

MODELLING AND SIMULATION OF METAL MATRIX COMPOSITE

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Abstract-This study aims to model the metal matrix composite- Aluminium SiC reinforced composite in FEA. It was decided to use aluminium alloy as the matrix material due to its low density and high strength-to-weight ratio, which is popular in the automotive industries. SiC was used as a reinforcement as it has been found to enhance the mechanical properties of the composite material. Ansys simulation and analysis of metal matrix composite's mechanical properties were like Deformation, Von Mises stress and weight of the material are carried out. In this project it was proposed to find out the ideal percentage of SiC with Aluminium to check for the least deformation, maximum stress withstanding capability and various mechanical properties associated with the composite material. Solid works was used for modelling and Ansys Workbench was used for analysing the properties of the Al-SiC rectangular plate first. After Obtaining the mechanical properties, a real time practical example by application of Gear's composite design and analysis in this project was carried out and simulated. Stress, strain, and deformation were calculated in Ansys by changing the percentage of SiC embedded in an Aluminium metal matrix from 10 to 15 percent, with an increment of 1% each time. Al-SiC composite with Aluminium matrix and Silicon carbide reinforcement has good mechanical qualities and reduces gear weight.

Keywords: Composite, Deformation, Stiffness, Weight, Stress, Gear, Rectangular bar

1. INTRODUCTION

A metal-ceramic composite material, aluminium-(silicon carbide) possesses silicon carbide particles scattered in an aluminium alloy matrix. Aluminium has a low density, is non-toxic, has a good thermal conductivity, has a remarkable resistance to corrosion, and is simple to cast, machine, and shape. When Aluminium and Silicon Carbide are combined together, the composite material's mechanical and thermal properties are significantly improved. These composites have a lower cost than pure aluminium. Composite materials have emerged as a superior solution for the replacement of metallic gears as a result of their ability to provide acceptable strength while simultaneously reducing weight. The mechanical properties of composites, such as their higher strength-to-weight ratio and increased hardness, reduce the likelihood of failure significantly. The goal of this study is to make the gear lighter while also enhancing the efficiency of the machine.

The deformation of gear constructed from composite materials with an aluminium matrix is comparable to that of gear made from steel. [1] Composite aluminium silicon carbide alloy materials are useful in a variety of engineering applications, Aluminium silicon carbide has a weight-to-strength ratio roughly thrice that of mild steel during tensile tests. [2] Gears manufactured from composite materials with an aluminium matrix have similar deformation to steel gears, when compared to steel gear, composite gear has three to seven times less mass and a greater load bearing capacity.[3] Aluminium fly ash metal matrix composite, has a weight that is 26.11% lower than the Connecting Rod, increases the factor of safety by 7.21%, and can withstand a higher stress level.[4] Aluminium Metal Matrix Composites with Silicon Carbide Particle Reinforcements are proving to be of greater use because of the enhanced mechanical and tribological features, such as being strong and stiff, the ability to withstand wear and tear and hard impacts, and not very easily prone to corrosion.[5] Composite materials offer sufficient strength while simultaneously reducing weight, and they are quickly becoming recognised as a superior option to the use of metallic gears, the mechanical properties of composites, such as their higher strength-to-weight ratio and increased hardness, reduce the likelihood of failure significantly.[6] When the composite material Al-SiC 10-15% is compared with aluminium alloy, there is a significant increase in stiffness range from 12%-17%, and the weight is comparable to the aluminium alloy.[7]The gear made of aluminium silicon carbide composite has 3-3.5 times less mass than the gear made of steel.[8]Composite gears have a greater load bearing capacity than steel gears.[9]The optimal percentage of the reinforcement that is SiC with Aluminium Alloy, the stress analysis, deformation and stiffness measures. was not reported. These properties were extensively studied in this research.[10]

2. EXPERIMENTAL INVESTIGATION

2.1 MATERIAL SELECTION:

2.1.1 Aluminium and Silicon Carbide (Al-SiC):

This project has been carried with varying Aluminium and silicon carbide where silicon carbide has been used as reinforcement, with varying percentages from 10-15% by incrementing the percentage by 1.

The Al-SiC composite material properties with varying percentage 10-15% by incrementing the percentage by 1 is displayed in the below table 1.

