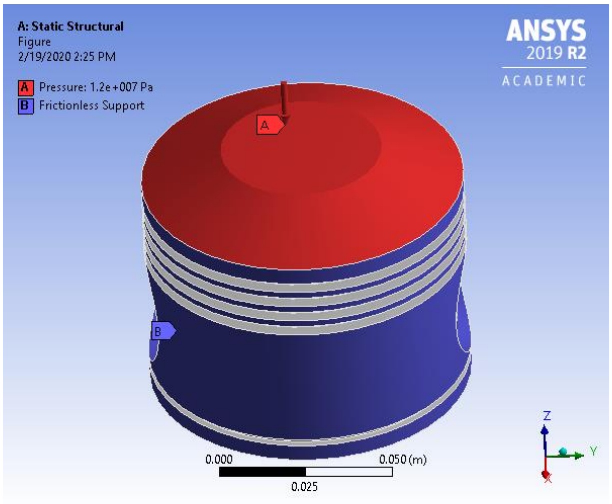


Fig12. Mechanical load and Frictionless Support on Crown-D Piston

VII. THERMAL LOADING AND COEFFICIENT OF HEAT TRANSFER

The crown of the piston has the maximum temperature as it is exposed to the combustion chamber in which combustion of fuel occurs and heat is also generated.

The temperature at the crown of the piston is around 450°C whereas the heat transfer coefficient of the piston is found to be around 540 W/(m²°C) from similar research carried out in research paper. The analysis which we are going to carry out is the steady state thermal analysis where temperature and convection are input parameters.

