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Fabrication and Investigation of the Mechanical Properties of Jute Fiber Reinforced Polymer Matrix Composites

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ABSTRACT: The study delves into jute fiber-reinforced epoxy composites, presenting them as sustainable alternatives to conventional materials. Derived from banana plants' pseudo stems, jute fiber boasts impressive mechanical properties and is abundant in regions where jute's are cultivated. When combined with epoxy resin, it demonstrates mechanical characteristics suitable for various industrial applications. The research highlights their potential across automotive, aerospace, construction, and consumer goods industries, emphasizing their lightweight, high-strength, high-flexibility, and eco-friendly attributes. By contributing to sustainable materials science, this study offers valuable insights into harnessing banana fiber for greener and more sustainable solutions in diverse sectors.

KEYWORDS: Composite materials, jute fiber, epoxy resin

I.INTRODUCTION

Recent interest in composite materials has led to exploration of natural fiber reinforcement, notably jute, due to its strength and eco-friendliness. Combining jute fibers with epoxy resin offers potential for enhanced mechanical properties. Fabrication involves impregnating fibers with resin and compression molding. Testing methods assess properties like strength and durability. This research aims to optimize fabrication, understand fiber effects, and explore applications of jute-epoxy composites. Sustainability is a key focus, aligning with global efforts. Overall, this work advances composite science and offers sustainable material solutions.

Composite materials are advanced materials engineered from two or more constituent materials with distinct physical or chemical properties. By combining these materials, composites offer unique and often superior properties compared to their individual components. Common constituents include fibers, such as glass, carbon, or aramid, embedded in a matrix, often a polymer resin. The fibers provide strength and stiffness, while the matrix binds them together and transfers loads. Composites are widely used in aerospace, automotive, marine, and construction industries due to their lightweight nature, high strength-to-weight ratio, corrosion resistance, and versatility. Examples include carbon fiber composites in aircraft and fiberglass reinforced plastics in boat hulls.

Jute fiber, extracted from the Corchorus plant, is a natural and eco-friendly material widely used in composite materials fabrication. Known for its high tensile strength, low cost, and biodegradability, jute fiber is an attractive reinforcement option in composite manufacturing. When combined with matrices like epoxy resin, jute fibers enhance the mechanical properties of the resulting composite, offering improved strength, stiffness, and impact resistance. This makes jute fiber composites suitable for a range of applications, including automotive components, construction materials, and consumer goods. Additionally, jute fibers' renewable and sustainable nature aligns with the growing demand for environmentally friendly materials in various industries.

Epoxy resin is a versatile and widely used thermosetting polymer in the fabrication of composite materials. It is renowned for its exceptional mechanical properties, including high strength, excellent adhesion, and resistance to chemicals and corrosion. When combined with reinforcement materials such as fibers (e.g., carbon, glass, or jute),

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epoxy resin forms a composite with enhanced mechanical performance and durability. Its low viscosity allows for easy impregnation of fibers, ensuring uniform distribution and optimal bonding within the composite structure. Epoxy resin composites find applications across diverse industries, including aerospace, marine, automotive, electronics, and construction, where lightweight and high-performance materials are essential for various structural and functional components.

II.LITERATURE REVIEW

1)A review on the tensile properties of natural fibre reinforced polymer composites Author:H Wang, N Pattarachaiyakoop and M Trada .This paper provides a comprehensive review of the tensile properties of natural fiber-reinforced polymer composites (NFRPCs), highlighting their increasing popularity among researchers and engineers. Natural fibers, prized for their low cost, good mechanical properties, and eco-friendliness, are replacing conventional fibers like glass and carbon in polymer composites. The interfacial adhesion between the matrix and fibers significantly influences the tensile properties, with chemical modifications enhancing bonding. Tensile strength generally peaks at an optimum fiber content before decreasing, while Young's modulus increases with fiber loading. The study also discusses mathematical modeling, with the rule of mixture and Halpin-Tsai equation proving effective in predicting composite properties.

2)Studies on Material and Mechanical Properties of Natural Fiber Reinforced Composites.Author:Dr P V Senthiil, Aakash Sirssht .Natural fibers have a rich history spanning over 3,000 years, with recent applications focusing on their combination with plastics to create composite materials. Various types of natural fibers, including flax, hemp, jute, and bamboo, have been extensively studied for their suitability in plastic composites. This work emphasizes the fabrication of polymer matrix composites using abundant natural fibers such as jute, coir, and hay. Engineering analysis is crucial for applying these composite materials to structures, with tests like flexural, hardness, water absorption, and wear resistance conducted to evaluate their properties. The goal is to utilize these natural fiber-reinforced polymer composites in automotive seat shell manufacturing, leveraging their desirable characteristics.