Table 1: Composite material Properties

Material	Density (kg/cm ³)	Poisson Ratio	Young Modulus (Gpa)
Al 10SiC	2.725	0.3245	80.79
Al 11SiC	2.720	0.3239	81.76
Al 12SiC	2.716	0.3234	82.74
Al 13SiC	2.711	0.3228	83.72
Al 14SiC	2.707	0.3223	84.70
Al 15SiC	2.702	0.3217	85.68

2.2 FINITE ELEMENT ANALYSIS(FEM):

Before manufacturing any component, it has to be designed and tested. In the modern day world there are much technological advancement, which has given an upper hand for all types of industries. Automobile industry looks to reduce the cost of material in order to gain customers. Before a product comes out for a sale it has to be tested for its strength, weight and other properties, for this a prototype needs to be manufactured and to be tested which adds cost to the material. If we are able to cut this cost then we can able to manufacture the material at a lower cost. So, FEM plays an important role in testing. It uses mathematical approach simulation techniques to calculate the properties and strength of material so the product cost is lowered.

2.4 EXPERIMENTATION:

In this research work a rectangular plate and Gear train has been designed in Solid works with use of following dimensions and properties as displayed in table 2 and 3.

Table 2: Specifications of Rectangular Plate

Length (mm)	Breadth (mm)	Height (mm)
300	150	100

Table 3: Specification of Gear train

Module	6
Gear width	30
Gear ratio	2
No. of teeth in pinion gear	20
No. of teeth in driver gear	40

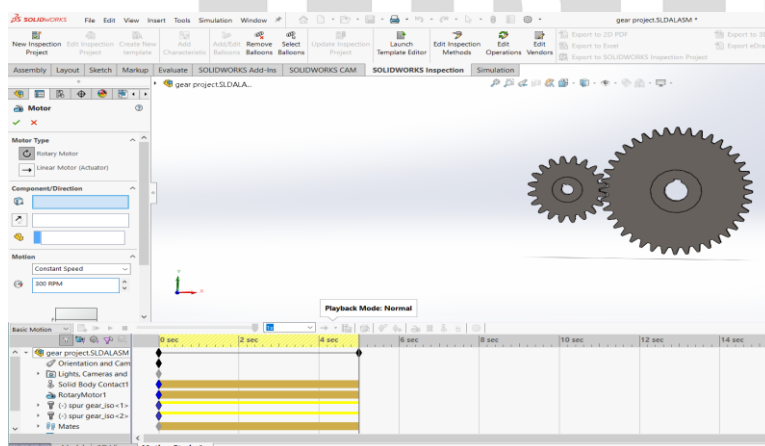


Figure 1: Assembly of Gear train

2.4.2 GEAR TRAIN:

After modelling the gear train it was imported to Ansys software and subsequent tests were conducted. Aluminium silicon carbide composite material was created by using a material combination module, silicon carbide percentage varying from 10-15% and corresponding material properties were noted for future reference. For the Gear train the Aluminium silicon carbide composite material was applied. To the driven gear's bore remote displacement was applied as displayed in figure 2 and the driver gear's bore frictionless support was given, further to that a moment of 1000N-m was applied in order to facilitate the motion of the gear train. For the above constraints the deformation and von-mises stress was noted.

