IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⵘ Impact Factor 8.066 ⵘ Peer-reviewed / Refereed journal ⵘ Vol. 10, Issue 8, August 2023

DOI: 10.17148/IARJSET.2023.10832

A COMPARISON OF THE MECHANICAL STRENGTH OF COMPOSITES MADE OF PLA - EPOXY AND PLA – EPOXY – ALUMINA COMPOSITES

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Abstract: PLA-Epoxy and PLA-Epoxy-Alumina reinforced composites are employed in various mechanically demanding applications. Polylactic acid (PLA) with epoxy resin form PLA-Epoxy composite. The matrix material epoxy resin gives the composite mechanical characteristics. However, PLA reinforces the composite's strength and rigidity. Production of a PLA-Epoxy-Alumina reinforced composite involves adding alumina particles to the matrix. Alumina particles reinforce the composite's mechanical strength and stiffness. A PLA-Epoxy-Alumina reinforced composite has better mechanical strength. Adding alumina particles to the composite increases its strength and stiffness, reducing stress-induced deformation and failure. Testing a composite material's tensile, compressive, and flexural strengths to determine its mechanical strength is routine. Alumina particles improve PLA-epoxy composite tensile, compressive, and flexural strength. However, many other factors affect composite material mechanical strength. The size, shape, and distribution of reinforcing particles, matrix material quality, and composite manufacturing technology all matter. As noted before, the above metrics are essential when comparing composite material mechanical strength.

Keywords: Composite materials, Mechanical strength, PLA-Epoxy composite, PLA-Epoxy-Alumina composite, Reinforced composites, Alumina particles, Matrix material.

I. INTRODUCTION

Composite materials, which mix varied elements to improve mechanical properties, are used in many industries that value strength [1]. These "composite materials." mix different elements to improve mechanical properties. These materials' PLA-epoxy and PLA-epoxy-alumina composites are promising for high-strength applications. PLA-Epoxy composites are made using PLA and epoxy resin. This composite uses epoxy as the matrix and PLA as the reinforcing material [2]. This composite becomes the PLA-Epoxy-Alumina reinforced composite when alumina particles are added. Alumina reinforces this composite's mechanical properties [3].

Mechanical strength is crucial when assessing composite material performance [4]. PLA and epoxy composites combine the mechanical qualities of the matrix material with PLA's reinforcing properties [5]. However, adding alumina particles to the PLA-Epoxy matrix increases its strength and stiffness, creating composites with exceptional mechanical properties [6]. This study compares the mechanical strength of PLA-Epoxy and PLA-Epoxy-Alumina composites to understand how alumina reinforcement affects performance.

Tensile, compressive, and flexural strengths are considered when determining a material's mechanical strength [7]. These parameters show how effectively a composite material can withstand loading. Even though alumina particles improve tensile, compressive, and flexural strength, several aspects affect composite mechanical behaviour [8]. The matrix material, manufacturing process, and reinforcing particles all affect the composite's mechanical strength [9].

This article compares the mechanical strength of PLA-Epoxy composites and PLA-Epoxy-Alumina composites in light of these factors. We hope to illuminate the difficulties of composite material design for maximum mechanical performance by studying various elements and alumina reinforcement. This allows us to

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A. AIM & OBJECTIVES

This research compares and contrasts the mechanical properties of two types of composites, one reinforced with polylactic acid (PLA) and epoxy and another with polylactic acid (PLA) and epoxy and alumina (PEA-Alumina).

- The goal is to compare the tensile strength of PLA-Epoxy and PLA-Epoxy-Alumina composites.
- The study examined the flexure performance of PLA-Epoxy and PLA-Epoxy-Alumina (10% and 20%) reinforced composites.
- The purpose of this study is to investigate how reinforcements impact the mechanical strength of composites.
- Examine how particle size, shape, and distribution affect composite mechanical strength.
- The study investigates how matrix quality affects composite mechanical strength.
- Investigating the impact of production parameters on composite mechanical strength.
- Analyse mechanical properties of PLA-Epoxy and PLA-Epoxy-Alumina (10% and 20%) reinforced composites to choose the best material for specific applications.
- This research will analyse the mechanical strength of PLA-Epoxy and PLA-Epoxy-Alumina (10% and 20%) reinforced composites to help manufacturers build or upgrade composite goods.

B. SCOPE OF THE PROJECT

This article will examine PLA-Epoxy and PLA-Epoxy-Alumina reinforced composite mechanical strength. This project will examine tensile, compressive, and flexural strength. Composite mechanical strength will be compared to reinforcing-material type, matrix quality, and production method.