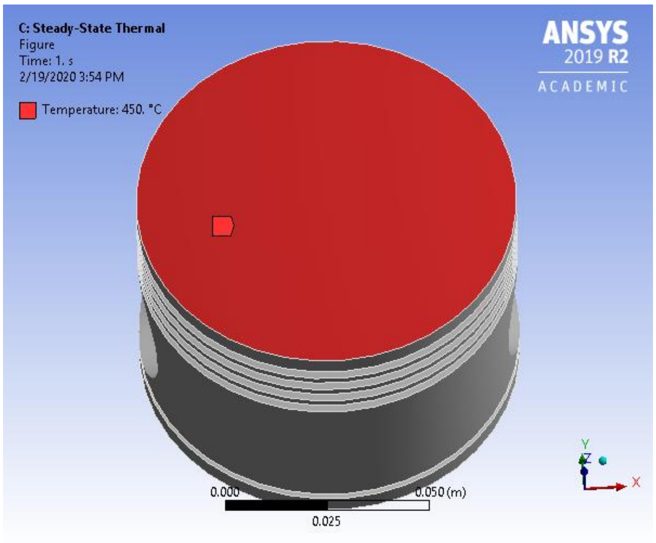


Fig13. Temperature on Crown-A Piston

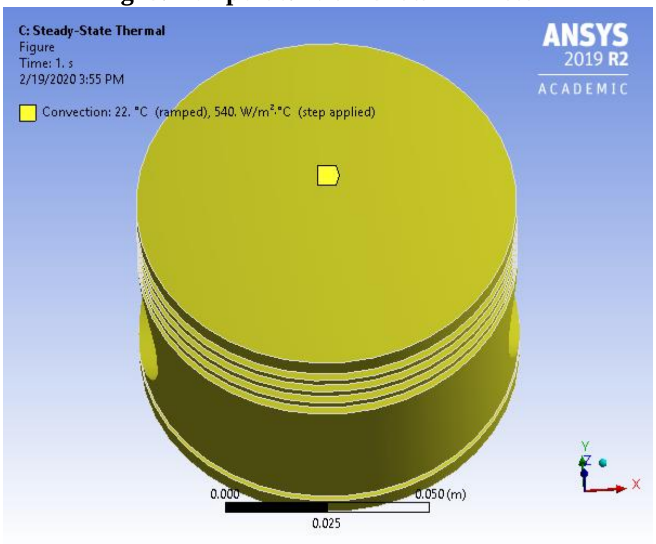


Fig14. Heat Transfer Coefficient on Crown-A Piston

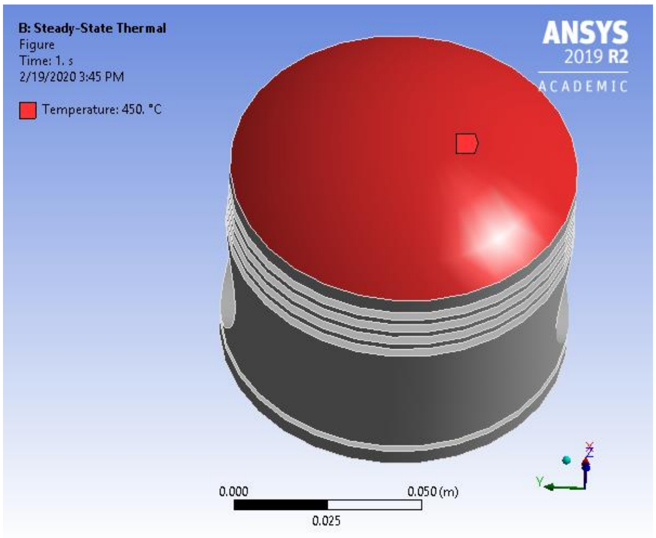


Fig15. Temperature on Crown-B Piston

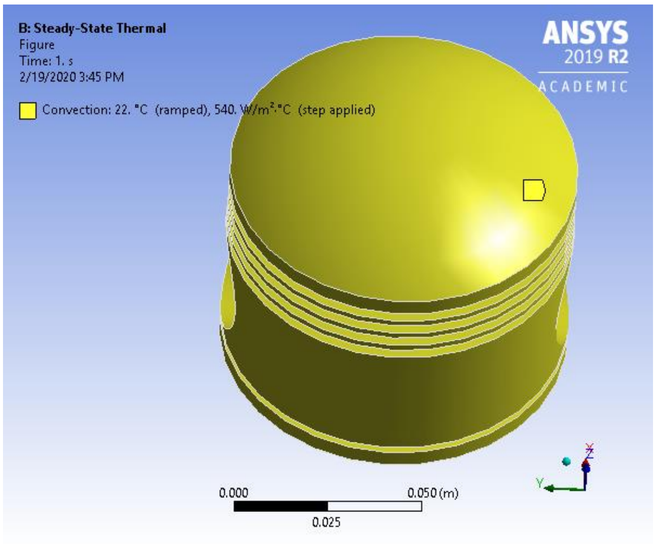


Fig16. Heat Transfer Coefficient on Crown-B Piston

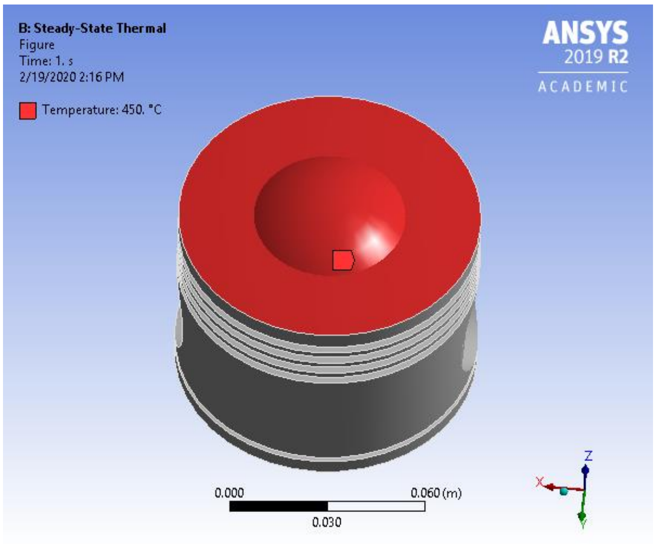


Fig17. Temperature on Crown-C Piston

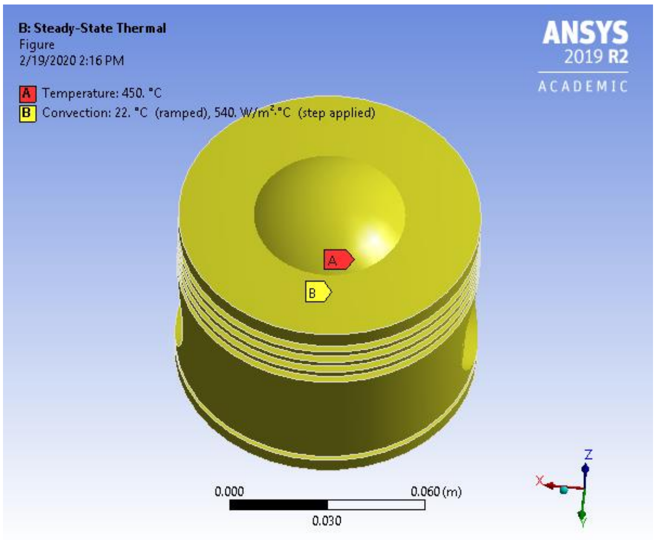


Fig18. Heat Transfer Coefficient on Crown-C Piston

Retrieval Number: E2751039520/2020©BEIESP
DOI: 10.35940/ijitee.E2751.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

