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DESIGN AND ANALYSIS OF A CRANKSHAFT FOR A HERMETICALLY SEALED COMPRESSOR USING AlSiC AND AISI 1118 MATERIALS

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ABSTRACT

Attaining long life and reliable performance of compressors for air conditioners and refrigerators requires a combination of well-designed equipment and systematic maintenance. Hermetically sealed compressor is a device that cannot be repaired and the whole device should be replaced if any issue arises. So the persistence of a device should be well designed to enhance the life support. The research focuses on optimizing the performance and reliability of the crankshaft in a hermetically sealed compressor, considering the utilization of two different materials: AlSiC alloy and AISI 1118. The study employs a comprehensive design and analysis approach, incorporating advanced engineering tools and techniques. Finite Element Analysis (FEA) is utilized to assess the structural integrity and, fatigue life of the crankshaft under operating conditions. The investigation aims to identify the material that offers superior mechanical properties contributing to enhanced overall performance and longevity of the compressor. Results from the analysis provide insights into the stress distribution, deformation patterns of the crankshaft made from AlSiC alloy and AISI 1118 materials. Comparative assessments will be conducted to determine the advantages and limitations of each material, and guidesthe selection process based on the specific requirements of the hermetically sealed compressor. Structural analysis are done for crankshaft using AlSiC alloy and AISI 1118 materials to find the strength, safety aspects and also emphases potential improvements in efficiency, durability, and overall system performance using these two materials in the context of a hermetically sealed compressor.

Keywords:

Analysis, Stress, Strain, Deformation, Fatigue Life, Crankshaft, AlSiC Alloy, AISI 1118 etc.

INTRODUCTION

Compressor

Compressor is one of the essential part of a refrigeration system. Compressing the refrigerant gas to raise its temperature and pressure is its main purpose. As the compressed gas condenses into a liquid and passes through the system, heat is released. The refrigerator can remove heat from its interior by this technique, keeping its contents cool.

There are different types of Refrigerating compressors that are commonly used:

Reciprocating Compressors: The most prevalent kind of compressors used in refrigerators are reciprocating compressors. The refrigerant gas is compressed by means of pistons that are powered by a crankshaft. They can be either semi-hermetic (usable) or hermetic (sealed).

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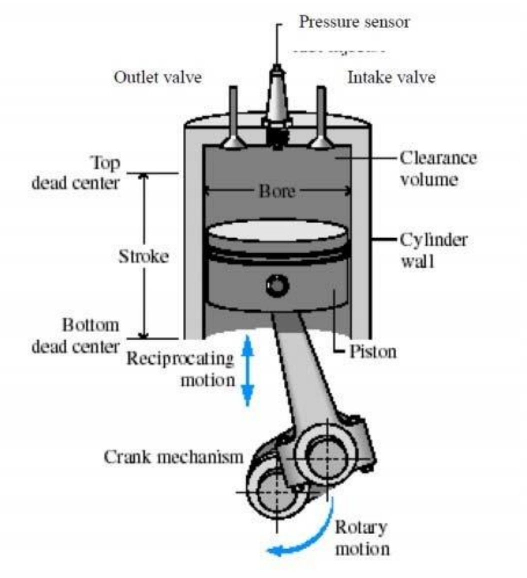

Figure 1.1: Reciprocating Compressors

Rotary Compressors: The refrigerant gas is compressed by means of a spinning mechanism in these compressors. When compared to reciprocating compressors, they are both quieter and more compact. Smaller refrigeration appliances like window air conditioners and mini-fridges frequently employ rotary compressors.

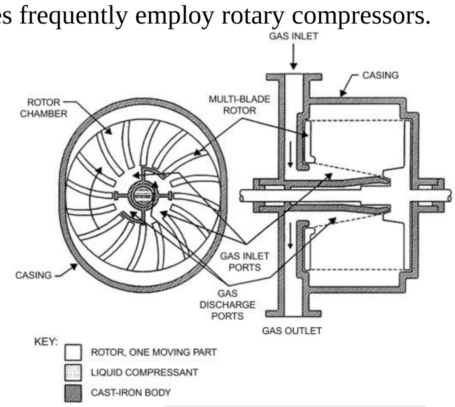

Figure 1.2: Rotary Compressors

Scroll Compressors: Scroll compressors compress the refrigerant gas using two spiral-shaped scrolls. As the other scroll revolves around the stationary one, it traps and compresses the gas. Because of its popularity for dependability and efficiency, scroll compressors are widely used in both commercial and household refrigeration systems.

