DESIGN AND ANALYSIS OF A PISTON USING VARIOUS ALLOY MATERIALS

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Abstract:

The piston is the heart of the engine and its working condition is the most important in it and one of the key parts of engine in the working environment. Pistons are designed with such features to satisfy the requirements light weight, good wear resistance, high strength etc. pistons are made of different materials for different requirements and applications. A single material cannot satisfy all the requirements. For example, a piston made using aluminium alloy give properties like lightness and ability to absorb high impact. Piston made using titanium alloy gives properties combination of strength and lightness. In this study it mainly focuses on evaluating the performance of automotive pistons made from three different materials: aluminium alloys, titanium alloys, and structural steel. In Solid Works, detailed piston designs are developed. Subsequently, these designs are imported into ANSYS Workbench for static structural and thermal analyses, simulating real-world operating conditions and loads. The analyses assess factors such as stress, total deformation and thermal behaviours. This study aims to provide a comprehensive understanding of the performance characteristics and suitability of each material for automotive piston applications. The results obtained serve as valuable insights for optimizing piston design and material selection to enhance engine performance, reliability, and efficiency.

I. INTRODUCTION

The piston is a crucial component in many mechanical systems, ranging from internal combustion engines to hydraulic and pneumatic systems. It's simple yet effective design allows for the conversion of pressure into mechanical energy, making it an indispensable part of various applications. There are different parts in the piston some of them are divided according to their functions some of them are the top surface of the piston is called as crown, the design of the crown is based on the requirements of the engine combustion chamber, and the surface of the crown is essentially in convex or concave forms. The bottom surface of the piston is called as the piston skirt. A piston is a cylindrical component that move back and forth inside a cylinder it's often found in moves back pumps, where it converts pressure into mechanical energy, in engines, the piston's movement helps to transfer energy from expanding gases to the crank shaft, which then drives the machine's motion.

II. Methodology

- Modelling of piston with the help of SolidWorks.
- Importing the piston model in "step" format of saving for further Analysis process.
- Gathering the material properties of the materials like density, yield strength and thermal conductivity values.
- Selection of suitable materials in ANSYS engineering data sources for our study.
- Meshing the Piston model in order to divide it into multiple elements for the analysis.
- Applying the boundary conditions to the piston.
- Performing Static Structural and Thermal Analysis on the piston.
- Determining various Stresses and Deformations individually for each material using Structural Analysis.
- Determining various Heat flux for the different materials.
- Comparison between four materials with respect to Stresses, Total Deformations and Heat flux generated during the study.

