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INFLUENCE OF SOFTENERS ON HAND OF HEAVY COTTON FABRICS

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Abstract

One of the most important characteristics of comfort is hand. It is well known that hand plays important role as the first characteristics entering to contact with consumer. Evaluation is carried out by consumer on the basis of his feeling evoked by textile with contact of his preceptors (fingers and palms). With development of new types of technologies and textile products the objective characterization of hand becomes more important. This together with transferring to computer-oriented methods leads to finding indirect but objective techniques for subjective hand evaluation based on the special regression types (multivariate calibration).

The heavy cotton fabrics used as military or protective textiles have often-unsatisfactory hand and other comfort parameters. The main challenge is therefore to improve their hand by the proper construction or finishing.

The main aim of this contribution is utilization of well-known KES (Kawabata Evaluation System) for estimation of the heavy cotton fabrics hand. The influence of softener concentration on the cotton military fabrics hand is quantified by sensitivity coefficient and paired correlation coefficient. For estimation of the minimal paired correlation coefficient indicating significant correlation the equation based on the Ruben transformation is derived. Fabric hand is specified by the primary hand values (*koshi, numeri and fukurami)* and by the total hand value (THV). The influence of softener concentration on the changes of mechanical and surface properties is investigated as well.

Introduction

One of the most important characteristics of fabrics comfort is hand. It is well known that hand plays important role as the first characteristics entering to contact with consumer. Evaluation is carried out by consumer on the basis of his feeling evoked by textile with contact of his preceptors (fingers and palms). With development of new types of technologies and textile products the objective characterization of hand becomes more important. This together with transferring to computer-oriented methods leads to finding indirect but objective techniques for subjective hand evaluation based on the special regression types (multivariate calibration).

The heavy cotton fabrics used as military or protective textiles have often-unsatisfactory hand and other comfort parameters. The main challenge is therefore to improve their hand by the proper construction or finishing. One relative simple way is to use so called softeners.

The main aim of this contribution is utilization of well-known KES (Kawabata Evaluation System) for creation of regression type models suitable for estimation of the heavy cotton fabrics total hand value (THV) and primary hand values in the dependence of softener concentration. The changes of properties correlated strongly with softener concentration are described by the sensitivity coefficient and paired correlation coefficient.

For estimation of the minimal paired correlation coefficient indicating significant correlation the equation based on the Ruben transformation is derived. The proposed methodology is used for quantification of softeners influence on improving of THV and fabrics selected properties.

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Objective methods for hand prediction

A lot of methods are used for indirect objective hand evaluation. These techniques can be divided to three groups according to used instruments:

a) Special instruments - the hand is result of the measurement. Drawing of textile through the nozzle of defined shape and evaluation of dependence "strength-displacement" course is usual principle (Militký and Bajzik (1998)).
b) Set of special instruments for measuring of properties corresponding to hand. Kawabata's evaluation system (KES) belongs here. It consists of four instruments for measuring of tensile, shear, bending, surface and compressive properties under special conditions of measuring. By these instruments 16 mechanical characteristics are measured (Militký and Bajzik (1998), Kawabata(1982)).
c) Standard instruments for evaluation of selected fabric properties connected with hand (Militký and Bajzik (1998), Bajzik, and Militký (2001)).

Techniques of objective hand evaluation can be divided to two groups according to data processing.

a) Result is one number characterizing hand - this number is very often obtained from conversion equation (e.g., regression model), where subjective hand is endogenous variable and measured properties are exogenous ones (Kawabata(1982)).
b) Result is the vector of numbers characterizing hand. Comparison of hand is then carried out on the basis of multivariate statistical methods e.g., factor analysis, discrimination analysis and cluster analysis (Meloun, Militký and Forina (1994)).

Applicability of various methods for objective hand prediction is connected with the choice of measured textiles properties.

