COTTON FIBER QUALITY CHARACTERIZATION BY COMPLEX INDICES

J. Militký and D. Křemenáková

The Technical University of Liberec

Liberec, Czech Republic

Inter-Regional Research Network on Cotton Alexandroupolis 2008

ACKNOWLEDGEMENTS: This work was supported by the research project Textile Research Center of Czech Ministry of Education 1M4674788501.

OUTLINE

- Fibers quality
- Cotton fibers basic properties
- Simple measures of cotton quality
- Application of utility value concept for creation of complex quality criterion („quality index“).
- Dependencies between cotton fiber properties and strength of yarns.

Fiber quality

- Natural fibers: changes of properties are very difficult (selection, breeding, gene manipulation).

⇒ focus to the optimal process ability and mixing.

Cotton, Bast Fibers, Wool.

- Chemical and synthetic fibers : by variation of fiber geometry (microfibers, cross section profile, texturing) and spinning conditions (rate of production, drawing degree, temperature treatment) is possible to markedly change majority of properties. The chemical modification is another way to change of properties.

⇒ focus to the general definition of quality according to the aim of utilization.

Viscose, Polyamides, Polyesters, Polyacrylonitrile, Polyolefines,

Cotton fiber quality

Cotton fiber properties:

- Fiber strength
- Fiber fineness
- Staple diagram parameters (UHM)
- Fiber maturity
- Impurities

Optimal cotton properties for maximum yarn strength

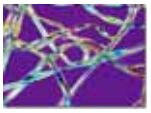
Technology:

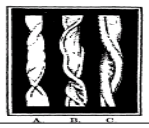
Ring spinning

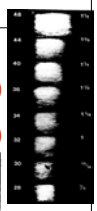
(length > strength > fineness)

Rotor spinning

(strength > fineness > length)







HVI results

Strengh **STR [cN/tex]**

Elongation ant break **EL [%]**

Upper half mean **UHM [mm]**

Uniformity index **UI [%]**

Short fiber content **SF [%]**

Thrash content **TR [%]**

Micronare **MIC [-]**

Fineness **FI [tex]**

Maturity **MAT [-]**

Uniformity ratios and descriptive designation	
Below 77	Very low
77-79	Low
80-82	Average
83-85	High
Above 85	Very high

Degree of Strength	HVI Strength (grams per tex)
Very Strong	31 & above
Strong	29-30
Average	26-28
Intermediate	24-25
Weak	23 & below

Some quality indices

Fiber quality index (FQI)

$$FQI = \frac{UHM * UI * STR}{MIC}$$

Spinning consistency index (SCI)

$$SCI = -414.67 + 2.9 * STR + 49.1 * UHM + 4.74 * UI - 9.32 * MIC + .95 * Rd + 0.36 * b$$

Premium discount index (PDI)

$$PDI = 22.15 * STR^{*} - 4.75 * EL^{*} - 4.37 UHM^{*} + 11.9 UI^{*} - 20.78 * SFC^{*} - 7.8 * MIC^{*}$$

Multiplicative analytic hierarchy process criterion (MIA)

$$MIA = \frac{STR^{0.27} * EL^{0.039} * UHM^{0.291} * UI^{0.145}}{MIC^{0.11} * SFC^{0.145}}$$

Geometric properties index I

Korickij – higher index higher quality

LVI measurements

mean length

$$IG = 0.1*L_m*(1-SF/100)*MAT*(FI)^{-0.5}$$

HVI measurements

$$IGa = \frac{UHM * UI * (100 - SF)}{10000 * MIC}$$

- *Ig* correlates with yarn mass unevenness by relation $CV = \frac{100 * A_2}{I_g \sqrt{T_P}}$

A_2 = 11.7 for long staple cottons and A_2 = 14.7 for medium staple cottons. T_P is yarn fineness

Cotton spinning ability

- *Cotton yield during spinning*

$$B = 95.4 - 2.9*TR$$

TR ..... thrash content.

- *Complex quality index I_K expressing the spinning ability of cottons*

$$I_K = A_4 * B * I_g^4 / C$$

C cotton price. A_4 = 0.0108 for long staple cottons and A_4 = 0.0141 for medium staple cottons.

These relation were derived from Russian cottons, LVI measurements and contain a lot of dimensional parameters

Disadvantages of indices

The main problem with all above mentioned characteristics of cotton fiber quality are:

- strong dependence on the units for individual cotton properties and methods for their evaluation,
- utilization of dimensional parameters based on the limited amount of experimental data (from the past crops),
- no inclusion of individual fiber properties importance for individual spinning technologies.
- no possibility to change parameters for new crops without tedious experimentation
- no defined ranges (limits) for quality indices.
- no possibility to include the direction of some properties influence to quality indices dependent on their real values (case of micronaire).

