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# Preliminary Analysis of the Pile Properties of Fur Knitting's During the Process of Compression

**Abstract**

*On the basis of a new layer model for compression of furs and fur fabrics, the mechanical parameters of fur such as permanent deformation $D_p$, squeezing susceptibility S, and elasticity E were determined. Three variants of knitted furs and three of natural furs were tested with the use of a tensile tester. In both fur groups, the best E and $D_p$ parameters were obtained for the minimum of apparent densities. However, similar permanent deformation and elasticity were obtained for both groups, and it should be stressed that the aerial densities of natural furs were 2-3 times higher than those of knitted furs. Tests carried out with the use of a tensile tester according to the proposed model allowed us to perform fur thickness determination at a pressure of N=0, as opposed to measurements with the use of a thickness meter, where the preliminary pressure can be different.*

**Key words:** *pile of knitted furs, compression process, permanent deformation, squeezing susceptibility, elasticity, apparent density.*

## Introduction

The mechanical properties of the fibre pile which become apparent during the process of fur knitting compression have essential importance for ready-made articles manufactured from knitted fur fabrics, such as sheepskin coats, furs, jackets, overcoats and plush toys. These properties are permanent deformation ($D_p$), squeezing susceptibility (S), and elasticity (E). The importance of the particular quality feature, and together with them the fur testing conditions, changes in dependence on fur destination. In this article a testing method is described which will allow us to test furs in a reproducible manner, especially regarding the measurement of fur thickness at pressure = 0.

## Geometrical Layer Model of Fur Knittings

Fur garments (or other articles) manufactured from natural furs, as well as those made from man-made fur knittings in the shape of weft knitted fabrics (with a pile of card web) and warp knitted fabrics (with a pile of broken threads), can be presented by a three-layer geometrical model as shown in Figure 1.

Layer 1: This layer is spread from thickness g′ to thickness $g_0$ (where g′ is the greatest height of single fibres (hairs), and the free thickness $g_0$ is determined by the experimental fur height at the pressure value =0); layer 1 is this layer in which only single fibres occur; this is a layer of minimum compression resistibility, yet it is also a layer which has essential importance for touch.

Layer 2: This is the real layer of the fibrous pile spread from thickness $g_0$ to thickness $g_d$ (where $g_d$ is the thickness of the dermis).

Layer 3: This layer of thickness $g_d$ consists of the dermis or of the knitting which joins the fibres.

The layer model, shown in Figure 1, is presented together with the hysteresis loop of the compression process of the fibrous pile which the model is interrelated with. This process is forced by pressure P, which increases from zero up to $P_f$ (the final maximum pressure). The particular pressure values point out the characteristic thickness of the pile $g_0$, $g_1$, and $g_2$ (where $g_1$ is the thickness at the maximum final pressure value, and $g_2$ the thickness after relaxation).

## Methods, Conditions and Test Parameters

**Standard method**

Conditions of the compression process according to standard [5] are illustrated in Figure 2 (a and b). The fur knitting is compressed at a preliminary pressure of $P_0$=0.2 cN/cm$^2$ over 30 s, compressed at a pressure of $P_f$=98.1 cN/cm$^2$ over 30 min, and finally again at the pressure of $P_0$=0.2 cN/cm$^2$ over 30 s. On the basis of the different thicknesses obtained (see Figure 2), the permanent deformation $D_p$ is determined. A graphic interpretation of the conditions of pile compression as presented above is shown in Figure 2, where Figure 2a is the illustration of the dependence g=f(P), and Figure 2b of the dependence g=f(τ). The value $\Delta\tau_1$ is the time needed for load changing.

