iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** IX **Month of publication:** September 2024

DOI: https://doi.org/10.22214/ijraset.2024.64160

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IX Sep 2024- Available at www.ijraset.com

Design and Failure Analysis of PistonUsing Ansys

Thimmegowda MB[1], Pavana BS2, Mohan Kumar KS[3]
[1] Senior Scale Lecturer, Dept, of Mechanical Engineering, Government Polytechnic, Nagamangala, Karnataka
[2] Lecturer, Dept, of Mechanical Engineering, Government Polytechnic, Turuvekere, Karnataka
[3]Lecturer, Dept, of Mechanical Engineering, SJ BGS Polytechnic, BG Nagar, Karnataka

Abstract: A piston is a component of reciprocating engines. The purpose of piston is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and a connecting rod. It is one of the most complex components of an automobile. In This project we are describes the Thermal analysis by using finite element method (FEM). The specifications used for designing the piston belong to four stroke single cylinder engine of piston. Modeling of piston is done using SOLID EDGE v20. static structural, Thermal and fatigue analysis is performed by using ANSYS WORKBENCH 2022 R1. The parameters used for the simulation are operating gas pressure, material properties of piston. The results predict the maximum stress and strain on pistons using FEA. The best material is selected based on static structural, thermal and fatigue analysis. The analysis results are used to optimize piston geometry of best two Materials.
Keywords: Piston, Solid Edge v20, static structural, Thermal and fatigue analysis.

I. INTRODUCTION

A piston is a component of reciprocating engines, reciprocating pumps, gas compressors, hydraulic cylinders 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 viaa 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.

II. LITERATURE REVIEW

The design of the piston is a complex process that involves several factors, such as the engine's operating conditions, performance requirements, material properties, and manufacturing processes. The piston's design must consider the piston's shape, size, weight, and material composition. Several studies have been conducted on the design of piston. "Design and Analysis of an Automotive Piston using Finite Element Method" by Amit Singh Yash Dhamecha and Vaibhav Saptarshi. This paper presents a finite element analysis (FEA) ofan automotive piston to evaluate its strength, stiffness, and deformation under various operating conditions. "A Review of Piston Failure Analysis in Internal Combustion Engines" by Amit Singh Chahar and Ashutosh Kumar. This review paper provides an overview of the causes and mechanisms of piston failures in internal combustion engines. It covers various types of failures, including thermal fatigue, mechanical fatigue, and lubrication-related failures.

Table – 1: Property of Aluminium Alloy

Density	2.77e-06 kg/mm^3
Young s Modulus	71000 MPa
Thermal Conductivity	0.14862 W/mm, ^0C
Specific Heat	8.75e+05 mJ/kg, ^0C
Tensile Yield Strength	280 MPa
Tensile Ultimate Strength	310 MPa

Table – 2: Property of Ti-6A1-4V

Modulus of Elasticity	113.8 GPa
Compressive Yield Strength	970 MPa
Tensile Strength	1450 MPa
Ultimate Strength	1860 MPa

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IX Sep 2024- Available at www.ijraset.com

III. METHODOLOGY

A. Analytical design of pistons based on design formulae and empirical relations.
B. 3-D piston models are created in SOLIDEDGE V20
C. Meshing and analysis of piston is done in ANSYS Workbench 2022 R1
D. Various stresses are determined by individually performing structural analysis, thermal analysis and thermos-mechanical analysis.
E. Various zones or regions where chances of damage in piston are possible are analyzed.
F. Comparison is made between the three materials in terms of stresses, deformation, strain, volume, weight, force and factor of safety.

1) Analysis of Step Head Piston for Aluminum Alloy

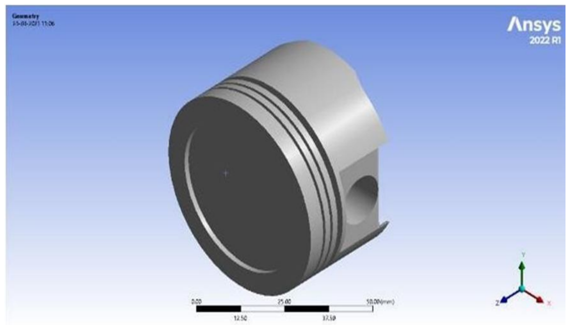


Fig-1: 3-D CAD Model of Step Head Piston

2) Material Assignment

For analysis of piston, the 3-D CAD model prepared in Solid edge v20. is converted in to IGES format so that it can be imported in ANSYS 2022R1. After importing the model in ANSYS, material properties are assigned in Engineering data.

Fig-2: Static Structural Standalone System

3) Meshing of Step Head piston

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 1 mm.

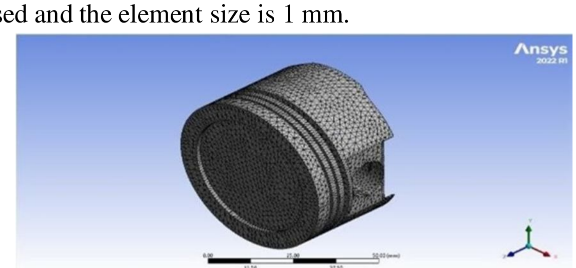


Fig-3: Meshing of Step Head Piston

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IX Sep 2024- Available at www.ijraset.com

4) Static Structural Analysis

In static structural analysis, boundary conditions like pressure and supports are applied. (Refer Table 4)

- Pressure at the head of piston: 20 MPa
- Fixed supports are applied at edges of piston pinhole.

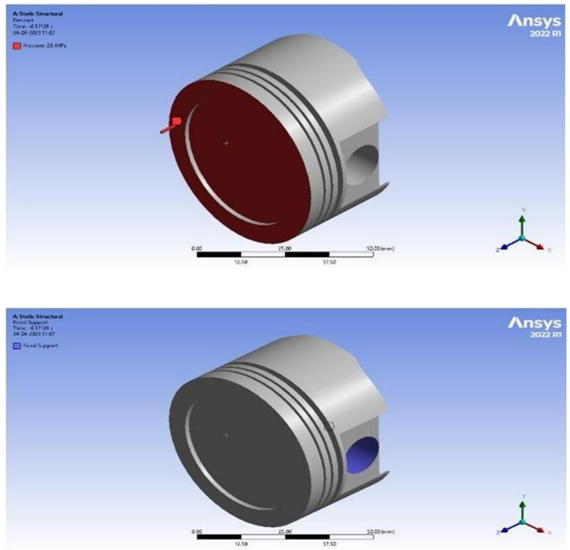


Fig-4: Applying Boundary Conditions

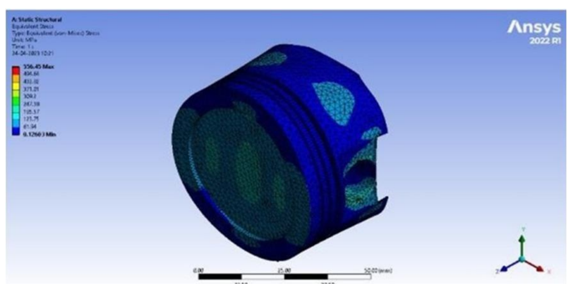


Fig-5: Equivalent Stresses

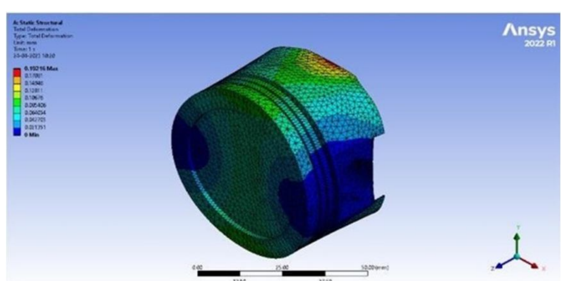


Fig-6: Total Deformation

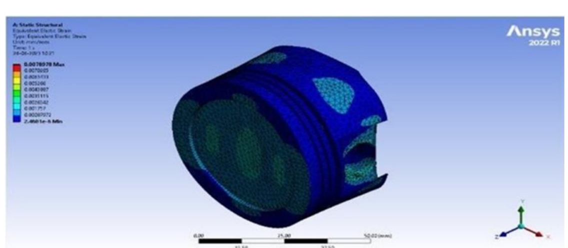


Fig-7: Equivalent Elastic Strain

5) Steady State Thermal Analysis

In steady state thermal analysis, boundary conditions like temperature and convection are applied.

