THE IMPACT OF FABRIC STRUCTURE AND FINISHING ON THE DRAPE BEHAVIOR OF TEXTILES

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Abstract
The aim of work is to find relations for the simulation of textile material behavior among the raw material, structure, production technology, measurable properties and drape properties of fabrics. The contribution reveals the relations between parameters that influence material behavior and the drape behavior. In order to be able to separate the impacts of material characteristics that influence drape behavior samples were tailored to especially these investigations. Fabrics with different structural characteristics but prepared with the same finishing technology and fabrics with the same structural characteristics but prepared with different finishing technologies.

Key words: Drape properties, Bending, Shearing

1. INTRODUCTION

Recently, the number of research projects on the computer simulation of properties of textiles has been continuously increasing for the last few years. The aim is to set up a computer material model that describes the spatial geometry of complex textile structures and makes it possible to dimension them on the basis of strength properties and hence the material properties can be planned. Spatial modeling of complex textile structures can be applied during the preparation for production of models in the apparel industry or during the visualization in 3D product design.
A series of special problems has to be overcome when developing a model that simulates the spatial mechanical behavior of textile structures in a realistic way, since these fabrics basically differ from other structural materials. These specific properties are extreme flexibility, crinkling owing to gravity, compressibility and a specially structured inner composition that are characteristic of textiles. Textile sheet-like products behave in a complex way since they react to small forces with large deformation and they are characterized by large-scale anisotropy. Especially bending rigidity and shear deformation differs from that of other sheet-like products such as paper. When manufacturing ready-made garments 3D products have to be produced from 2D sheet-like materials so that the textile surface fits the spatial form without any crinkle e.g. around the shoulder or hip. The properties of the fabric influence this fitting to a great extent. Investigating the drape behavior we should separate the free deformation caused by weight of the fabric and deformation caused by force (R. D. Reumann, 2000).
The aim of our work is to find relations for the simulation of material behavior among the raw material, structure, production technology, measurable properties and drape properties of fabrics. The contribution reveals the relations between parameters that influence material behavior and the drape behavior.

2. IMPACT OF THE STRUCTURE OF THE FABRICS ON DRAPE BEHAVIOR

Drapeability is a three-dimensional phenomenon, caused by the force of gravity on textile fabric. The fabric hangs because of its own mass that causes large displacements and small tensional, shearing and bending deformations, which is shown in a form of resulting folds. Relationship between projection of deformed form (area of draping shadow) and un-deformed fabrics is defined as drape coefficient. The high

value of drape coefficient means that the fabric is stiff and therefore it could be difficult to reform. Alternatively, low value of drape coefficient means easier reform and at the same time, better adaptation of fabric to the shape of cloth (Geršak, J., 2003).
The drape properties are influenced by several factors such as weight per unit area [gm^{-2}], pattern, composition of the fabric, production technology, finishing etc. The bending rigidity B of the fabric, when it has an open weave structure, is determined by the rigidity of the yarns (Cooper, D.N.E, 1960):

$$B = N \cdot T_t \cdot c^3 \tag{1}$$

where N is yarn count [p/cm]; T_t is yarn fineness [tex] and c is bending length [cm]. H. Moroka, M. Niwa (1976) has investigated the relationship among drape coefficient, bending rigidity and weight per unit area. The linear regression model created by *J. Milikity, J. Velekova, L. Hes (2003)*, which describes the relationship among the drape coefficient (DC), the bending stiffness (B), the shearing force (S) and the weight per unit area (W) shows that

$$DC = b_0 + b_1 * B + b_2 * S + b_3 W \tag{2}$$

there is only a little interaction between drape coefficient and shearing force.
From point of view of effect of fabrics pattern is know that the fabrics with greater yarn floating blend more than plain weave fabrics. The drape coefficient of plain weave fabrics or panama weave fabrics, which it is traced back to plain weave fabric, are greater because of the many, tight cross points than the twill fabrics produced from the same yarn. As a consequence they show higher bending and shearing rigidity. It is useful to investigate the drape coefficient in accordance to the cover factor, or weaving coefficient X_{rel} (3) (M. Jederán, G. Való, 1984). The weaving coefficient is calculated from the yarn fineness $T_{tex\ weft}$ (T_{texV}), the $T_{tex\ warp}$ ($Tt_{ex\ L}$), the weave constant in weft (k_V) and warp (k_L) direction, and the number of weft (n_V) and warp yarn (n_L) in the pattern:

$$X_{rel} = \frac{\left(\sqrt{T_{texV}} + A_L\sqrt{T_{texL}}\right)\left(\sqrt{T_{texL}} + A_V\sqrt{T_{texV}}\right)}{\left(\sqrt{T_{texV}} + \sqrt{T_{texL}}\right)^2} \qquad A_L = k_L/n_V, \qquad A_V = k_V/n_L \tag{3}$$

and the drape coefficient DC has the form:

$$DC = b_0 + b_1 * X \tag{4}$$

where DC is drape coefficient [%]; X is weaving coefficient.
We have investigated 25 samples to explore similar relationship, but here we can publish only some of the results connected with drape.

3. EXPERIMENTS

In order to be able to separate the impacts of material characteristics that influence drape behavior samples were tailored to especially these investigations.

3.1 Fabrics used

The samples can be classified into two main groups, Table 1:

- *Cotton fabrics with different structural characteristics but prepared with the same finishing technology (sample 1-4)*

Manufacturing fabrics for the experiments: 13 fabric samples of different structure were woven on the weaving machines (Dornier DLW SN, 8 dobby, air jet) chosen in the mill. The warp yarn and warp density was the same and only one parameter was changed at a time compared to the base fabric. When the setting versions were determined, 2 to 4 significant values were assigned to each parameter. Finishing after weaving only involved desizing.

- *Viscose (sample 5-6) and cotton / Lycra fabrics (sample 7-8) with the same structural characteristics but prepared with different finishing technologies.*

Sample 5 and 6 were finished with the same recipe containing the treating bath resin with low formaldehyde concentration (Reaknitt BFA), softener which was a fatty acid condensate (Tubingal WBH) and anti-slipping agent (Fornax W). During soft finishing another anti-slipping agent Syntharesin and silicone softener (Tubingal FAM) were used. Silicone softener was applied in double quantity compared to the normal finishing. The treating temperature was 180 °C and the contact time was 1 minute. Softeners

improve the touch and in the meantime decrease the seam slippage. The anti-slipping agent works opposite the softener. In order to achieve an optimal seam slippage and good touch these two auxiliaries should use in an optimal concentration in the same treating bath.
Sample 7 was desized, bleached and then emerized. Improving the handle softener, anti-slipping agent and a polyurethane containing auxiliary (Arristan PMD) were applied during finishing. The polyurethane creates a thin film on the fabric surface, makes durable the soft, emerized touch even after several washes. The singed and mercerized fabric was finished with resin, filler (Arristan GW) and combined softeners (Tubingal WBH - fatty acid condensate and Tubingal WES - silicone softener). The filler makes the fabrics stiffer without any change in the quality of touch, which is essential in producing trousers.
In case of sample 8 the emerized fabric was finished in the same way as sample 7. The singed and mercerized fabric was finished with resin and softener which was a fatty acid condensate.