3) Natural Fiber Reinforced Composite Material for Product Design: A Short Review M. A. Azman , M. R. M. Asyraf ,A. Khalina,Michal Petr ˚u,C. M. Ruzaidi S. M. Sapuan ,W. B. Wan Nik M. R. Ishak ,R. A. Ilyas and M. J. Suriani
Natural fibers have attracted great attention from industrial players and researchers for the exploitation of polymer composites because of their “greener” nature and contribution to sustainable practice. Various industries have shifted toward sustainable technology in order to improve the balance between the environment and social and economic concerns. This manuscript aims to provide a brief review of the development of the foremost natural fiber-reinforced polymer composite (NFRPC) product designs and their applications. The first part of the manuscript presents a summary of the background of various natural fibers and their composites in the context of engineering applications. The behaviors of NFPCs vary with fiber type, source, and structure. Several drawbacks of NFPCs, e.g., higher water absorption rate, inferior fire resistance, and lower mechanical properties, have limited their applications. This has necessitated the development of good practice in systematic engineering design in order to attain optimized NRPC products. Product design and manufacturing engineering need to move in a mutually considerate manner in order to produce successful natural fiber-based composite material products. The design process involves concept design, material selection, and finally, the manufacturing of the design. Numerous products have been commercialized using natural fibers, e.g., sports equipment, musical instruments, and electronic products. In the end, this review provides a guideline for the product design process based on natural fibers, which subsequently leads to a sustainable design.

4) Natural fiber reinforced composites: Sustainable materials for emerging applications. Author:Muhammad Yasir Khalid ,Al Rashid b, Zia Ullah Arif a,Waqas Ahmed a, Hassan Arshad a,Asad Ali Zaidi c.The manuscript discusses the growing interest in natural fiber-reinforced polymer composites (NFRPCs) due to their eco-friendly characteristics and their role in sustainable practices. It highlights the diverse applications of NFRPCs across various industries and emphasizes the importance of systematic engineering design to overcome their drawbacks. The design process involves concept design, material selection, and manufacturing, aiming for optimized NFRPC products. Despite challenges like water absorption and inferior fire resistance, NFRPCs have been successfully utilized in products such as sports equipment, musical instruments, and electronics. Ultimately, the review provides a guideline for sustainable product design based on natural fibers

5)Natural fiber–reinforced composites: A review on material, manufacturing,and machinability Author:Amirhossein Lotfi1 , Huaizhong Li1 , Dzung Viet Dao1 and Gangadhara Prusty The growing interest in natural fiber–reinforced composites (NFRCs) stems from their cost-effectiveness, biodegradability, and eco-friendly nature, alongside decent

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mechanical properties. However, widespread adoption faces challenges in manufacturing complexity, limited machinability knowledge, and susceptibility to defects. This review delves into NFRCs, highlighting manufacturing techniques, mechanical property assessment, applications, and machinability considerations. It addresses challenges like machining-induced damage, the impact of fiber properties, and essential machining parameters. By providing insights into these aspects, the article aims to equip readers with a foundational understanding of NFRC technologies and their current research landscape.

III.METHODOLOGY

3.1 MATERIALS.

The materials used in this experiment for fabrication are jute fibers, epoxy resin and hardener. The jute 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 jute fiber

Fig 3.2 epoxy resin and hardener.

3.2. PREPARATION OF COMPOSITES

The preparation process involves compression moulding, wherein uniform fiber mats are crafted from 30cm jute fibers. These mats, constituting two layers, are impregnated with epoxy resin for reinforcement. The resin is mixed with hardener to ensure effective binding. Prior to assembly, the jute fibers undergo sun-drying for over 24 hours to eliminate moisture. The fibers are then positioned on a base plate atop a table, and filled with epoxy resin. Subsequently, the second layer is added before the resin solidifies. Compression ensues at 32°C, 6MPa pressure, and 65% average relative humidity. Four samples are crafted, each varying in the weight percentage of matrix and reinforcement.

hSl	Composite	Jute 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

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3.3. MECHANICAL TESTING

3.3.1. Tensile test

Tensile strength, a pivotal mechanical characteristic, gauges a material's resilience against pulling forces, crucial for evaluating its viability in tension-prone applications. This property, established via standardized testing, offers crucial insights into a material's structural robustness and longevity. Material composition, microstructure, and fabrication methods are key factors impacting tensile strength. The Universal Testing Machine (UTM) is employed to conduct the tensile test, adhering to the ASTM D3039 standard for specimen preparation. Additionally, modulus of elasticity, fracture toughness, and ductility are complementary metrics often evaluated alongside tensile strength to comprehensively assess material performance and suitability for diverse engineering applications.

Fig 3.3 universal testing machine

3.3.2. Flexural test

Flexural strength evaluates a material's ability to resist bending without breaking, pivotal in structural engineering for designing components exposed to bending loads. It's determined through bend tests, indicating the maximum stress a material can endure before failure. Material composition, processing techniques, and environmental factors influence flexural strength. High flexural strength materials are favored for load-bearing structures in construction, aerospace, and automotive sectors. Understanding flexural strength aids in material selection and structural design optimization for enhanced performance and safety. Flexural specimens are meticulously prepared following ASTM D790 standards, with tests conducted utilizing the Universal Testing Machine (UTM) to ensure consistent and accurate evaluations.