- Temperature at head of piston: 2000°C
- Film coefficients are applied to different regions of piston.

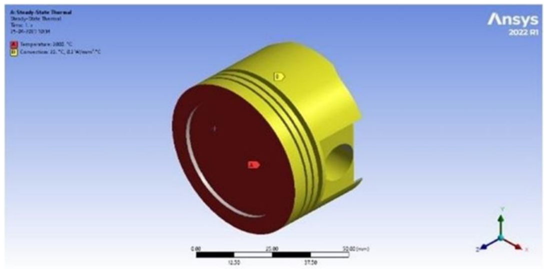


Fig-8: Applying Temperature and Convection Boundary

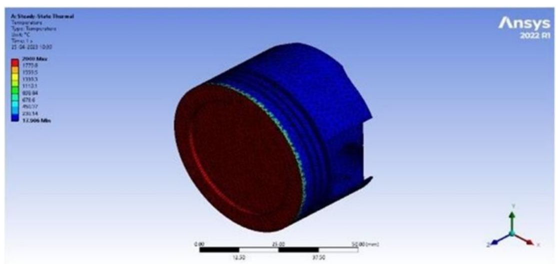


Fig-9: Temperature

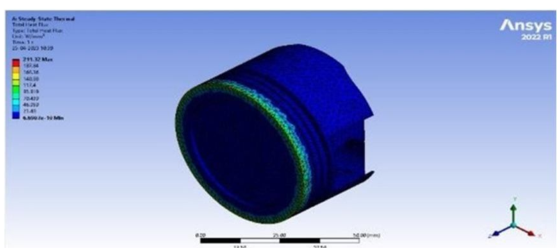


Fig-10: Total Heat Flux

6) Fatigue Analysis

Fatigue analysis is a process used to assess the structural durability and lifespan of components subjected to cyclic loading.

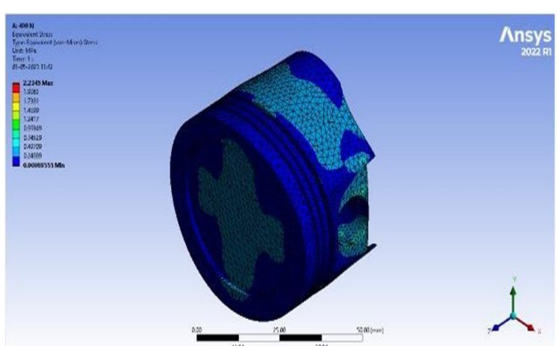


Fig-11: Equivalent Stresses

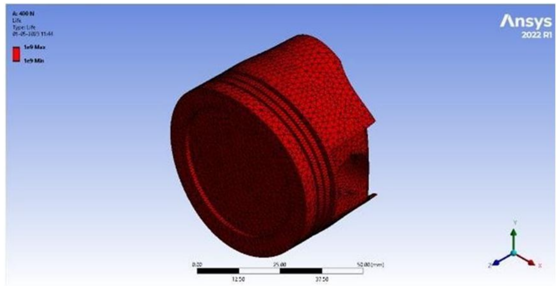


Fig-12: Life

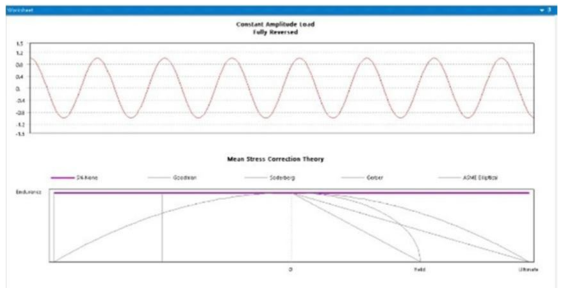


Fig-13: Stress Life

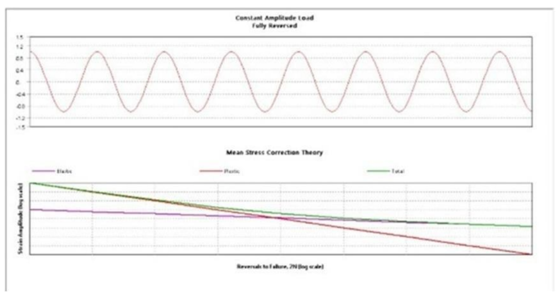


Fig-14: Strain Life

7) *Analysis of Flat Head Piston for Ti-6A1-4V*

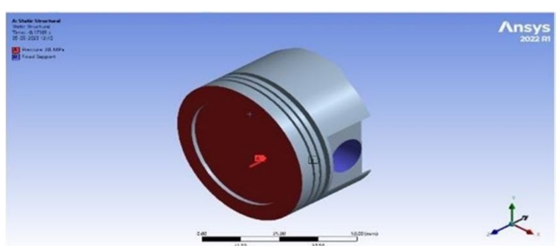


Fig-15: Applying Boundary Conditions

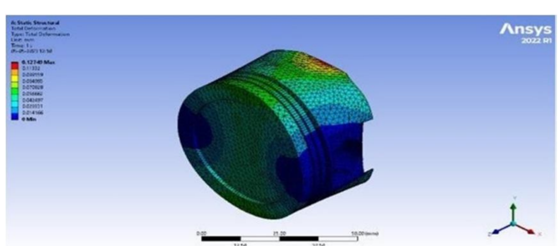


Fig-16: Total Deformation

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IX Sep 2024- Available at www.ijraset.com

