

Experimental Study of Tamarindus Indica Bark Powder and Neem Gum Powder Reinforced Natural Composite

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Abstract

Researchers are increasingly interested in using natural fillers because they are lightweight, strong, biodegradable, and environmentally safe. In this study, a composite material is made by combining epoxy resin with tamarind bark powder and neem gum powder. Tamarind bark is known for its good mechanical and heat-resistant properties, while neem gum also provides strong support in mechanical applications. Epoxy resin is a popular and affordable thermosetting polymer with good performance. The composite is prepared with varying amounts of tamarind bark powder—0%, 10%, 15%, 20%, 25%, and 30%—while neem gum is reduced in the same steps from 30% to 0%. The hand lay-up technique is used to make the test samples. These samples are then tested for their mechanical strength, including tensile, compressive, flexural, and impact properties, using standard ASTM procedures. To understand the material's structure, scanning electron microscopy (SEM) is used, and X-ray diffraction (XRD) helps to study the surface and crystal structure. Among all the combinations, the composite containing 20% tamarindus indica bark powder and 15% neem gum powder with epoxy resin showed the most promising mechanical results.

Keywords: Tamarindus indica bark powder, neem gum powder, epoxy resin.

1. Introduction

Composite materials are engineered materials made by combining two or more constituent materials with significantly different physical or chemical properties. When combined these materials create a composite with properties superior to those of the individual components. The main purpose of using composite materials is to leverage the strengths of the constituents while compensating for their weaknesses.

The proposed composite material will be fabricated using date seed powder and neem gum powder as natural fillers within an epoxy resin matrix. Epoxy resin is a highly regarded thermoset polymer, known for its excellent cost-to-performance ratio and strong adhesive properties. Date palm seeds offer notable mechanical and thermal properties, making them suitable for reinforcing polymer matrices due to their effective interfacial bonding. Preliminary results indicate that increasing the proportion of neem gum powder leads to a reduction in mechanical properties such as tensile and flexural strength. However, this does not significantly compromise the overall integrity or quality of the composite material [1]. Azadirachta indica (neem gum) was taken as natural filler material in epoxy matrix with different fraction and mechanical properties like tensile, flexural and impact tests were found for five different specimens. It was observed that the incorporation of this new bio filler material exhibited improvement in the mechanical properties of composite. 40% volume

fraction of *Azadirachta indica* filler reinforced composite exhibited maximum tensile strength. The flexural strength and effect strength of the composite came about at 30 to 40 vol part of filler material [2]. Mechanical investigation on neem/banyan fibers reinforced with ceramic powder particulates hybrid polymer composite helmet is done to examine the mechanical properties such as impact, flexural, hardness and water absorption capacity. Neem and banyan fibers are used different proportions and composition of neem and banyan (5:1) give the higher impact and less water absorption and finally concluded that (5:1) composition of neem and banyan fiber utilizes to fabricate the helmet for motorcycle driving accessories [3]. Neem gum doesn't have a dissolving point agreeing to the TG-DTA examination. Electrical resistivity and thickness of neem gum diminishes with expanding temperature. Neem gum can be utilized in numerous applications due to its splendid mechanical properties [4]. Neem gum powder is used to improve the both physical and mechanical properties and neem gum powder is used in various percentages like 0.2, 0.4, 0.6, 0.8, 1.0 & 1.2%. The mechanical properties of concrete are increased at the dosage of 0.4% of neem gum powder. Workability also increases with increase of neem gum powder. Finally, concluded that optimum dosage of neem gum powder is 0.4%. [5]. the life of composite laminates can reveal from fatigue analysis in samples 'A' withstand more cycles in rotation 5979 compared with the other two samples which indicates when increasing bi-directional banyan is woven mat weight percentage was given the positive influence of variable fatigue load at the same time short neem fibers are shows less efficient life of hybrid composite [6].

The knowledge gap in earlier investigations

The neem gum-based composite exhibits favorable mechanical properties, particularly in terms of flexural and impact strength. However, its applicability may be limited to specific use cases. To potentially enhance these mechanical properties, the incorporation of additional reinforcing materials is being considered. Therefore, an experimental study is proposed involving *Tamarindus indica* bark powder, neem gum powder, and epoxy resin, with the objective of improving the overall mechanical performance of the composite material.

2. Experimental Set up

2.1 Materials Used

A. *Tamarindus indica* bark powder

Tamarindus indica, commonly referred to as tamarind, is a tropical tree whose bark has been traditionally used in various industries due to its rich chemical composition. Recently, *Tamarindus indica* bark powder has gained interest in engineering applications, particularly in material science and composites, due to its natural, sustainable, and eco-friendly properties.



