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COMPLEX COTTON FIBER QUALITY CHARACTERIZATION

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There were proposed complex characteristic of cotton fiber quality based on the results of HVI or standard measurements of cotton fiber properties. According to the general definition, the quality is characterized by several properties expressing the ability of a product to fulfill functions it was designed for. The degree of quality (complex criterion) can be expressed as cotton quality index U. The method for complex evaluation of cotton fiber performance based on this idea is presented. The results of HVI measurements are used as input data.

Keywords: cotton fiber quality, complex indices, utility value concept, HVI data.

1. Introduction

According to the general definition, the quality is characterized by several properties expressing the ability of a product to fulfill functions it was designed for. The degree of quality (complex criterion) is often expressed as utility value U [1]. Evidently, general quality of textiles is characterized by many of various utility properties R_i (i = 1,…m). These are such properties that make it possible for the product to fulfill its function. Utility value

$U \in <0, 1>$ aggregates in some certain way partial quality properties [2], [3].

The purpose of the paper is to describe the complex evaluation of cotton fiber quality (cotton quality index U) based on this idea. The results of HVI measurements are used as input information. The applicability of cotton quality index is demonstrated on the simulation-based examples.

2. Cotton Fiber Quality

There exists a plenty of standard and HVI techniques for characterization of cotton fibers. It is known that there are some differences in the principles of measurements and the results of AFIS and HVI spectrum apparatus. The differences exist between measurements of fiber strengths based on the bundles concept or single fiber concept as well [4]. Despite of these differences it is possible to specify basic cotton fiber properties having potential influence to the cotton yarn strength [5] :

Fiber length (expressed as upper half mean UHM [mm]),

fiber length uniformity (expressed as uniformity index UI [%]),

fiber strength (as bundle strength STR [cN/tex]),

fiber elongation ant break (EL [%])

fiber fineness and maturity (expressed by micronaire reading MIC [-]),

short fiber content (SF [%]),

thrash content (TR [%]).

The importances of these properties are generally dependent on the spinning technology. The relative weight b of above listed properties (as importance percentages divided by 100 and then standardized - sum of weights should be one) are given in the Tab. 1.

Table I

Property/ weight	Rotor yarn	Ring yarn
UI [%]	0.20	0.22
MIC [-]	0.16	0.17
UHM [mm]	0.14	0.24
STR [g/tex]	0.28	0.22
EL [%]	0.09	0.06
SF [%]	0.06	0.06
TR [%]	0.07	0.03

The values in the Tab. 1 were derived from pie graphs presented in the work (Rasked (2002)). One of first attempts to create aggregated criterion of cotton fiber quality was fiber quality index (FQI) expressed by relation [6]. For HVI results is FQI expressed in the form

$$FQI = \frac{UHM\,UI\,STR}{MIC}. \quad (1)$$

Some other criteria are based on the regression models connecting fiber properties with parameters characterized spinning ability or quality of yarn (characterized by yarn strength). The spinning consistency index (SCI) is connected with cotton HVI properties through regression model [7]:

$$SCI = -414.67 + 2.9STR + 49.1UHM + 4.74UI - 9.32MIC + 0.95Rd + 0.36b, \quad (2)$$

where Rd is reflectance degree and b is yellowness of fiber. Based on the regression equation relating fiber properties with yarn strength the premium discount index (PDI) was derived [8]. The multiplicative analytic hierarchy process (MIA) criterion can be expressed by relation [8]

$$MIA = \frac{STR^{0.27}EL^{0.039}UHM^{0.291}UI^{0.145}}{MIC^{0.11}SFC^{0.145}}. \quad (3)$$

In the book [9] so called geometric properties index (IG) was introduced. For HVI measured properties can be IG expressed as

$$IGa = \frac{UHM\ UI\,(100 - SF)}{10000\sqrt{MIC}}. \quad (4)$$

The relation (4) is very rough because the micronaire is combination of fiber fineness and maturity. Index IG correlates with yarn mass unevenness and yarn strength variation coefficient [9].

The main problem with utilization of above-mentioned properties for quality characterization is multivariate character of information, various units and lack of transformation to the utility scale.

3. Utility Value Concept

Evaluation of quality based on complex criterion (cotton quality index U) is closely related to the well-known problem of complex evaluation of variants [3]. For complex evaluation of variants, the X matrix of the (n x m) order is available containing for individual $V_1, \ldots, V_n$ variants (X matrix rows) the values of selected $R_1, \ldots, R_m$ characteristics (X matrix columns).

