

# Utilization of Aluminium Epoxy Composites Reinforcing with Pineapple Fibers and Sugarcane Bagasse for Disc Brake Application

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This study investigates the feasibility of utilizing Aluminium epoxy composites reinforced with hybrid natural fibers like Pineapple fibers and sugarcane bagasse as eco-friendly replacements for asbestos material in disc brakes applications. The static and dynamic analysis are performed on a disc brake model which is modelled in the solid works. Static analysis elucidates the material's stress, strain, deformation under fixed loading conditions, incorporating factor of safety to assess the material's margin of safety. Dynamic analysis focuses on the braking system's natural frequency characteristics during braking events. The findings from the computational simulations provide valuable insights to the composite's suitability for offering a pathway towards sustainable and high-performance disc brake solutions. The composites were fabricated using a combination of hand lay up process and compression moulding techniques. Various weight fractions of pineapple fibers and sugarcane bagasse were incorporated into aluminium epoxy matrix to optimize the mechanical properties of the composite material. The aluminium and epoxy matrix composition 10% & 40% kept constant and pineapple fibers & sugarcane bagasse changing composition by 20% & 30%, 30% & 20%, 40% & 10% respectively. Finally, the mechanical properties i.e. Tensile strength, Flexural strength, Impact strength of the three different compositions of sample specimens were concluded as per ASTM standards.

**Keywords:** Aluminium & epoxy, hybrid natural fibers, pineapple, sugarcane bagasse, hand lay-up process

1. Introduction

COMPOSITE MATERIAL

A composite material is a combination of two or more distinct materials with different physical or chemical properties. These materials are combined to create a new material with characteristics that are different from those of individual components. The goal is often to produce a material that exhibits the new desirable properties of each component while mitigating their individual limitations. They produce a material with characteristics different from their original properties. The two main components within a composite are the matrix and fibers.

NEED OF A COMPOSITE MATERIAL

Composite materials have become integral to modern engineering and manufacturing due to their exceptional properties and versatility. One of the primary reasons for their widespread use is their high strength to weight ratio. Durability and longevity are also key benefits of the composite materials. In addition to their light weight nature, composite materials are renowned for their corrosion resistance. This makes them ideal for applications in harsh environments where traditional materials would degrade quickly.

CLASSIFICATION OF NATURAL FIBERS

- 1. Plant fibers
- 2. Animal fibers
- 3. Mineral fibers

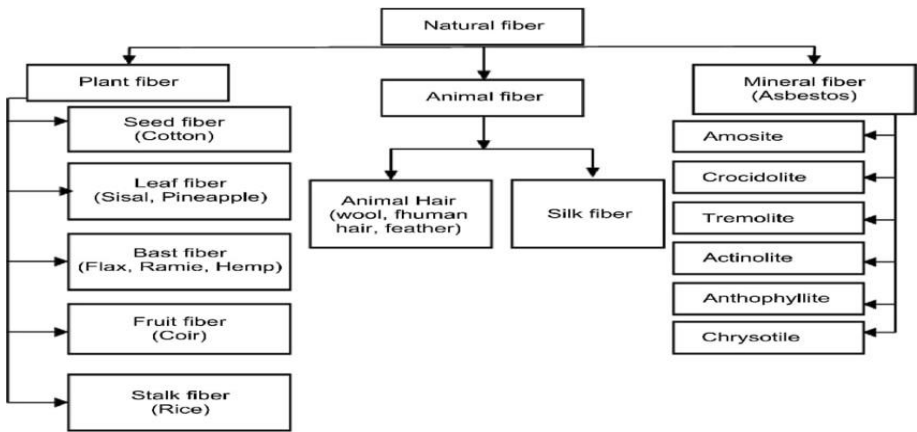


Figure 1: Classification of natural fibers

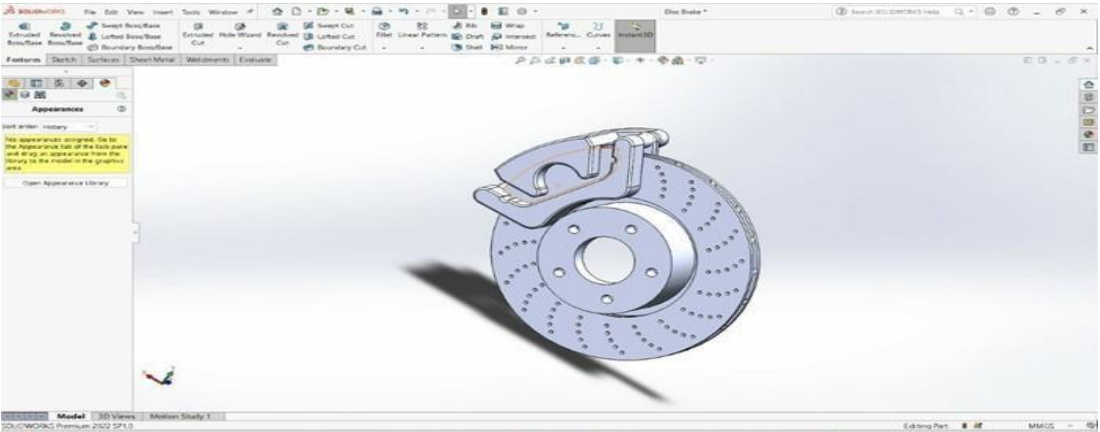
2. Literature Review

1. Jang, H. & Kim, S.J[1]: This study examines the effects of antimony trisulfide on the tribological properties of brake friction materials. The research highlights how varying compositions influence friction stability and wear rates, emphasizing the role of antimony trisulfide in enhancing friction performance and wear resistance.