Fig.1A: Tamarindus indica bark Fig.1B: Neem gum Fig.1C: Epoxy resin and hardener

Composition and Properties

Various bioactive compounds in the form of tannins, polyphenols, flavonoids, and carbohydrates make up the composition of Tamarindus indica bark. All these constituents provide its mechanical and chemical properties, thus making it a promising candidate for reinforcement in composite materials, especially for the development of bio composites or natural fiber composites. Advantages offered by tamarind bark powder include:

- **High Thermal Stability:** Presence of polyphenolic compounds increases the thermal resistance of the material, making it ideal for those applications whose working conditions are towards heating.
- **Antioxidant and Antimicrobial Properties:** These properties could improve the durability and lifespan by resisting microbial degradation.
- **Biodegradability:** As it is a natural material, tamarind bark powder is biodegradable, an environmentally friendly alternative to synthetic fillers or reinforcements. Benefits
- **Sustainability:** Tamarind bark is a renewable resource, which makes it suitable for green engineering and sustainable manufacturing.
- **Cost-Effectiveness:** As a natural and abundant material, tamarind bark powder is cheaper than synthetic fillers or reinforcements.
- **Eco-Friendly:** Tamarind bark powder is biodegradable and does not contribute to environmental pollution, which is in line with the growing trend of using eco-friendly materials in engineering.

B. Neem gum powder

Neem gum, a natural polysaccharide from the neem tree, offers unique properties like film formation, tackiness, and biodegradability, making it a sustainable alternative to synthetic materials. It enhances the toughness, impact resistance, and thermal stability of composites, particularly when combined with resins like epoxy, and is widely used in automotive, construction, and packaging applications. Neem gum's biodegradability makes it ideal for eco-friendly products like agricultural films and biodegradable plastics. It also proves to be a greener substitute for synthetic adhesives in industries like paper, plywood, and textiles due to its adhesive properties. Neem gum is effective in water purification, removing impurities without producing harmful by-products, which is another environmental advantage.

Advantages

- **Eco-Friendly:** Neem gum is biodegradable and sustainable, reducing environmental impact.
- **Cost-Effective:** Readily available and affordable compared to synthetic materials.

- **Biocompatibility:** Non-toxic, making it suitable for healthcare and food-related applications.
- **Film Formation and Adhesion:** Forms strong films and offers good adhesive properties for coatings and binders.

C. Epoxy resin

Epoxy resin is a type of synthetic thermosetting polymer known for its exceptional adhesive properties, chemical resistance, and durability. It is widely used in various industrial, construction, and artistic applications. The term "epoxy" refers to the chemical group in its structure, which is the result of a reaction between epoxide groups and curing agents (also called hardeners). Once cured, epoxy resin forms a strong, rigid, and resistant material that adheres to a wide range of surfaces.

Composition and Chemistry of Epoxy Resin

Epoxy resins are usually prepared by a two-component system:

- 1. Resin (Part A):** This is the base component, which contains the epoxy monomers or oligomers.
- 2. Hardener (Part B):** This component contains curing agents (such as polyamines or anhydrides), which trigger the cross-linking reaction when mixed with the resin.

When the two parts are combined, polymerization occurs as a chemical reaction. This results in the formation of a dense network of cross-linked polymers that yields a hard, solid material. Factors influencing the curing process include temperature, type of hardener, and the resin to hardener ratio.

Epoxy Resin Key Properties

1. Strong Adhesion
2. Durability
3. Chemical Resistance
4. Water Proofing
5. Thermal Stability
6. Low Shrinkage

2.2 Specimen composition

Table.1: Specimen composition

Specimen number	Tamarindus indica bark powder (wt.%)	Neem gum powder (wt.%)	Epoxy resin (wt.%)
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1	0	30	70
2	10	25	65
3	15	20	65
4	20	15	65
5	25	10	65
6	30	0	70

2.3 Experimental Procedure:

1. Mould Preparation:

The moulds were fabricated using galvanized iron (GI) sheets in accordance with ASTM standards.

2. Mixing of Resin and Hardener:

Epoxy resin and hardener were accurately weighed in a 2:1 weight ratio and thoroughly mixed for approximately 5–6 minutes to ensure a homogeneous blend.

3. Filler Preparation:

Tamarindus indica bark powder and neem gum powder was weighed as per the composition specified for Sample 1.

4. Composite Mixture Preparation:

The weighed Tamarindus indica bark powder and neem gum powder was gradually incorporated into the pre-mixed epoxy resin matrix (2:1 ratio) in a mixing bowl. Care was taken to mix the constituents uniformly and to avoid the entrapment of air bubbles, as the presence of air pockets can adversely affect the mechanical strength of the composite.

5. Mould Sealing and Lubrication:

Transparent white adhesive tape was applied to seal the ends of the GI moulds. Coconut oil was applied evenly across the inner surfaces of the moulds to facilitate easy removal of the cured specimens.

6. Casting:

The prepared composite mixture was carefully poured into the GI moulds.

7. Repetition for Additional Samples:

This procedure was repeated for the remaining five samples, resulting in a total of six distinct specimens, which were stored separately.

8. **Curing:**

The specimens were allowed to cure at ambient room temperature for a duration of 24 hours, as per the standard curing time of epoxy resin (typically 24–32 hours).

9. **Post-Curing Processing:**

Once cured, the specimens were gently removed from the moulds. Surface finishing was performed using appropriate tools, including rough and smooth files, to achieve the desired surface texture.

2.4 Testing of specimens

➤ **Tensile test:**

The tensile Tests has been done in the universal testing machine. Fig 2A shows the tensile test specimen. As per the ASTM D638 the specimen is prepared with 165 mm long, 13 mm wide, 3.2 mm thick. All 6 specimens are prepared with these specifications.

