A NEW APPROACH FOR FABRİC SENSORY PERFORMANCE EVALUATİON

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ABSTRACT
This paper introduces a novel approach for evaluating fabric sensory responses. First, the problems in existing techniques are analyzed, and a more scientific scheme based on the computer pattern recognition technique is introduced and the details of the measurement, data processing and calculation of the ultimate parameters are discussed. The actual prototype of the instrument and some applications are then provided. Finally, it is shown that the technique can also be utilized to evaluate some visual attributes such as drape and wrinkle recovery.

Key Words: fabric sensory responses; tactle and sight; a different approach; applications.

1. INTRODUCTION

Sensory properties (attributes) of textiles refer to the textile qualities perceived by human senses (mainly, **sighting**: color, surface texture and texture change[1], shaping and draping[2, 3]; **touching**: fabric hand (handle) [4]; increasingly, **smelling**: smell after laundry[5]; and **sounding** : sound from rubbing between fabric/other surfaces during movement). Since fabric responses from both touching and sighting are evoked by the same group of fabric physical properties[6, 7], our discussion hereafter will focus on touch and sight, unless specified otherwise.

The importance of the sensory properties of textiles is indisputable and self-apparent. It is hard to imagine a consumer will buy a textile product without first looking and touching it, and sensory properties is often the reason why a consumer rejects a product [8]. The success of any new fiber type, new finish or new textile product is largely dependent on the acceptance of its fabric sensory properties[5].

However, assessment of this quality attribute until very recently largely relies on human sensory judgment, which in many cases is not reliable. Furthermore, while it is common knowledge to textile scientists that the **sensory properties** are originated from the physical properties of the fabric, there is no approach by which this connection can be demonstrated directly. This is mainly due to the fact that such **sensory properties** are basically a reflection of the overall fabric quality, attributed to many individual fabric properties.

As demonstrated in earlier work [9, 10], the nature of fabric hand can be described by two seemingly contradictory aspects: on one hand, it represents an esthetic concept, a reflection of personal sensory preferences; on the other hand, it is indeed an attribute depending on market background, consumer perception and product types [11]. Despite this seemingly intrinsic barrier, the assessment of fabric hand is still meaningful, partly because it is extremely desirable in many practical cases.

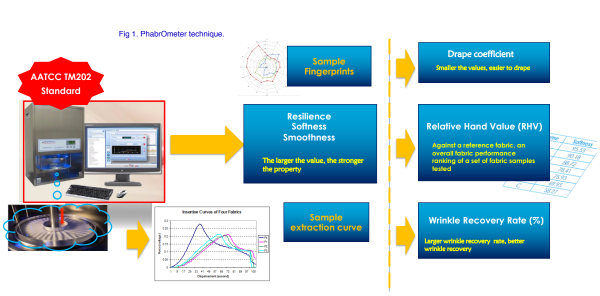
2. EXISTING INSTRUMENTS FOR FABRIC HAND EVALUATION

Successful resolution of the fabric hand problem will not only provide a powerful quality assurance method for the textile industry, it will also offer solutions to other consumer product questions, where product quality relies on tactile sensory evaluation, e.g. softness of pillows and comfort of pants. In addition, it has some implications or may shed light on our understanding of the relationship between physical stimuli and physiological, psychological and perceptual response.

Peirce in 1930 [4] first proposed to evaluate fabric hand based on physical measurement data. Since then, there have been several major attempts in using instrument to measure fabric hand. All these efforts climaxed in 1970 when Kawabata and his co-workers in Japan developed the now well known KES-FB system [12] for fabric hand evaluation. In 1990, another instrument called the FAST system [13] was developed which is basically a simplified version of the Japanese KES-FB system and therefore shares the similar issues.

In general the existing methods and systems can be roughly divided into two categories. The first approach is to measure fabric sample only once; tests in this category include the widely used cantilever method, the heart-loop method, etc., both described in ASTM D 1388, and the circular bend test in ASTM D 4032. The major problem with this type is that they provide only a single parameter that cannot completely define a phenomenon as complex as fabric hand. Moreover, none of the parameters targeted can serve as a consistent indicator for human tactile sensation. The second group consists of both the KES [12] and the FAST [13]systems which, although capable of measuring various mechanical and structural properties of a fabric sample, still failing to associate the measurements with human sensory responses, effectively [14, 15].

