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# HOW TOUGH IS RATTAN? INSIGHTS FROM CHARPY IMPACT TESTING ON SINGLE FIBRES

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**Abstract**

*Rattan, a widely used non-timber forest product in Malaysia, plays a crucial role in the furniture and craft industries due to its cost-effectiveness and environmental benefits compared to synthetic fibres such as lignocellulosic fibre. Despite its potential, limited research has been conducted on the incorporation of rattan fibres into polymeric composites. This study investigates the impact resistance of epoxy matrix composites reinforced with rattan fibres, particularly in laminated hybrid configurations with aramid. Composites were fabricated using the vacuum bagging technique, and impact strength was assessed through Charpy impact tests per ASTM standards. Various laminate stacking sequences and thicknesses were evaluated. The results revealed that impact strength improved with increased lamination thickness, with the optimal configuration being a 7-layer laminate comprising four plain-woven rattan layers and three aramid layers. This configuration achieved an average energy absorption of 26.10 J and a tensile strength of 372.89 kJ/m². Morphological analysis confirmed effective bonding between the natural and synthetic fibres, supporting the viability of hybrid composites for low-impact applications. Overall, the findings highlight rattan's potential as a sustainable reinforcement material in polymeric composites, offering an eco-friendly alternative for enhancing the performance and sustainability of furniture and related products.*

**Keywords :** Impact strength, Lamination; Low-velocity impact, Mechanical properties, Stacking-configuration,

## I. Introduction

Natural fibres are gaining significant attention as reinforcements in polymer matrix composites due to their excellent mechanical properties, renewability, environmental friendliness, and cost-effectiveness [I–II]. However, their quality can be inconsistent, influenced by factors such as climatic conditions (e.g., dew retting, enzyme treatments), growth environments, and limited processing technologies [III–IV]. In contrast, synthetic fibres typically offer superior and more consistent mechanical performance but are often expensive, energy-intensive to produce, and may pose health risks. Plastic fillers serve as another alternative, offering lightweight characteristics, enhanced mechanical properties, and improved safety during handling. In response to the growing demand for sustainable composite materials, rattan has emerged as a promising natural fibre alternative to synthetic reinforcements [V–VII].

In recent years, a significant number of studies have focused on natural fibre composites, including jute [VIII–IX], kenaf [X–XI], pineapple [XII–XIII], sisal [XIV–XV], hemp [XVI–XVII], coir [XVIII–XIX], and henequen [XX–XXI] as reinforcements in polymer composites. However, research on rattan fibre-based epoxy composites remains limited. Therefore, this study aims to explore new sources of natural fibres, with a particular focus on rattan.

Commonly referred to as climbing palms, rattans are widely used in the construction of furniture and household products. Their extensive usage and economic importance highlight their potential as a sustainable alternative to synthetic and conventional materials. Rattans belong to the Palm, Calamus, and Arecaceae families, comprising approximately 600 species across 13 genera, predominantly found in Southeast Asia and the Pacific regions [XXII–XXIII]. Rattan also holds a significant position in the global market, with an annual trade value exceeding USD 6.5 billion [XXIV]. Indonesia is the largest contributor to the rattan industry, cultivating approximately 37,000 hectares, followed by Malaysia with around 31,000 hectares.

The single-fibre tensile test is the most commonly used method for evaluating the tensile properties of fibres, both synthetic and natural [XXVII–XXIX]. This technique yields reliable measurements of fibre strength and modulus. In this study, one of the primary objectives is to analyse the tensile strength of individual rattan fibres for potential application in woven fabric production.

While significant advancements have been made in rattan fibre research, further investigation is needed to enhance the quality of promising species, particularly Calamus caesius. Traditionally, Calamus caesius has been utilised by rural communities to craft baskets, carpets, and other woven items. Its round cane shape, skin peel, and natural curvature provide high-quality raw materials for innovative rattan-based furniture. Additionally, it is commonly used for binding and reinforcement in larger-diameter cane structures. The quality and tone of rattan are influenced by factors such as age, moisture content, and exposure to light during its growth cycle [XXX–XLI].

