STUDENT EDITORIAL

From Raw Materials to Composites: Different Fabrication Techniques for Unsaturated Polyester/ Coconut Coir Fibre Composites

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Introduction

Generally, polymer composites consist of fibres embedded in the polymer to enhance mechanical properties of the composites. The fibres in these polymer composites can be varied in form, composition, orientation, length-to-diameter (L/D) ratio and size. Each of these variations affects the mechanical properties of the polymer composites (Callister and Rethwisch, 2020).

Additionally, there are several fabrication methods for composite materials, such as injection moulding, autoclave moulding, filament winding, pultrusion, resin transfer moulding (RTM), hand lay-up, spray lay-up, compression moulding and vacuum infusion (Nagavally, 2017; Rajak, 2019). The current study focused on composite materials made from natural fibre and thermosetting matrix, primarily using three different fabrications, which are compression moulding, hand lay-up and vacuum infusion processes. Both compression moulding and vacuum infusion moulding are closed moulding processes, while the hand lay-up is an open moulding process (Nagavally, 2017). Different fabrication methods for polymer composites result in different mechanical properties and the choice of fabrication method also depends on the specific application and its requirements (Rajak, 2019).

Hong et al. (2024) studied denim fabric-reinforced unsaturated polyester composites produced using various processing methods. Their research highlighted that different fabrication methods for thermosetting composite materials result in varying mechanical properties. The variation is due to defects such as void formation, delamination and reinforcement agglomeration, which occur differently depending on the fabrication methods and affect the properties of the composites.

In the present study, coconut coir fibre-reinforced unsaturated polyester composites were prepared using different fabrication techniques and the tensile properties of these composites were investigated.

Materials

Coconut coir fibre in mat form (CCM) and unsaturated polyester (UP) were used as the raw materials of the thermosetting composite. CCM acted as reinforcement while UP acted as the polymer matrix. Both CCM and the UP were purchased from Taurenz Resources, Kedah, Malaysia. The CCM was in randomly orientated fibre in mat form. Before preparing the UP/CCM composite samples, 1 wt % of hardener, which is methyl ethyl ketone peroxide (MEKP) was mixed with the UP before proceeding to produce the thermosetting composite samples using different techniques. Additionally, the gel time of the UP resin was 20 minutes with the addition of 1 wt % of MEKP at room temperature. Hence, all fabrications of composites were done within 20 minutes to avoid the composite sample cured during the fabrication process.

Preparation of UP Composites with Different Techniques
1 wt % of the MEKP was mixed with the UP resin and stirred for 2 minutes. A total of 100 g of this mixture was used for the different fabrication methods, as explained below:

Compression moulding

The releasing agent was applied on the mould and the CCM was placed on the mould. The UP resin was then poured onto the CCM and impregnated using a brusher to press the UP resin into the CCM. The compression pressure of 2.1 MPa was applied to compress the UP composite for 10 minutes and force out any trapped air bubbles. No heat is required for this process. The UP/CCM composite was left for curing at room temperature for 24 hours. The setup of the compression moulding technique was shown in Figure 1.

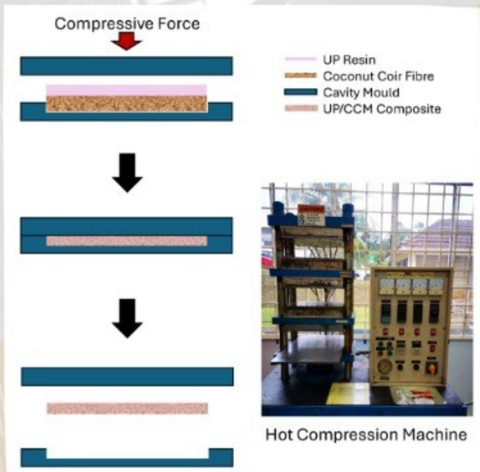

Figure 1: The setup of compression moulding

Hand Lay-up

The UP resin was applied to the CCM layer by layer using a brush, impregnating the CCM. A roller was used to remove air bubbles from the UP composite. The UP/CCM composite was then left to cure for 24 hours. Figure 2 shows the fabrication method of hand lay-up.