III. Results And Discussions

3.1. Static Structural Analysis:

3.1.1. Total Deformation:

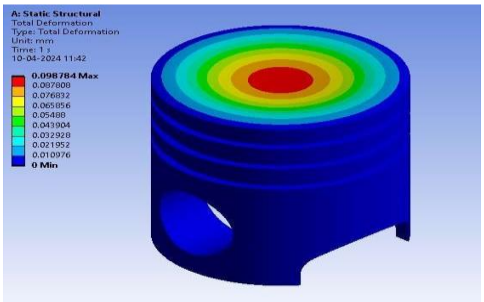

Fig 1.1: Aluminium alloys Total Deformation

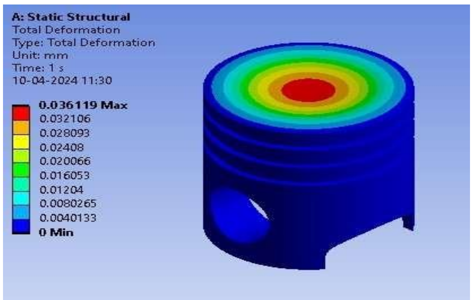

Fig 1.2: Structural Steel total deformation

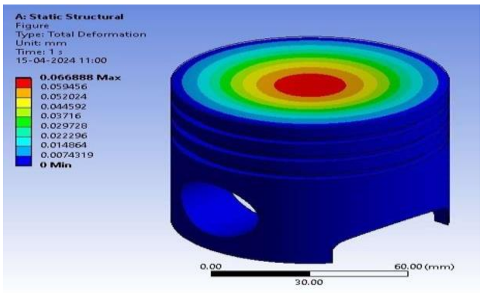

Fig 1.3: Cast Iron total deformation

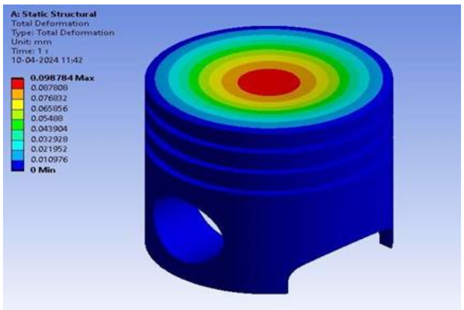

Fig1.4: Titanium Alloys Total Deformation

The Maximum and Minimum Total Deformations of the piston made of different materials are tabulated below.

Table 1.1: Total Deformation

Material	Minimum Deformation(mm)	Maximum Deformation(mm)
Aluminium Alloys	0	0.09878
Titanium Alloys	0	0.07074
Structural Steel	0	0.03611
Cast Iron	0	0.06688

3.1.2. Equivalent Stress:

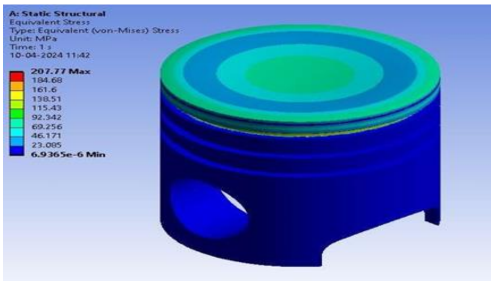

Fig 1.5: Aluminium alloys Equivalent stress

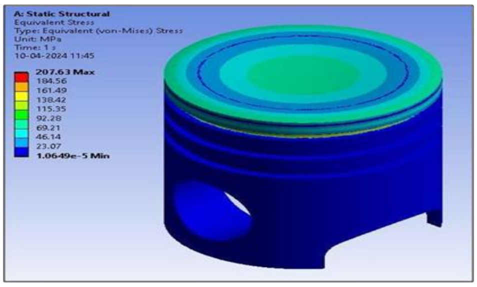

Fig 1.6: Titanium Alloys Equivalent stress

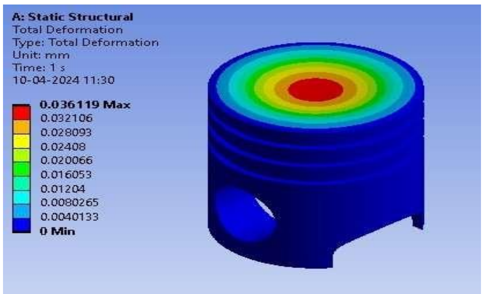

Fig 1.7: Structural Steel Equivalent stress

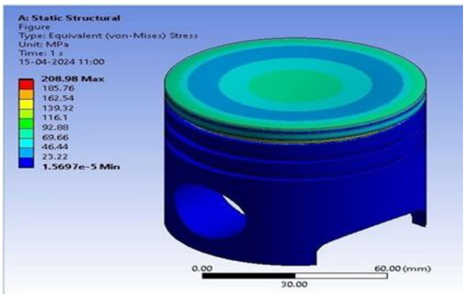

Fig 1.8: Cast Iron Equivalent stress

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The Maximum and Minimum Equivalent Stresses of the piston made of different materials are tabulated below.

