THE COMFORT PERFORMANCE OF WOOL LIGHT FABRICS BASED ON SUBJECTIVE, OBJECTIVE EVALUATION

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ABSTRACT
The textile and clothing industry, aware of the marketing evolution cannot neglect the requests of comfort, which has been an increased and actual exigency of the clothing goods consumers. There is an urgent need to evaluate and quantify the comfort properties of textile in general. This work aims to make a study of the different types of lightweight wool fabrics, based on the objective evaluation of thermophysiological and sensorial comfort, according to real preferences, with the goal of creating "comfort standards" and to develop a simple sensorial comfort "predictable model", based on correlation studies, that from objective properties, predicts the subjective valuations of comfort. Thus we can define a comfort quality profile (sensorial and thermophysiological), allowing to create a "comfort label" of easy interpretation, similar to the textiles "clean and conservation label", currently used in the textiles and clothes industry labelling. This label will certify the quality and prestige of these textiles, towards the modern consumer's needs and demands.

Keywords: Comfort; Comfort Label; Data Mining; Wool Materials

INTRODUCTION

The comfort is a "pleasant state of physiological, psychological and, physical harmony between a human being and the environment", being a universal basic requirement for man, the clothing in this field plays a grate role.
The textile and clothing industry, aware of the marketing evolution cannot neglect these requests of comfort, which has been an increased and actual exigency of conscientious clothing goods consumers.
This trend together with the search for lighter and lighter fabrics have significantly influenced the recent evolution of the wool textile industry, since the weight of traditional woven fabrics for jackets and suits has decreased in a probable irreversible way. The wool products became suitable for all the seasons including Spring and Summer.
Therefore, comfort has become one of the most important aspects of clothing, mainly for next to skin garments such as trousers for summer. The perceived comfort of wearers of these garments depends largely on the tactile and thermo-physiological properties of the fabrics. Several thermal,

mechanical and physical properties can be critical from the comfort point of view and they have to be considered in the textile design areas.

Furthermore, environmental conditions and the physical activity of the users also influence the perception of clothes comfort. All these variables contribute for the high complexity of the clothing comfort evaluation and quantification, that until today have been evaluated by customers, textiles manufactures and clothing industry in a empirical way by handle or “feeling well when dressed". This is a completely subjective evaluation, based on ones feelings and experiences, without any scientific base.

Many researchers have investigated comfort over the past years, but up to now, there has been no one clear definition of comfort, since this subjective perception differs from person to person. For example, Fourt and Hollies stated that physical comfort might be greatly influenced by tactile and thermal sensations arising from contact between skin and the immediate environment [1]. Slater defined comfort as "a pleasant state of physiological, psychological and physical harmony between a human being and the environment" [2]. From this point of view, we can consider comfort one of the most important aspects of clothing and we may suggest to classify it into four big groups: Psycho-aesthetic, Ergonomic, Sensorial and Thermophysiological comfort [3].

Psycho-aesthetic (or aesthetic psychological) comfort bears little relation to the fabric's technical properties and is mainly related to the aesthetic appeal and the fashion trend prevailing in the society. It is the subjective perception of the clothing by the five senses, which contributes to the overall well-being of the wearer.

Ergonomic comfort is related to the body movement comfort, the ability of a garment to allow freedom of movements, has to do with body shaping, clothing patens making and sewing.

Sensorial or tactile comfort, many times just simply identified by “hand”, is essentially a result of how much stress is generated in the fabric and how it is distributed over the skin and therefore has a strong relationship with both the mechanical and surface properties of the fabric. There is quite a difference in fabric handle preferences from individual to individual due to differences in their cultural background and/or climatic differences and sometimes preferences may even be opposite [4].

Thermophysiological comfort is related to the fabric's ability to maintain skin temperature and allow transfer of perspiration produced from the body. Factors affecting the thermal behavior of clothing will include the dry thermal insulation, transfer of moisture and vapor through clothing (sweat), heat exchange with clothing (conduction, convection, radiation, evaporation and condensation), compression (caused by high wind), pumping effects (caused by body movement), air penetration (through fabrics, vents and openings), etc. [5].

From this context, surges the present work, which aims to make a study of the different types of lightweight wool fabrics, based on the objective evaluation of thermophysiological and sensorial comfort, according to real preferences, with the goal of creating “comfort standards” and to develop a simple sensorial comfort “predictable model”.

A predictable model based on correlation studies that from objective properties, predicts the subjective valuations of sensorial comfort, for men summer suits fabrics. In the methodology applied to develop this model, we divided the work in two parts. In the first part, it was carried out the subjective evaluation of the materials, using a psychophysical methodology that enables you to quantify the descriptive aspects of hand sensation (subjective evaluation by a panel of experts and consumers) whereby the "paired- comparison method” was applied. In this way, we obtained a ranking of fabrics classified by the "Total Hand Value/Qualities".