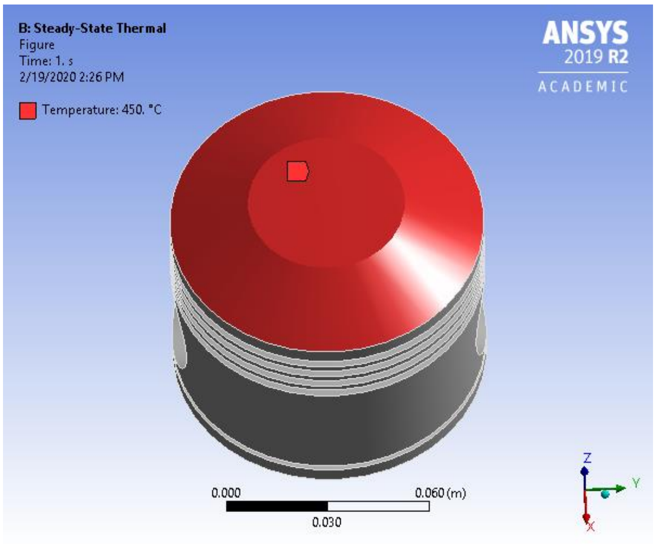


Fig19. Temperature on Crown-C Piston

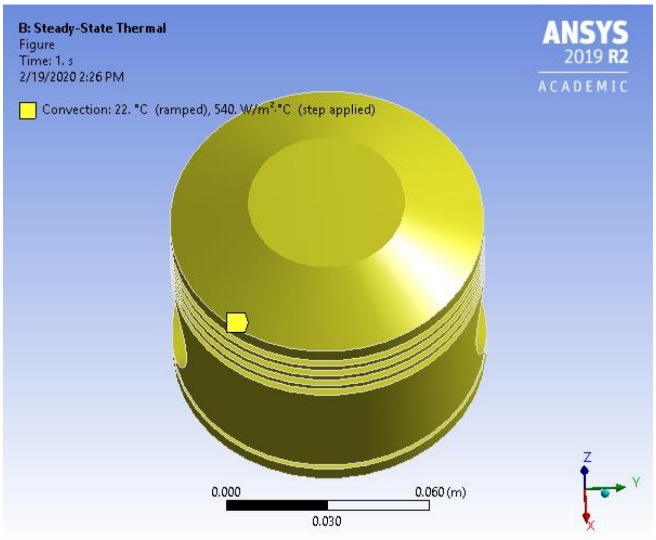


Fig20. Heat Transfer Coefficient on Crown-D Piston

VIII. STATIC STRUCTURAL ANALYSIS ON PISTON

We have carried out static structural analysis of the piston by considering various crown geometries of the piston and also various piston materials.

- In static structural analysis first we have imported the part which was modeled in CATIA software and then we imparted material properties to the imported model in ANSYS.
- The second step is to generate virtual cells with the help of virtual topography.
- The third step is to perform the mesh, which is to divide the whole complex geometry into discrete small elements.
- The fourth step involves imparting the loading condition of the piston and pressure of around 12MPa is applied on the crown of the piston and then frictionless supports have been assigned to the piston.
- The last step of the structural analysis is to select the required parameters like total deformation; maximum shear stress and equivalent (von-misses) stress then generate the solution for the piston.