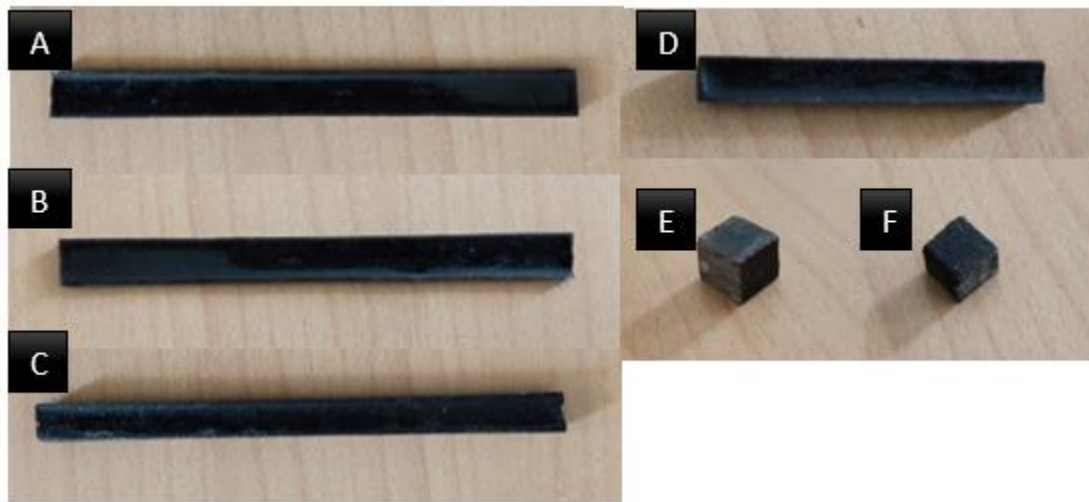


Fig.2: (A) tensile test specimen (B) Compression test specimen (C) Flexural test specimen (D) Impact test specimen (E) SEM test specimen (F) XRD test specimen

➤ **Compression test:**

The compression tests have been done in the universal testing machine. Fig 2B shows the compression test specimen. As per the ASTM D3410 the composite material has to be prepared with 140-155 mm long and with uniform rectangular cross section & width of 12 mm or 25 mm. All the specimens are prepared with 155*12*3.2 mm for compression test

➤ **Flexural test:**

The flexural tests have been done in the universal testing machine. Fig 2C shows the Flexural test specimen. As per the ASTM D790 the most common size for plastic moulding compounds is 127 mm long, 12.7 mm wide and 3.2 mm thick. The all 6 specimens for flexural test are prepared with 127*12.7*3.2 mm.

➤ **Impact test:**

The impact tests are done in Izod impact testing machine. Fig 2D shows the impact test specimen. The specimen specifications for Izod impact test are 64 x 12.7 x 3.2 mm.

➤ **Scanning electron microscopy analysis**

SEM is an imaging technology that was widely used with good resolution but better than most for the direct resolution of ordinary optical microscopy. Instead of shining light for enlarged images on object, which allows the passage and interaction by beam electrons inside such a sample structure of interest which shows a high and varied detailed signalling of an excellent topographical presentation of the material to add to knowing either its contents as well or crystalline configuration as well. To perform SEM analysis the specimen specifications are 10 x 10 x 10 mm. Fig 2E shows the scanning electron microscopy test specimen.

➤ **X-Ray diffraction test:**

X-ray diffraction is a very powerful analytical technique that studies the crystallographic structure, composition, and physical properties of materials. It works by directing X-rays onto a sample and then analyzing the pattern of X-rays that are diffracted or scattered by the atoms in the material. XRD is widely used in material science, chemistry, physics, geology, and biology for identifying crystalline phases, measuring unit cell dimensions, and determining the arrangement of atoms within a crystal lattice. To perform XRD test the specimen specifications are 10 x 10 x 10 mm. Fig 2F shows the XRD test specimen.

3. Results and Discussion

3.1 Tensile test results:

Table 2: Tensile test results

Sample	Maximum load (N)	Tensile stress at max load (Mpa)	Modulus (automatic young's) (Mpa)
1	912.87	30.43	2152.14
2	927.62	30.92	1959.68
3	1160.80	38.69	1643.52
4	1380.79	46.03	2574.93