As a result of research by Pan and his coworkers since 1983 [10, 16-18], a new instrument called PhabrOmeter fabric test system, as shown in Fig. 1, has been established and commercialized to evaluate sensory attributes of various types of fibrous sheets.



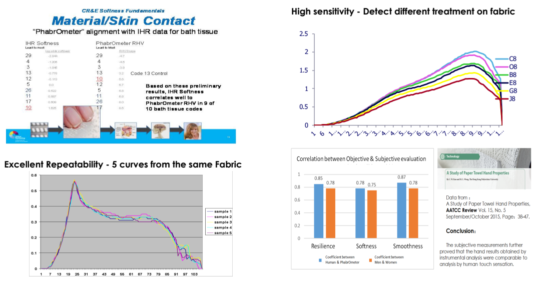


Fig. 2 PhabrOmeter performance

Unlike the Japanese KES system, no attempt is made to separately measure individual fabric properties deemed to be associated with fabric sensory attributes. Instead, this instrument is based on the existing fabric extraction method [19], with some critical modifications. A force-displacement curve is thus generated during the fabric extraction process, which has been shown to relate to the bending, biaxial extension, creasing and dynamic friction properties of fabrics [10, 16, 17]. Then a computer algorithm was developed based on the pattern recognition technique to derive a series of parameters defining fabric hand, including a Relative Hand Value, the fabric Softness, Smoothness, and Stiffness etc. The instrument has been adopted by various companies in many countries, and some successful applications have been reported [8][40, 41]. In addition, an AATCC standard test method for the PhabrOmeter, AATCC TM202, has been established to guide the users [20].

3. A FEW KEY ISSUES IN FABRIC HAND EVALUATION BY INSTRUMENT

3.1. A unified parameter for fabric classification

First of all, giving the huge variety of fabric types, an intrinsic fabric parameter termed the fabric linear density λ was proposed that reflects the influence of both fabric weight and thickness on the fabric extraction resistance. This index is demonstrated to be directed closely to the fabric properties, and can be viewed as a “constitutive number”. The experimental results confirmed that grouping fabrics based on this linear density λ indeed a feasible and effective approach [21].

3.2. On fabric measurement approach

The group of the KES [12], the FAST [13] and other similar systems which, although capable of measuring various mechanical and structural properties of a fabric sample, yet unable to associate their measurements with human sensory responses efficiently [14, 15]. Moreover, the fabrics are deformed on these materials as 2 D sheets, whereas Amirbayat and Hearle [22, 23] already summarized the principles of the fabric mechanics: in contrast to continuous solid sheets or films, there is no direct connection between the in-plane and out-of-plane mechanical properties; also fabrics in use will experience simultaneous in-plane membrane deformation and out-of-plane bending deformation in double curvature.

Both theoretical analysis and experimental tests [24] have demonstrated the invalidity of flat fabric samples used in most instruments for fabric hand testing. Whereas PhabrOmeter presents a more sophisticated deformation of forced drape and closer to the practical fabric behaviors. It thus justifies the status of PhabrOmeter as the AATCC standard test for fabric hand [20].

3.3. The fabric thermal properties

First, in any thermal transfer process, particularly in porous materials like textiles, there are essentially two distinctive stages involved; the transient and the steady. Although the transient stage is important for fabric touch, it lasts only fractions of a second and thus impractical to measure it with a fabric hand machine. There are however several attempts to measure the steady thermal properties.

