

Finite Element Analysis of Spur Gear Manufactured of Al7475-Sic Composites

Er. Farman^{1,*}, Manoj Kumar Gupta²

Abstract

The spur gear is used in power transmission systems in industrial and automotive sectors. But sometimes, these gears have problems with their teeth due to excessive stress and wear. Some gears don't work as well, so in the present work better material is used to make them work well. Composite materials, which is known for their optimal strength-to-weight ratio and weight reduction benefits. So, these materials are considered substitutes for metallic gears. In this study steel gears are replaced with composite gears composed of aluminum and silicon carbide. This composite material provides better mechanical properties, like improved strength-to-weight ratio, increased hardness, and reduced failure risk, through solid modeling using SolidWorks and structural analysis conducted through ANSYS software. The spur gear performance is evaluated with different material compositions. This analysis aims to identify the most suitable material composition for gear so that the induced elastic strain and deformation is within limits. The optimized materials are selected for the casting of prototype spur gears.

Keywords: Aluminum, silicon carbide, fea analysis, elastic strain, total deformation

INTRODUCTION

Gear is one of the most important part in a mechanical power transmission structure, and in industrial rotating machinery. Gear is a fundamental component in machinery, and play important role in transmitting torque, altering power characteristics, and enabling the functioning of various mechanical systems. The evolution of gear technology has seen a shift towards advanced materials, and in this context, ceramic materials are good substitute. Among these, composite of Aluminum and Silicon Carbide stand out for their exceptional hardness, resistance to wear, and low friction characteristics.

The combination of Aluminum (Al) and Silicon Carbide (Sic) in a composite material has become a focal point in materials science and engineering. This composite, called as Al-Sic, Combine together the lightweight properties of aluminum with the strength and hardness of silicon carbide. In this research, we will use Al-Sic composite, to understand its deformation and strain behavior for gear. On combining these two materials, there is balance of strength and weight. The stress value increases with

increasing the reinforcement [1]. If the gear operate within their yield strength limits, non-metallic gear offers several benefits over traditional materials [2]. The impact of vibration is mitigated through the use of damping [3].

LITERATURE REVIEW

- Yichang Liu, Chunlin Tian et al. [4] Conducted modal analysis through ANSYS Workbench to figure out how a worm and worm gear vibrate and move naturally. By applying different boundary conditions and settings, they identified different ways they can move. The

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highest vibration was seen in the sixth way they can move, and the lowest was in the first way, both for the worm and the worm gear.

- Omesh Goyal et al. [5] They studied a gear by looking at how it vibrates naturally. This gear was made of a material called EN353, and they used properties like Young's Modulus 221 GPa and Poisson's ratio 0.26. They applied certain conditions to the gear to see how it moves and used a computer program called ANSYS Workbench for the study. They found that the gear shakes the most at its sixth mode and shakes the least at its first mode.
- Pawar P. B et al. [6]. They have studied on the development of a composite material through the addition of Silicon Carbide in Aluminum metal by different mass ratios. They used a technique called stir casting to create this composite. To figure out how strong and tough it was, they did tests like hardness and microstructure tests. They discovered that this new composite, called Al-Sic, is tougher and harder than regular aluminum. When they added more Silicon Carbide, the material became even harder and tougher.
- Md Yahiya et al. [7]. FEA analysis is done for helical gear. The comparison of bending and compressive stresses was done theoretically & by using Ansys software for both ceramic & steel.
- A.Y Gidado et al. [8]. The face width of gear and helix angle are important geometrical parameters, which affect the stress distribution in gear design. So, the aim of this study was to conduct a parametric investigation by changing the face width, to find its impact on the bending stress of helical gears. To analyze stress variations related to face width, five different models of helical gears were generated while maintaining other parameters constant.
- SEKAR et al. [9]. They have studied on the composite of Al7475 and Sic. This composite was prepared by stir casting techniques and find out the different mechanical properties.
- Rathore and Tiwari's [10]. study introduces novel stress relief features like circular and elliptical holes to reduce root bending stress in spur gears, enhancing their fatigue life significantly. By employing finite element analysis and optimization techniques, they propose optimal sizes and locations for these features, offering a practical approach to improve gear reliability and performance.
- Ram Kirshna Reddy [11]. The automotive and aerospace sectors are witnessing a surge in demand for lightweight, high-strength materials, leading to the exploration of composites. Aluminum metal matrix composites (AMMCs) are reinforced with various materials like Sic, fly ash, Aloe Vera, and rice husk to enhance properties such as strength and thermal performance. This study explores the effects of these reinforcements on AMMC characteristics, highlighting their cost-effectiveness and ease of manufacturing.
- Subhash Chavadaki et. al. [12]. This study examines the deformation and bending stress at various root radii of gear, with two functionally graded materials (FGM): AISI 4140 alloy and Ti6242-S alloy. The findings indicate that for both materials, the stress diminishes as the root radius increases.