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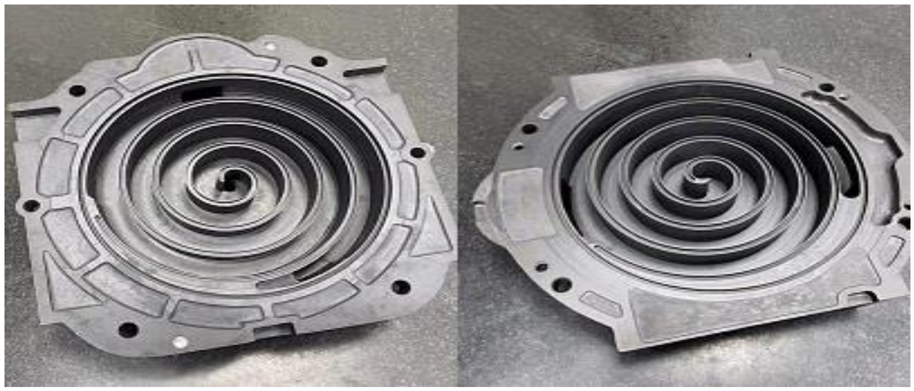

Figure 1.3: Scroll Compressors

Centrifugal Compressors: The refrigerant gas is compressed in these compressors by use of a revolving impeller. Because of their great capacity and efficiency, they are frequently utilized in big industrial refrigeration systems.

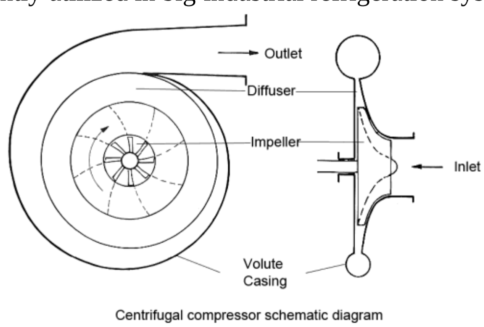

Figure 1.4: Centrifugal Compressors

Hermetically Sealed compressor

In air conditioning and refrigeration applications, a hermetically sealed compressor is a popular kind of compressor. The compressor motor and the compressor itself are contained within a single enclosure that is welded shut to prevent any refrigerant or impurity leaks, giving it the characteristic of being entirely sealed.

Hermetic compressors are well-known for being dependable, efficient, and small in size. Their sealed design reduces energy loss and aids in preserving system efficiency at its best. They are frequently found in many different applications, including as air conditioning systems, heat pumps, commercial freezers, and domestic refrigerators.

Hermetic compressors are usually unserviceable in the field due to their sealed construction. Rather, in order to preserve system integrity, a failing compressor is frequently replaced as a single unit.

Specifications

• Design Reciprocating
• No. of cylinders 2
• Speed 3500 rpm
• Weight including oil 27.7 kgs
• Suction pressure 5.34 kg/cm2 or 76Psi
\• Discharge pressure 21.09 kg/cm2 or 300Psi
• Power input 2075 watts
• Application Room Air conditioner
• Frequency 60 Hz

