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FABRIC DRAPE PREDICTION

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The main aim of this contribution is selection of optimal model of drape from family of hard regression models according to prediction potency. The combination of classical parametric regression and exploratory tools (partial regression graphs) is used. As the soft models the neural network realized by radial basic functions is selected. The complex study based on the measurements of Cusick's drape coefficient (from draped fabric images) and mechanical characteristics measured on the KES apparatus for huge fabrics set are used for evaluation of the optimal model. The predictive ability is tested by using of the 12 fabrics not used for model creation.

Keywords: drape prediction, bending, shearing, regression diagnostics.

1. Introduction

It is well known that textile fabrics are hierarchically structured with high anisotropy and nonlinear viscoelastic response. They undergo large complex deformations as response to relatively small forces. One of such deformation is fabric drape, which can be assumed as complex buckling and shearing of an original planar configuration. The drape behavior is mechanically very complex phenomena connected with fabric weight and various characteristics as bending rigidity and shear resistance. There are known empirical models based on the one-third rule applied to bending and shear.

The main aim of this contribution is comparison of hard and soft (neural network) models and selection of optimal one from point of view of prediction potency. The measurements of Cusick's drape coefficient (from draped fabric images) and mechanical characteristics measured on the KES apparatus for the 79 fabric data set are used for evaluation of model. The predictive ability is tested by the 12 fabrics not used for model creation.

2. Evaluation of Drapeability

Numerous “drape tests” have been reported. Well known is F.R.L. Drape meter. The sample holder consists of two flat plates circular in shape (area Po) mounted on a shaft coming through the base. The circular fabric sample of area P_m is sandwiched between the plates and the shaft is raised until the overhanging portions of the sample no longer touch the base. The image of this draped pattern is cast onto a sheet of ground glass by means of a lens system. The drape coefficient is then defined as percent of the annular – ring area covered by the draped sample DC.

$$DC = \frac{P_m - P_p}{P_m - P_o}. \qquad (1)$$

There a lot of methods for evaluation of the draped sample area Pp exist. Classical is tracing of draped sample image on a thin piece of paper and evaluation of projected pattern area by weighting or by using of plan meter. In work [1] the mechanical integrator was proposed. Modern techniques are based on the using of image analysis for determination of projected area. Pp.

There exist a lot of works oriented to measurement of mechanic properties in static and dynamic state and correlation with static and dynamic drape [8]. Circular shape of flat plates is replaced by pentagonal shape etc. The review of traditional and modern methods for drape characterization is described in thesis [10]. The static drape coefficient is generally unstable. The drape shape changes easily by minute acting of force on draped fabrics. For improving of stability of measurements the specific system of drape measurement (samples handling, shape capturing and sample hanging) has been proposed. The error of measurement is then reduced below 4%. [13]. Dynamic drape testers are capable to include the dynamic effects as well [11].

3. Drape and mechanical characteristics

Cusick [6] suggested that bending and shearing modules were the main factors describing drape behavior of fabrics. The bending characteristics are in general more important. The quadratic regression model predicting drape from bending length and shear angle was selected [6]. Publication of Morooka and Niwa [3] provides the basis for determination a drape coefficient DC from bending rigidity and the weight of fabric.

$$DC = 5.1 + 115\sqrt[3]{(B_{90}/W)} + 131.1\sqrt[3]{(B_0/W)} + 1.2\sqrt[3]{(B_{45}/W)}, \qquad (2)$$

where B_{90} is bending rigidity [g cm^2/cm] along warp, B_0 along weft and B_{45} in bias direction, W [mg/cm^2] is fabric weight. This regression equation was derived from 138 samples of woven fabrics and mechanical properties were measured by KES system, If B_{90} and B_0 are only measured the modified form

$$DC = 11.3 + 213.5\sqrt[3]{(B_a/W)} \qquad (3)$$

is proposed, Here B_a is average between bending rigidity in the warp and weft directions. Seto and Niwa [14] included to the model for drape prediction the bending 2HB and shear 2HG hysteresis as well. The so called Niwa model has the form

$$DC = b_0 + b_1\sqrt[3]{(B/W)} + b_2\sqrt[3]{(2HB/W)} + b_3\sqrt[3]{(G/W)} + b_4\sqrt[3]{(2HG/W)}\,. \qquad (4)$$

The bending rigidity B, bending hysteresis 2HB, shear rigidity G and shear hysteresis 2HG were measured on KES and have units used in this system.

It has been found that drape coefficient correlates well with $\sqrt[3]{B/W}$ and $\sqrt{HG/W}$ where HG is shear hysteresis [8]. The main disadvantage of above described relations is dimensional non-homogeneity and nonlinear pattern in partial regression graphs indicating not suitable transformation. These and other models for prediction of drape DC were compared in the work of Militký and all. [9].

4. Experimental part

The set of 79 selected commercial fabrics were used for evaluation drape coefficient and mechanical characteristics. The area weight of these fabrics varied from 55 to 350 g/m^2 and sett were in the range 100 - 900 [1/10cm]. Plain, twill, satin and derived weaves were used. Material composition ranged from pure cotton, polyester, viscose and wool to two component blends. The majority of fabrics were dyed and finished. For testing of models predictability the set II of 12 gray fabrics was used.

The drapeometer of FRL type with circular fabric sample dimension P_m = 706.9 mm^2 and sample holder circular plate area Po = 254.5 mm^2 was used for evaluation of drape ability. The special procedure improving stability of results was applied. The projected area Pp was computed from digital image of draped sample by the image analysis system LUCIA. The shapes of projected patterns were from circular (no node) to very complex (till 10 nodes).

The tensile, bending and shear mechanical characteristics were measured on KES system. Based on the preliminary knowledge from testing and dimensional analysis the 4 potential variables were chosen. These variables are given in the table I.

