SUBJECTIVE AND OBJECTIVE EVALUATION OF FABRIC HANDLE CHARACTERISTICS

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by

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(The candidate confirms that the work submitted is his own and that appropriate credit
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Abstract

This dissertation presents the discussion amongst previous researchers to clearly define fabric hand accurately. In general, the assessment of fabric hand can be accomplished by subjective and objective methods.

Subjective assessment treats fabric hand as a psychological reaction obtained from the sense of touch. On the other hand, objective assessment attempts to find the relationships between fabric hand and some physical or mechanical properties of a fabric measured objectively.

Equipment and test methods to measure mechanical properties which are evolved over a number of years before the development of the KES-F system are highlighted.

The principle measurements of the KES-FB and the FAST system are clearly explained, as well as the use of the interpreted data.

An alternative approach which is more simple, inexpensive and reliable for objective hand evaluation has been suggested to replace all the previous equipment.

Lastly, the applications of fabric objective measurement in the field of the textile and clothing industries were highlighted.

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CHAPTER ONE

INTRODUCTION

1.1   Background

The basic elements of the textile industry are fibres, yarn, fabrics and finishes. Technological development later results in a new or modified product being introduced to the apparel market and one of the first assessments made is that of hand. Fabric hand is the fundamental aspect, which determines the success or failure of many new products. The hand is one of the most important factors in the evaluation of fabrics. Hand is thus a psychological phenomenon. It assumes the ability of the fingers to make a sensitive and discriminating assessment, and of the mind to integrate and express the results in a single value judgement. Unfortunately, one thing is certain about terms associated with hand, and that is the fact that poor agreement exists among those who use them.

1.2   Objectives

a)   To study the development of fabric assessment in terms of hand.

b)   To understand the techniques used in fabric assessment.

c)   To understand the principle of measurement of KES-FB and FAST instruments.

d)   To show the application of fabric objective measurement.

1.3   Definition of Hand

In order to describe fabric hand satisfactorily, it must be adequately defined. Very often when attempts to define hand are made, the definition is highly dependent upon the individual investigator's scope of interest.

Peirce (1930) describes hand as being the judgment of the buyer which depends on time, place, seasons, fashions and personal preferences. What human finger sense, on the other hand, depends upon the physical properties of the cloth. Thus, data from

physical measurements can provide a basis upon which to exercise judgement. For example, in describing the strength of a fabric, no one relies on personal judgment since numerical data of strength tests give excellent evaluation of the material.

Schwarz (1939) defines fabric hand to be a property judged as a function of the feel of the material and explains that the sensation of stiffness or limpness, hardness or softness, and roughness or smoothness constitutes hand. He reports on the desirability of physical testing which may analyse and reflect the sensations felt and which can assign numerical values to the measurements of these parameters.

Hoffman and Beste (1951), in a study of fiber properties related to fabric hand, report that fabric hand means the impressions which arise when fabrics are touched, squeezed, rubbed or otherwise handled. The handling of a fabric may be conveyed by visual impressions as well as tactile sensations, so it seems proper to include lustre and covering power in the properties considered.

Thorndike and Varley (1961) studied the frictional property of fabric as related to hand and define hand as being a person's estimation when feeling the cloth between fingers and thumb. Their discussion on subjective judgment of fabric hand is based on the assumption that one of the influencal factors is the static and dynamic coefficient of friction between the cloth surface and the thumb or fingers. Other properties of the material may also be involved such as flexibility and thickness when making such an assessment of cloth quality.

Kitazawa and Susami (1968) introduced the term "synthesized handle" during their investigation on hand of heavy fabrics related to mechanical properties. The variable difference in the results of hand assessment by different assessors is an important factor in defining hand. Communication between assessors may constitute a common idea even though each assessor forms his own idea about the pattern of a given fabric. The common and qualitative idea formed by an assessor about the multiplicity of resembling samples is defined as "synthesized handle". The synthesized handle of a fabric is governed by a series of basic mechanical properties. Consequently, it is possible to develop a correlation between the synthesized handle and the pattern of the

mechanical properties of standard samples, provided that this standard pattern can be established.

