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Develop Models for Predicting Fabric Friction and Directional Variation in Fabric Mechanical and Visco–elastic Properties

Fabric Friction

The friction results obtained on fabrics varying broadly in structure and fiber material, and reported in previous reports, were rationalized using a modified version of Wilson's model which included fabric compressional coefficient, L, estimated experimentally, as a measure of hardness, and apparent area of contact, A_a, estimated theoretically by Pierce's model, as a measure of the number of asperities of contact. Using these modifications, the final models for the constants C and n which characterize frictional behavior of fabrics by the equation $(F/A) = C (N/A)^n$ can be given as follows.

$$C = k\,S\,L^{-\gamma}\,A_a^{1-\gamma} \tag{1}$$

$$n = B\,(1-\gamma) + \gamma \tag{2}$$

In these equations, S is the specific shear strength of the adhesion junctions, γ is the factor related to the shape of the general pressure(P)–area(A) curve given by the relationship $P=KA^{\alpha}$ where $\alpha = (\gamma^{-1} - 1)$, and k and B are model constants.

Using these models (Equations 1 and 2) the effects of fabric structure parameters, picks per inch and yarn twist, on frictional behavior could be rationalized effectively. An example of the results which give a comparison between the experimentally determined and the theoretically predicted values of C(Equation 1) is shown in Figure 1. Currently, a paper is being written for submission to Textile Research Journal for publication on this work.

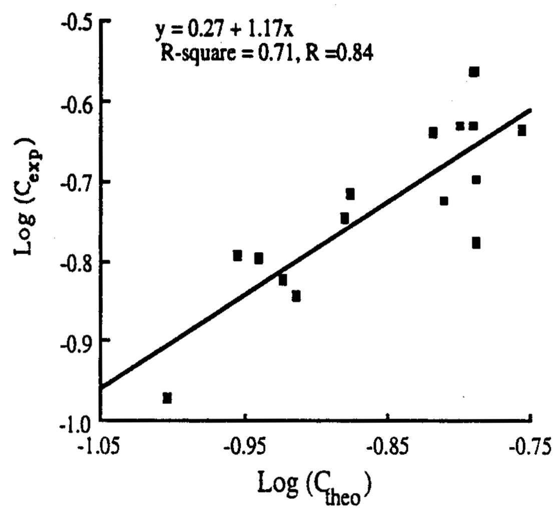


Figure 1. Theoretical values of friction parameter, C , versus experimental values of friction parameter, C, for all the filament polyester model fabrics. ($\gamma = 0.90$)

Fabric Mechanical and Viscoelastic Properties

The fabrics must endure stresses and strains of variety of levels during conversion into final products as well as during end use, specially industrial. The sewability, seam quality, style and drape of garments and performance in which fabrics are subjected to multidirectional forces are additionally affected by the variation in mechanical and visco–elastic properties of fabrics. The information available from such a study will allow us to understand and predict (1) the behavior of a fabric when subjected to pull from different directions, and (2) style and drape, and performance in manufacturing of fabrics. The focus of activity in this area has been on measuring the variation in mechanical properties with direction and modelling the behavior using theoretical/empirical approaches.

The tensile properties of five different fabrics, varying broadly in construction and yarn material (Table 1), were measured using ASTM method D5035 (Strip test method). The properties measured were in seven different directions (0°, 15°, 30°, 45°, 60°, 75°, 90° >from the warp direction).

The results obtained clearly show that the properties vary greatly with the direction of testing and the structure of the fabric. An example of results is given in Figure 1. Currently, the results obtained are being analyzed and modelled using a finite–deformation theory. Also, the impact the directional variation in mechanical properties has on fabric sewability and seam quality is being examined.

Table 1. Fabric Specifications

FABRIC	Fabric Counts EPI	Yarn Number (Denier) PPI	warp	Weave filling	Fiber	
A	66	95	150	150	2/2 twill	polyester
B	109	60	70	150	plain	polyester
C	58	50	200	200	plain	nylon
D	212	56	70	150	satin	polyester
E	80	69	2/47*	1/34*	2/2 twill	wool