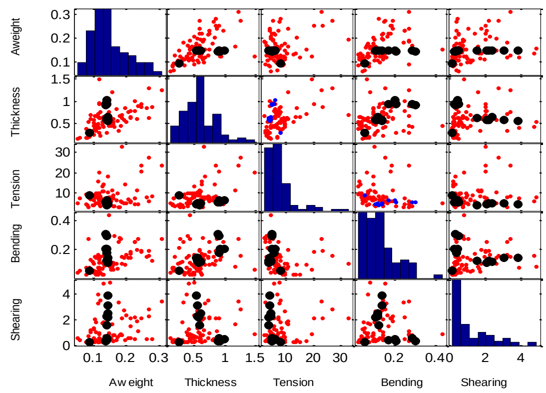
Table I

Symbols	Characteristic name
RT	Tensile resilience
B	Bending rigidity
G	Shear stiffness
W	Weight per unit area

5. Results and discussion

Both set I and II were analyzed by multivariate statistical methods for evaluation of potential sources of heterogeneity (clusters and outliers). The variables form tab. I and fabric thickness t [mm] were investigated. Set I was used for model creation and set II was used for testing of models predictive ability.

The paired dependencies between selected variables are given in Picture 1.Thicker black circles are markers of points in set II.



Picture 1. Paired dependencies between selected fabric properties (thicker black circles are points of set II)

It is visible that set II is not separated from data in set I and therefore the prediction will be not outside of boundaries of individual variables used for models creation. There exist paired dependencies especially between thickness and area weight, thickness and tensile energy, bending and area weight, and bending and shearing.

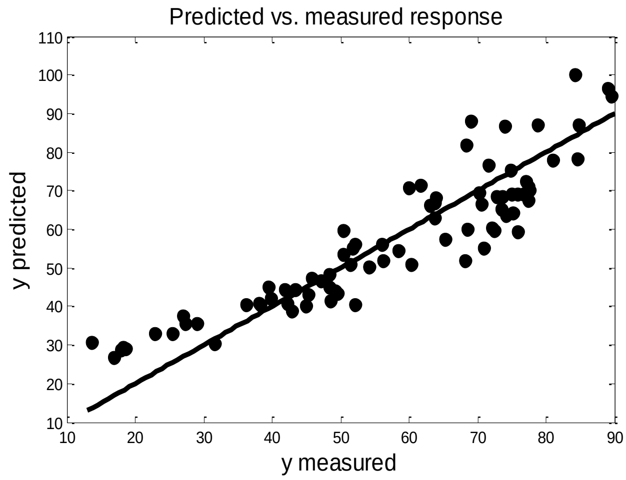
Prediction ability of regression model was characterized by relative predicted multiple correlation coefficients PR [4]. The three main variables x_1 = B/W, x_2 = G/W and x_3 = RT/W were selected. In the first run the modified regression model

$$DC = b_o + b_1\sqrt[3]{x_1} + b_2\sqrt[3]{x_2} + +b_3 x_3 \quad (5)$$

was selected. The predicted correlation coefficient 80.6 % is relatively high but the dependence between measured and predicted drape DC is slightly curved and scattered (see. Picture 2).

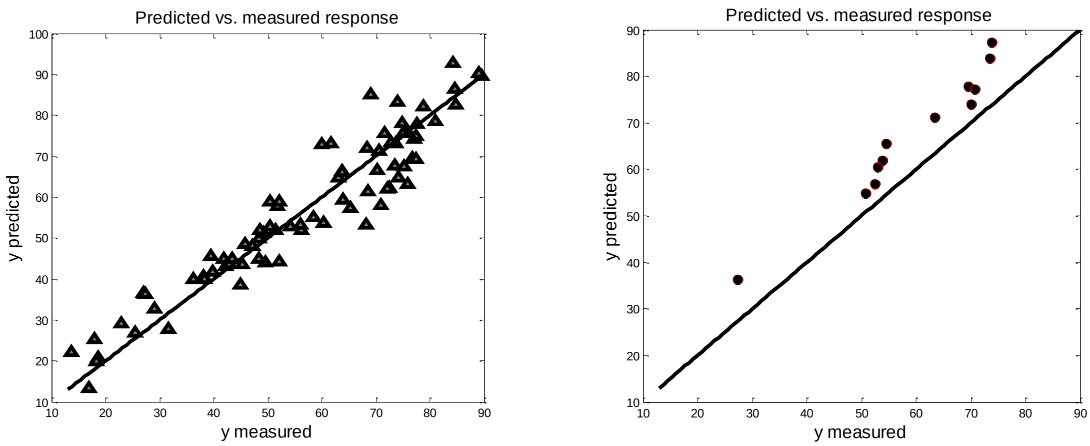
Optimal regression model was created by using of transformation of these variables leading to the maximum degree of linearity in the partial regression plot (PRP) [4] . The optimal model has the form

$$DC = 111.98 - 25.5\sqrt{\frac{W}{B}} + 14.8\ln(\frac{G}{W}) - 10.57\sqrt[4]{\frac{RT}{W}} \quad (6)$$



Picture 2. Relation between measured and predicted drape for model (5)

Corresponding relative predicted correlation coefficient is 89.4%. The relation between predicted and measured drape for this model is shown on the Picture 3.



a) b)

Picture. 3. Relation between measured and predicted drape for optimal model (5)
a) data set I used for model creation, b) data set II not used for model creation

The good prediction ability of eqn. (5) for prediction of drape from set II is clearly visible.

6. Conclusions

Optimal regression model for *DC* is very simple and suitable for prediction of drape from KES measurements. The use of neural network model is probably acceptable when it is not time for regression model building by interactive manner with help of computer.

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