INFLUENCE OF CURING TEMPERATURE ON MECHANICAL PROPERTIES OF WOVEN JUTE REINFORCED POLYESTER COMPOSITE

Z. Mustafa[1], N.H. Idrus[1], S.H.S.M. Fadzullah[2], A.B. Hadzley[1], Z. Shamsudin[1], N.S.A.M. Razali[1] and N.I. Omar[3]

[1] Advanced Manufacturing Centre,
Faculty of Manufacturing Engineering,
Universiti Teknikal Malaysia Melaka, Malaysia.

[2] Centre for Advance Research on Energy (CARe),
Faculty of Mechanical Engineering,
Universiti Teknikal Malaysia Melaka, Malaysia.

[3]Faculty of Engineering Technology,
Universiti Teknikal Malaysia Melaka, Malaysia.

Corresponding Author's Email: [1]zaleha@utem.edu.my

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ABSTRACT: The aim of this work is to evaluate the influence of curing temperature onto the mechanical properties of woven jute/polyester composite using warm compression moulding. 40 vol.% woven jute fibres were compressed moulded at a pressure of 2.0 MPa, holding time of 900s by varying the fabrication temperature in three levels which are 150°C, 170°C and 180 °C. The mechanical and thermal properties were characterized using flexural and impact testing, DSC and TGA. Optimum mechanical properties are achieved at moulding temperature of 170°C. The flexural strength and flexural modulus at the optimised moulding temperature are 37.20 MPa and 0.84 GPa respectively, while their impact strength is 19.38 kJm-2. Morphological examination revealed that the composite failed in brittle manner and due to fibre pull-out indicating of weak interface.

KEYWORDS: *Hot Compression; Unsaturated Polyester; Woven Jute; Curing Temperature*

1.0 INTRODUCTION

In the recent years, interest in study of incorporation of natural fibres in polymer composite has increased due to their various advantages over the conventional fibres such as low density, high specific properties, biodegradable as well as sustainable. Jute fibre is one of the natural fibres that garner the intention of the researchers due to their economic higher strength and modulus compared with other natural fibre such as coir, flax, sisal and rami [1-3] Jute fibre reinforced polymer composites are potentially to be used in primary structural application and interior housing component. While their excellent insulating properties make it a good candidate to be used in automotive application such as door, ceiling and passenger compartments panels [2].

Natural fibre is naturally hydrophilic and often causes incompatible to be use in hydrophobic polymeric matric. Thus, fibre treatment on the natural fibres is often adopted to improve their characteristic and provide better unison when used in combination with a more hydrophobic polymer. Natural fibres such as jute were normally treated either by alkaline treatment or coupling agent such as oligomeric siloxane to improve its wettability in epoxy matrix thus resulting in higher mechanical properties [4-7].

The common fabrication processes for natural fibre based in the thermoset polymeric matrix such as polyester and epoxy is via hand lay-up, vacuum bagging and vacuum infusion. While these processes are relatively easy to perform, it is time consuming. This is due to the longer time for curing process in which normally carried out at room temperature. Alternatively, warm compression moulding technique could provide solution for the faster curing time. Previous study showed that fabrication of thermoset based composite laminate are often influence by parameters such as temperature, pressure and holding time [4-10], where it can be used in combination to enhance the properties of the composite. Thus, the purpose of this paper is to optimise the effect of the curing temperature on the mechanical properties of jute-reinforced polyester composites fabricated by hot compression moulding method.

2.0 MATERIALS AND METHODS

2.1 Materials

Jute fibres are used as reinforcement in the form of woven supplied by Composite Evolution (UK) under commercial name of Biotex-Jute. It has thermal decomposition of 230˚C and specific gravity of 1.3 g/cm3. Unsaturated polyester resin (PCCR 733-6544) is supply by Revertex Sdn. Bhd. is used as matrix, with tensile strength of 40 MPa, density of 1.09 g/cm3 and melting temperature of 54 ˚C. Methyl Ethyl Ketone Peroxide (MEKP) is used as catalyst.

2.2 Composite Fabrication

Prior to fabrication, the woven jute mat were alkaline treated in 5% sodium hydroxide (NaOH) solution for 30 minutes. It was then washed thoroughly to remove any trace of alkali [11]. The mats were then dried at 70°C in an oven for 2 hours followed by drying in room temperature for 48 hours.

