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Mechanical Characterization of Banana Fiber Reinforced Polymer Matrix Composites

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ABSTRACT: This study thoroughly examines banana fiber-reinforced epoxy composites as sustainable alternatives to conventional materials. Banana fiber, sourced from banana plants' pseudo stems, offers remarkable mechanical properties and is abundant in regions where bananas are cultivated. When combined with epoxy resin, it exhibits mechanical characteristics suitable for various industrial applications. Emphasizing their potential in automotive, aerospace, construction, and consumer goods industries, the study underscores their lightweight, high-strength, high-flexible, and eco-friendly attributes. Ultimately, this research contributes significantly to advancing sustainable materials science, offering valuable insights into utilizing banana fiber for greener and more sustainable solutions.

KEYWORDS: Composite materials, Banana fiber, epoxy resin

I. INTRODUCTION

A composite material is a combination of two or more distinct materials with different physical or chemical properties. These materials work together to create a new material with improved properties such as strength, stiffness, and lightweight characteristics. Basically it is a combination of reinforcement and matrix. Here we are using banana fiber and epoxy resin an reinforcement and matrix. Common examples for composite material include fiberglass, carbon fiber, reinforced concrete, wood particle composite metal matrix composite, natural fibre reinforced polymer. Composites are widely used in aerospace, automotive, construction, and sporting goods industries due to their versatility and superior performance compared to individual materials. Natural fibers are derived from plants, animals, or minerals and have been used for thousands of years by humans for various purposes. These fibers offer a range of desirable properties such as breathability, comfort, biodegradability, and sustainability. Common natural fibers include cotton, wool, silk, jute, and banana. Cotton, sourced from the cotton tree. Silk, produced by silkworms. Jute, extracted from the jute plant's

Banana fiber, derived from the pseudo stem and leaves of banana plants, is a versatile natural fiber with a range of applications. Historically used in regions where bananas are cultivated, such as Southeast Asia and Africa, banana fiber has gained attention for its eco-friendly properties and potential for sustainable development. The process of extracting banana fiber involves stripping the outer layers of the pseudo stem or leaves, soaking them in water to soften the fibers, and then hand- or machine-processed to separate and refine the fibers. The resulting fiber is strong, durable, and biodegradable, making it suitable for various applications. This paper contain mechanical test like tensile test, flexural test, impact test.Due to its renewable nature and minimal environmental impact, banana fiber represents a sustainable alternative to synthetic fibers.

Polymer matrix is a key component in composite materials, providing structure and cohesion to the material. It consists of a polymer resin that binds together reinforcing fibers or particles. The polymer matrix can be made from various materials such as epoxy, polyester, vinyl ester, or phenolic resins. Epoxy resin is a versatile and durable material widely used in various applications such as construction, manufacturing, and crafts. It consists of two components, a resin and a hardener, which are mixed together to create a strong and adhesive compound. Epoxy resin is valued for its exceptional bonding strength, water resistance, and ability to create a glossy finish. It is commonly used for coating surfaces, laminating materials, and casting molds. Additionally, epoxy resin is popular in artistic creation such as

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creating jewellery, paintings, and sculptures due to its clear, glass-like appearance when cured. However, it is important to use epoxy resin in a well-ventilated area and follow safety precautions, as it can emit harmful fumes during the curing process.

II.LITERATURE REVIEW

1) Comprehensive Review of Advanced Composite Materials Based on Polymer Matrices, Author – Rachid Hsissoua ,Rajaa Seghiria, Zakaria Benzekria, Miloudi Hilalib, Mohamed Rafika, Ahmed Elharf. This review provides an insightful exploration of advanced composite materials, highlighting their diverse properties and applications across various polymer matrices. The meticulous examination of macromolecular matrices underscores the nuanced advantages they offer, while the discussion on formulation processes elucidates the intricate interplay between constituent materials. This resource undoubtedly serves as a valuable guide for researchers, engineers, and practitioners, facilitating innovation and advancement in polymer-based composites.

2) Exploring the Versatility of Composite Materials in Biomedical Applications, Author - Munonyedi Kelvin Egbo
this paper offers a thorough exploration of the expanding role of composite materials in biomedical applications, emphasizing their customizable properties to meet the diverse needs of the field. The overview of composite materials, coupled with insights into their manufacturing processes, lays a solid foundation for understanding their potential in biomedicine. The discussion on applications, from orthopedic implants to drug delivery systems, highlights the versatility of composites in addressing various medical challenges. Furthermore, addressing considerations like biocompatibility and sterilization underscores the importance of integrating composites into medical devices effectively. Overall, this comprehensive review is poised to drive further research and innovation in leveraging composite materials for biomedical advancements, ultimately improving patient care and treatment outcomes.

3) Advancements in Natural Fiber Reinforced Green Composites: Mechanical Responses and Commercial Applications Author - Sripathi Dev Sharma Kopparthy , Anil N. Netravali this review offers a thorough exploration of natural fiber reinforced green composites (NFRGCs) and their growing significance in sustainable engineering. By utilizing biodegradable resins, these composites provide promising solutions for reducing environmental impact across various industries. The categorization of NFRGCs based on fiber-resin combinations and mechanical properties offers valuable insights into their diversity and applicability. Additionally, the review delves into key research areas, highlighting advancements in green composite technology and serving as a valuable resource for researchers, engineers, and manufacturers. By inspiring innovation and guiding the development of next-generation NFRGC-based products, this review contributes to the advancement of sustainable structural materials. Overall, it provides a comprehensive outlook on the potential of NFRGCs, serving as a valuable reference for material selection and advanced research in the field of structural materials.

