e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

STATIC STRUCTURAL AND THERMAL ANALYSIS OF A SINGLE CYLINGER ENGINE

Jegan[*1], Dinesh[*2], Kaushik Chand[*3], Rahim Firthous[*4]

[*1]Professor, Department Of Mechanical Engineering, Velammal College Of Engineering And Technology, Madurai, India.

[*2,3,4]Department Of Mechanical Engineering, Velammal College Of Engineering And Technology, Madurai India.

ABSTRACT

The Static Structural and Thermal Analysis of a Single-Cylinder Engine aims to evaluate the mechanical strength and thermal performance of engine components under real-world operating conditions. This project focuses on the design, modeling, and analysis of a single-cylinder engine specifically intended for vehicle applications. The primary objective is to analyze key factors such as total deformation, equivalent stress, equivalent strain, and temperature distribution to ensure the engine's reliability and efficiency. The design process considers crucial aspects like material selection, applied loads, and thermal effects, ensuring that the engine can withstand operational forces and heat variations.

Keywords: Static Structural, Single-Cylinder Engine, Operating Conditions, Material Selection.

I. INTRODUCTION

First commercial Internal combustion Single Stroke Engine was patented by Étienne Lenoir, a Belgian inventor in 1959. This single stroke engine replaced the large and heavy steam engines used in locomotives. This engine ran on coal gas and air mixture by the ignition {jumping sparks} by Ruhmkorff coil. However, this engine required a powerful water-cooling system. Later Nicolaus August Otto, a German engineer started the construction of a replica of the Lenoir engine. He proposed that instead of using gas, it would work better if fueled with ethyl alcohol. Later Gottlieb Daimler and Wilhelm Maybach patented an improved single cylinder engine in 1883. This engine generated 1HP and was relatively small and used petrol as fuel. Nowadays single stroke engines can be found with diesel variation also. A single stroke engine only uses one stroke piston to rotate the output shaft continuously to complete a cycle.

II. LITERATURE REVIEW

Manjunatha.T. R, Dr. Byre Gowda. H. V, Prabhunandan. G. S, (2013) Design and Static Structural Analysis of Cylinder and Piston of Two Stage Reciprocating Compressors Using ANSYS

Swati S. Chougule, Vinayak H. Khatawate, (2013), Piston Strength Analysis Using FEM, International Journal of Engineering Research and Applications, 3, pp.124 126.focused on the main objective of this paper is to investigate and Analysis the stress distribution of piston during combustion process at actual engine conditions.

Chaitanyaet. Al. (2014) This report's main goal is to use Ansys Work Bench to analyze heat properties in cylinder fins of varied densities, styles, and materials. Temperatures 28 and various quantities of heat that change over time are measured via transient heat measurement.

Ashok et al. Al. (2015) The primary goal of our study is to construct the cylindrical head utilizing SOLIDWORKS modelling techniques and common formulae. Stable thermal analyses are performed using ANSYS Instruments.

OBJECTIVE OF THE PAPER

The primary objective is to analyze key factors such as total deformation, equivalent stress, equivalent strain, and temperature distribution to ensure the engine's reliability and efficiencyThe study aims to:

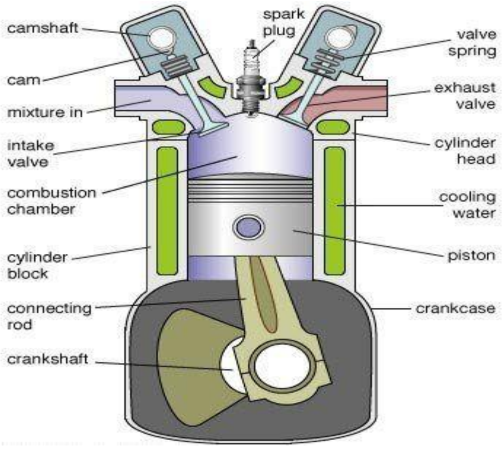
1. To achieve an accurate representation of the engine, the 3D modeling is done using SOLIDWORKS, a leading CAD software that enables precise design and component detailing.
2. The structural and thermal analysis is carried out using Finite Element Analysis (FEA) tools, such as ANSYS, to simulate real-world conditions and optimize the engine’s performance.

3. This involves evaluating stress distribution, material deformation, and heat dissipation to enhance durability and efficiency.

4. By integrating advanced design and analysis techniques, this project provides a comprehensive assessment of the structural integrity and thermal efficiency of a single cylinder engine, ensuring its suitability for vehicle applications.

III. METHODOLOGY

Unlike multi-cylinder engines that distribute power generation across multiple pistons, a single-cylinder engine relies entirely on one combustion chamber, making it more prone to vibrations, heat concentration, and mechanical stresses. Despite these challenges, it remains a preferred choice in applications where simplicity and fuel efficiency are prioritized. This chapter explores the working advantages, limitations, and applications of single-cylinder engines to understand their significance in various industries.

