Abstract

The short-fibre based "*nonwoven fabrics*" are recently being used in transportation and infrastructural industries in addition to various products of decorative,filtration,insulation and disposable nature.The needle-punching is one of the high-speed and low-cost processes for the mechanical interlocking of the random mixture (without any specific pattern) of curved short fibres in this type of textile fabrics. Research on the mechanics of "*needle-punched nonwoven*" is a subject of ongoing research to explore its potential towards durable and high strength application areas(*e.g.*,ground stabilization, protective clothing, military helmets, geo-synthetic etc).Similarly, the short-fiber reinforced composites are attracting the attention of civil and transport industries, as they have reasonable strength, stiffness and impact resistance with a lower fabrication cost and higher production rate, as compared to the continuous fiber reinforced composites.An attempt is made in this thesis to improve the understanding of the mechanics of "*needle-punched nonwoven*" and short-fibre based "*fiberweb composites*" by a combined experimental and theoretical / numerical approach.

First part of the thesis is focussed on the tensile stiffness and strength of "*needle-punched nonwoven*", prepared from short fibres. At the beginning, extensive experimental investigation is conducted to investigate the effect of process parameters (areal weight, punch density and depth of penetration) on the physical and tensile properties of polypropylene nonwoven fabrics under uni-axial and bi-axial loads. Thereafter, high strength aramid fibres are mixed (homogeneous and layer-wise pattern)with the ductile polypropylene fibres to prepare hybrid nonwovens using the carding and needle-punching techniques to explore their competence in important application

areas demanding both strength and ductility.The realistic fibre orientation distribution and fibre-to-fibre slippage is used to correlate the tensile strength of nonwovens with the tensile strength of individual fibres using the Hearle's theory of nonwovens.

Next, an attempt is made to develop a finite element model of the needle-punched nonwovens using an idealized fiber network. The randomly placed (entangled or non-entangled) curved polypropylene fibers are assumed to be hyperbolic (cosine or sine) within the representative area element (RAE). The orientation of individual fibers is randomly fixed, while, the fiber interlocking is deterministically defined in the indigenously prepared MATLAB code.A two-node fiber element is employed to simulate the tension only behavior of individual fibers in the presence of frictional forces from the surrounding fibers. The present finite element model of representative 50 randomly oriented hyperbolic fibers predicts the tensile behavior of nonwoven qualitatively and quantitatively.

The second section of the thesis deals with the Kevlar-polypropylene fiberweb composites. Kevlar and polypropylene fibres of 51 mm cut-length are mixed together to prepare a hybrid nonwoven and compression moulding technique is employed to prepare the hybrid nonwoven. These fiberweb reinforced composites are tested for physical properties such as density, volume fraction, void fraction and the fiber orientation. Thereafter, extensive experimental investigation is carried out to determine the stiffness, strength and failure mechanism of fiberweb composites under tension, compression, shear, bending, and impact loads. An effort is also made to discuss experimental results in the light of theoretical models. A modified rule of mixture that considers the tensile strength of fiber and matrix, realistic fiber orientation factor and void content predicted the tensile properties quite satisfactorily. The flexural behavior was correlated well with the distinct material response under tension and compression.