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Processing of Flax Fibre Thermoplastic Composites

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The ecological advantages of flax fibre reinforced thermoplastic composites make them an attractive alternative to glass fibre reinforced polymer composites with comparable specific properties. However, one must overcome the relatively high viscosities of engineering polymers whilst respecting the low degradation temperature and inherent variation of natural fibres. We demonstrate that this may be achieved, and complex geometries can be produced.

The production of flax fibres requires much less energy than the production of their synthetic counterparts (flax fibres: ~6.5 MJ/kg, carbon fibres: 289 MJ/kg and glass fibres: 48 MJ/kg). However, a major challenge when working with natural fibres is their variability (both stochastic and seasonal) and their low degradation temperature (Fig. 1).

Polypropylene (PP) as a matrix is attractive due to its low cost and ease of processing; however, it is less suited for high performance natural fibre composites due to low mechanical performance. Polymers such as co-polyoxymethylene (coPOM), cellulose derived thermoplastic (Cell_TP) and poly-L-lactide (PLLA) can offer comparatively high stiffness, strength, toughness and low creep. These polymers have inherently high viscosities (Fig. 2) and unfavourable wetting characteristics compared to epoxy (EP).

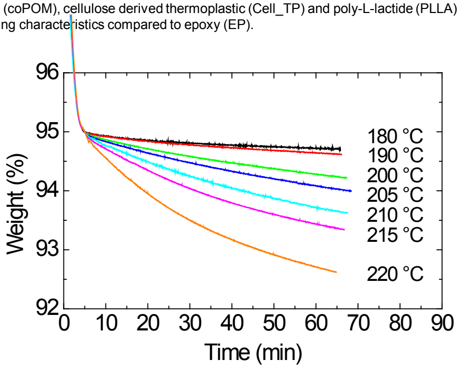

Fig. 1 Thermogravimetric analysis of flax fibres

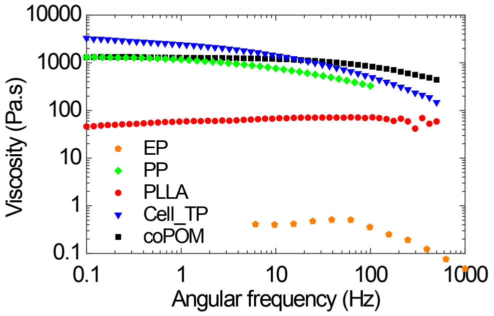

Fig. 2 Viscosity as a function of frequency of the studied matrix materials at 190 °C

By characterising the surface energies of polymer melts and the flax natural fibres, one may understand the physics of wetting and spreading of the polymer during impregnation.
Surface functionalisation of the fibre further aids impregnation of the polymer and fibre-matrix adhesion. This enhances the mechanical properties of the composite.

When exposing the flax fibre to a plasma and impregnating them via a novel process, one may achieve flax fibre composites with fibre volume fractions of 55 % and void contents of less than 2 % (Fig. 3).

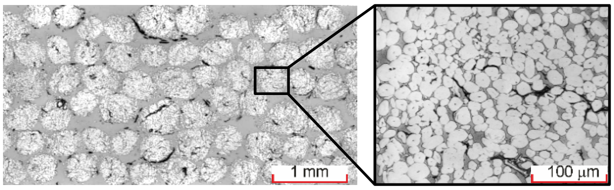

Fig. 3 Optical microscopy of flax fibre PLLA composite

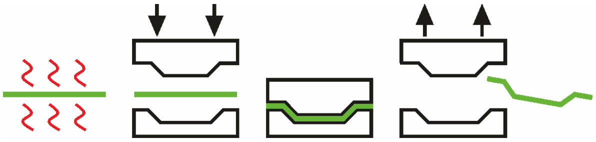

Fig. 4 Schematic of thermoplastic composite process line

Flax fibre thermoplastic layers with varying fibre orientation may be processed into organo-sheets. These sheets may be used to form complex parts via a stamping process (Fig. 4), for example a bicycle saddle shape (Fig. 6) in a cost effective and fast process.

Thermoplastic matrices allow for part welding. Thus, integral parts may be manufactured in a single processing step or by direct injection moulding.

At the end of service, the material may be recycled via reprocessing, down-cycling, or energy recovery, proving its sustainability in mobility.

Fig. 5 From flax plants and cellulose based polymers to natural fibre composite parts

Fig. 6 Flax fibre thermoplastic composite saddle shell

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