3.3.3. Impact test

The impact test is vital for determining a material's capacity to endure abrupt loading, particularly significant in assessing toughness and longevity, notably in metals and polymers. Utilizing methods such as Charpy tests, this evaluation quantifies the energy absorbed during fracture. Material composition, microstructure, and temperature are pivotal factors influencing impact resistance. In automotive, aerospace, and construction sectors, impact testing plays a crucial role in designing components critical for safety. A thorough comprehension of a material's impact resistance is indispensable for guaranteeing product dependability and user well-being, ensuring that safety-critical components meet stringent performance standards.

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Fig 3.4 impact tester

IV.RESULT AND DISCUSSION

4.1 TENSILE TEST ANALYSIS

The study investigates the tensile properties of jute fiber reinforced composite specimens with varying volume fractions using Dak System Inc's Universal Testing Machine (UTM). The stress versus elongation graph directly from the machine illustrates the performance of different combinations. Notably, the composite with 85% jute fiber and 15% epoxy resin polymer exhibits the highest elongation, indicating superior mechanical behavior compared to other combinations tested. This finding suggests that optimizing the volume fraction of jute fiber and epoxy resin can enhance the tensile strength and elongation properties of the composite material, potentially offering insights for applications in various industries requiring robust yet flexible materials.

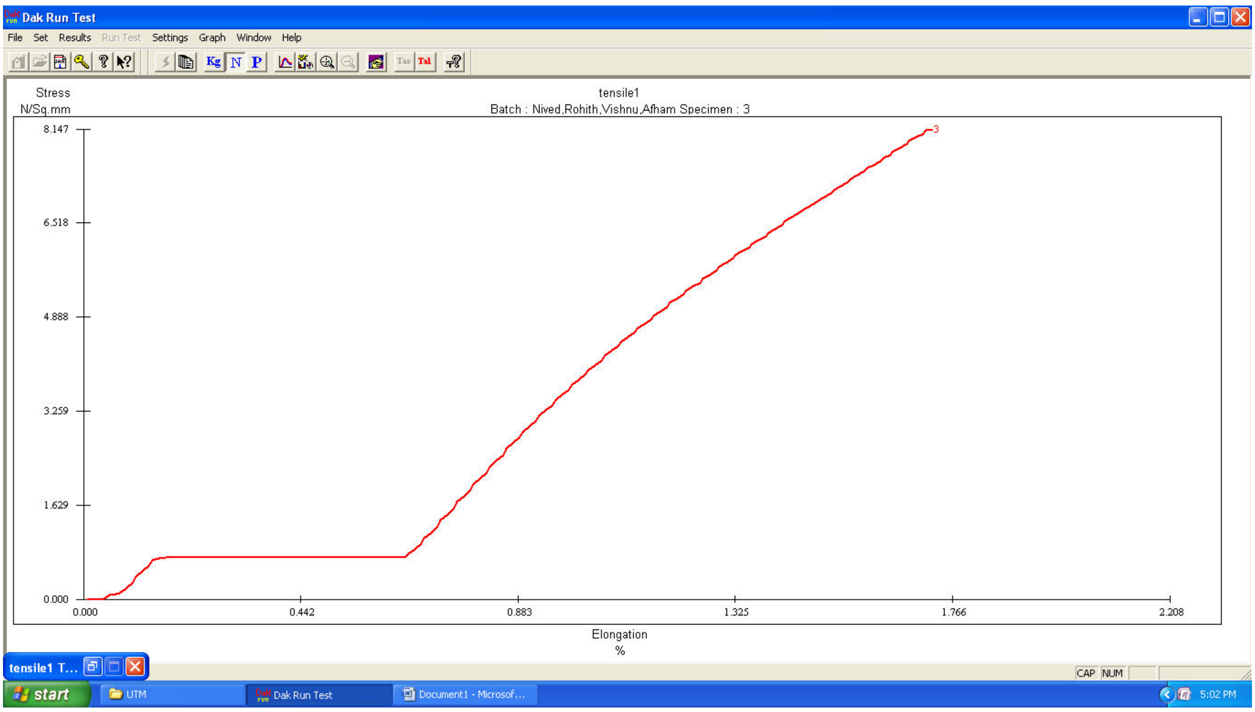

fig 4.1 stress-elongation curve of specimen C1

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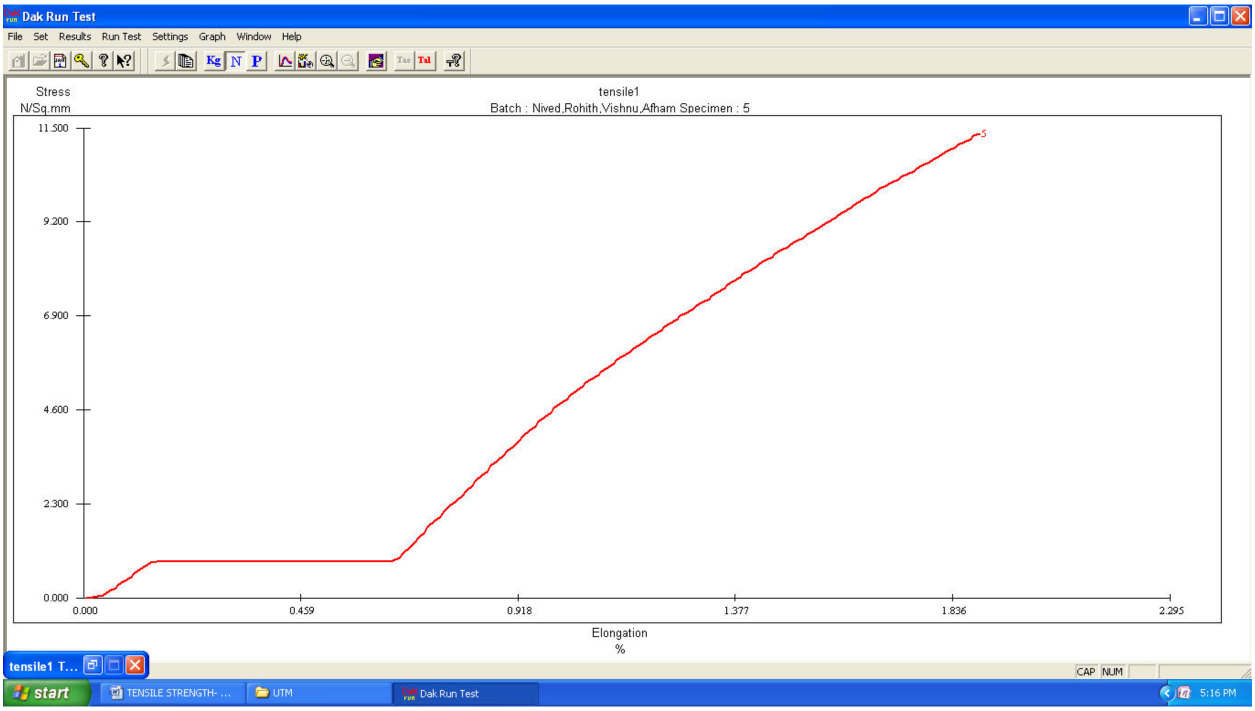

