Structural Analysis Of IC Engine Piston

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ABSTRACT

The primary objective of this research was to characterise and evaluate the stress distribution in pistons under actual engine settings. This investigation incorporates both a fea analysis and a mechanical structural examination. The research used the piston's operating load, force, and material properties. The piston is the most intricate and important part of an internal combustion engine, thus it must be in excellent working condition for the car to run smoothly. Piston failure is often caused by mechanical and thermal loads. Boundary conditions are used to analyse a piston, and these circumstances might include things like operational pressure on the piston head and uneven load distribution from the piston, both of which can cause the process to fail. Pure Aluminium Alloy, Aluminium 2024 Alloy, and Aluminium 7068 Alloy are just few of the materials that might be evaluated in this comparative research.

Keywords: Aluminium , Aluminium 2024 alloy , Aluminium 7068 alloy , structural analysis.

1. INTRODUCTION

The piston is an integral part of internal combustion engines that use reciprocating motion to power the engine. The cylinder and the piston rings contain and seal off the moving portion. Piston rods in internal combustion engines are responsible for transferring the force generated by the expanding gas in the cylinder to the crankshaft. Pistons may sustain fatigue damage at work from being exposed to cyclic gas pressure and inertial forces, such as piston side wear, piston head fractures, and so on. Therefore, several parameters must be addressed in optimising the design of the piston. This study employs a thermal analysis of the piston at different temperatures in different strokes [1]-[5] and a piston analysis with a pressure force acting at the top of the piston. Design engineers might benefit from this study if it leads to improvements in the piston design process. In this study, we compute the various stress estimates using pressure analysis, temperature analysis, and thermo-mechanical analysis to pinpoint the potential areas of piston damage. Optimization of the piston design through analysis is a breeze. One of the most important aspects of piston design is predicting how heat will spread over the piston's surface so that we can optimise the piston's thermal characteristics at a lower price. The thermal expansion coefficient of the aluminium alloy used to make most of the pistons is 80 percent better than that of the cast iron cylinder bore material. Therefore, there are slight deviations from design clearances in actual operations. Because of this, it is essential to comprehend the piston's thermal behaviour in order to build a more effective compressor. Piston design should prioritise a tight seal between the piston and cylinder. High-speed machines benefit greatly from lighter pistons because of the decreased inertia they provide. Because of temperature-induced expansion, the piston's diameter must be less than the cylinder's. The necessary clearance is calculated by taking into account the piston's coefficient of thermal expansion and the temperature difference between the cylinder and the piston [6]-[10].

2. RELATED WORK

A piston may be found in reciprocating engines, reciprocating pumps, gas compressors, and pneumatic cylinders, among other things. The cylinder and the piston rings contain and seal off the moving portion. Piston rods and connecting rods in an engine serve to transfer the force generated by the expansion of the gas in the cylinder to the crankshaft. In a pump, the fluid in the cylinder is compressed or discharged by means of force delivered from the crankshaft to the piston. The piston may also serve as a valve in some engines by covering and uncovering perforations in the cylinder.

This section of a piston from an internal combustion engine displays the gudgeon pin.

The pressure of expanding combustion gases in the combustion chamber space at the top of the cylinder acts on an internal combustion engine. The connecting rod then transfers the force to the crankshaft. A swivelling gudgeon pin links the connecting rod to the piston (US: wrist pin) (US: wrist pin). There is no piston rod or crosshead as in a steam engine, and this pin is housed within the piston itself (except big two stroke engines).

The pin, which is composed of hardened steel and is attached in the piston but free to move in the connecting rod, is fixed in the piston. Some designs use a "completely floating" layout, in which one or both parts are free to move about. To prevent any of the pins from moving laterally or burrowing into the cylinder wall, a circlip is utilised.

Figure.1. Pistons for the Trunk

When it comes to trunk pistons, the length you get is directly related to the diameter you use. Both the piston and the crosshead, they are cylindrical in shape. Since the connecting rod is at an angle for most of each rotation, the piston exerts lateral force on the cylinder wall. With a longer piston, this is made easier. Trunk pistons have been widely used in engines since since the invention of the internal combustion engine. Once common in both gasoline and diesel engines, slipper pistons have now been shown to be more efficient at high speeds. Most trunk pistons, particularly those used in diesel engines, include a groove for an oil ring below the gudgeon pin, in addition to the rings between the gudgeon pin and the crown. The phrase "trunk piston" was originally used to describe an early kind of nautical steam engine known as a "trunk engine." As a first, these were the first engines to integrate the gudgeon pin into the piston, reducing the overall size. To reduce the bulk, they did away with the piston rod and crosshead seen in traditional steam engines. There was no resemblance between the trunk piston and these engine pistons, which were unusually large in diameter and double-acting. Their "trunk" was really just a little cylinder in the middle of the piston.