Table 1: Characteristics of the fabrics

<table>
<tr><th>Samples</th><th>Parameters</th><th>Weight [g/m²]</th><th>Base fabric</th><th colspan="5">Setting versions</th></tr>
<tr><td>1</td><td>Weave</td><td rowspan="4">190</td><td rowspan="4">Plain weave,
100 % cotton
25 tex
42/20 yarn cm^{-1}
(in warp/weft direction)</td><td>panama $P\frac{3.}{.3}$</td><td>weft rep $Pw\frac{3.}{.3}$</td><td>Twill $K\frac{2.}{.1}Z$ $K\frac{.1.}{1.1}S$</td><td>Twill $K\frac{3.}{.2}Z$</td><td>Atlas (6-yarn)</td></tr>
<tr><td>2</td><td>Raw material of weft yarn</td><td colspan="2">67% viskose/33% linen</td><td colspan="3">50% polyesther/50% cotton</td></tr>
<tr><td>3</td><td>Fineness of weft yarn</td><td>29.4 tex</td><td colspan="2">16.6 tex</td><td colspan="2">10 tex</td></tr>
<tr><td>4</td><td>Weft yarn density</td><td colspan="2">160 /10 cm,</td><td colspan="3">120 /10 cm</td></tr>
<tr><td>5</td><td>Finishing</td><td>90</td><td>100% printed viscose with filament 333 dtex (1)</td><td>normal finishing (2)</td><td colspan="2">sanforizing (3)</td><td colspan="2">soft finishing (4)</td></tr>
<tr><td>6</td><td>Finishing</td><td>90</td><td>100% printed viscose with filament 200 dtex (1)</td><td>normal finishing (2)</td><td colspan="2">sanforizing (3)</td><td colspan="2">soft finishing (4)</td></tr>
<tr><td>7</td><td>Finishing</td><td>220</td><td>98% cotton /2% Lycra</td><td colspan="2">singeing, mercerization</td><td colspan="3">emerizing, softening</td></tr>
<tr><td>8</td><td>Finishing</td><td>130</td><td>96% cotton /4% Lycra</td><td colspan="2">singeing, mercerization</td><td colspan="3">emerizing, softening</td></tr>
</table>

3.2 Methods

The samples described in Table 1 were studied more thoroughly and with a wider range of investigations. Several measurements were carried out in the Laboratory for Clothing Engineering, University of Maribor. The following characteristics were investigated:

- strength and strain properties in different directions in case of tensile, shear, bending and compression tests; surface properties of fabrics using the KES FB AUTO system
- drape behavior with Cusik drape tester (using Drape Analyser programme packages).

The rest of the measurements were carried out in the laboratory of Department of Textile Technology, Budapest Polytechnic:

- drape behavior with weight measurement
- bending properties with Flexometer
- dynamic friction properties with own developed instrument.

4. RESULTS AND DISCUSSION

On the basis of the research the impact of fabric structure and finishing on the drape behavior of fabrics the achieved results can be presented in the following form:

- the impact of fabric structure on the mechanical properties of fabrics and their drape behavior,
- effect of finishing on the alteration of the mechanical properties of fabrics and
- influence of kind of finishing on drape coefficient of fabrics.

4.1 The impact of fabric structure on the mechanical properties of fabrics and their drape behavior

The analysis of the impact of fabric structure on mechanical properties of the fabrics indicates that individual parameters of fabric structere as well as weaving parameters directly impact mechanical properties. It can be stated that as the yarn pre-tension during weaving increasing, the extension EMT and extensibility EL (EL = EMT/LT) of fabric in which they are weaved decrease, whereas the bending rigidity B increases, Fig. 1.

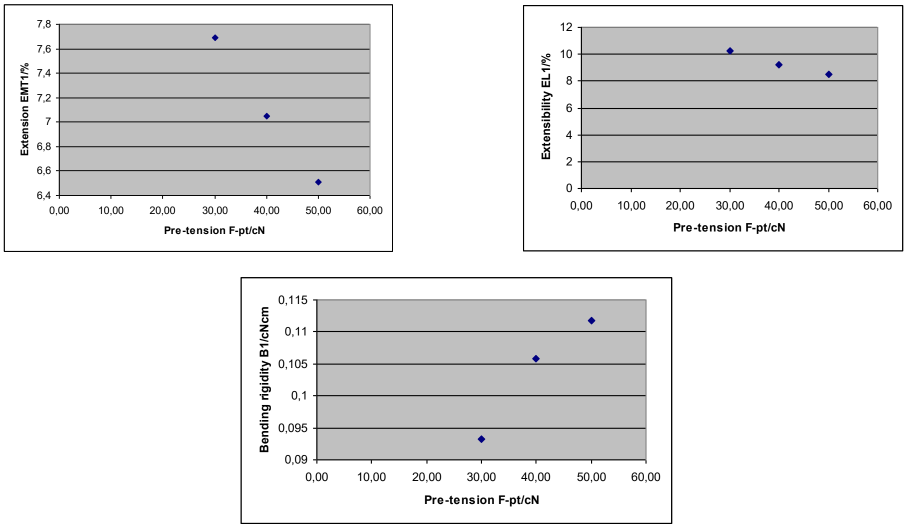


Figure 1 Influence of pre-tension of weft yarn on the mechanical properties of fabrics

