ESTIMATION OF COTTON YARNS COMPLEX QUALITY INDEX BASED ON THE USTER STATISTICS Jiří Militký Dana Křemenáková Textile Faculty, Technical University Liberec, Czech Republic

<u>Abstract</u>

One of main task in characterization of cotton yarn complex quality index is proper combination of individual yarn properties according to their usefulness. This index can be simply created based on the complex quality indices. The degree of quality (complex criterion) is here expressed as utility value U (see. Militký 1980). Evidently, general quality of cotton yarns is characterized by various utility properties R_i (i = 1,...m) obtained here from Uster statistics (variation coefficient of yarn fineness, mass unevenness CV, hairiness, variation coefficient of yarn strength, deformation at break, deformation work, thick places, thin places, neps). Utility value $U \in <0, 1>$ aggregates then in some certain way these properties (see. Černý et all 1980).

The purpose of the paper is to describe the construction of this type criterion by using characteristics based on the Uster statistics. The application of U is demonstrated on the example of rotor cotton yarns with one level of fineness and two level of twist coefficients produced in Czech Republic. The program CQTEX written in MATLAB is briefly mentioned. The influence of cotton fiber quality index on the quality index of cotton yarns is discussed as well.

Introduction

Standard evaluation of textile product quality is closely connected with area of their application (Militký 2010). Yarns quality is generally different from standard definitions because yarns are obviously intermediate products and their specific aim of application is not precisely known. Quality of yarns is therefore expressed by the combination of general measurable characteristics specified by the standards or by empirical equations. According to the Czech standard ON 80 2120 are cotton yarns classified into three classes (extra, standard, non standard). The class extra for cottons III combed - $14 \div 50$ tex should have at least the strength 14 N tex⁻¹, maximum variance coefficient of strength 13.5 % and maximum variance coefficient of fineness 3%. In Russian standards GOST 1119 – 70

$$I_{K} = \frac{TENA}{JEM \ CVTE}$$

where TENA is yarn strength [N tex⁻¹], JEM is yarn fineness [Tex] and CVTE is strength variation coefficient. The well known system of Uster Statistics contains a set of properties connected with yarns quality. These characteristics are measured by the Uster devices.

Aim of this contribution is description of the construction of yarn complex type criterion by using characteristics based on the Uster statistics (Anonym 2004). The application of U is demonstrated on the example of rotor cotton yarns with one level of fineness and two level of twist coefficients produced in Czech Republic. The program CQTEX written in MATLAB is briefly mentioned. The influence of cotton fiber quality index on the quality index of cotton yarns is discussed as well.

Materials and Methods

The cotton yarn complex quality index is calculated from selected properties used in the Uster statistics. For the case of cotton rotor yarns the following characteristics were selected (Anonym 2004):

VTEX [.%] (variation coefficient of yarn fineness) measured as mass unevenness between lengths 100 m, TENA [.cN/tex] (yarn strength) measured by the Uster Tensorapid tensile testing machine UTR4, ELON [%] (deformation at break) measured by the Uster Tensorapid tensile testing machine UTR4,

CVTE [%] (variation coefficient of yarn strength), BWORK [N.cm] (deformation work till break), CVU [%] (mass unevenness) measured by the Uster Tester UT3, TEN [1/1000m] (thin places) measured by the Uster Tester UT3, TLU [1/1000m] (thick places) measured by the Uster Tester UT3, NOP [1/1000m] (neps) measured by the Uster Tester UT3, CHL [-] (hairiness,) measured by the Uster Tester UT3.

The relative weight characterizing importance of individual characteristics are given in the tab. 1. These weights were obtained by the analyzing of the experts meaning.

Uster statistics US(u) contain the selected quality characteristics of yarns expressed as complement to the quantile function i.e. $US = 1 - F^{-1}(u)$ for selected probability levels in the range 0.05 to 0.95. These statistics are presented in the form of graphical dependence of US(u) on the yarn fineness (see. fig. 1 for the case of mass unevenness CVU).



Figure 1. Uster statistics for mass unevenness CVU

These graphs can be replaced by the power regression models. For example for mass unevenness CVU from Uster Tester the following equations were obtained.

 $US(0.05) = 7.927 * (590/Tex)^{0.16741}$ $US(0.95) = 11.1175 * (590/Tex)^{0.13658}$

Other equations are part of program CQTEX. As not acceptable values L (see. eqn (1)) of individual characteristics the US(0.95) were selected. The US (0.05) were selected as just fully acceptable values H (see. eqn (1)). These values calculated from power type dependences are shown in the tab.1.