2. Blau, P.J[2]: Blau provides an extensive overview of the compositions, functions, and testing of friction brake materials. The work discusses various additives used in brake composites and their impact on friction and wear properties, serving as a foundational reference for understanding material design in brake systems.
3. Eriksson, M., Jacobson, S., & Tison, J[3]: This research focuses on the influence of metallic fibers on the friction performance of sintered friction materials. The study finds that the addition of metallic fibers can significantly improve the mechanical properties and friction stability of brake pads.
4. Chan, D. & Stachowiak, G.W[4]: A comprehensive review of automotive brake friction materials, this paper covers the evolution of materials from asbestos to modern composites. The review emphasizes the development of environmentally friendly and high-performance materials.
5. Bijwe, J[5]: Bijwe's review highlights recent developments in non-asbestos fiber-reinforced friction materials. The study discusses various types of fibers and fillers used to replace asbestos, focusing on their mechanical and tribological properties.
6. Jang, H. & Park, J.H[6]: This paper investigates the friction and wear characteristics of brake friction materials containing carbon nanotubes (CNTs). The findings suggest that CNTs enhance thermal stability and reduce wear, making them a promising additive for high-performance brake pads.
7. Grooten, M., Sauer, B., & Graf, S[7]: The influence of rotor material on the friction behavior of brake pads is examined. The study concludes that different rotor materials can significantly affect the friction coefficient and wear rate, highlighting the importance of matching pad and rotor materials.
8. Ibrahim, I.A., Mohamed, F.A., & Lavernia, E.J[8]: This review on particulate reinforced metal matrix composites provides insights into the mechanical properties and potential applications of these materials in brake systems. The study emphasizes the role of particle reinforcement in enhancing wear resistance.
9. Kennedy, F.E[9]: Kennedy discusses surface interactions and micro-tribology in automotive brake systems. The research provides a detailed analysis of the contact mechanics and frictional behavior of brake materials, offering a micro-scale perspective on material performance.
10. Bijwe, J., Nidhi, P., & Biswas, S.K[10]: This study explores tribological studies on brake-pad materials based on newly developed resin. The research highlights the improvements in friction stability and wear resistance achieved through resin modification.
11. Sarkar, S. & Tewari, P.C[11]: The development of non-asbestos friction materials is discussed, focusing on alternative fibers and fillers. The study emphasizes the importance of balancing performance, cost, and environmental impact in material selection.
12. Zhou, X., Que, P., & Huang, S[12]: This paper examines the influence of graphite type on the friction and wear of copper-graphite composite materials. The research finds that different graphite types can significantly alter the tribological properties, affecting both friction and wear behavior.

13. Mazumdar, P.K[13]: Mazumdar's book on polymer matrix composites provides a thorough overview of the materials, processing methods, and applications of polymer composites in various industries, including brake systems

3. STATIC AND DYNAMIC ANALYSIS OF DISC BRAKE



Dimensions of the disc brake model

- 1. Diameter of the Disc Brake = 150 mm
- 2. Thickness of the Disc Brake = 1 mm

Firstly, the disc brake is designed in the solid works as per required dimensions to perform static and dynamic analysis on the disc brake model. Then the designed disc brake model is imported to the ANSYS work bench then the static and dynamic analysis are performed on the disc brake model with the different materials i.e. Asbestos and the Aluminium epoxy composites reinforcing with Pineapple fibers and Sugarcane bagasse with three compositions. After the completion of static and dynamic analysis by the comparison of the results the best material is suggested for the disc brake’s applications.

Material properties

Table 3.1: Asbestos properties

| Material | Density    | Youngs modulus | Poisson’s ratio | Yield strength |
|----------|------------|----------------|-----------------|----------------|
| Asbestos | 2.8 g/ cm³ | 40 GPa         | 0.3             | 50 MPa         |

Table 3.2: Properties of aluminium 10%, epoxy 40%, pineapple 20%, sugarcane 30%

| Materials | Density    | Youngs modulus | Poisson’s ratio | Yield strength |
|-----------|------------|----------------|-----------------|----------------|
| Aluminium | 2.7 g/cm³  | 69 Gpa         | 0.33            | 200 Mpa        |
| Epoxy     | 1.2 g/cm³  | 3.5 Gpa        | 0.35            | 50 Mpa         |
| Pineapple | 0.5 g/cm³  | 0.1 Gpa        | 0.3             | 1 Mpa          |
| Sugarcane | 0.5 g/cm³  | 0.1 Gpa        | 0.3             | 1 Mpa          |
| Composite | 1.43 g/cm³ | 10.35 Gpa      | 0.33            | 65 Mpa         |