Paper will examine mechanical properties of PLA-Epoxy and PLA-Epoxy-Alumina reinforced composites, including reinforcing particle effects, matrix material quality, and manufacturing process parameters.

Research will recommend composite materials for certain uses. This study will not examine composite materials' thermal, electrical, and optical properties.

This paper covers only this experiment's data gathering, equipment, and supplies. The results may not apply to other PLA-Epoxy and PLA-Epoxy-Alumina reinforced composite materials because this study did not examine them.

II. MATERIAL AND METHODS

A. ALUMINA

Alumina, commonly known as aluminium oxide (Al2O3), is a ceramic substance that is highly sought after for use as reinforcement in composite materials due to its remarkable mechanical qualities. When it comes to hardness, thermal stability, and wear resistance, alumina is unrivalled. Because of these qualities, it is a promising option for improving the mechanical performance of composite materials, especially in those that place high demands on strength and durability.

B. PLA (POLY LACTIC ACID)

The biodegradable thermoplastic polylactic acid (PLA) can replace petroleum-based polymers. PLA is eco-friendly because of maize starch, sugarcane, and cassava. Packaging, medical devices, and composites benefit from its mechanical qualities and ease of production.

PLA is biocompatible, low-toxic, and can be made using standard polymer production methods because to its unique molecular structure. PLA is a good reinforcement because of its thermal stability, moderate strength, and high stiffness. PLA strengthens composites in this study. When combined with epoxy resin, it improves composite mechanical properties. PLA balances composite matrix mechanical performance-critical characteristics.

C. EPOXY

Due to its chemical resistance, mechanical characteristics, and adhesive strength, epoxy resin is used in composites. Epoxy resins are tightly crosslinked polymer networks formed by reacting epoxy monomers with a hardener. Due to their network structure, epoxy resins are used in aeroplanes, consumer goods, and other sectors.

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Epoxy resins improve composite mechanical properties and bond to numerous substrates. They can be blended with fibres and particles to increase their versatility. Epoxy resins' mechanical load transmission and distribution make them popular in composite matrix materials.

The PLA-Epoxy and PLA-Epoxy-Alumina composites use epoxy resin as the matrix. Binding the reinforcing components gives the composite strength and stiffness. Epoxy cures into a continuous matrix that improves composites' mechanical properties.

III. EXPERIMENTAL

A. PREPARATION OF LAMINATE

Using molten PLA, epoxy, and alumina to laminate differs. These steps are needed:

- Grade PLA, epoxy resin, and alumina for quality and applicability. Make sure materials melt and work.
- Melting PLA HOT PLA melts at 160–180°C in an extruder or plate. Watch PLA temperature to avoid overheating.
- Blending and Preparing Epoxy Mix epoxy glue and hardener per package guidelines while PLA melts. Do this while PLA melts. Combine all parts for homogeneity.
- PLA and epoxy melt. If PLA melts, epoxy. Mix PLA long-term to evenly spread epoxy.
- Combined PLA and epoxy with alumina or prefabricated zirconia. This completes incorporation. Alumina uniformly distributes after stirring.
- Moulding or casting: Neither: The injection moulding machines inject PLA-epoxy-alumina. Make sure the mould has a release agent for laminate removal following solidification. Repeatable lamination.
- Cooling liquid before solidification. Moulds cool faster in cooling chambers or media. Consider both.
- Carefully remove laminate from mould after hardening and room temperature. Trim, shape, or sand more laminate to achieve size and quality.
- After curing, laminate durability and mechanical qualities may improve. The epoxy system decides. The epoxy maker warms laminate.

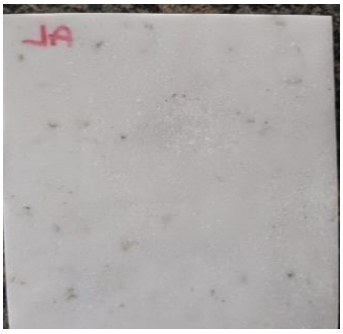

Fig. 1. Lamination Plate

B. TENSILE TEST

Mechanical properties such as tensile strength, elongation at break, and Young's modulus were evaluated for the PLA-Epoxy and PLA-Epoxy-Alumina composites using tensile testing. This test mimics tension and gives insight into how composites respond to axial loading.

C. FLEXURAL TEST

The flexural strength and flexural modulus of the PLA-Epoxy and PLA-Epoxy-Alumina composites were evaluated using flexural testing, also known as three-point bending testing. By imitating real-world situations like beams or panels being subjected to external forces, this test sheds light on the materials' behaviour under bending stresses.