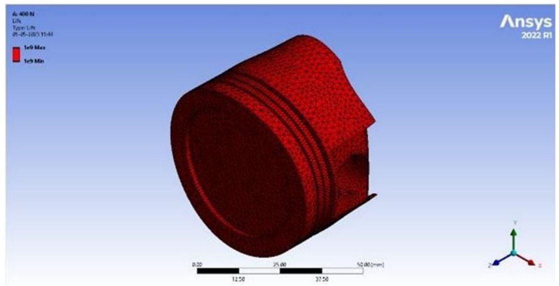


Fig-17: Equivalent Stresses

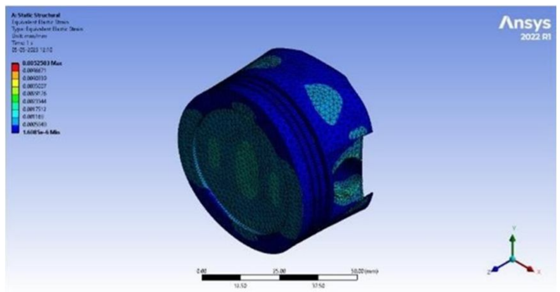


Fig-18: Equivalent Elastic Strain

8) Steady State Thermal Analysis

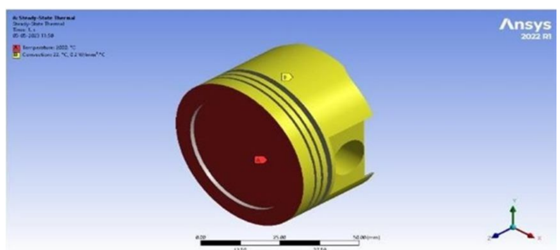


Fig-19: Applying Temperature and Convection Boundary

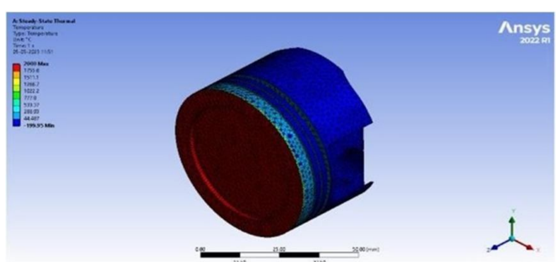


Fig-20: Temperature

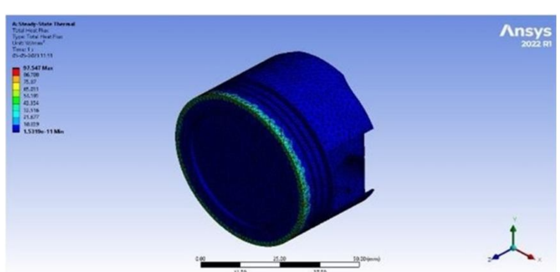


Fig-21: Total Heat Flux

9) Fatigue Analysis

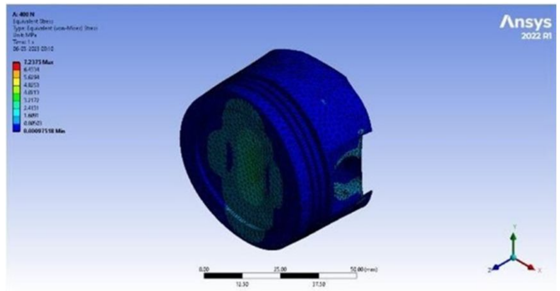


Fig-22: Equivalent Stresses

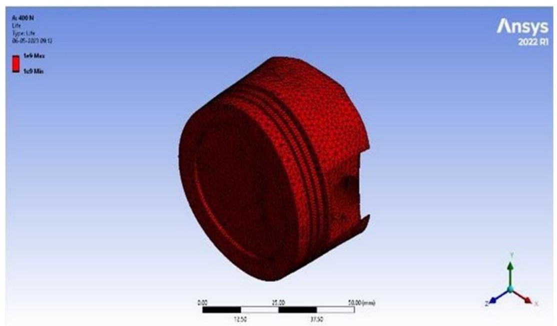


Fig-23: Life

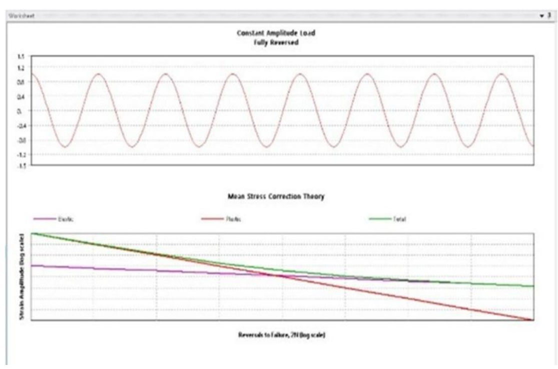


Fig-24: Strain Life

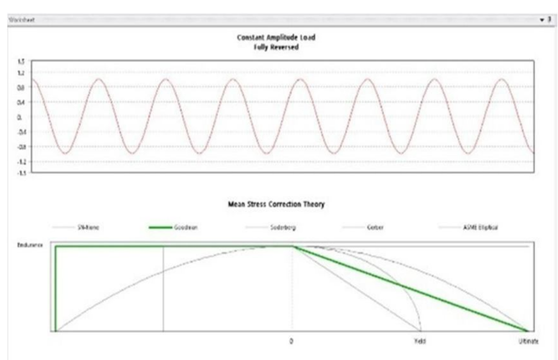


Fig-25: Stress Life

10) Analysis of Flat Head Piston for Aluminum Alloy

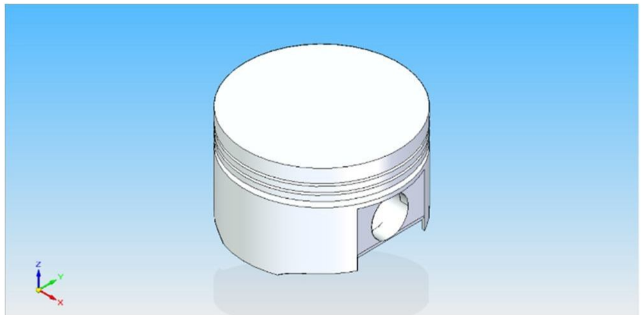


Fig-26: 3-D CAD Model of Flat Head Piston

11) Meshing of Flat Head piston Model

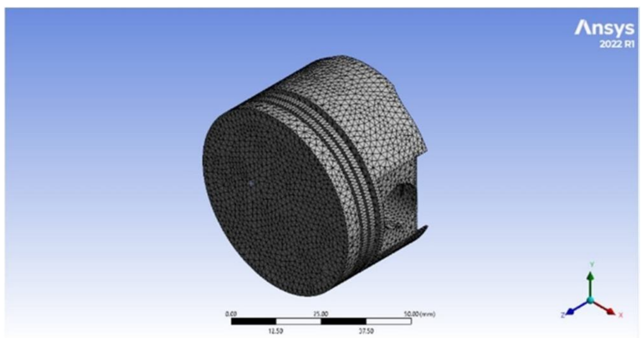


Fig-27: Meshing of Flat Head Piston

