National Textile Center
FY 2003 (Year 12) Continuing Project Proposal

Project No. S01-AE32

Competency: Management Systems

Developing a Design-Oriented Fabric Comfort Model

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Objective:
This project is in its second year. Our primary objective has been to develop a "Design-Oriented Fabric Comfort Model". The purpose of this model is twofold:

- To establish a clear characterization of fabric and garment comfort using three independent but coordinated approaches: (a) structural modeling of the fabric/skin interaction phenomena, (b) experimental analysis of existing specially-designed fabrics and garments that have proven to provide good handle and good comfort effects, and (c) empirical modeling of the fabric comfort phenomenon using a combination of physical, neural-network, and fuzzylogic analysis.
- To develop a comfort design/manufacturing program to assist spinners, weavers, knitters, and garment manufacturers in producing fabrics of desirable levels of comfort suitable for different modes of applications including: normal/relaxing modes, high physical activity modes, and special task modes.

The key fundamental problem that this project addresses is the establishment of an integrated comfort output parameter that can be adopted to fully characterize the comfort phenomenon. Currently, comfort is not defined by a unique parameter. Instead, many parameters are used in isolated fashion, some of which are often conflicting. Over the entire course of this work, our team hopes to accomplish the following:

1. To complete the development of the design-oriented model (the neurophysiological aspect of the model has been completed, and thermophysiological aspects are now being incorporated in the model)
2. To verify the model for different fabrics and garment types (the neurophysiological aspect of the model has been verified for 26 different fabric products and analysis of 10 different garment categories is now being performed)
3. To produce fabric models of pre-specified comfort-related characteristics following the criteria dictated by the design-oriented comfort model (Efforts in this regard have started using single-jersey knit fabric of different structural characteristics)
4. To disseminate the knowledge base to the industry (we now have 11 industrial contacts)

Progress Statement:
The progress by percent of accomplishment and relevant numbers is summarized in the four points mentioned above. In addition, we have published or presented 8 publications in National and International conferences and in refereed journals (see list of these publications in the annual report). Currently, two more refereed articles are being prepared. These articles are coauthored by professors from three different universities on the project.

Technical details of the progress of this work were presented in the Annual Report. Major accomplishments fulfilled up to date are summarized below:

- The structural model developed in the first year of this project has been verified and validated particularly from a neurophysiological viewpoint. A portion of this validation analysis is reported in the annual report
- A unique method (described in the annual report) has been developed by Auburn University to measure the true area of contact between fabric and other surfaces including human skin. This method is now being used as a reference method for more efficient optical-based techniques.
- Many design parameters including fabric density, thickness, weight, cover factor, yarn twist, hairiness, and fiber type have been investigated in the context of the design-oriented structural model.
- Thermal analysis has been performed by Auburn University and Georgia Tech and correlations between the fabric thermal insulation and the area ratio determined from the structural model has been determined. These correlations clearly validate the use of the A-Ratio as an integrated comfort parameter.
- Parameters characterizing the absorption and wicking effects of woven and knit fabric have been tested and efforts to incorporate some of these parameters in the design-oriented comfort model are being made. This work is being done in NCSU.
- Human thermal profiling using different garments and under different levels of physical activity and different environmental conditions is being performed by the Department of Consumer Affairs at Auburn University. Thermal profiles were found to directly relate to the fabric/skin contact.

Currently, we are finishing the development of a complete comfort laboratory at Auburn University. This laboratory will cover most nuerophysiological and thermophysiological measures. We believe it will be a state-of-the-art laboratory. More importantly, it will be based on true and reliable evaluation of design parameters related to fabric and garment comfort. A critical mission of this laboratory will be to establish universal standards of fabric comfort measures. Since the Annual Report, we have added "The Almberta Device", a unique device that measure fabric/garment thermal properties.

Next Year's Goals:

Our focus next year will be to apply the design-oriented model on a wide range of garments. We have collected over 200 different types of garments, mostly garments in direct contact with human skin. In addition to the neurophysiological aspects, verification of the model in the context of thermal characteristics and moisture transfer will also be made. This verification is critical for finalizing the development of the integrated design-oriented model. In addition, analysis based on actual wearer will be performed using a combination of psychological scaling and fuzzy logic analysis.

We anticipate the completion of three Ph.D's during the course of the third year using the analysis and the results of this project.