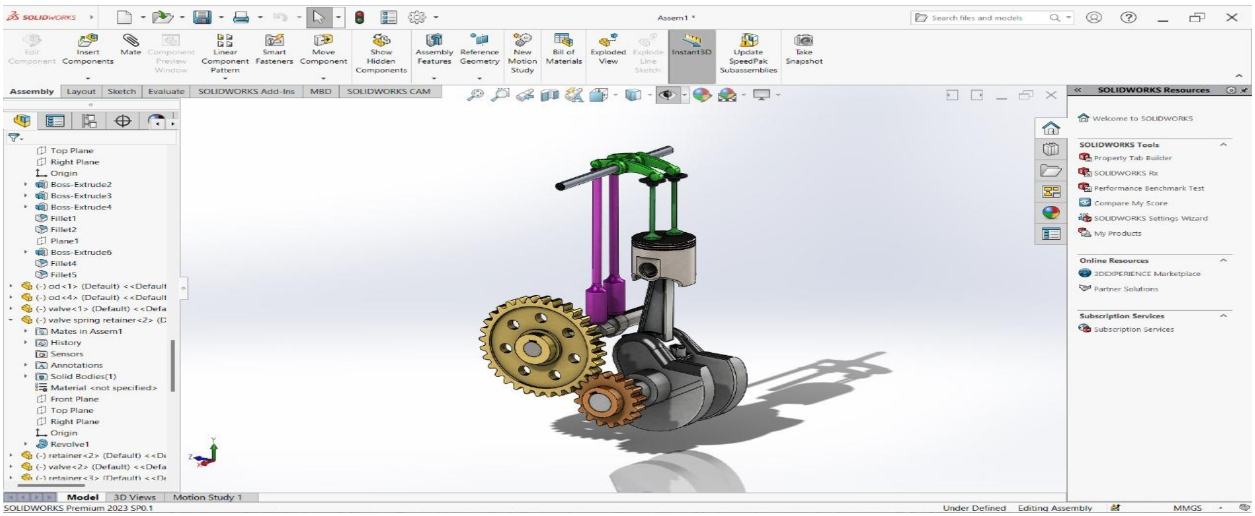


Key Features:

- Wrap Feature
- Advanced Hole Wizard
- Sweep Profile
- Magnetic Mates

Types of Analysis:

- **Modal type history**
- **Harmonic**
- **Random Vibration**
- **Response Spectrum Analysis.**



THE POWER OUTPUT DEPENDS ON SEVERAL FACTORS, INCLUDING:

- Engine displacement (size of the cylinder)
- Fuel type (petrol, diesel, or gas)
- Compression ratio
- Ignition system efficiency

IV. ANALYSIS PROCEDURE

1.Selection of Analysis Method

In ANSYS software,Workbench is used for analyzing process of different Methods. Now clicking on the Ansys workbench we will find a Analysis Methods table on the left side of the interface. In our project we had selected the two methods namely;

- Static-structural Analysis
- Steady-State Thermal Analysis

2. Selection of Engineering Data/Materials

By clicking on the Engineering data icon , we should choose the Engineering Materials for Analysing the Piston head Model. We can select the materials and their properties based on our analysis method. In our project we had selected three different materials, namely;

- Aluminium alloy
- 316 Stainless Steel

3. IMPORT THE MODEL

After completion of material selection, next step is to import the geometry 3D model of Piston head into Ansys workbench.

4. SETUP OF THE 3D-MODEL

After completion of importing the 3D model ,we can Assign the units and also we can edit the model. Each part of the piston head model gets assigned by the different geometry materials for Analysing based on the different properties of materials. we have to assign the material to all the parts in the model

5. MESHING

Meshing the model will divide the large component into small elements and nodes, which will make the component easy and convenient to perform the analysis.

1. Display type = Element Quality
2. Physical preferences = Mechanical
3. Element size = 2.35mm
4. Span angle Centre = Fine
5. Smoothing = Medium

6. APPLYING BOUNDARY CONDITIONS IN STRUCTURAL AND THERMAL ANALYSIS METHODS

The main conditions of loading available in FEA include force, pressure and temperature.These can be applied to points, surfaces, edges, nodes and elements. In our project of Analysis on Piston head in Structural Method, the boundary parameters are Pressure and Fixed Support.

In case of Steady-state Thermal analysis, the boundary conditions involved for study of heat dissipation and heat flux rate are as follows;

Ambient temperature, Temperature, Convection are applied on the surface of the piston head parts.