Lundgren's (1969) concept of fabric hand is that hand is considered as the summation of the "weighted" contributions of stimuli evoked by a fabric on the major sensory centers presumably present in the human hand. Such centers can be uniquely sensitive to such physical properties as roughness, stiffness, bulk and thermal characteristic. He also states that the term "hand" is used to describe the tactile and muscular (kinaesthetic) sensations produced by a fabric.

Matsuo et al. (1971) define hand, in general terms, as what man sensorily assesses from the mechanical properties of a fabric. These researchers classify hand terminology by using and defining new terms such as "whole hand", "characterized hand" and "evaluated hand". According to their definitions, the "whole hand" of a fabric is what is sensorily transformed from all the mechanical properties of the fabric. When "whole hand" is judged in values, it is transferred to what is called "evaluated hand" which depends on both functional and aesthetic factors. Evaluated hand may also be influenced by fashion, climate, social status and personal taste. When the "whole hand" of a fabric is compared with that of a standard fabric, attention has to be given to the differences in "whole hand" between the two fabrics. Therefore, the hand of the fabric which is compared with the standard must be characterized by descriptive adjectives and is classified as "characterized hand". They list five mechanical properties, i.e., stretching, shearing, bending, compression, and surface friction as principle parameters to define "basic hand". They assume that to each of the mechanical properties there corresponds a sensitivity which man detects sensorily regardless of the extent of the sensitivity. Therefore, "whole hand" corresponds to the assemblage of the basic mechanical properties.

Kobayashi (1973) has applied information theory to an analysis of fabric hand. He regards hand as a tactile evaluation judged from physical stimuli resulting from mechanical properties. He further suggests that visual factors should also taken into consideration to evaluate the hand on a broader scale.

Kawabata (1975) proposed a conception about hand by the hypotheses that hand of a fabric can be completely expressed by the physical property of a fabric ignoring the important and variable human contribution to the assessment of fabric aesthetics.

1.4 Assessment of Hand

Fabric assessment can be analyzed in 2 particular ways:

1.4.1 Subjective assessment

1.4.2 Objective assessment

1.4.1 Subjective assessment

Subjective assessment treats fabric hand as a psychological reaction obtained from the sense of touch. Apparently it is a valuable method that has traditionally been used by textile technologists and researchers. Although it is probably the most widely discussed aspect of fabric assessment, it is not so well understood due to the reliance on subjective judgements.

The first attempts of hand evaluation of textiles in an organised and quantitative manner were published as early as 1926 and have continued up to the present time. Extensive studies have been made by Binns (1934) of the subjective assessment of hand, with particular reference to rank correlation between judges from varying technical and sociological backgrounds. In the study two wool fabric categories (milled and clear) were investigated, with six cloths in each category. Because small numbers of cloths were involved, all samples in a particular category were presented together for ranking. The judges were asked to rank the samples directly according to hand, from best to worst, without any suggestion of what primary hand qualities to look for. The judges made up the following two groups:

a)   Twenty-two manufacturers and buyers of dress goods similar to those used for the test. Each held a responsible position in the trade and was widely experienced.

b)   Six boys between fifteen and eighteen years of age. One had matriculated and was continuing his studies, two were intellectually inclined, and the remaining three were more skilled in handiwork.

Results from the investigation were analysed using Spearman rank correlation and Binns concluded that while the tactual or handle judgement appears to be native and immediate, it does not imply that any person is qualified to buy or sell textiles; there are many other factors to be considered.

Two basic procedures of subjective hand evaluation were proposed by Howorth (1964):

a)   Direct method – is based on principle of sorting of individual textiles to defined subjective grade ordinal scale (e.g., 0 – very poor, 1 – sufficient, 5 – very good, 6 – excellent)

b)   Comparative method – is based on sorting of textiles according to subjective criterion of evaluation (e.g., ordering from textiles with the most pleasant hand to textiles with the worst hand)

Bogaty et al (1956) have studied subjective harshness of fabric with the understanding that harshness is used to describe hand as a "catch-all" word. A series of whipcord suiting made of wool, mohair, viscose and nylon were assessed by panels in both "single fabric" and "paired" methods against soft-harsh paired words. The results show that the judgement of pairs or the inclusion of a standard for reference has no advantage to discriminate fabric harshness. Instead, the "single fabric" method appears to be as efficient and economical as the other methods. They suggest that fiber diameter and the length of the fibers projecting from the fabric surface are likely to affect the subjective harshness.