The jute/polyester composite panels were fabricated by using hot compression moulding technique. Composite with 40 vol. % of jute were fabricated using five layers of woven jute mat in a 300 mm X 300 mm x 3 mm mould. The matrix solution consisting of MEEK was poured into mould and brush-up by hand to ensure that the entire cavity is filled. It was then compressed moulded at a pressure of 2.0 MPa and holding time of 900s by varying the fabrication temperature in three levels (150°C, 170°C and 180 °C). The composite then were cut into 100 mm long x 20 mm width x 3 mm thick for flexural and impact testing.

2.3 Thermal Analysis

A differential scanning calorimetry (DSC) test was carried out on TA Instruments DSC Q1000 (New Castle, USA) with a heating rate of 10 K/min up to 250 °C to confirm the glass and melting temperature of the resin. Thermogravimetric analysis (TGA) was carried out on the composites using of a Shimadzu thermal analyser from 30°C up to 700°C at a heating rate of 10 °C/min under nitrogen atmosphere.

2.4 Mechanical Testing

The flexural properties were characterized using three point bending tests on universal testing machine (INSTRON 3385) with cross head speed of 2 mm/min following ASTM D790 standard. Specimen with the span to depth ratio of 16:1 was used. The pendulum Charpy impact testing was carried out on Instron CEAST 9050 Impact System with Data Acquisition and Control (ASTM D6110) to determine their absorbed impact energy according to the ASTM D6110. Five testing were repeated for each of compression moulding temperature used.

2.5 Morphology Examination

The fracture surface of the Charpy impact test samples were examined using a scanning electron microscope (SEM, Philips XL30S FEG, Netherland) at room temperature, operated at 5 kV. Prior to testing, the entire sample surface was platinum coated by sputtering method.

3.0 RESULTS AND DISCUSSION

3.1 Characterization Analysis

The DSC results confirmed the glass transition temperature (Tg) and melting temperature (Tm) of the neat polyester is at the range of 54°C and 150°C respectively. Both temperatures are essential in predicting the process temperature of impregnating of the jute fibre and as the parameters of hot press forming process.

The thermal decomposition behaviour of the neat resin and, untreated and treated jute fibres and woven jute/polyester composite (compressed at 150°C) are shown in Figure 1. Neat resin decomposition is in the range of 175°C – 450°C characterized by mass loss of 90 wt. %. The final residue of the neat resin is 3 wt. %. In the case of the jute fibres, a slight shift of the degradation onset and a clear evident reduction of the mass loss can be noticed for untreated and treated fibres. Untreated jute fibres showed faster decomposition compare to treated fibres as early as 120°C before rapid decomposition from 230°C to 400°C with mass loss of 76 wt.%. The final residue for both jute fibres is 18 wt. %.

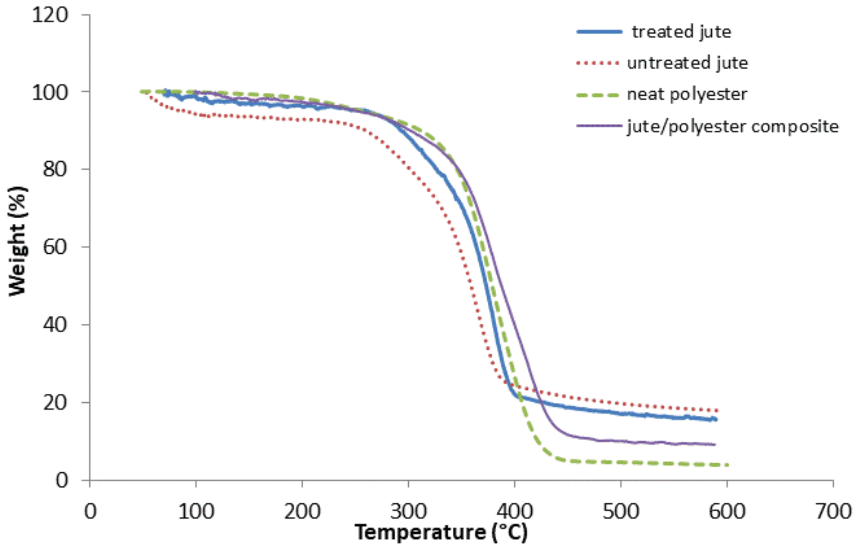

Figure 1: TGA analysis of neat resin, jute fibres and woven jute/polyester composite

