MECHANICAL PROPERTIES OF HYBRID NEEDLEPUNCHED NONWOVEN STRUCTURES AND THEIR COMPOSITES

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by

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Dedicated
to
my parents and my wife

CERTIFICATE

This is to certify that the thesis entitled **“Mechanical Properties of Hybrid Needlepunched Nonwoven Structures and their Composites”** being submitted by **Mr. M M Alamgir Sayeed,** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** in the Department of Textile Technology, is a record of bonafide research work carried out by him. Mr. Sayeed has worked under my guidance and supervision and fulfilled all the requirements for the submission of the thesis.

The results contained in this thesis have not been submitted, in part or full, to any other university or Institute for the award of any degree or diploma.

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(M M Alamgir Sayeed)

Abstract

The present work deals with the hybrid needlepunched nonwoven structures prepared from jute and polypropylene (PP) fibres in defined weight proportions. These hybrid needlepunched nonwoven structures were potentially explored for two main applications, i.e. geotextiles and reinforcement in composites. Hence, the main aim of the study was to investigate the physical and mechanical properties of Jute/PP hybrid needlepunched nonwoven structures and their composites. A comparison was also made between various physical and mechanical properties of Jute/PP hybrid nonwoven structures and 100% polypropylene based needlepunched nonwoven. A hybrid needlepunched nonwoven structure consisting of 40 wt. % jute fibres had similar tensile properties corresponding to 100% polypropylene based nonwoven specifically in the preferential (cross-machine) direction. For geotextile application, two types of mechanical damages (circular hole and horizontal cut) were artificially induced in Jute/PP hybrid nonwovens and their tensile properties were analysed. In the present study, horizontal cuts were found to be more detrimental than circular hole based on the residual tensile strengths. The interface shear behaviour of Jute/PP hybrid needlepunched nonwovens and locally available *Badarpur* sand was also investigated by using large-size direct shear tests. The surface morphology of sand particles was also investigated based on the images obtained from scanning electron microscopy (SEM) and quantitatively analysed by means of Wadell roundness and degree of angularity methods. The internal friction angle of sand particles was found to be high and similar in magnitude to that of the interface friction angle of sand-nonwovens, determined under three different normal stresses.

Jute/PP hybrid needlepunched nonwovens were also intended to be used as reinforcements in composites. Accordingly, the jute fibres were treated with 4 wt. % sodium hydroxide (NaOH) solution not only to enhance their tensile properties but also to reduce their hydrophilic characteristics in order to make them compatible with PP (hydrophobic) matrix. The enhancement in the tensile strength of jute fibres after alkali treatment was analysed by two-parameter Weibull distribution model. This model clearly suggested that the enhancement in the tensile properties of jute fibres should be presented by probabilistic tensile strength of jute fibres rather than the average tensile strength method. Subsequently, a series of hybrid needlepunched nonwovens were prepared by formulating blends of alkali treated jute and polypropylene fibres in the same weight proportions as that of nonwovens formulated from untreated jute and PP fibres. The physical and mechanical properties of these untreated and alkali treated jute fibres based hybrid nonwoven structures were compared and analysed. In general, the alkali treated Jute/PP hybrid nonwovens exhibited better mechanical properties than their corresponding blended nonwovens consisting of untreated jute and PP fibres specifically in the preferential (cross-machine) direction. A series of alkali treated Jute/PP nonwoven reinforced composites were then fabricated using the film stacking method and subsequently tested for their physical and mechanical properties. In general, increasing the amount of alkali treated jute fibres in the nonwoven reinforced composites has improved their mechanical properties. The effect of stacking sequences of preferentially and non-preferentially aligned nonwovens within the composites has also been studied. The flexural and tensile moduli of composites were significantly improved, when nonwovens consisting of preferentially and non-preferentially oriented jute fibres were stacked in an alternate manner. Moreover, the tensile modulus of the nonwoven composites was also predicted based on the modified rule of mixture methods. A good agreement was observed between the theoretical and experimental results of tensile modulus of Jute/PP nonwoven reinforced composites.

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