Table 3.3: Properties of aluminium 10%, epoxy 40%, pineapple 30%, sugarcane 20%

| Materials | Density                | Youngs modulus | Poisson's ratio | Yield strength |
|-----------|------------------------|----------------|-----------------|----------------|
| Aluminium | 2.7 g/cm <sup>3</sup>  | 69 Gpa         | 0.33            | 200 Mpa        |
| Epoxy     | 1.2 g/cm <sup>3</sup>  | 3.5 Gpa        | 0.35            | 50 Mpa         |
| Pineapple | 0.5 g/cm <sup>3</sup>  | 0.1 Gpa        | 0.3             | 1 Mpa          |
| Sugarcane | 0.5 g/cm <sup>3</sup>  | 0.1 Gpa        | 0.3             | 1 Mpa          |
| Composite | 1.34 g/cm <sup>3</sup> | 9.45 Gpa       | 0.33            | 58 Mpa         |

Table 3.4: Properties of aluminium 10%, epoxy 40%, pineapple 40%, sugarcane 10%

| Materials | Density                | Youngs modulus | Poisson's ratio | Yield strength |
|-----------|------------------------|----------------|-----------------|----------------|
| Aluminium | 2.7 g/cm <sup>3</sup>  | 69 Gpa         | 0.33            | 200 Mpa        |
| Epoxy     | 1.2 g/cm <sup>3</sup>  | 3.5 Gpa        | 0.35            | 50 Mpa         |
| Pineapple | 0.5 g/cm <sup>3</sup>  | 0.1 Gpa        | 0.3             | 1 Mpa          |
| Sugarcane | 0.5 g/cm <sup>3</sup>  | 0.1 Gpa        | 0.3             | 1 Mpa          |
| Composite | 1.23 g/cm <sup>3</sup> | 7.35 Gpa       | 0.33            | 45 Mpa         |

## Meshing

Meshing is the process of dividing a complex geometric domain into smaller, simpler shapes called elements or cells. In computational fluid dynamics (CFD) and finite element analysis (FEA), meshing is used to discretize the geometry, here element size used 1mm.

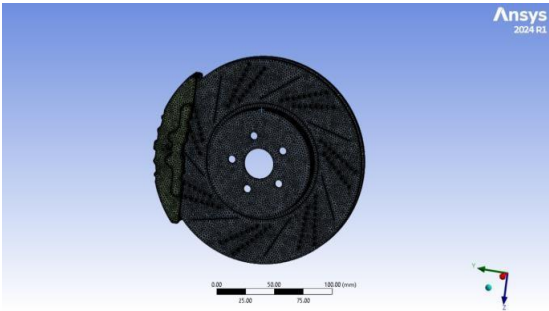
## Triangular meshing

Triangular type of meshing is used in this analysis of disc brake because of the circular shape of the disc brake. Triangular elements can better conform to curved boundaries like those in circular shapes compared to quadrilateral elements. It can provide better mesh quality in regions with high curvature, such as the perimeter of the circle. These meshes are easier to generate, especially for irregular shapes like circles, as they require less effort in meshing compared to quadrilateral meshes. So, when dealing with circular shapes in ANSYS simulations, using triangular mesh can offer advantages in terms of accuracy, mesh quality, and ease of generation.

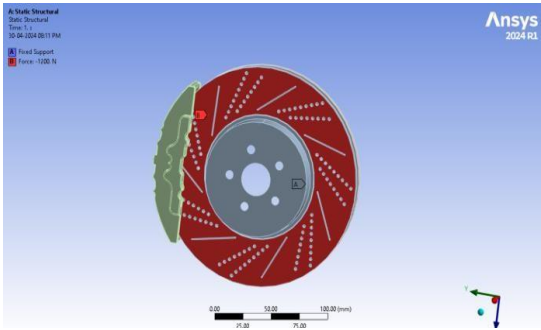
Force□ apply □1200N Fixed support selects holes Results solve, safety factor