12) Static Structural Analysis

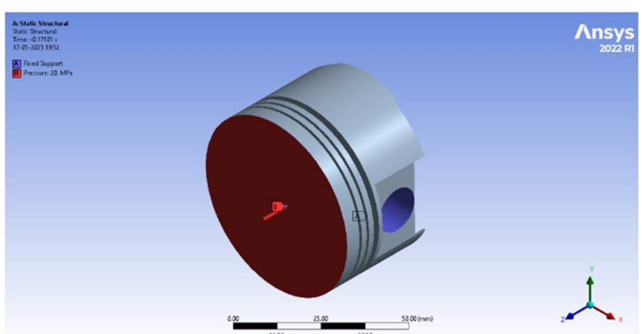


Fig-28: Applying Boundary Conditions

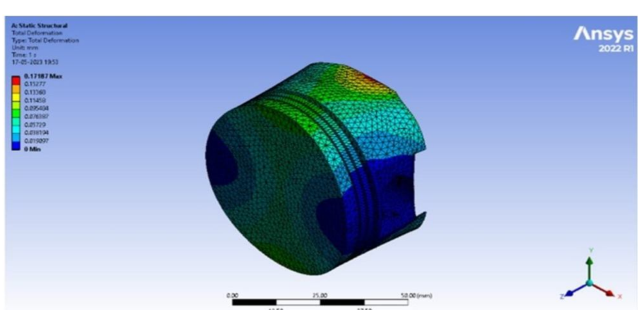


Fig-29: Total Deformation

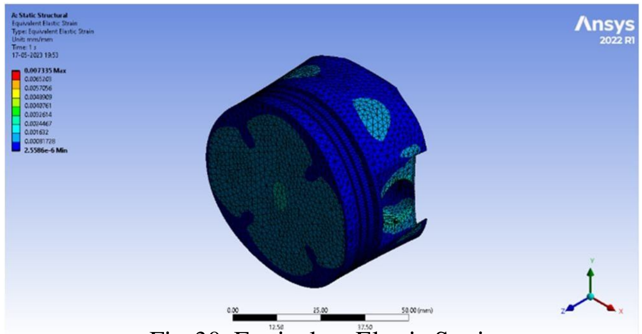


Fig-30: Equivalent Elastic Strain

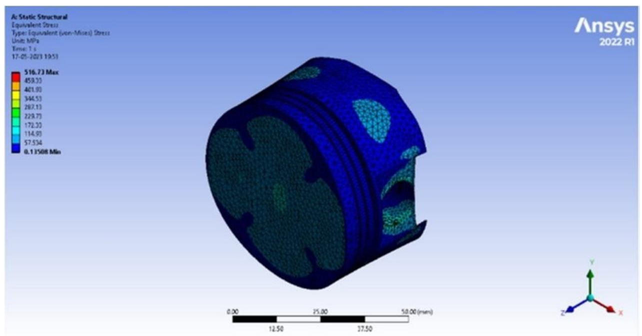


Fig-31: Equivalent Stresses

13) Steady State Thermal Analysis

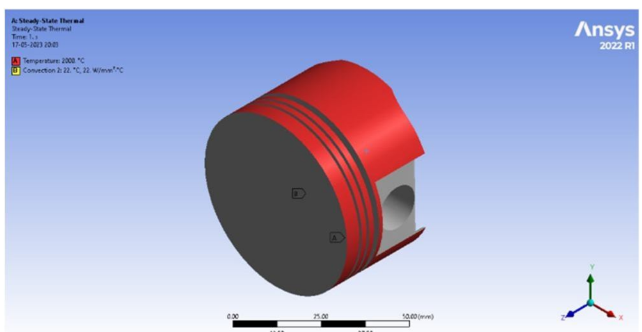


Fig-32: Applying Temperature and Convection Boundary

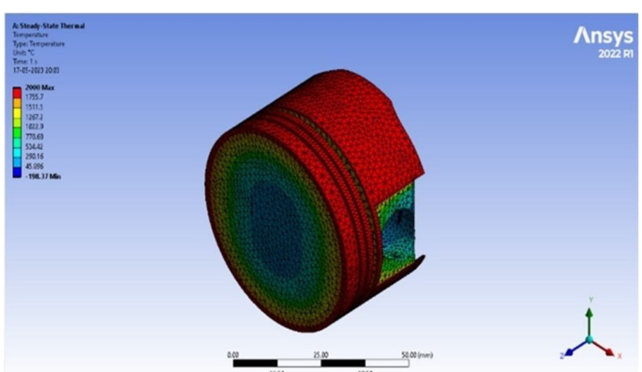


Fig-33: Temperature

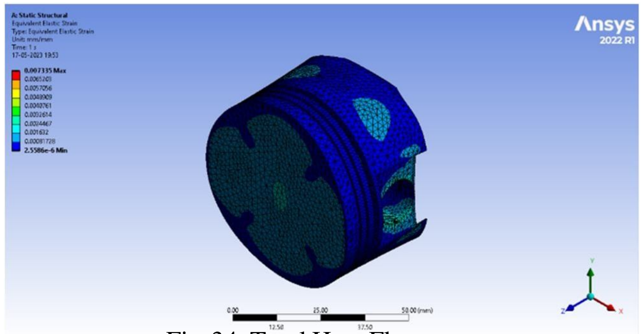


Fig-34: Total Heat Flux

14) Fatigue Analysis

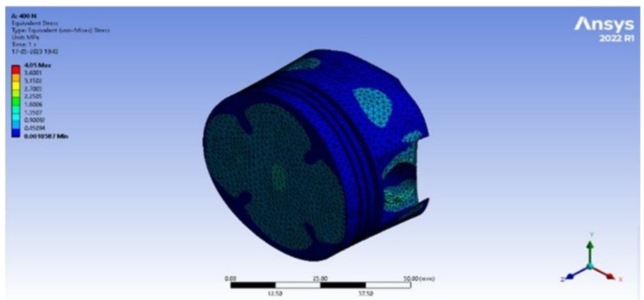


Fig-35: Equivalent Stresses

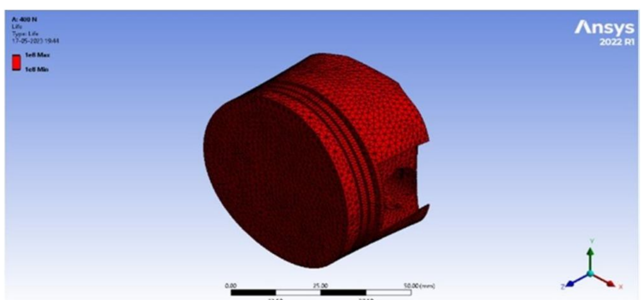


Fig-36: Life

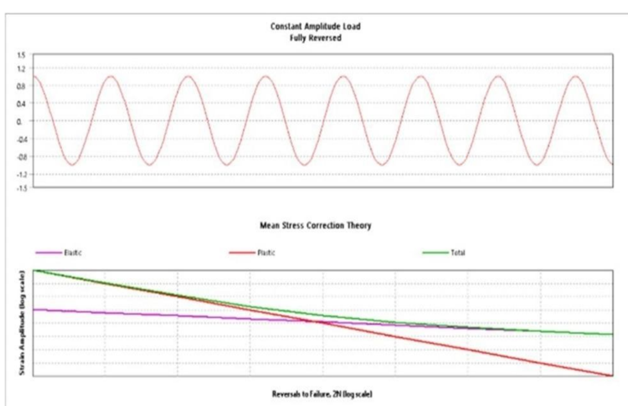


Fig-37: Strain Life

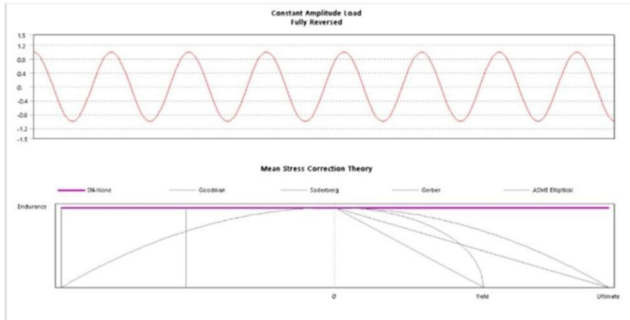


Fig-38: Stress Life

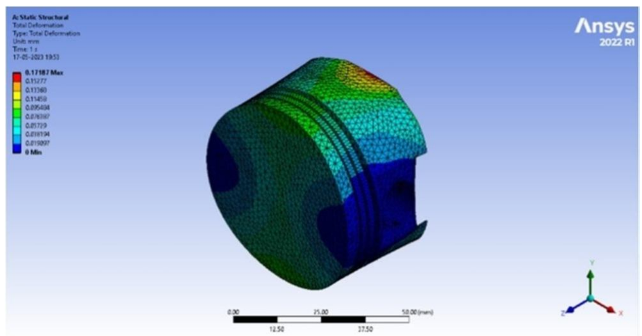


Fig-39: Total Deformation