4) Utilization of Banana Fiber: From Waste to Value-Added Products and Polymer Reinforcement. Author - R.W.I.B. Priyadarshana, P.E. Kaliyadasa, S.R.W.M.C.J.K. Ranawana, K.G.C. Senarathna. It's fascinating to learn about the extensive potential of banana fiber, which is often overlooked as waste after harvesting the fruit. The review highlights the various innovative products that can be derived from banana fiber, spanning from textiles and paper to packaging materials and handicrafts. Additionally, its utilization as a reinforcement in polymeric materials showcases its ability to enhance mechanical properties and sustainability in composite materials. This review not only emphasizes the multifaceted benefits of utilizing banana fiber but also underscores the opportunities for sustainable waste management and the creation of eco-friendly materials with diverse industrial applications. It's encouraging to see such efforts driving research and innovation towards maximizing the potential of this renewable resource for addressing environmental challenges and promoting sustainable development.

5)Advancing Thermoset Technology: The Rise of Multifunctional Epoxy Resins
Author - JaworskiC.Capricho ,BronwynFox ,NisharHameed. The exploration of multifunctional epoxy resins marks a significant step forward in thermoset technology, catering to evolving industry demands and enabling innovative applications. This paper delves into desirable properties such as toughness, flexibility, rapid curing potential, self-healing ability, reprocessability, recyclability, high-temperature stability, and conductivity, which have immense potential for revolutionizing thermosetting polymers. By synthesizing epoxy resins with these attributes, researchers aim to achieve significant advancements in thermoset materials, addressing emerging industry requirements and facilitating the development of novel applications. The comprehensive examination of multifunctional epoxy resins presented in this paper aims to stimulate further research and development, propelling the evolution of thermoset materials towards greater versatility, sustainability, and performance.

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6) Development and Characterization of Hybrid Bio-Composites Reinforced with Tamarind Seed Powder and Banana Fiber. Author - R. Karthikeyan, C. Shilaja, A. Sivalingam, P. Gopinath. The study highlights the utilization of natural resources like tamarind seed powder and banana fiber as reinforcement materials in epoxy resin matrix to create hybrid bio-composites. Through systematic experimentation, significant improvements in mechanical properties and water absorption capabilities were observed in the fabricated hybrid bio-composites. This underscores the potential of these materials for various applications, showcasing enhanced performance and resistance to water absorption. Overall, the findings contribute to the growing research on sustainable materials, emphasizing the viability of utilizing natural resources in composite materials for both environmental and engineering applications.

6)Fabrication and Characterization of Non-Woven Banana Fiber Reinforced Epoxy Composites. Author - S.P. Gairola, Y.K. Tyagi, Brijesh Gangil, Ankush Sharma. The article demonstrates the fabrication and characterization of non-woven banana fiber reinforced epoxy composites, showcasing their potential for diverse engineering applications. The study highlights how varying the fiber content influences the physical and mechanical properties of the composites, with notable improvements observed in tensile strength, flexural strength, impact strength, and hardness. By optimizing the fiber content, it's possible to tailor the mechanical properties of the composites to meet specific requirements

III.METHODOLOGY

3.1 MATERIALS.

The materials used in this experiment for fabrication are banana fibers, epoxy resin and hardener. The banana fibers are collected from Coimbatore district, Tamil Nadu, India. The epoxy resin and the hardener are purchased from a local dealer in Kozhikode district, Kerala India.

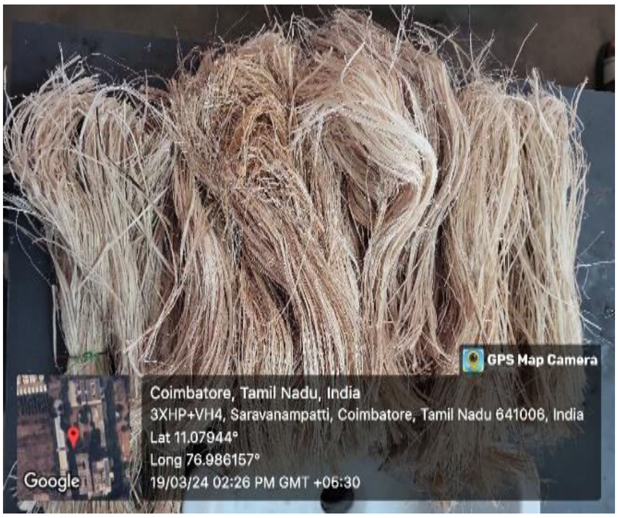

Fig 3.1 processed banana fiber

Fig 3.2 epoxy resin and hardener.