**Modified method**

The basic tests of the quality features of the selected fur fabrics were carried

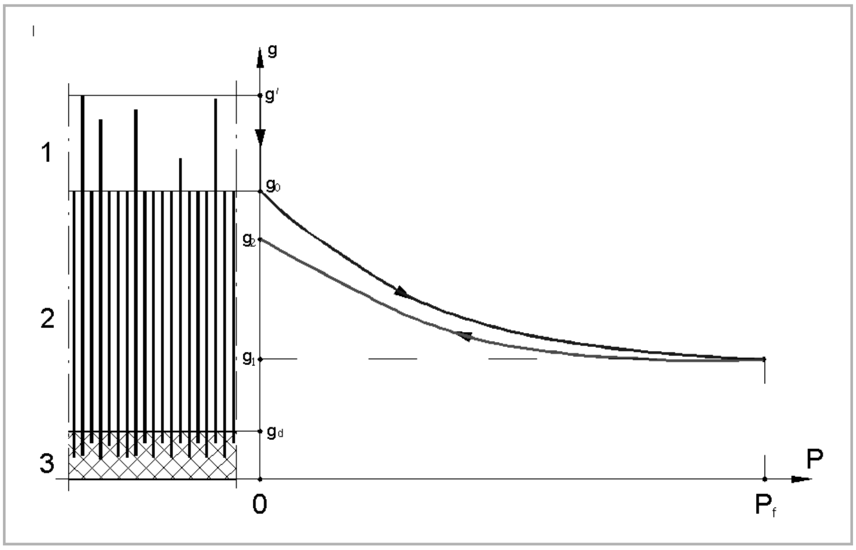


*Figure 1. The layer model of fur products with the graph of compression the fur product; all symbols and denotations are explained in the text.*

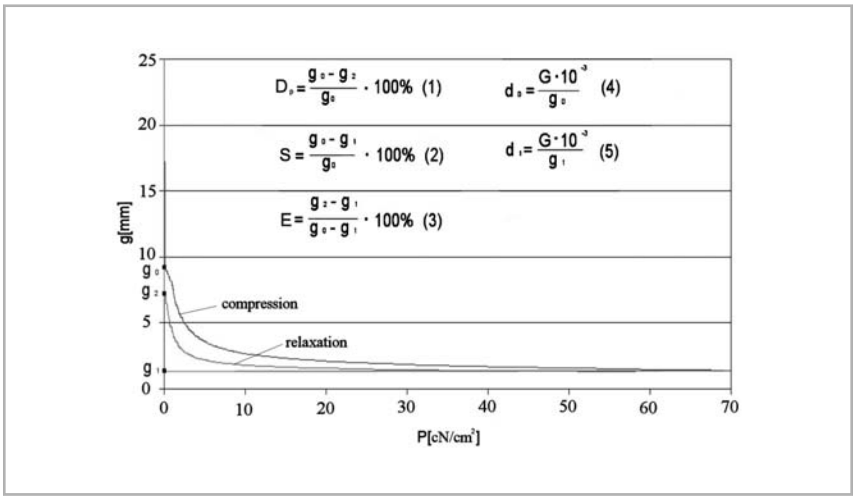


*Figure 3. The process of compression of the knitted fur pile; 1 - compression, 2 - relaxation.*

out by the compression process conducted with the use of the H 50K-S tensile tester. The distinctive feature of these investigations is the determination of the fur fabric's thickness $g_0$ at the pressure P=0. The thickness $g_0$ is the experimental boundary between the first layer, the layer of singular fibres, and the second layer, that which is characteristic for the fibrous pile. Furthermore, the thickness $g_0$ is the basis for a uniform thickness comparison, in contradistinction to other methods described by different authors [1,2,3,5] where differentiated pressure values are applied.

## Test Results

Six 'outer' fur materials (3 natural and 3 knitted) of an approximate thickness of g=10 mm and an aerial mass G from

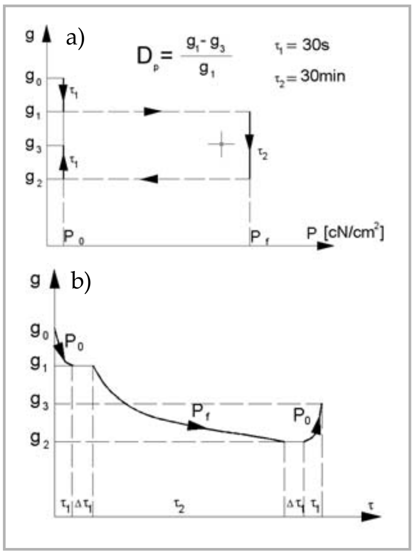


*Figure 2. Graphs of compression of the fibrous pile of fur products according to standard [5]; a - the dependence g=f(P), b - the dependence g=f(τ), where τ - time.*

