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Tensile Properties of Hybrid Jute/Roselle Reinforced Polyester Composites

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Abstract. Hybrid reinforced composites can exhibit a huge effect on the tensile properties because of their enhanced stiffness and high strength of the structure when contrasted with fibre reinforced pure composites, which comprise similar materials only. The purpose of this study is to investigate the tensile properties of hybrid jute/roselle woven reinforced polyester composites. The composite's stacking sequences and orientation with different layering numbers of 2 and 3-layer consist of pure jute (J), pure roselle (Ro), and hybridised jute and roselle (J-Ro) composites will be evaluated. The hand lay-up technique method is employed to fabricate the composite specimens test. According to the findings of this study, with the addition of bi-layer of pure woven jute or roselle and hybrid jute/roselle in polyester composites, the tensile strength (TS) has increased from 12% to 41% and 13% to 42% for tensile modulus (TM), respectively. Tri-layer composites are highest TS and TM when jute fibre is applied at the top and bottom of the laminate as skin layers and roselle fibre position in the middle layer, which is attributable to higher elastic modulus tensile strength of jute fibre when contrasted with roselle. This study discovers that the roselle and jute fibres as the reinforcements embedded into the polyester matrix can produce high strength composite materials. Moreover, hybrid jute-roselle composite is suggested to have a higher potential for future development in the industry.

INTRODUCTION

Natural fibres have been utilised these days to replace man-made fibres (synthetic) such as glass, carbon and Kevlar to reinforce polymer composite in a few applications [1]. Besides, natural fibres are lightweight, lower cost, have relatively good specific strength and modulus, reduced occupational health problems in manufacturing (non-toxic). These renewable, biodegradable, and abundant resources are critical in a few applications such as automotive

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applications, great material damping, particular great properties and an advantageous "green image" product application [2,3].

A hybrid natural fibre composite is a combination of different kinds of natural fibres. Hybrid composites have a great advantage when systems experience various applicable conditions in a functional period [4]. Although technologies using natural fibres hybrid composites are still in the research and development (R&D) phases, natural fibres hybrid composites are mainly in automobile parts. A few critical factors are driving the use of natural fibre by the European car industry are cost, lightweight and renewable materials [5]. Studies show that natural fibre composites can lead to a 20% reduction in cost and a 30% reduction in weight for an automotive component [6,7]. Furthermore, according to previous research, the lightweight components lead to lower fuel consumption, strong recycling opportunities, reduced waste disposal, and greenhouse emissions. Internal panels, door panels, seat backs, headliners, trays, dashboards, bumpers, spoilers, and body parts are the interior of automotive components made [8,9].

Different types of woven fabrics structures have significant influences on the mechanical properties of the composites [10–12], proving that woven architecture provides great uniformity and better distribution in warps and weft direction compared to other types of arrangement. Due to the high interlace between warp and weft directions, the reason is enhanced interfacial bonding between fibre and matrix [13]. The stacking sequence can be categorised according to types of materials, fibre orientation of each constituent lamina, fibre configuration, and weaving pattern of plies. Any combinations of two or more mentioned features could be done in the fabrication process of laminated composites [14]. Selecting the correct stacking sequence achieves structural optimisation with maximum tensile strength and tensile modulus of the composites [15].

Based on the literature reviews on hybrid and woven composites, it can be seen that woven structures are indeed significant apart from the mechanical properties of materials. Therefore, this study aims to investigate the effect of layering stacking sequence and orientation on the tensile properties of hybrid jute/roselle reinforced unsaturated polyester composites. Furthermore, the effect of layering size and stacking sequence of the woven fibre in the laminate composite will be compared.