3.2. PREPARATION OF COMPOSITES

The preparation process is by applying pressure using compression moulding. The fiber mats of uniform thickness were prepared from banana fibers of 30cm length. The composite consists of 2 layers. The mats were impregnated with epoxy resin. Hardener is mixed with epoxy resin to give effective binding. Initially the banana fibers are dried under the hot sun to remove the moisture for more than 24 hours. The banana fibers are mounted on the base plate which is placed on the table, and then it is filled with the epoxy resin. Before the resin gets dried up the second layer must be mounted on it. The specimen is then pressed at a temperature of 32°C, under the pressure of 6MPa, and the average relative humidity of 65%. Four such samples were prepared with difference in weight percentage of matrix and reinforcement

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hSl	Composite	Banana fiber (wt %)	Epoxy resin (wt%)
1	C1	70	30
2	C2	75	25
3	C3	80	20
4	C4	85	15

Table 3.1 weight percentage of matrix and reinforcement

3.3. MECHANICAL TESTING

3.3.1. Tensile test

Tensile strength is a fundamental mechanical property that measures a material's ability to withstand pulling forces without breaking. It is crucial in engineering for assessing the suitability of materials in applications subjected to tension. Determined through standardized testing, tensile strength provides insights into a material's structural integrity and durability. Factors influencing tensile strength include material composition, microstructure, and processing techniques. The tensile test is performed on the Universal Testing Machine (UTM) and test specimens were prepared as per the ASTM D3039 standard.

Fig 3.3 universal testing machine

3.3.2. Flexural test

Flexural strength assesses a material's resistance to bending without fracturing. It's crucial in structural engineering for designing components subjected to bending loads. Determined through bend tests, flexural strength indicates the maximum stress a material can withstand before failure. Factors influencing flexural strength include material composition, processing techniques, and environmental conditions. High flexural strength materials are preferred for load-bearing structures like beams and panels in construction, aerospace, and automotive industries. Understanding flexural strength aids in material selection and structural design for optimal performance and safety. The flexural specimens are prepared as per the ASTM D790 standards and the test has been carried out using the same UTM

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3.3.3. Impact test

The impact test evaluates a material's ability to withstand sudden loading conditions. It's crucial for assessing toughness and durability, especially in metals and polymers. The testing methods include Charpy tests, measuring energy absorbed during fracture. Factors affecting impact resistance include material composition, microstructure, and temperature. Impact testing is essential in automotive, aerospace, and construction industries for designing safety-critical components. Understanding a material's impact resistance helps ensure product reliability and user safety.

Fig 3.4 impact tester

IV. RESULT AND DISCUSSION

4.1 TENSILE TEST ANALYSIS

The banana fiber reinforced composite specimen are prepared with different volume fractions and tested on the dak system inc's universal testing machine (UTM). The typical stress versus elongation graph generated directly from the machine for tensile test. The tensile strength of the different combinations of the banana fiber epoxy composites are presented below. From the figure it has been clearly indicated that the 85% banana fiber and 15% epoxy resin polymer composites shows the maximum elongation and this ratio performing better than the other composite combinations tested

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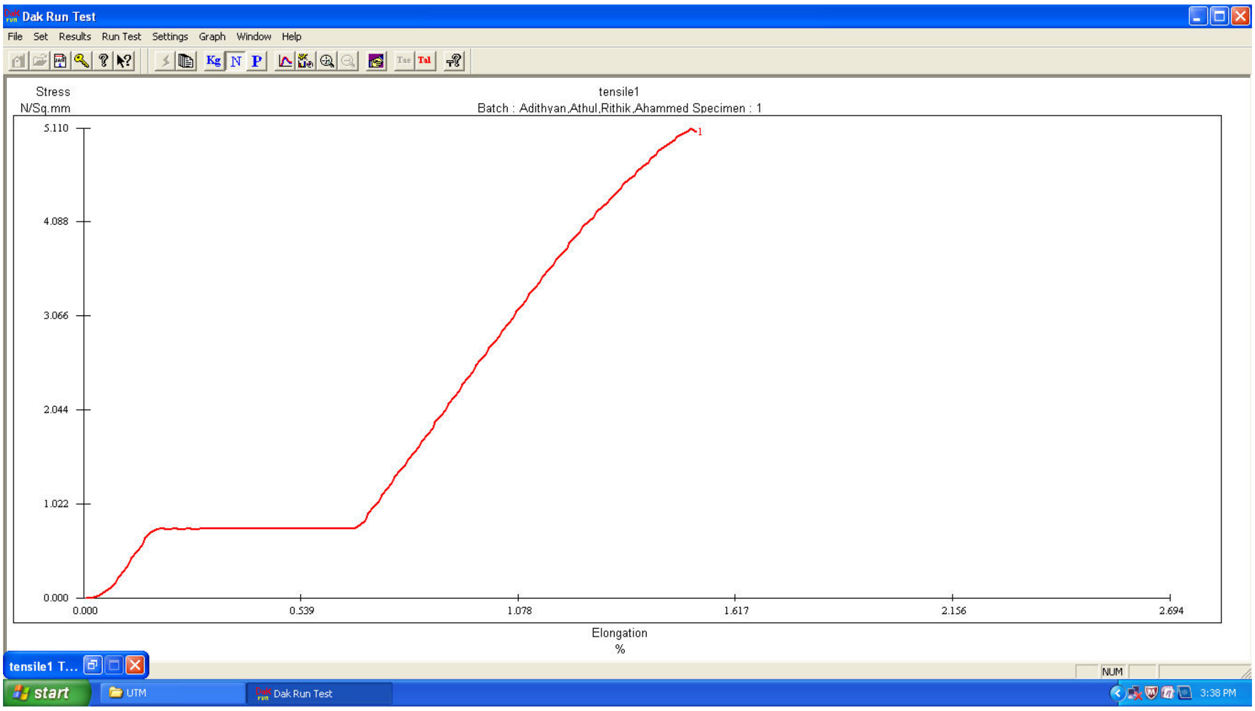