The x_{ij} element of the matrix thus expresses the value of the j - th characteristic of R_j for the i-th variant of V_i. The aim is to sort individual variants in the order of their importance.

Let we have K utility properties $R_1, \ldots, R_K$ (cotton fiber properties selected in the Table I). Based on the direct or indirect measurements it is possible to obtain some quality characteristics $x_1, \ldots, x_K$ (mean value, variance, quantiles etc.). These characteristics represent utility properties. Functional transformation of quality characteristics (based often on the psycho physical laws) lead to partial utility functions

$$u_i = f(x_i, L, H), \quad (5)$$

where L is value of characteristic for just non acceptable cotton (u_i = 0.01) and H is value of characteristic for just fully acceptable product (u_i = 1). Cotton quality index (U) i.e. utility value is weighted average of u_i with weights b_i corresponding to the importance of utility properties. For the cases of cotton fibers quality utility properties and weights are already selected (see. Tab. 1). For aggregation the weighted geometric mean can be used [1].

For expressing quality of cotton fibers it is sufficient to replace standardization and nonlinear transformation to the partial utility function by the piecewise linear transformation.

For one side bounded properties quality is monotone increasing or decreasing function of quality characteristic x and therefore the piecewise linear transformation has form shown on the Picture 1. For the case of LB (lower is better) properties were limits selected according to the known ranges published e.g. in [5]

Thrash content TR [%] L = 6 H = 2

Short fibre content SF [%] L = 18 H = 6

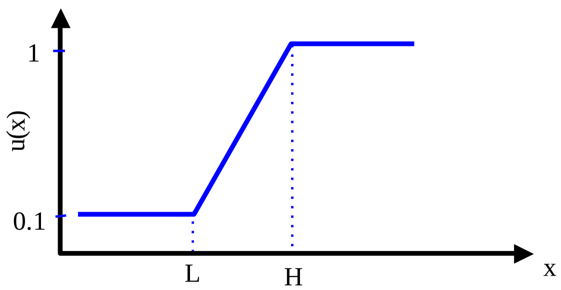
For the case UB (upper is better) properties were limits selected according to the known ranges published e.g. in [5]

Strength HVI STR [g/tex] L = 23 H = 31

Length UHM [mm] L = 25 H = 32

Uniformity index UI [%] L =77 H = 85

Elongation EL [%] L = 5 H = 7.7



Picture 1. Transformation for one side bounded cotton properties (L is lower limit and H is upper limit)

For two side bounded properties quality is monotone decreasing function of property value x on both sides from optimal (constant) region and therefore has the piecewise linear transformation form shown on the Picture 2.

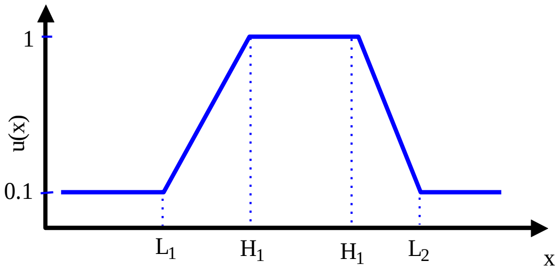


Fig. 2 Transformation for two side bounded cotton properties (L_1, L_2 are lower limits and H_1, H_2 are upper limits)

For this case were limits selected according to the relation[5]

Micronaire MIC [-] 1 = 3.4, H1 = 3.7 L2 = 5, H2 = 4.2

The weighted geometrical average U characterizing cotton fibers quality i.e cotton quality index is then simply calculated by the relation

$$U = \exp\left(\sum_{j=1}^{m} b_j \ln(u_j)\right). \quad (6)$$

When forming the aggregating function U from experimentally determined values of individual utility properties, the statistical character of the x_j quantities should be considered and the corresponding variance D(U) should be also determined.

4. Program QCOTTON

Program QCOTTON written in MATLAB is based on the above-proposed procedure. The Bootstrap type technique described in [10] has been applied for computation of the statistical characteristics of cotton quality index. This technique is based on the assumption that for each utility property R_j the mean value x_j and variance s^2_j are determined by standard treatment of the measured data. The procedure of the statistical characteristics of cotton quality index U estimation is divided to the following parts:

I. Generation of $x^{(k)}_j$ (j=1,.....m) values having normal distribution with mean values x_j and variances s^2_j.

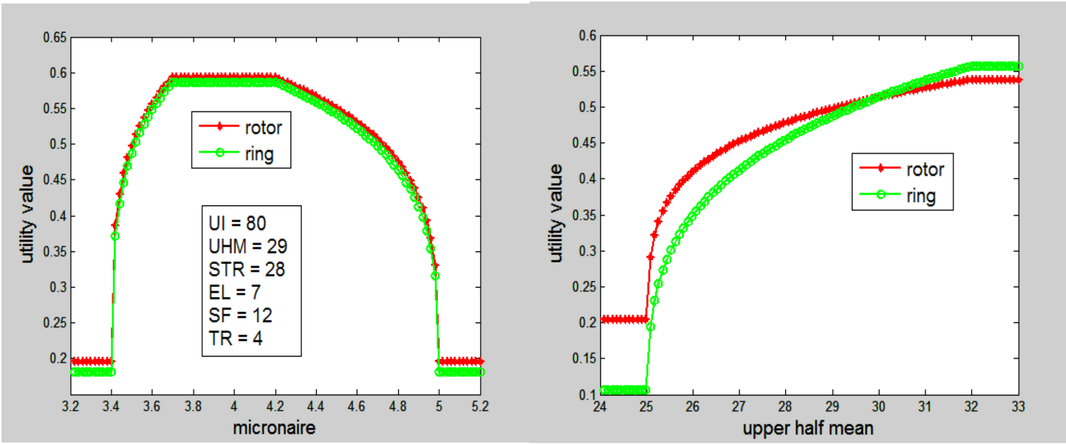
II. Calculation of the cotton quality index $U^{(k)}$ using the relation (7).

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

IV. Construction of a histogram from the values $U^{(k)}$ (k=1,.....n) and computation of the estimators of E(U), D(U).

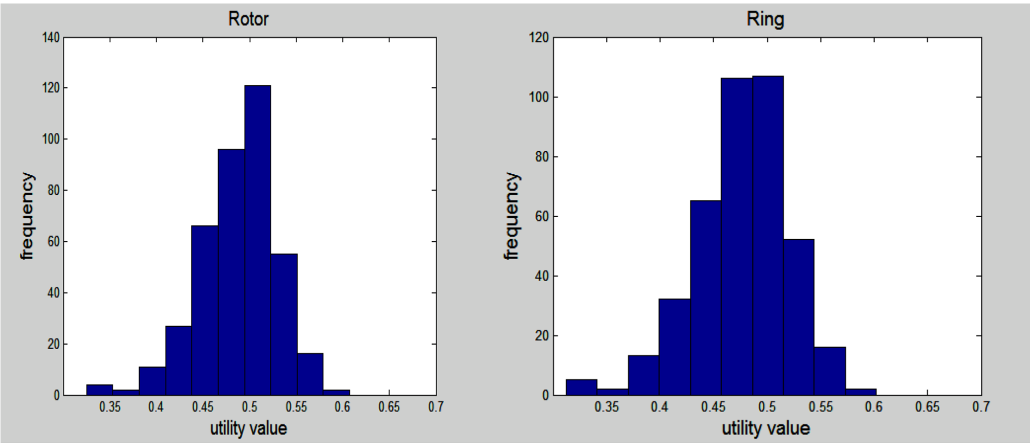
5. Simulation Results

The influence of micronaire changes and upper half mean changes to the cotton quality index of some ideal cotton fiber is shown on the Picture 3.



Picture 3. Influence of MIC and UHM on utility value

In accordance with expectation increase of UHM leads to better quality expressed by U value. Micronaire influence is more complex because the small values indicate immature cottons and high values are for too coarse cottons. The distribution of U for the idealized case when relative errors of measurement CV are 3 % for all properties are given on the Picture 4.



Picture 4. Distribution of U values for measurements with 3 %precision

There are visible differences between the U values for rotor and ring yarn weighting coefficients.

<u>Complex criterion (weights for rotor) :</u>

Mean	lower limit	upper limit
0.49 ¨	0.4.86	0.494

<u>Complex criterion (weights for ring) :</u>

Mean	lower limit	upper limit
0.479 ¨	0.4.75	0.484

The differences between both types of weights are not so high but the confidence intervals are not overlapped and conclusion is "this cotton is significantly better for rotor yarn production".

CONCLUSIONS

Described procedure for evaluation of cotton quality index (U) can be very simply modified for other selected properties or other set of weights. This is important for future cotton varieties. Based on preliminary results it will be probably necessary to solve problems with some cotton varieties having small micronaire due to fineness and relatively high strength. For these cases will be necessary to add restriction to the L_1 and H_1.

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