## Triangular Meshing

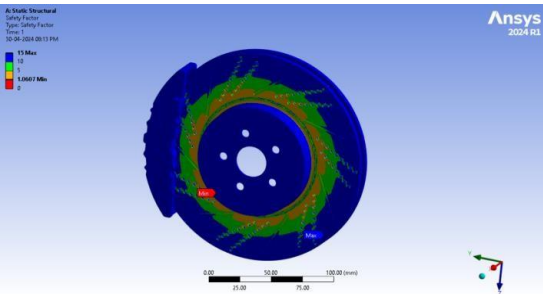
Triangular Meshing



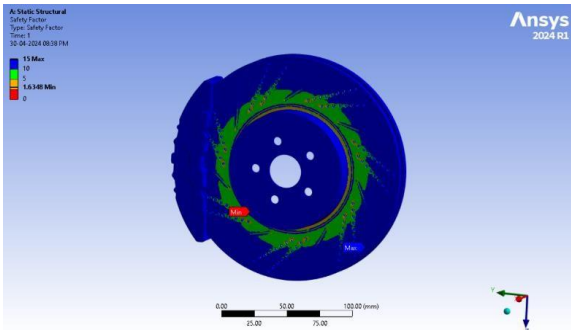
Fixed boundary conditions



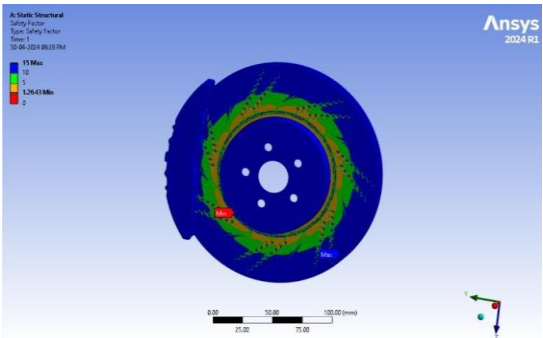
Safety factor for the materials Asbestos



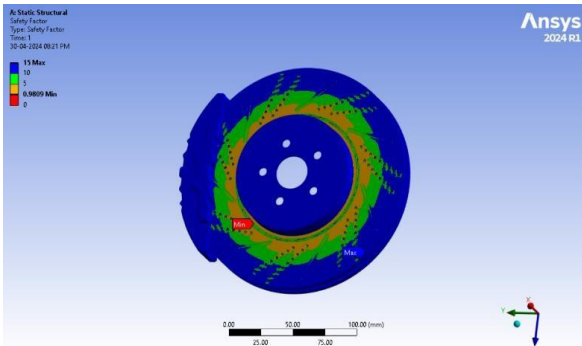
Al 10%, epoxy 40%, pineapple 20%, sugarcane 30%



Al 10%, epoxy 40%, pineapple 30%, sugarcane 20%



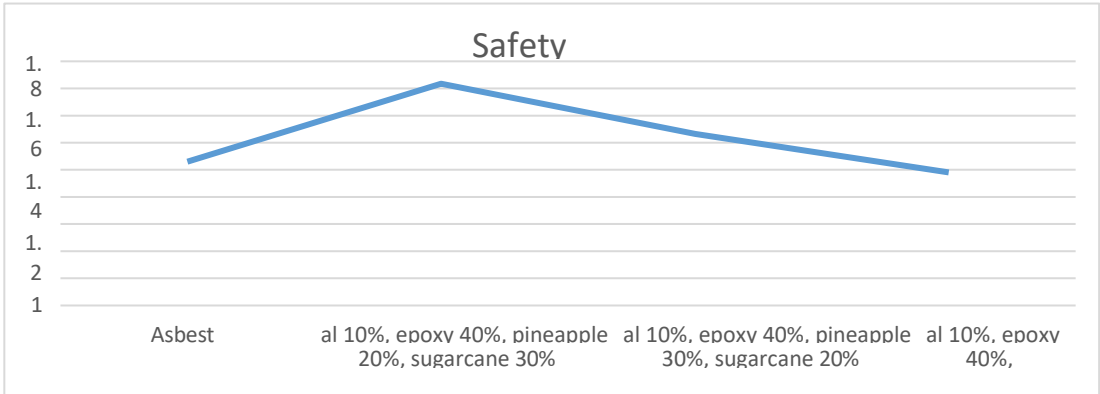
Al 10%, epoxy 40%, pineapple 40%, sugarcane 10%



Safety factor values for different materials

|               | Asbestos | Al 10%, epoxy 40%,<br>pineapple 20%, sugarcane<br>30% | Al 10%, epoxy 40%,<br>pineapple 30%, sugarcane<br>20% | Al 10%, epoxy 40%,<br>pineapple 40%, sugarcane<br>10% |
|---------------|----------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|
| Safety factor | 1.0607   | 1.6348                                                | 1.2643                                                | 0.9809                                                |

