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Biorest: Welding Arm Support Made from Galangal Fibre

Ainul Azniza[1*], Rosmawati[2], & Siti Nur Haslinah[1]

[1]Jabatan Kejuruteraan Mekanikal/ Politeknik Merlimau Melaka,77300, Melaka, MALAYSIA

[2]Jabatan Kejuruteraan Petrokimia /Politeknik Tun Syed Nasir Syed Ismail 84600, MALAYSIA

*Corresponding author email: ainul@pmm.edu.my

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Abstract: In the welding industry, one of the major issues that frequently reduces productivity and work quality is the presence of non-ergonomic working postures and muscle fatigue caused by prolonged tasks. These conditions not only affect welders' performance but also contribute to musculoskeletal disorders. In response to the need for a more ergonomic and environmentally friendly support device, a new approach has been introduced through the development of an Adjustable Welding Arm Rest using galangal stem fibres as the primary material. This natural fibre was selected due to its availability, lightweight properties, and suitable mechanical strength for industrial applications. The objective of this study is to design and develop an adjustable arm support device and to evaluate the mechanical strength and durability of galangal fibres based on different weaving techniques. The development process includes Computer-Aided Design (CAD), prototype fabrication, and Charpy impact testing on three types of fibre weaves: shredded, braided, and twisted. The results show that the shredded weave achieved the highest average impact energy of 23 J, outperforming the other weaving techniques. This indicates that the shredded method yields the best impact resistance and is suitable for applications in lightweight structural components. The use of natural materials such as galangal fibres also reduces production costs and supports sustainable manufacturing practices. Overall, the Adjustable Welding Arm Rest made from galangal fibres has strong potential to serve as an alternative to synthetic materials while meeting contemporary ergonomic requirements in the welding industry.

Keywords: Galangal fibre, adjustable arm rest, charpy test, fibre weaving, industrial ergonomics, technological integration, policy support

1. Introduction

Although welding tasks may appear routine, welders are required to maintain a static posture for extended periods. This condition causes significant strain on the shoulders and arms and increases the risk of musculoskeletal injuries, especially affecting the shoulders, back, and wrists. Haslam and Waterson (2014) highlighted that ergonomic factors play a major role in determining work efficiency and safety, particularly in fields involving repetitive movements and static postures. Most existing welding support devices are non-adjustable and do not consider individual posture needs, resulting in prolonged muscular stress. Meanwhile, sustainability-focused studies have demonstrated the potential of natural materials such as pineapple leaf fibres, sugarcane bagasse, and kenaf in composite applications due to their strength and biodegradability (Al-Oqla et al., 2024; Mulenga et al., 2021; Sujito & Prasetyo, 2021).

In many heavy industries, welding work still involves awkward postures, including static bending, constrained arm positioning, or prolonged standing without support. A recent study by Islam Avi, Rahman, Hossain, and Islam (2024) confirmed that poorly optimized welder postures significantly contribute to musculoskeletal disorders, emphasizing the need for effective ergonomic support tools. With rising awareness of occupational health and sustainability, there is increased demand for ergonomic and eco-friendly work-assistive tools.

Corresponding author: ainul@pmm.edu.my

Galangal fibres (Alpinia galanga) are gaining attention due to their availability, lightweight nature, biodegradability, and promising mechanical properties. Studies by Babu et al. (2025) and Mustapha et al. (2012) revealed that chemically treated galangal fibres improve elasticity modulus, thermal stability, and tensile strength reaching up to 33 MPa making them suitable for lightweight structural reinforcements.

The Biorest project aims to address two main challenges: providing ergonomic support in welding work and exploring sustainable bio-composite materials. This study focuses on developing an adjustable arm support using galangal fibres, with three weaving techniques tested (shredded, braided, twisted) to assess impact resistance and overall durability. Beyond technical innovation, Biorest emphasizes sustainability through circular economy principles, reduction of synthetic materials, and improved workplace ergonomics. Based on the actual needs in workshops and factories, Biorest has strong potential to become an ergonomic support device that provides real impact to the welding industry.