Vacuum Infusion

The vacuum infusion setup was presented as shown in Figure 3. Releasing agent was first applied to the acrylic mould to ensure easy removal of the UP composite from the mould. The CCM was put on the acrylic mould and covered with peel ply, infusion mesh layer and vacuum bag. The vacuum bag was sealed to the acrylic mould using sealant tape to ensure proper sealing. The vacuum pump was then connected, and the UP resin was sucked into the mould through the vacuum process, which removed air and impregnated the CCM with the UP resin. After curing and hardening within the vacuum bag for 24 hours, the UP/CCM composite was demoulded by removing the vacuum bag.

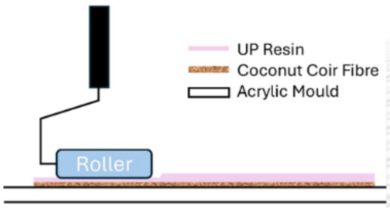

Figure 2: Fabrication method of hand lay-up

Post-curing Process

After curing for 24 hours at room temperature, all samples from compression moulding, hand lay-up and vacuum infusion were removed from moulds and placed in an oven at 60 °C for 1 hour for post-curing. This step was to ensure that all samples were fully cured.

Tensile Test

The tensile properties (ultimate tensile strength, modulus of elasticity and elongation at break) were measured using 10 Tons Universal Tensile Tester (Shimadzu's AGS-X Series). Each specimen was cut to the standard Type IV dimensions according to ASTM D638. A total of 5 specimens from each fabrication method were tested to get an average value. The tests were conducted at a crosshead speed of 10 mm/min and performed at room temperature.

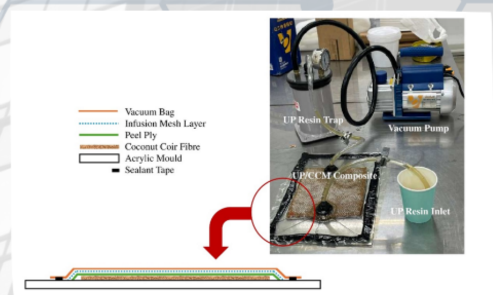

Figure 3: Setup of vacuum infusion moulding

Results and Discussion

Figure 4 shows that the tensile strength of the UP/CCM composites increased as compared to neat UP, regardless of the fabrication method used. This is due to the incorporation of the CCM, which reinforces the tensile strength of the composites, allowing them to withstand more stress than neat UP before failure. The stress transferred from UP matrix to the CCM fibres within the composites. El-Wazery et al. (2017) also stated that when the fibres reinforcements are incorporated into a weak polymer matrix, the reinforcements share the major load. Therefore, the strength and stiffness of the composite materials depend on the strength and stiffness of the reinforcement.

When comparing different fabrication techniques, the results show that the UP/CCM composite produced by compression moulding shows the highest tensile strength, followed by the vacuum infusion UP/CCM composite, with the hand lay-up UP/CCM composite having the lowest tensile strength. The higher tensile strength of the compression-moulded composite has fewer trapped air bubbles, as the compressive force is applied during the process, which effectively removes most of the air bubbles from the composites. These bubbles act as weak points in the specimen, causing stress concentrations that initiate cracks and lead to failure during tensile testing.

In vacuum infusion, the vacuum pump helps to extract air bubbles, many of which become trapped on the infusion mesh layer, resulting in fewer bubbles within the composite as compared to hand lay-up composite. However, in the hand lay-up method, it is difficult to remove bubbles from the composite using the roller, leading to more air being trapped in the composite. These trapped bubbles weaken the composite, resulting in the lowest tensile strength among the three fabrication methods.

