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Structural flax/PLA biocomposites: understanding of their thermo-mechanical behaviour

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1.1 Introduction

The extended use of bio-composites for the manufacturing of vehicle components would benefit largely the industry [1]. However, the properties of biocomposite, their mechanical performance under different environments and the effect of different loading conditions are still unclear [2-4]. Systematic studies have been conducted on flax/PLA biocomposites, to determine the phenomena dominating their mechanical behaviour and their potential use in structural automotive applications.

1.2 Materials

A 2x2 twill commingled/pre-impregnated Flax/PLA fabric (mixed flax and PLA fibres) was provided by Composites Evolution using a Poly(L-lactide) acid (PLA) based on lactides acquired from corn starch fermentation supplied by Natureworks. For comparative reasons flax/epoxy samples have also been tested. All samples were manufactured by MaHyTec. A 0/90^0 balanced woven fabric provided by LINEO (FlaxPly BL300) was combined with a bio-sourced epoxy resin based mainly on epoxidised pine oil waste from Amroy (Epobiox LV with hardener Ca23).

1.3 Characterisation

For the study of fracture surfaces obtained as a result of mechanical testing of samples and the morphology of the composite, a scanning field emission gun microscope (SEM) was used; DSC was performed on a TA instruments Q200 to evaluate the degree of crystallinity of the PLA in the composite. The glass transition temperature (T_g), cold crystallization and melting temperatures (T_m) were also determined. To assess the temperature of decomposition and the rate of degradation of the materials DMA testing was performed. All tensile tests were performed according to the ASTM 3039 standard on an Instron 5500R electro-mechanical machine. For the temperature studies a thermal chamber was attached to allow temperature control from -40 to 150°C with a step of 1°C.

1.4 Results and discussion

The strength and stiffness of flax/PLA samples – 72 MPa and 13GPa respectively – indicate a very promising material to replace traditional choices in load bearing application. SEM micrographs show that the interfacial adhesion of the constituents is still a challenge and modifications need to be applied on the fibre's surface in order to improve it. The stress-strain law is non-linear with the non-linearity introduced due to viscous behaviour of the material combined with a certain level of damage accumulation throughout the testing. DMA results show deterioration of the composite properties with a tan delta peak at around 74-76 °C. An increase of the storage modulus is however visible after 80 °C, explained due to the cold crystallization transition of the amorphous part of the PLA. The flax fibres have a positive effect on the thermal response.

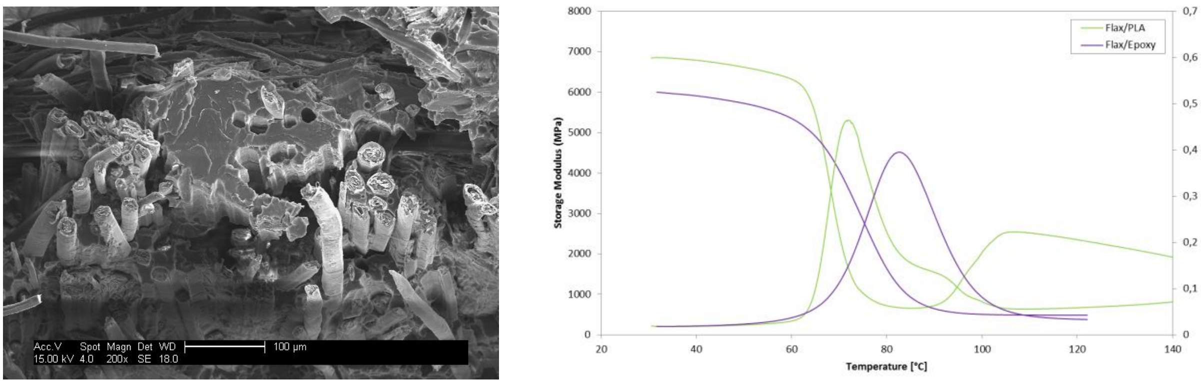

Figure 1: *(left)* Overview of the fracture surfaces; *(right)* **s**torage modulus and tan delta from studied composites

Temperature affects enormously the properties of flax/PLA. At 50 °C the stiffness is reduced by half, and the ultimate strength is reduced significantly. Strain rate has also an effect on the material and its viscous behaviour. Strength and modulus increase with increasing strain rates, while elongation at break reduces respectively. A modulus of 22 GPa was recorded in 4.2 m/sec crosshead velocity. The mechanical properties of flax/PLA were compared with a more commonly used a studied flax/epoxy material. Although flax/epoxy has some advantages in terms of strength and thermal stability, flax/PLA has significantly higher modulus.

Table 1: Tensile properties for flax/PLA composites under different environmental and loading conditions

		Modulus [GPa]	Strength [MPa]	Elongation [%]
	Flax/Epoxy	7.6 (0.4)	90 (4.8)	1.85 (0.2)
	Flax/PLA	13 (0.9)	72.2 (2.0)	1.5 (0.08)
Temperature	Flax/PLA - 50 °C	6.2 (1.0)	53.2 (3.2)	2.4 (0.14)
	Flax/PLA - 65 °C	7 (1.5)	35.7 (2.8)	2.04 (0.19)
	Flax/PLA - 110 °C	5 (0.3)	15.5 (1.6)	3.2 (0.4)
Crosshead displacement	Flax/PLA 2mm/min	13 (0.9)	72.2 (2.0)	1.5 (0.08)
	Flax/PLA - 0.5 m/sec	14 (0.7)	87.1 (3.8)	1.5 (0.09)
	Flax/PLA - 4.2 m/sec	22 (2.2)	95.7 (6.2)	1.3 (0.15)

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1.6 References

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