15) Analysis of Flat Head Piston for Ti-6A1-4V

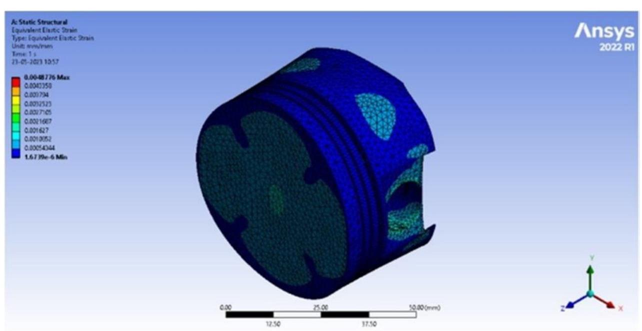


Fig-40: Equivalent Elastic Strain

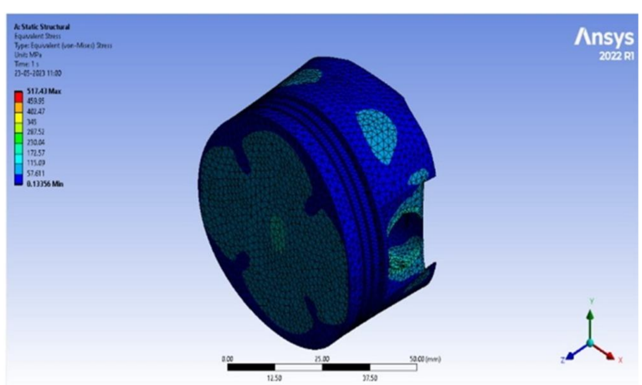


Fig-41: Equivalent Stresses

16) Steady State Thermal Analysis

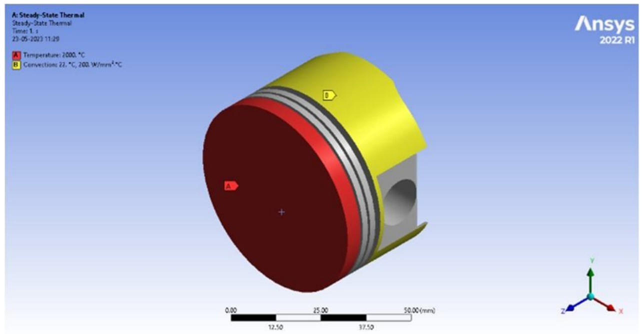


Fig-42: Applying Temperature and Convection Boundary

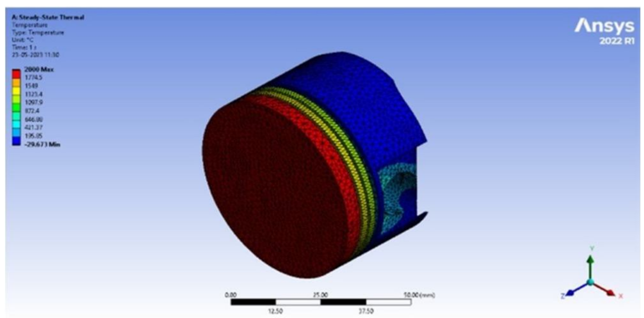


Fig-43: Temperature

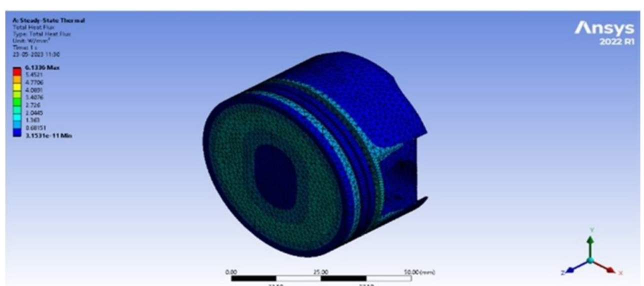


Fig-44: Total Heat Flux

17) Fatigue Analysis

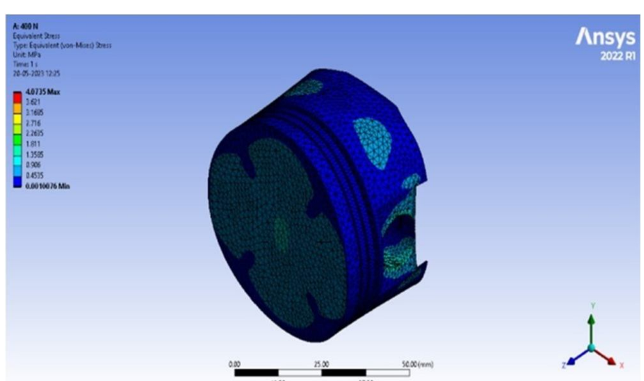


Fig-45: Equivalent Stresses

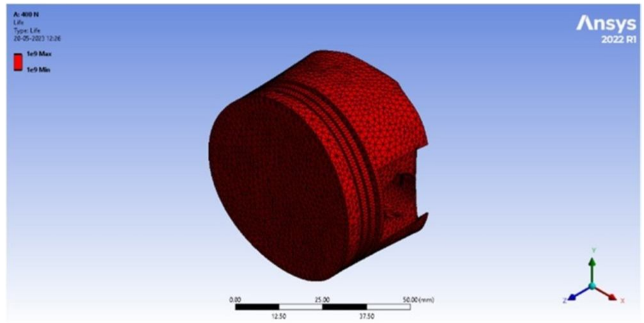


Fig-46: Life

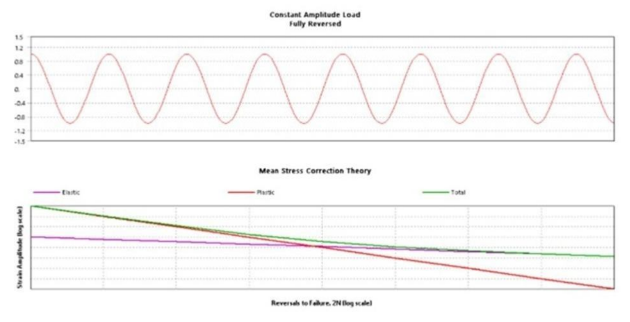


Fig-47: Strain Life

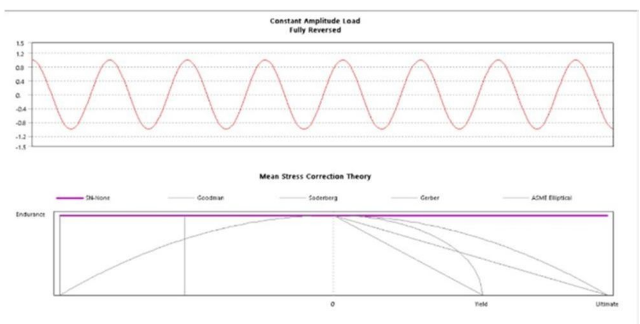


Fig-48: Stress Life

18) Analysis of Dom Head Piston for Aluminum Alloy

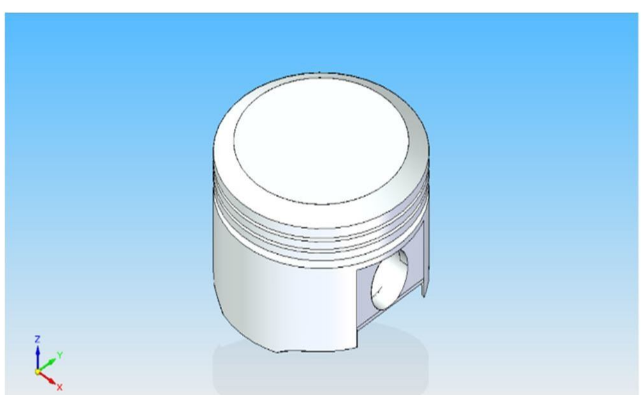


Fig-49: 3-D CAD Model of Dom Piston

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IX Sep 2024- Available at www.ijraset.com