It is highly intuitive to think that the thermal properties of the fibers would play a critical role since the sensation of warmth of a fabric is after all a reflection of the fibers in the fabric. In fact, the steady tactile sense is a contact reflection, and is highly related to the so-called effusivity $\mathrm{E} = \sqrt{k \rho c_p}$ where k is the thermal conductivity (W/m K), ρ is the density (kg/m^3) and c_p is the specific heat capacity (J/kg K) of the material. A surface with a higher effusivity value feels cooler. Obviously, the narrow range of the thermal conductivities k of various textile fibers (0.1 ~ 0.3 W/m K) cannot account for the vast scope of the cooling sensation perceived by touching different fabrics. However, since the material density ρ and the specific heat capacity c_p are either determined by or heavily dependent on the structure of the fabric, the latter plays a much dominant role here. Therefore we adjust the thermal behavior of the cloth by controlling its density; for the same fiber type, when fabric density is high as in a *T*-shirt, it can keep us cool in summer, whereas in winter we wear cloth made of low density fluffy fabric as in a coat to maintain the body warmth, whereas such density diversity has already been included in the PhabrOmeter parameters.

4. THE PRINCIPLES OF PHABROMETER

4.1 Measurement scheme—the fabric extraction method

The measurement of PhabrOmeter is indeed simple and quick for comprehensive information. For a properly designed nozzle, if we examine the fabric extraction process carefully, we will find that during the process the sample is deformed under a very complex yet low stress state including multi-axial tensile, shearing and bending as well as frictional actions, similar to the stress state when we handle a fabric. Consequently, all the information related to fabric hand is reflected by the resulting load–displacement extraction curve. Previously, researchers made use of only one feature of the curve, e.g. the peak or the slope at a point, and discarded the rest of the curve. If we can identify and derive all the information and classify it in terms of known fabric attributes, the significance is indubitable.

4.2 Data processing and feature identification

Once the fabric extraction process is done and the extraction curve (displacement vs. extraction force) is discretized into a data set X, the data set is then treated by an eigen-transformation, resulting in the so-called feature set (the eigenvectors) Y [25, 26]:

- The feature set Y is much smaller in dimension than the original set X, and is orthogonal, i.e. all the components of Y are independent of each other and they each contribute different yet complementary information in defining fabric hand.
- The relative importance of each component is also determined via the corresponding eigenvalue.
- The physical meanings of the (first three) components are ascertained for describing the different attributes of fabric hand, using calibration techniques.
- The fingerprint technique using the eigenvectors Y is very useful for product comparison and analysis.

4.3 Connecting to human sensory preference

For convenience, a weighted overall relative hand value (RHV) is defined for fabric hand ranking, either in terms of consumer preference or in terms of a preassigned quality standard. This way any new fabric can be judged relatively to the preferred sample based on RHV value between them.

4.4 Fabric drape and wrinkle recovery evaluations

It is obvious that fabric hand and drape are interconnected in a consistent way. The fabric extraction test is in fact a forced drape. Hence the RHV value, or individual hand attribute, can be used or interpreted for fabric drape behavior or fabric formability.

During a fabric extraction test, fabric samples experience complex wrinkles yet with high repeatability. Thus, by testing a fabric twice using the present system, with a given recovery time interval between the tests, any differences in terms of the defined fabric hand parameters can be used as indicators of the ability of the fabric to recover from a given wrinkle state.

5. EXAMPLES OF USING PHABROMETER

5.1 Repeatability, sensitivity, relation to sensory assessment

Fig. 2 shows the PhabrOmeter tests results for repeatability and sensitivity to validate the reliability of the measurement. There are also two examples of RHV value in comparison with the professional sensory panel conclusion.

Fig. 3 PhabrOmeter applications

5.2 PhabrOmeter applications

Fig. 3 are the patent applications where different companies adopted PhabrOmeter in their projects.

6. CONCLUSIONS

Fabric sensory attributes are measured by PhabrOmeter in which a fabric extraction process deforms a fabric sample in a way similar to sensory assessment, and all related information is thus contained in the extraction curve. The curve is then transformed into the so-called feature set via a pattern recognition algorithm.

The feature set is much smaller in dimension with all components independent yet complementary of each other. The physical meanings of the (first three most important) components are calibrated to represent the different attributes of fabric hand.

For convenience, a weighted overall relative fabric hand value RHV is defined for fabric hand ranking, either in terms of consumer preference or in terms of a preassigned quality standard. The technique is reliable, sensitive and easy to operate and has been elected an AATCC TM 202 standard for fabric hand evaluation and applied to many products.

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