7. SOLUTION & RESULTS

After giving the boundary conditions, we solve the model. In solution we should add the parameters or Factors which we want as the Results.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

ANALYSIS OF PISTON

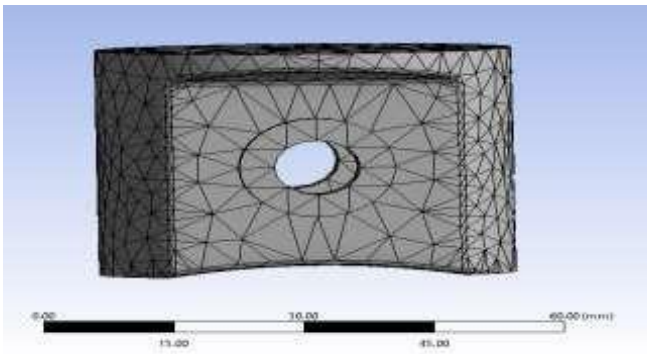


Fig.4.1. Tetrahedron meshing of piston

Number of nodes	7417
Number of elements	3797

BOUNDARY CONDITIONS:

Pressure applied over piston is 500000 Pa

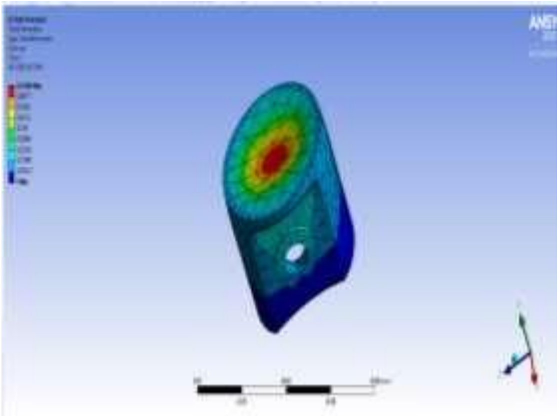


Fig.4.2. Total Deformation

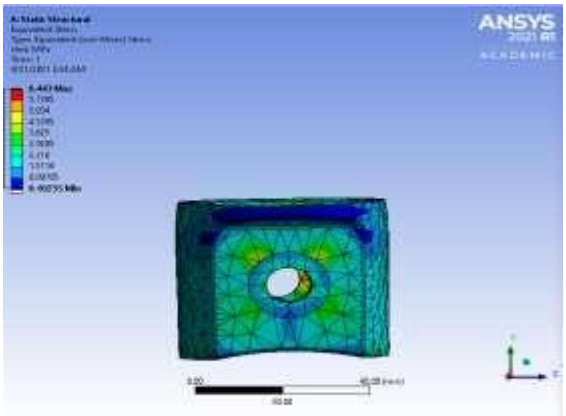


Fig.4.3. Equivalent stress

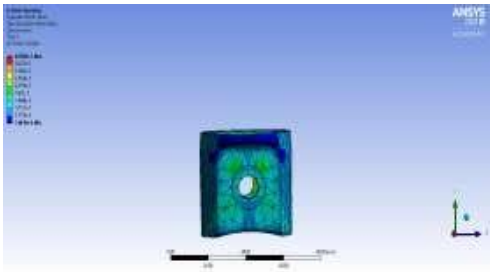


Fig.4.4. Equivalent Elastic Strain

Results of Structural analysis of Piston:

Parameter	Total Deformation(m)	Equivalent Stress(pa)	Equivalent Elastic Strain(m/m)
Minimum	0	0.10255	1.4039e-6
Maximum	0.001692	6.443	4.058e-5
Average	0.00075221	2.9205	1.882e-5