Parameter	Weight w	Lowest L	Highest H
VTEX	0,17	1,5	0,7
TENA	0,10	11,72	14,32
ELON	0,07	4,93	6,49
CVTE	0,13	12,50	7,50
BWORK	0,07	2,4296	3,8183
CVU	0,13	18,12	14,43
TEN	0,07	157,70	33,33
TLU	0,07	244,30	68,70
NOP	0,07	1291,37	370,15
CHL	0,13	4,91	3,48

Table 1. Individual yarn quality properties weights and limits

Tested Yarns

The 34 rotor yarns were prepared under comparable conditions. Seventeen kinds of cottons commonly used in Czech Republic were selected. The 100% cotton yarns (composed from pure cotton lots) were produced in one level of yarn count Jem = 16,5tex and two levels of Phrix twist coefficient alf = 73, 85. The HVI system was used for determining fiber parameters. Fiber length parameters UHM, UI, SF, fiber bundle strength STR, elongation EL, micronaire MIC and trash content

The fibres parameters were classified according to Uster Grades. All analysed fibres characteristics were set to the five level grades (1 very good, 2 good, 3 middle, 4 low, 5 very low). The way of setting grade depends on the background of evaluated property. Higher value seems better quality in case of *UHM*, *UI*, *STR* and in opposite of it, the lower value seems better quality for example in case of *SFI* and *CNT*. Colour in terms of yellowness and reflectance were classify according to HVI colour grades diagram for upland cotton (yellowness – 1 white, 2 light spotted, 3 spotted, 4 tinged, 5 yellow stained, *RD* - 1 good middling, 2 strict middling, 3 middling, 4 strict low middling, 5 low middling, 6 strict good ordinary, 7 good ordinary). In fig. 2 is shown that cotton varieties used in this experiment are covering the wide range of characteristics.



Figure 2 Diagram of cotton fibre characteristics (lot)

The yarn quality characteristics were measured by the Uster Tensorapid 4 tensile testing machine and Uster Tester 3 machine under standard conditions.

Yarn utility value

The textile product or semi product quality is characterized by several properties expressing their ability to fulfill

functions it was designed for. The degree of quality (complex criterion) is often expressed as utility value U (see e.g. [1]). Evidently, general quality of textiles is characterized by many of various utility properties X_i (i = 1,...m). These are such properties that make it possible for the product to fulfill its function. Utility value $U \in \langle 0, 1 \rangle$ aggregates in fact partial quality properties.

Evaluation of quality based on complex criterion is closely related to the well-known problem of complex evaluation of variants (see. Černý et all 1980). For complex evaluation of variants, the \mathbf{R} matrix of the (n x m) order is available containing for individual V_1, \ldots, V_n variants (\mathbf{R} matrix rows) the values of selected R_1, \ldots, R_m characteristics (\mathbf{R} matrix columns) The R_{ij} element of the matrix thus expresses the value of the *j* - th characteristic of X_j for the *i*-th variant of V_i . The aim is to sort individual variants in the order of their importance. In economics several different methods are used in this field and most of them are based on preferential relations [(see. Černý et all 1980). A special technique is the so called "useful effect method" or "base variant method". Base variant practically represents an ideal state where individual characteristics get optimum values.

When applying the method of base variant for expressing of textiles quality, the following problems have to be solved:

- Selection of X_i characteristics corresponding to utility properties,
- Determination of preferential functions $u(R_{ij})$ expressing "partial quality" for chosen utility property,
- Assessment of the importance of individual utility properties,
- Proper aggregation, i.e., determination of the U function.

When expressing quality, each fabric is generally compared as for two specific base variants. One of them expresses an ideal state of an absolutely satisfactory product H where U is near one, the other a state of a just unsatisfactory product L where U is near zero. In sequel the "i" index for the *i* - th variant of V_i is left out. Utility properties X_i (i = 1,...,m) are chosen in several ways. The utility properties for yarns are simply based on the

Utility properties X_j (i = 1,....m) are chosen in several ways. The utility properties for yarns are simply based on the Uster statistics.

Relative contribution of utility properties to general quality is usually expressed by weights w_i whose standard is set to make $\Sigma w_i = 1$. In relation to their choice, various aspects for expressing the utility may be given preference. For the case of distance computation are weights w_i usually known or may be simply estimated.

The first step in calculation of utility function U is transformation of individual R_i (i = 1,....m) measured values to the standardized W_i form using base characteristics and a subsequent determination of partial utility functions $u_j=u(W_j)$. There are many special procedures and they differ by the scale in which individual utility properties are expressed. Yarn properties used in the Uster statistics are only in the cardinal scales i.e. expressed in some units. During their standardization the fact should be taken in account that there are two types of cardinal characteristics. <u>One-side bounded characteristics</u> are of two basic types. For the characteristics of <u>first type</u> (HB - higher is better) it is valid: after the $H_j > L_i$ value has been exceeded utility does not change any more (TENA, ELON and BWORK).

For the characteristics of second type (LB - lower is better) it is valid: till the $H_j < L_i$ value has been reached utility is maximum and does not change (rest of characteristics). Both types can be treated by the same manner .Standardization is computed approximately as a piecewise linear function. In this case the proper lower L_i and upper H_i limits for each property X_i should be specified (see fig. 3 for the case of HB).