Utility Value Concept I

Let we have K utility properties R_1 ,...,R_K (cotton fiber properties measured by HVI). Based on the direct or indirect measurements it is possible to obtain some **quality characteristics** x_1 ,...,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

$$u_i = f(x_i, L, H)$$

L is value of characteristic for just non acceptable cotton ($u_i = 0.1$) and H is value of characteristic for just fully acceptable product ($u_i = 1$)

Utility value *U* (quality index) is weighted average of u_i with weights β_i

$$U = ave(u_i, \beta_i)$$

Utility Value concept II

Weights β_i correspond to the importance of given utility property and are closely connected with **area of cotton application**.

The weighted **geometric mean** used as average has following advantages:

- For zero value of u_i is also U = 0. This means that non acceptable utility property cannot be replaced by combinations of other utility properties.
- Geometric mean is for not constant u_i always lower that arithmetic mean. This reflects evaluation based on the concept that the values of utility properties close to unsatisfactory cottons are more important for expressing the quality than those close to optimum cotton.

$$U = \exp\left(\sum_{j=1}^{m} \beta_j \ln(u_j)\right)$$

Utility Value Computation

Basic steps:

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

Utility value generally reflect the aim of application

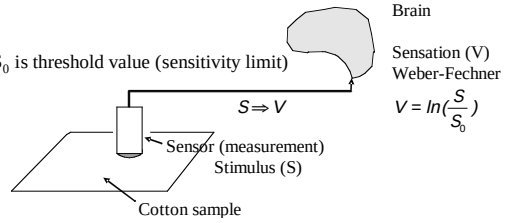
Producer – preference of technological parameters of production.

Contractor – preferences of easy measurable properties and stability of products properties..

Consumer – preference of parameters corresponding with product utilization (organoleptic properties, appearance, durability etc.).

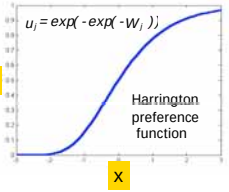
Partial utility functions

Partial utility function is psycho physical variable expressing the sensation of quality induced by (measured) characteristic of cotton property



Partial Utility Functions

u(x)



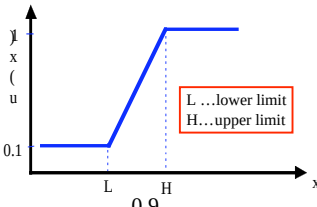
Cardinal characteristics - are usually expressed in physical units. There are two types of cardinal characteristics.

- One-side bounded characteristics are those where after the H_j value has been exceeded utility does not change any more (strength, length, etc.). After standardization the partial utility function is computed e.g. by using Harrington preference function.
- Two-sides bounded characteristics are those where on both sides from "the optimum" partial utility decreases. (e.g. maturity)

For practical applications it is sufficient to replace standardization and nonlinear transformation to the partial utility function by the piecewise linear transformation.

One side bounded properties (cotton quality index)

- Degree of quality is monotone increasing or decreasing function of quality characteristic x.

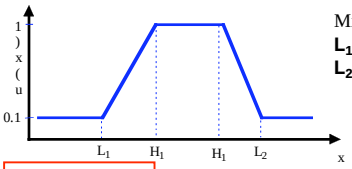


$$u(x) = \frac{0.9}{H - L}(x - H) + 1$$

LB (lower is better) properties
Thrash content **TR [%]**
L=6 H=2
Short fiber content **SF [%]**
L=18 H=6
UB (upper is better) properties
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

Two side bounded properties (cotton quality index)

- Degree of quality is monotone decreasing function of property value x on both sides from optimal (constant) region.

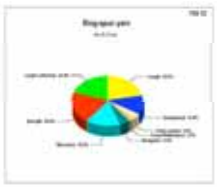


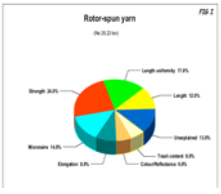
L_1, L_2 …lower limits
H_1, H_2 …upper limits

Micronaire **MIC** [-]
L_1=3.4 H_1=3.7
L_2=5 H_2=4.2

Weights for cotto quality index

- Contribution of HVI characteristics to yarn strength
- Weight b of characteristics is percentages divided by 100 and then standardized (sum of weights should be one).





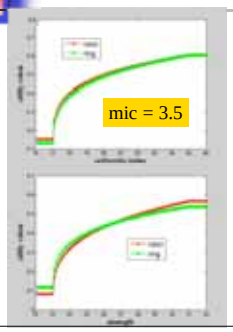
Property weight	Rotor	Ring
UI [%]	0.20	0.22
MIC [-]	0.16	0.17
UHM [mm	0.14	0.24
STR [g/tex]	0.28	0.22
EL [%]	0.09	0.06
SF [%]	0.06	0.06
TR [%]	0.07	0.03