In this paper, the study also investigates the strength performance of rattan yarn fibre composites in laminated hybrid configurations with aramid, aiming to assess their suitability for structural and low-impact applications.

## II. Methodology

The Charpy impact test was employed to evaluate the impact strength of the composite materials. This method not only measures energy absorption during fracture but also provides insights into the relative brittleness or toughness of the specimens under dynamic loading conditions.

### Impact Tests Sample Configurations

The Charpy impact test setup consists of a specimen holder with anvils, a pendulum with a fixed weight, and a rotating arm mounted to the main frame. Figure 1 illustrates the Charpy test apparatus used in this study. The specimens were carefully aligned with the pendulum's path to ensure accurate measurement of the energy absorbed, recorded in joules. An unsaturated thermoset epoxy resin, ApoxiAmite, was used to impregnate the fibres in each mould. For each rattan fibre volume fraction, seven composite specimens were fabricated. All samples were machined with a V-notch per ASTM D6110 and prepared following ISO standards, ensuring consistent geometry for reliable testing.

The Charpy impact tests were conducted to evaluate energy absorption and identify the types of failure exhibited by the different laminate configurations. Observed failure modes included hinge failure, delamination, and complete fracture. Each specimen was tested under a loading condition aligned with its laminate structure. Testing was performed at the Mechanical Engineering Laboratory, Technical University Malaysia, Malacca, using a Eurotech ET-2206-50 J impact testing machine. This equipment operates with a maximum impact energy of 50 J, an impact velocity of 3.85 m/s, and a pendulum elevation angle of 120 degrees. The Charpy test serves as a reliable method to determine the internal energy absorption capacity of composite materials under sudden impact. For each woven rattan laminate configuration, five batches of specimens were tested, and the average value was reported. Figure 1 displays the specimens before testing, showing uniform geometry and consistent fibre alignment. All samples were fabricated using the vacuum bagging technique to ensure adequate resin infiltration and laminate quality across the varying stacking configurations.


**Fig. 1.** Woven rattan fibre reinforced polymer before impact

## III. Results and Discussion

Figure 2 illustrates the macroscopic characteristics of a representative specimen fractured during Charpy impact testing. It was observed that the inclusion of thicker fibres resulted in a distinct fracture pattern compared to the integration of finer fibres, which typically produced a clean, transverse rupture. With the incorporation of as little as 10% fibre, the fracture no longer followed a purely transverse path.

As expected in a monolithic polymer matrix, cracks initiated at the V-notch and propagated transversely across the resin. However, upon encountering a fibre, the fracture path deviated along the fibre–matrix interface. In some cases, when struck by the Charpy hammer, long fibres were pulled out from the matrix without fracturing; instead, they bent or delaminated, indicating partial energy dissipation through fibre deflection. These observations confirm that both the number of layers and the laminate stacking configuration significantly influence the impact behaviour and energy absorption of the composite specimens.