METHODOLOGY

Materials

Plain woven jute and roselle fibres are purchased from Impiana Enterprise Engineering Kuala Lumpur, Malaysia. These raw materials are cut into 30 cm x 30 cm to fit into a mould. Unsaturated polyester Reversol P-9539 NW manufactured by Revertex (Malaysia) is selected for the material handling of laminates and resin supplied by Impian Z Enterprise (Malaysia). Reversol P-9539 NW has adaptability being used with the hand lay-up process. PT supplies Methyl Ethyl Ketone Peroxide (MEKP). Kawaguchi Kimia Indonesia is utilised as the hardener to act as a catalyst in cultivating encompassing temperature gel and cure. The unsaturated polyester resin is measured by weight, and the percentage of catalyst used in resin is 1%, which indicated 10 ml of catalyst to 1 kg of resin.

An aluminium sheet metal frame (40 cm × 40 cm) with the hollow section with the dimension of 30 cm (L) x 30 cm (W) x 3 mm (T) is prepared for the lay-up process, as shown in Figure 1. First, two flat metal plates of the same size as the needed laminates are manufactured to be set and placed at the top and base of the frame, making the mould.

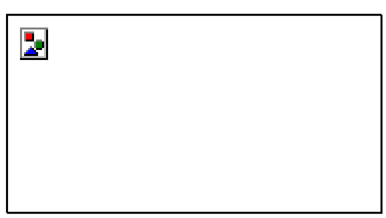

FIGURE 1. Sheet metal mould

Fabrication of composite plates

A hand lay-up technique was utilised for the fabrication of composite laminates. Releasing agent or wax was initially sprayed to coat the inner mould surface to keep the staying of the composite plate towards the shape surface for the simplicity of expulsion. The mixture of unsaturated polyester resin and hardener (MEKP) was then poured into the mould. Each fibre layer was put over the highest point of resin more than once when the needed thickness was gotten, considering texture alignment tolerance [16]. At that point, the mould was left for 24 hours at room temperature for the process of curing. In the meantime, the mould was compressed with a hydraulic press machine to guarantee viscidity between the fibre-matrix interfaces. As a result, both pure and hybrid composites plates with the layering number of 2 and 3 were produced in the desired sequence, as shown in Figure 2.

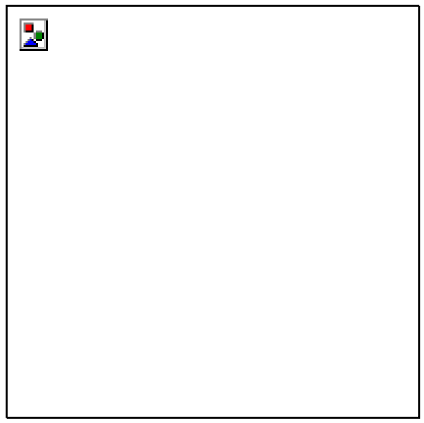

FIGURE 2. Layering number and stacking sequence of pure and hybrid jute roselle

Specimen fabrication

The composite sheet laminates were cut into specimens with the correct shape following ASTM D 638–04 for the tensile test. The various layering number and stacking sequences of woven pure and hybrid jute (Ju) – roselle (Ro) were considered, as shown in Table 1.

TABLE 1. Configuration specimens for tensile test

Type of laminates	No of layers	Stacking sequence
Pure	2	Ju/Ju (warp)
		Ju/Ju (weft)
		Ro/Ro (warp)
		Ro/Ro (weft)
	3	Ju/Ju/Ju (warp)
		Ju/Ju/Ju (weft)
		Ro/Ro/Ro (warp)
		Ro/Ro/Ro (weft)
Hybrid	2	Ju/Ro (warp)
		Ju/Ro (weft)
	3	Ju/Ro/Ju (warp)
		Ju/Ro/Ju (weft)
		Ju/Ju/Ro (warp)
		Ju/Ju/Ro (weft)
		Ju/Ro/Ro (warp)
		Ju/Ro/Ro (weft)
		Ro/Ju/Ro (warp)
		Ro/Ju/Ro (weft)
Polyester	1	-

Tensile testing

The specimens according to ASTM D 638–04 are used to determine the tensile properties such as tensile strength and tensile modulus. A crosshead speed of 2 mm/min using a universal INSTRON 3369 universal testing machine and five specimens are tested, and the average value is recorded.