Table 1.2: Equivalent Stress

Material	Minimum Stress (Mpa)	Maximum Stress (Mpa)
Aluminium Alloys	0.000069365	207.77
Titanium Alloys	0.000010649	207.63
Structural Steel	0.000011155	208.36
Cast Iron	0.000015697	208.98

3.1.3. **Total Heat Flux:**

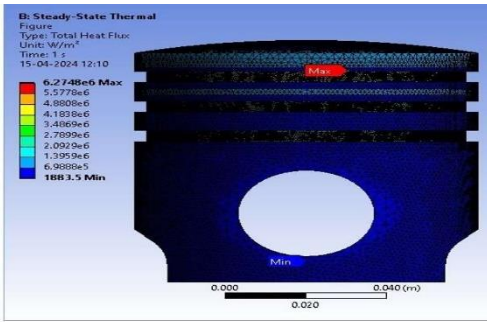

Fig 1.9: Aluminium alloys Total Heat Flux

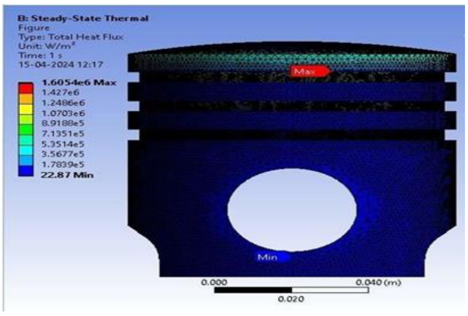

Fig 1.10: Titanium alloys Total Heat Flux

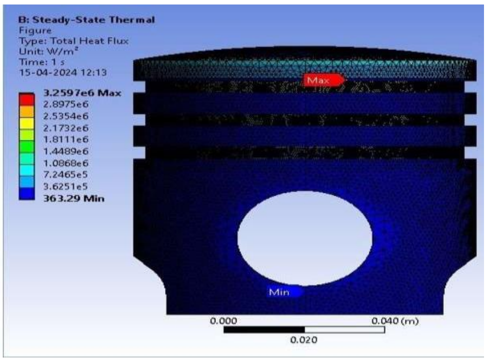

Fig 1.11: Structural Steel Total Heat Flux

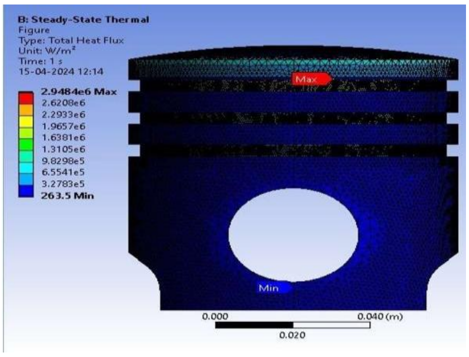

Fig 1.12: Cast Iron Total Heat Flux

The Maximum and Minimum Total Heat Flux of the piston made of different materials are tabulated below.

Table 1.3: Total Heat Flux

Material	Minimum Heat Flux(W/m²)	Maximum Heat Flux(W/m²)
Aluminium Alloys	1883.5	6.2748e6
Titanium Alloys	22.87	1.6054e6
Structural Steel	363.29	3.2597e6
Cast Iron	263.5	2.9484e6

IV. Conclusion:

In this project, we conducted a comprehensive design and analysis of a piston using various alloy materials, including aluminum alloys, titanium alloys, structural steel, and cast iron. Based on the analysis, Titanium Alloys emerges as the most suitable material for the piston. This is due to its superior mechanical properties, particularly in Total Heat Flux that allows to lower thermal expansion. The yield strength of the Titanium alloys is 930 Mpa and we got Equivalent stress about 207.63 Mpa. So, it can with higher loads while in working condition Although aluminum alloys exhibit excellent thermal conductivity, their higher deformation compared to structural steel might be a drawback in applications where dimensional stability is critical. Structural Steel, while showing good mechanical properties and lower deformation than aluminum, are generally have more density compared to Titanium alloys. So**,** for this study, titanium alloys stand out as the most balanced option, offering a combination of lightness, strength, and high-temperature stability. While they have lower thermal conductivity, their superior mechanical properties make them suitable for high-performance automotive engines.

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