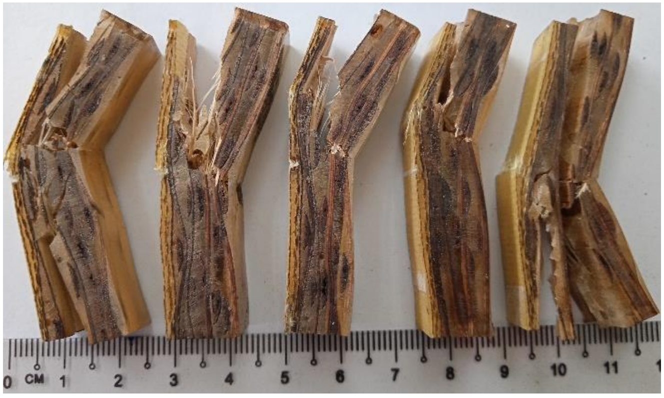


**Fig. 2**: Woven rattan composite after impact

## IV. Results and Discussion

This research highlights the potential of rattan fibres as a sustainable reinforcement material in polymer composites, particularly for applications requiring moderate impact resistance. The incorporation of aramid layers into rattan-based laminates significantly enhanced their mechanical performance, with the 7-layer hybrid configuration exhibiting the highest energy absorption of 26.10 J and a tensile strength of 372.89 kJ/m². Morphological analysis further confirmed effective fibre–matrix integration, reinforcing the suitability of these composites for advanced engineering applications. These findings emphasize the environmental and economic benefits of using rattan fibres, supporting their broader adoption in sectors such as furniture manufacturing, automotive components, and construction. Further studies are recommended to refine fabrication techniques and optimize fibre architecture for improved composite performance.

Figure 3 presents the impact strength results for different lamination configurations compared to the control sample composed entirely of epoxy resin (100%). The configuration with 7 layers—4 plain woven rattan and 3 layers of aramid—

demonstrated the highest average energy absorbed at 26.10 J and a tensile strength of 372.89 kJ/m². In this case, part of the sample bent under the hammer's force without breaking into pieces, which deviates from the typical outcome expected in a Charpy impact test. This partial fracture condition limits the accuracy of the impact toughness measurement, as specimens that do not fully fracture tend to undervalue the actual impact resistance. The enhanced impact resistance observed can be attributed to the role of the rattan fibres, especially when they are well-aligned. Rattan fibres act as reinforcement, and the increase in fibre quantity or size—as seen in Table 1—results in higher absorbed impact energy. This is primarily due to the fibre's flexibility and pull-out mechanism, which allows them to slip out of the matrix rather than fracture. This mechanism enables the composite to absorb more energy, thus increasing the energy required to fracture the samples.

The relatively small standard deviation in impact strength suggests that the measurements are consistent and within control. This consistency supports the observation that thicker fibre laminations correspond to greater impact strength. Furthermore, the findings suggest that the impact strength of the woven rattan composite is directly related to the volume fraction of rattan fibres within the matrix.

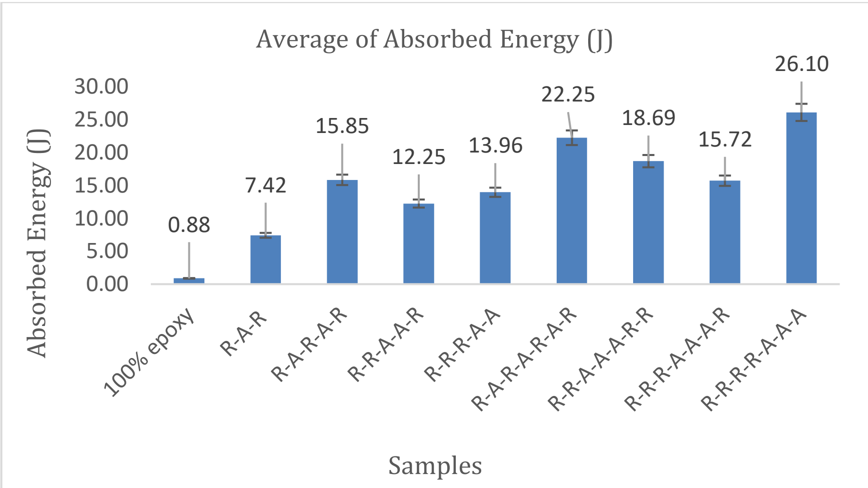


**Fig. 3**. Impact energy absorbed for woven rattan fibre reinforced polymer in different configurations

The higher impact resistance of epoxy compared to the resin matrix also contributes to the improved performance of the laminates. Nonetheless, critical factors such as fibre-matrix bonding and alignment significantly influence the impact fracture behaviour of polymer composites reinforced with long, aligned rattan fibres. In this study, the predominant fracture mechanism observed was fibre pull-out, attributed to weak interfacial bonding between the rattan fibres and the resin matrix.