fig 4.1 stress-elongation curve of specimen C1

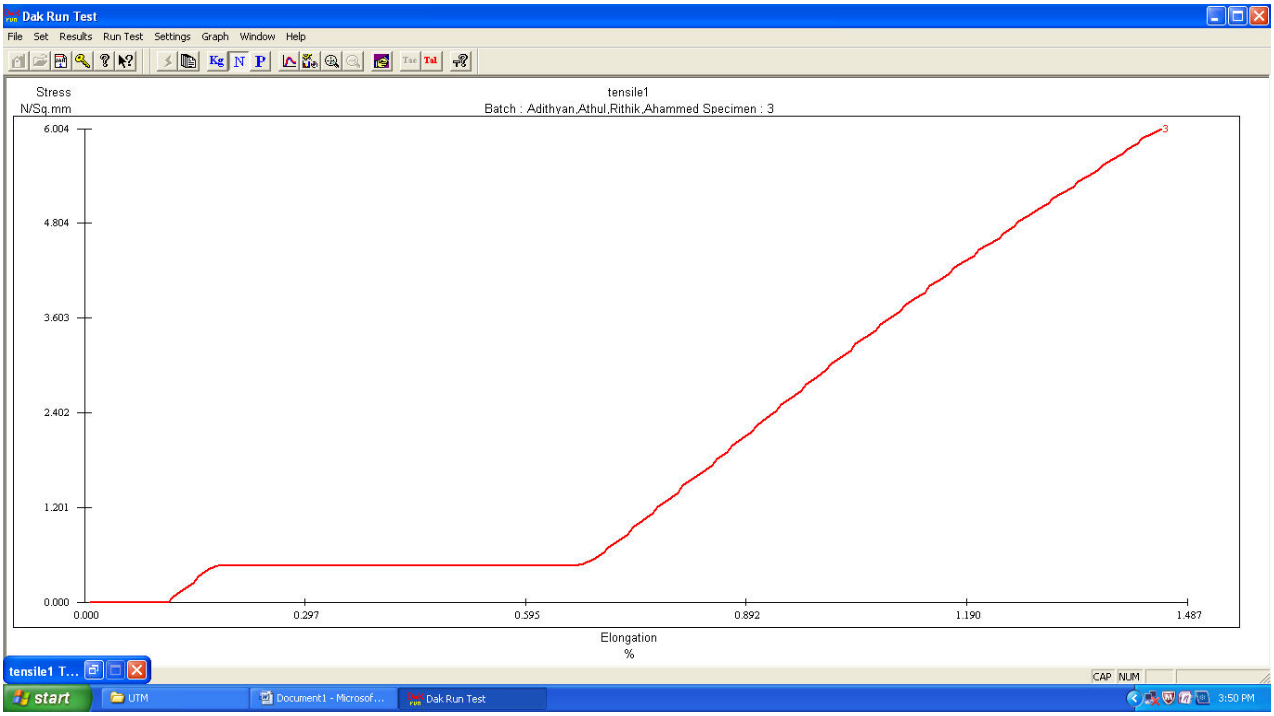

fig 4.2 stress-elongation curve of specimen C2

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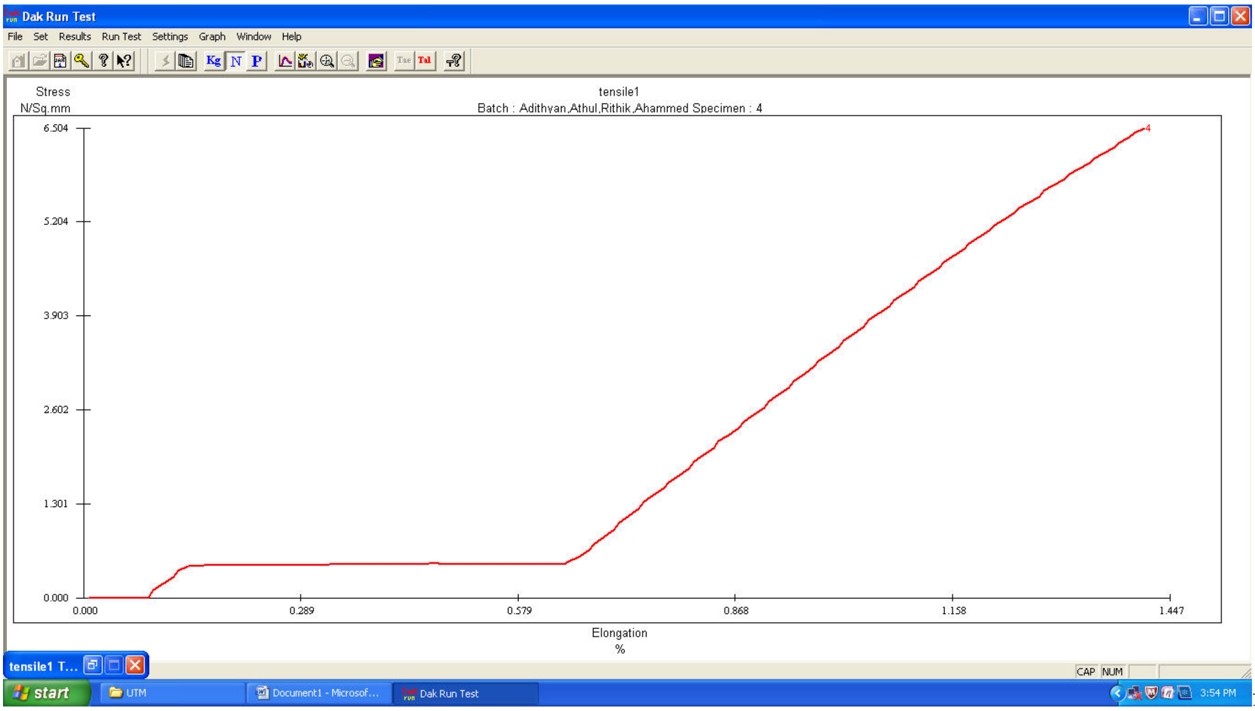