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Compressor Components

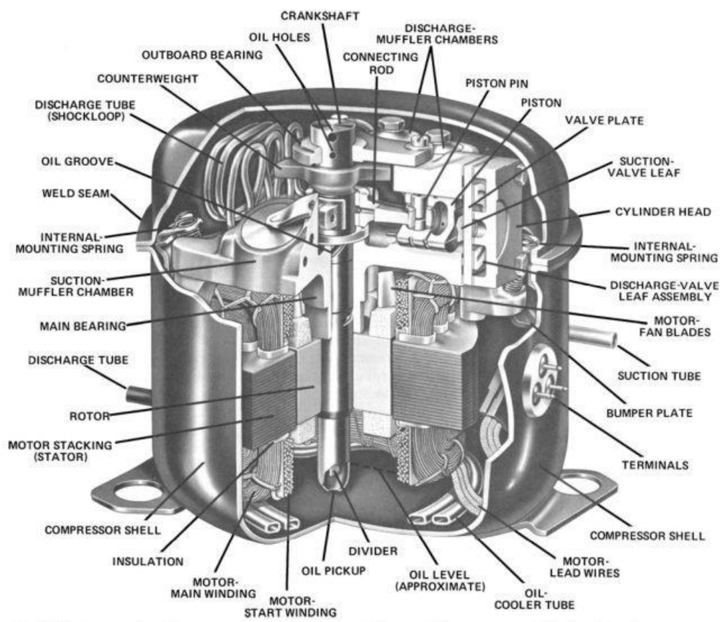

Figure 1.5: Hermetically sealed Compressor

key features and characteristics of hermetically sealed compressors:

- **Sealed Enclosure:**
  A welded or brazed housing encloses the complete compressor assembly, which includes the motor and compressor parts. This construction guarantees that the refrigerant stays contained within the system and keeps any outside elements—like moisture or dirt—from getting inside the compressor.
- **Motor and Compressor Integration**:
  The motor and compressor are combined into one unit in a hermetic compressor. By reducing the amount of moving components and simplifying the design, this integration can increase efficiency and dependability.
- **No Serviceable Parts**:
  In general, hermetic compressors are not meant to be maintained or repaired directly. Rather than being fixed, a hermetic compressor is frequently replaced as a single unit when it breaks. This is so that the compressor's integrity wouldn't be jeopardized by opening the sealed casing, which would expose internal components to impurities.
- **Efficient and Compact**:
  Hermetic compressors are well-known for their effective performance and small size. They are appropriate for a variety of refrigeration and air conditioning applications, including residential, commercial, and industrial systems, because of their sealed construction, which reduces energy losses and refrigerant leakage.

Crankshaft

A compressor's crankshaft plays a crucial role in transforming the pistons' reciprocating action into rotational motion. Usually, a connecting rod is used in a compressor to join the crankshaft and piston assembly. The crankshaft rotates as a result of the connecting rods transmitting the motion of the pistons as they oscillate inside their cylinders.

The crankshaft experiences cyclic loading all the time when it is in operation. This gives rise to fatigue. Consequently, variables influencing Its durability and service life must be taken into account during the design process. In the manufacturing sector, designing

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and developing a crankshaft that can withstand cyclic loading without failing is crucial. The goal is always to produce a crankshaft with a low weight and a high fatigue strength. Greater efficiency and power production are produced by a lighter crankshaft.