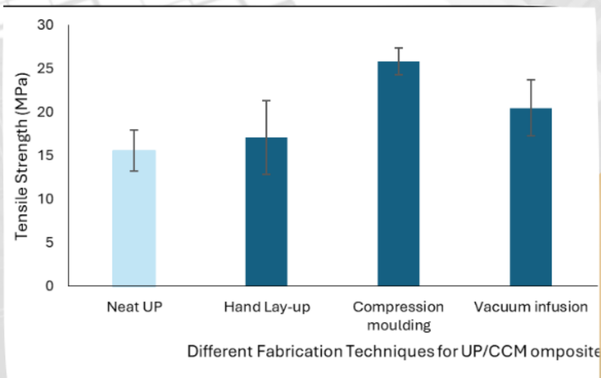

Figure 4: Tensile strength of neat UP and UP/CCM composites produced using different fabrication methods

Based on Figure 5, the modulus of elasticity of all UP/CCM composites is higher than neat UP. This increase is attributed to the incorporation of the higher stiffness fibres, which improves the overall stiffness of the UP/CCM composites. The modulus of elasticity results for the specimens produced using the three different fabrication techniques follow the same trend as the tensile strength results.

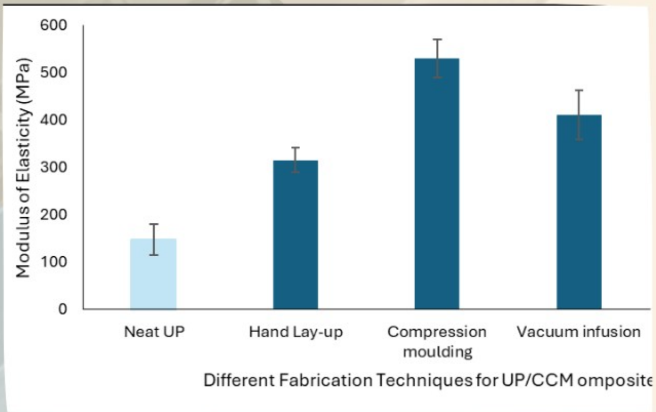

Figure 5: Modulus of elasticity of neat UP and UP/CCM composites produced using different fabrication methods

Figure 6 shows the elongation at break for both neat UP and UP/CCM composites. The neat UP shows higher elongation at break than all UP composites. This is likely because the incorporation of the fibres reduces the chain mobility of the UP, increasing the rigidity of the composites. Among of three fabrication methods, the compression moulded composites showed the highest elongation at break, followed by vacuum infusion composites, with the hand lay-up composites showing the lowest. This is due to the fact that the presence of numerous air bubbles in the hand lay-up composites leads to rapid crack formation when subjected to tensile forces.

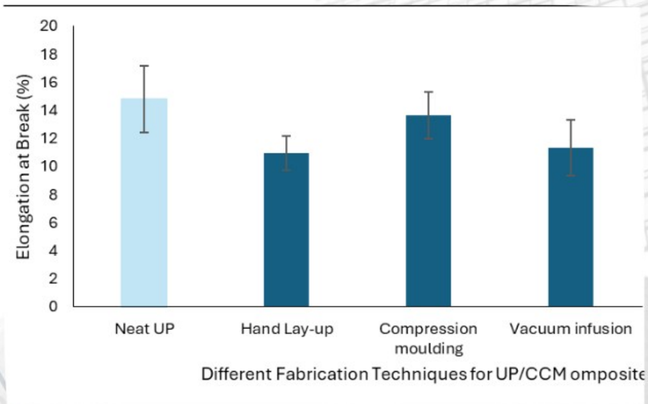

Figure 6: Elongation at break of neat UP and UP/CCM composites produced using different fabrication methods

Conclusion

In summary, the incorporation of CCM into UP enhances the ultimate tensile strength and modulus of elasticity but reduces the elongation at break of UP/CCM composites across all three fabrication techniques. Among the fabrication techniques, compression-moulded specimens showed the highest ultimate tensile strength, modulus of elasticity and elongation at break. This could be due to using the compression moulding process, which more effectively removes the air bubbles from the UP composites as compared to the vacuum infusion and hand lay-up. The presence of the air bubbles can create stress concentrations and initiate the failure during testing.

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A biannual magazine PP18691/01/2018(034114)/ISSN2289-9030

MATERIALS MIND

Issue 42

April 2025

www.iomm.org.my

Institute of Materials, Malaysia

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ISSN 2289-9030

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