fig 4.2 stress-elongation curve of specimen C2

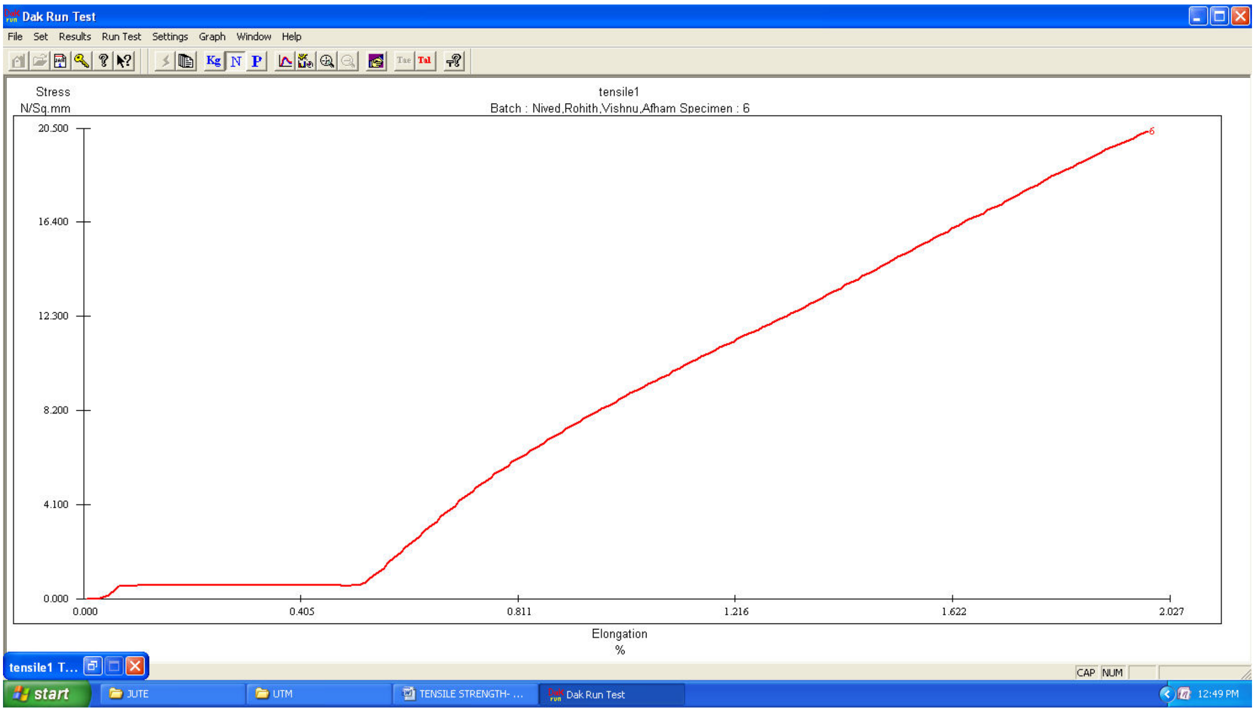

fig 4.3stress-elongation curve of specimen C3

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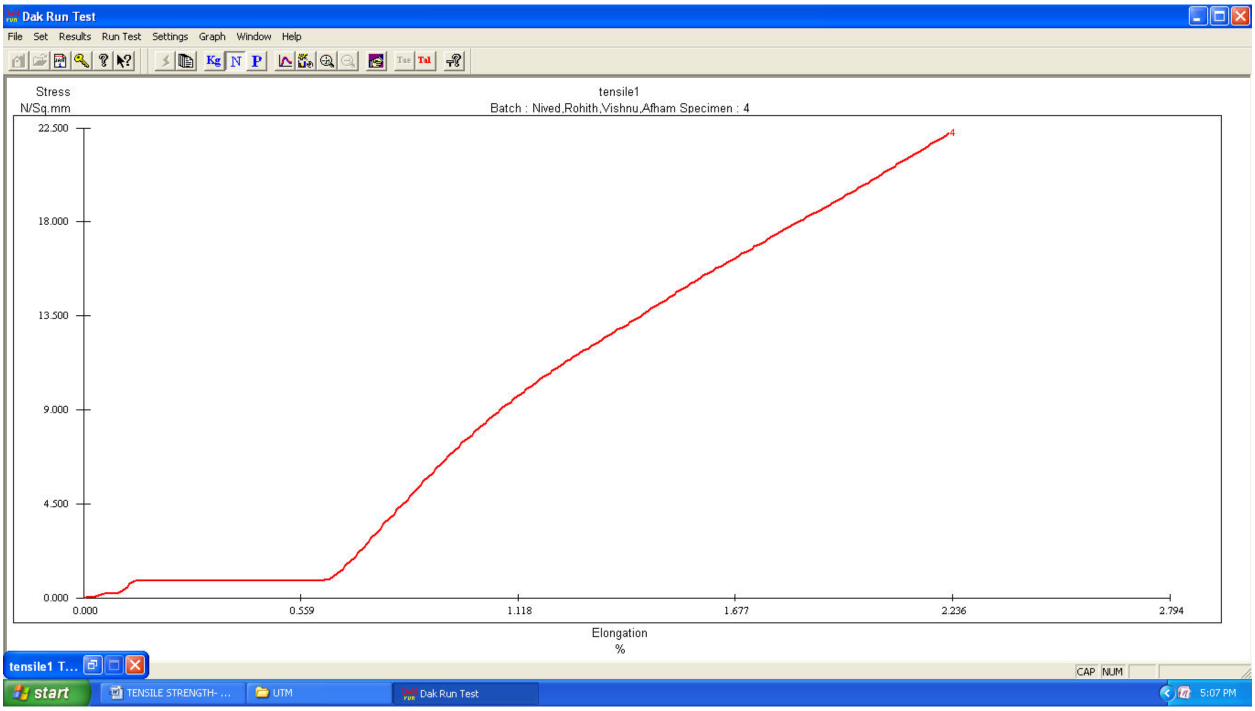

fig 4.4 stress-elongation curve of specimen C4

4.2 FLEXURAL TEST ANALYSIS

The flexural properties of jute fiber mixed with epoxy resin composites are analyzed across four different proportions, and the results are depicted in the provided figure. Notably, the specimen containing 80% jute fiber and 20% epoxy composite demonstrates the highest flexural stress, measuring 26.7257 N/Sq.mm. This finding highlights the optimal combination for achieving maximum flexural strength among the tested proportions. It suggests that adjusting the volume fractions of jute fiber and epoxy resin can significantly influence the flexural properties of the composite material, offering valuable insights for applications requiring high flexural strength and durability.