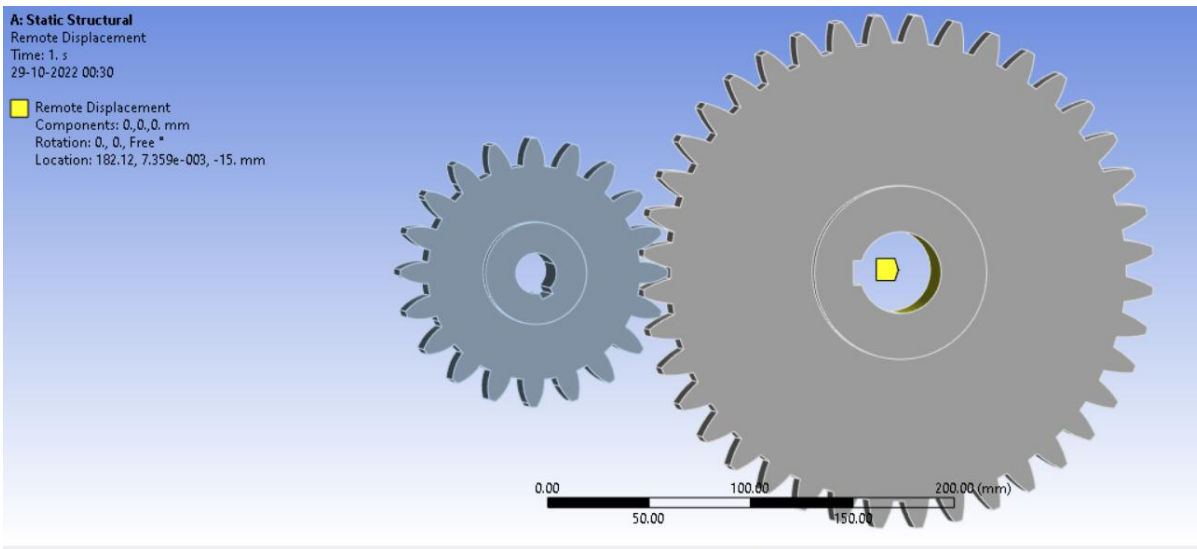


Figure 2: Remote displacement applied to driven gear

3.RESULTS AND DISCUSSION

3.1 PARAMETERS OBTAINED:

By testing the rectangular plate and Gear train by above mentioned constraints the value of deformation, von-mises stress, stiffness, weight of the component were analysed in order to obtain a better result for Aluminium silicon carbide composite material.

1. Deformation and Von-mises stress of the material
2. Weight of the Gear train
3. Stiffness of the material

3.1.1 DEFORMATION AND VON-MISES STRESS OF THE MATERIAL:

1)FOR RECTANGULAR PLATE:

When a material is subjected to a load it undergoes a distortion, it may bend or even break. In this research project load varying from 150 N to 200 N applied on the surface and both ends of the rectangular plate were fixed. The deformation and stress of the rectangular plate with varying percentage of Silicon carbide percentage from 10-15% by incrementing the percentage by 1 as displayed in the below figures 3.

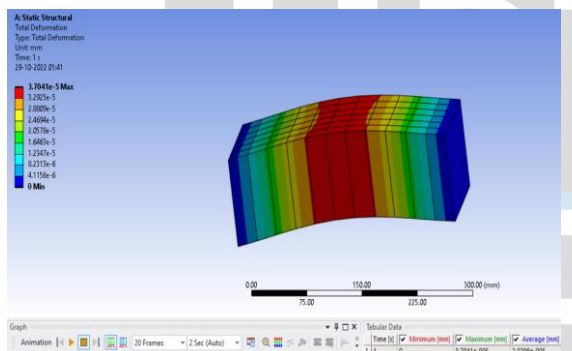


Figure 3: Deformation of rectangular plate (Al- SiC 10%)

Table 4: Deformation and Von-mises stress for varying load from 150 N to 200 N

Material		Load (N)					
		150N	160N	170N	180N	190N	200N
Al 10 SiC	Stress (Mpa)	1.502	1.1202	1.1903	1.2603	1.3303	1.4003
	Deformation (10 ⁻⁴ mm)	2.778	2.9633	3.1485	3.3337	3.5189	3.7041

Al 11 SiC	Stress (Mpa)	1.0502	1.1202	1.1902	1.260 2	1.3302	1.4002
	Deformation (10 ⁻⁴ mm)	2.7738	2.9587	3.1436	3.328 5	3.5135	3.6984
Al 12 SiC	Stress (Mpa)	1.0501	1.1201	1.1902	1.260 2	1.3302	1.4002
	Deformation (10 ⁻⁴ mm)	2.7695	2.9542	3.1388	3.323 4	3.5081	3.6927
Al 13 SiC	Stress (Mpa)	1.0501	1.1201	1.1901	1.260 1	1.3301	1.4001
	Deformation (10 ⁻⁴ mm)	2.7653	2.9497	3.1340	3.318 4	3.5027	3.6871
Al 14 SiC	Stress (Mpa)	1.050	1.120	1.190	1.260	1.3301	1.4001
	Deformation (10 ⁻⁴ mm)	2.7611	2.9451	3.1292	3.313 3	3.4974	3.6814
Al 15 SiC	Stress (Mpa)	1.050	1.120	1.190	1.260	1.330	1.400
	Deformation (10 ⁻⁴ mm)	2.7569	2.9407	3.1294	3.308 2	3.4920	3.6758

It has been observed from table 4 that by increasing the percentage of silicon carbide in Aluminium silicon carbide composite material the deformation and Von-mises stress of the rectangular plate is decreasing for varying load.

2) FOR GEARS:

As mentioned in figure 2 the constraints were given and a moment of 1000 N-m was applied and Aluminium silicon carbide composite material was selected to the component and deformation and stress were obtained.