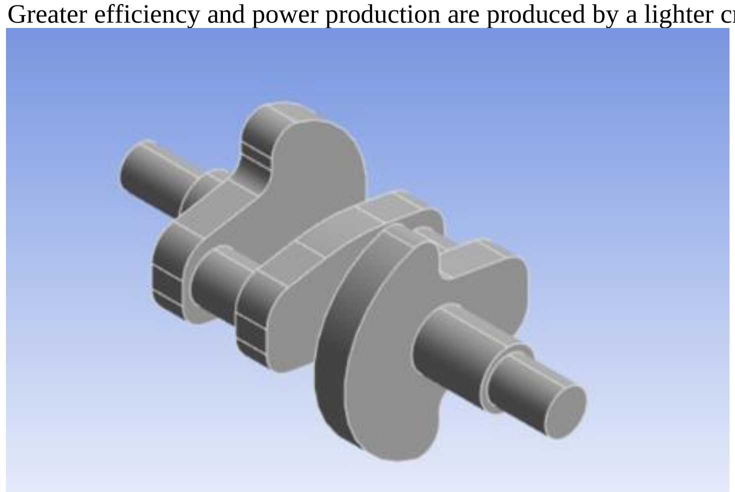

Figure 1.6: Crankshaft 3D

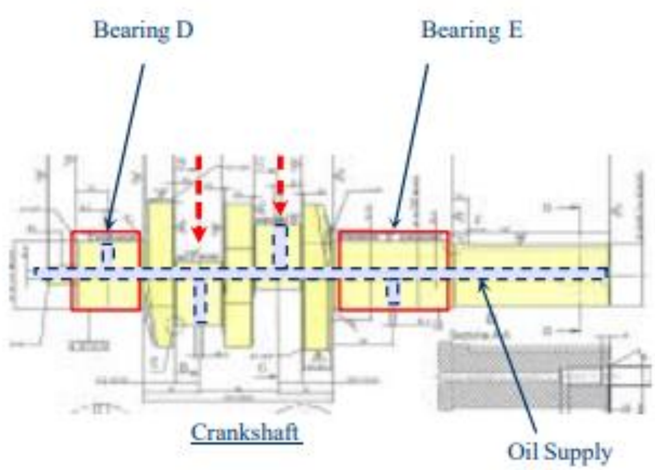

Figure 1.7: crankshaft 2D

PROBLEM DEFINATION

One of the most frequent issues with crankshaft cyclic loads is fatigue failure. Crankshaft filler sections experience stress concentration, which may result in the beginning of a fracture and ultimately leads to Crankshaft failure. It is a problem for all engineers to create a crankshaft of acceptable material that can have adequate fatigue strength, service life, and durability. Reduced weight in the crankshaft boosts performance and power output. Material changes also allow for cost savings.

METHODOLOGY

CATIA Software

Applications for CATIA are many and include consumer items, electronics, shipbuilding plant design, automobile, aircraft, and industrial machinery. CATIA is now used for designing everything from clothes and jewels to an aircraft. Possessing the capability and operational range to handle the entire process of developing a product: CATIA provides completely integrated assistance for product engineering, from the first specification to the finished product. It reduces development processes and makes it easier to reuse product

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design expertise, enabling businesses to react more quickly to market demands.
Due to its applicational advantage of Commands in using the CATIA, the design of the Crankshaft is done in this Software.

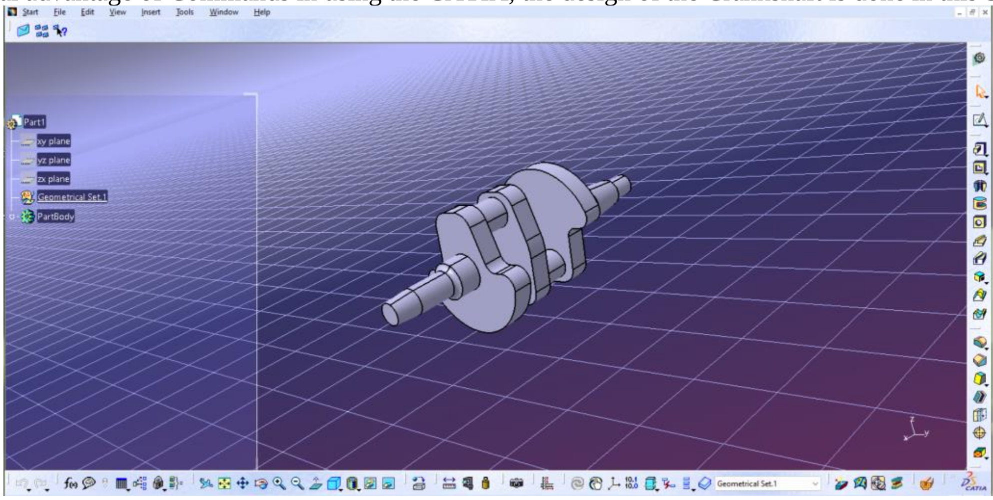

Figure 3.1: Design of Crankshaft in CATIA V5

ANSYS Software

A finite element analysis's goal is to simulate a structure's behaviour under a system of loads. To achieve this, every influencing aspect needs to be taken into account in order to establish whether or not they have a significant impact on the ultimate outcome. Numerous programs are employed for this objective. Pro-E, NISA, MSC, NASTRAN, ANSYS, Unigraphics, etc.

Swanson Analysis Systems Inc. is the developer and maintainer of the self-contained general purpose finite element program known as ANSYS. The program consists of numerous interconnected routines whose primary goal is to solve an engineering problem using the Finite Element Method. A comprehensive answer to design issues is offered by ANSYS. It includes of powerful design features such complete parametric solid modelling, design optimization and auto meshing.