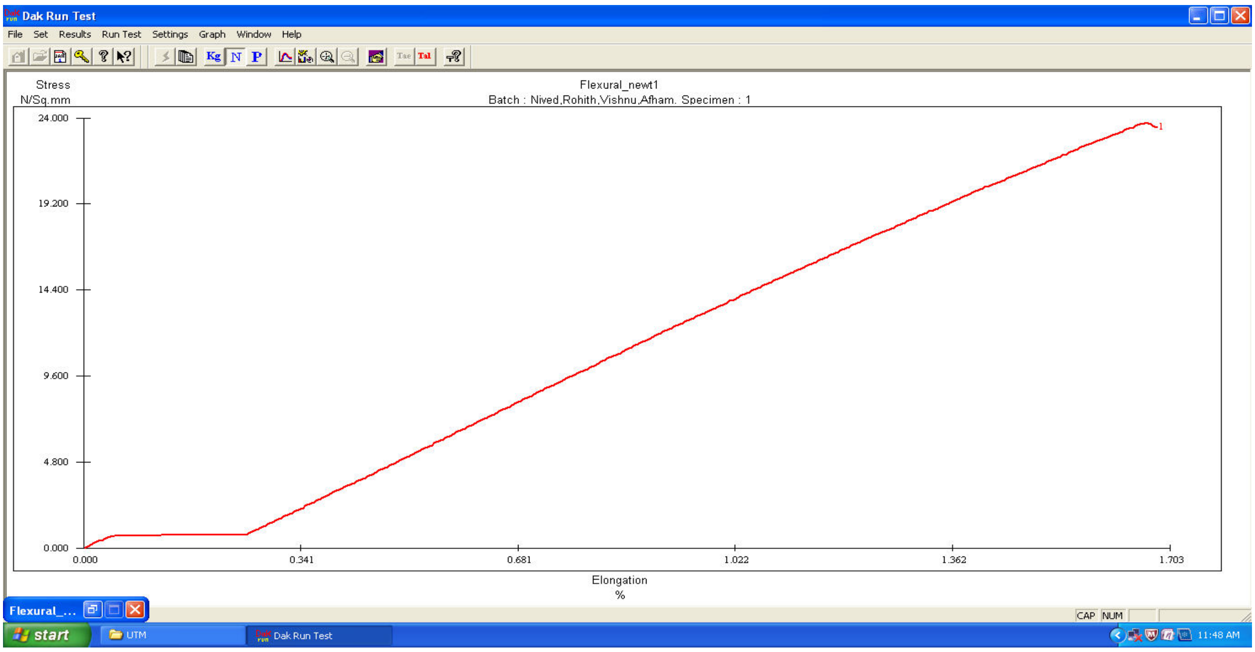

fig 4.5 stress-elongation curve of specimen C1

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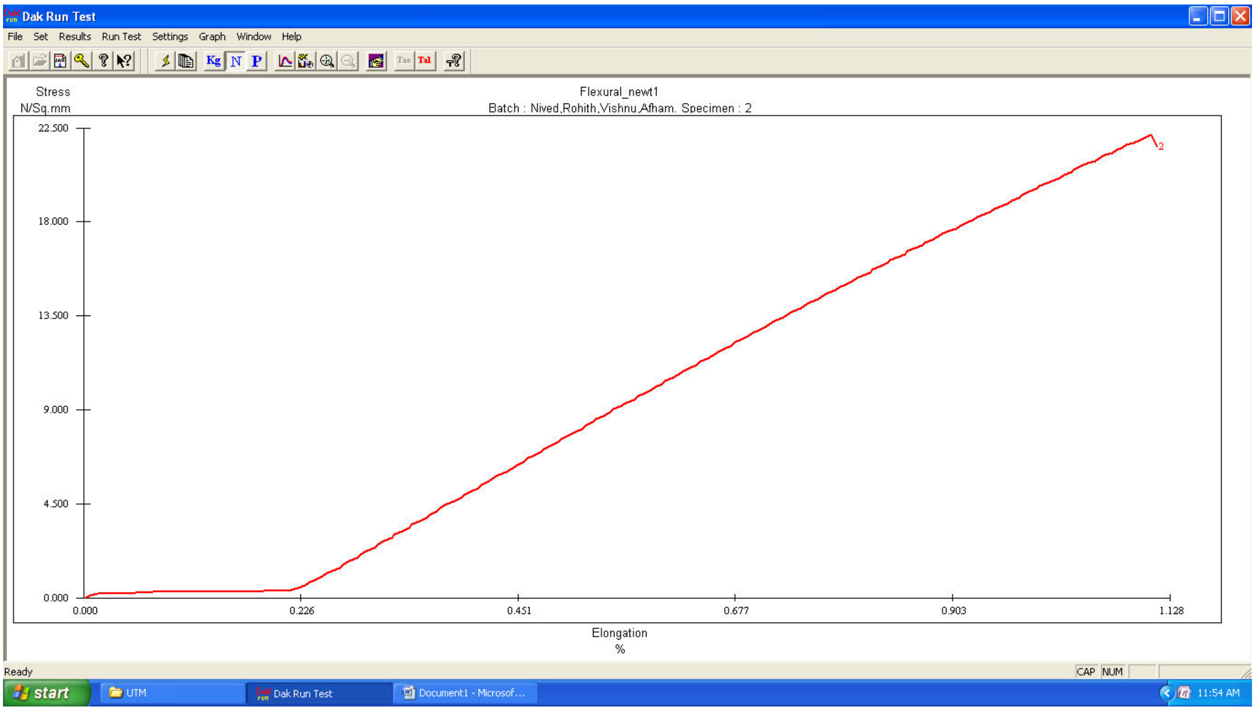