19) Meshing of Dom Head piston Model

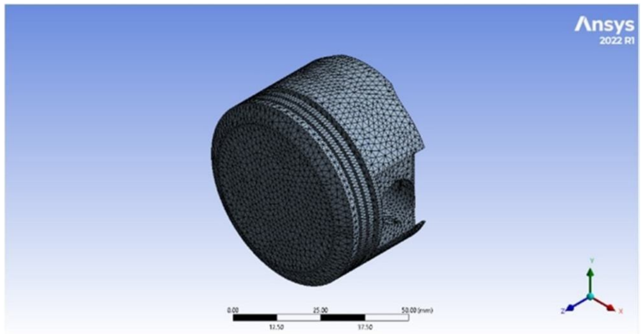


Fig-50: Meshing of Dom Head Piston

20) Static Structural Analysis

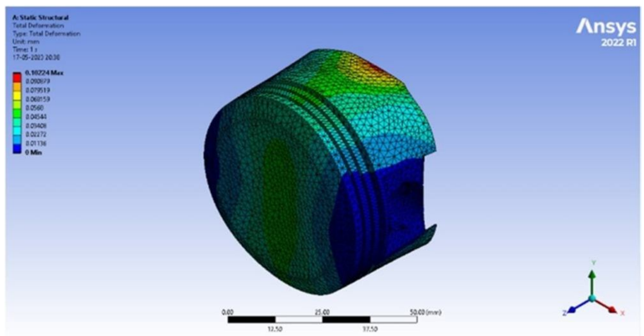


Fig-51: Total Deformation

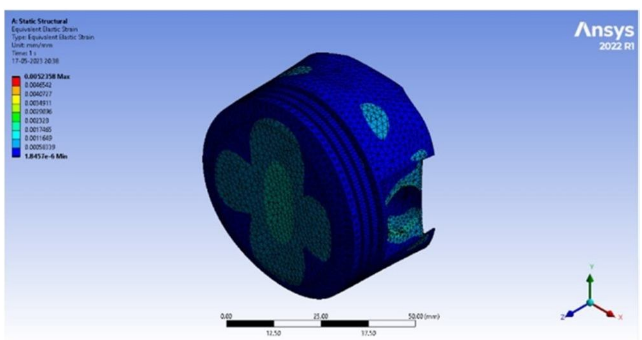


Fig-52: Equivalent Elastic Strain

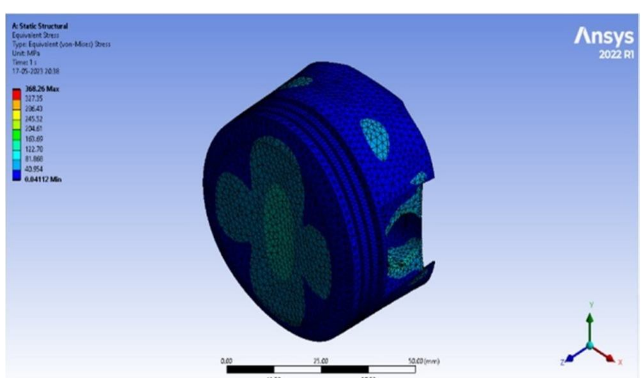


Fig-53: Equivalent Stresses

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IX Sep 2024- Available at www.ijraset.com

21) Steady State Thermal Analysis

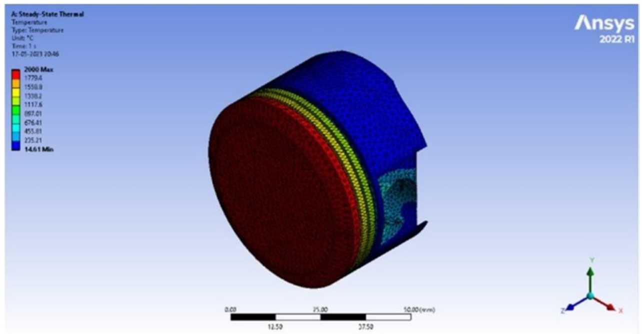


Fig-54: Temperature

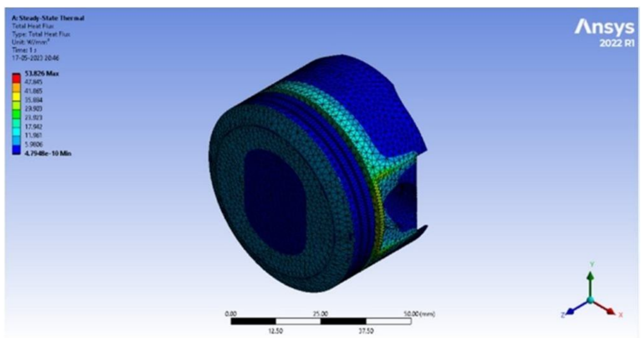


Fig-55: Total Heat Flux

22) Fatigue Analysis

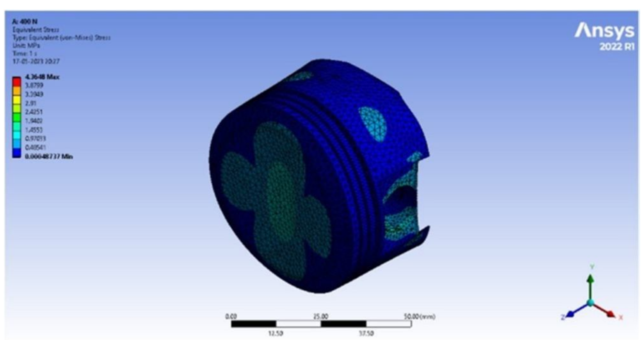


Fig-56: Equivalent Stresses

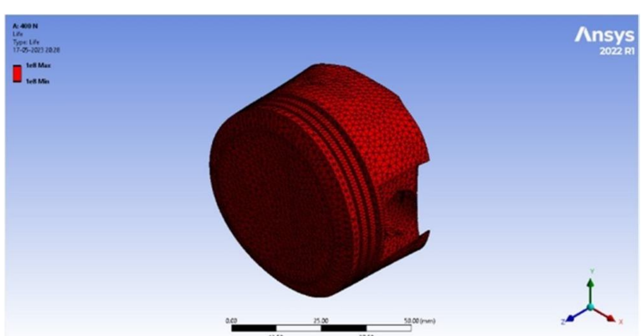


Fig-57: Life

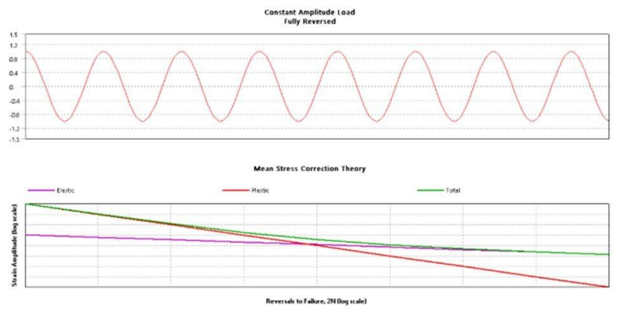


Fig-58: Strain Life

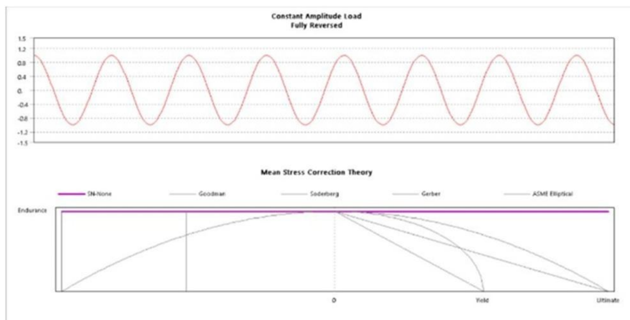


Fig-59: Stress Life

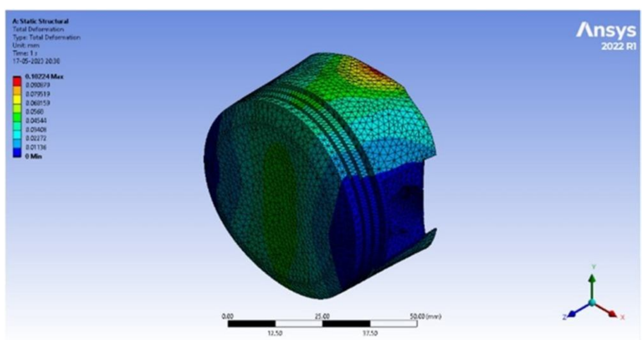


Fig-60: Total Deformation.