Large, low-speed Diesel engines may have side strains on the piston and may benefit from additional reinforcement. Commonly employed in such motors are crosshead piston designs. A second, smaller piston is created by extending a massive piston rod downward from the first piston. Piston rings and gaskets are moved around by the main piston, which also acts as a seal. A mechanical guide, the smaller piston's only purpose. The gudgeon pin is housed in a little cylinder that also acts as a guide for the trunk. Since the crosshead's lubricating oil is shielded from the combustion chamber's high temperatures, it is less likely to get contaminated with soot particles, is less likely to degrade as a result of heat, and may be thinner and less viscous than the trunk piston's oil. There may be just half as much resistance between the piston and the crosshead as there would be with a piston in the trunk. Due to the extra weight, these pistons are not used in high-performance engines.

The term "slipper piston" refers to a gasoline engine component that has been shrunk and lightened to the greatest extent possible. In the most severe example, they consist only of the piston crown, the support for the piston rings, and the minimum amount of the piston skirt necessary to leave two lands and prevent the piston from rolling in the bore. Around the gudgeon pin, the piston sides skirt away from the cylinder wall. We want to reduce the reciprocating mass as much as possible so that the engine can run at greater speeds while being easy to balance. The piston friction with the cylinder wall is larger than the fluid pressure on the piston head, hence decreasing inertia improves the mechanical efficiency of the engine. One additional benefit may be less drag on the cylinder wall, since the area of the skirt that glides up and down the cylinder will be cut in half. However, the piston rings—the pieces that fit closest in the bore and the wrist pin bearing surfaces—are the primary source of friction, which significantly lessens the benefit.

Piston rings seal off the combustion chamber, transferring heat to the cylinder wall and controlling oil consumption. Piston ring seals combustion chamber by both internal and external pressure. Inherent pressure refers to the intrinsic spring force that expands a piston ring based on the design and properties of the material used. When the diameter of a piston ring has to be reduced due to pressure, a lot of force is needed. The free piston ring gap in the absence of compression defines the inherent pressure. The free piston ring gap is the space between the piston ring's ends while the piston is at atmospheric pressure. More force is applied by the piston ring when it is compressed in the cylinder bore the larger the free piston ring gap.

To create a reliable seal, a piston ring's radial fit to the cylinder wall must be consistent and positive. Piston rings have their own internal pressure that causes the radial fit. For the piston to remain hermetically sealed, the piston ring must also do its job.

Figure.2. Piston Ring

3. **OPTIMIZATION OF PISTON**

After a precise finite element model was built, a strategy for the optimization process could be formulated. Lightening the load on the piston's bearings was a primary objective during optimization. The reason behind the goal: Cut down on the quantity of stuff you utilise. Specifically, the following limitations are in place:

I Limitations on Production (ii) Design stress or maximum allowable Vonmisses stress (iv) In order to keep the maximum vonmisses stress within the allowable limit and the factor of safety over 1.5, we performed a static structural analysis to estimate the stresses under each loading condition (v).

Thickening of the Rings, Both Radially and Axially Maximum Barrel Thickness (c) Top Land Width (d) Other Ring Land Widths (e)

Aluminum, a chemical element with the symbol Al and atomic number 13, is a member of the boron group. It is a white, malleable metal that is velvety to the touch. Aluminum is the most common metal and the third most prevalent element in the Earth's crust (after oxygen and silicon). It accounts for around 8% of the mass of the Earth's solid surface.

Natural aluminium is very rare and can only be discovered in extreme reducing environments due to its high reactivity. Rather, it is more likely to be discovered in one of more than 270 possible mineral mixtures. The ore bauxite is the primary source of aluminium production.

Aluminum is unique due to its low density and the passivation phenomenon, which gives it corrosion resistance. The aerospace industry relies heavily on aluminium and its alloys for structural components, and this is true of many other transportation and construction industries as well. At least in terms of mass, the most valuable aluminium compounds are the oxides and sulphates.