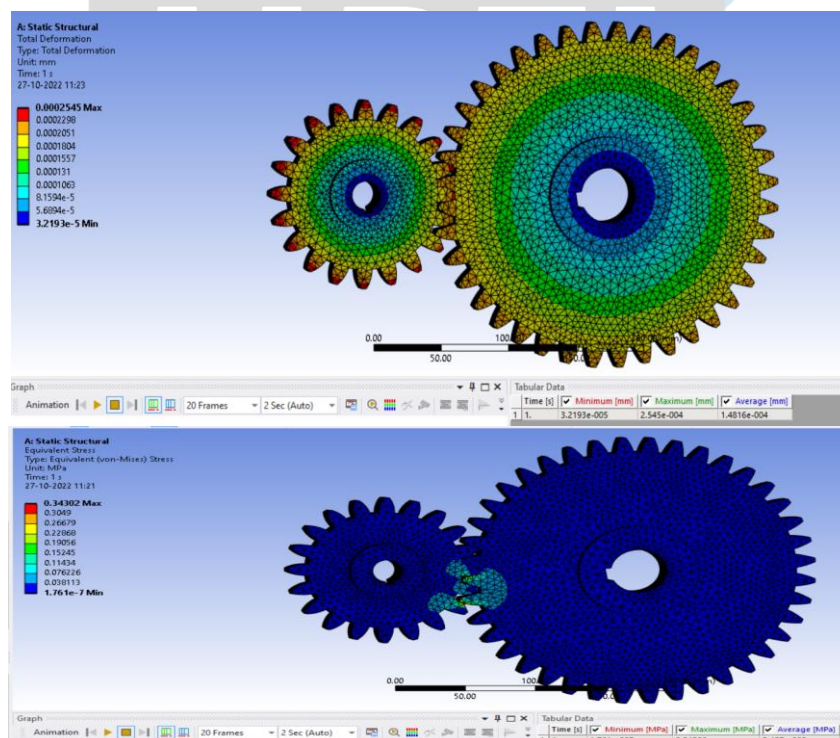


Figure 4: Total Deformation and V.M Stress of Gear train (Al 10 SiC)

Table 5: Total Deformation and V.M Stress of Gear train for composite materials

Material	Total Deformation (10 ⁻⁴ mm)	Stress (Mpa)
Al 10 SiC	2.545	0.34302
Al 11 SiC	2.5148	0.34298
Al 12 SiC	2.4853	0.34295
Al 13 SiC	2.4565	0.34291
Al 14 SiC	2.4284	0.34288
Al 15 SiC	2.4009	0.34284
Aluminium Alloy	2.8926	0.34334
Steel	1.0328	0.34166

It has been observed from table 5 that by increasing the percentage of silicon carbide in Aluminium silicon carbide composite material the deformation and V.M Stress of the Gear train is decreasing for applied moment.

3.1.2 WEIGHT OF THE GEAR TRAIN:

In this research project the gear train weight has been calculated to obtain desired result

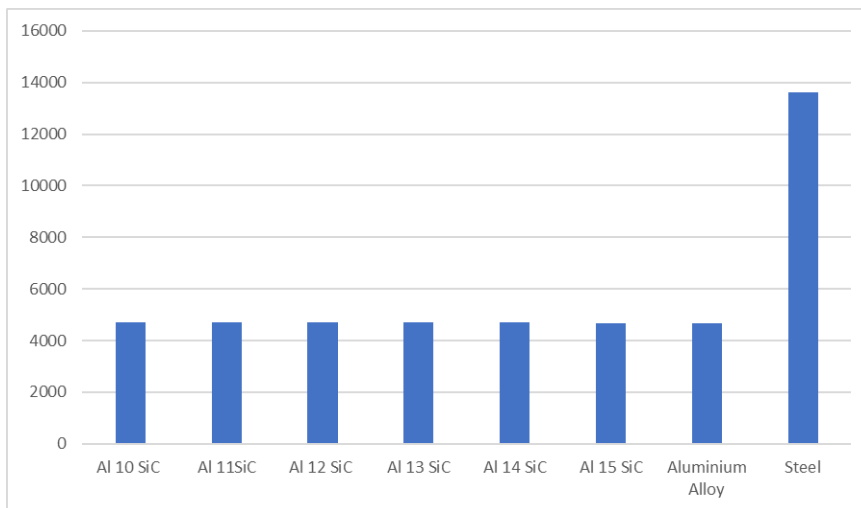


Figure 5: Weight of gear train for composite material

It has been observed from Figure 5 that by increasing the amount of percentage of silicon carbide in Aluminium silicon carbide composite material the weight of the Gear train is gradually decreasing. When it is compared to case hardened steel, the weight of a gear train with Al-SiC composite material is 3-3.5 times lesser.

