THE EFFECT OF CRYSTALLINITY IN HEMP/POLYLACTIDE COMPOSITES ON FRACTURE TOUGHNESS

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Introduction

Plane-strain fracture toughness (K_{Ic}) of random short hemp fibre reinforced polylactide (PLA) bio-composites was investigated along with the effect of loading rate, fibre treatment and PLA crystallinity. Fracture toughness testing was carried out at loading rates varying from 0.5 mm/min to 20 mm/min using single-edge-notched bending specimens of 0 to 30 wt% untreated fibre content.

Results and Discussion

Results showed that K_Q (trial K_{Ic}) of composites decreased as loading rate increased, until stabilising to give K_{Ic} values at a loading rate of 10 mm/min and higher (Fig.1).

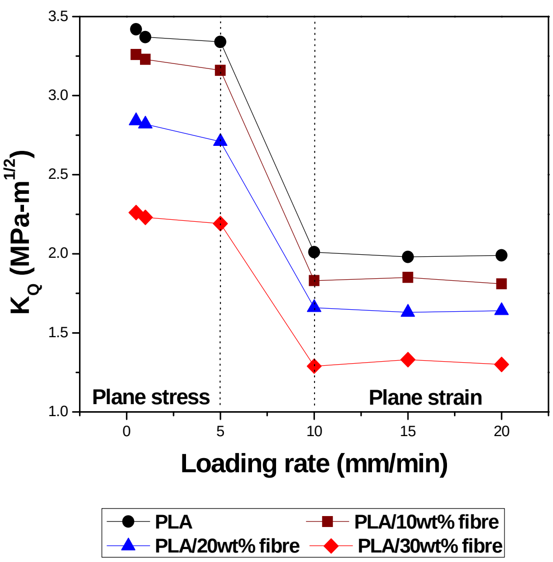

Figure 1. K_Q **as a function of loading rate at different fibre contents.**

The reduction of crazing as well as a more direct crack path observed in PLA samples provided explanation for reduction of K_{Ic} (Fig.2). Typical crack paths of PLA/hemp composites did not propagate directly across the sample but appeared to have been influenced by the presence of fibres such that increased fibre volume fraction resulted in a more irregular crack path. For composites tested at lower testing rates, evidence of localised matrix tearing was present suggesting limited plastic deformation. Closer examination of the crack propagation path indicated that the two fracture surfaces were not completely separated, but rather connected by the deformed matrix. There was a significant reduction in the plastic flow and/or matrix tearing and the two fracture surfaces were completely separated ahead of the starter crack when composite samples were tested at higher loading rates.

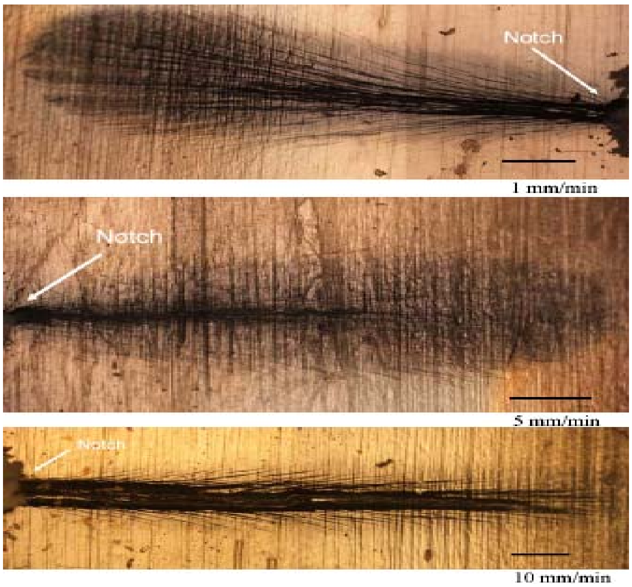

Figure 2. Light micrographs of crazing in PLA during fracture toughness.

K_{Ic} of composites was found to decrease with increased fibre content and alkali fibre treatment (Fig. 3) coinciding with increased PLA crystallinity (Figs. 4 and 5) which could be influencing K_{Ic} [1].