fig 4.6 stress-elongation curve of specimen C2

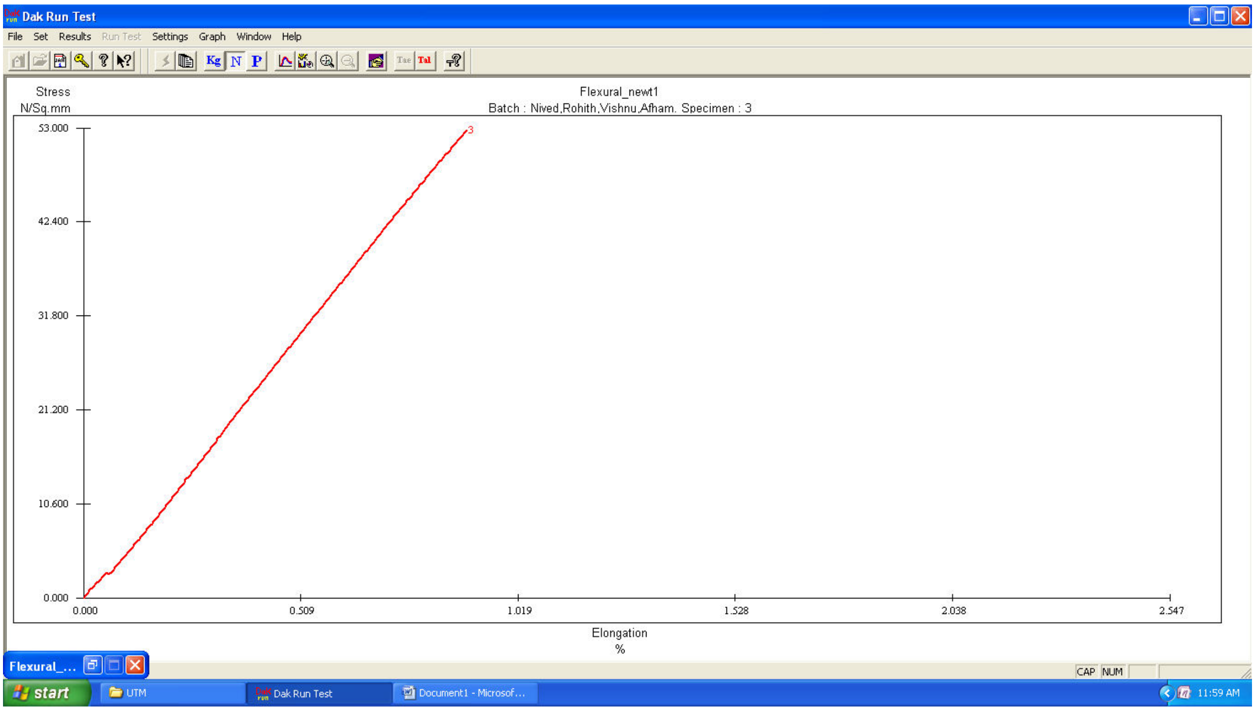

fig 4.7 stress-elongation curve of specimen C3

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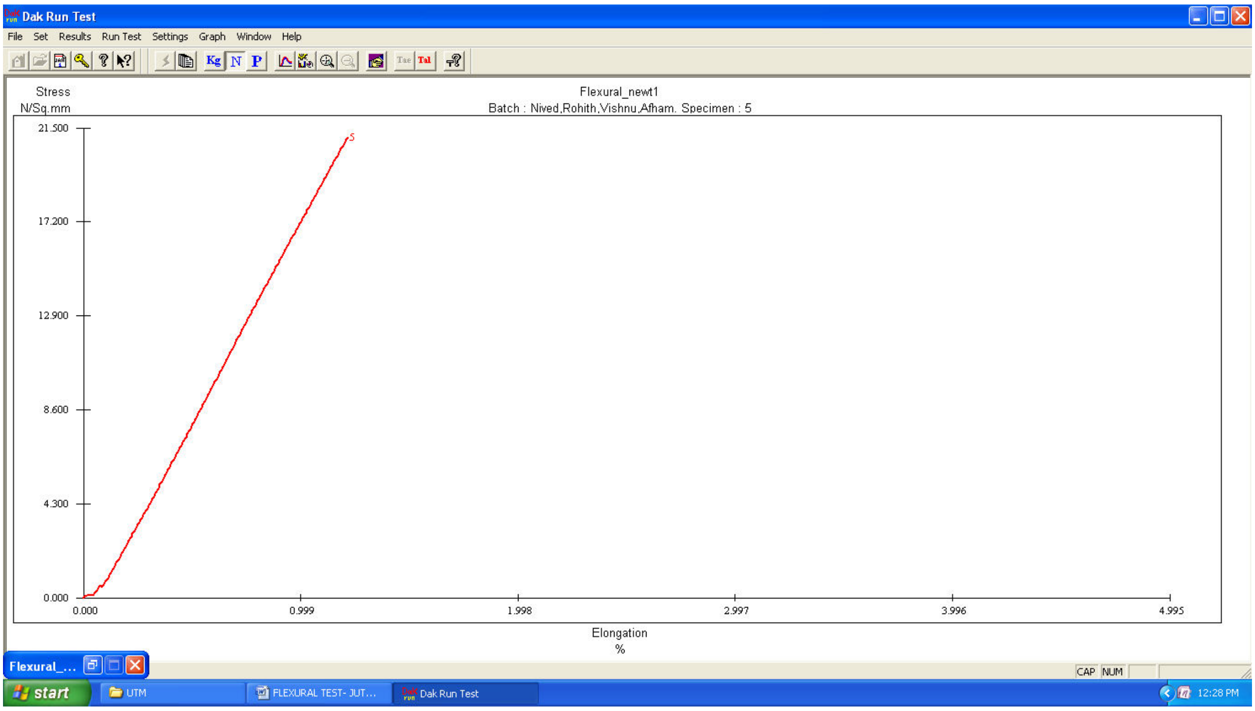