1.1 Problem Statement

Welding activities in the heavy industrial sector are still associated with a high incidence rate of musculoskeletal disorders (MSDs), particularly involving the back, neck, and wrists. A study by Cherry et al. (2025) showed that welders record a higher incidence of musculoskeletal disorders compared to non-welding workers, which in turn negatively affects their quality of life. These findings are also supported by the study of Molefe and Musonda (2023) in South Africa, which found that 67% of welders experienced discomfort and physical pain, while nearly 80% reported neck strain due to prolonged bending posture during long working periods. The study by Chandra and Arora (2024) in India further showed that nearly 90% of welders were at high-risk levels based on RULA assessment, although appropriate ergonomic interventions can significantly reduce these risk scores.

Among the various contributing factors, the lack of ergonomic arm-support devices has been identified as a major cause of muscle fatigue and shoulder strain among welders. The absence of physical support for the hand and arm positions causes the load to be borne entirely by the user’s muscles throughout the working period, thereby increasing the risk of repetitive injuries. The study by Zheng et al. (2025) found that most existing arm-support devices are too rigid and cannot be adjusted according to variations in shoulder, elbow, and wrist angles during actual operation. Although the study by Mohd Nasir et al. (2018) proved that the use of adjustable arm rests can reduce muscle fatigue by up to 25% during two hours of continuous work, most existing designs still use synthetic materials that are not environmentally friendly and do not align with sustainability principles.

In the context of biocomposite materials, the study by Sheeba et al. (2023) showed that natural fibres of *Acacia pennata* treated with potassium permanganate ($KMnO_4$) solution are able to increase the mechanical modulus and thermal stability of the composite. These findings are in line with the study of Babu et al. (2025), which reported high mechanical performance for *Alpinia galanga* after permanganate treatment, indicating the potential of bio-materials such as galangal fibre for lightweight and impact-resistant structural applications.

However, previous studies have not yet emphasized the use of natural materials such as *Alpinia galanga* fibres as the main component in the design of ergonomic support devices for welding work. In addition, there has been no comprehensive evaluation of the variations in fibre weaving techniques that may influence impact strength and user comfort. This knowledge gap indicates the need to explore the use of sustainable biocomposite materials in the development of arm-support devices that are not only ergonomic but also capable of reducing muscle fatigue and supporting healthier and more environmentally friendly working practices.

1.2 Research Objectives

i. To design and develop an adjustable welding arm rest using natural materials (*Alpinia galanga*) as the main structural component.
ii. To compare the mechanical performance of three fibre weaving techniques (shredded, braided, twisted) in terms of impact strength and ergonomic comfort.

2. Research Methodology

This study was conducted experimentally through several main phases, beginning with the selection of fibre weaving methods, followed by the fabrication process of the arm-support pad, and subsequently the material testing. Each step in this process was systematically designed and illustrated in the form of a flowchart as shown in Figure 1 to facilitate understanding of the study’s workflow.

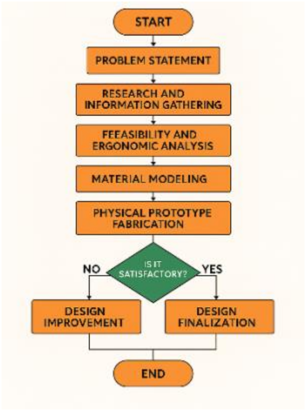

Fig. 1: Flowchart of the Experimental Research Method

2.1 Study Design

Product design is an essential element in ensuring functional effectiveness, ergonomic comfort, and ease of manufacturing. The technical drawings produced using Autodesk Inventor software allow the structural representation of the pad to be conveyed more accurately and in greater detail.

These drawings include assembly drawings, a Bill of Materials (BoM), and isometric views that show the orientation and overall shape of the product from various angles. This visualization assists in the prototype development phase and serves as an important reference during the manufacturing and testing processes. Figure 2 shows the assembly drawing and the Bill of Materials.