The flexural strength and flexural modulus of woven jute/polyester composite are plotted in Figure 2. It was observed that the flexural strength increased when moulded at 170 °C from 36.06 ± 0.64 MPa (150 °C) to 37.20 ± 0.84 MPa, indicating better wettability is achieved with increased of moulding temperature. However further increase of the moulding temperature to 180°C significantly reduces the flexural properties to 26.70 ± 0.72 MPa. Such reduction in modulus value could possibly due to thermal degradation of the composite at temperature above 170 °C as indicated by the TGA analysis earlier. Similar trend is observed in the flexural modulus behaviour. As the moulding temperature is increased from 150 °C to 170 °C, the modulus is increased from 0.68 ± 0.02 GPa to 0.84 ± 0.08 GPa respectively. Further increased of the moulding temperature has caused degradation in their rigidity value to 0.77 ± 0.08 GPa at 180 °C.

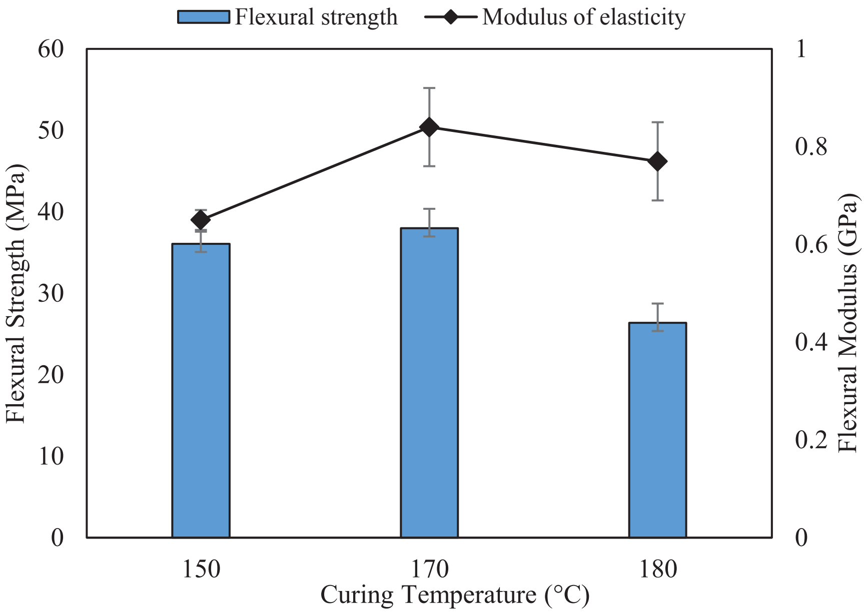

Figure 2: Effect of curing temperature on flexural properties of jute/polyester composite

The curing temperature was also found to play a significant role in improving the impact properties of the composites (Figure 3). The composite gained higher specific Charpy energy when the curing temperature is increased and reached their maximum value of 19.38 ± 0.03 kJ/m2 at 170 °C before decreased to 14.90 ± 0.13 kJ/m2 when compressed at 180°C. It is also observed that the impact strength of the composite at curing temperature of 180°C is still higher compare to at 150°C. Such observation could be due to changes of resin viscosity at higher moulding temperature. Similar trend was discussed in literature [12] where impact strength of the sisal/polyester composite was observed at higher temperature.

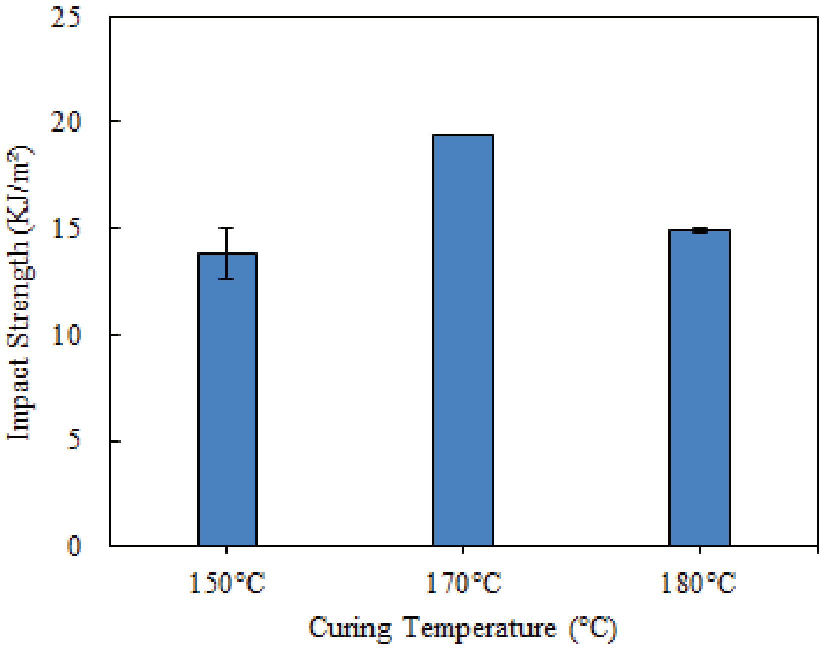

Figure 3: Effect of curing temperature on Charpy impact properties of jute/polyester composite