Hoffman (1965) proposes a psychometric approach to analyzing consumer opinion regarding fabric feel, appearance and aesthetics. This approach, which consists of psychology, mathematics, compute and human ingenuity is claimed to be most effective combination for the measurement of people's opinion. Tools used include paired comparisons, disguised replication, scaling, depth interviewing, semantic differential, factor analysis, similarity testing and proximity maps. He asserts that

application of the psychometric approach will be uniquely effective in hand assessment.

Kawabata (1973) started his detailed investigation of the subjective nature of fabric hand on Japanese men's winter suits. The research was carried out under the auspices of the Hand Evaluation and Standardisation Committee (HESC) of the Textile Machinery Society of Japan. After a long discussion the team of HESC recognised three attributes, which they termed the primary hand values and to which they give the names Koshi, Numeri and Fukurami. They arranged for twenty experts to assess the three primary hands of 500 samples of winter suiting fabrics and adopting appropriate statistical techniques. The subjective hand value was obtained by dividing the fabric into eleven groups, placed them in order of rank from 10 (giving the strongest impression) to 0 (with no feeling). These numbers were called the Primary Hand Value (PHV). Furthermore, they also asked the experts to provide an overall evaluation, and place the fabric in order of preference on a scale of 0 to 5 from unacceptable to excellent. They termed this ranking the Total Hand Value (THV). Subsequently, Kawabata and industrial colleagues extended their investigations to men's summer suitings and to women's fabrics.

Vaughn and Kim (1975) summarize the techniques of subjective assessment in an effort to describe the problem of the objective measurement of the subjective phenomenon of fabric hand. They also categorized the techniques into two broad method; the absolute method and relative ranking method. In the absolute method, the subjective hand parameters under study are assigned a numerical scale. The numerical results are then treated statistically. The advantages of this method is having a definite scale of judgment and allowing for the opinions of a large group of judges to be evaluated with relatively few observations. However, the disadvantage is that individual assessor's scale of judgment may differ from one another considerably and change when evaluating a number of samples.

The relative ranking method is further divided into the "paired method" and "all fabric at a time method". In the "paired" method two fabrics are presented at a time for determination of the better fabric in terms of a specified hand parameter. This method is based on one's ability to judge small difference consistently and all possible

combinations of pairs are presented in random order to the assessors. The total number of times that the fabric is judged better then one of the others is designated its "rank score" and this score is further analyzed statistically. This method allowed a large number of different fabrics can be evaluated by relatively few assessors. Another form of the relative method of ranking is the presentation of all fabrics at one time and arranging them in order. The disadvantage of this method is that the assessor been influenced by the hand parameter during the investigation and furthermore the fatigue effect causes serious consequences

Winakor et al (1980) used a 99-point scale with bipolar word pairs. Judges indicated the certainty with which the polar descriptors described the hand of fabric samples by assigning a whole number between 1 and 99. 1 for strong agreement with the left-hand descriptor of the polar pair, 99 for strong agreement with the right-hand descriptor, and 50 for uncertainty whether the left or right-hand descriptor better describe the hand of the sample. They found that the semantic differential and the 99-point certainty scale functioned well in the subjective hand assessment of the selected test fabrics.

Stearn et al (1983) compared the judging abilities of expert and consumer judges in the course of an analysis of measurements of fabric handle and mechanical properties. They used a panel of judges consisting of eighteen Australian, fourteen Indian, eight Japanese and thirteen New Zealand experts plus nine Australian consumers. These judges assigned 'total-hand values' to 214 men's winter suiting in a test regime that included the use of replicates of fabric type. This permitted the consistency of individual judges, as well as the variability between judges, to be examined. In part of their analysis, the panel were reduced from 62 to 39 judges before the first consumer judge would have been excluded. It was concluded that, although the consumer judges showed greater variability than the experts, this could not be attributed to greater randomness in their assessments.