Approach:

Our approach has been based on developing a design-oriented structural model relating the A-Ratio, or the ratio between the true area of fabric/skin contact and the corresponding apparent area, to different neurophysiological and thermophysiological comfort parameters. In addition to the fundamental analysis leading to the development of this model, we have also used many experimental techniques for verification and validation analysis. Accordingly, the fundamental analysis was accompanied by empirical modeling and numerical analysis to provide more realistic analysis of the complex interactive nature of different comfort-related parameters.

The general form of the design-oriented structural model is as follows (see Annual report for details):

$$\frac{A_t}{A_{app}} = C_M K^{-\gamma} M_a^{1-\gamma} K_t^{\gamma} E^{\gamma} V^{3\gamma} (\phi(t))^{\gamma}$$

Team members from the three universities have worked closely to verify and modify this model on both microscopic and macroscopic scales (see Figure 1). The results of this analysis will be reported in the end of the final year in the form of values of comfort-related structural parameters with corresponding values of comfort index.

These parameters are expected to assist in producing different levels of comfort by design according to specific physical activity levels and environmental conditions.

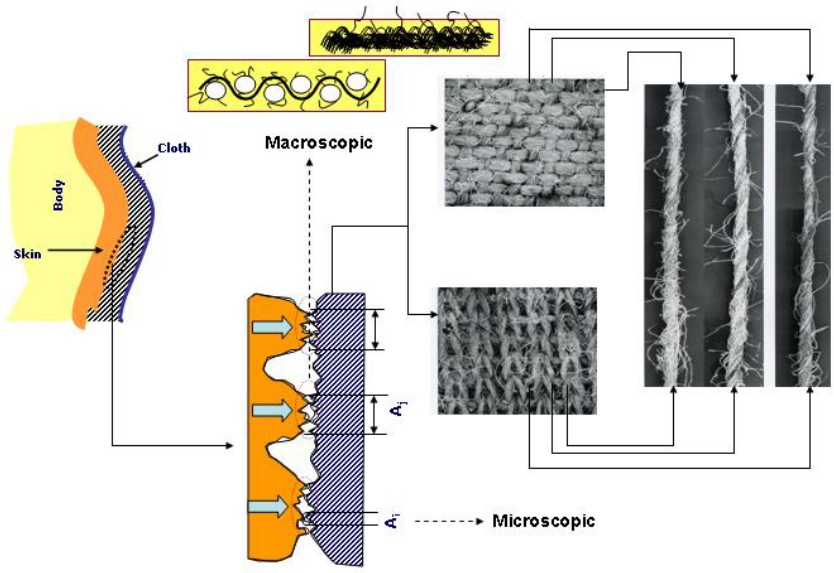

Figure 1. Macroscopic and Microscopic Fabric/Skin Areas of Contact

Critical experiments used in this study cover a wide range of analysis of the nurophysiological comfort parameters (roughness, stiffness, smoothness, crispness, fullness, cooling, warmness, etc.) and thermophysiological comfort parameters (heat transfer, moisture transfer, and wind speed). In addition, the team designed and constructed two testing devices: handle tester and surface roughness tester. Many experiments are also conducted using actual wearer under different physical activity levels and different environmental conditions.

Outreach to Industry:

As indicated earlier, we have established 11 industrial contacts. These are as follows: : (1) Decathlon Sportwear Corporation (Ian Wilkinson), (2) ElSaiad-Trecot (M. Saiad), (3) Buhler Yarns Corp (David Sasso), (4) Manifattura di-Legnano (Irene Raggio), (5) TJY (Kim Walker), (6) Cotton Incorporated (Mike Watson & William Rearrick), (7) SENSORA Co., (8) USDA, SRRC (Kearney Robert), (9) KATO-TECH Company, (10) Glen Raven Knit Fabrics, Glen Raven, N.C., (11) Swift Spinning (Trey Hodges)

The purpose of these contacts is primarily to evaluate the merits of this study particularly in assisting the industry in producing garments and fabrics providing optimum comfort by design. Some industrial representatives have provided samples of unique comfort-related characteristics for the purpose of verification of the study approach.

New Resources Required:

This is the third year of this study. Many resources have been already gathered. However, we plan to add other equipment including a skin-model and moisture transfer simulation device. We also intend to use external consultant from the area of testing and characterization of fabric comfort.