Unfortunately, no known form of life takes use of aluminium salts in its metabolism, despite their widespread presence in the environment. Aluminum is widely present, thus it seems sense that plants and animals can withstand it without any problems. Because aluminium compounds are so ubiquitous, researchers are always curious about their potential beneficial or harmful effects on living organisms.

4. INTRODUCTION TO CAD/CAM/CAE

After an accurate finite element model was built, a strategy for the optimization technique was developed. Optimizing for mass reduction was a primary focus. Role of the goal: Cut down on the resources you commit to this. Please note the following limitations:

I Produced item limitations (ii) Allowable design stress or maximum Vonmisses stress (iv) After performing a static structural analysis, stresses under each loading condition were examined, and locations where unnecessary material might be cut out to keep the maximum vonmisses stress within the allowable limit and the factor of safety at or above 1.5. (v).

Thickness of the Ring, Both Radially and Axially Maximum Barrel Thickness, Other Ring Land Widths, and the Top Land Width

The chemical element aluminium (atomic number 13, symbol Al) is a member of the boron group. Silver is a soft, ductile, whitish metal. After oxygen and silicon, aluminium is the most prevalent metal and the third most abundant element in the Earth's crust. By mass, it constitutes around 8% of Earth's solid surface.

Due to its high reactivity, aluminium is seldom encountered in its native state outside of extreme reducing environments. On the other hand, it might be present in over 270 different mineral mixtures. Most aluminium comes from a mineral called bauxite.

Passivation, a unique property of aluminium, makes it resistant to corrosion. The aerospace industry relies heavily on aluminium and its alloys for structural components, and this is true not just for aeroplanes but also for other forms of transportation and building materials. For practical purposes, the oxides and sulphates are the most important aluminium compounds.

Even though aluminium salts are widespread in nature, no known organism can use them metabolically. It seems sense that, considering how common it is, aluminium would be accepted well by plants and animals. The potential beneficial (or harmful) biological activity of aluminium compounds is of continual interest owing to their pervasive presence in modern life.

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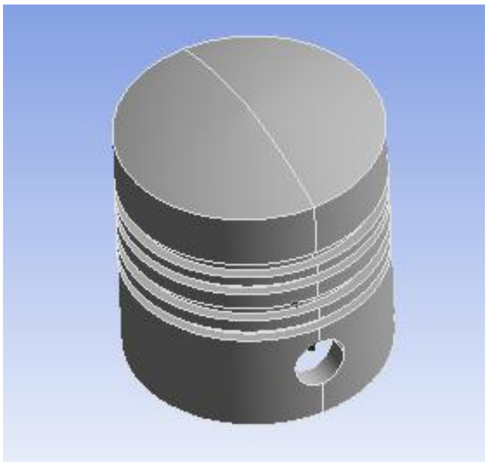

Figure.3.3D diagram of piston

Engineers use ANSYS to model interactions in various disciplines of physics, including structural, vibration, fluid dynamics, heat transport, and electromagnetics. As a result, ANSYS, which allows you to simulate testing or working settings, allows you to test in a virtual environment before making product prototypes. Furthermore, 3D simulations in a virtual environment may be used to identify and improve weak areas, compute life, and predict potential issues.

The modular nature of ANSYS software, as shown in the table below, allows users to choose just the functions they need. By integrating CAD and FEA connection modules, ANSYS may be coupled with other commonly used engineering applications on the desktop. With its "pre processing" capabilities, ANSYS can input CAD data and generate a geometry. In the same preprocessing, a finite element model (also known as a mesh) is created, which is necessary for computing. The outcomes of specifying loadings and doing analysis may be examined numerically and graphically. With its multitude of contact methods, time-based loading characteristics, and nonlinear material models, ANSYS can perform advanced engineering studies rapidly, safely, and realistically. Heat is transmitted from one point to another and between bodies in most engineering applications. This transmission is fueled by temperature differences (a temperature gradient), and it moves from hot to cold places. Because of their coefficient of thermal expansion (sometimes abbreviated CTE in engineering literature), these temperature differences cause mechanical stresses and strains in bodies. • The amount of heat transfer is directly proportional to the size of the temperature gradient and the thermal resistance of the material(s) involved.

