

Thesis Title: Design and development of textile fibre reinforced structural composites for automotive applications

Abstract

Due to strict environmental regulations aimed at reducing carbon footprints, the automotive industry is now intending to produce electric and solar-powered vehicles, with weight reduction being a key factor. This thesis focuses on the development of textile fibre reinforced structural composites using natural and man-made fibres by both conventional and novel friction stir processing (FSP) methods for automotive applications. Efforts are being made to use different textile fibres (E-glass, basalt, carbon, and sisal) to produce textile structural composites, textile nanocomposites, novel metal matrix composites, and natural fibre reinforced composites. In addition, this research introduces a novel methodical mechanics-based approach for the development of a mesoscale FEM model using SOLIDWORKS for composite reinforced with different textile structures to predict tensile, flexural, and bearing performance.

The first section of this research investigates the mechanical behavior of the textile structural composite (TSC) panels produced from different textile structures such as chopped fibre, unidirectional (UD), bidirectional (2D plain), and three-dimensional (3D) orthogonal woven structures using two different high-performance fibres (glass and basalt) for automotive components such as door and bonnet of a car. The next section of this research aims to investigate the improvement in mechanical, thermal, and viscoelastic properties of textile structure-based nanocomposite material using glass and basalt fibres by incorporating graphene nanoplatelets (GNP) filler with 0, 0.25, 0.5, 0.75, and 1 wt.% into the epoxy matrix via the VARTM technique. The glass fibre-reinforced textile structural nanocomposites (GFRTSNC) and basalt fibre-reinforced textile structural nanocomposites (BFRTSNC) were investigated for their mechanical performance with respect to tensile, flexural, and impact loading.

The third section dealt with the manufacturing of novel textile fibre-reinforced aluminum metal matrix composites (TFRAMMC) by incorporating high-performance fibres in three forms (i.e., long, chopped, and flakes) using the FSP technique. The composites were characterized for their tensile, flexural, and impact performance to explore their load-bearing capacity and energy absorbency. In the fourth section the author investigated the impact of different thermoset resins, alkaline treatment (different NaOH concentrations), and fibre architecture on the mechanical behavior of sisal fibre-reinforced textile structural composite (SFRTSC) panels developed from different textile structures such as chopped fibre, UD, 2D, and 3D orthogonal woven structures for automotive applications. In addition, the TGA and DMA of the SFRTSC panels were also carried out.

Next section of this research aims to investigate the effect of different machinability processes such as drilling, abrasive water jet machining (AWJM), and laser beam machining (LBM) along with different fibre architectures on the behavior of machined hole, bearing strength (joint performance), and failure mechanism of different textile fibre-reinforced structural composites (TFRSC) fabricated using glass, basalt, and sisal fibres suitable for automotive applications. In the last section of this research, weight reduction and fuel-saving analysis were carried out by employing textile fibre reinforced structural composite material as a substitute for traditional automotive metal body panels. By substituting metal doors, hood, and bumper in a vehicle with TSC panels, a combined weight reduction of 72.11 kg can be achieved. The calculated weight reduction corresponds to approximately 7.75 % of the total vehicle weight. The fuel economy analysis demonstrated that a weight reduction of 7.75% could lead to a fuel consumption decrease of about 5.4%.