fig 4.3stress-elongation curve of specimen C3

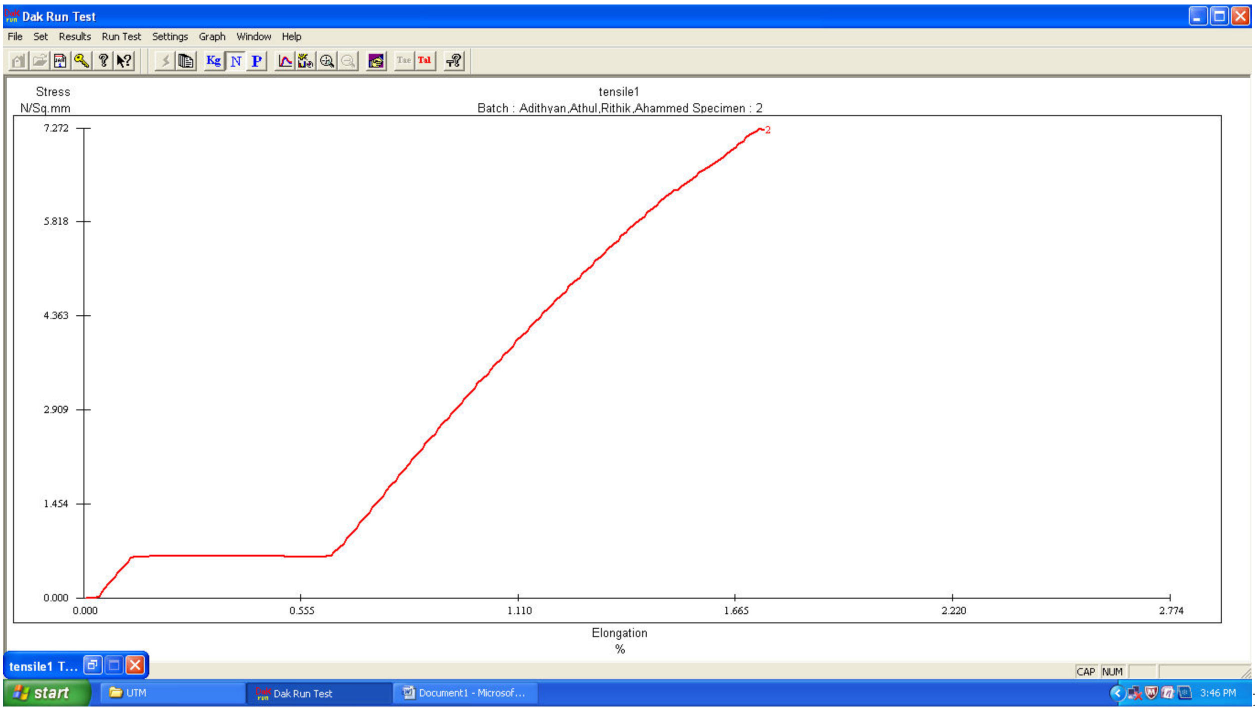

fig 4.4 stress-elongation curve of specimen C4

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4.2 FLEXURAL TEST ANALYSIS

The flexural properties of four different proportion of banana fiber mix with epoxy resin composite are shown below from this fig shown below it is clear that the specimen with 80% banana fiber and 20% epoxy composite has maximum flexural stress of 26.7257 N/Sq.mm comparing with other three proportion

