DEVELOPMENT AND CHARACTERISATION OF BAST AND BASALT FIBRE HYBRID POLYMER COMPOSITES FOR AUTOMOTIVE APPLICATIONS

Anjum Saleem

Thesis for the degree of Doctor of Philosophy at the University of Borås to be publicly defended on March 25th 2021, 10.00 AM at University of Borås, 501 90 Borås

Language: English

Faculty opponent:

Roberts Joffe, Professor at Luleå University of Technology, Sweden

PhD thesis available at: Swedish Centre for Resource Recovery
University of Borås, SE-501 90 Borås

UNIVERSITY
OF BORÅS

ABSTRACT

Natural fibres such as kenaf, hemp, and flax, also known as bast fibres, offer several benefits such as low density, low cost, carbon dioxide neutrality, sustainability and renewability. In Europe, their composites are used intensively by almost all car manufacturers, mostly in interior applications. Compared to glass fibres, they are safe in processing, renewable, and recyclable. Other than that, their specific mechanical properties are either close to or at times higher than glass fibres. They have great potential to replace a segment of the glass fibre reinforced composites in automotive applications. The shortcomings of bast fibres are their poor mechanical strength, varying fibre characteristics (because of climate, cultivation, soil), and low processing temperature (approximately 200°C). Therefore, they cannot meet the structural and durability demands of automobile parts as do glass fibres.

This research work aimed to improve the mechanical performance of bast fibre reinforced polymer composites by hybridisation with high performance natural basalt fibres. They are natural inorganic fibres with mechanical and thermal properties higher than bast fibres and close to or higher than common glass fibres (E-glass). As bast fibres, flax, hemp, and kenaf were selected for reinforcement. Polypropylene and acrylic based polyester resin were used as matrix. The target was to prepare the composites by established processing methods for the applications of natural fibre reinforced composites in the automotive sector, such as carding, resin impregnation, and compression moulding.

The first step in the production of composites was the preparation of nonwovens by carding process and needle punching. It was challenging to card fine and brittle basalt fibres. The carding process was therefore intensively optimised so that the nonwovens could be produced without fibre damage and with homogeneously distributed fibres. For thermoplastic composites, nonwovens were prepared with polypropylene fibres. The reference composition was a mixture of polypropylene and bast fibres (50:50). For the hybrid compositions, the bast content was gradually replaced by basalt fibres. Nonwovens were ready for compression moulding immediately after their production. Nonwovens for thermoset resin impregnation were prepared with only natural fibres. The reference composition was a mixture of flax and kenaf (50:50). For the hybrid compositions, the bast content in the reference composition was gradually replaced with basalt fibres. The nonwovens were first impregnated with acrylic based polyester resin and compression moulded after drying.

The compression moulded flat plates were analysed for their mechanical, thermal, and morphological properties. The mechanical performance was characterised by flexural, tensile, and Charpy impact analysis. Thermal analysis included thermogravimetry, differential scanning calorimetry, heat deflection temperature, and thermal conductivity. The morphological properties regarding fibre matrix interaction and fibre distribution were studied by scanning electron microscopy.

The material characterisation showed significant improvement in mechanical performance by the addition of basalt fibres. It was found that the basalt fibres not only improved the strength and stiffness of the composites, but simultaneously increased the energy absorption as well. The fracture surface analysis confirmed a better fibre matrix adhesion in thermoset composites than in thermoplastic composites because of chemical compatibility between thermoset and bast fibres. It was found that selecting basalt fibres with appropriate sizing could significantly influence the fibre matrix bonding and is a deciding factor in defining the optimal mechanical performance of the composite. It was shown that bonding could also be improved by polymer modification, which is, however, an expensive method. The competitive performance of thermoset composites was compared with thermoplastic composites. Furthermore, the composites were processed to the final parts at lab and industrial scale, to study their processability for the implementation of material in practical applications. This study highlights the potential of basalt fibres to improve the mechanical performance of bast fibre reinforced composites by hybridisation while stressing the importance of fibre matrix interaction to define the composite's performance.

Keywords: Flax, Hemp, Kenaf, Basalt fibres, Polypropylene, Acrylic based polyester resins, Flexural, Tensile, Impact strength