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INFLUENCE OF PRODUCTION TECHNOLOGY ON THE HAIRINESS INDEX OF COTTON YARN

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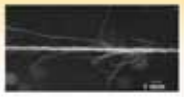
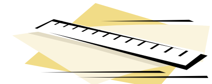


Hairiness Evaluation



• Yarn hairiness 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.

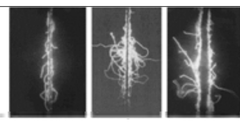
• The most popular instrument is the Uster hairiness system, which characterizes the hairiness by H value, and is defined as the total length of all hairs within one centimeter of yarn.

• The system introduced by Zweigle, counts the number of hairs of defined lengths. The S3 gives the number of hairs of 3mm and longer.

• The standard method compress the data into a single value H or S3 (avoiding important spatial information).

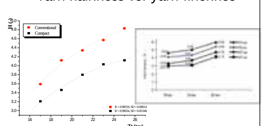
• Some laboratory systems dealing with image processing, decomposing the hairiness into two exponential functions

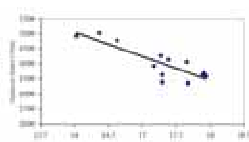
Facts about Hairiness



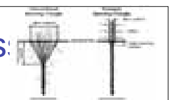
- There exist a high correlation between the number of protruding ends and the number of fibers in the yarn cross-section.
- Torsion rigidity flexural rigidity, fiber length and fiber fineness of the fibers are the most important properties affecting yarn hairiness.
- The number of protruding ends is independent of twist, whereas the number of loops decreases when the yarn twist increases because of a greater degree of binding between the fibers owing to twist.

Yarn hairiness vs. yarn finennes





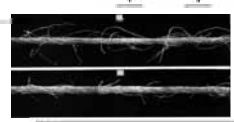
Benefits of Hairiness Reduction



Ring- Compact Spinning

Advantages of Compact yarn

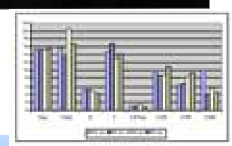
• Hairiness reduction up to 70 %



• Reduction of the sizing agent consumption: 30 - 50 %

• Reduction of the number of warp breaks in weaving: 30-40 %

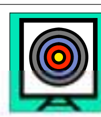
• Increase abrasion resistance: 60 - 140 %



Parameters of 15 tex yarns from PJ4 and ET - Parame

co – combed, ca – carded, Tex – linear density of yarns; CVm – mass non-uniformity according to Uster [%]; E - elongation [%]; T – breaking tenacity [cN/tex]; CVTex, CVE, CVF, CVS [%] – coefficient of variation of linear density of yarns, of elongation, of breaking force, of twist.

Outlines



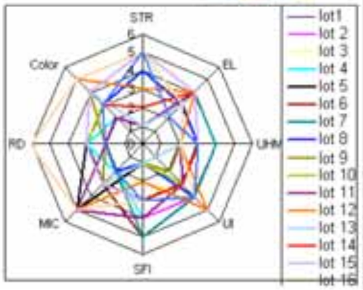
- The main aim of this contribution is prediction of OE cotton yarn hairiness from fiber parameters, and yarn construction parameters.
- Characterization of mutual relations between hairiness index H, cotton fiber parameters (from HVI) yarn fineness and yarn twist by using of correlation map for paired correlation coefficients and for partial correlation coefficients.
- Creation of predictive regression model for hairiness index H based on the nonlinear extension of linear regression (utilization of partial regression plot)

Experimental Part

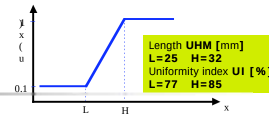
- The rotor yarns were prepared under comparable conditions.
- Seventeen kinds of cottons were at disposal and 100% cotton yarns were produced in five levels of yarn count *Jem* (16,5tex, 20tex, 27tex, 37tex, and 50tex) and two levels of Phrix twist coefficient *alf* in respect to the yarn count.
- The HVI system was used for determining different fiber parameters. Fiber length parameters *UHM*, *UI*, *SFI*, fiber bundle strength *STR*, elongation *EL*, trash content *CNT*, reflectance *RD* and color – yellowness +*b* were measured.
- The cumulative hairiness index *H* was measured by Uster Tester 4 under standard conditions.

Cotton Fibers

All analyzed fiber characteristics were classified to the five Level grades (1 very good, 2 good, 3 middle, 4 low, 5 very low). Higher value corresponds to better quality



Cotton Fiber Quality

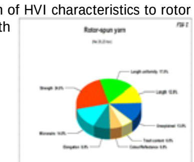


$$u(x) = \frac{0.9}{H - L}(x - H) + 1$$

Basic steps:

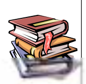
- Selection of *HVI* characteristics x_i corresponding to utility properties R_i,
- Determination of preferential functions $u(x_i)$ expressing "partial quality" for chosen utility property,
- Assessment of the importance of individual utility properties,
- Proper aggregation, i.e., determination of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