D. IMPACT TEST

To measure the impact resistance and toughness of the PLA-Epoxy and PLA-Epoxy-Alumina composites, impact testing, specifically the Charpy or Izod test, was carried out. The impact or shock absorption capacity of a material is measured by subjecting it to a series of abrupt loads.

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IV. RESULT AND DISCUSSION

A. DENSITY TEST

(a) (b) (c)

Fig. 2. (a) PLA-Epoxy Composite Sample for Density Test, (b) PLA -Epoxy -10% Alumina Composite for Density Test, (c) PLA-Epoxy-20% Alumina Composite for Density Test

Table: 1. Density Test

Density Test	
Sample Id	Density(g/CC)
PLA-Epoxy Composite	0.8518
PLA -Epoxy -10% Alumina Composite	0.8571
PLA-Epoxy-20% Alumina Composite	0.8387

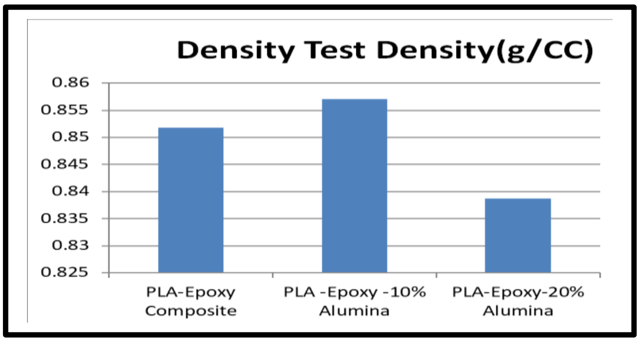
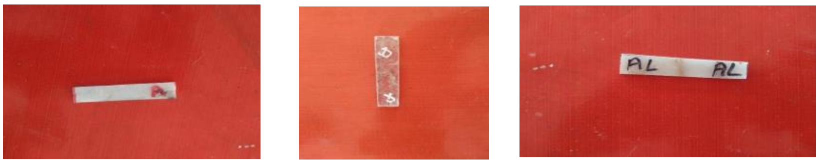


Fig. 3. Comparison Chart for Density Test

B. Hardness test



(a) (b) (c)

Fig. 4. (a) PLA-Epoxy Composite Sample for Hardness Test, (b) PLA -Epoxy -10% Alumina Composite for Hardness Test, (c) PLA-Epoxy-20% Alumina Composite for Hardness Test

Table: 2. Hardness Test

Hardness test	
Sample Id	Mean
PLA-Epoxy Composite	83.5
PLA -Epoxy -10% Alumina Composite	86.4
PLA-Epoxy-20% Alumina Composite	86.2

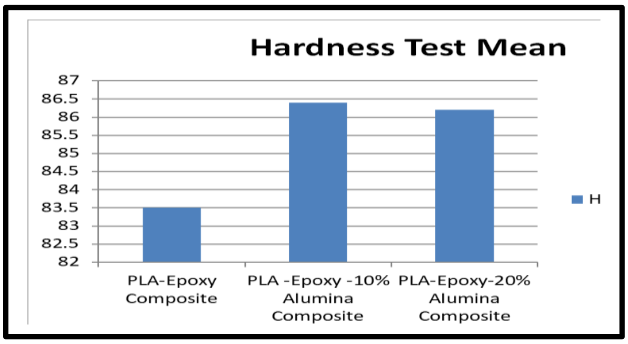


Fig. 5. Comparison Chart for Hardness Test

DOI: 10.17148/IARJSET.2023.10832

C. Tensile Test

(a) (b) (c)

Fig. 6. (a) PLA-Epoxy Composite Sample for Tensile Test, (b) PLA -Epoxy -10% Alumina Composite for Tensile Test, (c) PLA-Epoxy-20% Alumina Composite for Tensile Test

Table: 3. Tensile Test

Tensile Test	
Sample Id	Tensile strength (N/mm2)
PLA-Epoxy Composite	16.91
PLA -Epoxy -10% Alumina Composite	24.53
PLA-Epoxy-20% Alumina Composite	23.77

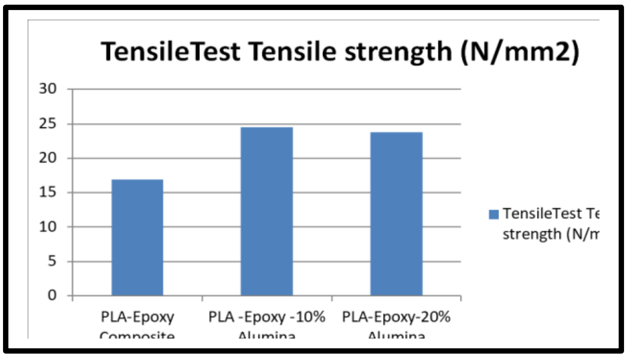


Fig. 7. Comparison Chart for Tensile Test

D. Flexural Test

(a) (b) (c)