David et al (1985) discussed the choice of descriptors with each judge and obtained words of opposite meaning so that lists of 'bipolar descriptors' were generated. The total list of words from all judges was collected and clustered and an attempt was made to associate groups of words with the published 'Standard Definitions of Terms Relating to Textiles' [ASTM Standards Part 33]. The judges evaluated a range of

men's winter-suiting fabrics against a list of fourteen bipolar descriptors. Subsequent analysis enabled them to eliminate pairs of words that did not give useful correlations and to identify seven pairs of descriptors that contributed most to judgements of 'total hand'.

1.4.2 Objective assessment

Objective assessment attempts to find the relationships between fabric hand and some physical or mechanical properties of a fabric objectively. It quantitatively describes fabric hand by using translation result from some measured values of relevant attributes of a fabric. Techniques used for objective hand evaluation are by special instruments for measuring properties of fabrics corresponding to hand.

Peirce (1930) launched a set of mechanical measurements containing flexible (bending) rigidity, compression and frictional property and extensibility, for the purpose of replacing the human sensation or personal evaluation for fabric hand. His remarkable work was undoubtedly of great importance for the development of fabric objective measurement. Since than fabric objective measurement has been focused mainly on mechanical properties, and its application has been confined largely to handle of fabric.

Winn and Schwarz (1939) used the Schiefer Flexometer and Gurley Stiffness Tester to measured fabric flexibility and drape. The physical parameters included bending length, flexural rigidity, bending modulus, chord length, radius of curvature and stiffness.

Winn and Schwarz (1940a) suggest that to compare hand parameter data from various objective test methods or apparatus for the purpose of obtaining an indication of the agreement among them, the statistical technique of rank correlation is useful. Two rank correlation methods have been applied to data associated with hand: the spearman coefficient of rank correlation and the Kendall coefficient of rank correlation for two sets of rank, and Kendall coefficient of concordance for more than two sets of ranks.

Winn and Schwarz (1940b) made a comparison of the results from four different stiffness tester, namely the Hanging Heart Loop test, the Gurley Stiffness Tester, the

Schiefer Flexometer and the M.I.T. Drapeometer, on cotton fabric given different treatments and finishes. They report that the Hanging Loop Test and the M.I.T. Drapeometer methods seems to possess the merits of sensitivity, simplicity and reproducibility of results.

Gunther (1952) used a ring method to express the hand of a fabric by one numerical value through the use of an apparatus which is assumed to measure the combined physical characteristics of hand without discriminating among individual parameters..

Kakiage (1958) describes a method of expressing fabric hand using a specially designed thickness gauge, by measuring the load-thickness relation of a fabric sample. He states that hand values from experiments on a series of fabrics agree well with the average actual feel of a group of ten persons.

Kitazawa and Susami (1968) express synthesized hand in terms of the constituting mechanical properties. They utilized a method in which the pattern of the mechanical properties is expressed as a position vector in the coordinate system of characteristic space and the pattern of a group of vectors is expressed as a region where the vectors of fabric samples exist.

1.5 Relationships between Subjective Evaluations and Objective Measurements

1.5.1 Rank Correlation, Multiple-factor Analysis, Component Analysis, Decision and Information theory and Canonical Correlation

Results of subjective assessments are often quantitatively associated with objective measurement data. To bridge the gap between the subjective assessments and objective measurements, statistical tools are universally used.

Dreby (1942) used rank correlation in linking sensory data with objective measurements. He reports three physical characteristics; flexibility, surface friction and compressibility to be the most important factors contributing to the hand of sift-finished fabrics. He demonstrates how certain physical properties affect the components of

fabric hand by comparing the average subjective rankings on pliability, surface smoothness, and compressibility. Furthermore he pointed out that objective measurement could be used to evaluate the effect of finishing agents and other factors on fabric hand and to control finishing processes. He also was pioneering in linking fabric objective measurement to finishing processes.