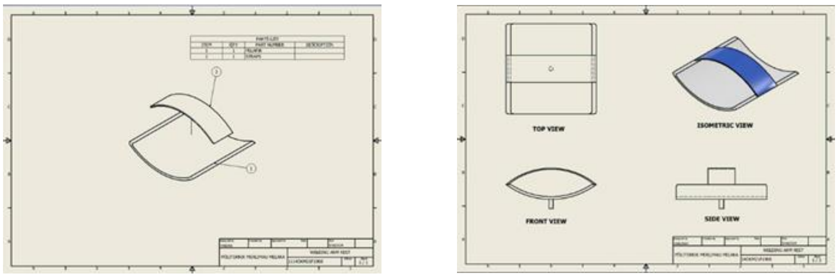

Fig. 2: Assembly Drawing and Bill of Materials

2.2 Study Design

In this study, three fibre arrangement methods were selected to evaluate their effects on the strength and durability of the produced pad material. These methods function to modify the physical structure of the fibres for the purpose of enhancing mechanical performance during testing.

The methods are as follows:

i. Shredded method– fibres are arranged straight without any knots or twisting, suitable for basic analysis of the material's original properties.
ii. Twisted method – fibres are twisted together to form a denser helical structure with the potential to increase tensile strength.
iii. Braided method– fibres are woven using a technique similar to a three-strand braid, providing additional strength as a result of the cross-linking pattern.

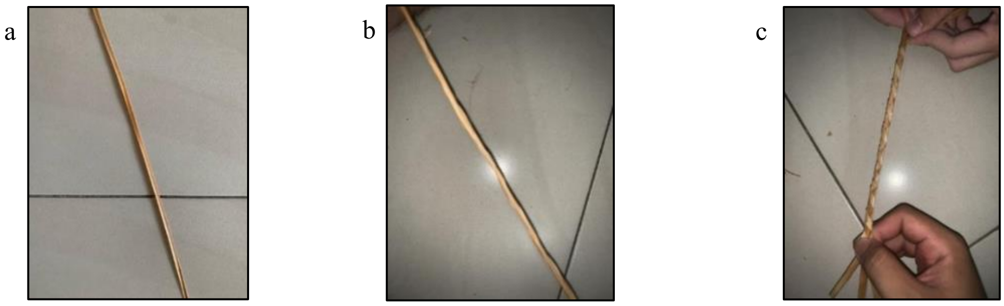

Fig. 3: (a) Shredded method; (b) Twisted method; (c) Braided method

2.3 Resin and Hardener Mixing Ratio

In the process of producing the pad using galangal flower fibres, binding materials such as resin and hardener play an important role in forming a strong and durable composite structure. In this study, the mixing ratio of resin to hardener used was 1:3, where one part resin was mixed with three parts hardener. This ratio was selected to ensure that the curing process occurs more efficiently and produces a strong bond between the fibres and the binding material. If the ratio is inaccurate, it may affect the structural stability and overall quality of the pad produced.

2.4 Preparation and Testing Process

The Charpy Test method was used to evaluate the impact resistance of the fibre material. To prepare the test samples, the mould produced from the initial fabrication was cut into a length of 7.5 cm to comply with the specifications of the Charpy testing machine. Next, the surface of the test material was carefully filed to ensure stability and uniformity during the testing process. At the same time, a V-notch with a depth of 3 mm was created at the centre of the test sample to meet Charpy standard requirements.

Fig. 4: Galangal FIbre Test Sample in Cylincdrical Mould

Fig. 5: Impact Resistance Testing Machine (*Charpy Impact Tester*)

Fig. 6: Position of Test Sample on the Charpy Machine Base

3. Research Findings and Analysis

Impact strength testing was conducted using the Charpy Test method to evaluate the durability of galangal fibres processed through various weaving techniques. Each technique produced fibre structures that differed in arrangement and density, which have the potential to influence the material's ability to absorb impact. Four categories of materials were tested:

1. Shredded Method
2. Braided Method
3. Twisted Method
4. Resin Material Without Additional Fibre (control)

Each method was tested using three separate samples (Sample 1, 2, and 3), and each sample underwent three repetitions (Test A, B, and C) to ensure consistency and data reliability. The impact energy values, measured in Joules, were recorded for each test as shown in the table and presented in graphical form as illustrated in Figure 7.