* worsted count

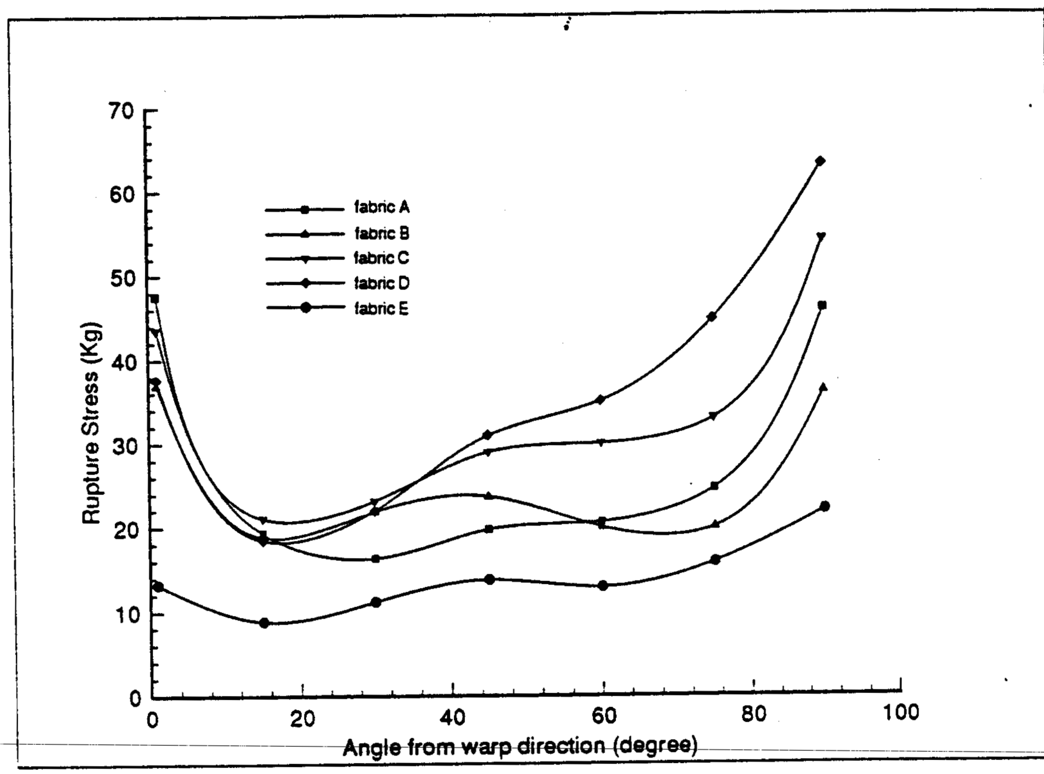


Figure 1. Stress Variation with Change of Angle

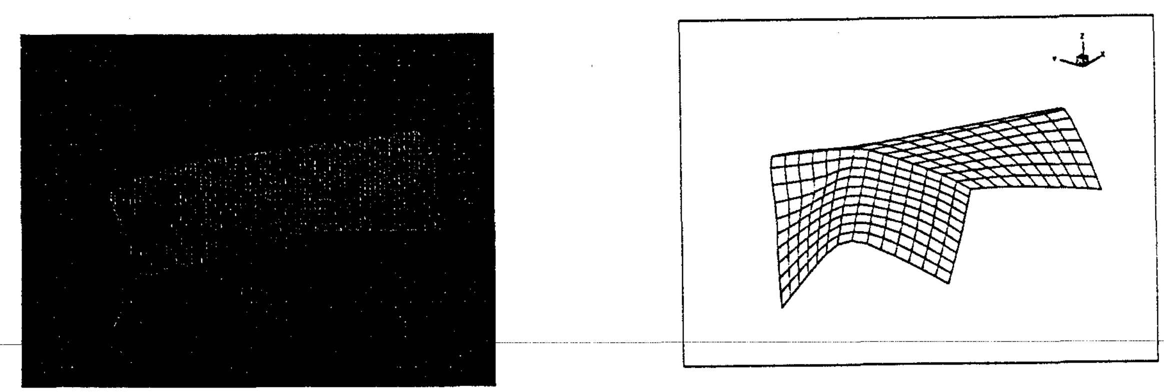
Computational/Experimental Determination of Fabric Drape and Motion

T. McDevitt– Flexible Fabric Mechanics Analysis Using Large Defection Beam Theory

The primary objective of this research was to develop a computer method to simulate the quasi–static motion of fabric parts during certain manufacturing processes in the apparel industry. Fabric parts are modeled as very flexible elastic beams that can accommodate stretching and bending in a single plane. Again, the equilibrium equations are solved using the finite element method. In solving for drape shapes and fabric configurations during manipulation, numerical problems are encountered when the fabric begins to buckle or wrinkle. In this project, a technique know as arc–length control has been implemented to treat these difficulties, and be able to simulate very complex load deflection paths. Attention has also been focused on generating finite element meshes that adapt to the severity of the deformation. Generally speaking, a numerical method requires more refinement (nodes) in the areas where the state variables (displacements) are varying the most rapidly. A method to distribute the finite element nodes to those regions of the fabric undergoing the most curvature has implemented.