Factor of safety graph

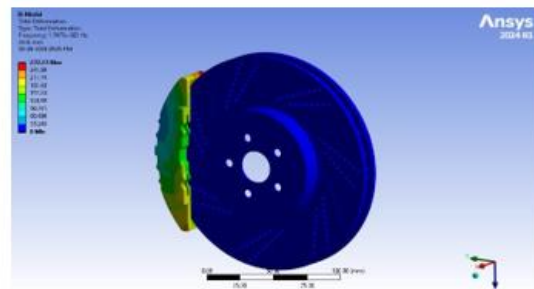


Graph 3.1: Factor of safety graph

DYNAMIC ANALYSIS

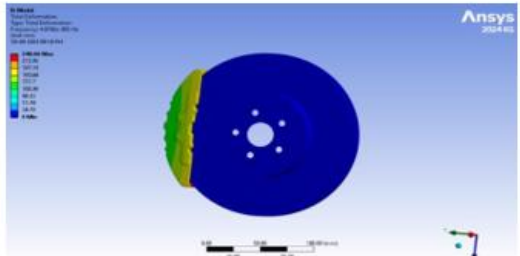
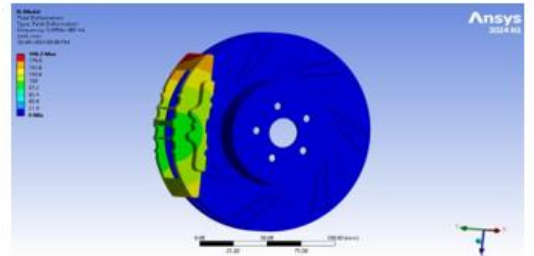
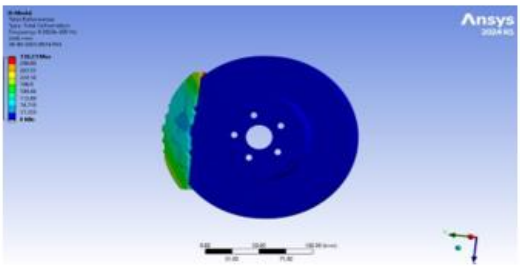
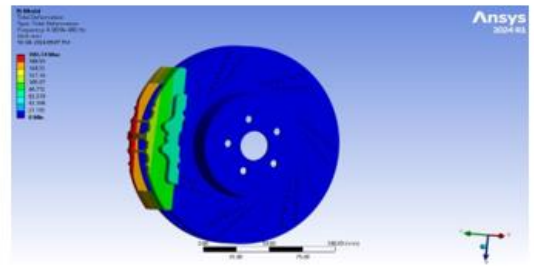
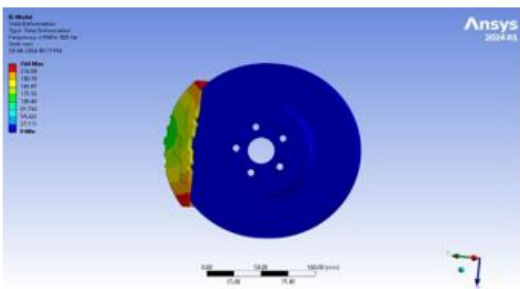
Asbestos

Mode 1, Mode 2, Mode 3



Al 10%, epoxy 40%, pineapple 20%, sugarcane 30%

Mode 1, Mode 2, Mode 3

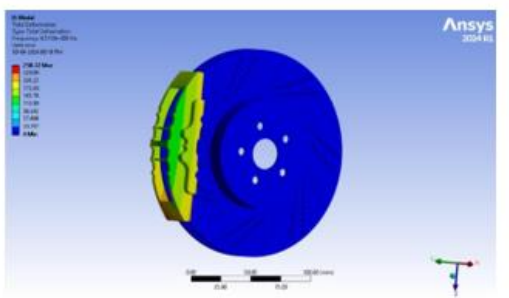
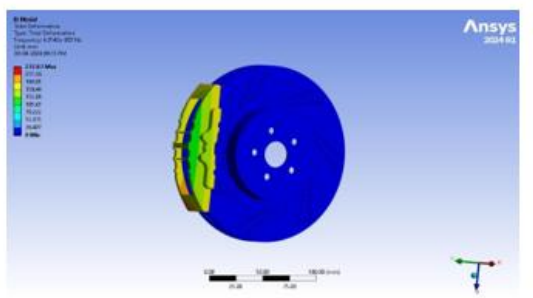
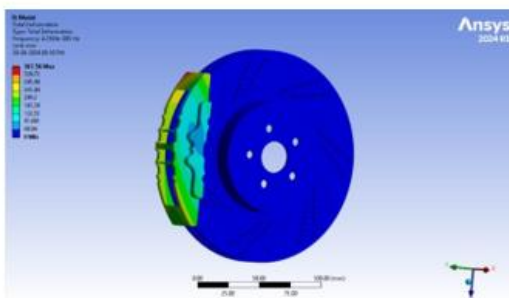
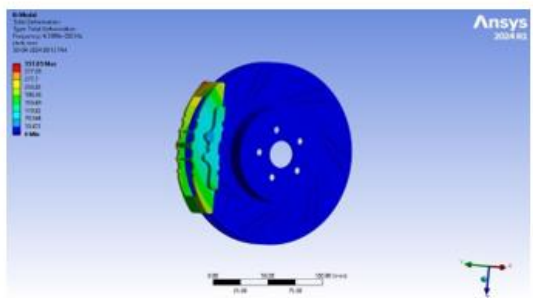
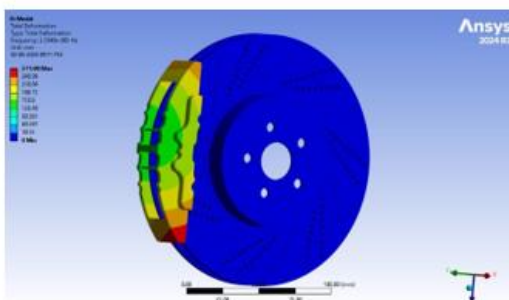
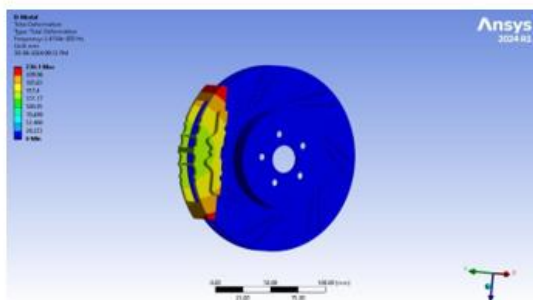


