FACTORS AFFECTING COTTON YARN HAIRINESS

Jiri Militky
Dana Kremenakova
Gabriela Krupincova
Sayed Ibrahim
Technical University of Liberec
Liberec, Czech Republic

Introduction

Yarn hairiness is one of important yarn parameters, which is used for yarn production quality control. It is usually characterized by the amount of free fibres (fibre loops, fibre ends) protruding from the compact body of yarn towards the outer yarn surface. Yarn hairiness is important because has great influence on the weaving process and parameters of textile product (porosity, permeability, transport of moisture, comfort, aesthetic properties and hand mainly). The main factors influencing hairiness are: type of fibres, yarn twist, yarn count, blending ratio and yarn production technology. This paper focuses in the influence of cotton fibre properties on yarn hairiness. It is generally accepted that fibre fineness, diameter, shape factor, length, flexural rigidity, torsion rigidity, tenacity, extension to break and friction are fibre parameters influencing hairiness of yarn significantly (Barella, 1983). The main aim of this contribution is prediction of yarn hairiness from fibre parameters, and yarn construction parameters.

Cotton Fibers Characterization

The enormous number of methods and their modifications has been proposed for characterization of cotton fibres. The HVI – High Volume Instruments are usually used for testing basic parameters of cotton fibres (e.g. fibre micronaire, length parameters, bundle strength and elongation, yellowness, reflectance and impurities). There are several factors influencing quality of cotton fibres and variability of parameters is relatively high in terms of cotton cultivars. There are many inter dependencies between cotton parameters leading to the strong multicollinearities. Therefore the complex quality criterion can be used together with fibre parameters in investigation of their influence to hairiness. The degree of cotton fibres quality can be determined by using cotton standards, complex criterion mentioned by several authors or by using of the utility value. Korickij proposed the IGa criterion based on cotton length in terms of upper half mean length UHM, uniformity index of staple length UI, short fibre content SFC and micronaire MIC (Korickij, 1983).

$$IGa = \frac{UHM \;\; UI \;\; (100 - SF)}{10000 \; \sqrt{MIC}} \, . \qquad (1)$$

The relation (1) is very rough because the micronaire is combination of fibre fineness and maturity. The main problem with Korickij approach is dependence on the cotton properties used for empirical function evaluation and no inclusion of individual fibre properties importance. More general concept based on the complex utility value was introduced by Militky (2007). Let we have K utility properties R1 ,...,RK (cotton fibre properties measured e. g. by HVI). Based on the direct or indirect measurements it is possible to obtain some quality characteristics x1 ,..., xK (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.

$$u_i = f(x_i, \, L, \, H) \, , \qquad (2)$$

where L is value of characteristic for just non acceptable cotton (ui = 0.01) and H is value of characteristic for just fully acceptable product (ui = 1). Utility value U (quality index) is weighted geometric average of ui with weights bi.

$$U = \exp\left(\sum_{j=1}^{m} b_j \;\; \ln\left(u_j\right)\right) . \qquad (3)$$

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

Experimental part

The rotor yarns were prepared under comparable conditions from one set of cottons (lot). The advantage of open-end technology is the shorter pre-spinning process without roving preparation. Seventeen kinds of cottons were at disposal and 100% cotton yarns were produced in five levels of yarn count Jem (16,5tex, 20tex, 27tex, 37tex, and 50tex) and two levels of Phrix twist coefficient alf in respect to the yarn count. The HVI system was used for determining different fibre parameters. Fibre length parameters UHM, UI, SFI, fibre bundle strength STR, elongation EL, trash content CNT, reflectance RD and colour – yellowness +b were measured. The cumulative hairiness index H was measured by Uster Tester 4 under standard conditions.

Results and discussion

The presence of possible outlying points was checked by the Mahalanobis distance plot (see Meloun *et al.,* 1992). This plot fro all fiber characteristics and alf, Jem is shown on the fig 1.

