Journal of
Experimental & Applied Mechanics
https://journals.stmjournals.com/joeam

ISSN: 2230-9845 (Online)
ISSN: 2321-516X (Print)
Volume 16, Issue 2, 2025
May–August
DOI (Journal): 10.37591/JoEAM

Research JoEAM

Investigation, Fabrication and Testing of Spur Gear Using Composite Material

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Abstract

Composite materials constitute one of the favorable, efficacious material zones for tomorrow's sustainable future through identification of materials with higher strength to weight ratio. A composite material is combination of two or more different materials with varied qualities that work together to create a material that is better than the sum of its parts. Therefore, finding some alternative material for various mechanical applications to accelerate the Indian composite industry is imperative. An attempt has been made to develop light-weight, more pressure sustainable and friction reducing industrial components with required properties using composite materials. Research work is related to spur gear to explain properties of composite material i.e. (50% Epoxy resin and 50% Silicon Carbide; 60% Epoxy resin and 40% Silicon Carbide; 70% Epoxy resin and 30% Silicon Carbide; 40% Epoxy resin and 60% Silicon Carbide; 30% Epoxy resin and 70% Silicon Carbide; and 1100 Aluminium. Also fabricate 1100 Aluminium alloy rods and composite material rods i.e. (50% Epoxy resin and 50% Silicon Carbide; 60% Epoxy resin and 40% Silicon Carbide; 70% Epoxy resin and 30% Silicon Carbide; 40% Epoxy resin and 60% Silicon Carbide; 30% Epoxy resin and 70% Silicon Carbide) tested at the Professor Ram Meghe Institute of Technology & Research, Badenra Lab, by various loading platforms and at various loading conditions i.e. Tensile test, Compressive test and Brinell hardness test. Finally. after analyzing the results of apple peeler machine, it was proved that composite spur gear performs better as compared to 1100 Aluminium spur gear.

Keywords: Spur gear, 1100 Aluminium alloys, epoxy resin and silicon carbide

INTRODUCTION

A composite material is made up of two or more different materials with varied qualities that work together to create a material that is better than the sum of its parts. Using clay, we created composite rods and blocks, which were then, evaluated using a Universal Testing Machine (UTM).

The tensile and compressive properties of materials are tested using a Universal Testing Machine (UTM), a very flexible mechanical testing apparatus. Determining the strength, durability, and elasticity of materials under varied load circumstances is a typical application in material science, engineering, and research.

One of the most basic and widely utilized gear types in mechanical systems is the spur gear. Its teeth, which are straight and parallel to the axis of rotation, are what define it. Usually, spur gears are used to transfer torque and motion between two parallel shafts. Thus, the Apple Peeler machine has a spur gear installed. Typically, structural steel and Aluminium alloy are utilized to make spur gears. However, the composite material used in this study to make spur gears minimizes weight, vibration, and

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Received Date: June 16, 2025
Accepted Date: July 01, 2025
Published Date: July 11, 2025

Citation: Prajwal V. Gedam, Nitin A. Wankhade. Investigation, Fabrication and Testing of Spur Gear Using Composite Material. Journal of Experimental & Applied Mechanics. 2025; 16(2): 1–8p.

increases pressure sustainability. Lastly, an analysis and comparison of the composite gear with the current 1100 Aluminium alloy (Al) gear is done [1].

METHODOLOGY

Flow of methodology:

- Study of the research material.
- Selection of materials.
- Fabrication of rods, spur gear, and testing.
- Development of the composite material spur gear.
- Fabrication of the pedal-operated apple peeler machine.

In this study, we began by reviewing 200 research papers to gain an understanding of the properties of composite materials (Table 1).

After reviewing the properties of 1100 Aluminium alloys, epoxy resin, and silicon carbide, including their density, Poisson's ratio, tensile and compressive strength, and modulus of elasticity, we began the manufacturing process of the 1100 Aluminium alloy spur gear and the composite material spur gear, which consists of epoxy resin and silicon carbide.

First, we gathered information on the procedure for making spur gears, understanding how they are manufactured. This included learning about gear machining, hobbing, hobbing speed, broaching, milling, shaving, and grinding. Once we had a clear understanding of these techniques, we proceeded with the spur gear manufacturing process.

Fabrication Process for manufacturing Epoxy Resin and Silicon Carbide Composite material Spur Gear

After making a mold from 1100 Aluminium alloy (Al), we used clay art instead of molding sand for molding purpose (Figure 1). Clay is mineral-rich, naturally occurring, and fine-grained dirt [2]. After that we built up a precise mold using 1100 Aluminium alloys (Al) spur gear.