**Table 1: Impact results of rattan reinforced epoxy composites in various laminated configurations**

| Samples | Average energy absorbed (J) | Charpy impact strength ($kJ/m^2$) | Breaking pattern |
|---|---|---|---|
| 100% epoxy | 0.88 | 87.52 | Split into two |
| R-A-R | 7.42 | 200.33 | Hinged |
| R-A-R-A-R | 15.85 | 316.90 | Delamination |
| R-R-A-A-R | 12.25 | 244.98 | Hinged |
| R-R-R-A-A | 13.96 | 279.12 | Split into two |
| R-A-R-A-R-A-R | 22.25 | 317.86 | Hinged |
| R-R-A-A-A-R-R | 18.69 | 264.71 | Delamination |
| R-R-R-A-A-A-R | 15.72 | 224.57 | Delamination |
| R-R-R-R-A-A-A | 26.10 | 372.89 | Hinged |

The findings of this study reveal several important insights into the impact strength and toughness of rattan fibre-reinforced composites. An exponential trend in impact strength was observed, which can be attributed to several underlying mechanisms, including delamination at the fibre–matrix interface, low interfacial shear stresses, tensile fracture propagation, and the rupture of microfibrils. Among the various configurations tested, hybrid laminates comprising four layers of rattan and three layers of aramid exhibited a significant exponential increase in toughness, demonstrating the synergistic benefits of combining natural and synthetic fibres.

Environmental conditions also influenced the test outcomes. Variations in room temperature during sample preparation and cooling had noticeable effects on the impact strength of different specimen groups. Furthermore, proper calibration of the impact testing apparatus was essential. The impact tester's indicator needle had to be correctly zeroed at the bottom of the scale, and initial mechanical offsets were accounted for through appropriate adjustments—whether positive or negative—in the energy values recorded.

The curing process played a crucial role in determining the final mechanical properties of the composites. A correct resin-to-hardener ratio was necessary to avoid the formation of bubbles and voids, which could compromise structural integrity. Results from the Charpy impact test confirmed that the inclusion of natural fibres significantly improved the toughness of unsaturated epoxy resin. In particular, composites incorporating continuous and aligned rattan fibres exhibited substantial increases in absorbed energy as fibre content increased, achieving some of the highest values reported for purely cellulosic fibre-based systems.

The enhanced toughness of these composites was primarily attributed to the reduction in interfacial shear stress between the rattan fibres and the epoxy matrix. This reduction promoted longitudinal fracture propagation along the fibre–matrix interface, leading to the formation of larger cracking surfaces compared to transverse fractures. As a result, the absorbed impact energy was markedly higher, highlighting the potential application of rattan fibre-reinforced composites in structural components requiring superior impact resistance.

## V. Conclusions

This study has demonstrated the significant potential of rattan fibres as a sustainable and effective reinforcement material in polymer composites, particularly when hybridized with aramid fibres. Through Charpy impact testing, it was shown that the mechanical performance of rattan-reinforced composites is highly influenced by fibre alignment, laminate configuration, and processing conditions. The optimal laminate configuration—comprising four layers of plain-woven rattan and three layers of aramid—achieved the highest average energy absorption of 26.10 J and a tensile strength of 372.89 kJ/m². The results revealed that increased fibre volume, proper fibre orientation, and strong fibre–matrix adhesion contribute significantly to enhanced toughness and energy absorption. Morphological observations further confirmed that fibre pull-out and interfacial delamination are the dominant energy-dissipating mechanisms, especially in well-aligned, multi-layered composites. Overall, the findings support the broader application of rattan fibre-reinforced polymer composites in sectors demanding lightweight, eco-friendly, and impact-resistant materials, such as furniture manufacturing, automotive interiors, and construction panels. Future work should focus on optimizing resin formulations, improving interfacial bonding techniques, and exploring other hybrid configurations to further enhance performance and commercial viability.

## Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

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