TENSILE MECHANICS OF REGULAR BRAIDED STRUCTURES

HARSHVARDHAN SARASWAT

DEPARTMENT OF TEXTILE TECHNOLOGY

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by

Harshvardhan Saraswat

Department of Textile Technology

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Dedicated to my loving parents

CERTIFICATE

This is to certify that the thesis entitled **"Tensile Mechanics of Regular Braided Structures"** being submitted by **Mr. Harshvardhan Saraswat,** 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. Harshvardhan Saraswat 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.

Dr. Amit Rawal

Associate Professor
Department of Textile Technology
Indian Institute of Technology Delhi
Hauz Khas, New Delhi – 110016
India

Date:

Place:

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Abstract

Braiding is a highly versatile and cost-effective method of producing structures that has been successfully used for numerous applications ranging from ropes, composites, biomedical, insulation to sports and recreation activities and the list of applications of braided structures is ever-increasing. The prediction of tensile property is a pre-requisite for the success of deployment of braided structures in these applications. In this research work, the mathematical models of stress-strain behaviour of biaxial and triaxial braided structures were developed on the basis of synergistic deformation behaviour of both twisted strands and square woven fabrics. These models have accounted for braid geometry, braid kinematics and constituent strand properties. A series of polypropylene monofilament based braided structures was fabricated with varying braid parameters in order to validate the tensile models. A good agreement was observed between the theoretical and experimental stress-strain curves of biaxial and triaxial braided structures. Various geometrical parameters including braid angle, crimp, and fibre volume fraction have been used as input parameters for predicting the tensile properties of braided structures. Accordingly, the mathematical models of these geometrical parameters for biaxial and triaxial braided structures have been developed for predefined strand geometries. The strand geometries were classified in the form of circular and lenticular shapes by defining strand(s) as monofilament or multi-filaments, respectively. Moreover, the elastic stiffness of biaxial, triaxial braids and their composites has also been analysed. The coordinate transformations of axial strand crimp along with the averaging of stiffness and compliance constants on the basis of the fibre volume fraction in triaxial braids have also been proposed. Specifically, the elastic stiffness of triaxial braided composites has been validated with the experimental data obtained from the literature.

A theoretical model of the *effective or true* stress-strain behaviour of tubular braid consisting of an elastic core has also been proposed based on defined braid geometry, core properties and tensile properties of helically undulated strands of filaments. The model has been validated with four sets of tubular braids consisting of rubber cores of predefined diameters. A theoretical analysis of some of the most important parameters including strand, core and braid on the tensile properties of braid-core systems has been presented. A simple analytical model for predicting the tensile behaviour of multi-layered braided structures has also been proposed by extending the previously developed model on ‘braid-elastic core’ system. The model was validated by preparing a series of multi-layered braided structures on circular braiding machine for obtaining various combinations of braid angles. In general, a good agreement was observed between the theoretical and experimental values of toughness and stress-strain characteristics of multi-layered braided structures. Braid angle of the outer layer was found to be a key parameter in determining the stress-strain characteristics of multi-layered braided structures.

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