Microscopic analysis

The tensile fractured specimen of bi-layer and tri-layer of pure and hybrid jute/roselle will be analysed under the microscope (Softop).

RESULT AND DISCUSSIONS

The tensile strength (TS) and tensile modulus (TM) of bi-layer pure and hybrid ju/ro composite have shown in Figure 3. The Figure showed that with the addition of a bi-layer of pure woven and hybrid ju/ro in unsaturated polyester resin (UPR), the TS has increased from 12% to 41% and 13% to 42% for TM. The bi-layer composite with stacking sequence of jute/jute in warp direction achieved the highest tensile strength at 33 MPa and tensile modulus at 1102 MPa and followed by jute/jute in weft direction with the tensile strength of 31.5 MPa and 1056 MPa for tensile modulus, respectively. Meanwhile, bi-layers of pure ro/ro in warp and weft direction (27.4 MPa and 26.2 MPa) are lower than pure jute composites. Although, as reported by a previous researcher [17], the tensile strength of roselle fibre is between 170–350 MPa, it is shown lower than the tensile strength of jute fibre is in the range of 393-800 MPa [18,19]. This result confirms that jute fibres are stronger and stiffer than roselle fibres based on their individual constituent properties.

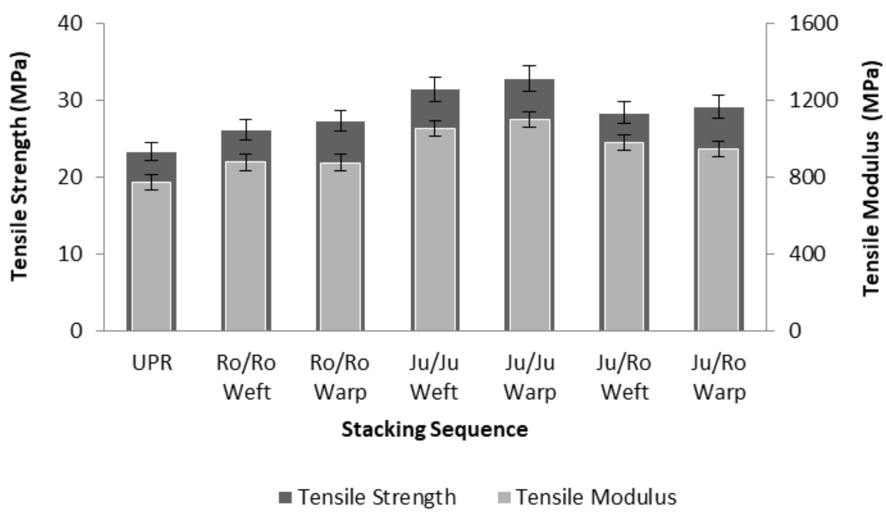

FIGURE 3. Tensile properties of bi-layer composites

The hybridisation of bi-layer ju/ro has shown a slight increase in TS and TM compare to the pure of roselle. The increment of TS and TM for hybrid jute/roselle in the weft direction is 8% and 12%, and for the warp, the direction has increased by 7% and 8%. It revealed that differences in the load-sharing properties of jute and roselle fibres along the longitudinal and transverse directions are attributed to the rise in tensile strength and tensile modulus of hybrid composites [13]. A comparison results from this study has shown that woven fibre in warp direction tends to have a higher value of tensile strength than fibre in the weft direction. A similar study found out by [20], the TS and TM of an untreated composite of woven jute fibre reinforced Poly(L-lactide) (PLLA) are greater in the direction of warp than in the direction of weft. The reason is the tension of the warp yarns is more uniform (Figure 4a) than that of the weft yarns due to warp yarn preparation (Figure 4b). Besides, a coated fabric is held uniformly in the warp direction during the coating process [21]. The parameter that can influence the mechanical properties of the composites is the hybrid layering and stacking sequence of the natural laminated fibre in the composites [22,23].

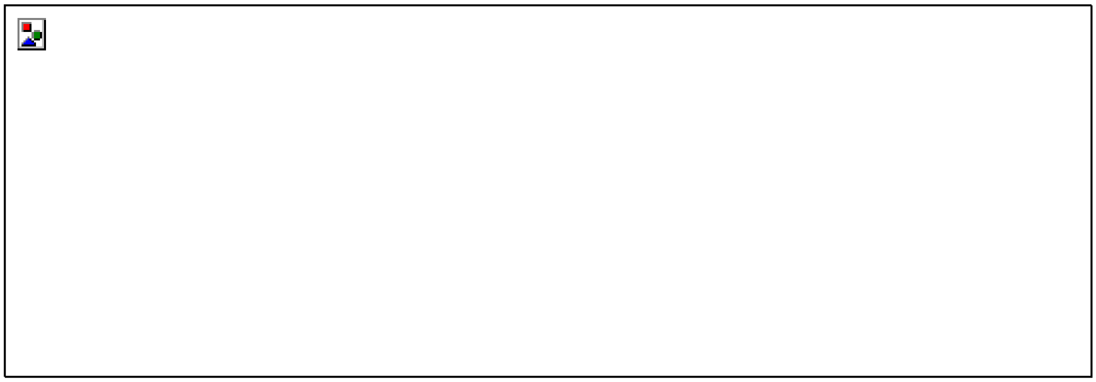

FIGURE 4. The physical structure of woven warp and weft fabric using Softop microscope

The visual inspection has been investigated under the microscope to study the morphological structure of the composites to identify the reason for the results further. From Figure 5a, it can seem that the bi-layer ju/ro composite in the warp direction does not have any void contents on the side and surface. However, it can seem that the bi-layer ro/ro composite in the weft direction has some void contents on the side and surface in Figure 5b. This defect can influence the tensile properties of hybrid composites [24].

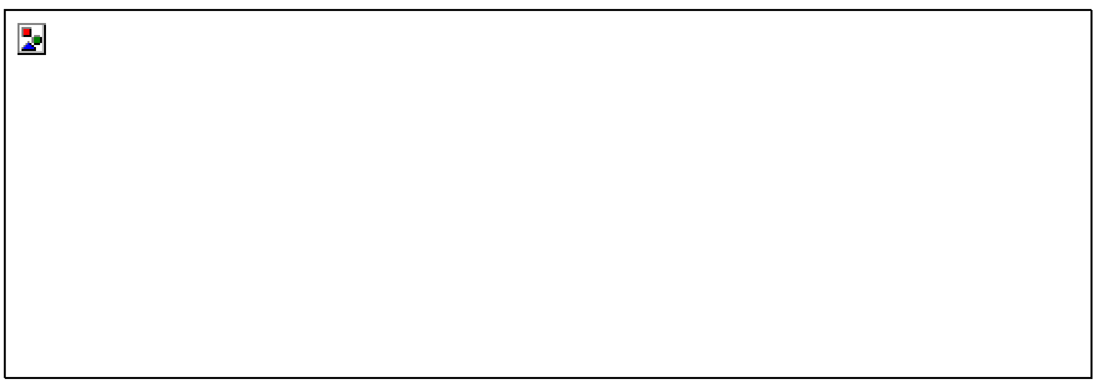

FIGURE 5. Fracture surface of a) hybrid jute/roselle in warp direction and b) pure roselle in weft direction

Figure 6 clearly show that the tri-layer composite with stacking sequence of pure jute (ju/ju/ju) in warp and weft direction achieved the highest tensile strength at 48.70 MPa and 45.6 MPa. Meanwhile, the tensile strength of tri-layer roselle is 35.20 MPa and 32 MPa for warp and weft direction, respectively. The result indicates that fibre in the warp direction tends to have a higher tensile strength value than fibre in the weft direction. The concept of various levels of the crimp and the looseness in the warp and weft directions are applied in the processing of woven fabric. Initially, warp yarn that determines the loom's lengths exists in a high degree of stretch. Then, a pre-stress is induced in the warp direction due to high stretching, thus generating greater tensile stress [25]. The crimp interchange between warp and weft yarns leads to the difference in tensile properties.

The tensile strength of the composite increased as the number of woven fibre layers increased. The tensile strength increment of tri-layer pure jute is approximately 32% (warp) and 31% (weft). The warp and weft direction of tri-layer roselle is 22% and 18.75%, respectively. The finding is consistent with findings of past studies by Tezara et al. [26], in which the increased layering sequence increases the composite's tensile properties. The fibre increases with the layering number of fibre. It is expected to have better tensile properties of the composites because more fibres are involved in sharing the loading or force acting on the system [27].

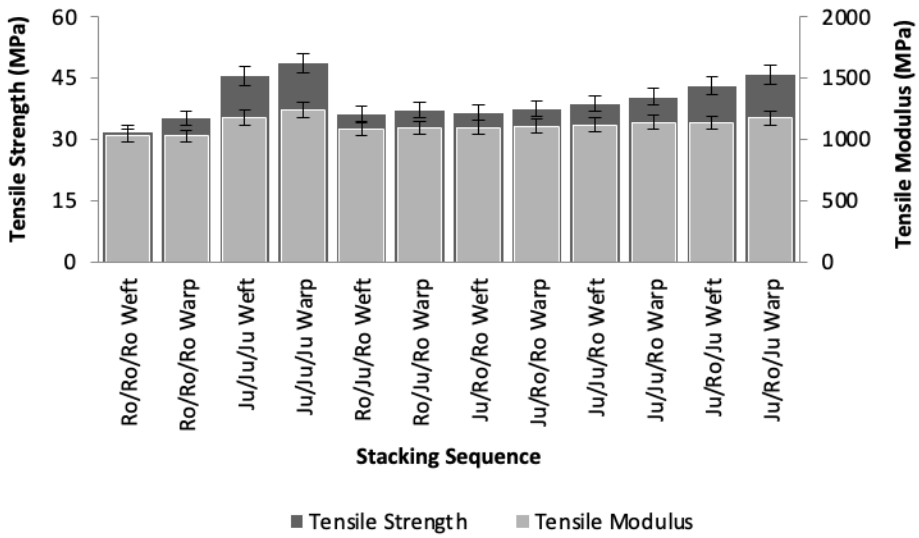

FIGURE 6. Tensile properties of tri-layer composites

The case of hybrid tri-layer shows that the stacking sequence of ju/ro/ju in the warp (45.9 MPa) and weft (43.2 MPa) has achieved the highest tensile strength compared to other types of sequences. In a tensile test, the load applied is parallel to the surface of a specimen. So many researchers have informed that the outer skin of hybrid composite with higher strength can prohibit stronger tensile behaviour [28,29]. It is prominent that the tensile strength of pure jute fibre is higher than pure roselle fibre [17,30]. The more superior behaviour of jute fibre acts as skin that can withstand the stress at the outer layer. Meanwhile, the roselle fibre acts as the inner core that can transfer the stress absorbed uniformly to every part of a composite of the specimen. Then, the tensile strength of the ju/ro/ju specimens can be stronger than the other hybrid jute and roselle specimens.

As seen in Figure 6, the tensile modulus of tri-layer composites follows a similar pattern to that of tensile strength. Modulus, commonly known as the modulus of elasticity, is a measurement of a material's ability to endure changes in length. When compared to bi-layer composites, tri-layer composites have a higher tensile modulus. At the same time, increasing the number of layers can increase stiffness, which is governed by Young's modulus. As expected, pure polyester composite has the lowest tensile modulus of 1030 MPa. In this study, a higher modulus indicates better structural integrity. In addition, the presence of woven fibre in the composite can help prevent shattering and improve the breaking point of the composite [31].

CONCLUSION

The effect of layering stacking sequence on hybrid jute/roselle tensile properties has been investigated. This study discovered that increasing the number of woven layerings increased the tensile properties of the composites. Compared to the weft direction, the warp direction of bi-layer and tri-layer composites has higher tensile properties. In comparison to pure roselle composites, the tensile characteristics of hybridised woven roselle with woven jute have significantly improved.

