PREDICTION OF BENDING PROPERTY OF WOVEN FABRICS USING COMPUTATIONAL MODELLING TECHNIQUES

by

GURUPRASAD R.

Department of Textile Technology

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Dedicated

To

My Parents

CERTIFICATE

This is to certify that the thesis entitled "Prediction of bending property of woven fabrics using computational modelling techniques" being submitted by Mr. R. Guruprasad to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy is a record of bona fide research work carried out by him. Mr. R. Guruprasad has worked under my guidance and supervision and fulfilled the requirements for submission of the thesis. The results contained in thesis have not been submitted, in part or full, to any other university for the award of any degree or diploma.

Prof. B. K. Behera

Department of Textile Technology

Indian Institute of Technology Delhi

New Delhi - 110016

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Date: R. Guruprasad

Place:

Abstract

Bending rigidity is one of the most important properties of fabrics and is a key component in deciding fabric handle and drape. It is an important contributor to fabric's formability, buckling behaviour, wrinkle-resistance and crease resistance. The bending behaviour of woven fabrics has been studied quite extensively over the years, but quantitative prediction of this property is still an issue that needs to be addressed to achieve the goal of design engineering of fabrics. An accurate modelling of the bending behaviour of fabric using the conventional analytical solutions requires rigorous mathematical procedures that are difficult to achieve from the pragmatic view point. Most available methods for prediction incorporate several assumptions to simplify the problem and to make it amenable to solution, which in turn, affects the modelling accuracy. The application of modern approach, therefore, was found necessary to solve this problem. The main objective of this dissertation work was to quantitatively predict the bending property of cotton woven fabrics using various computational modelling techniques. The application of number of soft computing techniques and the computer simulation using finite element method have been explored in this research.

A detailed literature review has been carried out to understand the potential and limitations of various prediction methodologies. Gaps in knowledge have been identified and some of the inconsistencies in application of methodologies have been noted. As a preliminary study, a set of cotton fabrics was manufactured and tested for bending properties. This exercise has been done to understand the nature of relationships that exist between various structural factors and the bending characteristics of woven fabrics. From the review on literature and the preliminary experimentation, input parameters for the prediction models have been selected.

The application of artificial neural network modelling for the prediction of bending property was first explored. Models were developed using independent and dependent fabric structural variables. In the first model, bending rigidity in warp and weft directions were predicted from the independent fabric construction variables, namely end density, pick density, warp count, weft count, warp twist factor, weft twist factor and weave design. A feedforward neural network architecture with a single hidden layer was formed and trained with backpropagation learning rule. On completion of training, the generalisation performance was tested using an independent test set. A sensitivity analysis was also carried out to investigate the robustness of the developed model. In the second model, three important fabric variables namely, fabric weight, fabric thickness and fabric cover have been used to predict the overall bending rigidity of the fabrics. The prediction performance was ascertained using an independent test set, followed by sensitivity analysis. As the knowledge of the network is contained in the network weights, a connection weight approach was employed to understand and rank the variable contributions in predicting the output.

In an attempt to improve the prediction results of Neural network model (BPNN), a hybrid modelling strategy has been attempted using genetic algorithms. The input-output parameters of second model have been considered for GA modelling. Genetic algorithm was used as a search tool to optimize the neurons and weight values of the backpropagation network. With GA finding the optimum zone in the search space, backpropagation learning was employed as a local search to reach global minimum.

Another hybrid strategy attempted for prediction was Adaptive neuro-fuzzy inference system (ANFIS). ANFIS uses a hybrid learning rule to model the relationships. Gaussian, Trapezoidal, triangular and generalised bell shaped functions have been applied. Neural network tunes the membership functions in such a way that the inputs were mapped to output.

Optimization results showed that G-bell membership function with [2 2 2] combination for each input gives satisfactory results.

The comparison of Backpropagation Neural network model (BPNN), GA based backpropgation model (GANN) and adaptive neuro-fuzzy (ANFIS) models based on their prediction performance showed that the performance of Neuro-Genetic model was better in comparison to other two models. All three models rank the contribution of input variables in the following order: 1. Fabric weight 2.Fabric thickness 3.Fabric cover.

The use of finite element analysis to predict the bending characteristics of woven fabrics has also been explored. The simulation of cantilever bending test has been attempted using nylon and cotton fabrics. Material isotropy was assumed in case of nylon fabric whereas orthotropic behaviour was assumed for a set of cotton fabrics. Geometric nonlinearity was accounted in the analysis. A parametric study was carried out to understand the importance of Poisson's ratio on fabric displacement during bending. The numerical technique of Finite element analysis shows some promising results. Parametric study showed that Poisson's ratio has a significant effect on output.

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