5	1354.14	45.14	2367.44
6	1013.21	33.77	2150.44

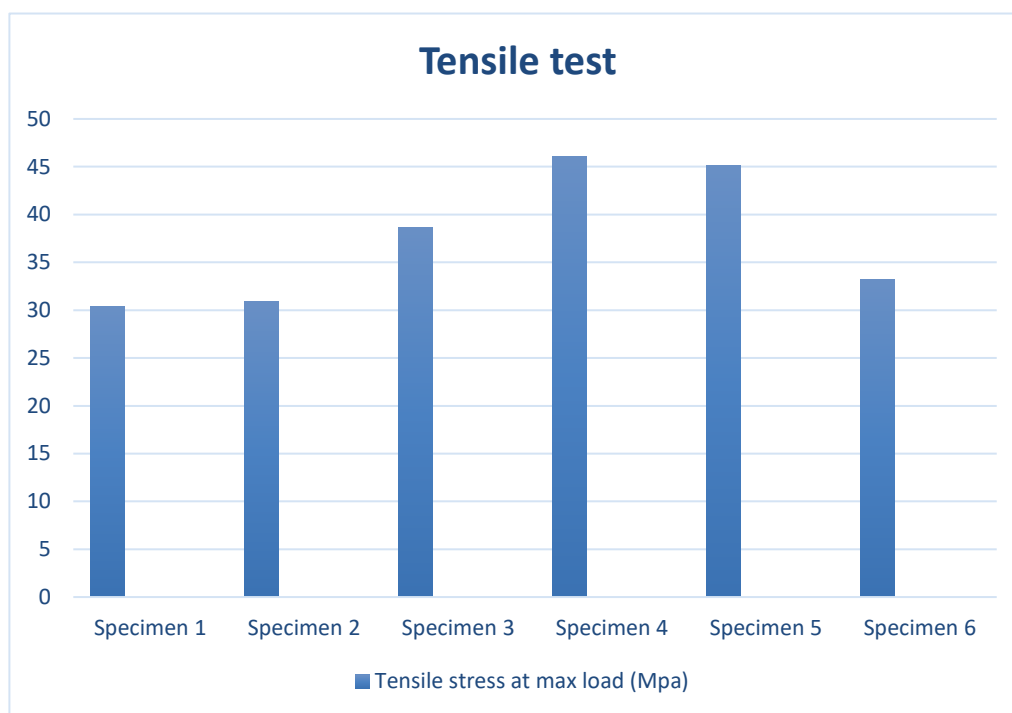


Fig.3: Bar graph for tensile test results

The tensile test has been done in universal testing machine and the following values are attained. Sample 4, made with 20% tamarind bark powder and 15% neem gum powder mixed into epoxy resin, showed the highest tensile strength of 46.03 MPa. This indicates that the composite is highly effective in withstanding tensile forces. Typical commercial plywood has a tensile strength ranging from 30 to 40 MPa, depending on the type and quality. Compared to this, the composite material developed in Sample 4 shows superior tensile performance. In addition to higher strength, this composite offer benefits like better moisture resistance, reduced weight, and eco-friendliness due to the use of natural fillers. The tensile strength is increased continuously up to sample 4 and then decreased. Up to sample 4 the tamarindus indica bark powder is increased so tensile strength is increased and then due to lack of neem gum powder the tensile strength is decreased.

3.2 Compression test results:

Table 3: Compression test results

Sample	Max load (KN)	Compressive test (Mpa)	Modulus (Mpa)
1	6.04	47.81	8350.31
2	6.09	48.17	4602.58
3	7.89	62.42	5553.46
4	8.37	66.20	5565.12
5	5.01	39.68	6123.67
6	4.41	34.64	6425.17

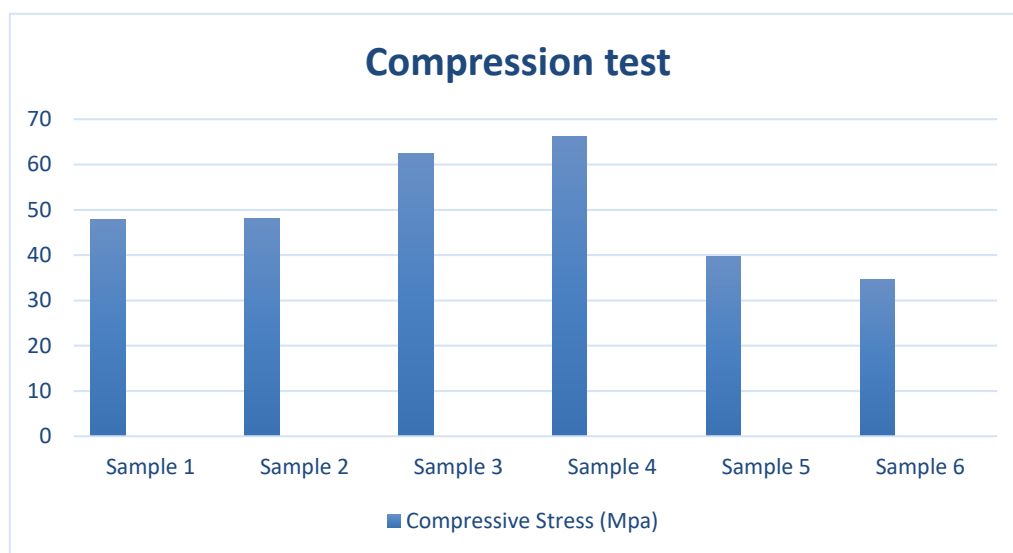


Fig.4: Bar graph for compression test results

The compression test also done in universal testing machine and the following values are attained. Sample 4, which contains 20% tamarind bark powder and 15% neem gum powder in epoxy resin, recorded the highest compressive strength of 66.20 MPa. This composition shows excellent resistance to compressive forces. Conventional plywood generally has a compressive strength ranging from 30 to 50 MPa, depending on the type and layers used. In comparison, the composite in Sample 4 offers noticeably higher compressive strength at 66.20 MPa. This suggests that the natural-fiber-reinforced composite can bear heavier loads and may perform better in structural or load-bearing applications. Additionally, its biodegradability and customization through filler content make it a sustainable alternative. The compressive strength is increased continuously up to sample 4 and then decreased. Up to sample 4 tamarindus indica bark powder is increased so the compressive strength is increased and then due to lack of neem gum powder compressive strength is decreased from sample 5.