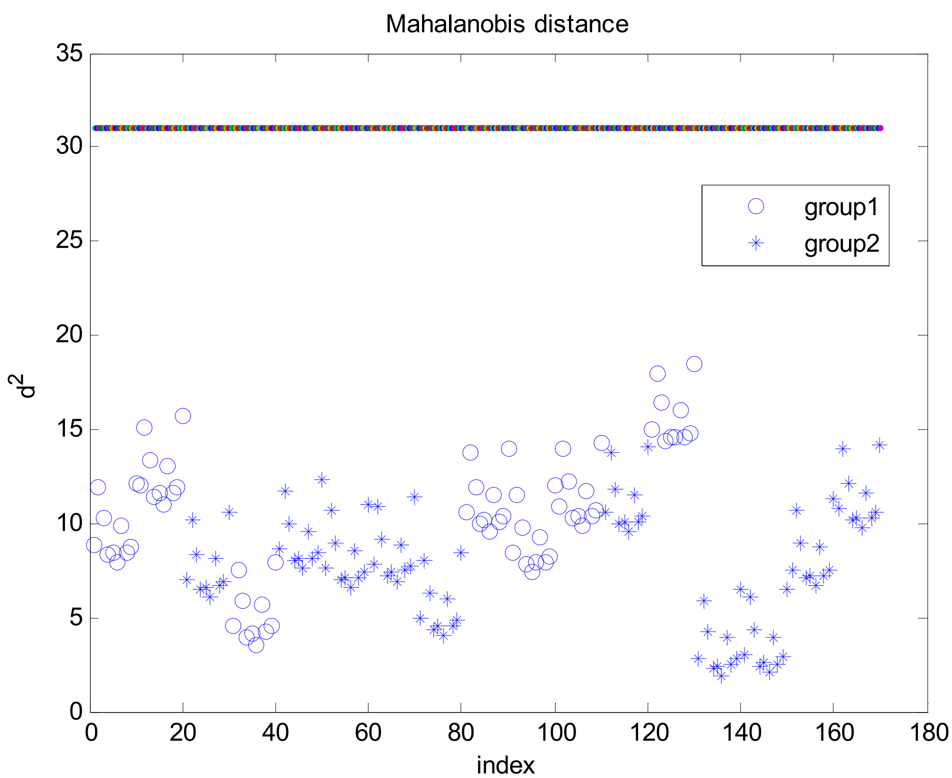


Fig. 1 Mahalanobis distance plot

It is visible that no point is over the limit for outlying points. The structured nature of data is visible from corresponding plot into first thee component of PCA (see Meloun *et al.,* 1992). This plot fro all fibres characteristics and alf, Jem is shown on the fig 2.

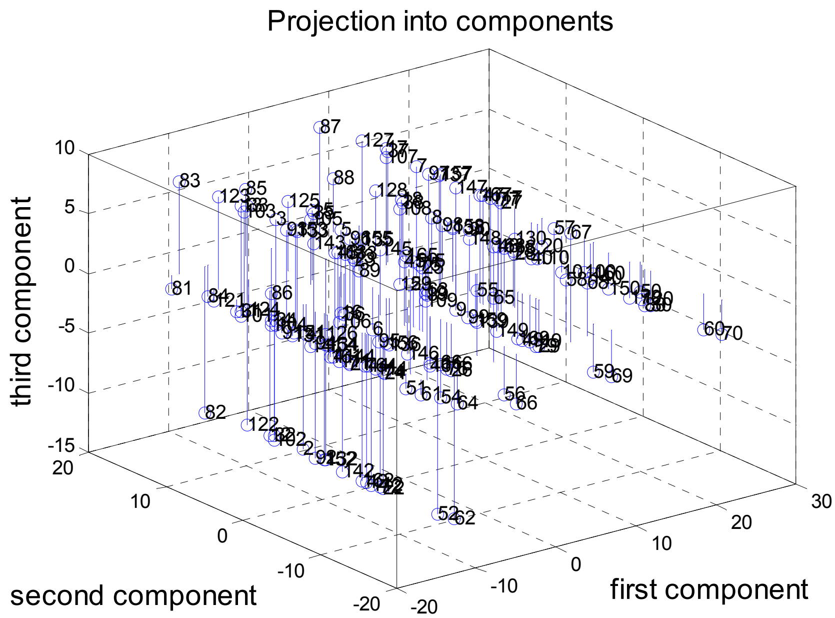


Fig. 2 PCA projection into first three components

The importance of individual variables to principal components is shown on the fig. 3. This component plot (see Meloun *et al.,* 1992) shows that the most important contribution to the first component are Jem (87.4 %) and alf (12.54 %).

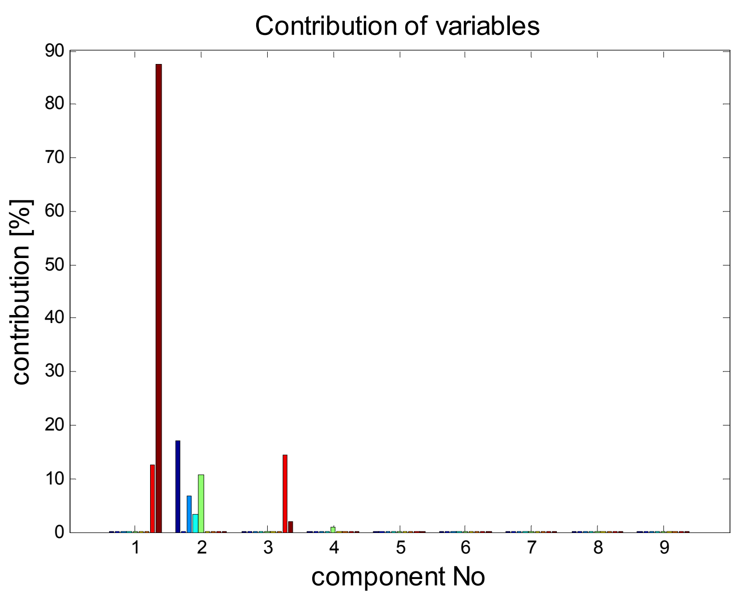


Fig. 3 Contribution of individual variables to the principal components

This simple multivariate analysis leads to conclusion that the most important from all investigated input parameters are Jem and alf. The fibre parameters are not so important for explaining the variability in data.