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

ANALYSIS OF CRANKSHAFT

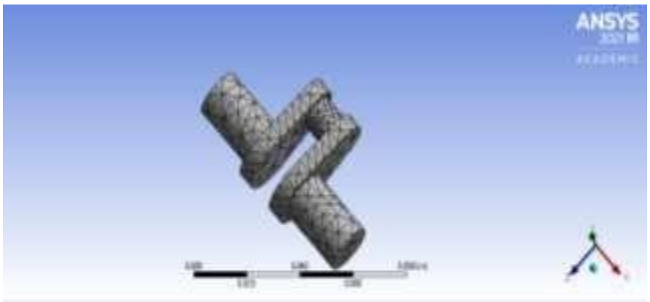


Fig.4.5 Tetrahedron meshing of Crankshaft

No. of Nodes	2734
No. of Elements	1449

Boundary conditions: 1.RotationalVelocity:10rad/sec 2.Force:10000N

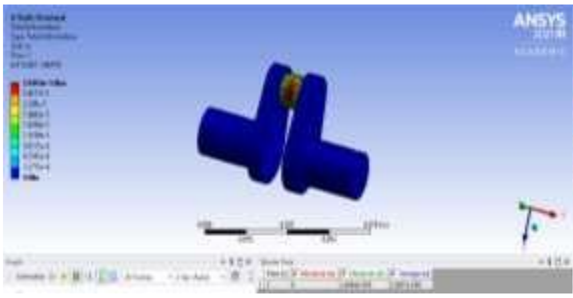


Fig.4.6 Total Deformation of Crankshaft

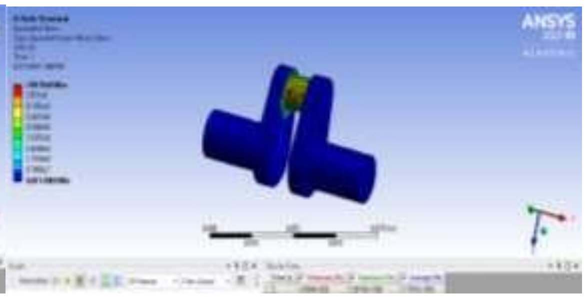


Fig.4.7. Equivalent Stress of Crankshaft

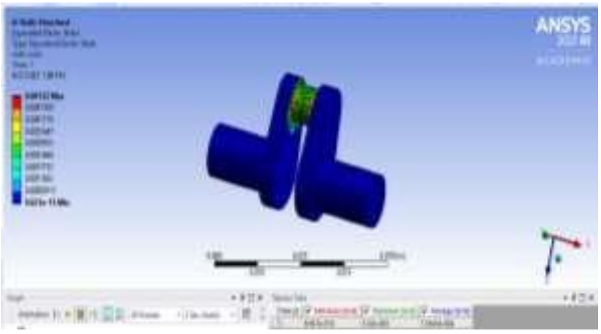


Fig.4.8. Equivalent Elastic Strain of Crankshaft

Result of Structural analysis of Crankshaft

	Total deformation(m)	**Equivalent Stress(pa)**	**Equivalent Elastic Strain(m/m)**
Maximum	2.9494e-5	7.8919e+8	5.32e-3
Minimum	0	1.3084e-3	9.921e-15
Average	3.2907e-6	1.1787e+8	7.5545e-4

V. CONCLUSION

- Here we obtain discrete and analysis of components in static and steady state thermal parameters.
- It is observed from the result table of all parameters of every component and assembly that the Equivalent Stress and Equivalent Strain and total deformation differ according to mesh size.
- According to the result Tetrahedron Fine meshing gives minimum deformation, Equivalent stress and Equivalent Elastic strain compared to Coarse and Medium Meshing.

- After doing thermal analysis we obtained final temperature and total flux respectively.
- Above observation gives an idea about the design and analysis of a single stroke cylinder engine, hence the FEA of assembly is done and is proved as safe.
- Since none of the deformation exceeds the given safety values.
- It has explained various parameters of analysis using ANSYS workbench software, This result will help in better optimization of the engine design.

VI. REFERENCES

[1] Gupta, R.S. Khurmi, J.K.). A textbook of machine design. Ram Nagar, New Delhi: Eurasia Publishing House. ISBN 81-219- 2537-1 (2008).

[2] Tulus, Ariffin A K, Abdullah S and Muhamad N (2006), "Presented the Heat Transfer Model of PistonPin", Proceedings

[3] of the 2nd IMT-GT Regional Conference of Mathematics, June 13-15, Statistics and Applications, University Sains Malaysia.

[4] Weibing Liu, MamtiminGeni, and Lie Yu, "Effect of Mesh Size of Finite Element Analysis in Model Analysis Periodic Symmetric Struts Support,Key Engineering Materials" Vol.462-463,2011,pp 1008 1012.

[5] F.S. Silva, "Analysis of a vehicle crankshaft failure," Engineering Failure Analysis 10 (2003) 605–616

[6] https://www.researchgate.net/publication/276061152_Structural_analysis_of_angle_plate_in_ansys/link/55504c4a08ae93634e c8c1a6/download

[7] Ajay, Arshad Mehmood, Abhishek Kumar Singh, Ankit Kumar, Numerical validation of thermal analysis of an automobile piston using ANSYS International Journal of Research in Engineering and Innovation Vol 2, Issue 4 (2018).

[8] Manoj Darwai, Anurag Kulshreshtha, Steady State Thermal and Structural Analysis of single acting cylinder Using Finite Element Simulation, 2017 IJSRST, Volume 3, Issue 7.

[9] Preeti, Anamika, Dr.H.C.Thakur , Thermal Analysis of Piston of IC engine International Journal of Scientific & Engineering Research, Volume 7, Issue 12, December-2016.

[10] Dilip Kumar Sonar, Madhura Chattopadhyay, Theoretical Analysis of Stress and Design of Piston Head using CATIA & ANSYS, International Journal of Engineering Science Invention, Volume 4, Issue 6, June 2015.