3.3 Flexural test results:

Table 4: Flexural test results

Sample	Max load (KN)	Max stress (Mpa)	Flex modulus (Mpa)
1	0.34	187.54	26998.50
2	0.39	217.28	30268.84
3	0.45	252.23	19593.18
4	0.52	289.40	44667.28
5	0.43	240.37	36602.12
6	0.39	217.89	34986.81

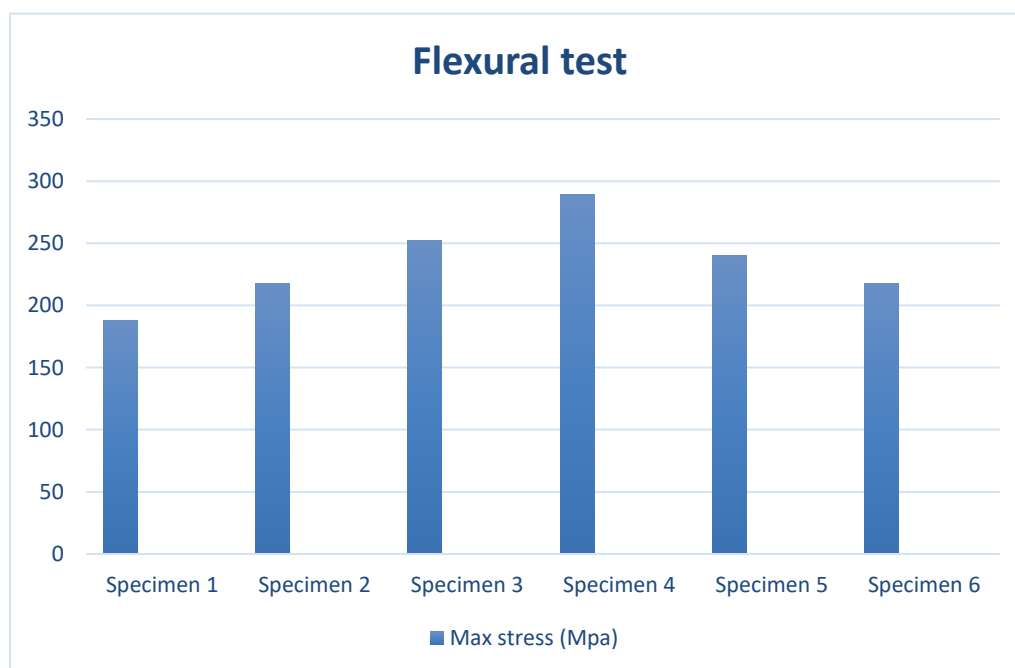


Fig.5: Bar graph for flexural test results

The flexural test is done in universal testing machine and the following values are attained. Sample 4, made with 20% tamarind bark powder and 15% neem gum powder in epoxy resin, achieved the highest flexural strength of 289.4 MPa. This indicates that the composite has excellent resistance to bending forces. Standard plywood typically has a flexural strength ranging from 70 to 100 MPa, depending on the grade and number of layers. In contrast, the composite material in Sample 4 shows a significantly higher flexural strength of 289.4 MPa. This makes it a much stronger option

for applications requiring high bending resistance, such as load-bearing panels, beams, or furniture components. The flexural strength is continuously increased up to sample 4 due to increase in tamarindus indica bark powder and then sample 5 and 6 strengths are decreased due to lack of neem gum powder.

3.4 Impact test results

Table 5: Impact test results

Sample	Impact strength (j/m)	Impact strength (kj/m ²)
1	21	0.021
2	21.6	0.0216
3	22.2	0.0222
4	23	0.023
5	23.4	0.0234
6	24	0.024

