Effect of water ageing on fatigue hysteresis of rubberwood reinforced recycled polypropylene composites

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ABSTRACT: In this study, the evaluation on the effect of the moisture towards the fatigue properties of rubberwood reinforced recycle polypropylene has been performed. The composites has been aged in water immersion for 30 days prior to the fatigue test. The tension-tension fatigue test was carried out at 4 Hz, R = = 0.1 and at 60 % of their ultimate tensile strength until failure. The fatigue damage behaviour was studied through changes in the hysteresis loop captured during the test. It was observed that the fatigue strength of the rubberwood/PP composite reduced after the ageing process, with fatigue life reduced from 630,030 cycles to 406,932 cycles respectively. In a non-ageing composite, the material has longer fatigue life, thus more apparent damage is observed compared to the aged specimens. The hysteresis loop of the non-aged composite is more open toward failure and extensive creep is also observed. The aged specimens showed less changes in the loop area as cyclic progress suggesting that fatigue failure is fracture dominated and very little volume damage has occurred.

Keywords: rubberwood composite; water ageing; hysteresis fatigue.

1. INTRODUCTION

Wood polymer composite (WPC) contains wood flour as the major component have excellent mechanical strength and stiffness [1]. These inexpensive filler materials often a by-product of the agricultural or timber industry used in combination with polymeric materials such as polypropylene, polyethene which are regarded not only as an excellent effort to preserve the natural resources, reduce the environmental issues but provide a cheaper alternative to the timber product [2, 3]. Over the years, there has been some ongoing interest in using cellulosic fibre composite for many applications that may be subjected to cyclic or alternating loads [4]. Wood polymer composites, like any natural fibre-based composite, are also susceptible to moisture. While the influence of hydrothermal ageing has been extensively studied in static conditions [5], their effect on the fatigue behaviour of the wood polymer composite has been poorly studied.

Thus this paper aims to examine the damage occurred in the rubberwood reinforced composite in tension-tension conditions. At the same time, to evaluate the influence of the water ageing onto their fatigue resistance. Hysteresis loops capture throughout the test is used to monitor the fatigue damage development in the rubberwood /polypropylene composite.

2. METHODOLOGY

The composite granule containing 50.3 wt.% recycled PP, 37.5 wt.% rubberwood flour and 7 wt.% calcium carbonate as filler are combined and extruded using a twin-screw extruder. More details manufacturing process are given in the authors' previous work [1]. The pellet then was compressed moulded using a hot press (Carver, USA) at 190 °C under 1000 psi and cut into a flat dumbbell shape according to ASTM D638 (Figure 1). Ten specimens were immersed in tap water at room temperature for 30 days. Monotonic and fatigue tests were conducted on a 20kN Shimadzu (Japan) servo-hydraulic testing machine. Both of the non-ageing and water aged specimens were subjected to monotonic tensile and tension-tension fatigue tests. The monotonic tension test was carried out at a cross-head speed of 2 mm/min. The fatigue test was carried out at constant amplitude loads in a sinusoidal waveform at a frequency of 4 Hz at a stress ratio (R = 0.1). The fatigue test was carried at 60 % ultimate strength (UTS) of the composite up to 1.5 million cycles or till failure. The number of cycles, force and displacement were recorded at every 0.05s of each cycle.

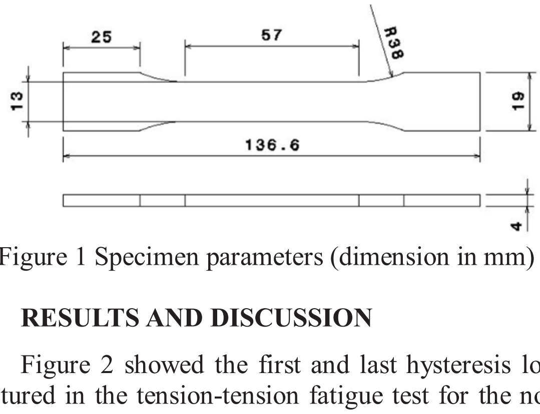

Figure 1 Specimen parameters (dimension in mm)

3. RESULTS AND DISCUSSION

Figure 2 showed the first and last hysteresis loop captured in the tension-tension fatigue test for the non-ageing and water aged of the specimens. For non- ageing specimens (Figure 2a), the stress peak is at 16 MPa equivalent to the 60% UTS resulted in longer fatigue life of 630,030 cycle fatigue life. It can be observed that the last cycle shifted along the positive strain axis indicated extensive creep has occurred. The loop area of the last cycle is more open and the dynamic modulus is decreased.