Abbott (1951) also used rank correlation to determine which objective methods, in terms of instruments and physical parameters, give the best fit with subjective evaluations of fabric properties such as stiffness and softness. Abbott compared seven different stiffness measurements: cantilever bending length, cantilever flexural rigidity, heart-loop bending length, heart-loop flexural rigidity, Schiefer Flexometer, Planoflex and Drapemeter. He found that cantilever flexural rigidity gave the best correlation with subjective stiffness over a diverse range of fabric styles and stiffness.

The technique of multiple factor analysis has been utilized in bridging subjective assessment with quantitative test data in a number of hand research studies. (1958), (1964), (1965). Howorth and Oliver (1958) used factor analysis in studying the relationship between subjective assessments of smoothness, softness, coarseness, thickness, weight, warmth and stiffness and objective measurement of weight, thickness, bending length, flexural rigidity, bending modulus, hardness and cover factor for twenty-seven worsted-type suiting fabrics. A three-factor solution was obtained which represented the relationship between the objective tests and subjective rankings. It was concluded that three physical tests namely, stiffness, smoothness and thickness would appear to yield a complete description of the handling qualities of worsted suiting materials.

Brand (1964) discusses component analysis as a method of studying aesthetic characteristics of fabrics with the overall goal of defining aesthetics as a function of measurable properties. A major portion of the work is devoted to relating aesthetic concepts, such as style, body, cover, surface texture, drape and resilience to polar-word scales. It is noted that elemental polar-word scales are more easily related to the physical properties than are concepts. Brand's approach which may be used on any of the aesthetic concepts, consists of four major steps : selecting polar-word scales, numerically scaling the words according to fabric style (paired comparison), relating

numerical scales to the aesthetic concepts (component analysis), and replacing the word scales with objectively measurable properties.

Stearn et al (1983) used component analysis to test a linear model that they had proposed to describe judgements of fabrics, taking account of the possibility that the judges held differing opinions of the quality of individual fabrics. Their results tended to confirm the validity of their model and showed that the judges were consistent, although they held markedly different opinions on the quality of specific unusual fabrics included in the set of samples.

Lundgren (1969) used decision and information theory to relate subjective hand evaluation with objective measurements. He bridges the subjective-objective gap by introducing a simple mathematical model defining physical properties as stimuli, subjective rankings as receptors and their matrix product as a receptor profile. The parameters of the model are smoothness, stiffness, compactness and thermal character. Subjective assessments were made by a panel using the "single fabric" method with a scale from 1 to 5. Objective measurement of surface friction, flexural rigidity and the ratio of weight to thickness were made by standard methods on three sets of fabric samples. The objective data matrix was a 3 x 3, and the subjective data matrix a 1 x 3.

Kobayashi (1973) applies information theory in an analysis of subjective hand of fabrics in three sets of 'synthesized" hand categories as "silk-like", "wool-like", and "linen-like" hand rather then in linking the subjective-objective gap in hand assessments. He state that since handle of a fabric is a subjective property judged by human senses, the uncertainty lies in its evaluation. In his investigation the subjective parameters consist of weight (light-heavy), thickness (thin-thick), fullness (lean-full), smoothness (rough-smooth), compressibility (hard-soft), flexibility (stiff-pliable) and resilience (limp-springy). On each of the seven parameters the information and entropy values are used to characterize a fabric as "silk-like", "wool-like" or "linen-like" hand.

Kawabata (1980) established the relationships between the fabric hand and its mechanical properties by selecting some of the most important fabric characteristics in affecting fabric hand. All the six properties are (a) tensile property (b) bending property (c) surface property (d) shearing property (e) compressional property and (f) weight

and thickness. Data from the mechanical properties were put into a transform formula to determine the fabric 'total hand value' which was designed to reflect the subjective hand as closely as possible.