IX. STATIC STRUCTURAL ANALYSIS OF PISTON WITH VARIOUS CROWN GEOMETRIES

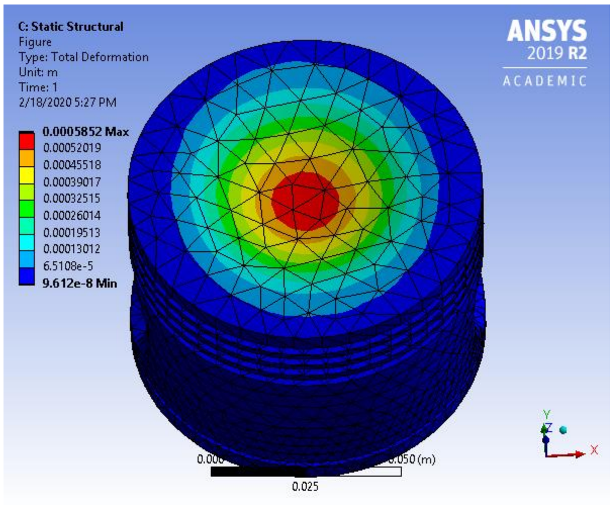


Fig21. Total Deformation of Crown-A Piston

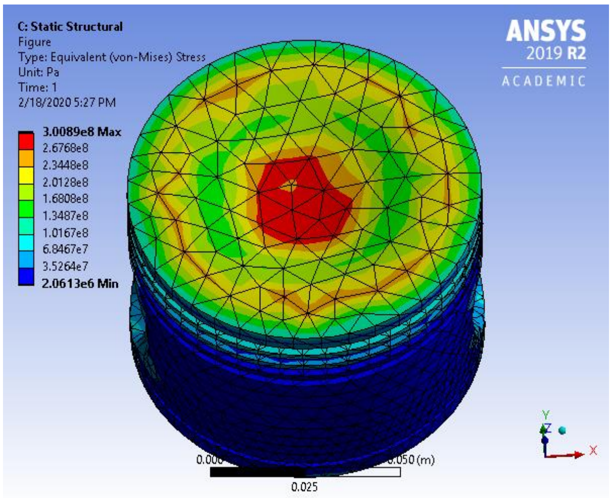


Fig22. Equivalent (Von-misses) stress of Crown-A Piston

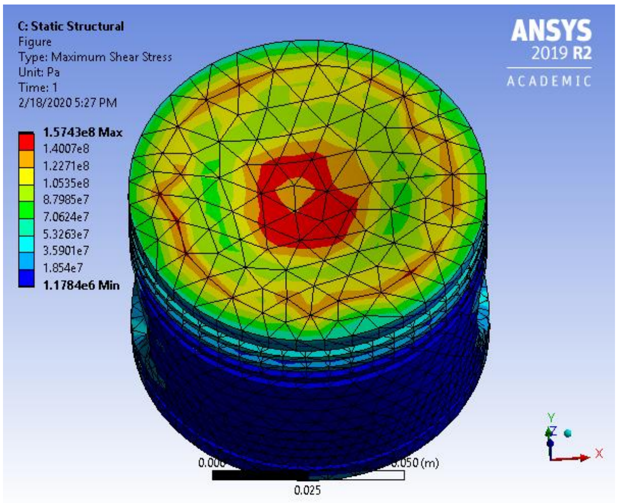


Fig23. Maximum Shear stress of Crown-A Piston

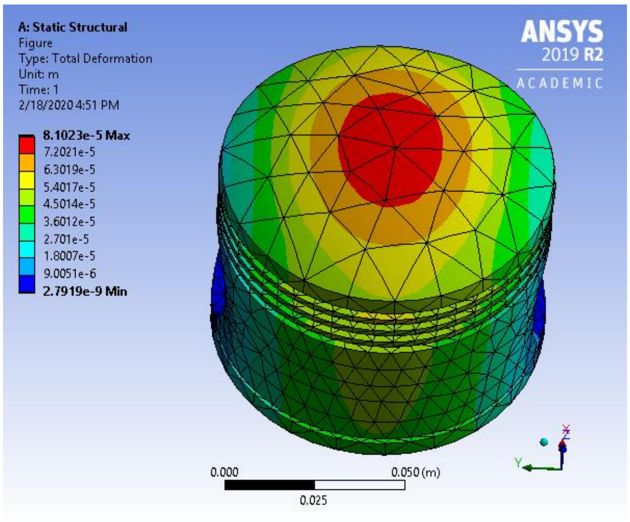


Fig24. Total Deformation of Crown-B Piston

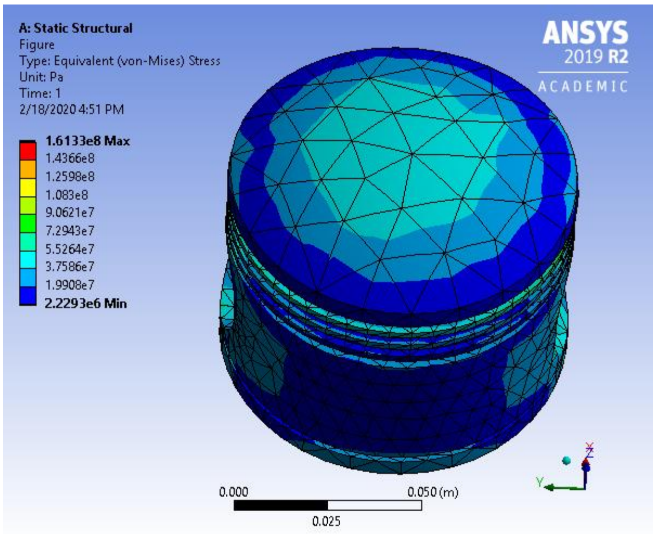


Fig25. Equivalent (Von-misses) stress of Crown-B Piston

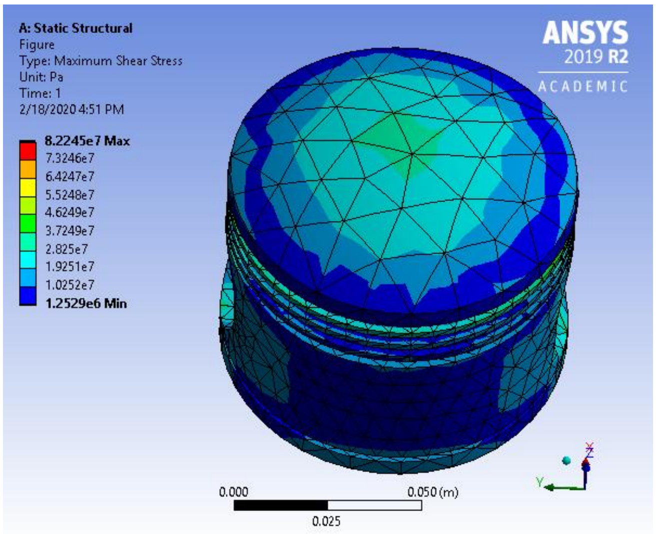


Fig26. Maximum Shear stress of Crown-B Piston

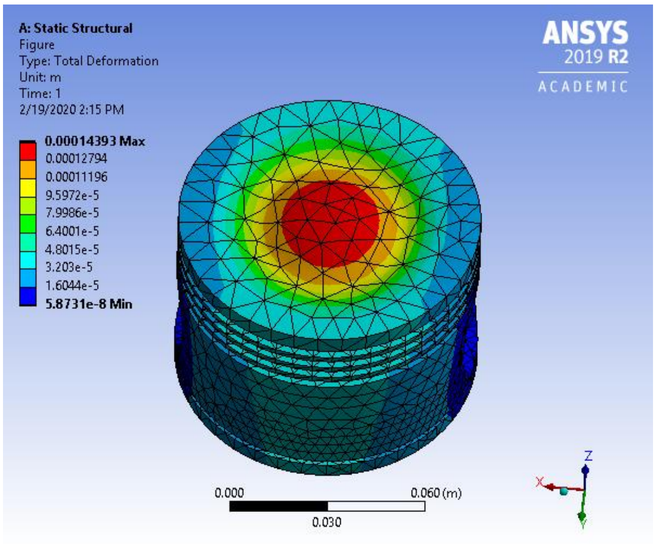


Fig27. Total Deformation of Crown-C Piston

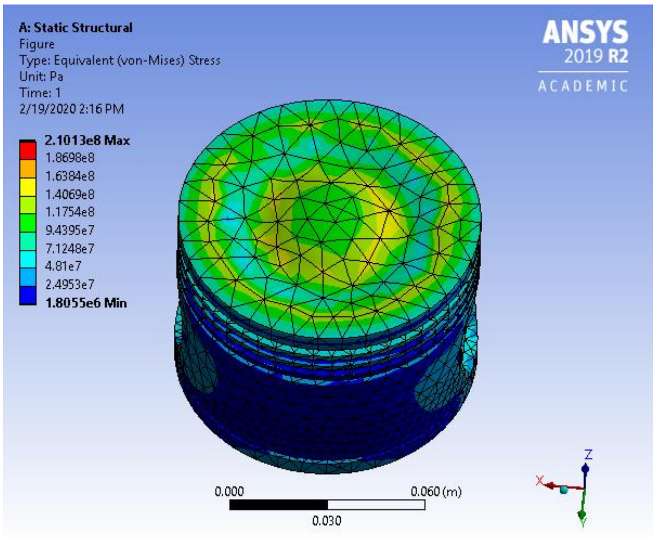