23) Analysis of Dom Piston for Ti-6A1-4V

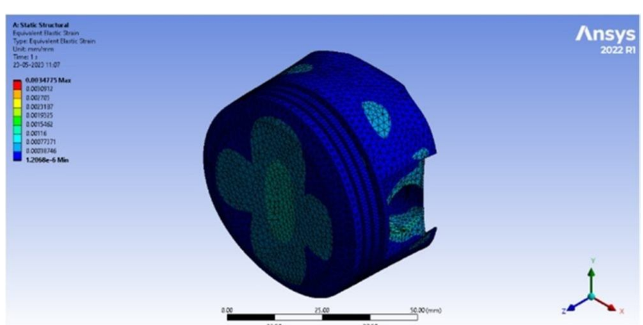


Fig-61: Equivalent Elastic Strain

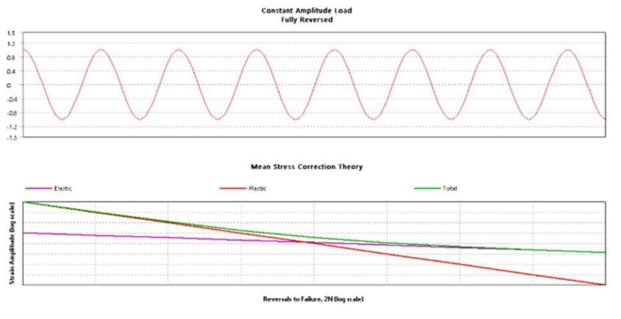


Fig-62: Equivalent Stresses

24) Steady State Thermal Analysis

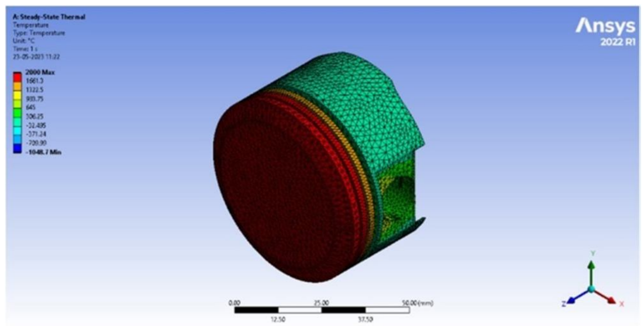


Fig-63: Temperature

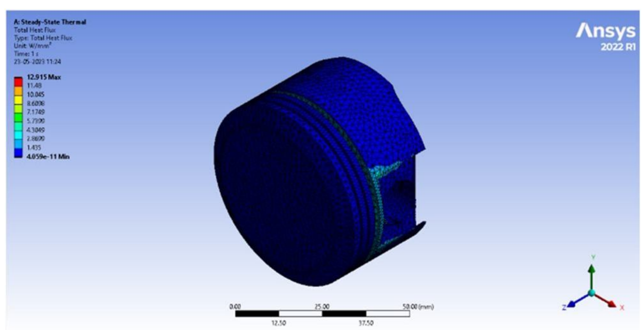


Fig-64: Total Heat Flux

25) Fatigue Analysis

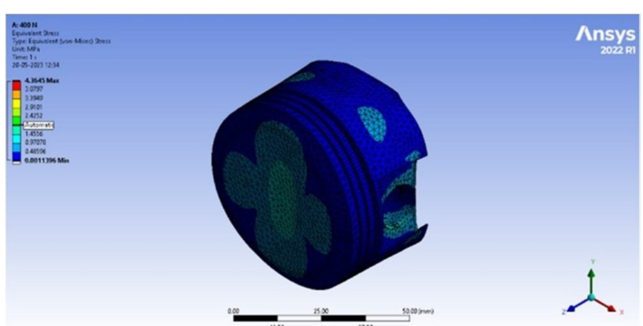


Fig-65: Equivalent Stresses

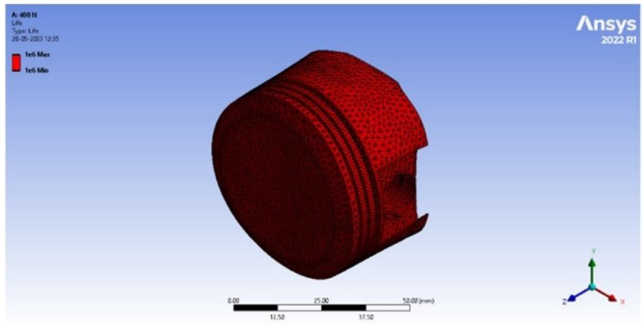


Fig-67: Life

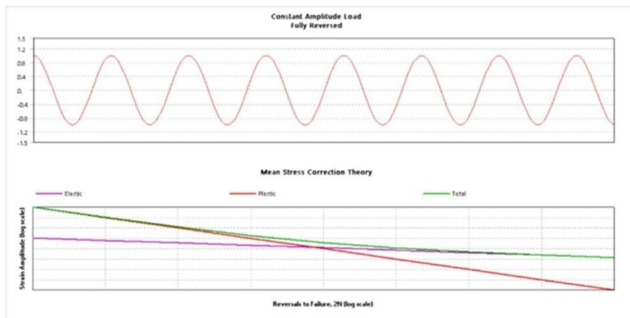


Fig-68: Strain Life

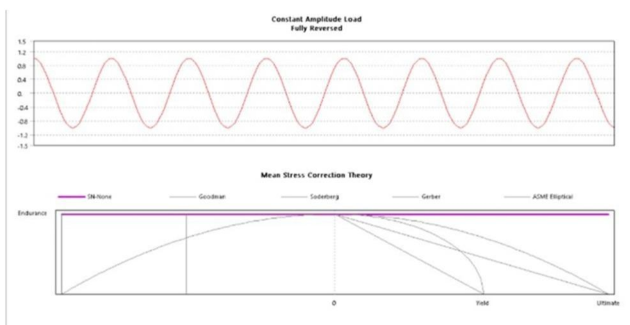


Fig-69: Stress Life

IV. RESULTS

A. Static Structural Analysis of Step Head

Table-4: Static Structural Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Equivalent Stress (MPa)	556.45	557.04
Total Deformation(mm)	0.19216	0.12749
Equivalent elastic strain (mm/mm)	0.0078978	0.0052503

1) Steady Thermal Analysis of Step Head

Table-5: Steady Thermal Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Temperature	2000	2000
Heat flux (W/mm^2)	211.32	97.547

2) Fatigue Analysis of Step Head

Table-6: Fatigue Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Equivalent Stress (MPa)	2.2345	7.2375
Factor of Safety	15	15
Life	1e9	1e9s

B. Static Structural Analysis of Flat Head

Table-4: Static Structural Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Equivalent Stress (MPa)	516.73	617.25
Total Deformation (mm)	0.18169	0.22602
Equivalent elastic strain (mm/mm)	0.00725	0.00552

1) Steady Thermal Analysis of Flat Head

Table-5: Steady Thermal Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Temperature	2000	2000
Heat flux (W/mm^2)	667.65	7.133

2) Fatigue Analysis of Flat Head

Table-6: Fatigue Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Equivalent Stress (MPa)	5.05	5.02545
Factor of Safety	15	15
Life	1e8	1e9s

C. Static Structural Analysis of Dom Head

Table-4: Static Structural Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Equivalent Stress (MPa)	3483.26	486.32
Total Deformation (mm)	0.20355	0.01365
Equivalent elastic strain (mm/mm)	0.007884	0.0073503

1) Steady Thermal Analysis of Dom Head

Table-5: Steady Thermal Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Temperature	2000	2000
Heat flux (W/mm^2)	44.353	13.6566

2) Fatigue Analysis of Dom Head

Table-6: Fatigue Analysis Results

PARAMETERS	VALUES	
	Aluminum Alloy	**Ti-6A1-4V**
Equivalent Stress (MPa)	5.3624	5.3469
Factor of Safety	15	15
Life	1e8	1e6

V. CONCLUSIONS

The titanium alloy Ti-6Al-4V is widely used in pistons of supercars and this led us to the assumption that if it is used in such high-performance cars, then it's possible that it can also be used in motorbikes. The material properties of titanium alloy were also suggesting the same but our analysis clearly demonstrates that it isn't a feasible option. From our analysis results, it is concluded that Ti-6Al-4V Dom Head Piston is the best material for piston.