**Al 10%, epoxy 40%, pineapple 20%, sugarcane 30%**

### Mode 1, Mode 2, Mode 3

**Al 10%, epoxy 40%, pineapple 20%, sugarcane 30%**

**Mode 1, Mode 2, Mode 3**



## FREQUENCY VALUES OF THE MATERIALS

Table 3.6: Frequency values of materials

|             | Asbestos    | al 10%, epoxy 40%,<br>pineapple 20%,<br>sugarcane 30% | al 10%, epoxy 40%,<br>pineapple 30%,<br>sugarcane 20% | al 10%, epoxy 40%,<br>pineapple 40%,<br>sugarcane 10% |
|-------------|-------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|
| Mode 1 (hz) | 1.7475e-003 | 2.9361e-003                                           | 2.6134e-003                                           | 2.5349e-003                                           |
| Mode 2 (hz) | 4.3039e-003 | 4.3829e-003                                           | 4.3999e-003                                           | 4.2928e-003                                           |
| Mode 3 (hz) | 5.4954e-003 | 4.9782e-003                                           | 4.9142e-003                                           | 4.5139e-003                                           |

#### 4. MATERIALS USED

The two main components within a composite are the matrix and fibers. The matrix is the base material while the fiber is what reinforces the material. In this experiment we used

- 1) Aluminium & Epoxy as Matrix. i.e. as base material.
- 2) Pineapple fibers & Sugarcane bagasse as reinforcing fibers.

**Aluminium & Epoxy:** Aluminium has lower density than that of other common metals, about one third of that steel. Its light weight nature makes it invaluable in aerospace for aircraft structures and components. In automotive industries, aluminum is used for engine components, body panels, and wheels to reduce weight and improve fuel efficiency. It's density is 2.7 g/cm<sup>3</sup>, Tensile strength is 90 -125 Mpa, Youngs modulus is 69 Gpa, poisson's ratio is 0.33.

**Epoxy resins:** These are the thermosetting polymers known for their excellent adhesive properties, chemical resistance and mechanical strength. They consist of two main components: a) The epoxy resin itself and curing agent. b) Hardner. Epoxy's density is 1.1 g/cm<sup>3</sup>, Tensile strength is 50 -80 Mpa, Youngs modulus is 4 Gpa, poisson's ratio is 0.35 – 0.40.

**Pineapple fibers:** Pine apple fibers possess unique physical and mechanical properties. Physically they are light weight and flexible these fibers are biodegradable and have good moisture absorption properties, making them suitable for textile applications. Pine apple fibers are also finding applications in the automotive industry, particularly in the production of interior components such as interior components such as seat covers door panels and head liners. Pineapple fibers density is 1.2 g/cm<sup>3</sup>, Tensile strength is 170 -240 Mpa, Youngs modulus is 20 - 30 Gpa, poisson's ratio is 0.2 – 0.4.

**Sugarcane Bagasse:** Sugarcane bagasse, which is an abundant waste fibrous residue of sugarcane, is used in apparel industry. Sugarcane is grown to extract sugar from its stalk. After the juice is extracted, the remaining sugarcane fiber pulp is called bagasse. Sugarcane bagasse density is 1.24 g/cm<sup>3</sup>, Tensile strength is 100 -180 Mpa, Youngs modulus is 27 Gpa, poisson's ratio is 0.2 – 0.4.

Mixing ratio of the hybrid natural composite material

Table 3.7: Mixing ratio of the hybrid natural composite material

| MATERIALS         | SAMPLE 1 | SAMPLE 2 | SAMPLE 3 |
|-------------------|----------|----------|----------|
| Aluminium         | 10%      | 10%      | 10%      |
| Epoxy             | 40%      | 40%      | 40%      |
| Pineapple fibers  | 20%      | 30%      | 40%      |
| Sugarcane bagasse | 30%      | 20%      | 10%      |

Fabrication of Composite material

The composite fiber is prepared by manually.

- 1) Prepare aluminum in powder form, epoxy and hardener. Prepare matrix material by

mixing 10% of aluminum

+ 40% of epoxy resin in 3 equal parts.