Fig28. Equivalent (Von-misses) stress of Crown-C Piston

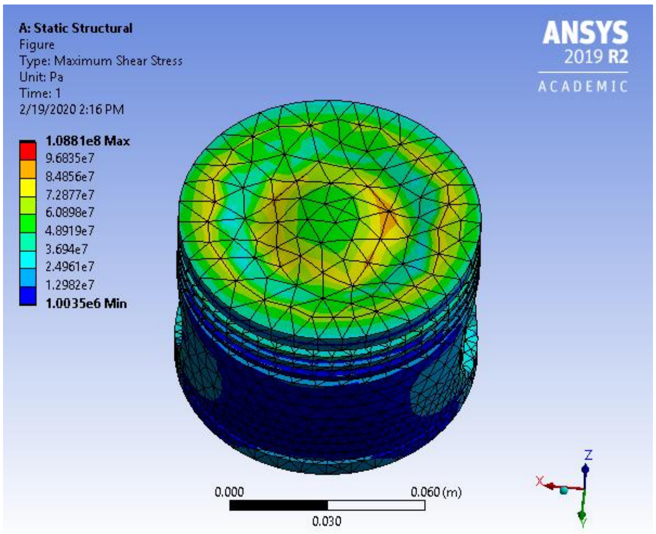


Fig29. Maximum Shear stress of Crown-C Piston

Retrieval Number: E2751039520/2020©BEIESP
DOI: 10.35940/ijitee.E2751.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

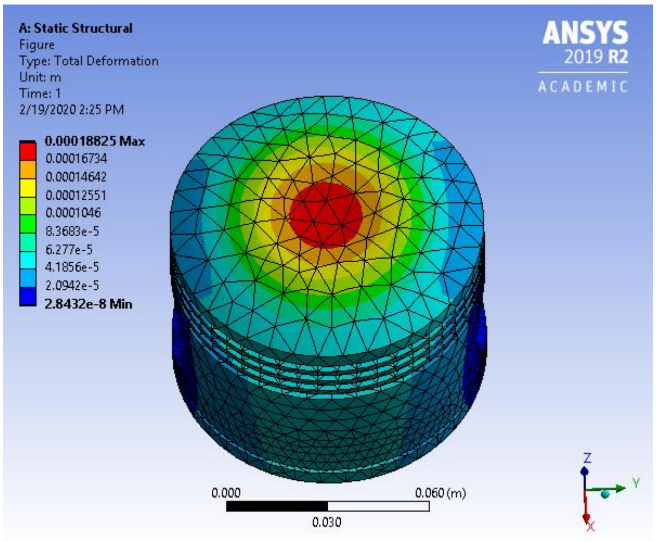


Fig30. Total Deformation of Crown-D Piston

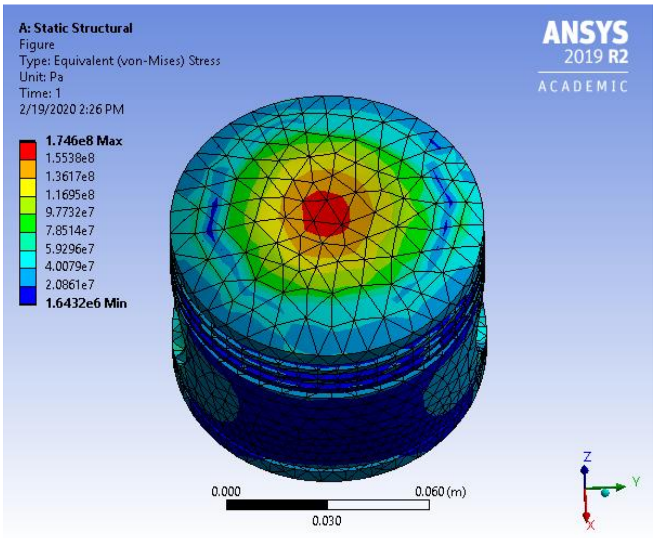


Fig31. Equivalent (Von-misses) stress of Crown-D Piston

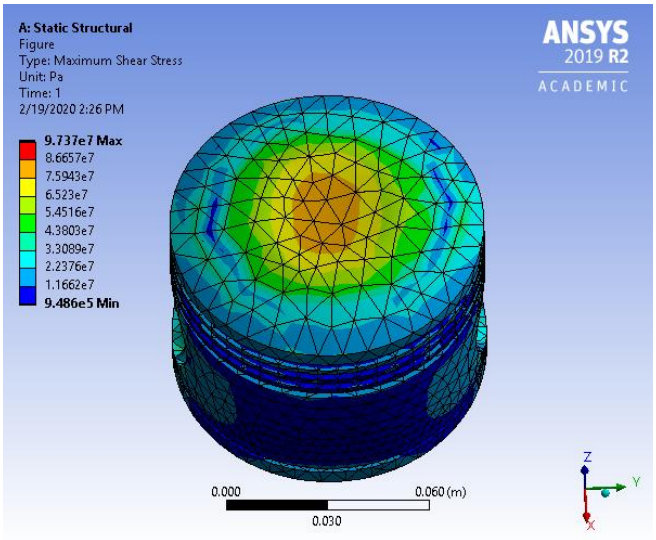


Fig32. Maximum Shear stress of Crown-D Piston

X. MINIMUM AND MAXIMUM DEFORMATION DUE TO MECHANICAL LOADS

Crown	Min Deformation in meter	Max Deformation in meter
A	9.61e-8	0.000585
B	2.79e-9	0.000081
C	5.87e-8	0.000143
D	2.84e-8	0.000188