The objective of this study is to use the composite (9) for gear and perform static structural analysis to determine the Equivalent Stress and Strain values for different compositions of Al7475 and Sic. This analysis aims to identify the best composition of Al7475 and Sic for the gear.

METHODOLOGY

Assumptions

- In static conditions, the complete load is exerted onto the apex of an individual tooth.
- The gears are completely aligned, ensuring the correct transmission of torque between them.
- In the static analysis, the driver gear remains stationary to find the strength of the gear system.
- There is frictionless contact between the gears.
- The applied load is uniformly distributed on the entire face width of gear.
- There is no interference between the tip of the tooth and root fillets of the paired teeth.

CAD Modeling

- The spur gear was designed in the SOLIDWORKS 2022 software.
- Specifications of gears (13) (14) (15) (16),

For pinion

- Module = 4mm
- Pitch circle diameter =120mm
- No of teeth = 30
- Pressure angle = 20 degree

For Gear

- Module = 4mm
- Pitch circle diameter =180mm
- No of teeth = 45
- Pressure angle = 20 degree

FEA (Finite Element Analysis)

Finite Element Analysis (FEA) is a numerical method employed in engineering to simulate and analyze the behavior of structures and components under different condition. FEA breaks down complex structures into smaller, simpler elements, which allow engineers to study their component behavior under different loads, forces, temperatures, and other environmental conditions.

Flow chart of FEA

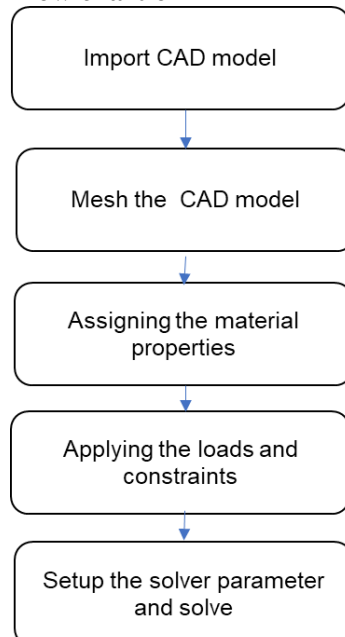


Figure 1. Flow chart of FEA

Meshing

Meshing is like breaking down a complicated shape into tiny, simple pieces. This is done in engineering to analyze and simulate how things behave under different conditions. It helps to understand the structure's or fluid's performance. The quality of the mesh is important for accurate results.

Element-Tetrahedral(quadratic)

- Element size - 3.00mm, No of Nodes-174603, No of Elements-37079.
- Mesh Quality

- Aspect Ratio – 1.4617.
- Jacobian- 1.4505.
- Skewness- 0.19572.
- Orthogonal Quality-0.9622.

