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Investigation of skin tribology and its effects on the tactile attributes of polymer fabrics

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ABSTRACT

The most fundamental interaction between a user and a product is physical touch. In fact, a significant amount of the perceived value of a product results from the initial touch experience by the potential customer, whether the product is an automobile interior or a portable music player. Therefore, the ability to engineer a product's tactile character to produce favorable sensory perceptions has the potential to revolutionize product design. Another major consideration is the potential for products to produce friction-induced injuries to skin such as blistering. Progress in this field has been hindered by the difficulties in drawing correlations between human sensory outcomes (e.g. softness, smoothness, leather-like feel) and quantitative physical properties (e.g. friction coefficient, elastic modulus). In this paper, a framework is proposed to address this issue with regards to polymer fabrics, which are used everywhere from clothing to protective wound-care products, and results are reported. Human evaluators were used in a modified Quantitative Descriptive Analysis (QDA) approach in order to identify four specific tactile attributes of fabric materials—sensible texture, abrasiveness, slipperiness, and fuzziness. The friction coefficients of the same fabrics against skin were measured by employing a three-axis dynamometer. The results were then correlated to sensory attributes by means of standard statistical methods. It was concluded from this work that human evaluators can score various fabrics along the above four tactile descriptors with significant statistical repeatability if "high" and "low" benchmark reference fabrics are made available during the evaluation. It was also observed that friction between fabric and skin is heavily dependent on both material type and fiber geometry, but that the impact of friction coefficient on tactility is still unclear. However, the methods presented in the paper may be used to further identify key fabric properties that are responsible for tactility.

1. Introduction

One of the most fundamental interactions that is made with a product is that of touch. A great deal of the perceived value of the product depends on the sensory attractiveness of the product. However, it has been extremely challenging for firms to optimize the tactile attributes of their products because little systematic work on correlating tactility with material parameters has been published. A key challenge in this pursuit is the complexity of the somatosensory system and human perception, and as such, both microscopic and macroscopic scales must be considered. Due to the prominence of the interactions between human skin and textiles, polymer fabrics have been an area of focus for studying perception [1–6]. Qualitative descriptors of fabrics have been described by researchers, and include softness, scratchiness, smoothness, or pleasant feels [6]. To make matters more complex, societal factors have led to multiple paradigms as to what is comfortable or unpleasant [1,2,4–7]. It is therefore obvious, that the fabric and fiber producer requires a more quantitative set of models to affect tactile parameters at a materials and processing level.

Currently, many manufacturers have limited technical knowledge of how specific material properties affect skin tribology and tactile attributes. In large part, the appropriate manufacturing and material parameters to produce acceptable tactility in a particular product are found through an iterative optimization procedure, without model-based reasoning to guide the procedure [1]. One method of investigating skin-on-fabric interactions has been the measurement of friction coefficient [2,4,5,7,8]. This work has not been limited to hands and fingers, but rather the interaction with large contact areas such as forearms [7,8], and subsequent rating of a degree of tactile agreeability of the material. Empirical studies have shown that friction coefficients during skin-to-fabric contact are virtually independent of load applied [2], but dependent on the level of moisture of the surfaces [4,5]. This indicates some of the sources of variation in results that have been reported in the literature. However, it also suggests that the measurement of fric-

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tion coefficient along with fabric weave parameters, fiber sizes, and material composition may provide the necessary foundation to developing a reliable model for efficiently optimizing a specific tactile attribute. With the ability to engineer fabrics to exhibit desired tactile properties, firms could specifically functionalize fabrics for a multitude of applications. Examples include sports applications, automotive interior materials, simulated leather products, and even medical consumables such as gauze and wraps for various skin conditions [2,8].

One of the greatest challenges in studying human sensory perception of a material is being able to describe and quantify the sensation in a manner that allows for a normalization of results of a large group of evaluators. This problem is twofold: metrics must be identified that have the same concrete meaning to various evaluators, and a quantitative scale must be established to assign a value to the fabric with respect to a particular metric. Techniques have been developed, largely in the arena of food evaluation, to produce quantitative and translational metrics for qualitative sensory assessments. One such technique is termed Quantitative Descriptive Analysis (QDA) has be successfully implemented in a number of studies involving sensory evaluation [11]. With QDA, a panel of evaluators that are familiar with a particular class of product identify a number of well-defined descriptors that describe an aspect of the sensory experience with the product class, and they agree on particular products within the class that exemplify “low” and “high” values for these descriptors. These descriptors can then be used to train to other evaluators if required. Because QDA produces quantitative results, outcomes can be analyzed using standard statistical techniques such as analysis of variance and other means of statistics [11].