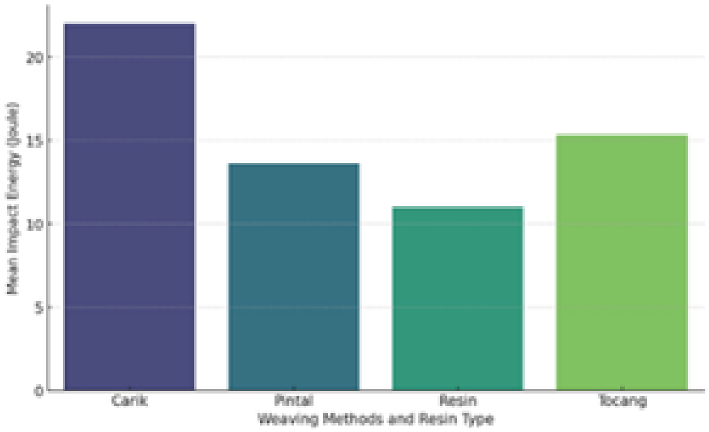

Fig. 7: Comparison of Average Impact Energy for Fibre Weaving Methods and Resin

Based on Figure 7, the shredded weaving method recorded the highest average impact energy, exceeding 21 J, indicating the best impact absorption performance compared to the braided method (15 J), twisted method (13.5 J), and resin without fibre (11 J). This proves that the presence of galangal fibre and the type of weaving technique play an important role in enhancing the impact strength of the material, with the shredded method being the most effective for lightweight and ergonomic structural applications such as welding arm supports. Table 1 shows the mean, maximum, minimum, and standard deviation analysis of the Charpy Impact Energy.

Table 1: Analysis of Mean, Maximum, Minimum and Standard Deviation of Charpy Impact Energy

Kaedah	Penerangan	Ringkasan Statistik (Min, Maks, Min, Sisihan Piawai)
Shredded	Tests A, B, and C were conducted to evaluate the impact performance of the material using three separate samples. The average impact energy values ranged between 18.0–25.0 J with a standard deviation of 10.0.	Test A: Mean = 23.0 J, Max = 33 J, Min = 13 J, Std = 10.0 Test B: Mean = 18.0 J, Max = 28 J, Min = 8 J, Std = 10.0 Test C: Mean = 25.0 J, Max = 35 J, Min = 15 J, Std = 10.0
Braided	The three tests showed lower average impact energy compared to the shredded method, but with better consistency.	Test A: Mean = 9.33 J, Max = 13 J, Min = 5 J, Std = 4.04 Test B: Mean = 18.33 J, Max = 22 J, Min = 14 J, Std = 4.04 Test C: Mean = 13.33 J, Max = 17 J, Min = 9 J, Std = 4.04
Resin	It showed high stability in Test A (without variation), but the average impact energy decreased significantly in the other tests.	Test A: Mean = 17.0 J, Max = 17 J, Min = 17 J, Std = – Test B: Mean = 4.0 J, Max = 4 J, Min = 4 J, Std = – Test C: Mean = 12.0 J, Max = 12 J, Min = 12 J, Std = –
Twisted	The average impact energy is at a moderate level with consistent values across the tests.	Test A: Mean = 11.33 J, Max = 15 J, Min = 7 J, Std = 4.04 Test B: Mean = 16.33 J, Max = 20 J, Min = 12 J, Std = 4.04 Test C: Mean = 18.33 J, Max = 22 J, Min = 14 J, Std = 4.04

Based on Table 1, the results of the Charpy test show that the shredded weaving method recorded the highest average impact energy, which is 25.0 J (Test C), with maximum values reaching up to 35 J and a minimum of 15 J. This method also consistently achieved the highest values across all tests (A, B, and C) compared to the other techniques. The braided method demonstrated the second-best performance, with average values ranging from 11.33 J to 18.33 J. The twisted method ranked third with moderate variation, while the resin without fibre recorded the lowest performance, with Test B showing only 4.0 J. This proves that the presence of fibres and the weaving pattern have a significant influence on the material's ability to absorb impact, with the shredded method being the most effective and stable for impact-resistant bio-composite structural applications.