Kawabata Evaluation System

The most widely known system for prediction of fabric hand is the Kawabata Evaluation System - KES (Kawabata(1982)). Kawabata's methodology assumes that fabric hand is derived from a combination of primary sensory factors such as softness, stiffness and roughness. A second assumption in Kawabata's approach is in notion that the ultimate judgment of hand of a fabric is dependent on the specification of end use area. The unique feature of Kawabata's devices lies in their ability to measure fabric mechanical properties at small strains and capability to characterize energy loss in mechanical deformation and recovery processes.

The KES systems of instrumentation for measuring the fundamental mechanical properties of fabric and regression type model for prediction of subjective hand are described in (Kawabata(1982)).

The properties being measured are grouped into six blocks as follows: Tensile property, Bending property, Surface property, Shearing property, Compressional property, Weight and Thickness. The characteristic values those represent the property of each of these six groups have been decided under the consideration such that the number of the characteristic values should be as small as possible, but enough for expressing the property of its block sufficiently. These characteristics are collected in the table I.

The calculation of total hand value (in the range 0-5, where 5 is the best) is based on the stage-wise regression analysis. In the first step the three primary hand values are computed. These primary hand values can be expressed by these characteristics:

koshi (stiffness in bending and shearing, fabric weight at the same thickness decrease koshi,)
numeri (smoothness described by small variation of frictional force, bending shearing and compressional properties have small rigidity)
fukurami (softness in compressional properties, smooth surface, fullness)

In the second step the total hand value (*THV*) is computed from primary hand values and specific constants. Details about measurement principles, sample preparation and computation of *koshi*, *numeri* , *fukurami* and *THV* are collected in (Kawabata(1982)).

Experimental part

The twill fabric for military clothing created from 100% Egyptian cotton was selected for experiments. The common fatty acid based softener was selected. The fabrics were treated by this softener at the concentrations 0, 1, 3 and 5 g/l by the standard procedure. The 16 characteristics connected with hand (see. table I) were measured on the KES system under standard conditions. For all parameters measurements were six times repeated. The mean values were used for creation of regression models.

Table I. Properties connected with hand, sensitivities (*SE*), intercepts (*ME*) and paired correlations (*r*)

Properties	Symbols		Characteristic value	unit	SE	ME	r
Tensile	LT	x_1	Linearity	-	-0.0003	1.033	-0.018
	WT	x_2	Tensile energy	$gf.cm/cm^2$	-0.0115	0.974	***-0.740***
	RT	x_3	Resilience	%	-0.0160	0.957	-0.676
Bending	B	x_4	Bending rigidity	$gf.cm^2/cm$	-0.0160	1.077	-0.396
	2HB	x_5	Hysteresis	$gf.cm^2/cm$	0.0081	1.188	0.101
Shearing	G	x_6	Shear stiffness	gf/cm.deg.	-0.0326	1.175	-0.395
	2HG	x_7	Hysteresis at ∅ = 0,50	gf/cm	-0.0092	1.391	-0.0563
	2HG5	x_8	Hysteresis at ∅ = 50	gf/cm	0.0102	1.175	0.139
Compression	LC	x_9	Linearity	-	-0.0163	0.813	-0.191
	WC	x_{10}	Compressional energy	$gf.cm/cm^2$	0.0074	1.098	0.153
	RC	x_{11}	Resilience	%	-0.0116	0.979	-0.608
Surface	MIU	x_{12}	Coefficient of Friction	-	0.0200	1.010	***0.969***
	MMD	x_{13}	Mean deviation of MIU	-	-0.0719	1.011	***-0.917***
	SMD	x_{14}	Geometrical roughness	micron	0.0029	1.076	0.057
Weight	W	x_{15}	Weight per unit area	mg/cm^2	-0.0157	1.02	***-0.86***
Thickness	T	x_{16}	Thickness at 0,5 gf/cm^2	mm	-0.0001	1.129	-0.0026

For computation of primary hand values and THV the program MUNEXP in MATLAB 7 was computed. This program is used for computation of the sensitivity values (*SE*), intercepts (*ME*) and paired correlations (*r*) characterizing the strength of softener influence. Results are given in the table I.