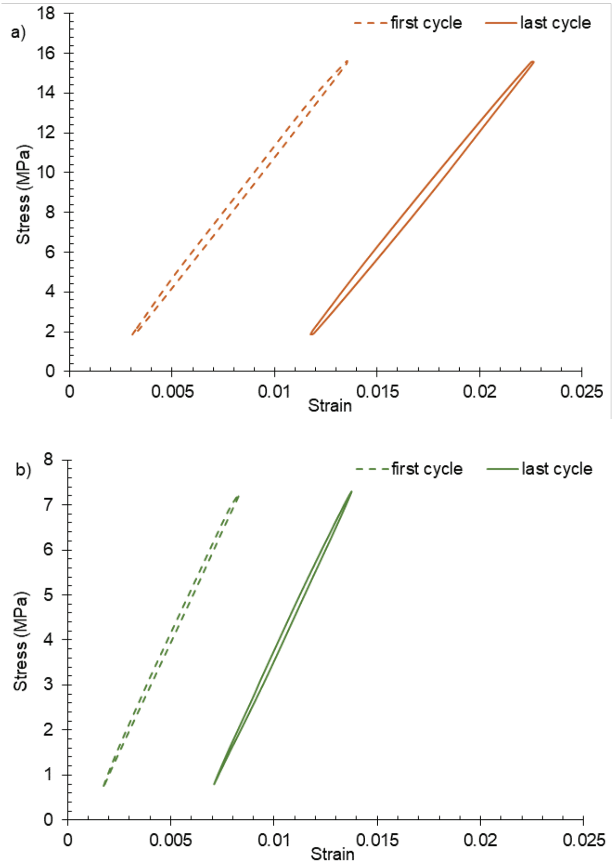

Figure 2 Fatigue hysteresis loop of (a) non-ageing and (b) aged rubberwood reinforced polypropylene composite at 60% UTS

The water aged rubberwood/ recycled PP composite experienced a reduction in their initial strength after exposure to the water immersion. The initial monotonic tensile strength is reduced from 26.33 MPa to 12.19 MPa. As the fatigue test is carried out with the same percentage of stress level (60 % UTS), the stress peak for the water aged composite is at 7.32 MPa. The fatigue life (N_f) for the aged composite is also lower with N_f = 406,932 cycles compare to the non-ageing composite. This is due to the present of the moisture from the ageing process has reduced the interface bonding between the fibre and matrix thus weakening their strength [1]. Figure 2b shows the hysteresis loop for the water ageing, shifted slightly along the positive strain axis indicated creep has occurred. The loop area of the first and last cycle is also almost identical. The slope of the curve is also not significantly decline prior to the fractured. The result is in agreement with Hacker and Ansell [6], suggesting that the fatigue failure of rubberwood/ PP composites is fracture dominated. The non-significant changes in the loop area suggesting a very little volume damage occurred in the composite system prior to their failure. This suggests that the presence of moisture reduced the fatigue resistance of the rubberwood/ PP composites.

4. CONCLUSION

The stress-strain hysteresis loop is used to assess the fatigue damage behaviour in the rubberwood reinforced polypropylene composite in tension-tension fatigue. The tensile fatigue life and their damage behaviour are influenced by exposure to moisture. The aged composite has a lower fatigue life than non-ageing composite which are 406,932 and 630,030 cycles respectively. This indicated the exposure to the moisture from the water ageing reduced their fatigue resistant. The fatigue hysteresis loop showed that the non-ageing composite has a more open area and extensive tensile creep compared to aged specimens, indicating that more damage is occurred in the non-aged composite system compare to the aged composite.

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