Investigations of correlation between fabric structures and mechanical properties of the fabrics indicate that fabric pattern has a strong impact on mechanical properties of the fabrics, Fig. 2.

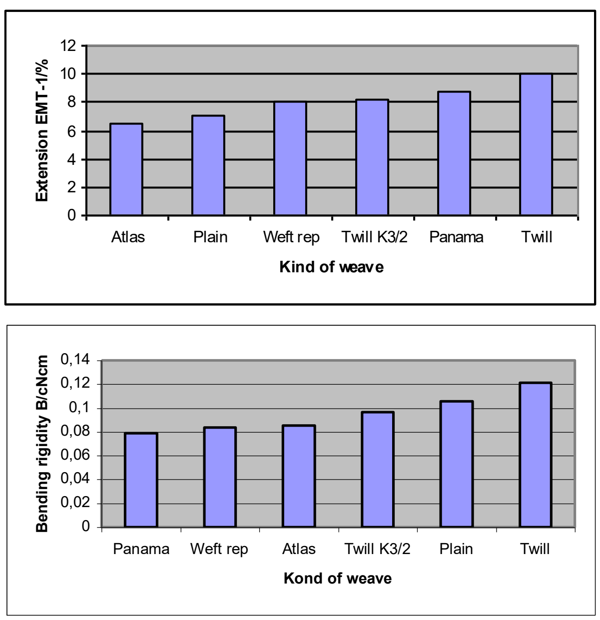


Figure 2 Influence of the fabric pattern on the mechanical properties of fabrics

Further the analysis of the results obtained for the relationship between parameters of fabric structure and drape behavior of fabric shows that parameters as are weaving coefficient, yarn density and fineness of weft yarn are directly associated with drape behaviour of fabric. Analysis of the results shows a tendency of drape coefficient DC to grow with growing values of weaving coefficient X_{rel} (3), Fig. 3.

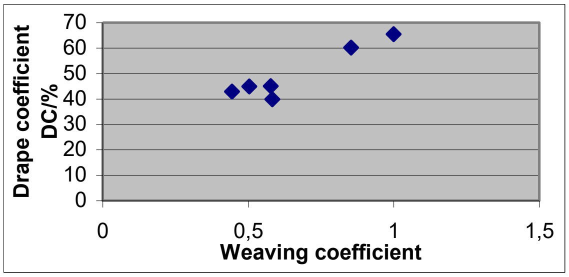


Figure 3 Influence of weaving coefficient of the fabrics with different pattern on drape coefficient DC

From equation (4), if X = weaving coefficient; the obtained partial correlation coefficient by linear regression analysis: R = 0.9455, b_0 = 19.734; b_1 = 45.423.

Furthermore it can be stated that increasing the yarn density as well as yarn fineness the bending rigidity and drape coefficient associated with it generally increases, Fig. 4, and increasing the twist it decreases. Textile sheet-like products with the same pattern are softer if they contain fewer weft yarns. From equation (4), if X = weft yarn density [p/10 cm]; the obtained coefficient by linear regression analysis: R = 0.9550, b_0 = 17.533; b_1 = 0.2488.