The Charpy impact fracture surface of the composite cured at 150 °C and 170 °C is shown in Figure 4. As the fibre volume fraction was fix at 40 vol. %, the properties of the composite were mainly controlled by the shear strength of the fibre/matrix interfaces produced during fabrication. At lower temperature, larger voids were observed (Figure 4a) and the composite failed due to jute fibres pulled-out (Figure 4b), an indication of weak bonding at the interface. As moulding temperature is increased to 170°C, (Figures 4c-4d), better matrix viscosity and wettability between the fibre/matrix was achieved, as in the voids size reduction (Figure 4c) and fibres surface appeared to be rougher with evident of matrix left behind (Figure 4d) [13-15]. This finding is similar to the work reported in the previous study [16] in which at fibres volume fraction above 0.35, the composite strength of long fibre jute/polyester changed from tensile to tensile–shear strength dominant.

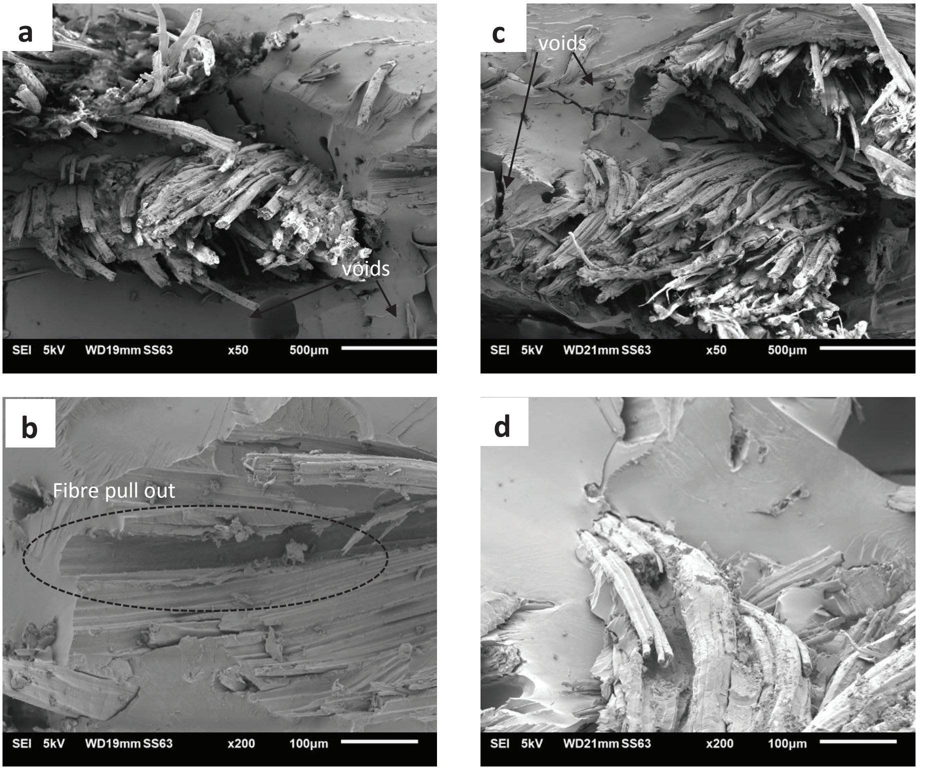

Figure-4. SEM micrographs of Charpy impact fracture of 40 vol.% jute/unsaturated polyester composites cured at (a)-(b) 150˚C and (c)-(d) 170˚C

4.0 CONCLUSIONS

Hot compression moulding allowed jute fibre to forms an intimate bond with polyester resin at a reducing fabrication time. The mechanical properties of the composite are influences by the degree of the moulding temperature indicating that both fibre and resin are susceptible to thermal degradation. The curing temperature of 170°C can be considered as a promising condition to attain better flexural and impact properties respectively.

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