There are three primary mechanisms in engineering applications:

1. Conduction
2. Convection
3. Radiation

ANSYS Workbench is a platform that combines simulation and parametric CAD systems with unparalleled automation and performance. The strength of ANSYS Workbench derives from years of expertise with ANSYS solver algorithms. In addition, the goal of ANSYS Workbench is to verify and improve the product in a virtual environment.

5. RESULT AND ANALYSIS

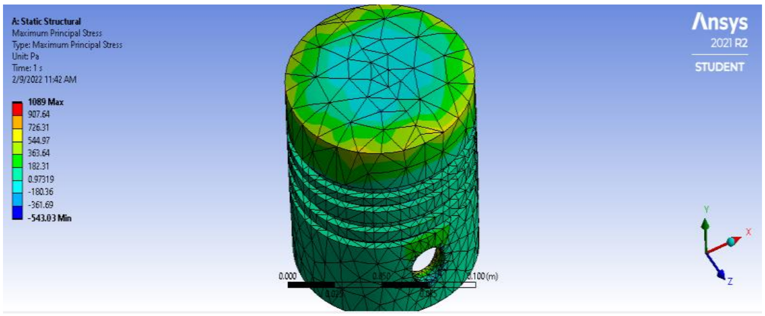

Figure.4. Max principal stress of aluminium alloy piston.

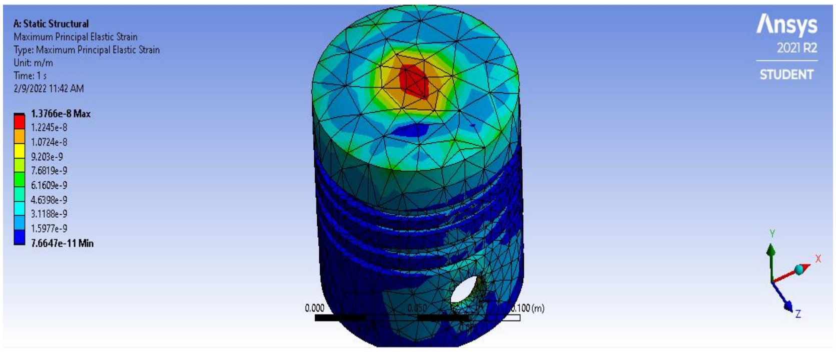

Figure.5. Max Principal Strain Of Aluminium Alloy Piston

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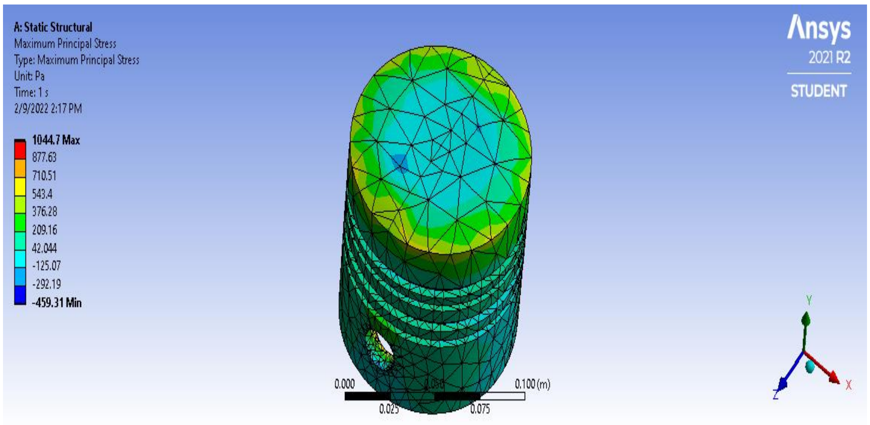

Figure.6. Fig. max principal stress of aluminium 2024alloy piston.

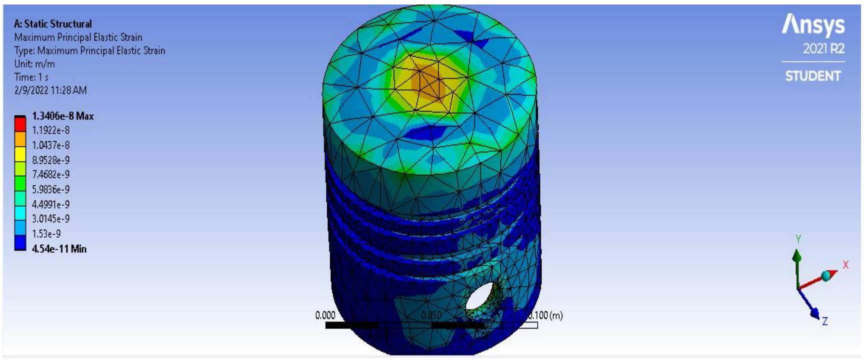

Figure.7. max principal strain of aluminium 2024alloy piston.