One the other part, we studied the fabric with objective measurements, thermal, physical and mechanical properties (KES-FB system), air and water vapour permeability. In this part, we used statistics multivariate analysis techniques to identify independent factors and their relative contribution for the objective evaluation of fabric hand.
Combining this sensory perception methodology, with established instrumental measures of fabrics characterization, it was possible to develop a better predictable relationship between sensorial, instrumental and comfort properties of fabrics.
The results of the two parts were correlated by neural network techniques, in order to quantify the comfort, contributing for the definition of comfort sensorial standards for lightweight wool fabrics.
This comfort quality profile (sensorial and thermophysiological), allow us to create a "comfort label" of easy interpretation, similar to the textiles "clean and conservation label", currently used in the textiles and clothes industry labelling. This label will certify the quality and prestige of these textiles, towards the modern consumer's needs and demands.

EXPERIMENTAL AND METHODS

For this study, we used light-weight (130-155 g/m^2) wool woven fabrics for making men summer suits by comparing different commercially available wool fabrics of high quality and very high quality, including "Italian cool wool" material. We included also some fabrics that were obviously different in tactile properties, a "springly touch" fabric, made with yarns of 38,5 tex (2/19,3 tex), manufactured with wool material considered economically standard, (fibber diameter of 20 μm). To give to this fabric a "fresh touch" we used yarns with twist and retwist Z, contrarily to all the other of materials that the yarns were manufactured by a traditional process of twist Z and retwist S, (it has also higher twist level comparing whit the others fabrics yarns). The total is 35 different wool materials.
The fabrics were finished in two different ways, piece dyeing and yarn top dyeing and the final dry finishing was the some for all the fabrics (Shearing, Continuous Decatizing, Kier Decatizing and Steaming).
Twenty-six fabrics properties were measured, seventeen indexes were mechanical and nine transport properties. All the tests were carried out under standard atmospheric conditions (20^{o}C±2 and 65%±2 RH).
The tensile and shear behavior of all fabrics were studied on a KES-FB1 (tensile shear tester) and the bending properties were measured using a KES-FB2 (pure bending tester). Compression properties and fabric thickness were measured with a KES-FB3 (compression tester) and surface roughness and friction were measured using the KES-FB4 (surface tester). All the seventeen parameters describing fabric mechanical properties were determined with these four Kawabata instruments by using the prescribed procedure [6], and are given in Table 1.
The transport properties were tested in the Air Permeability Tester, the thermal properties in Alambeta and Termolabo, the Water Vapor Permeability Index in the Water Vapor Permeability Tester.

The principal components analysis method has been used to know how many factors we can fix, so we run the analysis choosing the option of finding factors with eigenvalues more than 1. This analysis is in some way a trial run to see how many factors there could be [7].
Applying the principal components analysis it shows that almost 77,2 % of the total variance is attributable to the three factors. The other factors together, account for only 22,8 % of the variance. Thus, a model of three factors may be adequate to represent the data. After fixing the three factors, the factor analysis techniques are been applied.
We use the most commonly rotation schema the Laiser's Varimax rotation; hence, we employ this in our analysis data to minimize the number of variables that have high loadings on a factor. The Table 1 shows the factors greater or equal to 0,75 after rotation.

Table 1: Factor Analysis Matrix after Rotation from the Fabrics Properties

Parameters	**Factor**		
	F1	**F2**	**F3**
EM - Elongation @ 500 gf/cm	0,8975	-------------	-------------
LT - Tensile Linearity	-------------	-------------	-------------
WT - Tensile Energy / Unit Area	0,7964	-------------	-------------
RT - Tensile Resilience	-------------	-------------	-------------
B - Bending Rigidity	0,8975	-------------	-------------
2HB - Bending Hysteresis	0,8975	-------------	-------------
G - Shear Stiffness	-------------	0,8975	-------------
2HG - Shear Hysteresis at $\Phi = 0{,}5°$	0,7548	-------------	-------------
2HG5 - Hysteresis at $\Phi = 5°$	-------------	0,8975	-------------
LC - Compressional Linearity	-------------	-------------	-------------
WC - Compressional Energy	0,8930	-------------	-------------
RC - Compressional Resilience	-------------	-------------	-------------
MIU - Coefficient of Friction	-------------	-------------	0,8169
MMD - Mean Deviation of MIU	-------------	-------------	-------------
SMD - Geometrical Roughness	-------------	-------------	-------------
W - Weight per Unit Area	0,9107	-------------	-------------
AP - Air Permeability ($l/m^2/s$)	0,8626	-------------	-------------
WVPI - Water Vapour Permeability Index	-------------	-------------	-------------
Qmax - Warm/Cold Feeling (W/m^2)	-0,7771	-------------	-------------
TC - Thermal Conductivity (W/mºk)	-------------	-------------	-------------
TID - Thermal Isolation at Dry State (%)	-------------	-------------	-------------
TIW - Thermal Isolation with Moisture (%)	-------------	-------------	-------------
CP - Compression Properties (%)	-------------	-------------	-------------
BD - Bulk Density (kg/m^3)	-------------	-------------	-------------
T - Thickness (mm)	0,9870	-------------	-------------
TD - Thermal Diffusivity (m^2/s)	-0,8066	-------------	-------------
% of variance	44,34	67,65	77,20

Simultaneity it was carried out the sensorial subjective evaluation of the materials, using a "paired- comparison method" wish enables us to quantify the descriptive aspects of hand

sensation (subjective evaluation by a panel of experts and consumers). In this way, we obtained a ranking of fabrics classified by the "Total Hand Value/Qualities" in the scale from 0 (poor), to 5 (very good) [8].
After the selections, of the objective properties (properties with the factors greater or equal to 0,75), and with the subjective valuations of "hand" made by the ranking of the materials we created a predictable model based on correlation studies using neural network techniques.