200 g/m² up to 1200 g/m² were selected for the tests (Table 1). The free thickness $g_0$ at P=0, the minimum thickness $g_1$ at the pressure of P=70 cN/cm² and the thickness $g_2$ after relaxation at P=0 were assessed from the tensile tester records (Figure 3). The free apparent density $d_0$ for thickness $g_0$ and the maximum density $d_1$ for thickness $g_1$ were calculated. Next, the parameters of permanent deformation $D_p$, squeezing susceptibility S, and elasticity E were calculated according to the mathematical equations listed below:

$$D_P = (g_0 - g_2)/g_0 \cdot 100\% \quad (1)$$

$$S = (g_0 - g_1)/g_0 \cdot 100\% \quad (2)$$

$$E = (g_2 - g_1)/(g_0 - g_1) \cdot 100\% \quad (3)$$

$$D_0 = G \cdot 10^{-3}/g_0 \quad (4)$$

$$D_1 = G \cdot 10^{-3}/g_1 \quad (5)$$

The apparent density displays an approximately linear increase in relation to the aerial mass; higher values may be observed for natural furs (Figure 4). Values of apparent density for a classical wool knitting (Lp) calculated for the quantities k=2, and k=3 of thread thickness are also shown in Figure 4. The calculation of those apparent densities was performed according to the following procedure:

The equation (6) for the aerial mass G was accepted as the basic equation for calculating the apparent densities:

$$G = 10^{-4} P_k P_r L Tt \quad (6)$$

where:
$P_k$ - wale stitch density,
$P_r$ - course stitch density,
L - thread length in the loop, and
Tt - thread number.

Taking into account equations (7 and 8) which determine the wale working-in factor $w_k$ and the course working-in factor $w_r$

$$w_k = L/A = 10^{-2} x LP_k \quad (7)$$

$$w_r = L/B = 10^{-2} x LP_r \quad (8)$$

where A and B are the flat dimensions of the loop, the product of working-in w was calculated:

$$w = w_k w_r \quad (9)$$

Next, the equations (10) and (11) were applied. The equation (10) is used for thread diameter (Φ) calculation, when the factor r related with the kind of raw material and the state of yarn processing should be considered and equation (11) determine the linear cover factor.

$$\Phi = r\, Tt^{-1/2}/1000^{-1/2} \quad (10)$$

$$z = L/\Phi \quad (11)$$

Equation (12), which defines the apparent density of the knitting, is modified

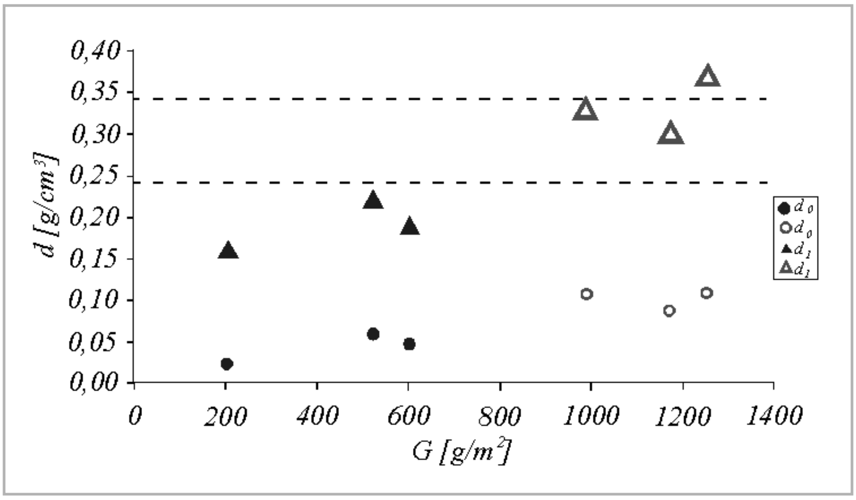


*Figure 4. Influence of the aerial mass G on the apparent density d; ●▲- knitted furs, ○△- natural furs.*

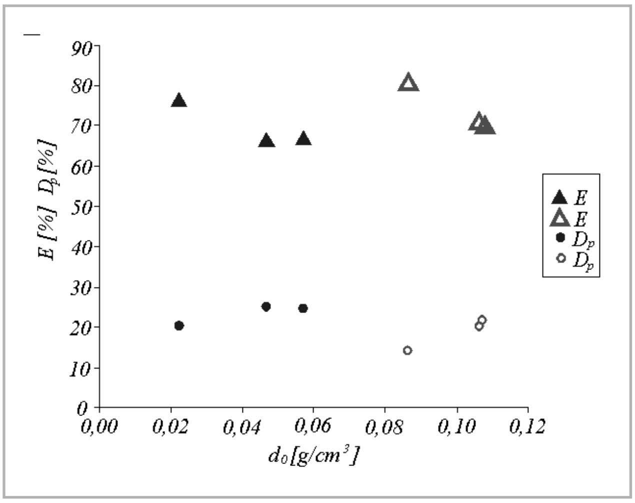


*Figure 5. Influence of the free apparent density $d_0$ on the permanent deformation $D_p$ and the elasticity F; ●▲- knitted furs, ○△- natural furs.*