It is possible to classify fibre parameter according to Uster Grades. All analysed fibre characteristics can be 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. 4 is shown that a lot used in this experiment was prepared in full scale of characteristics.

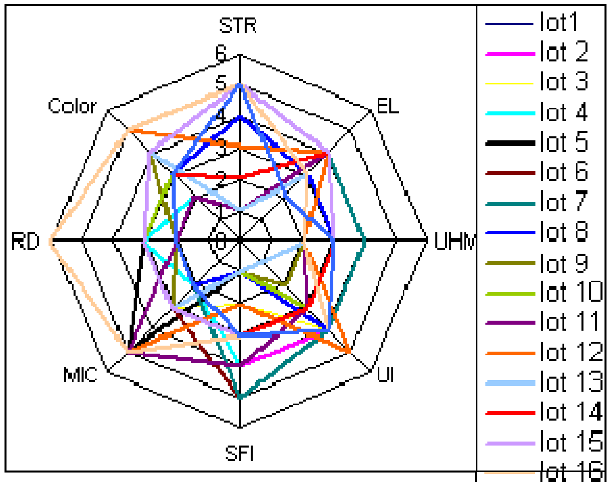
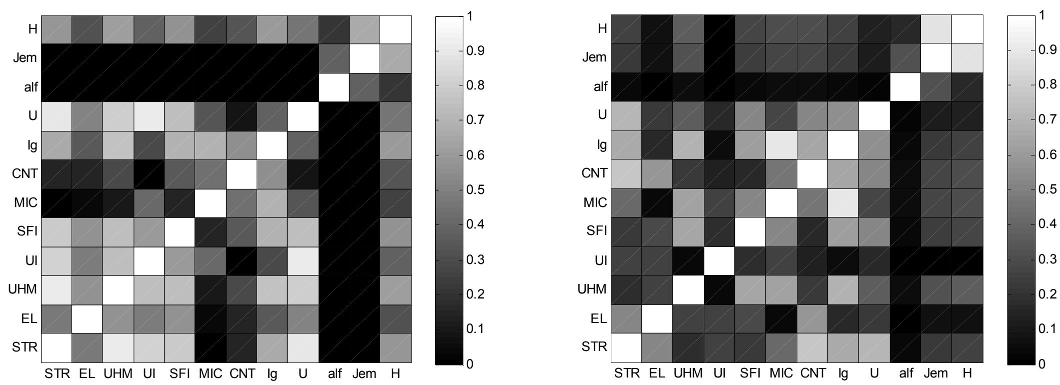


Fig.4 Diagram of cotton fibre characteristics (lot)

For estimation of mutual dependencies matrices of paired correlation coefficients and partial correlation coefficients were computed. The importance of these coefficients was evaluated by so called p values (1-p is computed confidence level). The complex characteristic IGa was computed from eqn. (1) and U from eqn. (3). Correlation map for paired correlation coefficients is on the fig 5a and for partial correlation on the fig. 5b. All fibre parameters and yarn construction parameters have significant paired correlations with hairiness. The non-significant partial correlations between EL, UI, U and yarn hairiness were found. Hairiness is dependent on the yarn fineness Jem mainly (partial correlation is 0.8892).



a **b**

Fig. 5 Correlation map for paired correlation coefficients (a) and for partial correlation coefficients (b).