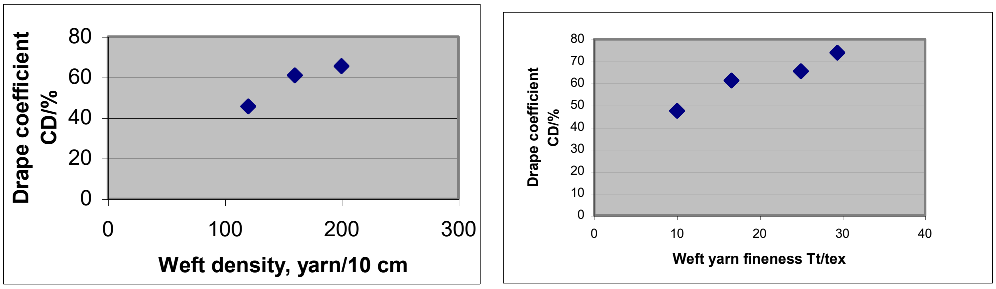
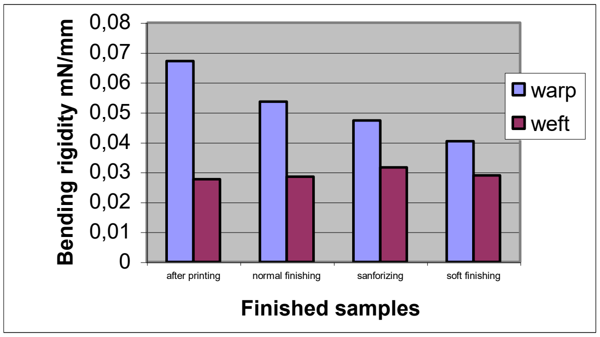


Figure 4 Drape coefficient CD of the fabrics with different weft yarn density fineness

Generally the fabric with rougher fibers is stiffer and the same is true investigating the effect of yarn fineness. From equation (4), if X = weft yarn fineness [tex], the coefficient is R = 0.9681, b_0 =37.171, b_1 =1.2286. For example, the drape coefficient of viscose fabrics with the same weight per unit area is smaller (by 18-28 %) if the fabric is produced from finer filament.

4.2 Effect of finishing on the alteration of mechanical properties of fabrics

The analysis of the effect of finishing on mechanical properties of the fabrics indicates that kind of finishing directly impact mechanical properties. The bending rigidity is influenced by 10-40 % by the different finishing, Fig. 5a. The bending rigidity of the soft finished sample is the smallest (it is 40 % of the sample without finishing), the measured values in warp and weft directions are almost the same, and as a consequence this fabric shows the smallest anisotropy.

a)


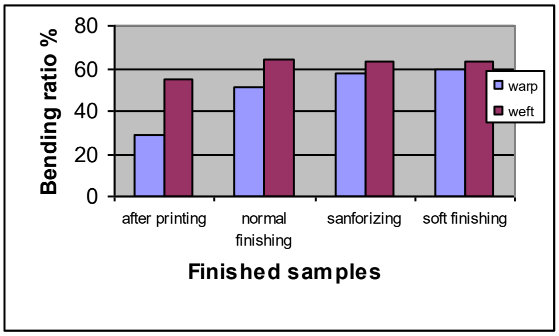
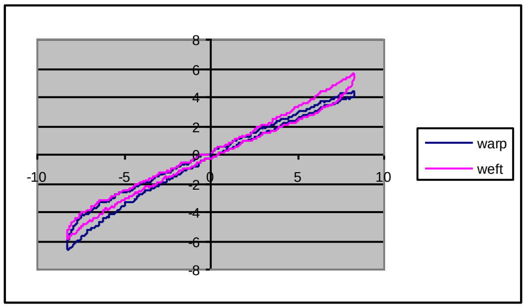
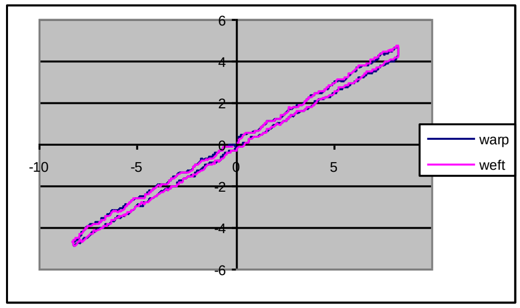
b)