3.2 STIFFNESS OF THE MATERIAL:

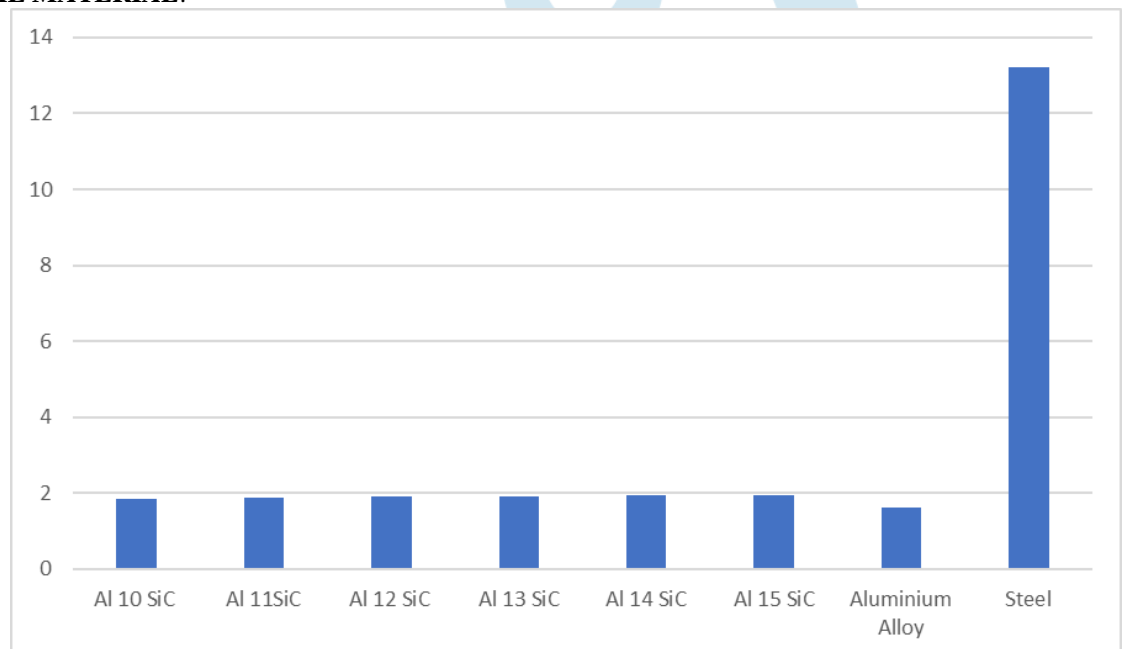


Figure 6: Stiffness of the materials

From Figure 6 it has been observed that by increasing the percentage of silicon carbide in Al-SiC composite material stiffness of the material is increasing. When the composite material Al-SiC 10-15% is compared with Aluminium alloy there is a huge increase in stiffness ranging from 12%-17%, also it weighs similar.

4.CONCLUSION

The primary purpose of the research was to produce a new composite gear that is less in weight, possesses superior mechanical qualities, and maintains appropriate levels of stress and deformation regardless of how much it is stretched or compressed. In this study, the various possible composite material compositions in order to identify the one that would function as a material for gears in the most efficient manner was analysed. After the FEA analysis of the rectangular plate, the same was carried out for the gear model. Analysis was conducted by comparing the gear's Von Mises stresses and deformations made by the various compositions of composite material. The following gear materials were utilised for comparison: aluminium alloy, steel, aluminium alloy, aluminium 90% SiC 10%, aluminium 89% SiC 11%, aluminium 88% SiC 12%, aluminium 87% SiC 13%, aluminium 86% SiC 14%, aluminium 85% SiC 15%. On the model of the gear, static load tests were carried out while subjected to a variety of influences of forces in the range of 150 to 200 N. The investigation's findings led to the following deductions and findings:

- The deformation of gear constructed from composite materials with an aluminium matrix is comparable to that of gear made from steel.
- When the composite material Al-SiC 10-15% is compared with aluminium alloy, there is a significant increase in stiffness range from 12%-17%, and the weight is comparable to the aluminium alloy.

- The gear made of aluminium silicon carbide composite has 3-3.5 times less mass than the gear made of steel.
 - Composite gears have a greater load bearing capacity than steel gears.
 - It has been noticed that the deformation and Von Misses Stress of the Gear train are reduced when the fraction of silicon carbide in an aluminium silicon carbide composite material is increased. This is the case when the applied moment is increased.
- On the basis of these results, one can reach the conclusion that composite materials outperform steel in a significant number of characteristics, and one can anticipate that in the near future, composite materials will see a great deal more application not only in gears, but also in other components of mechanical structures.

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