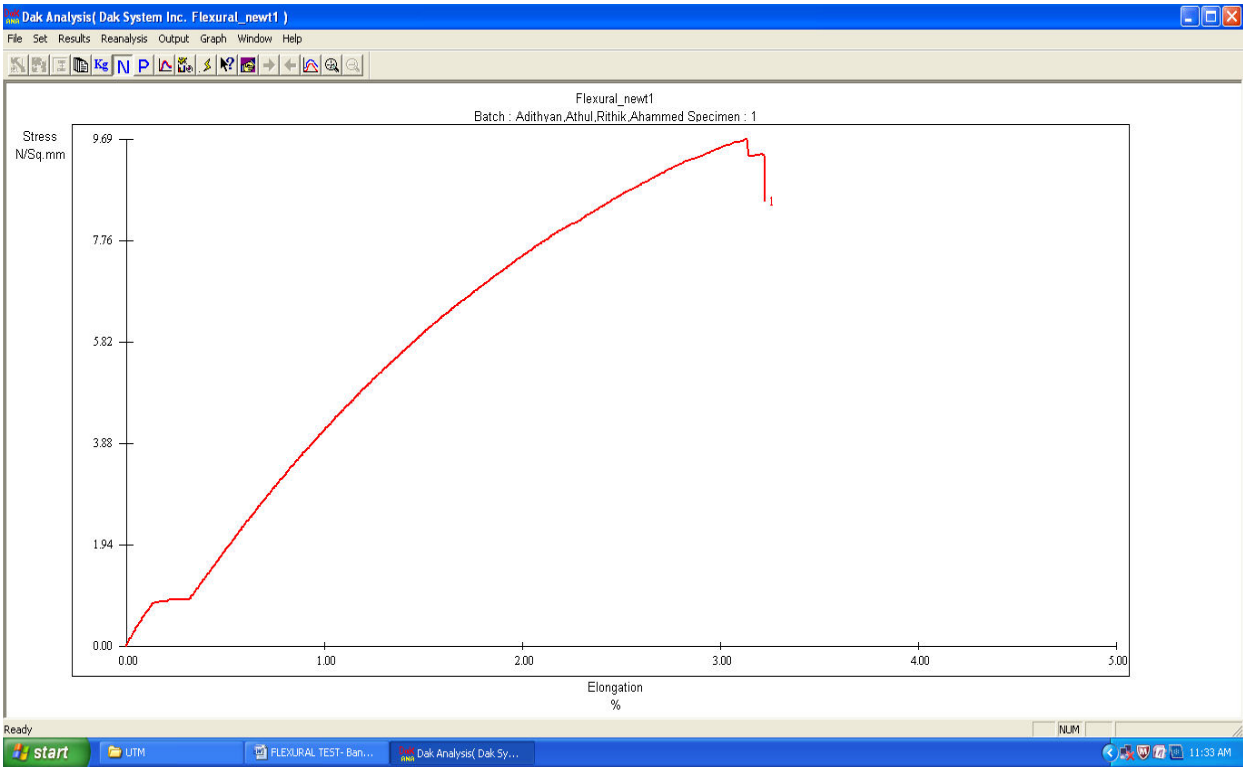

fig 4.5 stress-elongation curve of specimen C1

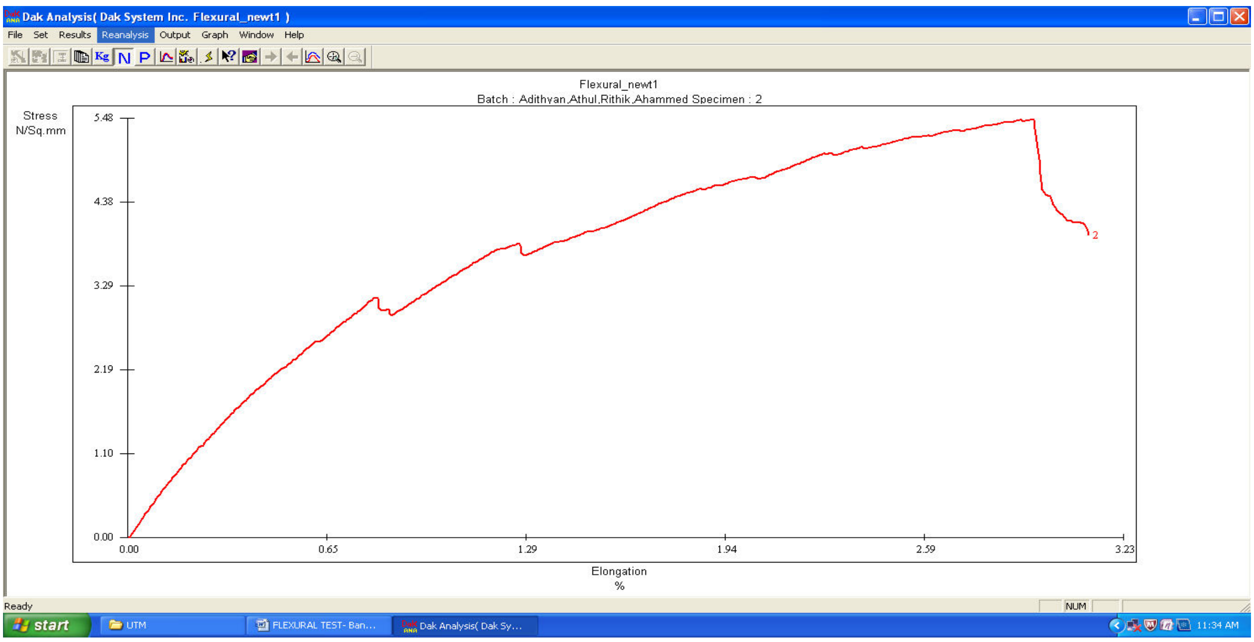