4. Discussion

The findings of the Charpy test conducted indicate significant variation among the fibre weaving methods in absorbing impact energy. Overall, the shredded weaving method recorded the highest average impact energy, reaching up to 25 J (Test C) with a maximum value of 35 J. This result shows that a loose fibre structure such as the shredded method is able to disperse impact energy more effectively compared to denser weaving techniques like the twisted and braided methods. These outcomes are also consistent with the findings of Babu et al. (2025), which reported that fibre structures that are not tightly packed allow more energy to be absorbed before failure occurs. The braided method demonstrated moderate performance, with average values ranging from 11.33 J to 18.33 J. This may be due to its tighter and more organized weaving pattern, which, although providing better shape stability, limits the material's ability to disperse impact energy. The twisted method ranked third, with averages ranging from 9.33 J to 18.33 J, showing moderate consistency but being less effective in terms of impact strength compared to the braided and shredded methods.

The resin samples without fibres showed the lowest performance in all tests, particularly in Test B with only 4.0 J. This clearly indicates that the presence of natural fibres plays a critical role in enhancing the impact resistance of the structure. Without fibres, the resin tends to exhibit brittle fracture behaviour and is unable to absorb impact effectively. These findings are supported by the study of Sheeba et al. (2023), which stated that chemically treated fibres (such as permanganate treatment) are capable of improving the modulus and thermal stability of bio-composite materials.

Interestingly, the data also shows that all galangal fibre–based samples recorded higher minimum values compared to resin alone, even though the maximum values varied. This suggests that although the weaving method influences the maximum strength, the presence of fibres itself provides structural stability, resulting in more consistent material performance. When analysed from an industrial application perspective, these findings indicate that the selection of weaving techniques not only affects structural strength but should also be considered in terms of manufacturability, user comfort, and ergonomic requirements. For instance, the shredded weave is not only strong but also more flexible to adapt to the shape of the arm support. This offers advantages in the design of support tools such as adjustable arm rests, which require a balance between mechanical durability and flexibility of form.

Overall, this discussion confirms that the objectives of the study have been achieved, namely identifying the best weaving technique (shredded) and demonstrating that the use of galangal fibres can enhance the mechanical performance of the support device compared to resin alone. This study has also successfully bridged the literature gap, which previously placed less emphasis on the combination of natural fibre weaving structures and ergonomic applications in real industrial environments.

5. Conclusion & Recommendations for Future Research

This study proves that the use of natural *Alpinia galanga* fibres is capable of enhancing mechanical performance in welding arm support applications, especially when combined with the shredded weaving technique. This method recorded the highest average impact energy and the most consistent performance compared to the twisted, braided, and resin-only samples. These findings confirm that not only does the presence of fibres play an important role in improving impact resistance, but the weaving structure also has a significant influence on the material's ability to absorb impact energy. In addition, the use of local fibres such as galangal makes the design more sustainable, cost-effective, and aligned with the circular economy agenda in producing environmentally friendly ergonomic products.

To strengthen the impact of this study, several recommendations are proposed for future research. First, follow-up studies should involve real user testing among welders to assess the comfort level and effectiveness of the arm support in practical use. Second, future research may evaluate the material's resistance to heat and extreme weather conditions to ensure suitability for actual workshop environments. Third, comparisons of the effects of different chemical treatments such as silane and alkali on the mechanical performance of the fibres should be explored to determine the most optimal treatment method. Additionally, fatigue testing is recommended to assess the long-term durability of the composite under repeated use. Lastly, research may be expanded by comparing the performance of *Alpinia galanga* fibres with other natural fibres such as kenaf, coconut coir, or banana fibres to evaluate the competitive potential of local materials.

These recommendations are important to elevate the BIOREST innovation to a higher level of commercial readiness. This product not only functions as an effective ergonomic support device but also has the potential to become a sustainable, high-quality, and competitive local-material-based product for future industrial applications.

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Conflict of Interest
The authors declare there is no conflict of interest

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