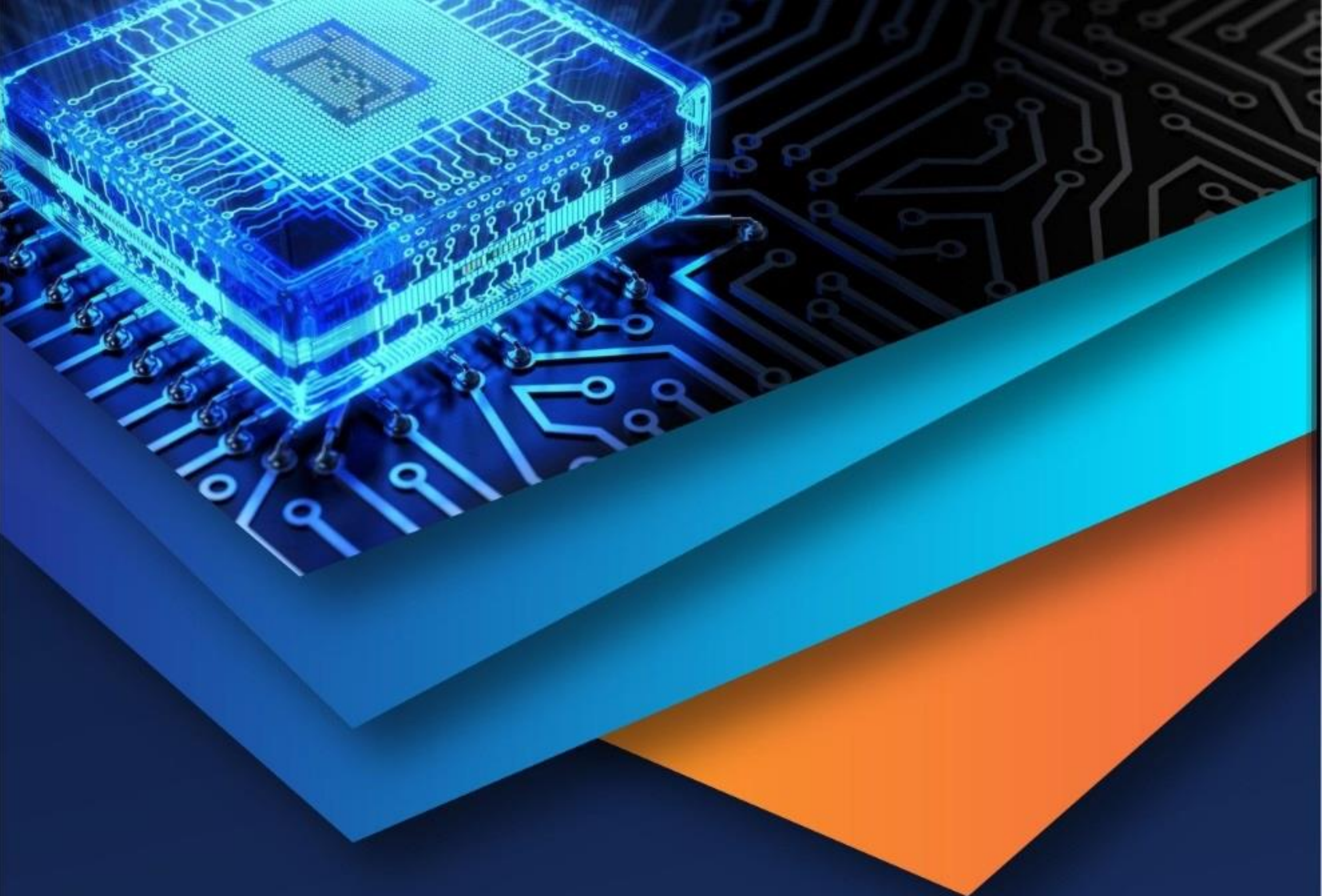
This is due to the following reasons.

1) Its Factor of Safety (F.O.S.) is maximum amongst the one material.
2) Mass of Aluminum alloy is also least.

This result is because of the design of the piston. The piston design of supercars is significantly different from the piston design of motorbikes. To make titanium alloy a feasible option, we need to make a lot of changes in the design of piston which will result in a change in the overall design of the engine which is beyond the scope of this work. Still, there's a lot that can be done. The same can be done for other motorbikes/vehicles too. Other analyses apart from thermal and structural can also be performed for these materials. Also, these materials can be compared on the basis of cost like cost of manufacturing, cost of machining, etc.

REFERENCES

[1] Vaishali R. Nimbarte and Prof. S.D. Khamankar, "Stress Analysis of Piston using Pressure Load and Thermal Load", IPASJ International Journal of Mechanical Engineering (IIJME), August 2015.
[2] Lokesh Singh, Suneer Singh Rawat, Taufeeque Hasan and Upendra Kumar, "Finite Element Analysis ofPiston in ANSYS", International Journal of Modern Trends in Engineering and Research.
[3] Gadde Anil Kumar and Chandolu Nehemya Raj, "Design and Analysis of an I.C. Engine Piston and Piston Rings by using Three Different Materials",
[4] International Journal of Advances in Mechanical andCivil Engineering, April 2017.
[5] Hitesh pandey, 2014 "Thermal Stress Analysis of a Speculative IC Engine Piston using CAE Tools" Int. Journal of Engineering Research and Applications Vol. 4, Issue 11(Version - 5), page.60- 64
[6] Dilip Kumar Sonar, 2015"Theoretical Analysis of Stress and Design of Piston Head using CATIA & ANSYS" International Journal of Engineering Science Invention. Volume 4 Issue 6 June 2015 Page .52-61
[7] A. P. Carlucci, A. Ficarella, D. Laforgia, and A. Renna, "Supercharging system behavior for high altitude operation of an aircraft 2-stroke diesel engine," Energy Conversion and Management, vol. 101, pp. 470–480, 2015.
[8] Z. Pan and Q. He, "High cycle fatigue analysis for oil pan of piston aviation kerosene engine," EngineeringFailure Analysis, vol. 49, pp. 104–112, 2015.
[9] L. Rebhi, B. Krstic, A. Boutemedjet et al., "Fatigue fracture analysis of an ADF antenna in a military aircraft," Engineering Failure Analysis, vol. 90, pp. 476–488, 2018.
[10] S. K. Bhaumik, M. Sujata, and M. A. Venkataswamy, "Fatigue failure of aircraft components," Engineering Failure Analysis, vol. 15, no. 6, pp. 675–694, 2008.
[11] B. Krstic, L. Rebhi, D. Trifkovic et al., "Investigation into recurring military helicopter landing gear failure," Engineering Failure Analysis, vol. 63, pp. 121–130, 2016.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY