



An experimental analysis on mechanical properties of jute/glass Fiber reinforced epoxy based hybrid composites

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ABSTRACT

A preliminary investigation on the impact properties and morphologies of unsaturated polyester reinforced with jute woven fabric recycled from used coffee bags with different moisture contents was conducted. The laminated structural effect of hybridization with glass woven fabric was also investigated. Jute/jute-laminated composites, and jute/glass/jute- and jute/jute/glass-laminated hybrid composites were fabricated by the hand lay-up method. Their impact properties were compared by drop-weight and the Izod impact tests. The acoustic emission (AE) technique was applied under a tensile load to detect micro-failure processes in the jute and jute/glass hybrid composites. The number of AE signals and the AE energy were monitored using two transducers with resonant frequencies of 140 kHz and 1 MHz. The results showed that the moisture content affected the mechanical properties of the composites. The strength and elongation at break of the jute yarn decreased with a decrease in moisture content. The AE characteristics and observations of the fracture surfaces revealed that the composites fabricated from jute fabric with low moisture content had a relatively higher initial fracture stress and higher resistance to micro-fractures. Moreover, the mechanical properties of the hybrid composites were significantly affected by the laminating structure.

Keywords: epoxy, jute fiber, composites, phase

INTRODUCTION

A mixture of at least two unmistakably different materials which are not solvent in one another and contrast in structure or chemical composition is characterized as a composite material. A material comprises of at least two stages are a composite materials. Concrete, mortar, fiber reinforced plastics, fiber reinforced metals and comparable fiber impregnated materials are the various blends of materials which are known as composite materials. The uses of composites over straight materials are highly due to their stiffness, fatigue strength and durability which enhance the structure more compact. By statement, composite comprises of two or more elements which combines of both physical and chemical phases. The reinforcement materials incorporated in base matrix helps in increasing strength and rigidity. It may be particles, fibres or platelets are economically used to improve the

mechanical strength which offers effective load transfer. Among different types of reinforced composites natural fibre reinforced polymer composites were commonly used due to its availability, low density, cost and improved energy recovery. Since natural fibre are classified as jute, banana, coconut, palm fibres, etc. Increased mechanical property simultaneously increases the fibre weight index which reduces the tensile strength.

Composite is a mixture of two or more constituents/ materials (or phases) with different physical/chemical properties at the macroscopic or microscopic scale. They are categorized by the geometry of the reinforcement (i.e., particulate, flake, and fibers) or by the type of matrix (i.e., polymer, metal, ceramic, and carbon). The idea behind the manufacturing of the composite is to optimize specific material properties, i.e., the properties of the matrix are to be improved by incorporating the reinforcement phase. In composites, reinforcements are the principal load carrying members while the surrounding matrix helps to keep them in their desired

locations, prevent them from environmental damages, and also acts as stress transfer medium. Various thermoplastic and thermosetting polymers reinforced with long fibers, short fibers, and mat (fabric) of natural and synthetic fibers such as hemp, jute banana, glass, carbon, and kevlar are used in a variety of applications

LITERATURE SURVEY

Title- Jute Fiber Reinforced Epoxy Composites And Comparison With The Glass And Neat Epoxy Composites. Author- Gujjala Raghavendra, Shakuntala Ojha, Sk Acharya And Sk Pal. Year-2014

The aim of this paper is to replace the traditional fiber composites with a natural-fiber composite in perception of tribological and mechanical accepts. A systematic study has been carried out to investigate jute fiber properties when incorporated into epoxy matrix. Thermogravimetric analysis has also been carried out for jute and epoxy for thermal property analysis. For a comparison purpose epoxy and glass fiber composites are prepared. The investigation reveals that, due to incorporation of jute into polymer epoxy shows better properties than the resins alone; but the properties are inferior to those of glass reinforced in terms of mechanical. When considering the tribological application, the jute fiber shows superior properties than neat and glass-reinforced epoxy composites. The worn out samples were studied using scanning electron microscope.

Title- Experimental Analysis On Mechanical Properties Of Jute And Bamboo Composites. Author- Abhin Tribikram Tripathy. Year- 2019

Recently, bio composite materials are synthesized using natural cellulose fibers as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, availability, renewability, degradable and being environmental-friendly. The present work attempts to make a sample which can be compatible enough to plastic based material. Manufacturing methodology and materials used to have better mechanical properties as well as to enhance the compatibility between fibers and the matrix. The biocomposite are prepared with the unsaturated polyester matrix and fibers such as jute, sisal, coconut, areca and banana using hand lay-up method with appropriate proportions to result in helmet shell structure. The fabricated helmet are planned to evaluate its mechanical properties such as tensile strength, impact strength and compression strength.

Title- Experimental And Numerical Investigation On The Tensile And Water Absorption Behavior Of Jute/Carbon Reinforced Epoxy Composite. Author- Abu Shaïd Sujon, Nagib Mehfuz, Mohammad Ahsan Habib. Year- 2020

Now a days traditional metallic and alloy material are replaced with the fiber based composite material in numerous engineering application. The effect of stacking sequence on tensile and flexural properties of epoxy-based carbon and jute fiber composites has been investigated experimentally and numerically in this paper. Six layers of woven unidirectional jute fiber and four-layer of carbon fiber has been fabricated by vacuum assisted resin infusion process with five different stacking sequences. The tensile and water absorption behaviors of the prepared composite samples were experimentally studied as per the standard of ASTM. The obtained results from the experiments revealed that the stacking sequence of the fiber has a great effect on the tensile and water absorption properties of the composite. To validate the experimental result of the tensile test, the exact 3 D model of the composite laminates were imported to a Finite Element Analysis (FEA) software with the exact experimental condition. The predicted FEA results were compared with the experimental results and a good similarity between them has been observed.

Title- Experimental Investigation Of Areca/Jute/Glass Fiber Reinforced Hybrid Composite Plates. Author- S.Dinesh, C.Elanchezhian And B.Vijayaramnath. Year- 2019

The hybrid composites have emerged has the potential reinforcement material for composites and thus gain attraction by many researchers. This is mainly due to their applicable benefits such as low density, low cost, renewable biodegradability and environmentally harmless and also comparatively good mechanical properties with synthetic fiber composites. In continuing to that, the industries are focused to find new materials to overcome the drawbacks. Due to this, great part of the scientific research is directed towards using areca plate, glass woven fiber and jute woven cloth. These fibers are combined to form hybrid composite materials which are fabricated by using epoxy resin with hardener. The performance of hybrid composite has extensive engineering applications such as Aeronautics, automotive industries and home applications.

METHODOLOGY

EXISTING SYSTEM

Natural fiber materials are dime a dozen in nature. Researchers are still working in this field to achieve composite materials with unique properties with low cost and environment friendly. For advanced composite matrix, thermosetting polymer i.e. epoxy resin is widely used for its good stiffness, dimensional stability and chemical resistance characteristic. Natural lingo-cellulosic fillers (bamboo, flax, jute, hemp, etc.) are environmentally friendly in nature as compared to

conventional reinforcing fibers (glass, carbon). 6,7 Luo and Netravali⁸ studied the tensile and flexural properties of the green composites with different pineapple fiber content and compared with the virgin resin. Belmares found that sisal, henequen, and palm fiber have very similar physical, chemical, and tensile properties. Wear is probably the most important yet the least implicit aspect of tribology. In the main part of tribo, the material removal by any means is called as wear. Depending upon different means, those were named in different types such as abrasion, adhesion, erosion, chemical, fretting wear, and corrosion.¹⁰ Sand erosion is a form of wear caused by particles impinging against a target face and removing material. In order to quantify the extent of the damage, it is usually expressed as the weight of material removed by unit weight of impacting particles.

PROPOSED SYSTEM

Jute is a natural fiber derived from the jute plant. Although you might not be familiar with its official name, you might recognize a term more commonly associated with this fabric: “burlap.” The allure of jute is multi-faced: not only is this plant-based fabric biodegradable and produced with a minimal carbon footprint, but it also provides tangible benefits to the environment. Jute is the second most commonly produced plant-based fiber—the ever-popular cotton takes the first spot. Jute is well-known for its strength and durability, though this coarse fabric isn’t as commonly used in clothing as much as in industrial and storage materials. There are a few different plant variations of jute. The two main types are white jute and dark jute, also known as tossa jute. The jute plant requires special growing conditions and soil, needing to be grown in warm, humid climates that have annual monsoon seasons. Jute is used to make furniture, chair covers, rugs, curtains, and other household furnishings. Furniture wrapped in jute rope, such as a headboard, a swinging chair, or a hammock, is a fantastic addition to a bohemian-inspired space. The natural, textured style of jute is a stylish accent against soft linens and plush pillows. Although the fibers can be dyed to almost any color, jute is commonly used in its natural shade, which is a light tan or golden hue. When mixed with other fibers, jute can make twine, string, and rope.

RELATED WORK

THE EXPERIMENTAL WORK DETAILS

In particular, natural fiber composites are promising materials for use in parts of automobiles. Given that natural fiber composites have lower weight, their application may result not only in improving vehicle fuel efficiency, but also in assisting in maintaining the

sustainability of manufactured materials. However, the strengths of natural fiber composites are comparably lower than that of their synthetic fiber counterparts. This is often a result of the incompatibility between natural fiber and the resin matrix. In addition, natural fiber is hydrophilic and possesses high moisture absorption potential. Absorption of moisture deforms the surface of the composites by swelling and creating voids. These factors currently limit the large-scale production of natural fiber composites.

Constituents

Natural fibre-reinforced composites have attracted a great deal of attention by the automotive industry mainly due to their sustainable characteristics and low cost. The use of sustainable composites is expected to continuously increase in this area as the cost and weight of vehicles could be partially reduced by replacing glass fibre composites and aluminium with natural fibre composites. Adhesive bonding is the preferred joining method for composites and is increasingly used in the automotive industry. However, the literature on natural fibre reinforced polymer composite adhesive joints is scarce and needs further investigation. The main objective of this study was to investigate experimentally adhesively bonded joints made of natural, synthetic and interlaminar hybrid fibre-reinforced polymer composites. The effect of the number of the interlaminar synthetic layers required in order to match the bonded joint efficiency of a fully synthetic GFRP bonded joint was studied. It was found that the failure load of the hybrid jute/glass adherend joints increased by increasing the number of external synthetic layers (i.e. the failure load of hybrid 3-layer joint increased by 28.6% compared to hybrid 2-layer joint) and reached the pure synthetic adherends joints efficiency due to the optimum compromise between the adherend material property (i.e. stiffness and strength) and a diminished bondline peel stress state.

MATERIALS AND METHODS

Bidirectional jute and glass plain woven fabrics were used as reinforcements. Jute fabrics (T10, 248 g/m²) were supplied by Sisalsul (São Paulo, Brazil) while the glass ones (RE200, 200 g/m²) were supplied by Barracuda Advanced Composites (Rio de Janeiro, Brazil). A two-component epoxy resin, HEX 135 SLOW, supplied by Barracuda Advanced Composites (Rio de Janeiro, Brazil) was used to fabricate the composites.

A structural, two-component epoxy adhesive, BetamateTM2096, supplied by Dow (São Paulo, Brazil) was used in the fabrication of the SLJs. The tensile data for the adhesive and resin used are summarized on Table 1.

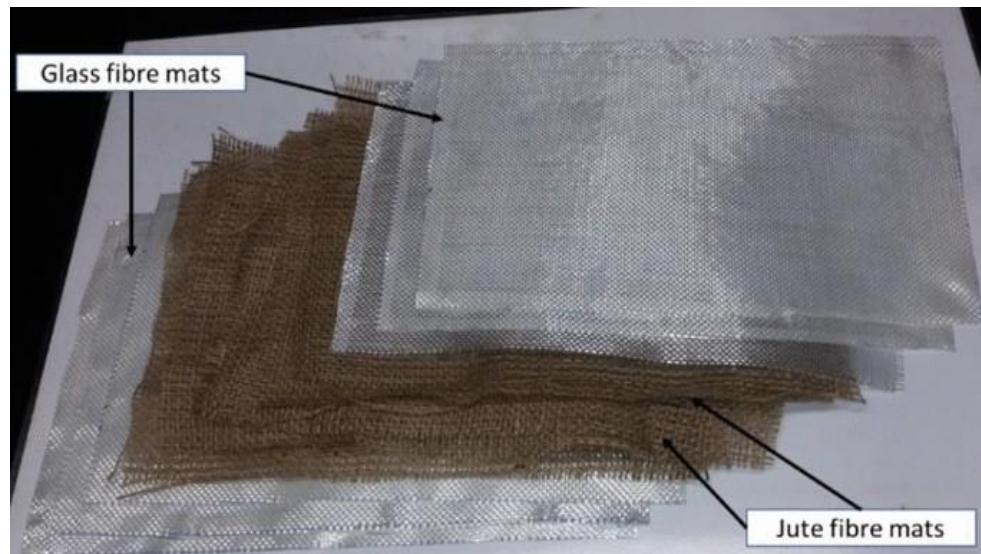
Table 1: Tensile data of the adhesive and resin used

Polymer	Tensile strength (MPa)	Young's modulus (GPa)	Tensile strain (%)
Eetamate™2096	34.27 ± 1.52	1.60 ± 0.10	8.04 ± 0.39
HEX 135 SLOW	60.92 ± 1.42	3.25 ± 0.008	3.20 ± 0.20

Composite specimen fabrication

Composite plates (pure synthetic, pure natural and hybrid) were fabricated using the hand lay-up technique followed by hot press compression moulding via a steel mould and a heated plate hydraulic press, Solab SL-20 (São Paulo, Brazil). The curing time was of 8 h at 70 °C as per manufacturer guidelines. Once cured, the adherends were cut from the composite plates (25 × 107.5 mm).

The hybrid composites were fabricated in such a way to have a stacking sequence that had a natural fibre core consisting of 5 layers of jute and an envelope of symmetrical glass fabric layers on either side. The number of glass layers varied on either side from 2 to 3 layers. The fibre weight percentage was kept at around 30% and the resin + hardener (100:33) at 70% of the final composite weight. Figure 1 shows the layer sequence of the natural and synthetic fabrics used for the fabrication of the hybrid composite adherends 3-layer glass fibre hybrid composite case ($G_3J_5G_3$).



Natural and synthetic fabrics used and stacking sequence for the fabrication of the hybrid composite adherends 3-layer glass fibre hybrid composite case ($G_3J_5G_3$)

The composite materials used as adherends received specific nomenclature as a function of synthetic layer number and stacking sequence (the subscript represents the number of layers):

- GFRP—Glass fibre reinforced composite;
- $G_2J_5G_2$ —2-layer glass fibre hybrid composite;

- $G_3J_5G_3$ —3-layer glass fibre hybrid composite;
- JFRP—Jute fibre reinforced composite.

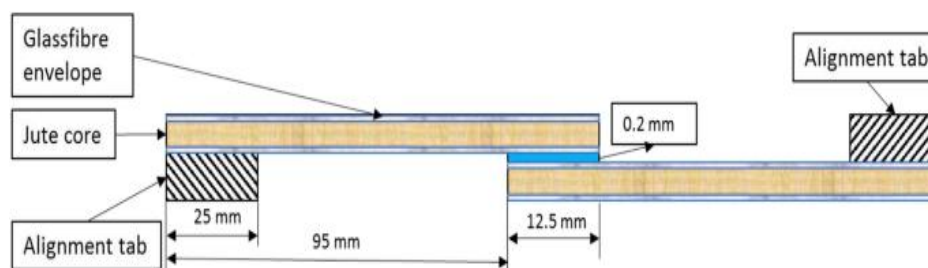
The materials used as adherends were characterised by tensile tests using a universal Instron®5966 testing machine (Norwood, Massachusetts, USA). A 10 kN load cell and a crosshead speed of 1 mm/min was used. Tensile stress–strain curves of all composite materials used as adherends were recorded and the calculated tensile data (the tensile strength, Young's modulus and strain) are summarised in Table 2.

Table 2: Tensile data of the composites used as adherends

Adherend material	Tensile strength (MPa)	Young's modulus (GPa)	Tensile strain (%)
GFRP	197.85 ± 19.54	20.16 ± 4.86	2.00
G ₃ J ₅ G ₃	136.30 ± 7.50	10.22 ± 0.24	1.45
G ₂ J ₅ G ₂	100.64 ± 2.39	7.48 ± 0.99	1.24
JFRP	80.02 ± 10.70	7.86 ± 0.74	0.92

FABRICATION

The geometry of the joint specimen can be seen in Fig. 2. A mould with steel spacers was used to maintain



the correct alignment of the adherends and avoid spew fillets [31]. The spacers also ensured the adhesive layer thickness of 0.2 mm and the overlap length of 12.5 mm. Alignment tabs were glued to the edges of the SLJs to align the specimen during the traction tests.

RESULTS AND DISCUSSION

TESTING METHODS

The main objective is to determine the material properties (Tensile Strength, Flexural Strength, and Scanning electron microscope, Erosion test apparatus) of natural fibre reinforced composite material by conducting the following respective tests.

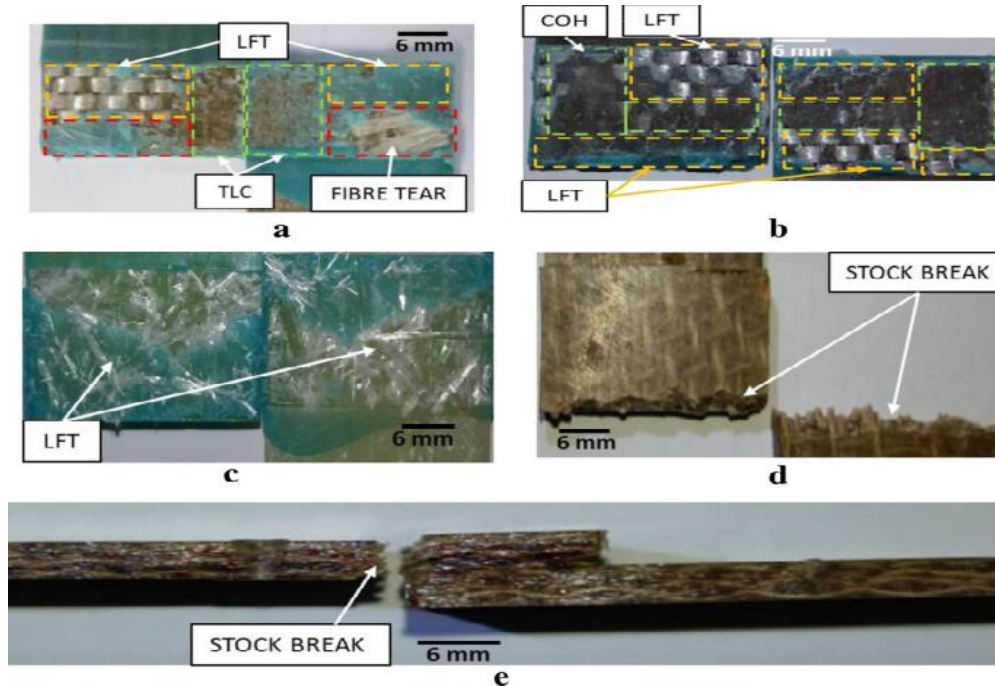
- Tensile Test
- Flexural Test
- Scanning electron microscope
- Erosion test apparatus

JOINT FAILURE MODES

The failure modes of composite bonded joint may occur either in the adherend (i.e. fibre tear, light fibre tear, thin layer cohesive failure and stock break failure), in the adherend/adhesive interface (adhesive failure) or within the adhesive layer (cohesive failure). Light fibre tear (LFT) and thin layer cohesive failures (TLC) are defined as close to the interface cohesive failures. LFT is defined as the presence of a thick adhesive layer on one

side and no adhesive on the other with some surface resin and few fibres removed from the interface. On the other hand, TLC is defined as a thick layer of adhesive on one side and a very thin adhesive layer on the other. Fibre tear failure is also called delamination and is defined as a more severe and widespread fibre removal and bundle failures. It is also common the observation of mixed modes, where any of the failure modes may occur alongside one another.

Figure 4 presents representative failure modes for all joints studied. From Fig. 4a, it can be seen that the failure mode of G₂J₅G₂ SLJs presented a mix of LFT, TLC and fibre tear (delamination). For the G₃J₅G₃ SLJs (see Fig. 4b), it can be seen that the majority of the failure surface was dominated by cohesive failure, mixed with TLC. Figure 4c depicts the failure mode of the GFRP SLJs, where widespread LFT can be seen. Finally, from Fig. 4d, e, the stock break failure of the JFRP SLJs group can be observed. The significant difference, in terms of failure mode, of GFRP and JFRP SLJs, is due to the fact that the jute fibre and its composite is more brittle. This, in turn means that the JFRP is less capable of rotating its edge to account for the increasing peel stress cause by the eccentricity of the load in an SLJ traction test.



Representative adhesive joint failure surfaces: a $G_2J_5G_2$; b $G_3J_5G_3$; c GFRP, d JFRP (top view) and e JFRP

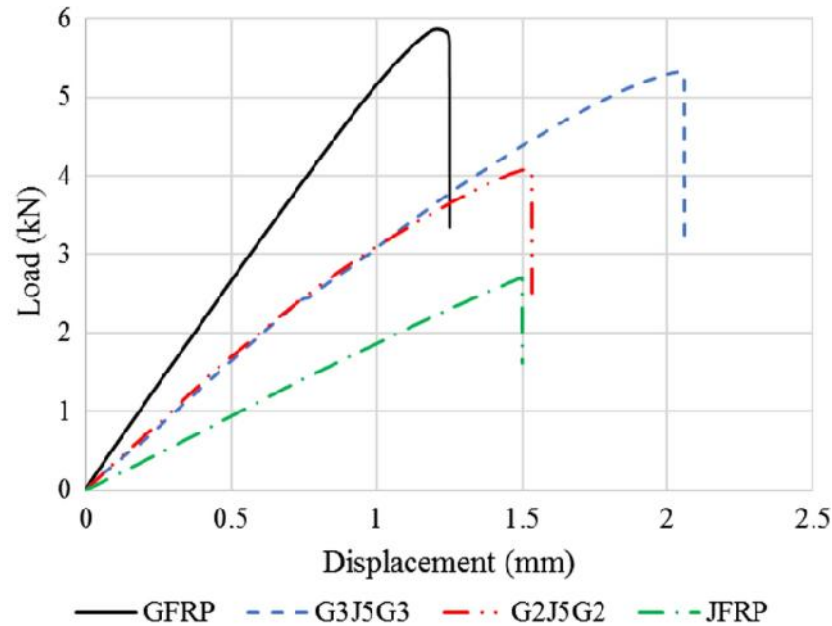
For further clarification on the failure mode of the joints, an electronic microscope was used to determine more precisely the failure modes and the transition zones. From Fig. 5, it is possible to see the LFT failure mode that is characteristic of a GFRP bonded joint. Patches of adhesive with some surface fibre removal as well as the removal of surface resin is apparent. The underlying bidirectional glass fabric however is not visible, indicating that this failure occurs very close to the interface. The crack path represents two LFT fronts from each overlap edge that meet in the middle with an extremely narrow transition zone. This failure mode is consistent with what has been previously noted in the literature [34, 35]. Figure 6 presents a detailed view of the hybrid 2-layer bonded joint failure surface. It can be observed from Fig. 6a that the top right zone of the hybrid 2-layer failure surface, roughly 25% of the area, was dominated by a generalized LFT mode. This is due to the clear removal of the surface resin of the other adherend, with the delamination of a few individual fibres. It can also be seen the faint warp/weft directions of the bidirectional mat. From Fig. 6b, one can observe the zone below that of the previously discussed zone. This zone is dominated by a generalized delamination (fibre tear) failure. Fibres of both the first and second layers were delaminated, indicating a significant peel stress state.

EFFECT OF ADHEREND TYPE ON THE BONDED JOINT PERFORMANCE

A presents representative load–displacement curves of SLJs as a function of adherend material, while Table 3 summarizes the data obtained from the test. It can be seen that the performance of the joints significantly varied. This is explained by the difference in the adhered material properties (see Table 2). The pure jute joint (JFRP), presented the lowest failure load as expected, as the pure jute adherends had the lowest properties and the SLJs failed in the adherends (see Fig. 4d and e). The hybrid 2-layer SLJs presented an improvement in average failure load when compared to the JFRP of approx. 27%, while the hybrid 3-layer SLJs presented an increase of failure load of approx. 48% when compared to JFRP. Furthermore, if the hybrid SLJs performance is compared, it was found that the failure load of the hybrid SLJs was significantly affected by the number of synthetic layers (i.e. an increase in average failure load of approx. 28% was found when the hybrid 3-layer SLJ is compared to the 2-layer joint). This is explained by the difference in the adherend material properties and its effect on the joint failure modes as increased material properties, (i.e. composite stiffness and transverse tensile strength), help mitigate tip rotation during shear loading as well as delamination failure onset. As described in the previous section, the failure mode of the hybrid 3-layer joint was defined by symmetrical LFT fronts from the overlap edges that progressed to LFT/COH mixed modes in the middle of the overlap. This is similar to the failure mode observed

for the pure synthetic (GFRP) SLJs. Similar mixed failure modes were observed in the literature for GFRP joints. On the other hand, the hybrid 2-layer joint failure mode displayed significant localized delamination on the overlap edge. Local delamination is linked to

catastrophic failure of the global structure. Therefore, the improved adherend properties of the hybrid 3-layer composite likely avoided localized delamination failure due to increased transverse tensile strength as well as bending stiffness.



Representative load–displacement curves of SLJs as a function of adherend material

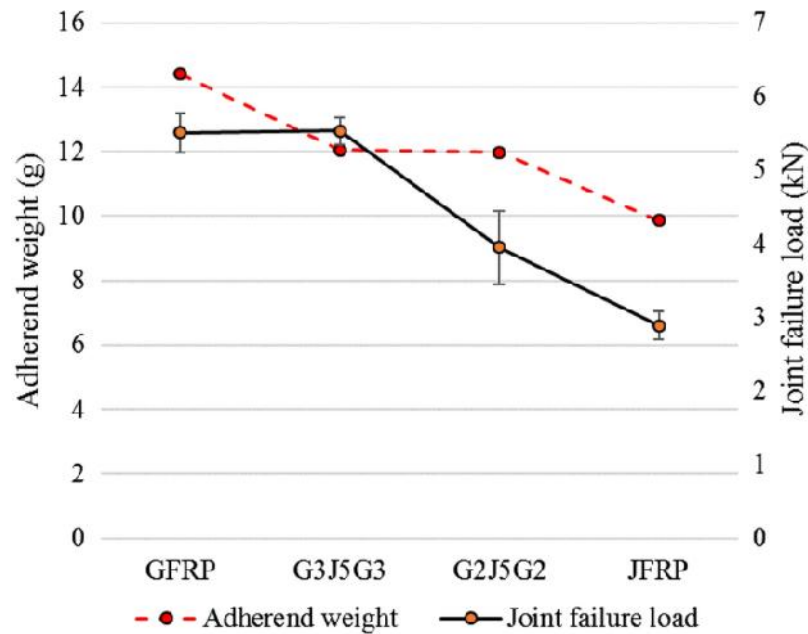
To summarize, the hybrid 3-layer ($G_3J_5G_3$) SLJs reached a compromise of adherend properties, which avoided the delamination failure-onset compared to the hybrid 2-layer joint counterpart. Therefore, the hybrid 3-layer joint managed to match the bonded joint performance of GFRP adherends.

Similar to the failure load, the rigidity of the joints also varied as a function of the adherend material, going from highest for the GFRP joints to lowest for the JFRP joints. The pure jute joint (JFRP), presented the lowest joint rigidity and a completely brittle behaviour. The lower ductility of the jute composite does not accommodate the overlap edge rotation due to load-axis eccentricity, therefore, it fails catastrophically earlier in the displacement.

The significant change in behaviour and joint rigidity observed for the GFRP, when compared to the hybrid joint cases, may be explained by the nearly

twofold increase in adherend rigidity (from approx. 10 GPa to 20 GPa), as seen in Table 2. Such a high adherend rigidity translates in lower tip rotation, which in turn, generates lower peak peel stresses at the overlap edge and these are responsible for damage onset. This has been observed in the literature, where an increase in the bending stiffness of the adherend material postpones damage initiation and consequently increases joint failure load [4, 6]. However, the hybrid cases (i.e. hybrid 2- and 3-layer bonded joint cases) presented identical joint rigidity up to a certain displacement (~1.2 mm). This is due to an earlier damage onset in the hybrid 2-layer joint.

A presents a comparison between adherend weight and joint failure load. It can be seen that the hybridization technique in the form of a 5-layer jute core sandwiched between 3 layers of glass had a significant impact on the average failure load to adherend weight ratio. This exemplifies the potential gains in weight savings and possible lowered fuel consumption with the application of this material in the automotive industry where high strength to weight ratio are important.



Comparison between adherend weight and joint failure load

CONCLUSION

In this study single-lap adhesively bonded joints made of natural, synthetic and interlaminar hybrid fibre-reinforced polymer composites were experimentally investigated. The effect of the number of the interlaminar synthetic layers required to match the bonded joint efficiency of a fully synthetic GFRP bonded joint was studied by testing SLJs bonded with a modern tough structural adhesive used in the automotive. The following conclusions can be drawn:

- A significant variation of joint behaviour was observed as a function of adherend material. The failure load of the hybrid adherend joints increased by increasing the number of external synthetic

layers (i.e. the failure load of hybrid 3-layer joint increased by 28.6% compared to hybrid 2-layer joint) and reached the pure synthetic adherends joints efficiency. This is due to the optimum compromise between the adherend material property (i.e. stiffness and strength) and a diminished bondline peel stress state.

- The failure modes of the bonded joints presented significant differences as a function of adherend material. The pure jute SLJs failed in the adherend. The hybrid 2-layer joint presented a mixed TLC/LFT as well as major delamination failures, while the hybrid 3-layer joint presented stable cohesive crack growth as well as mixed TLC/LFT, similar to pure synthetic SLJs failure mode.

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