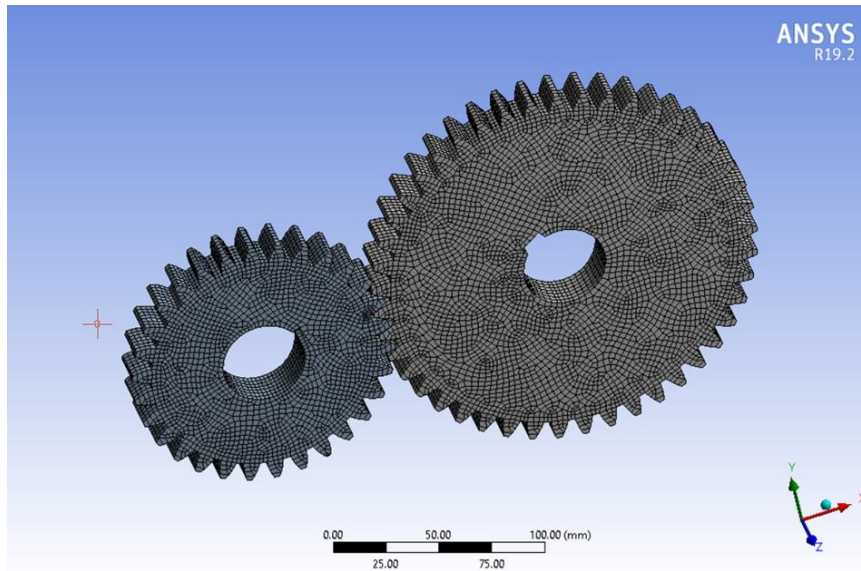


Figure 2. Meshing.

Material properties

- Material properties are taken from (9) (16).

Load And Boundary Condition

- After meshing, pinion is subjected to load of 1000N.
- Fixed support is provided to gear.
- Frictionless support is provided to pinion.

RESULTS OF STATIC ANALYSIS

The values of Equivalent Elastic strain, Equivalent Stress, and Total Deformation is shown in Figure 3, Figure 4, Figure 5 for Al7475+0%SiC.