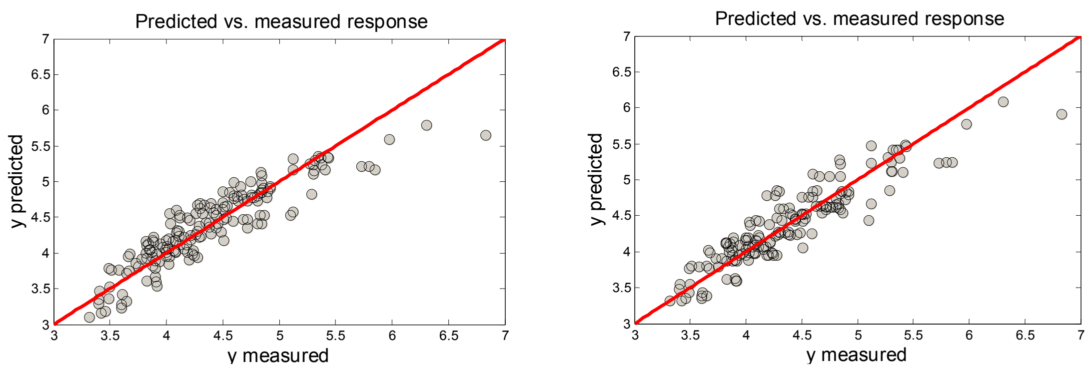
The standard or powerful regression methods can be used for prediction of hairiness (Meloun *et al.,* 1992). This approach is limited due to mutual correlation between variables (multicolinearity) and limited range of technological yarn creation parameters (yarn count, yarn twist). Multiple regression models for yarn hairiness prediction, from yarn parameters (yarn count, yarn twist) and fiber complex criterion (IGa and U) or fiber length characteristic UHM were created. The MEP criterion of regression was evaluated together with estimators of regression coefficients for individual variables, multiple correlation coefficient R and multiple prediction correlation coefficient Rp (Meloun *et al.,* 1992). The summarization of selected prediction models quality and the estimators of regression coefficients for individual variables are shown in the table 1.

Table. 1 Summarization of prediction model

R^2	R^2_p	MEP	Estimator for *Jem*	Estimator for *alfa*	Estimator for *U*	Estimator for *UHM*	Estimator for *abs*
0.83	0.82	0.067	0.0377	-0.0047	0.0216	-0.109	6.63
0.82	0.81	0.068	0.0365	-	-	-0.0981	6.09
0.84	**0.84**	**0.059**	**0.000553***	**-**	**-**	**82.9****	**0.87**

*) Jem^2 **) 1/UHM

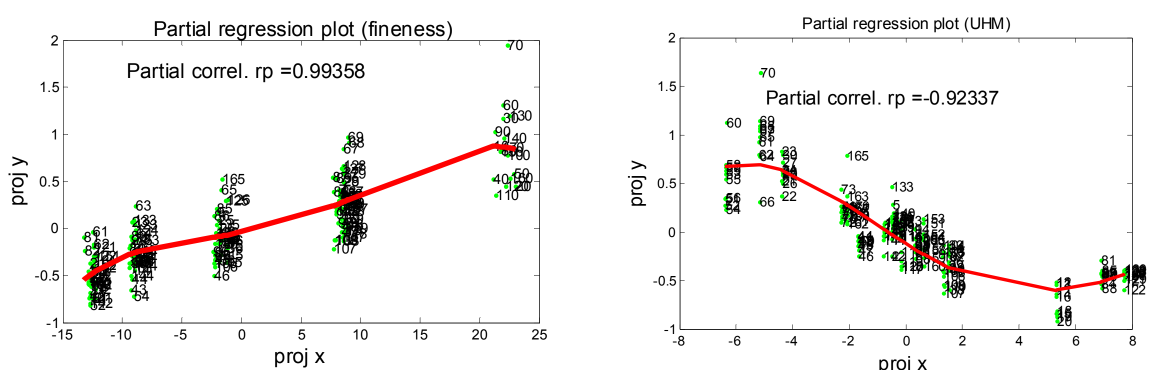
In the first row of table1 are results of the cumulative hairiness index *H* prediction by linear model containing statistically important parameters (*Jem, alfa, U, UHM*). The relation between predicted and measured cumulative hairiness index *H* are shown on the fig. 6a. In the second row are results of the cumulative hairiness index *H* prediction by linear model containing the most statistically important parameters (*Jem, UHM*) only.



a b

Fig. 6 Relation between predicted and measured cumulative hairiness index *H* (a) full linear model (b) linear model containing Jem^2 and 1/UHM only.

The corresponding partial regression graphs are shown on the fig. 7



a b

Fig. 7 Partial regression graphs (a) fineness (b) UHM.

It is clear that partial regressions are not linear but can be simply linearized by power transformation of exogenous variables. According to the shape of partial regression graphs the variable JEM was replaced by power two transformation Jem^2 and variable UHM was replaced by reciprocal transformation 1/UHM. Results for this modified linear model are given in the last row of table 1 and the relation between predicted and measured cumulative hairiness index *H* are shown on the fig. 6b. The final predictive model has the form

$$H = 0.87 + 0.000553*Jem2 + 82.9/UHM$$

This model is relatively simple and has good predictive power.

Conclusion

It was found that yarn hairiness is critically dependent on the yarn fineness (Jem) and fibre length characterized by *UHM*. Coarse fibres have higher hairiness. The influence of twist is not so high but in agreement with empirical findings the higher twist leads to the lower hairiness. The influence of majority of fibre parameters is not important.

Acknowledgements

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