Fig. 8. (a) PLA-Epoxy Composite Sample for Flexural Test , (b) PLA -Epoxy -10% Alumina Composite for Flexural Test , (c) PLA-Epoxy-20% Alumina Composite for Flexural Test

Table: 4. Flexural Test

Flexural Test	
Sample Id	Flexural strength (N/mm2)
PLA-Epoxy Composite	32.24
PLA -Epoxy -10% Alumina Composite	91.41
PLA- Epoxy-20% Alumina Composite	60.53

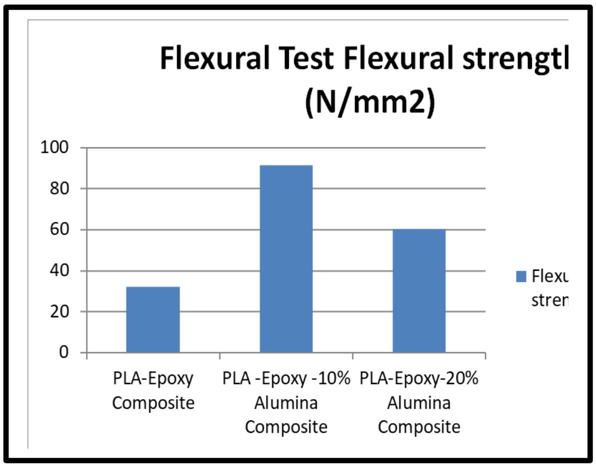


Fig. 9. Comparison Chart for Flexural Test

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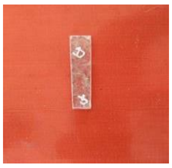
6.5 Impact Test

(a)


(b)


(c)

Fig. 10. (a) PLA-Epoxy Composite Sample for Impact Test, (b) PLA -Epoxy -10% Alumina Composite for Impact Test, (c) PLA-Epoxy-20% Alumina Composite for Impact Test

Table: 5. Impact Test

Impact Test	
Sample Id	Impact Energy (J)
PLA-Epoxy Composite	3.1
PLA -Epoxy -10% Alumina Composite	3.3
PLA-Epoxy-20% Alumina Composite	3.2

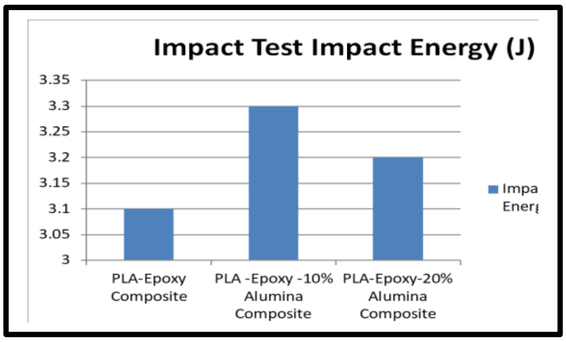


Fig. 11. Comparison Chart for Impact Test

V. CONCLUSION

Tensile, flexural, impact, and hardness strength for PLA with epoxy alone, epoxy with 10% alumina, and epoxy with 20% alumina showed the following: PLA and epoxy composites with alumina particles offer increased tensile strength. Tensile strength may rise greater with 10% alumina composite than 20%. Flexible Strength Alumina particles boost PLA epoxy composite flexural strength. The 10% alumina composite may have stronger flexural strength than the 20% composite. PLA and epoxy composites containing alumina particles better resist impact. More alumina (20%) may enhance impact strength than the composite with 20%. Alumina particles in PLA epoxy composites may increase hardness, which is good. A composite with 10% or 20% alumina may be harder than PLA with epoxy alone. Alumina enhances tensile, flexural, impact, and hardness in PLA composites with epoxy, according to studies. Higher alumina concentration (20%) improves mechanical characteristics. These findings propose strengthening PLA and epoxy composites with alumina. However, alumina particle size, distribution, and dispersion and composite processing procedures may impact the results. Important to remember specific results.