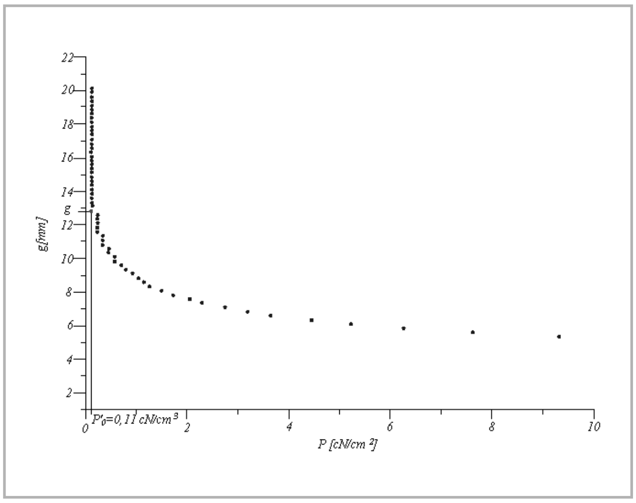


*Figure 6. Compression of the fibrous pile enlarged.*

| Product assortment | Raw material | G | $g_0$ | $g_1$ | $g_2$ | $d_0$ | $d_1$ | $D_p$ | S | E |
|---|---|---|---|---|---|---|---|---|---|---|
| | | g/m$^2$ | mm | mm | mm | g/cm$^3$ | g/cm$^3$ | % | % | % |
| knitted fur white | PAN | 204 | 9.17 | 1.3 | 7.32 | 0.022 | 0.146 | 20.2 | 84.7 | 76.2 |
| knitted fur brown | PAN | 524 | 9.17 | 2.4 | 6.92 | 0.057 | 0.218 | 24.5 | 73.8 | 66.8 |
| knitted fur russet | PAN | 604 | 12.87 | 3.2 | 9.62 | 0.046 | 0.189 | 25.3 | 75.1 | 66.4 |
| natural fur dark blue | wool | 988 | 9.27 | 3 | 7.42 | 0.106 | 0.329 | 20.0 | 67.6 | 70.5 |
| natural fur brown | wool | 1172 | 13.57 | 3.9 | 11.65 | 0.086 | 0.301 | 14.1 | 71.3 | 80.1 |
| natural fur white | wool | 1252 | 11.57 | 3.4 | 9.17 | 0.108 | 0.368 | 20.7 | 70.6 | 70.6 |

*Table 1. Test results of the selected fur products.*

using equations (6,7,8,9,10, and 11), and finally we obtain equation (13):

$$d = 10^{-3} \cdot G/k\Phi \qquad (12)$$

$$d = 1/k\ w/z\ r^2 \qquad (13)$$

Accepting w=21.73; z=20; and r=1.26, according to Munden, we obtain:

$$D=0.68/k \qquad (14)$$

Now, when we substitute the quantities for k assumed at the beginning of this calculation, we obtain:
for k=2, the apparent density d=0.24 g/cm$^3$, and
for k=3, the apparent density d=0.34 g/cm$^3$.

As can be seen from Figure 4, the level of apparent density characteristic for such a knitting as that assumed above after compression at a pressure of 70 cN/cm$^2$ is achieved only by natural furs. It can be expected that the apparent density has fundamental importance for the resistance of heat- and air-flow, as well as for other factors.

Higher elasticity E and lower permanent deformation $D_p$ can be observed for the 1st and 5th variant characterised by the lowest densities in the groups of both knitted and natural furs (Figure 5). These phenomena result from better fibre selection in both variants. Apart from the features mentioned above, it should be noted that the values of E and $D_p$ are similar for natural and knitted furs, despite the aerial masses of knitted furs being 2-3 times lower than of the natural furs.

The visual estimation of the pressures related to thickness $g_0$, $g_1$, and $g_2$, performed on the basis of the records presented in Figure 3, allowed us to assume that the value of P is equal to zero. A more precise assessment of $P_0$ on the basis of the measurement results achieved with the use of the tensile tester recorder show that the preliminary pressure for all the fur knittings tested $P_0'$=0.11 cm$^2$. This value can be considered as the upper limit of the error of the measurement system used (Figure 6).

## Summary

- The process of compression was related to a geometrical layer model of fur garments (products).
- The importance of the free thickness $g_0$ for pressure P=0 obtained by research methods of compression fur garments is emphasised.
- The preliminary test results for the selected assortment do not favour natural furs, despite their higher aerial masses. On the other hand, they call attention to the importance of the free apparent density of fibrous pile for the quality of fur garments.

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