Table 1. Mechanical properties of aluminium (Al) and composite material gear.

	Aluminium (Al)	**Epoxy resin/silicon carbide (SiC)**
Density	2700 kg/m^3	2150 kg/m^3
Young Modulus	150 GPA	226 GPA
Poisson’s Ratio	0.3	0.3
Tensile Strength	110 MPa	157 Mpa
Compressive strength	140 MPa	170 MPa
Modulus of Elasticity	70.3 GPA	193 GPA

Figure 1. Clay material.

ISSN: 2230-9845 (Online), ISSN: 2321-516X (Print)

The epoxy resin comes in two parts: a hardener and a resin. The hardener and resin are combined in a 2:1 ratio. Then Silicon carbide in a particle form is added and then poured in the mold cavity, and left to set for 70–72 h for getting perfect hardness (Figure 2). After 72 h, take the gear out of cavity and wash it gently with water. Now, composite (epoxy resin and silicon carbide) gear is ready to use in the assembly [3].

Next, it was returned to the workshop where five main methods of surface finishing commonly used in gear manufacturing were applied. These methods ensured the gear's surface was smooth and well-defined, contributing to its overall performance. Once the gear was completed, we visited the Prof. Ram Meghe Institute of Technology & Research, Badenra Lab, where we measured various critical dimensions of the gear using a tool maker microscope. These measurements included the pitch, addendum, dedendum, circular pitch, pitch outside diameter, teeth height, backlash, face width, total depth, pressure angle, and module of the gear [4]. These precise measurements ensured that the gear met all required specifications for functionality and quality (Figure 3).

TESTING PROCEDURE

Pitch, addendum, dedendum, circular pitch, pitch outside diameter, teeth height, backslash, face width, total depth, pressure angle and module of the gear are measured on the tool maker microscope; and with the help of clay manufacturing method process, three composite material rods and three composite materials blocks are prepared for tensile, compressive and Brinell hardness test [5].

Figure 2. Clay mold.

Figure 3. Composite gear.

Now after fabricating composite gear, five rods are prepared for tensile and compressive test (50% Epoxy Resin and 50% Silicon Carbide; 60% Epoxy Resin and 40% Silicon Carbide; 70% Epoxy Resin and 30% Silicon Carbide; 60% Silicon Carbide and 40% Epoxy Resin; and 70% Silicon Carbide and 30% Epoxy Resin); also 1 block is prepared for Brinell Hardness testing.

TENSILE TEST

At the Prof. Ram Meghe Institute of Technology & Research in Badenra, we conducted tensile testing. For a tensile test, components having a diameter of 18 mm and a gauge length of 168 mm were machined from the composites and tested for tension strength. The tests were run using a universal testing machine (UTM) which was connected to a computer for later software-assisted analysis [6]. All the tests were performed at ambient temperatures (Figure 4).

At a strain rate of 0.6 mm/min and in displacement control mode, a 19.6 kN universal testing machine was used to characterize the tensile properties of an epoxy resin and silicon carbide composite material. The tensile strength of the epoxy resin and silicon carbide composites increases at 20 wt% [7].

UTM Compressive Test

Universal Testing Machine (UTM) is used to conduct both tensile and compression tests. The compression (force-deformation) test is fundamental to and one of the most crucial analyses for determining the mechanical properties of fresh produce (Figure 5). The force deformation test demonstrates the product's response to varying degrees of compression. The specimen dimensions for the compression test are 12 mm in diameter and 20 mm in length (Figure 6).

Brinell Hardness Test

The Brinell Hardness Test is one of the oldest and most widely used methods for determining the hardness of metals and alloys. In this test, a hard steel or tungsten carbide ball, typically 10 mm in diameter, is pressed into the surface of the material under a specified load (commonly 500 to 3000 kgf) for a standard period, usually 10 to 15 seconds.

FABRICATION OF APPLE PEELER MACHINE

After fabricating the 1100 Aluminium alloys, epoxy resin and silicon carbide composite material spur gear, and testing its tensile, compressive and Brinell hardness test, the next step was to design apple peeler machine in CREO software. Then the shaft, apple peeler cutter, frame material, mug, and pedal were brought in for manufacturing apple peeler machine (Figure 7).

Figure 4. UTM (tensile test).

ISSN: 2230-9845 (Online), ISSN: 2321-516X (Print)

Figure 5. UTM (compression test).

Figure 6. Brinell hardness tester machine.