REFERENCES

[1]. Li, Z., et al. (2020). Mechanical and Thermal Properties of Poly(lactic acid)/Epoxy Resin Blend Composites. Polymers, 12(9), 2007.
[2]. Zhou, S., et al. (2020). Enhancing Mechanical Properties of Poly(lactic acid) by Incorporating Epoxy Resin. Polymers, 12(3), 648.
[3]. Murillo, E. A., et al. (2019). Effect of Alumina on the Properties of PLA-Epoxy Hybrid Composites. Polímeros: Ciência e Tecnologia, 29(2), e2019027.
[4]. Yew, M. C., et al. (2018). Mechanical Properties of Poly(lactic acid)/Epoxy Composites. Materials Today: Proceedings, 5(11), 22747-22754.
[5]. Singla, A., et al. (2017). A Review on Natural Fiber Reinforced Polymer Composite and Its Applications. International Journal of Polymer Science, 2017, 3526130.
[6]. Chen, M., et al. (2015). Mechanical and Morphological Properties of Polylactic Acid/Epoxy (PLA/EP) Blend Composites. Journal of Applied Polymer Science, 132(43), 42713.

ISO 3297:2007 Certified ⁜ Impact Factor 8.066 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 10, Issue 8, August 2023

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[7]. Zhai, L., et al. (2021). Reinforcement of Poly(lactic acid) Composites: A Review. Composites Part B: Engineering, 220, 109027.
[8]. Yu, S., et al. (2021). Mechanical Performance and Thermal Conductivity of Poly(lactic acid) Reinforced by Graphene Nanoplatelets. Journal of Polymers and the Environment, 29(4), 1474-1484.
[9]. Garg, A., et al. (2020). Investigation on Mechanical Properties of Poly(lactic acid)/Epoxy Resin Composite for Automotive Applications. Journal of Reinforced Plastics and Composites, 39(8), 306-318.
[10]. Naz, A., et al. (2019). Effect of Graphene Nanoplatelets on the Mechanical and Thermal Properties of Poly(lactic acid)/Epoxy Composites. Journal of Industrial Textiles, 49(4), 652-672.
[11]. Zhu, J., et al. (2018). Preparation and Properties of Poly(lactic acid)/Epoxy Resin Blend Reinforced with Nano-Silica. Journal of Applied Polymer Science, 135(22), 46352.
[12]. Chen, S., et al. (2017). Reinforcing Effects of Bamboo Fiber on Mechanical Properties and Crystallization Behaviors of Poly(lactic acid)/Epoxy Resin Composites. Polymer Composites, 38(3), 556-562.
[13]. Xu, Y., et al. (2016). The Mechanical Properties and Water Absorption Behavior of PLA/epoxy Reinforced by Cellulose Nanofibers. Journal of Applied Polymer Science, 133(17), 43248.
[14]. Arjmandi, R., et al. (2016). A Review on the Tensile Properties of PLA- Based Nanocomposites. Polymer Reviews, 56(4), 685-712.
[15]. Huda, M. S., et al. (2014). Mechanical, Thermal, and Biodegradable Properties of Poly(lactic acid) Reinforced with Lignocellulosic Fillers. Journal of Biobased Materials and Bioenergy, 8(2), 184-197.
[16]. Kundan, A., et al. (2014). A Review of the Recent Advances in Bio- Based Polylactic Acid (PLA) Composites. Composites Part B: Engineering, 56, 680-705.
[17]. Xiong, H., et al. (2012). Reinforcement Effect of Graphene Oxide on the Mechanical Properties of Poly(lactic acid). Journal of Applied Polymer Science, 126(S1), E289E297.
[18]. Grigoryeva, O. P., et al. (2011). Mechanical Properties of Polymer Composites Based on Polylactide Filled with Inorganic Nanoparticles. Journal of Applied Polymer Science, 121(6), 3176-3183.
[19]. Zhao, Q., et al. (2019). Mechanical and Thermal Properties of Polylactic Acid Composites Reinforced with Aluminum Nitride. Polymers, 11(6), 952.
[20]. Zeng, J., et al. (2017). Effect of Graphene Oxide Nanoplatelets on Mechanical and
[21]. Thermal Properties of Poly(lactic acid) Composites. Journal of Polymer Research, 24(11), 189.
[22]. Li, S., et al. (2017). Mechanical and Thermal Properties of Poly(lactic acid) Composites Reinforced by Short Carbon Fiber. Journal of Polymer Engineering, 37(6), 555-561.
[23]. Taz, S. H., et al. (2016). Mechanical and Thermal Properties of Poly(lactic acid)/Epoxy Composites: Effects of Epoxy Content and Curing Time. Polymer Bulletin, 73(10), 2677-2693.
[24]. Zhou, C., et al. (2015). Enhanced Mechanical Properties and Thermal Stability of Poly(lactic acid) Composites Reinforced with Functionalized Graphene Nanoplatelets. Composites Science and Technology, 119, 114-122.
[25]. Li, C., et al. (2014). Mechanical Properties of Poly(lactic acid) Composites Reinforced by Different Carbon Nanofillers. Journal of Applied Polymer Science, 131(5), 40054.