Results and discussion

For quantification of softener influence on the changes of properties and hand characteristics the approach based on the linear regression was selected. For the property *P(c)* the linear regression model has the form

$$P(c)/P(0) = ME + SE * c \tag{1}$$

where *P(0)* is value of property at zero concentration of softener, *SE* has meaning of sensitivity to presence of softener (first standardized derivative) and *ME* intercept should be for ideal case equal to one. The paired correlation coefficient *r* between *P* and *c* was computed as indicator of the strength of "linear" dependence. The limit (lowest) value of *r* is dependent on the number of points (pairs *P(c)*, *c*) used for evaluation of parameters *ME* and *SE* by the least squares method. It is known that the so called Rubens transformation (Meloun, Militký and Forina (1994)).

$$Ru = \frac{r * \sqrt{n - 2.5}}{\sqrt{1 - 0.5 * r^2}} \tag{2}$$

leads to improving of the normality. Under assumption of no correlation has variable *Ru* standard normal distribution. For significance level 0.95 (corresponding normal quantile is 1.645) is then lowest absolute value of correlation coefficient r_m expressed in the form

$$r_m = \sqrt{\frac{2.706}{n+1.147}} \tag{3}$$

For the case of investigated dependences is $n = 4$ and therefore the lowest absolute value is $r_m = 0.725$. The properties from table I having higher correlation coefficient (marked by italic bold) are *WT*, *MIU*, *MMD* and *W*. The highest paired correlations are for properties based on the surface friction (*MIU*, *MMD*). Regression lines for friction characteristics are shown on the fig. 1.

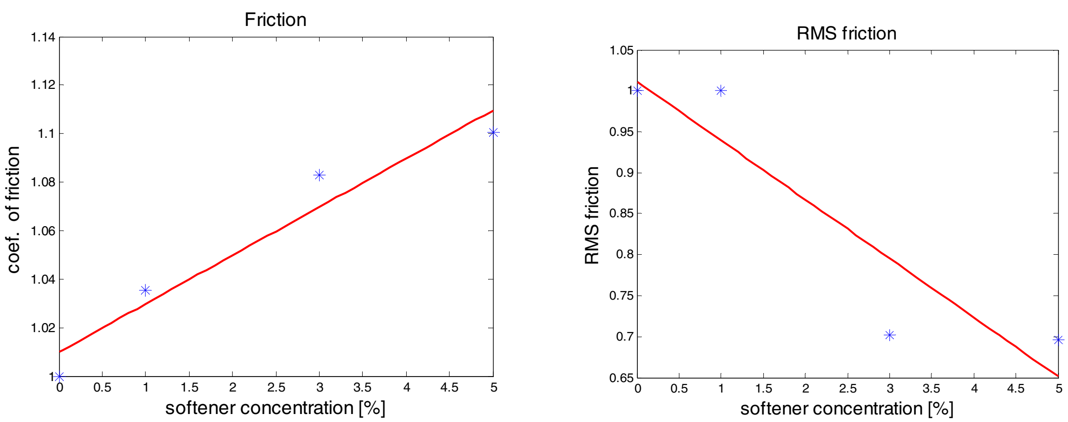

Fig. 1 Dependence of friction characteristics on the softener concentration

The increasing of friction due to softener presence is probably caused by increasing of number of contacts between fabric and friction element. Decreasing of *RMS friction* (*MMD*) due to softener presence is connected with increasing of primary hand value numeri. Values of *SE* for these properties indicate the highest sensitivity to softener presence. Tensile energy *WT* is decreasing due to presence of softener. This indicates softer response of fabrics. The decreasing of weight *W* in the presence of softener is probably caused by the dimensional changes during technology of softening. Rests of characteristics are not significantly changed due to softener presence.