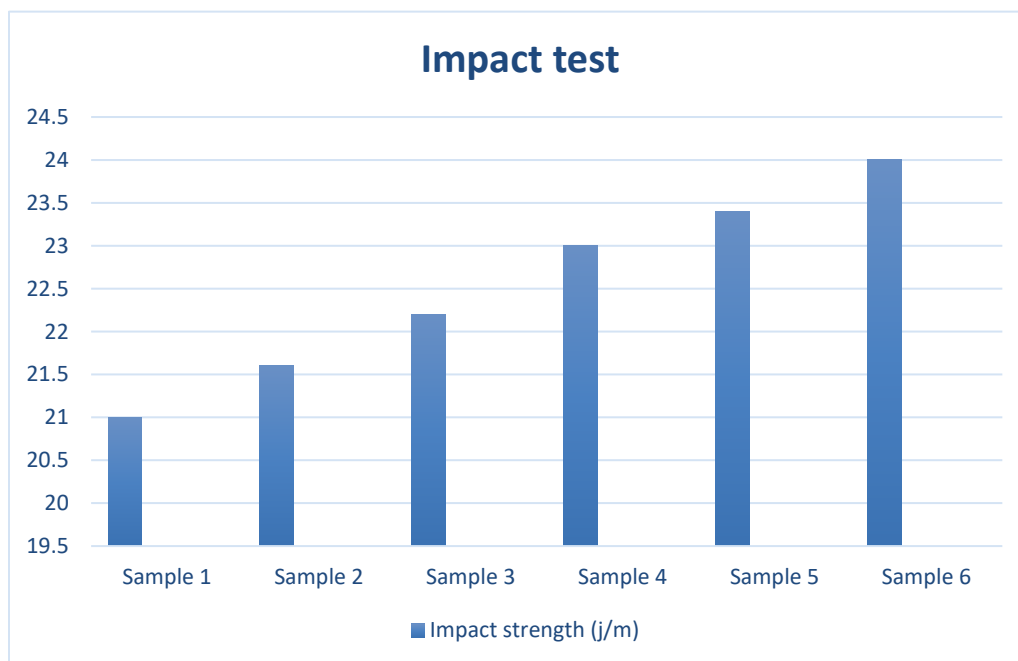


Fig.6: Bar graph for impact test results

The impact test has been done in the Izod impact testing machine and the following values are attained. The highest impact strength is obtained by the sample 6 with 24 j/m which is prepared with the composition of tamarindus indica bark powder 30% and there is no neem gum powder in it. Here all the values are continuously increasing due to increasing the weight percentage of tamarindus indica bark powder. The presence of tannins, polyphenols, flavonoids, and carbohydrates in the tamarindus indica bark powder gives more impact strength.

3.5 Scanning electron microscopy results

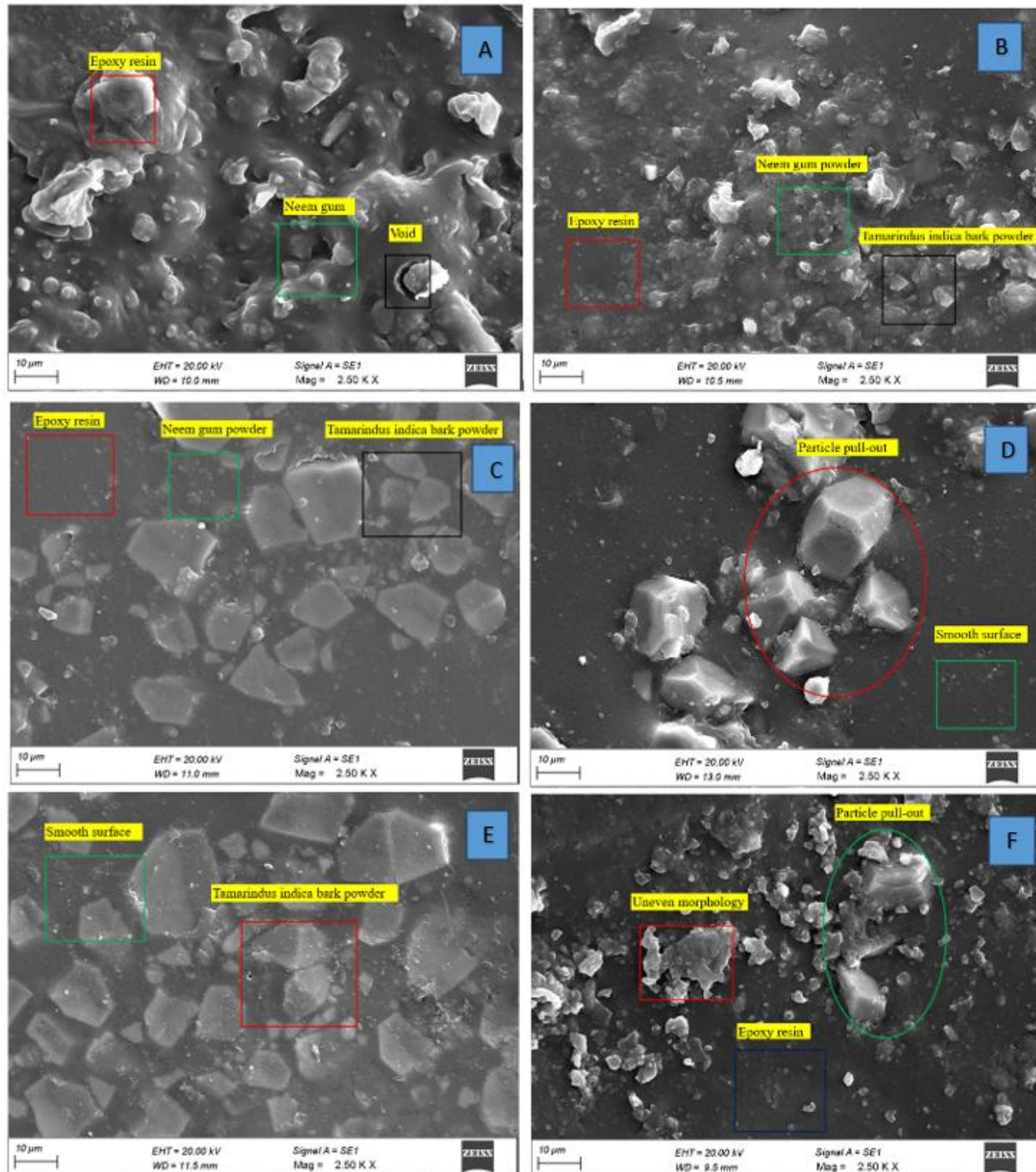


Fig.7: Microstructural images of (A) sample 1, (B) sample 2, (C) sample 3, (D) sample 4, (E) sample 5, (F) sample 6 with 2500X magnification.