fig 4.6 stress-elongation curve of specimen C2

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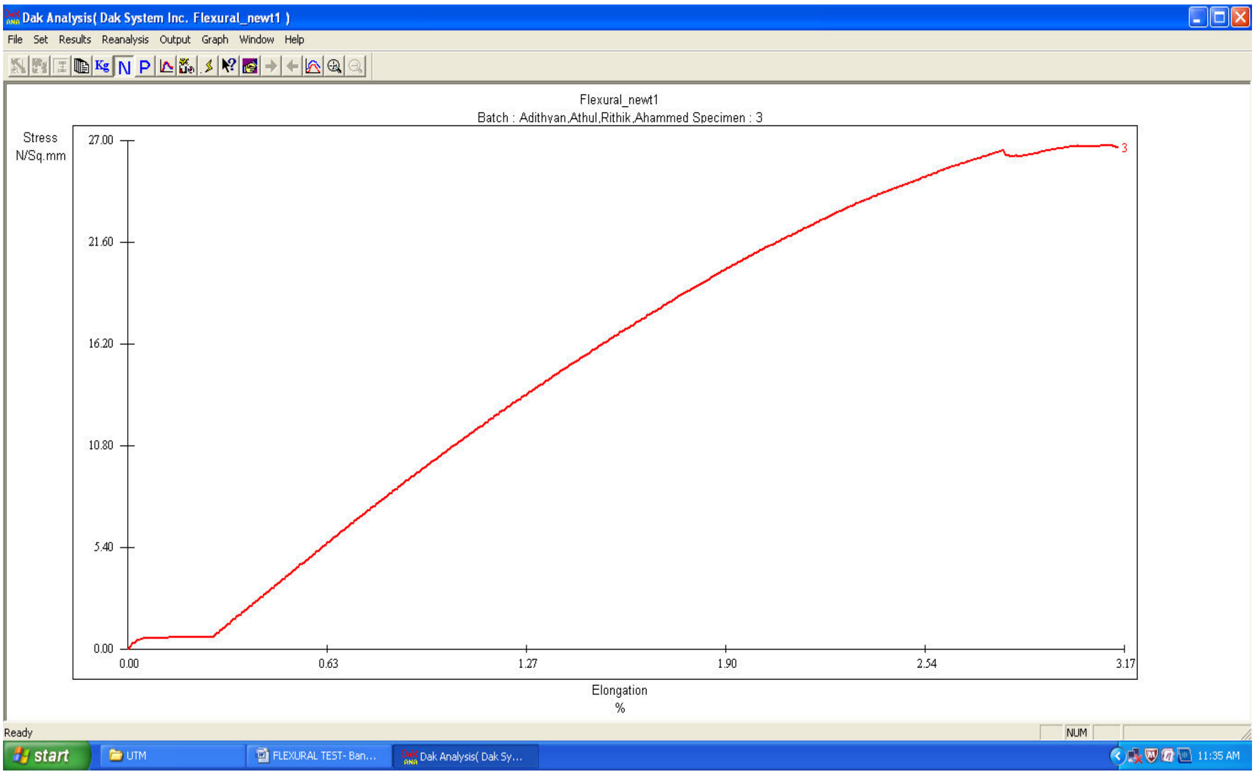