Li et al (1991) used canonical correlation technique for analysing the relationship between subjective-preference votes for garments derived from a range of different fabrics and objective factors measured for the same fabrics. Their analysis was performed by using CANCORR from an SAS package. They explain that, given two sets of variables, CANCORR finds a linear combination from each set (a canonical variable) such that the correlation between the two canonical variables is maximised.(the first canonical correlation). Later CANCORR continues by finding a second set of canonical variables, unrelated to the first pair that produces the next highest correlation coefficient. This process continues until the number of pairs of canonical variables equals the number of variables in the smaller group. They found three significant canonical correlations, indicating that three dimensions of the objective physical factors were significantly related to the subjective preference votes.

1.5.2 Linear-regression Analysis

Dawes and Owen (1971) used regression analysis in their studies and developed regression equations to describe subjective rankings on a certain qualitative hand characteristic as a function of measurable physical parameters. It should be noted that a statistically technique such as regression analysis is basically a curve-fitting method and the equations developed are generally intended to describe historical data.

Kawabata et al (1982) used stepwise-linear-regression to develop his equations for predicting primary-hand value such as KOSHI, NUMERI and FUKURAMI. He originally used the equation :

$$Y = C_0 + \sum_{i=1}^{n} C_i x_i$$

where Y represents a subjective hand value, C_o and C_i are constants, the x_i are derived from sixteen objectively measured KES-F parameters and $n = 16$ because all sixteen variables were always included in the model.

1.5.3 Weber-fechner Law and Stevens's Power Law

Matsuo et al (1971) used the Weber-Fechner law to translate instrumental measurements of a wide range of fabric mechanical properties into corresponding hand parameters. They did not, however, attempt to relate these to actual subjective evaluations but represented whole fabric hands graphically in the form of rather complex 'polar profiles'.

Elder et al (1984) used Stevens's power law to examine the relationships between subjectively measured softness and (a) compression and (b) percentage compressibility and also between subjective stiffness and (a) flexural rigidity and (b) coercive couple. Excellent correlation between softness and compression was found, correlation coefficients for the Stevens-law relationship being between 0.967 and 0.997, with significance always better then the 0.01 level. Good correlations were also obtained for the others results and this is the evidence to show that Stevens's law appears to be an excellent model for prediction of fabric handle from objective measurements.

Hu et al (1993) carried out subjective evaluation on 39 men's-suiting fabrics against Japanese HESC standards in order to obtain hand value relating to stiffness, smoothness, and softness and fullness. These subjective Hand value were then compared with calculated Hand Values obtained from 17 objectively measured KES-F parameters by using the four mathematical models such as linear (1), Kawabata (2), Weber-Fechner (3) and Stevens (4). They showed conclusively that Stevens's power law give much smaller errors then the other methods in predicting all three Hand Value.

1.6   Other Methods

1.6.1   Weighted Euclidean Distance

Pan et al (1988a) have introduced a new approached to calculating Total Hand Value (THV) from objective measurements. They noted the problem that the subjective acceptability of fabric for a given end-use varies markedly both within and between national panels of expert judges. There is difficulty with the communication between judges, the low assessment sensitivity, and above all the time-consuming nature of the whole assessment procedure. The conclusion is that a reliable subjective evaluation of fabric handle is possible, but obviously the method does not facilitate rapid development of textile products. They commented on the unsuitability of the Kawabata method of obtaining Total Hand Value for markets other than Japan. The KES-F or FB system uses multivariate regression to relate the subjective assessment results completed by the Japanese experts to the objectively measured data and to formulate the equations for handle value calculation. They also noted the mathematical limitations of multivariate regression analysis in cases where there is collinearity of the data.

Pan et al therefore proposed a method for calculating Total Hand value from objective measurements without recourse to any subjective evaluation. This objective measure for Total Hand Value is described as a 'weighted Euclidean distance', which represents the distance between the sample and a standard in an n dimensional space, where the n dimensions are represented by n objectively measured fabric parameters. Thus, if each of two fabric samples is described by a vector X and n components

$$X_1 = (X_{11}, X_{12}, \ldots\ldots X_{1n})$$

$$X_2 = (X_{21}, X_{22}, \ldots\ldots X_{2n})$$

The expression of the Euclidean distance D between them is :

$$D(X_1 X_2) = \left(\sum_{k=1}^{n} (X_{1k} - X_{2k})^2 \right)^{\frac{1}{2}}$$