Figure 3. One side bounded properties

Simultaneous standardization and transformation to the partial utility function is realized by calculating of quantity

$$u_{i} = \frac{0.9}{H_{i} - L_{i}} (R_{i} - H_{i}) + 1$$
(1)

To determine the aggregating function U the most suitable is the weighted geometrical average that meets the following requirements:

 \circ The values of utility properties close to absolutely unsatisfactory base variant are more important for expressing the quality than those close to optimum base variant,

• Unsatisfactory value of utility properties cannot be compensated by values of other characteristics (if a fabric is absolutely unsatisfactory in one quality criterion then its utility is practically zero).

The weighted geometrical average U is calculated by the relation

$$U = \exp\left(\sum_{i=1}^{m} w_i \ln\left(u_i\right)\right)$$
(2)

The U value is used as complex yarn quality criterion for all yarn variants.

Program CQTEX

Aim of program CQTEX is to calculate the complex yarn quality criterion for yarns tested by the Uster tester and Tensorapid devices. As not acceptable values L (see. eqn (1)) of individual characteristics the US(0.95) are computed. The US(0.05) are computed as just fully acceptable values H (see. eqn (1)). The values calculated from power type regression models are used.

When forming the aggregating function U from experimentally determined values of yarns properties, the statistical character of the R_j quantities should be considered and the corresponding variance D(U) should be also determined besides the U. One procedure for estimating of E(U) and D(U) based on Taylor series expansion is given in the paper (Militký 2010). In program CQTEX written in MATLAB the technique described in (Meloun, Militký, Forina 1993) has been applied. It is based on the assumption that for each utility property X_j the mean value R_j and variance s_j^2 are determined by statistical treatment of the measured data or based on previous knowledge.

The proper determination procedure of the utility value U of statistical characteristics consists of the following parts:

I. Generation of $R^{(k)}_{j}$ (j=1,....m) values having normal distribution with mean values Rj and variances s^2_{j} . The pseudorandom number generator built in MATLAB is here used.

II. Calculation of the utility value $U^{(k)}$ using the relation (1).

III. The steps I and II are repeated for k=1,...,s (usually s = 600 is chosen).

IV. Construction of a non-parametric estimator of probability density function and histogram from the values $U^{(k)}$ (k=1,....n) and computation of the E(U), D(U) estimates. To characterize the form of utility value distribution, skewness and kurtosis are determined, too.

The procedure can be easily modified in case that some values R_j corresponding to utility property X_j do not have normal distribution.

Results and Discussion

By using of the above described program CQTEX in MATLAB the mean E(U), variance D(U), skewness and kurtoisis values for all three variants were estimated. Mean values are graphically summarized in fig. 4.



Figure 4. Mean values of yarn complex quality criterion for various lot of cotton fibers

It is visible that the complex yarn quality is dependent on the used cotton fibers and is better for higher twist level. The cotton fiber quality index was calculated by the same procedure (details are given in (Militký et all.2004)). The dependence between complex yarn quality and cotton fiber complex quality index is shown in the fig. 5.



Figure 5. Dependence of yarn complex quality criterion on the cotton fibers complex quality index

Correlation between both quality indices is relatively low. The influence of cotton fibers complex quality index on the yarn strength *TENA* is shown in the fig. 6 and on the yarn mass unevenness *CVU* is on the fig 7.



Figure 6. Dependence of yarn strength TENA on the cotton fibers complex quality index



Figure 7. Dependence of yarn mass unevenness CVU on the cotton fibers complex quality index

The correlation between yarn strength and the cotton fibers complex quality index is important (above 0.7) which supports the importance of cotton fiber quality for yarns mechanical characteristics. On the other hand there are no correlations between yarn mass unevenness and the cotton fibers complex quality index. The unevenness characteristics and hairiness are therefore influenced by the yarn production and random variations. Therefore it is possible to change quality of yarns by the selection of proper technological parameters of yarn production as well.

<u>Summary</u>

Evidently expressing the quality based on complex variant evaluation is of a universal character (fibers, yarns etc.). There are, of course, many other techniques; some of them (e.g. polar property diagram) do not even carry out any aggregation. The advantage of the complex quality criterion U manifests itself especially in the case when quality of a whole series of yarns is being compared. Main improvement is proper functioning for the cases of one side bounded properties.

It can be expected that procedures for objective evaluation of yarns quality will keep on developing and they will thus simplify a complex adjustments of manufacturing process in respect of their required utility. The application in the computer aided textile design will be more precisely oriented to the better quality of products.

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References

Anonym 2004 Uster Statistics, Uster Technologies A.G. Switzerland

Černý M., Gluckhaufová D. and Toms M. 1980. Methods for Complex Evaluation of Variants, Academia Praha (in Czech)

Meloun M., Militký J. and Forina M. 1993. Chemometrics in Instrumental Analysis, Ellis Horwood, London

Militký J. 1980. Statistical properties of complex quality indices, Proc. Conf. STAQUAREL 80, Praha (in Czech)

Militký J., Křemenáková D., Krupincová G., and Ripka J. 2004. Proc. 2 nd. Int. Text. Conf, - Magic World of Textiles, Dubrovnik

Militký J. 2010. Complex quality evaluation of textile fabrics, Proc. Conf. CLOTECH, Radom