fig 4. 8 stress-elongation curve of specimen C4

4.3 Impact strength analysis

An impact test was conducted to analyze the sudden load carrying capacity of jute fiber reinforced composite samples, utilizing a Charpy impact testing machine to measure energy loss. The impact strength comparison among various combinations of jute fiber reinforced polymer composites is illustrated in the provided figure. Notably, the composite comprising 85% jute fiber and 15% epoxy resin polymer demonstrates superior performance compared to other combinations, withstanding an impact load of 1.29 Joules. This finding underscores the effectiveness of optimizing the volume fractions of jute fiber and epoxy resin to enhance the impact resistance of the composite material, offering valuable insights for applications requiring robust impact performance.

No of reading	C1	C2	C3	C4
1	1.60	1.78	4.61	6.93
2	1.52	2.05	6.34	5.34

Table 4.1. impact strength comparison

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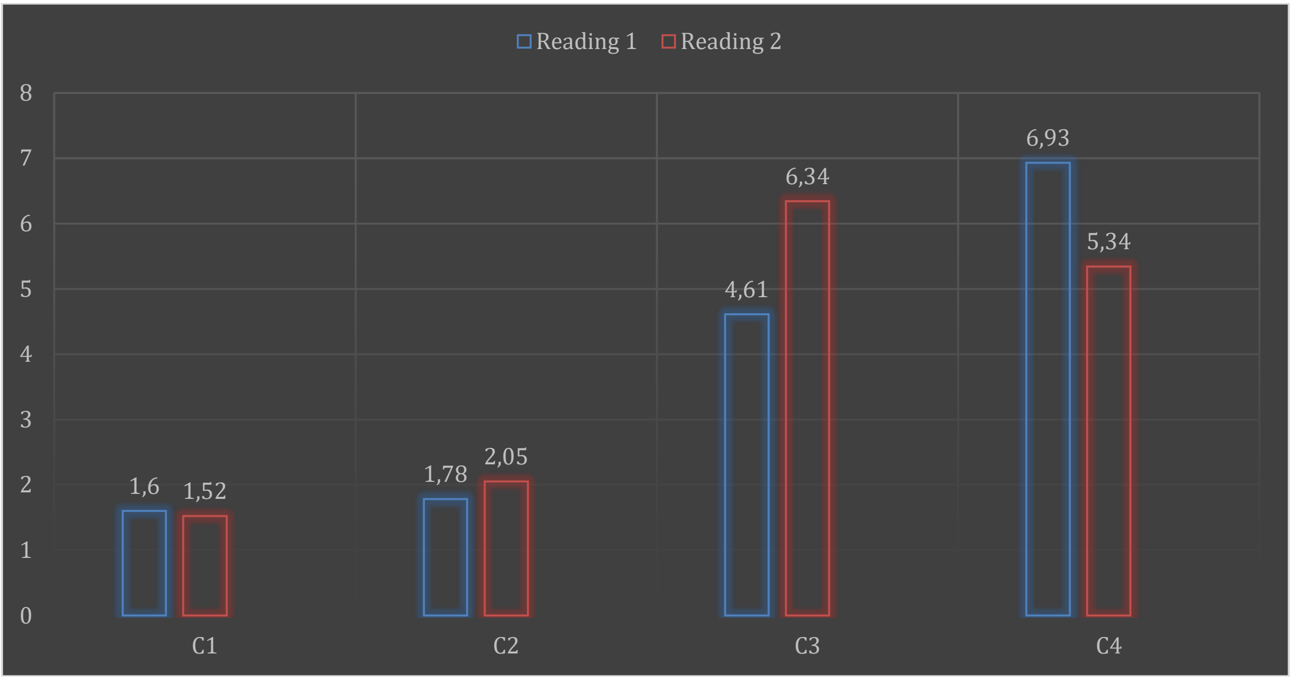

Fig 4.9 Graphical representation of impact strength

V. CONCLUSION

In conclusion, jute fiber reinforced epoxy resin composite materials offer a compelling blend of strength, sustainability, and versatility. By harnessing the natural properties of jute fibers and the exceptional mechanical characteristics of epoxy resin, these composites provide a lightweight yet durable solution for various applications across industries. Their eco-friendly nature aligns with the growing demand for sustainable materials, while their enhanced mechanical properties make them suitable for diverse structural and functional purposes. As technology advances and environmental concerns escalate, jute fiber reinforced epoxy resin composites are poised to play a significant role in shaping the future of composite materials, offering a balance between performance and sustainability.

In the experimental study, the jute 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 22.261N/Sq.mm which is hold by the 85% jute fiber and 15% epoxy resin composites. The maximum flexural stress is 52.6919 N/Sq.mm and this is hold by 80% jute fiber and 20% epoxy resin composites samples. The maximum impact strength hold by the 85% glass fiber and 15% epoxy resin composites is 6.93 Joules. From the experimental study it can be suggested that, the 85% jute 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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