XI. MINIMUM AND MAXIMUM EQUIVALENT (VON-MISSES) STRESS

Crown	Min Stress in Pa	Max Stress in Pa
A	2.06e6	3.00e8
B	2.22e6	1.61e8
C	1.80e6	2.10e8
D	1.64e6	1.74e8

XII. MINIMUM AND MAXIMUM SHEAR STRESS

Crown	Min Stress in Pa	Max Stress in Pa
A	1.17e6	1.57e8
B	1.25e6	8.22e7
C	1.00e6	1.08e8
D	9.48e5	9.73e7

XIII. STEADY STATE THERMAL ANALYSIS OF PISTON WITH VARIOUS CROWN GEOMETRIES

We have carried out steady state thermal analysis and found out temperature distribution and heat flux.

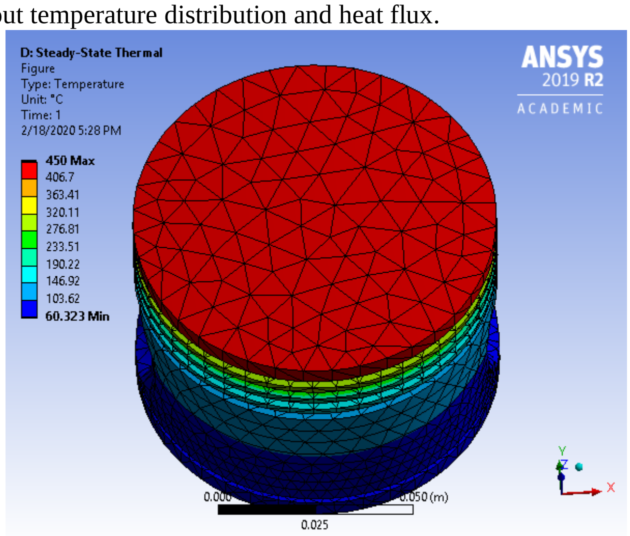


Fig33. Temperature distribution on Crown-A piston

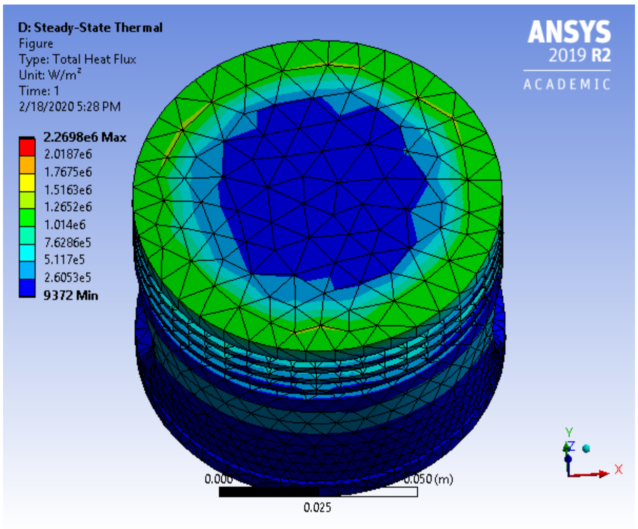


Fig34. Total Heat Flux on Crown-A piston

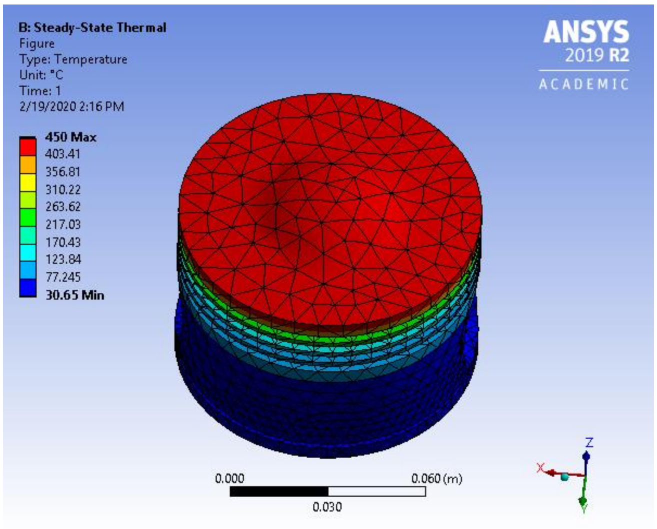


Fig37. Temperature distribution on Crown-C piston