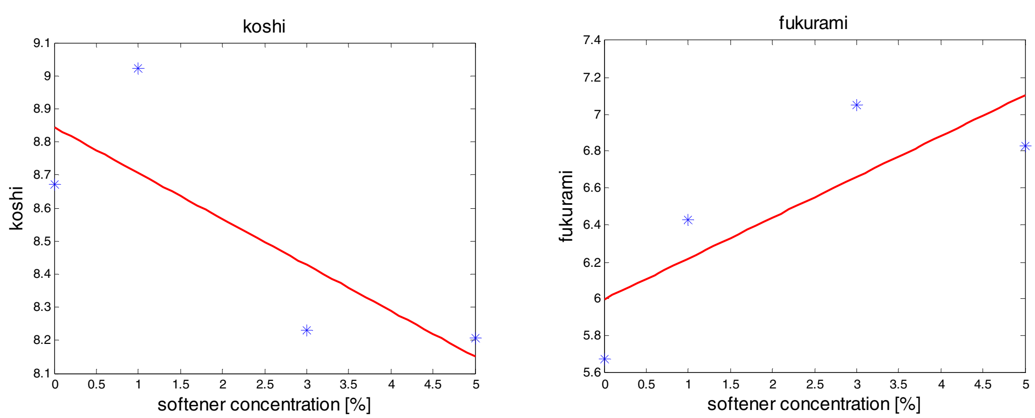

Fig. 2 Dependence of *koshi* and *fukurami* on the softener concentration

The dependencies of primary hand values and total hand values on softener concentration are shown on the fig. 2 and fig. 3.

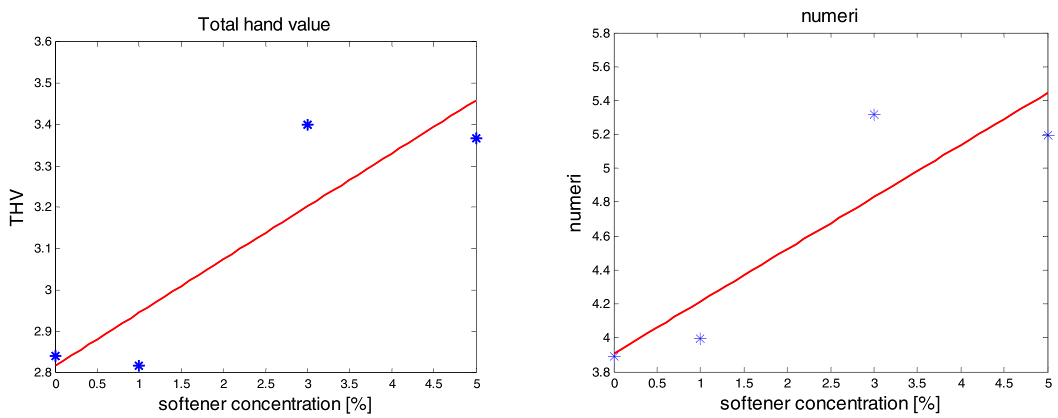

Fig. 3 Dependence of THV and *numeri* on the softener concentration

The results of linear regression are given in the table II (no standardization by *P(0)* division) .

Table II. Results of linear regression for dependence of hand characteristics on softener concentration

Parameter	**SE**	**ME**	**r**
THV	0.1284	2.8172	***0.890***
KOSHI	-0.1388	8.8443	***-0.788***
NUMERI	0.3074	3.9075	***0.894***
FUKURAMI	0.2207	5.9991	***0.810***

Results in the table II and figs 2, 3 indicate the strong influence of hand characteristics on the softener concentration. According to the expectation are *koshi* negatively and rest of hand characteristics positively correlated with softener presence.

Conclusion

Based on the presented results is clear that the softener has strong influence on the surface frictional properties. These properties changes have positive influence on the total hand value and *numeri* primary hand mainly. The changes of mechanical properties are not very strong.

Acknowledgement

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