Figure 5 The effect of finishing on a) bending rigidity and b) bending ratio

Moreover the bending ratio of the soft finished sample measured by FLEXOMETER is the greatest; therefore it has the softest touch, Fig. 5b. After sanforizing the fabric shrinks 1-2 % in warp direction, achieving a more relaxed state with higher flexibility, that's why the measured results are similar to that of the soft finished samples.
The shearing rigidity is higher before finishing in warp direction than in weft direction, Fig. 6a. It decreases in a larger scale in case of fabric produced by finer filament after finishing.
The friction between the fibers of textile sheet-like product decreases using softener. It is proved by the results obtained from dynamic friction measurement, moreover the small shearing hysteresis (2HG5) measured in case of soft finished sample. The shearing hysteresis of the finished sample also shows that there is no difference in warp and weft direction, Fig. 6b.



a)

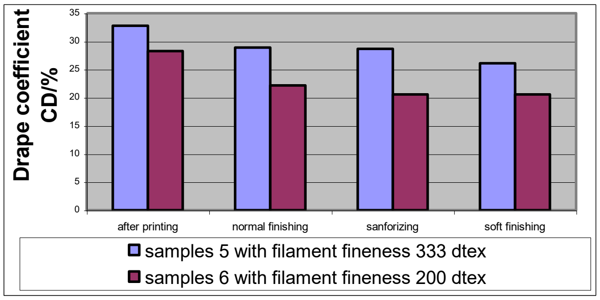


b)

Figure 6 Shearing hysteresis of fabrics produced by different finishing a) before finishing; b) soft fnishing

4.3 Effect of finishing on drape coefficient of fabrics

The analysis of the results shows that the drape coefficient is modified by different finishing. The drape coefficient of soft finished samples is smaller by 20 - 30 % than that of the samples without finishing (after printing). The finishing modifies the fabric structure, what is reflected in alteration of mechanical properties of fabrics, which influence the drape coefficient. There is no significant difference among samples with different finishing.
Furthermore it can be shows that for example, the drape coefficient of viscose fabrics with the same weight per unit area is smaller (by 18 - 28 %), if the fabric is produced from finer filament. It is clear from Figure 7a that the finishing influences the drape.



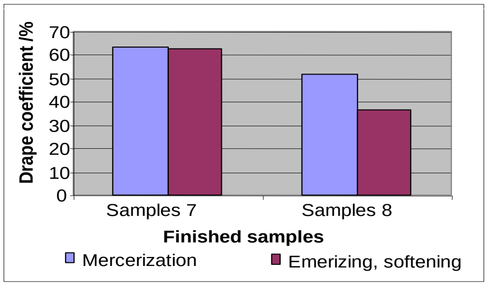


Figure 7 Drape coefficient of the fabrics produced by different finishing;
a) sample 5 and 6 b) sample 7 and 8

Emerizing and softening influence the drape properties significantly only in case of sample 8, which has smaller weight per unit area. It results in decreasing the drape coefficient by 30 %, Fig. 7b. The pattern of sample 7 is atlas and it has higher weight per unit area, as a consequence it can be emerized in a more difficult way.

5. SUMMARY

The analysis of results of research of the impact of fabric structure and finishing on the drape behavior of fabrics have shown a significant correlation. The finishing modifies the fabric structure, what is reflected in alteration of mechanical properties of fabrics, which influence the drape coefficient.

Our wide range investigations support that the drape behavior is the most complex properties of the fabrics. We have tried to explore the effect of the structure of the fabric and the finishing technology on the drape properties of the fabrics.
The results have been evaluating statistically in order to see that the different factors how influences the drape properties. We have obtained data to set up a relationship between the measured physical properties and the drape properties. These results have been using to develop a computing model that simulates the spatial mechanical behavior of fabrics in the preparation for production of models in the apparel industry (J. Kuzmina, P. Tamás, M. Halász, (2005), Tamás, P., Halász, M., Gräff, J. (2005)).
The aim is that our results help the designers to plan not only by trials, intuition, or using their experience, but applying exact scientific results for achieving the waiting of the customers in a higher level. Analyzing the finished products the finishing technology can be optimalized.

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