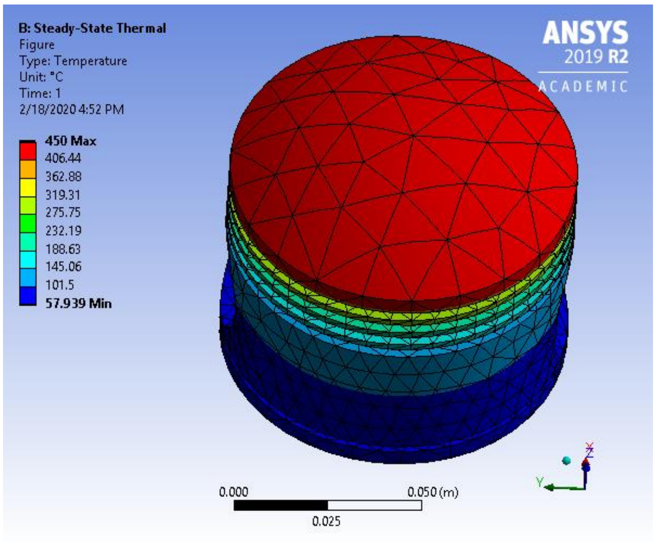


Fig35. Temperature distribution on Crown-B piston

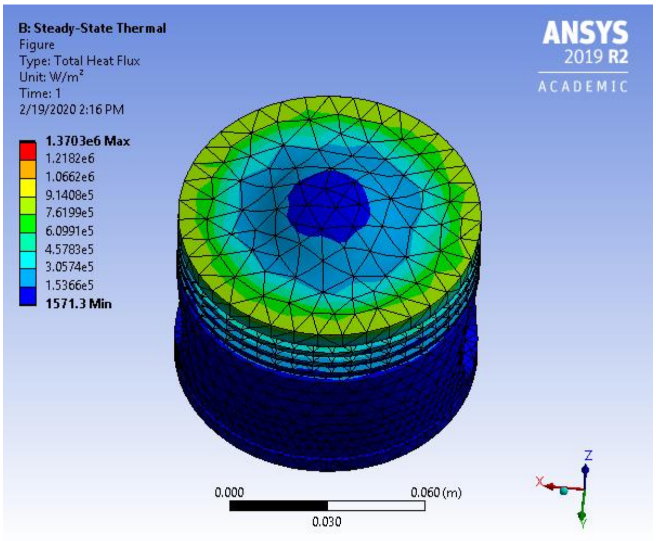


Fig38. Total Heat Flux on Crown-C piston

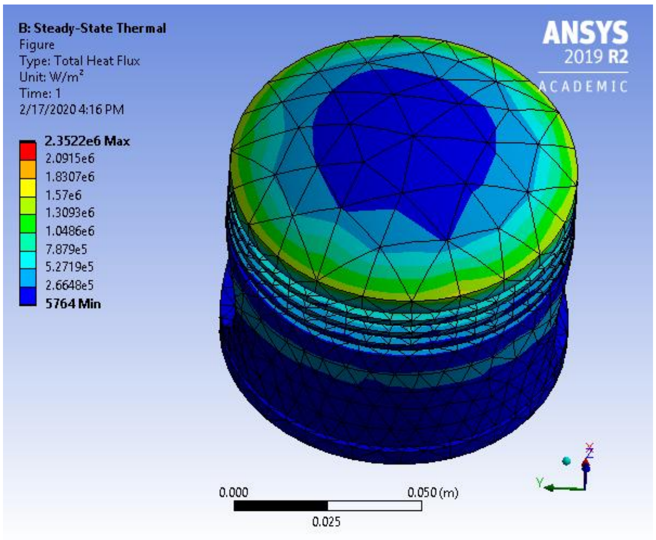


Fig36. Total Heat Flux on Crown-B piston

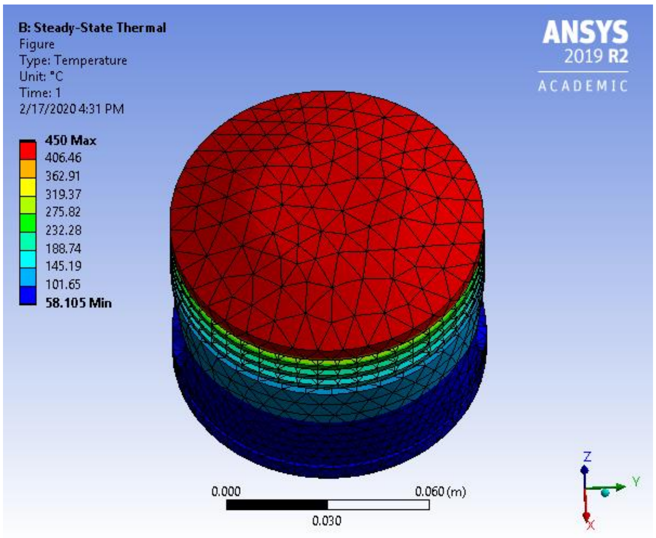


Fig39. Temperature distribution on Crown-D piston

Retrieval Number: E2751039520/2020©BEIESP
DOI: 10.35940/ijitee.E2751.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

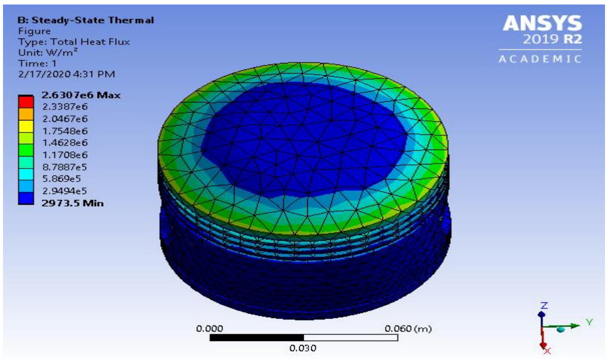


Fig40. Total Heat Flux on Crown-D piston

XIV. MINIMUM AND MAXIMUM TEMPERATURE OF PISTON DUE TO THERMAL LOADS

Crown	Min Temperature in °C	Max Temperature in °C
A	60.32	450
B	57.93	450
C	30.65	450
D	58.10	450