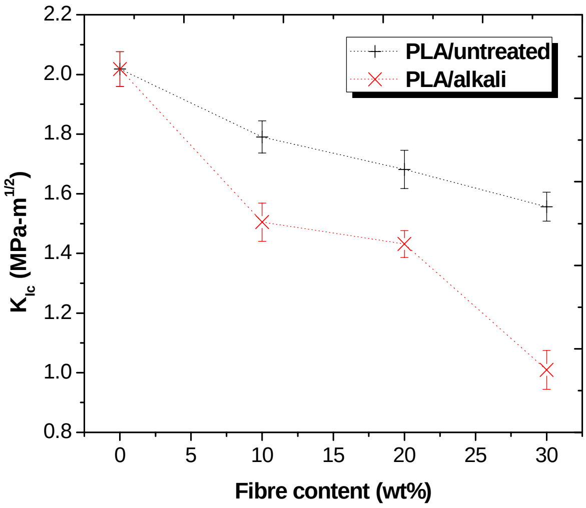

Figure 3. K_{Ic} **versus fibre content for untreated and alkali treated fibre.**

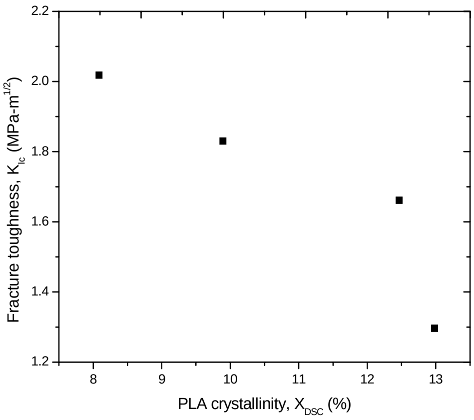

Figure 4. Relationship between K_{Ic} and crystallinity for PLA and composites of different fibre contents.

a)

b)

Figure 5. Transcrystalline layer of PLA with a) untreated and b) treated hemp fibre surfaces.

Exposure of more crystalline cellulose with fibre treatment appeared to be enabling hemp fibre to act as a better nucleating agent for PLA (Fig.5). The degree of PLA crystallinity was controlled by heat treatment or "annealing" to effectively isolate the effect of crystallinity from fibre content (Fig.6). By changing crystallinity in otherwise similar samples it was found that reduction of composite K_{Ic} can be attributed to increased crystallinity (Fig.7).

Conclusions

It has been shown that K_{Ic} of hemp/PLA composites is influenced by crystallinity. It is suggested that transcrystallinity within the composites has a large influence on the fracture behaviour of composites and may serve as an easy path for crack propagation. However, increased stress concentration, when there is increased fibre content and increased interfacial strength with treatment could also contribute to reduction of K_{Ic} for composites. It is concluded that it is possible to improve fracture toughness of this type of composite by controlling crystallinity during composite production.

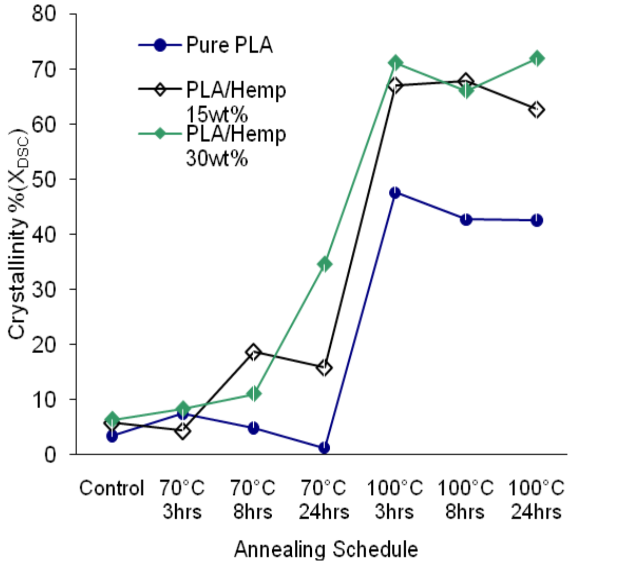

Figure 6. PLA crystallinity for different annealing treatments

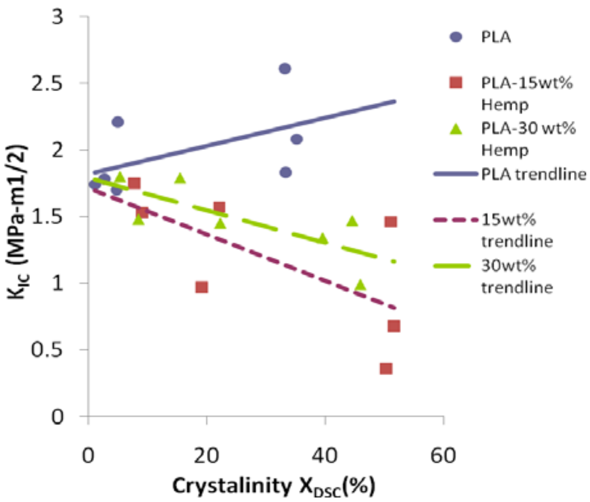

Figure 7. K_{Ic} versus crystallinity isolated from fibre content for alkali treated fibre composites.

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Reference

[1] M. Todo, P. Sang Dae, K. Arakawa, and M. Koganemaru, Effect of crystallinity and loading-rate on mode I fracture behavior of poly(lactic acid). Polymer 47 (2006) 1357.