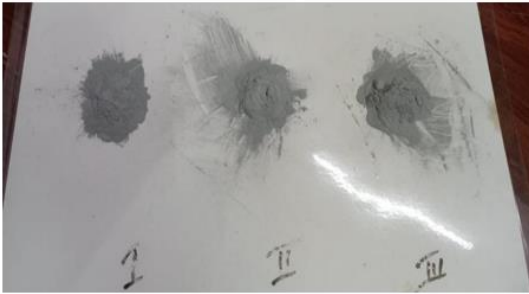


Figure 3.4: aluminium in powder form



Figure 3.5: epoxy & hardener

2) collect the pine apple fibers, sugarcane bagasse as reinforcing fibers.



Figure 3.6: pineapple fibers



Figure 3.7: sugarcane bagasse

3) Firstly, mix the 10% aluminium + 40% epoxy resin+ 20% pine apple fibers +30% sugarcane bagasse in a container thoroughly.

4) The following picture is the resulting mixture of the composite material.



Figure 3.8: Final mixture of the composite material

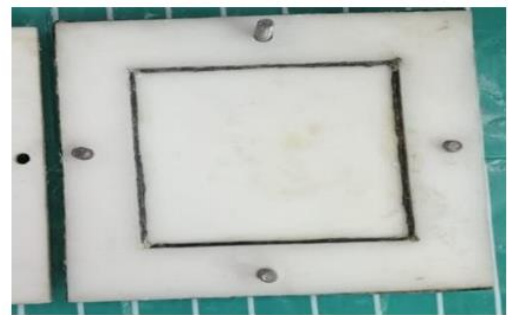


Figure 3.9: mould for pouring the composite material

5) Pour resulting final mixture of composite material in the mould of dimensions 200\*100\*10 mm

6) Before pouring the composite material into the mould apply wax on the mould surfaces because smooth removal of the composite material after drying the composite

material.

7) After the removal of composite material plate that composite material plate is cut into the three sample specimens as per the ASTM standards to determine the Tensile strength, Flexural strength, Impact strength.

8) Next that specimens are ready for Tensile test, Flexural test, Impact test.

#### CUTTING OF SAMPLE TEST SPECIMENS AS PER ASTM STANDARDS

1. Tensile test specimen was cut into dog bone shape of 165\*13\*8 mm as per ASTM D 3039 standards.

2. Flexural test specimen was cut into flat rectangular shape of 90\*13\*8 mm as per ASTM D 790 Standards.

3. Impact test specimen was cut into flat rectangular shape of 70\*13\*8 mm as per ASTM D 256 Standards

#### MECHANICAL TESTING

##### TENSILE TESTING

A tensile test is a Mechanical test used to test the behaviour of the materials when subjected to the tensile (pulling) forces. The commonly used specimen for tensile test is the dog-bone type. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is (165\*13\*8) mm.



Figure 3.10: UTM machine for Tensile testing

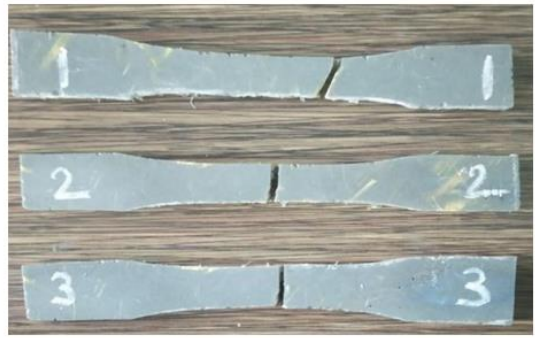


Figure 3.11: Broken specimens after Tensile test

##### FLEXURAL TESTING

The flexure test method measures behavior of materials subjected to simple beam loading. It is also called a transverse beam test with some materials. Most commonly the specimen lies on a support span and the load is applied to the center by the loading nose producing three points bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test.



Figure 3.12: Flexural testing machine



Figure 3.13: Broken specimens after flexural test

IMPACT TESTING

An impact test measures the material’s ability to absorb energy and withstand a sudden force or shock. The procedure typically involves striking a test specimen with a controlled force and observing the resulting behavior. It is usually used to test the toughness of metals, but similar tests are used for polymers, ceramics and composites. Izod Impact test specimen is machined to a square or round section, with either one, two or three notches. The specimen is clamped vertically on the anvil with the notch facing the Hammer