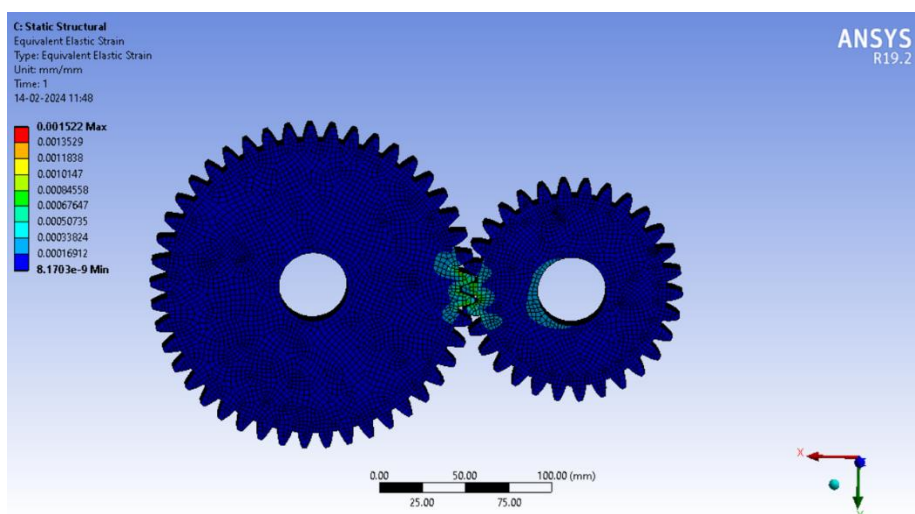


Figure 3. Equivalent elastic strain

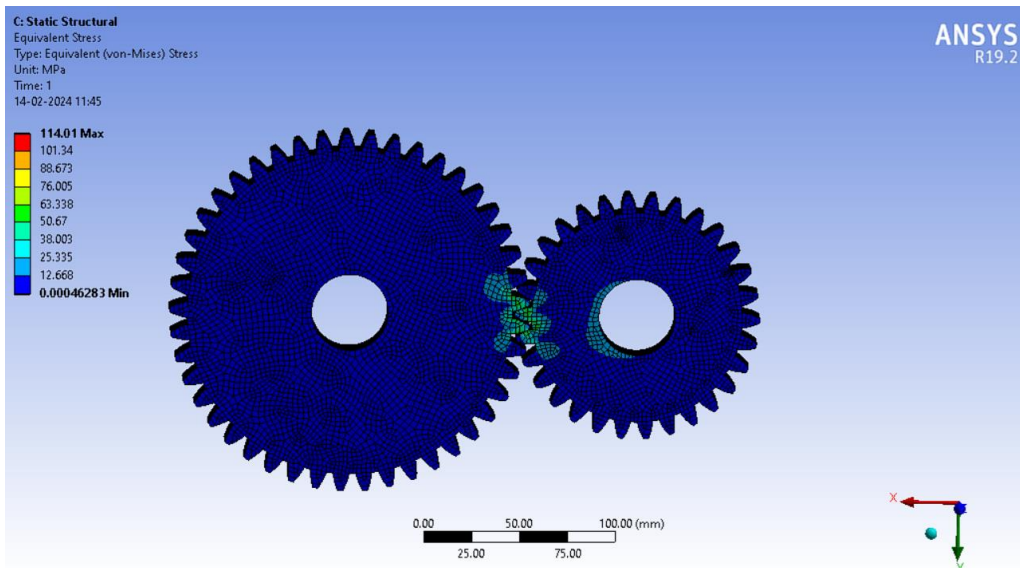


Figure 4. Equivalent stress.

The maximum value of Equivalent Stress and Strain is obtained at the teeth of gear.

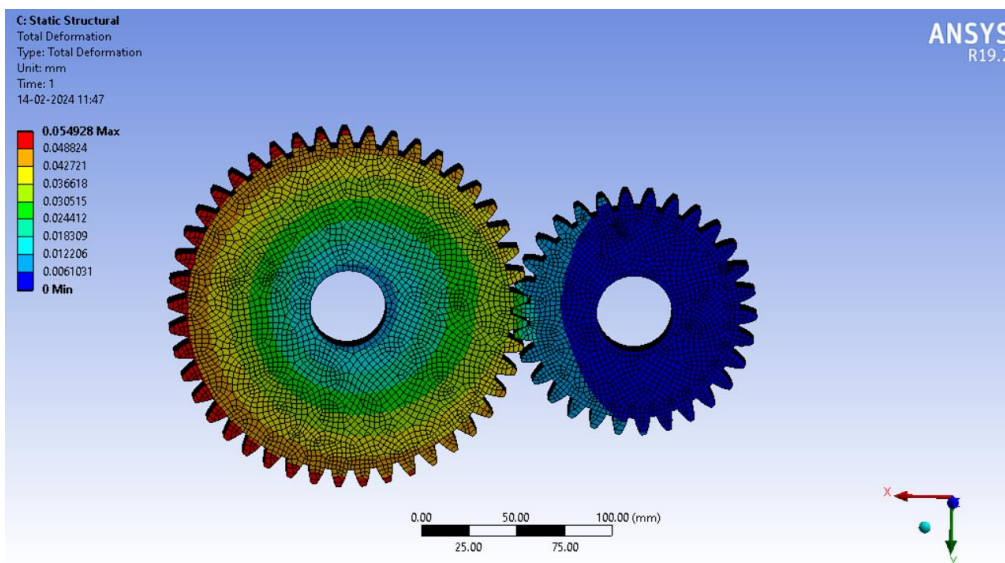


Figure 5. Total deformation

The values of Total Deformation and Equivalent Elastic Strain for different composition of SiC with Al7475 is shown in Table 1

Table 1. Comparison of results

S. No.	Description	Total deformation(mm)	Equivalent elastic strain
1	Al7475+0%SiC	0.05492	0.001522
2	Al7475+5%SiC	0.04394	0.001217
3	Al7475+10%SiC	0.03661	0.001014
4	Al7475+15%SiC	0.03138	0.000869
5	Structural Steel	0.02019	0.000570

CONCLUSION

- Comparison of results of different composition of Silicon Carbide with Al7475 is shown in Table 1
- Weight of the gear is decreased around 60% with present composite material in comparison of steel.
- The stress generated in the gear is within limits, so it is safe against failure.
- It is seen that at Al7475+15%SiC, the value for total deformation and elastic strain is similar to steel.

FUTURE SCOPE

- Dynamic analysis of gear for these materials.
- Modal analysis to find the critical frequency.

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