- The Analysis is that is chosen is Static structural analysis

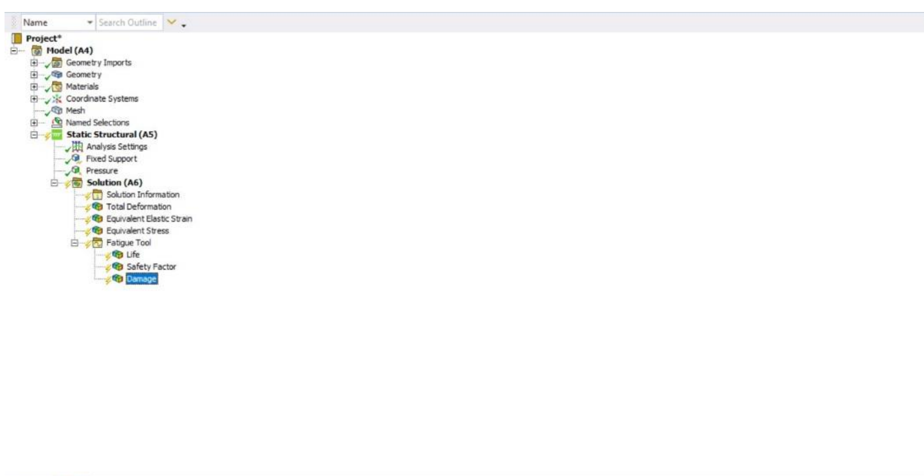

Figure 3.2: Static Structural analysis

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- The Materials are selected by entering the mechanical and thermal properties of the material.

I. Silica Carbide based Aluminium Alloy Properties

Youngs modulus	430 GPa
Tensile strength	207 Mpa
Poisson's ratio	0.25-0.30
Density	2540 Kg/m3
Thermal conductivity coefficient	175 W/m-k

Table 3.1: Silica Carbide based Aluminium Alloy Properties

I. AISI 1118 Material Properties

Youngs modulus	140 GPa
Tensile strength	525 MPa
Poisson's ratio	0.27-0.30
Density	7850 Kg/m3
Thermal conductivity coefficient	49.8 W/m-k
Yield strength	315MPa

Table 3.2: AISI 1118 Material Properties

- The Designed crankshaft file that is to be analysed is imported.
- Meshing

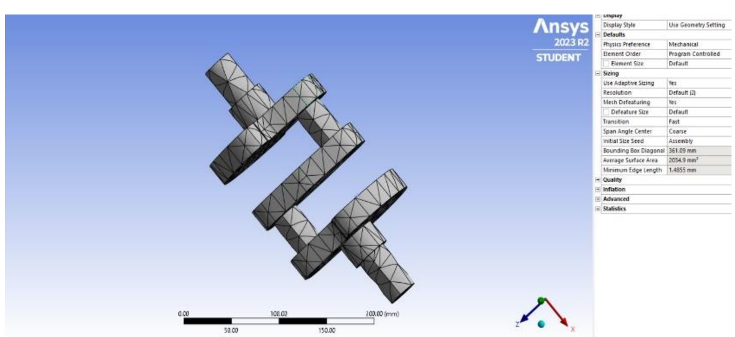

Figure 3.3: Meshing

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- Applying Fixed supports and pressure areas to the crankshaft.

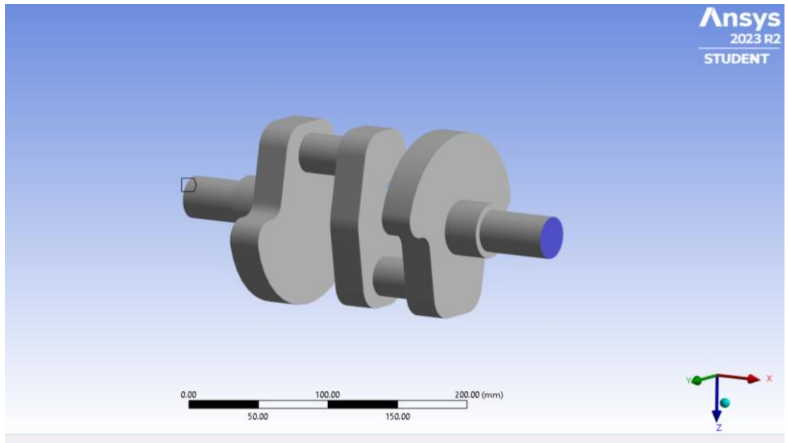

Figure 3.4: Fixed Supports.