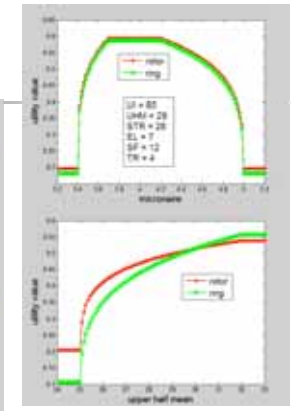
Utility function computation

In program COMPLEX written in MATLAB the simulation technique is applied. It is based on the assumption that for each utility property R_j the mean value x_j and variance s^2_j are determined from the measured data. **Utility value *U* determination**

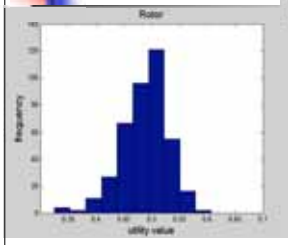
I. Generation of $x(k)_j$ (j=1,.....m) values having normal distribution with mean values x_j and variances s^2_j. The pseudorandom number generator built in MATLAB is used.
II. Calculation of the utility value $U(k)$
III. The steps I and II are repeated for $k = 1,.....n$ (usually $n = 600$ is chosen).
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.

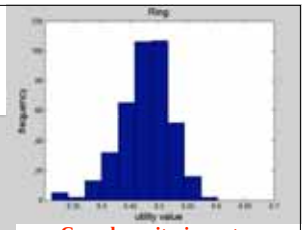
Simulation results I





Simulation results II





Coefficient of variation = 3 %

Complex criterion rotor :

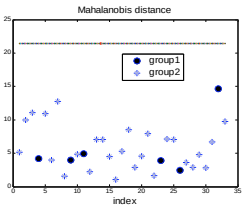
Mean	lower limit	upper limit
4.90e-001	4.86e-001	4.94e-001

Complex criterion ring :

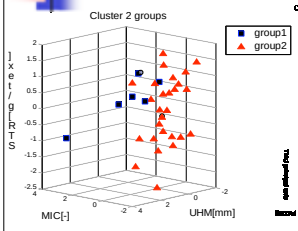
Mean	lower limit	upper limit
4.79e-001	4.75e-001	4.84e-001

Experimental part

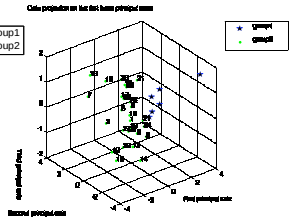
- The results of the crop study of 1997 and 1998, which includes 33 sets of cottons were used for comparison of *U* with some other cotton quality indices.
- For different cotton varieties the ^2_d International Textile Center (USA) evaluated the all characteristics required to computation of cotton quality index U excluding thrash content (in evaluation of U the value *TR = 2* was selected).



Cottons varieties



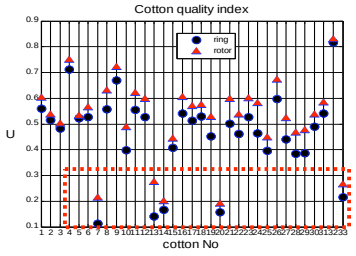
Clustering



Principal component plot

Cotton quality index

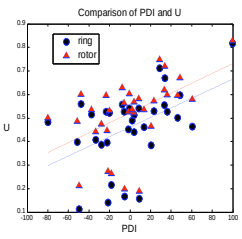
The cotton quality index *U* for all cotton varieties



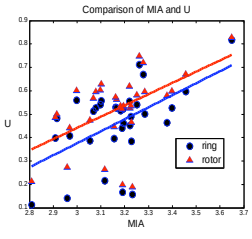
It is visible that according to the cotton quality index are cotton varieties separated into two groups. In the low value of *U* are cottons with very low UHM (No. 7, 13, 33) or very high micronaire (No. 7, 14, 20, 33).

Inter dependencies

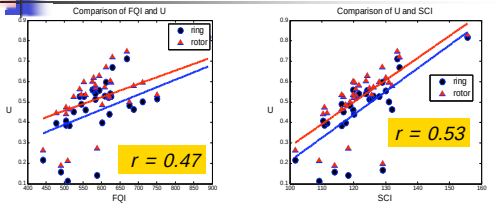
r = 0.434



r = 0.692



Inter dependencies



The best correlation exists between U and SCI. In each cases are visible the outlying points with very low values of *U*. Main reason of this deviations are higher low limits for UHM (25 mm) and low higher limit for MIC (5) used for computation of U.

Application of U

The complex criterion U (cotton quality index) can be used for creation of:

1.Control charts (on line monitoring and control of production)
2. Expressing of spinning ability of cotton fibers

The differences between utility values for various cottons can be visualized by comparing of corresponding confidence intervals

Complex criterion of quality i.e. cotton quality index is useful for prediction of usefulness of cotton fibers in textile mills or for characterization of differences between various varieties.

Conclusion

- Described procedure for evaluation of cotton quality index (U) can be very simply modified for other selected properties or other set of weights.
- 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.