STRUCTURAL ANALYSIS OF PISTON USING ALUMINIUM 7068 ALLOY

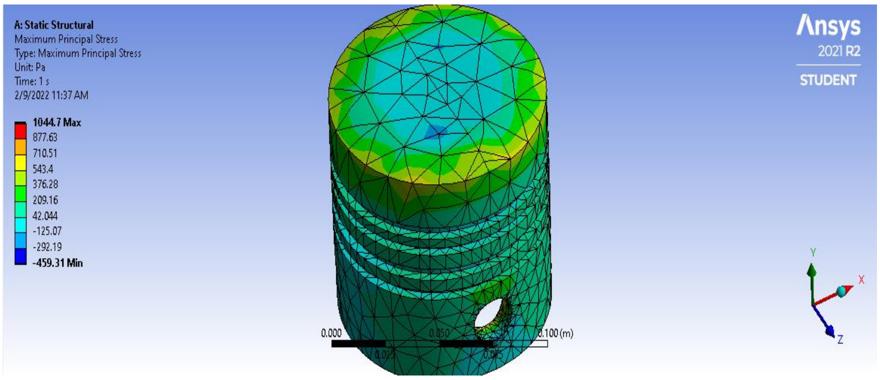

Figure.8. max principal stress of aluminium 7068alloy piston.

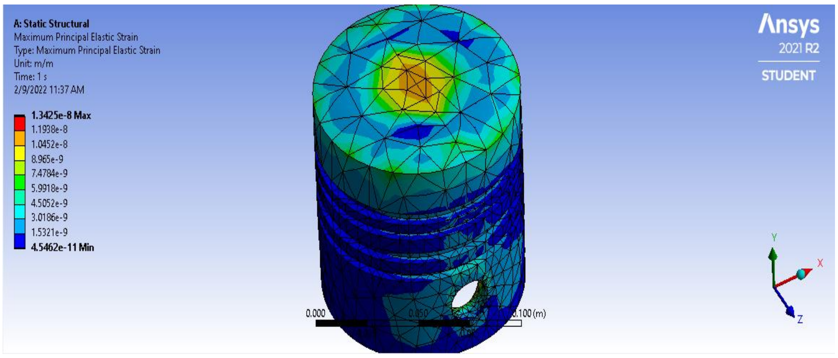

Figure.9.max principal strain of aluminium 7068alloy piston.

Table.1.COMPARISON TABLE

S. NO.	CONTENT		PISTON METAL TYPES		
			Aluminium alloy	Aluminium 2024	Aluminium 7068
1.	Total deformation	Max	2.5311e -9	2.4847e-9	2.4881e-9
		Min	0	0	0
2.	Equivalent stress	Max	1424.2	1398.9	1398.9
		Min	10.417	10.723	10.723
3.	Equivalent elastic strain	Max	2.0124e-8	1.9198e-8	1.9224e-8
		Min	2.6084e-10	2.4143e-10	2.4176e-10
4.	Maximum principal stress	Max	1089	1044.7	1044.7
		Min	-543.03	-459.31	-459.31
5.	Maximum principal strain	Max	1.3766e-8	1.3406e-8	1.3425e-8
		Min	7.6647e-11	4.54e-11	4.5462e-11

6. CONCLUSION

Three-dimensional models of pistons are constructed using the data. The CATIA V5R20 software was used to create the 3D model. The next step is to import the models into ANSYS WORKBENCH 14.5 to do a structural analysis of the piston. With a relevance of 100 and an element size of 10mm, a fine mesh is produced. To perform a structural analysis, input pressure is supplied to the piston's top, while the side holes provide support. Maximum principle stress and maximum principal strain are also determined, along with the total deformation, equivalent stress, equivalent elastic strain, and equivalent stress. These results show that, depending on the criteria, the pure aluminium alloy delivers the best results.

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