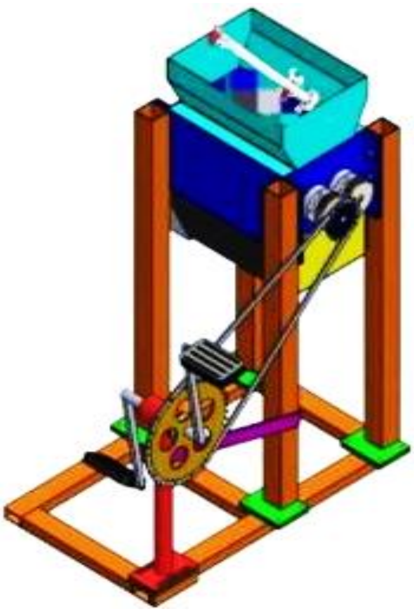

Figure 7. Pedal operated apple peeler machine using CREO software.

Material Requirement
- Frame,
- Apple peel Cutter,
- Shaft,
- Chain and Sprocket wheel mechanism, and
- Pedal (Figure 8).

RESULT AND DISCUSSION
Comparison of 1100 Aluminium alloys spur gear and composite material spur gear (Consisting of Epoxy resin and Silicon carbide) [8, 9]
The result of mechanical properties testing shows not much difference between them given different composition; and the strength decreases in proportion to an increase in the amount of filler material composition (Table 2).

The results are compared with the 1100 Aluminium alloys materials used for making gears; one metal and one polymer material used for gear making is taken and their strengths are compared. Tables 3–7 give the comparison between the materials.

Figure 8. Pedal operated apple peeler machine.

Table 2. Tensile test result of composite materials rod (Epoxy Resins and Silicon Carbide).

S. No.	% of Epoxy resin added	% of silicon carbide added	Applied force	Tensile strength
1	50%	50%	19.550 kN	116 MPa
2	60%	40%	19.35 kN	115 MPa
3	70%	30%	19.12 kN	113 MPa
4	40%	60%	16.2 kN	111 MPa
5	30%	70%	15.1 kN	109 MPa

Table 3. Tensile test result of 1100 Al rod (Epoxy Resins and Silicon Carbide).

S. No.	Applied force	Compressive strength
1	18.2 kN	98 MPa

Table 4. Compressive test result of composite materials spurs gear (Epoxy Resins and Silicon Carbide).

S. No.	% of Epoxy resin added	% of Silicon carbide added	Applied force	Compressive strength
1	50%	50%	30.350 kN	151 MPa
2	60%	40%	36.280 kN	180 MPa
3	70%	30%	39.452 kN	196 MPa
4	40%	60%	30.350 kN	151 MPa
5	30%	70%	29.292 kN	148 MPa

Table 5. Compressive test result of 1100 Aluminium alloy spurs gear.

S. No.	Applied force	Compressive strength
1	29.165 kN	145 MPa

Table 6. Composite materials (Epoxy Resin and Silicon Carbide) Brinell hardness test result.

Material	Ball dia. (mm)	Test load (kgf)	Dia. of indentation	Brinell hardness No.
50% Epoxy Resin and 50% Silicon Carbide	10 mm	1000	3.1 mm	130
		1500	3.7 mm	134
		2000	4.1 mm	145
		2500	4.3 mm	164
		3000	4.4 mm	188

Table 7. 1100 Aluminium alloy Brinell hardness test result.

Material	Ball dia. (mm)	Test load (kgf)	Dia. of indentation	Brinell hardness No.
1100 Aluminium alloy	10 mm	1000	2.4 mm	117
		1500	2.9 mm	133
		2000	3.2 mm	141
		2500	3.5 mm	142
		3000	4 mm	143

CONCLUSION

It was observed that from the tables that, density of the composite material made of epoxy resin and silicon carbide is significantly lower than the density of 1100 Aluminium alloy, which results in a significant decrease of weight in the case of the composite material that we have demonstrated to be effective in power transmission.

It was found that the compressive strength of composite material is higher than that of 1100 Aluminium Alloy by around 10–20%, which indicates that composite material can withstand more compressive stress. This was shown from the results.

It is also observed that composite materials exhibit greater pressure sustainability compared to 1100 Aluminium alloys. The maximum pressure sustained is recorded at 19.550 kN. In the composite, epoxy resins and silicon carbide are identified as the key constituents.

The stresses that are formed in composite material are also found to be higher. This means that composite material is more dependable for the higher stresses that are generated during the functioning of spur gear in comparison to 1100 Aluminium Alloy spur gear material. The frictional stress resulted in lower composite material stress than 1100 Aluminium alloys.

Epoxy resins and silicon carbide appear to be the better alternatives to the 1100 Aluminium Alloy when it comes to replacing the spur gear material. This is based on the result that was presented earlier.

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