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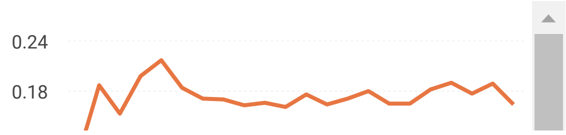

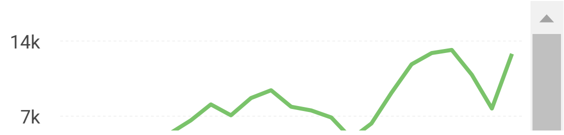

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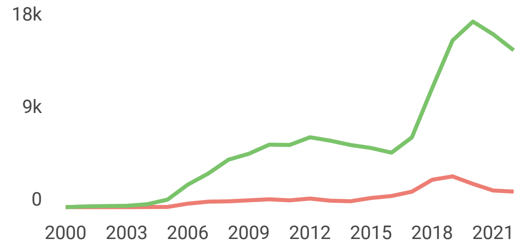

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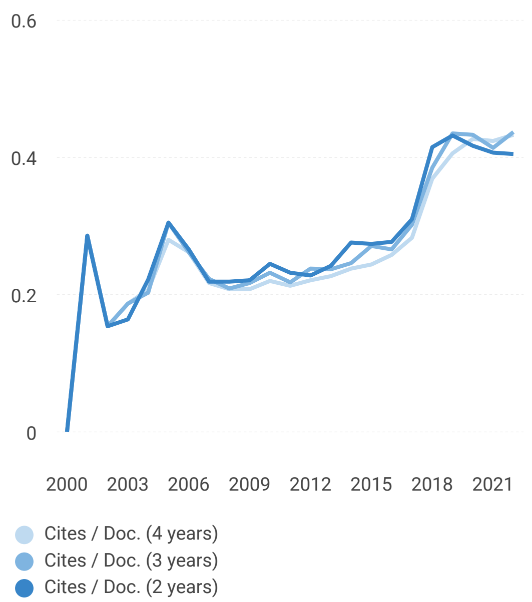

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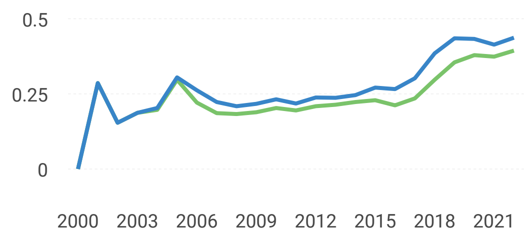

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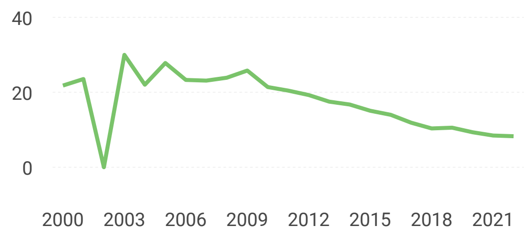

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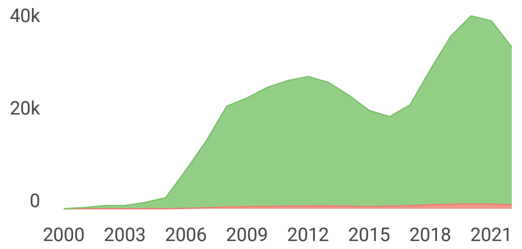

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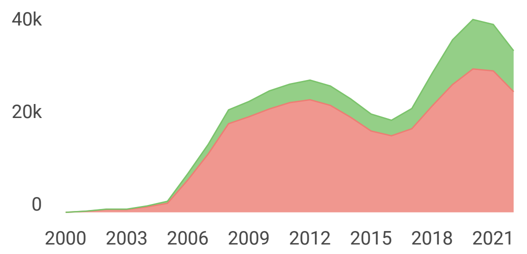

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