XV. MINIMUM AND MAXIMUM HEAT FLUX DUE TO THERMAL LOADS

Crown	Min Heat Flux in W/m²	Max Heat Flux in W/m²
A	9372.0	2.26e6
B	5764.0	2.35e6
C	1571.3	1.37e6
D	2973.5	2.63e6

XVI. RESULTS AND DISCUSSIONS

We have performed static structural and thermal analysis on the pistons with various crown geometries and found out that the total deformation, equivalent (von-misses) stress and maximum shear stress is less in the case of piston with crown-b geometry when compared to other geometries, Whereas the temperature and total heat flux is less in the case of piston with crown-c geometry. With this information we can determine that piston with crown-b geometry undergoes less deformation under mechanical loads which thereby increases the life of the piston and piston with crown-c geometry shows low heat flux and temperature value which helps us understand that less heat is being transferred from piston crown to the piston skirt which also enhances the life of the piston.

XVII. CONCLUSION

The results obtained from this research paper help us conclude that changing design parameters of the piston like changing the crown of the piston can enhance the life of the piston. In our case piston with crown-b geometry showed least deformation under mechanical load and can be used in engines where mechanical loads acting are high as it undergoes least deformation, whereas piston with crow-c geometry can be used in engines where high thermal load is present as much heat is not transferred throughout the piston due to its crown geometry and the temperature of the piston is also low.

REFERENCES

1. G.V.N. Kaushik, "Thermal and Static Structural Analysis on Piston," International Journal of Innovative Technology and Exploring Engineering, Volume-8 Issue-7 May, 2019
2. Vinay Khatod, Meet Bakotia, "Design and Analysis of Combined F-Head Type Engine with Tapered Piston," International Journal of Pure and Applied Mathematics, Volume 119 No.10 2018
3. Mani Sai Kamal, "Structural and Thermal Analysis of I.C.Engine Piston head with Concave and Convex Shapes," International Journal of Mechanical and Production Engineering, Volume-5 Issue7 July 2017
4. Preeti Kumari, Anamika, Dr H.C.Thakur, "Thermal Analysis of Piston of I.C.Engine," International Journal of Scientific and Engineering Research, Volume 7, Issue 12, December-2016
5. Amitanand.B.Suralikerimath, Veerendrakumar, "Study on Design and Static Analysis of Piston Head," International Journal of Research in Engineering and Technology, Volume-5 Issue-10, October-2016
6. Mohit Juneja, Dilip Verma, "Design and Analysis of Piston for Four Stroke Engine using CAE Tools," International Journal of Mechanical and Industrial Engineering, Volume-4, Issue-1, September 2016
7. Raja, "Design and Analysis of Internal Combustion Engine Piston," International Journal of Advanced Science and Engineering Research, Volume-1, Issue-1, June 2016
8. J.C.Jessin, P.Maheswaram, M.Syed Abuthahir, K.Vijayan, "Design and Analysis of an I.C.Engine Piston Head to Increas the Torque on Crankshaft," International Journal of Innovative Research in Science, Engineering and Technology, Volume-5, Issue-5, May 2016
9. Aditya Kumar Gupta, Vinay Kumar Tripathi, "Design Analysis and Optimization of Internal Combustion Engine Piston using CAE tool ANSYS," Volume-4, Issue-11, November 2014

AUTHORS PROFILE

Mohd Abdul Rahman, is currently pursuing masters of engineering at Methodist college of engineering and technology in the field of mechanical engineering with computer aided designing and manufacturing as specialization. He has completed his bachelor's degree in mechanical engineering from Deccan College of engineering and technology. He has worked on Designing and Drafting of HVAC system for a commercial building as major project during his bachelor's degree. He has researched on areas of thermal engineering involving the HVAC system to find the suitable HVAC system. He has also worked on exhaust system of buildings to suggest the best exhaust system for the building.

Dr. P.Ravi Chander, is currently working as Assistant professor at Methodist college of engineering and technology and has researched areas of heat transfer and IC engine. The author is expert in dealing with subject areas of thermodynamics, fluid mechanics and heat transfer. The author holds a doctorate degree in the field of mechanical engineering and has organized various National level fests like Techno Fests, Innovations at different colleges. The author has 14 years teaching experience in mechanical engineering and one year industrial engineering experience and has published papers in 14 international journals and one national journal. He has membership of ISTE, Combustion Institute and IAENG. He has published a book titled 'Energy Auditing and Energy Conservation in Agriculture'.

M. Prasad, is currently working as an assistant professor at Methodist College of engineering and technology and the author is coordinator for masters of engineering program. He has a total experience of 14 years in teaching and has handled different subjects related to design engineering and holds a master's degree in mechanical engineering. The author is expert in areas like machine design, design of machine elements and mechanical technology. He is currently working with research subject Design modeling and analysis of differential gear box for LCV'S. Research interest of this author is in design engineering and has also published more than 10 research papers in different international journals. He has organized various workshops and seminars. The author holds memberships of ISTE-LM105681, IWS-LO1900, IAENG-206060.