Contribution of HVI characteristics to rotor yarn strength

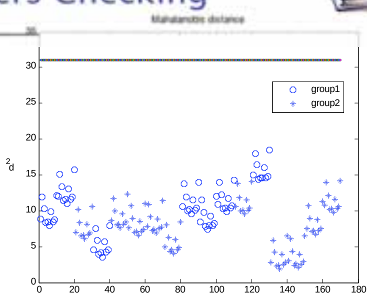


$$U = exp(\sum_{j=1}^{m} \beta_j ln(u_j))$$

Outliers Checking

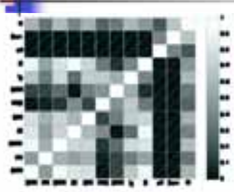


The presence of possible outlying points was checked by the **Mahalanobis** distance plot for all fibers characteristics and *alf*, *Jem*

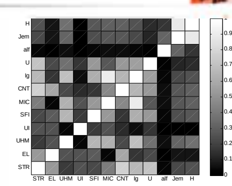


$$d^2_i = (x_i - x_A)^T S^{-1} (x_i - x_A) \qquad out(\alpha_{1-\alpha}\mu, \Sigma) = \left(x \in R^p : (x - \mu)^T \Sigma^{-1} (x - \mu) > \chi^2_{1-\alpha}\right)$$

Correlation maps



paired correlation coefficients



partial correlation coefficients

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 0.889)

Partial regression plot I

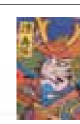
Partial regression plot (PRL) uses the residuals from the regression of y on the predictor x_j, graphed against the residuals from the regression of x_j on the other predictors.

- $\mathbf{u}_j = \mathbf{P}_{(j)} \mathbf{y}$ … residual vector of regression of variable **y** on the other variables which form columns of the matrix $\mathbf{X}_{(j)}$
- $\mathbf{v}_j = \mathbf{P}_{(j)} \mathbf{x}_j$ … residual vector of regression of variable $\mathbf{x}_j$ on the other variables which form columns of the matrix $\mathbf{X}_{(j)}$

$$\mathbf{P}_{(j)} = \mathbf{E} - \mathbf{X}_{(j)} (\mathbf{X}_{(j)}^T \mathbf{X}_{(j)})^{-1} \mathbf{X}_{(j)}^T . \qquad \mathbf{y} = \mathbf{X}_{(j)} \beta^* + \mathbf{x}_j c + \varepsilon_i$$

$$\mathbf{P}_{(j)} \mathbf{y} = \mathbf{P}_{(j)} \mathbf{x}_j c + \mathbf{P}_{(j)} \varepsilon$$

Partial regression plot II

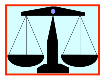


If the term $\mathbf{x}_j$ is correctly specified the partial regression graph forms straight line. Random pattern shows unimportance of $\mathbf{x}_j$ for explaining the variability of **y**. The (PRL) has the following properties:

- The slope c in PRL is identical with estimate b_j in a full model.
- The correlation coefficient in PRL is equal to the partial correlation coefficient R_{yxj}.
- Residuals in PRL are identical with residuals for full model.
- The influential points, nonlinearities and violations of least squares assumptions are markedly visualized.

$y_p = X\ b$ $\quad S(\mathbf{b}) = || \mathbf{y} - \mathbf{X}\ \mathbf{b} ||_2$

$\mathbf{b} = (\mathbf{X}^T\mathbf{X})^{-1}\ \mathbf{X}^T\ \mathbf{y}$



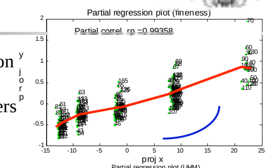
Predictive models

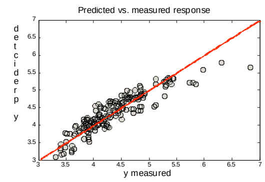
Multiple regression models for yarn hairiness prediction, from yarn parameters (yarn count, yarn twist) and fiber complex criterion (*U*) or fiber length characteristic *UHM* were created. The MEP criterion of regression, estimators of regression coefficients for individual variables, multiple correlation coefficient *R* and multiple prediction correlation coefficient *Rp* were evaluated *) Jem^2 **) 1/UHM

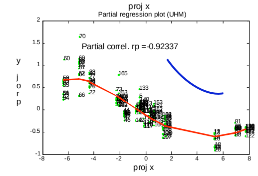
R^2	R^2_p	MEP	Estimator for *Jem*	Estimator for *alfa*	Estimator for *U*	Estimator for *UHM*	Estimator for *abs*
0.83	0.82	0.067	0.0377	-0.0047	0.0216	-0.109	6.63
0.82	0.81	0.068	0.0365	-	-	-0.0981	6.09
0.84	**0.84**	**0.059**	**0.000553***	**-**	**-**	**82.9****	**0.87**

Linear regression

- The hairiness index *H* prediction by linear model containing statistically important parameters (*Jem, alfa, U, UHM*)

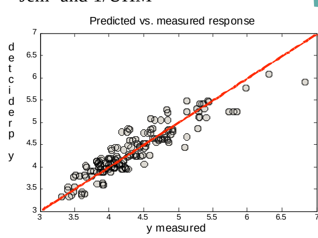






Non linear extension

Jem^2 and 1/UHM



H = 0.87 + 0.000553*Jem^2 + 82.9/UHM

Conclusions

- 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.

Thank you for your attention