S. Deng– 3D Fabric Drape Mechanics

This project is an ongoing extension of our capability to model three dimensional fabric drape over complicated surfaces. The use of large displacement shell theory to model the fabrics behavior has proved to be very successful. A very interesting aspect of this work is the discovery of multiple numerical solutions for seemingly simple fabric shapes. The solutions of the highly nonlinear equilibrium equations is non–unique. The challenge is to determine which of the several solutions is the physical realizable one, or whether multiple physical solutions are possible. Figure 1 shows the drape of a fabric part over a pair of intersecting cylinders. This problem demonstrates that the method can treat general part shapes and complex contact surfaces. We are also able to simulate the drape of fabric parts that show a nonlinear moment curvature relationship.



(a) Experiment Result

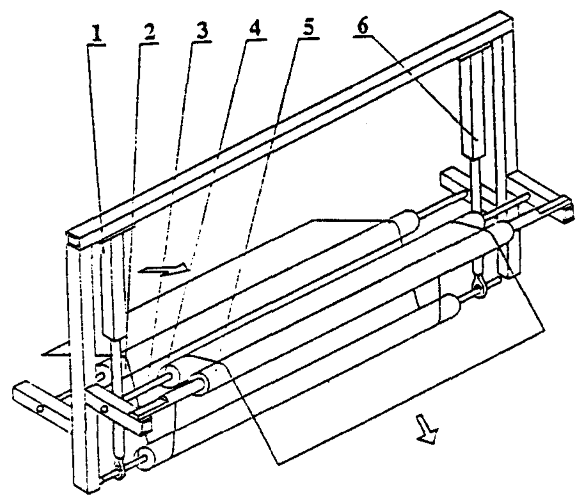
(b) Linear Material Solution

Figure 1. Comparison of Numerical Solutions and Experimental Result for Fabric Draping Over Intersecting Cylinders

Develop an "Intelligent" Closed Loop System to Control the Roll Making Process

A feed–back control system for fabric roll–making has been developed. The control system, in principle, would allow production of fabric rolls with optimal levels of internal stresses. The system is also designed to minimize variation of stresses.

Traditionally, fabric rolls are produced without any particular concern for the winding tension or roll–size. Their levels are mainly dictated by the unit process or the experiential knowledge of the operator. Generally, the winding tension remains somewhat constant during any process. It has been demonstrated in this research that in case of constant tension winding the fabric inside the roll may actually buckle and may cause permanent deformation of the fabric. This is particularly undesirable for easily deformable or delicate fabrics such as certain types of fine woolen or knit fabrics. To demonstrate the levels of stresses developed in fabric rolls and their variation strain measurement systems for both compressive and tensile strains have been developed. A miniature compression load cell has been used to measure the radial compressive stresses within a roll. The result shows initial rapid increase in compressive stress near the core followed be a levelling off near the top. This suggests that after a certain number of layers on the core the hoop stresses are not transmitted to the core from further layers. Maybe the intermediate layers together act as a non–deformable rigid cylinder. To measure the in–plane stresses foil–type strain gages have been used. It was necessary to develop special mounting techniques to obtain any meaningful measurement of strains in fabric layers. The results show that in some layers the fabric is actually under in–plane compressive stresses, even though, the web tension in the fabric at the time of winding was positive. These results substantiate earlier results of theoretical analyses during this project.



1,6: Electric Cylinders 2,4: Guide Cylinders 3: Moving Cylinders
5: Tension Measurement Cylinders

Figure 1. Tension Control System for Roll–making

In the control system developed in this project the winding tension is used as the control parameter Since our last report the control system has been modified to eliminate noise vibrations and to improve stability of the control. Figure 1 shows the improved control system. In this, the vertical position of a control cylinder is precisely controlled to generate various levels of wrap angle which in turn determines the outgoing tension in the fabric. The measured tension in the fabric web is used to control the position of the control cylinder. The control cylinder is driven by two electric cylinders working in unison. A new and improved software for the control system has been developed by using a graphical programming language LabView2. Using this program the winding tension can be controlled as function of time.