fig 4.7 stress-elongation curve of specimen C3

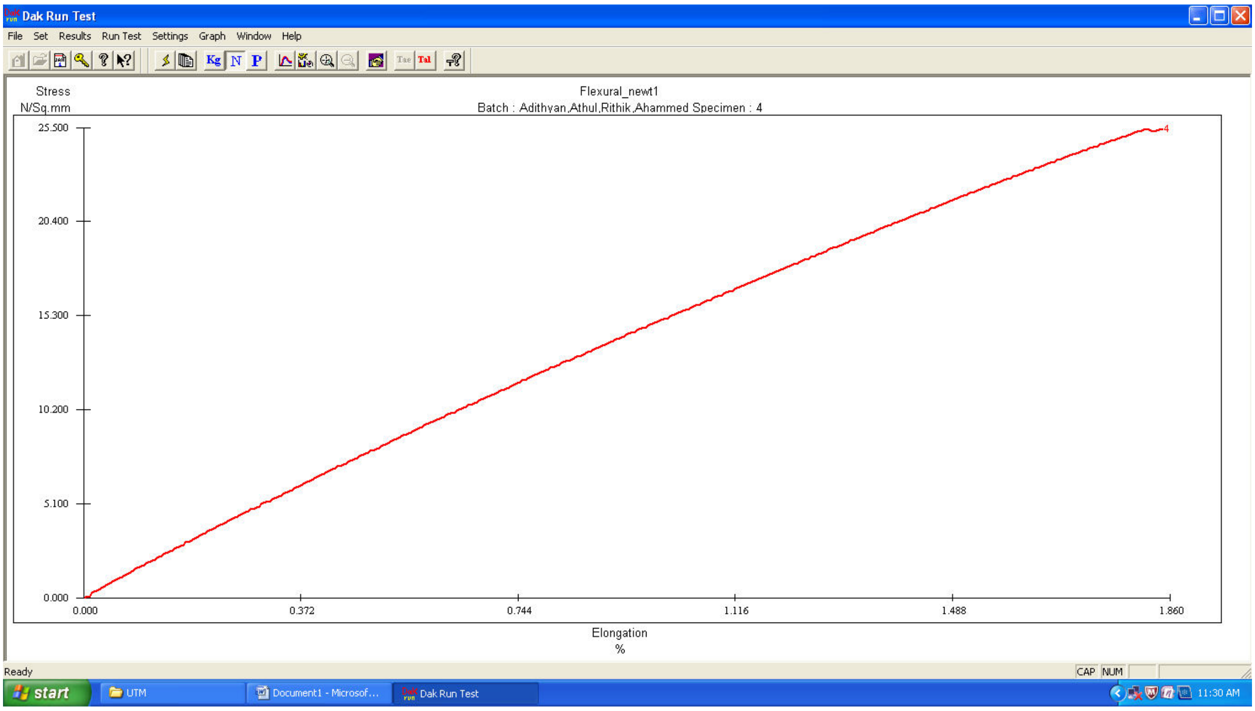

fig 4. 8 stress-elongation curve of specimen C4

4.3 Impact strength analysis

For analysing the sudden load carrying capacity of the banana fiber reinforced composite samples an impact test is carried out. The energy loss is found out on the results obtained from the Charpy impact testing machine. The impact

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strength comparison of the different combination of banana fiber reinforced polymer composites is presented in figure below from the figure it can be observed that, the 85% banana fiber and 15% epoxy resin polymer composites are performing better than the other composite combinations tested which can hold the impact load of 1.29 Joules

No of reading	C1	C2	C3	C4
1	0.29	0.48	0.63	1.29
2	0.20	0.32	0.45	1.03

Table 4.1. impact strength comparison

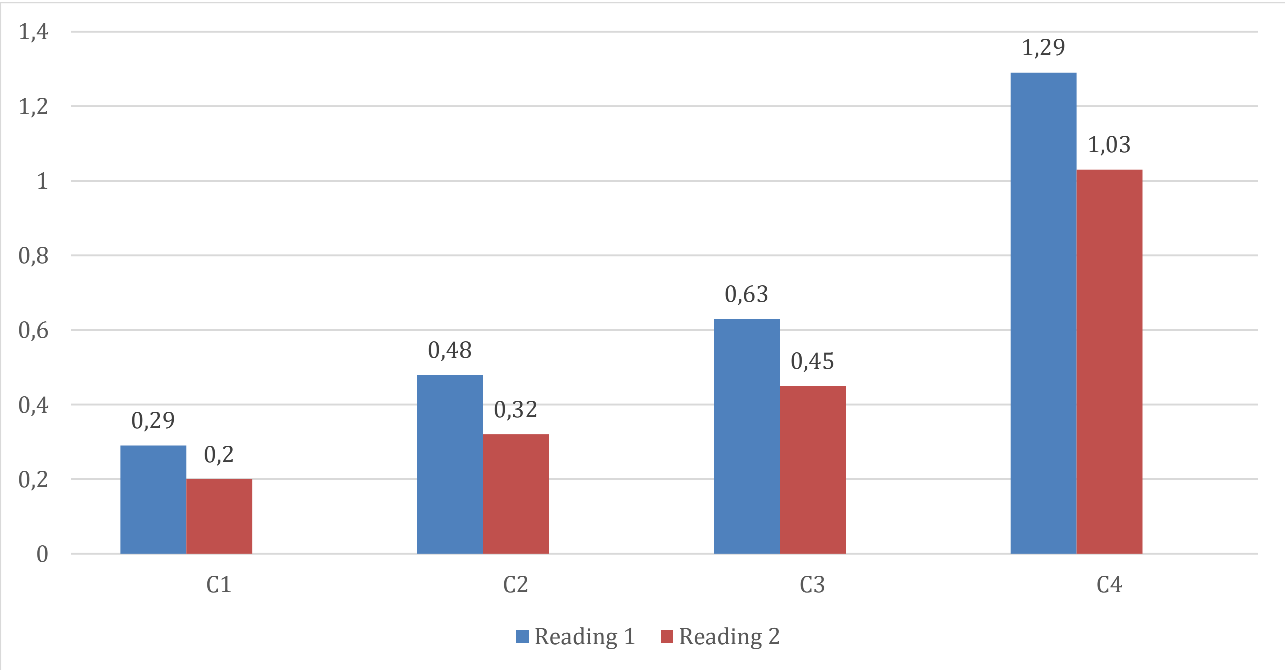

Fig 4.9 Graphical representation of impact strength

VI. CONCLUSION

In conclusion, the mechanical characterization of banana fiber mixed with epoxy resin reveals promising results across various tests including tensile, flexural, and impact assessments. The combination demonstrates notable strength, flexibility, and impact resistance, suggesting its potential as a viable alternative material in various industrial applications. Further research could explore optimization techniques to enhance its mechanical properties and expand its practical use in engineering and manufacturing fields.

In the experimental study, the banana fibers are used as a reinforcing material with epoxy matrix, the composites have been fabricated and physical characteristics of these materials are examined. From the experiment, the following conclusions have been drawn.
The maximum tensile stress is 7.2705 N/Sq.mm which is hold by the 85% banana fiber and 15% epoxy resin composites. The maximum flexural stress is 26.7257 N/Sq.mm and this is hold by 80% banana fiber and 20% epoxy

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resin composites samples. The maximum impact strength hold by the 85% glass fiber and 15% epoxy resin composites is 1.29 Joules. From the experimental study it can be suggested that, the 85% banana fiber and 15% epoxy resin composite materials can withstand the higher loads when compared to the other combinations and used as an alternate material for conventional fiber reinforced polymer composites.

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