Figure 3.14: Impact testing machine

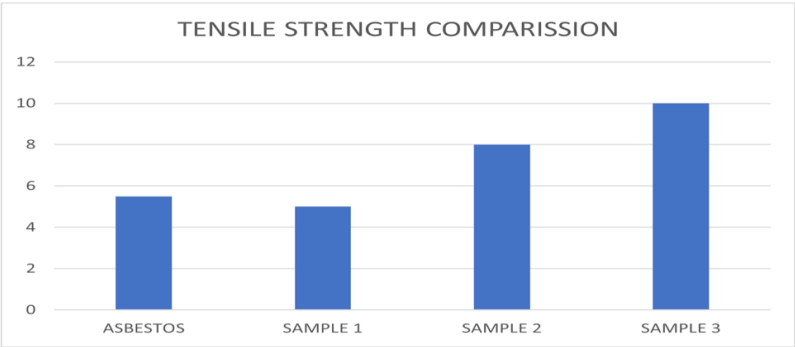


Figure 3.15: Broken specimens after impact test

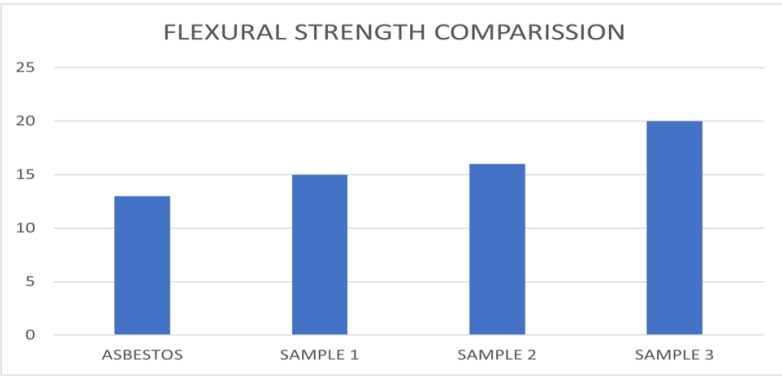
5. RESULTS

TENSILE, FLEXURAL, IMPACT STRENGTH RESULTS

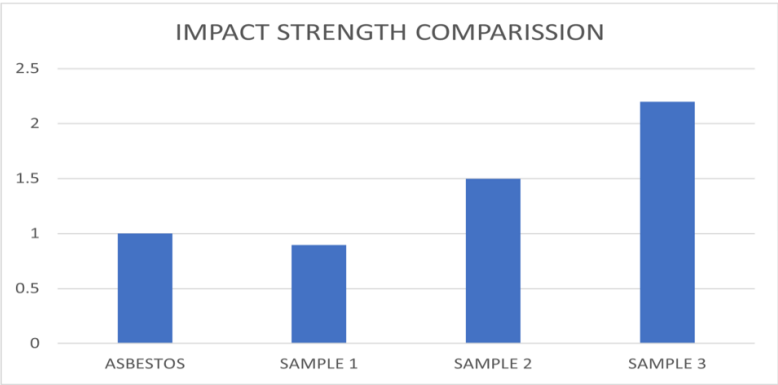
| SLNO | MATERIAL COMPOSITION                                                         | TENSILE STRENGTH | FLEXURAL STRENGTH | IMPACT STRENGTH |
|------|------------------------------------------------------------------------------|------------------|-------------------|-----------------|
| 1    | SAMPLE 1: Al 10% + Epoxy 40% + Pineapple Fibers 20 % + sugarcane bagasse 30% | 5 Mpa            | 15 Mpa            | 0.9 J           |
| 2    | SAMPLE 1: Al 10% + Epoxy 40% + Pineapple Fibers 20 % + sugarcane bagasse 30% | 8 Mpa            | 16 Mpa            | 1.5 J           |
| 3    | SAMPLE 1: Al 10% + Epoxy 40% + Pineapple Fibers 20 % + sugarcane bagasse 30% | 10 Mpa           | 20 Mpa            | 2.15 J          |



Graph 5.1: Tensile strength graph comparison



Graph 5.2: Flexural strength graph comparison



Graph 5.3: impact strength comparison

6. CONCLUSIONS

In this project different types of composite materials are analyzed with the help of ANSYS tool, in this process disc brake designed with the help of solid works tool, on disc brake applied boundary conditions 1200N, and then calculated results like deformation and stress and strain and safety factor values.

From design considerations any object should maintain minimum safety factor value above 1.5, if safety factor value less than 1, then the object undergoes permanent deformations, based on this, asbestos has minimum safety factor value has 1 only, it means this is the maximum capacity of the asbestos material. Al 10%, epoxy 40%, pineapple 20%, sugarcane 30% has obtained the highest safety factor value of 1.6348, it means this composition has highest strength, longevity and durability compare to asbestos material. From dynamic analysis results also, it has highest natural frequency values, it means it can withstand more vibrations, it indicates greater stiffness & rigidity, improved stability. After the completion of the mechanical testing for the specimens the it has been observed that

The equal & higher Tensile strength is observed for the sample 3 has 10 Mpa. The higher Flexural strength is observed for sample 3 has 20 Mpa. The higher impact strength is observed for sample 3 has 2.15 Joules.

Whereas the Asbestos material's Tensile strength is 5.5 Mpa, Flexural strength is 13 Mpa, Impact strength is 1 joule.

The sample 3 - Aluminium 10%, Epoxy 40%, Pineapple 40%, Sugarcane 10% has obtained the higher values of tensile strength, flexural strength, impact strength when compared to asbestos material. Finally, it is concluded that the composite material Aluminium 10%, Epoxy 40%, Pineapple 40%, Sugarcane 10% is alternative of the asbestos material for the disc brake's application.

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