Surface of the particles appears rough and porous in Fig.7A. Voids or empty spaces occurred due to air entrapment or poor adhesion between the neem gum powder and epoxy resin. The particles vary in size and shape with some being irregular is neem gum powder. The neem gum particles appear to be well distributed within the epoxy resin matrix. The even distribution of particles suggests that the mixing process was effective in achieving a homogeneous composite material. The good interfacial bonding indicates that the neem gum particles are well-integrated into the epoxy matrix, which could contribute to the overall strength and stability of the composite. This composite material might be suitable for applications where good mechanical properties and biodegradability are desired, such as packing, construction or automotive parts. The surface appears relatively smooth with some irregularities and particles dispersed throughout in Fig.7B. The particles are not uniformly distributed, indicating potential agglomeration or uneven mixing during the preparation process. The particles vary in size with some appearing smaller is neem gum powder and other larger particles are tamarindus indica bark powder. The surface appears rough with a heterogenous distribution of particles in the Fig.7C. The irregular particles dispersed throughout the matrix are tamarindus indica bark powder. Good interfacial bonding indicating that the neem gum particles and tamarindus indica bark powder into the epoxy resin. The smooth and continuous phase is the neem gum powder and epoxy resin. In Fig.7D Good mixing and even distribution of neem gum and tamarindus indica powder indica bark powder within the epoxy resin. Clusters of particles or large agglomerates would suggest inadequate mixing which could weaken the composites mechanical properties. Uniform distribution where the particles are consistently spread across the surface. Irregular shape and size are the tamarindus indica bark powder. In Fig. 7E the Smooth and even surface is epoxy resin. Uneven distribution of tamarindus indica bark powder due to improper preparation or curing. Tamarindus indica bark powder particles are mixed like cluster form. Irregular shape and sizes are tamarindus indica bark powder. The good bonding helps to increase in the mechanical properties. In Fig.7F More voids or empty spaces are observed due to poor adhesion between the powder and epoxy resin matrix. The surface looks rough or uneven due to poor dispersion. Due to poor adhesion, the mechanical properties may be reduced.

3.6 X-Ray diffraction test results

To study the crystallographic structure, composition, and physical properties of materials the XRD test is done in the x-ray diffractometer. Copper is used in this x-ray diffraction because it is easy to cool and produce strong k-alpha and k- beta lines. Copper anodes are by far the most common, since copper gives the shortest wavelength above 1Å.