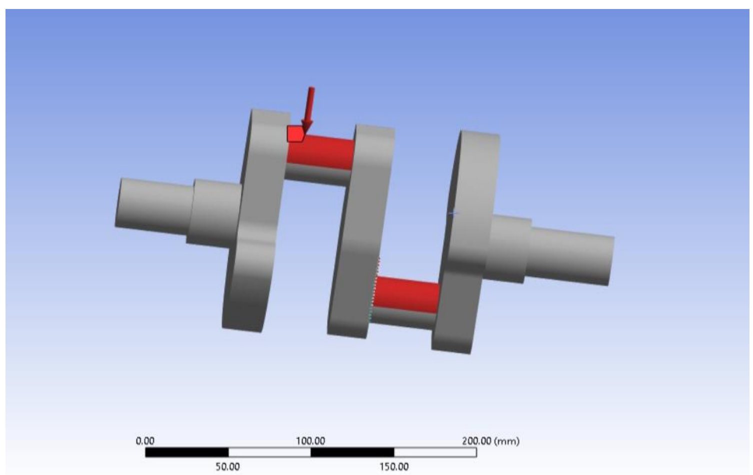

Figure 3.5: **Pressure applied area and direction.**

- By clicking on solve button after selecting the required tools the following solution will be presented.

a) Total deformation

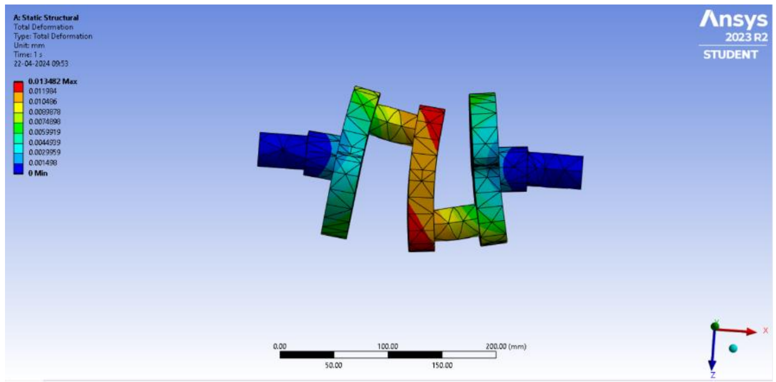

Figure 3.6: **Total deformation of AISI 1118 Material**

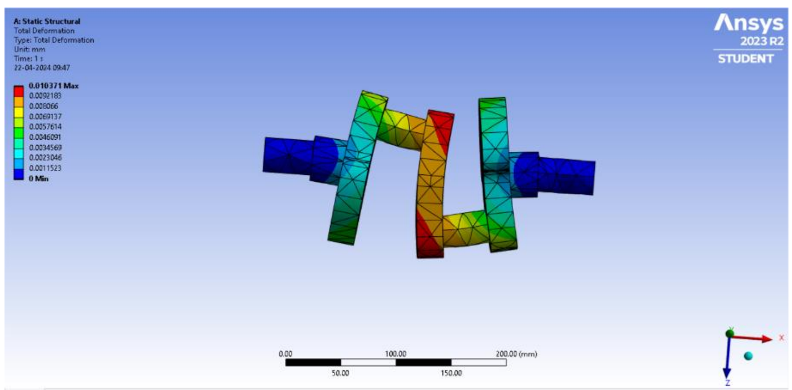

Figure 3.7: **Total Deformation of AlSiC Alloy**

b) Equivalent stress

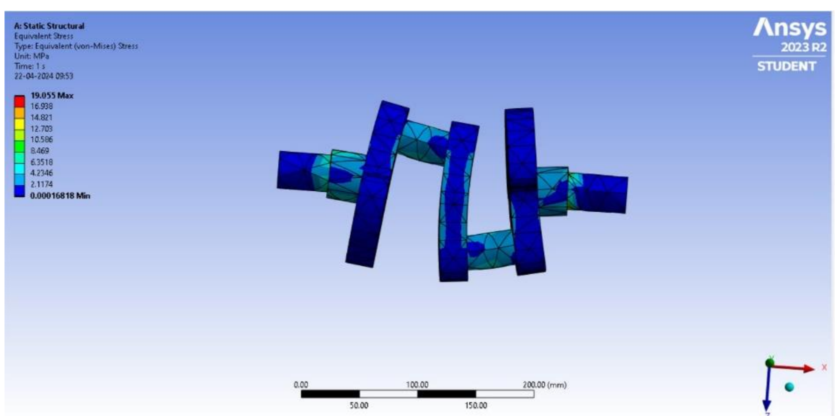

Figure 3.8: **Equivalent stress of AISI 1118 Material**

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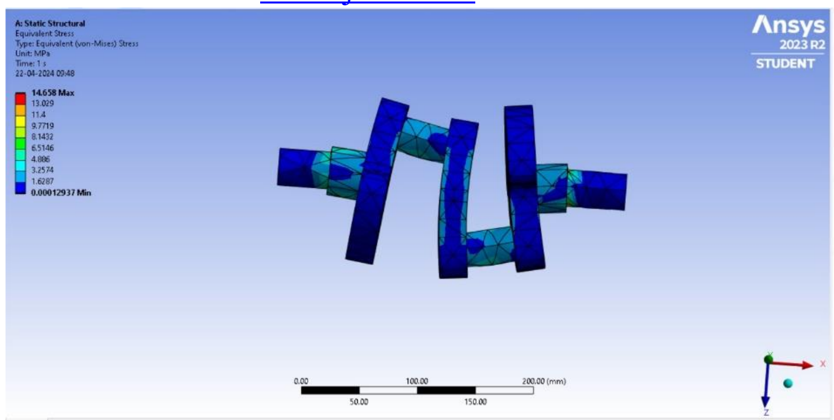