A neural network is a massively parallel-distributed processor that has a natural propensity for storing experimental knowledge and making it available for use. It resembles the brain in two respects: knowledge is acquired by network through a learning process and interneuron connection strengths known as synaptic weights are used to store the knowledge.
Neural networks are being applied to an increasing large number of real world problems. Their primary advantage is that they can solve problems that are too complex for conventional statistical problems that do not have an algorithmic solution or for which an algorithmic solution is too complex to be defined.
Neural networks are a good tool in the fabric comfort field because can give good predictions to some aspects of textile comfort [9].
In this research, we applied the neural networks to design lightweight wool fabrics comfort where the inputs are the objective properties selected (14 neurons), the internal layer is composed by 5 neurons and the Total Hand Value/Quality is the output.

RESULTS

Analysis multivariate techniques are been applied to the data and the results show that almost 77 % of the total variance is attributable to three factors. The first factor explains 44.34 % of the total variance and associates of this factor are the tensile and bending properties, some thermal parameters, air permeability and construction characteristics, such as, thickness and weight per unit area. The second factor is associated with the shearing parameter and the third with one of the surfer's properties. With the application of the multivariate analysis statistics, we reduced the size of objective properties from twenty-six to fourteen.
In the same way, the next step was to use a neural network, which has a self-learning ability, able to model nonlinear functions such as the relationship between this objective measurement and subjective sensory perceptions, in order to predict subjective sensorial perception (Total Hand Value) from objective and easy to measure parameters. The Figure 1, shows the table with the real and the predict values for Total Hand Quality for this group of materials, where we can distinguish the "Italian Cool Wool" with the "hand" evaluation around "Very Goog", from the "spring touch fabrics" with poorer Hand Quality and in a intermediated qualification we have the high quality fabrics.
For the quantification of the thermophysiological comfort (not part of this paper) we use the Fanger´s methods. These methods published in the book *Thermal Comfort* by Fanger (1970) are on the base of the creation of the ASHRAE Standards, (American Society of Heating and Ventilating Engineers) and is now the most influential and widely used throughout the world [5].

We use part of the scale of the PMV (Predicted Mean Vote): warm +2; slightly warm + 1; neutral 0; slightly cool -1; cool -2.

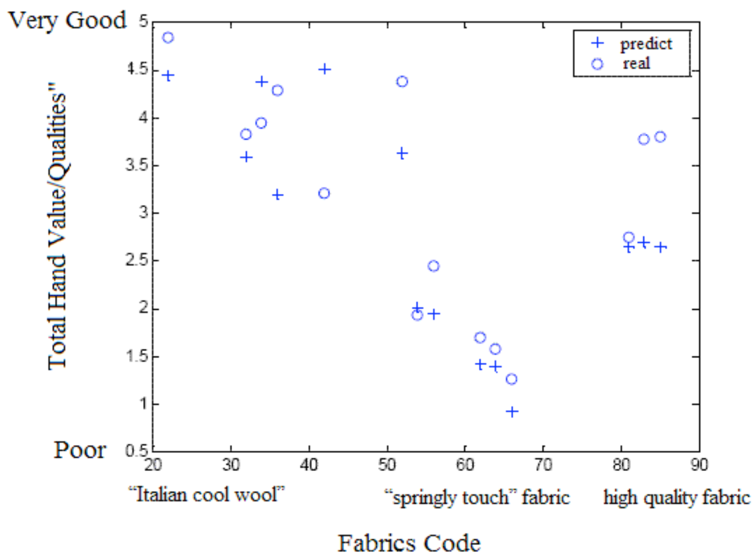

Figure 1: Total Hand Quality, real and the predict values from a neural network application.

CONCLUSIONS

With this work we defined a comfort quality profile (sensorial and thermophysiological), that allow us to create a "comfort label" of easy interpretation, similar to the textiles "clean and conservation label", currently used in the textiles and clothes industry labelling. This label (is in the process of registration®) will certify the quality and prestige of these textiles, towards the modern consumer's needs and demands.

This work, shows also, that the potential of the data mining techniques, namely multivariate analysis, neural network and the comfort science, applied in textiles and apparel production, is a powerful tool in the quality control, permitting to identify the most appropriate physical and mechanical properties to define the comfort of the wool light fabrics, reducing the number of variables and time testing which is a big advantage for the wool industry.

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