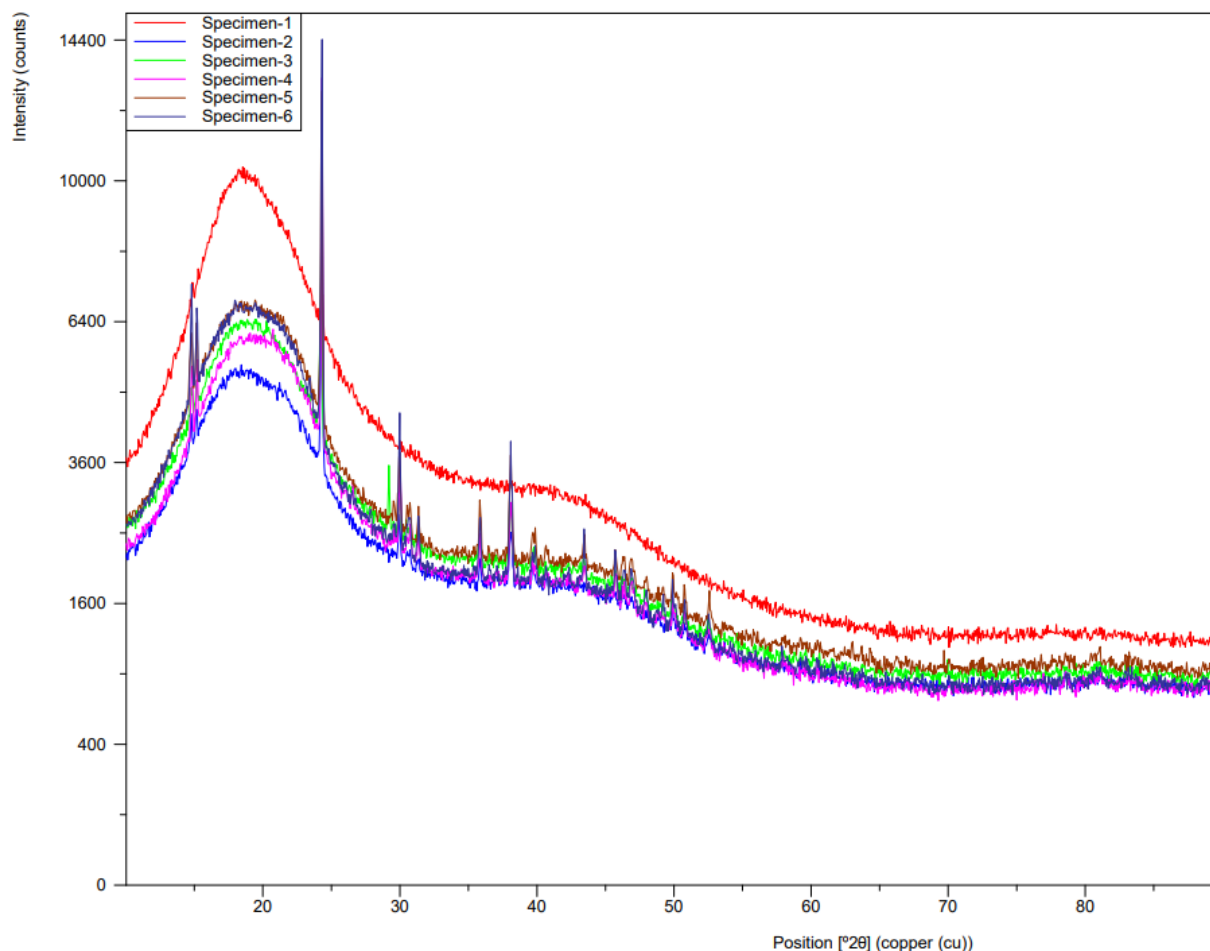


Fig.8: XRD graph

Red colour line in the fig.8 Shows specimen 1. Broad peak indicating an amorphous or poorly crystalline structure. No sharp peaks meaning, it lacks a well-defined crystalline phase. Likely the least desirable sample due to low crystallinity. Thick blue colour line in the fig.8 shows specimen 2. A mixture of broad and sharp peaks indicating both amorphous and crystalline structure. Sharp peaks suggest some crystalline structure though the amorphous background reduces overall quality. Better than sample 1, but the presence of broad background suggests it is not fully crystalline. Green colour line in the fig.8 shows specimen 3. Very similar to sample 2 with a mix of crystalline and amorphous phases. Sharp peaks indicate some crystallinity, but the overall peak sharpness is still not ideal. Comparable to sample 2, but still not the best. Magenta (pink+ purple) colour line in the fig.8 shows specimen 4. Multiple sharp peaks with one dominant intense peak (~10,000 counts). The presence of a broad background peak suggests, a slight amorphous phase, but the well-defined sharp peaks indicate good crystallinity. A well crystallized sample with some amorphous content, likely one of the better samples. Brown colour line in the fig.8 shows specimen 5. Similar to sample 4, but with slightly lower overall peak intensities indicating either reduced crystallinity or lower sample quality. A good sample, but slightly less crystallized or lower quality than sample 4. Light blue colour line in fig.8 shows specimen 6. Sharp peaks are visible but less

defined compared to sample 4 & 5. The slight peak broadening or noise may be due to sample preparation issues. Still a relatively good crystalline sample, but slightly inferior to sample 4 and 5 in terms of peak definition.

Recommendation:

Sample 4 appears to be the best sample overall, with the highest intensity and most well-defined peaks. It has strong crystalline characteristics with some minor amorphous background but is clearly better than the others in terms of crystallinity and overall quality.

4. Conclusion

The Experimental study on Tamarindus indica bark powder and neem gum powder reinforced with epoxy resin leads to the following conclusions.

Overall, the combination of 20% tamarind bark powder and 15% neem gum powder reinforced with epoxy resin provides superior mechanical properties. It demonstrates high strength under bending, tensile, and compressive loads. The composite also offers improved resistance to moisture and termites, contributing to a longer service life, especially in harsh conditions. Its adaptability allows it to be molded into modern, curved, or ergonomic shapes. Additionally, the use of natural fillers makes it a promising eco-friendly alternative to conventional materials. Due to its high flexural strength along with moderate tensile and compressive strength, this composite is well-suited for use in various structural applications. It can be effectively used in automotive interior components such as dashboards, door panels, and seat backs. Additionally, it is suitable for sports equipment like bicycle frames, skateboards, paddles, and archery bows. The material is also ideal for furniture parts, including chair legs, bed frames, and table supports.

5. Future work

This composite material is fabricated using the hand lay-up method; however, employing other fabrication techniques may result in variations in mechanical performance. While the material shows moderate impact strength, incorporating additional natural fillers could potentially enhance its overall mechanical properties.

Conflict of Interest

The authors confirm that there is no conflicts of interest in publishing this article.

Author's contribution

P Purushotham- conceptualization, idea, previous studies, all calculations, writing of article, reviewing and editing.

Dr. B. Chandra Mohan Reddy- Conceptualization, methodology, supervision, reviewing and editing.

Other Ethics Statements

All the authors have read and agreed to the published version of the manuscript.

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