Methodologies for sensory evaluation, such as those related to tactile behavior, must pay particular attention to the influence of auxiliary human senses that are not directly of interest. This is the case with regards to visual bias in tactile research. Investigators have reported that if not closely controlled, visual cues take precedence over the other senses. Ramachandran and Rogers-Ramachandran describe an early experiment, where visual bias produced by seeing an object will dominate the sensory evaluation regardless of tactile variations between materials [9]. Confounding this issue however, Yenket and Gatewood tested this concept with regards to fabrics, with a study to determine the impact of fabric color on the way consumers perceive the tactile attributes of the fabric. They concluded that material color does not influence the way a material feels. They further conclude that vision as a whole does not have a significant effect on the way individuals describe sample feel [10]. There is concern with the study that there was not significant use of control groups in a blind situation to draw such far-reaching conclusions. What these contradictory results suggest is that it is mandatory in tactile investigation that the effects of visual bias be accounted for and minimized when possible.

Table 1
Description of fabric samples.

Sample	Description
A	100% Satin, knit acetate
B	90% Polyester, 10% Spandex (Synthetic Velvet)
C	65% Polyester, 12% Wool, 8% Rayon, 8% Acrylic, 6% Cotton, 1% Metallic
D	100% Nylon
E	100% Cotton (Denim)
F	100% Cotton (T-shirt knit)
G	100% Polyester (Bed linen)
H	65% Polyester, 35% Cotton (Broad Cloth)
I	50% Polyester, 50% Cotton
J	100% Polyester (Costume Satin)
K	Textured velvet blend with unknown fibers
L	Corduroy
M	100% Polyester (Suede)
N	100% Polyester (Shawl knit)

Each of these fabrics exhibit topographic directions that can be discerned by either the senses of sight or touch. This directionality is visible on the macroscopic level for some specimens, or microscopically for others. For instance, samples D (nylon) and L (corduroy) can be seen in Figs. 1 and 2 with their directionality clearly evident.

The purpose of this investigation was to determine if coefficient of friction can be used as a metric to characterize various commercially available polymer-based fabrics and to identify useful tactile descriptors for such materials. Another aspect of the work was to begin to determine if any correlations could be identified with friction coefficient and the sensory descriptors that might lead to a predictive model in the long term. The study involved both human evaluators and instrumentation-based research in order to accomplish these objectives. Furthermore, the study involved a model of a useful protocol for performing future tactile research.

2. Materials and methods

2.1. Fabric samples

Fourteen commercially available fabrics of varying compositions were used in this study to determine descriptors for tactility. These materials were chosen to enable a diversity of material types, blend ratios, and weave styles. Commercial descriptions for each material, with appropriate materials balance, can be found in Table 1. One sample of interest, nylon fabric, is shown at two magnifications (Figs. 1 and 2) to illustrate a simple weave pattern and representative directionality of the fabrics.

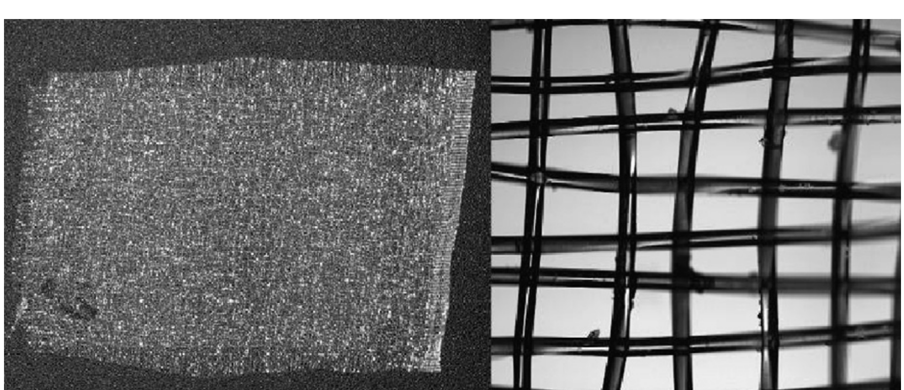

Fig. 1. Representative swatches of nylon (sample D) at (a) low and (b)high magnifications.