Figure 3.9: **Equivalent stress of AlSiC Alloy**

c) Equivalent Elastic Strain

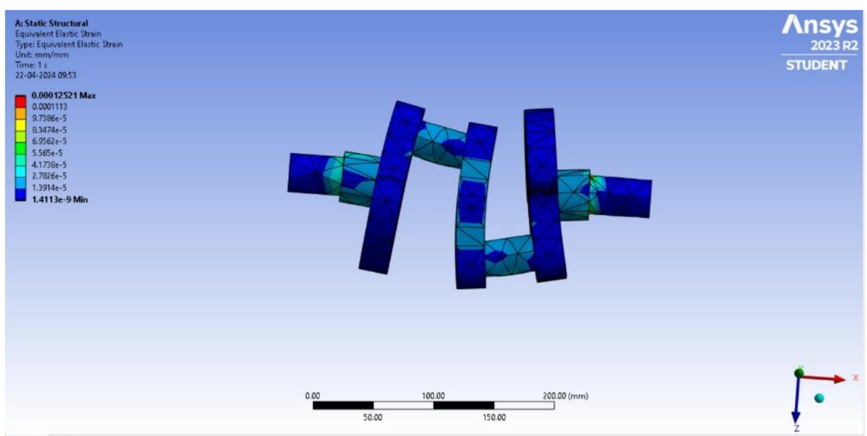

Figure 3.10: **Equivalent Elastic Strain of AISI 1118 Material**

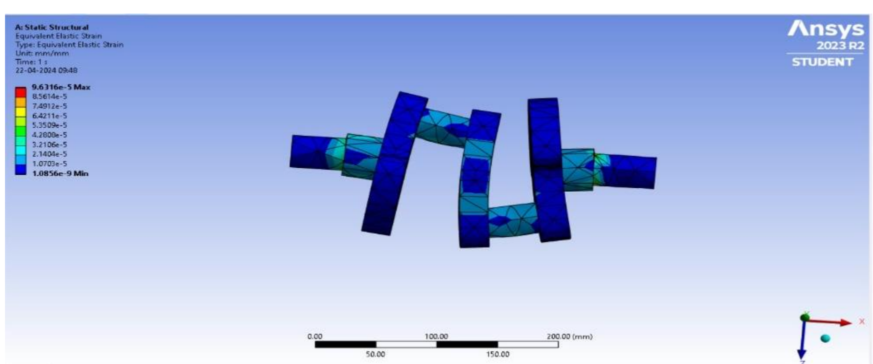

Figure 3.11: **Equivalent Elastic Strain of AlSiC Alloy**

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d) Factor of Safety

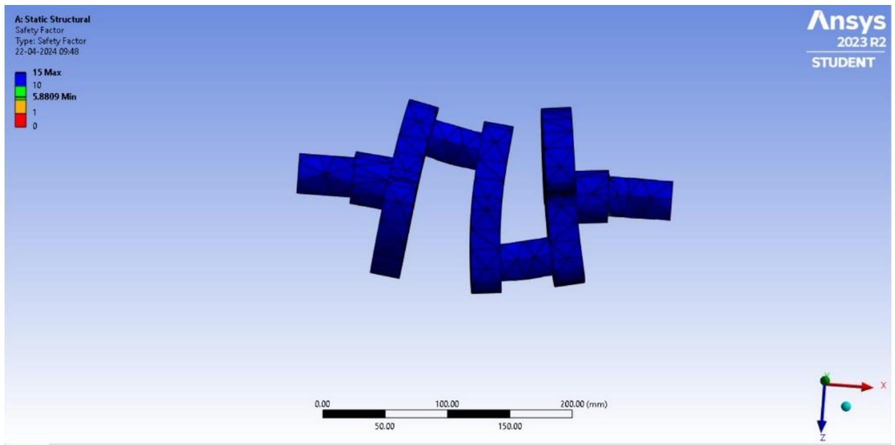

Figure 3.12: **Factor of Safety of AISI 1118 Material**

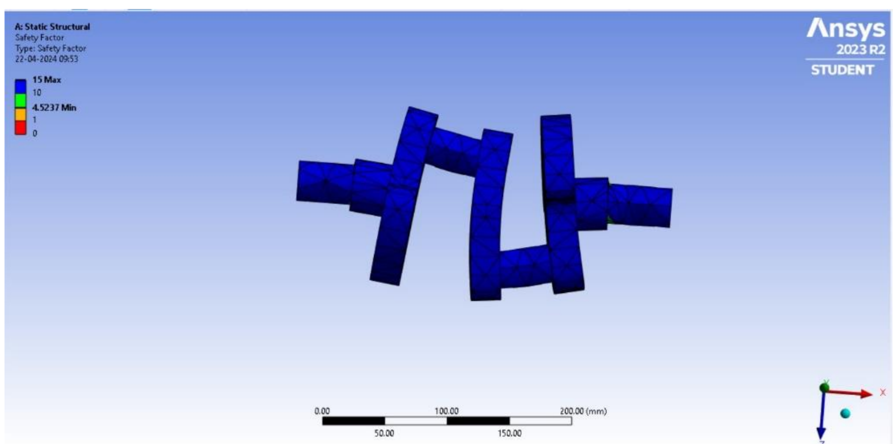

Figure 3.13: **Factor of Safety of AlSiC Alloy**

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RESULTS

The Stress, Strain, Deformation and Factor of safety of both materials are compared to identify the optimal material that can be used as a crankshaft of a compressor.

	AISI 1118	AlSiC Alloy
Total Deformation (mm)	0.013482	0.010371
Equivalent Stress (MPa)	19.055	14.658
Equivalent Strain (mm)	1.25e-4	9.6316e-5
Factor of Safety	5.889 - 15	4.5237 - 15
LIfe	1e+6	1e+7

CONCLUSION

The crankshaft made of aluminum alloy weighs around one-third less than steel. When compared to the aluminum alloy,the total deformation of the AISI 1118 material is somewhat higher. However, the AISI 1118 material has a higher equivalent stress, strain, and lesser safety factor than the aluminum alloy, and Alluminium alloy crankshaft life is longer than that of steel. Therefore, AlSiC alloy is the best material to employ in place of AISI 1118 material for the crankshaft.

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