Form Durability of Clothing Laminates from the Standpoint of Maintenance Procedures

Abstract
To improve the aesthetics of the clothing (jackets), special insert materials are used during production. During usage, clothing comes into contact with various factors (physical, chemical, mechanical and biological) which cause deformation and wear [10]. Maintenance procedures such as dry-cleaning or washing often cause the durability of the garment’s form to deteriorate. For the owner and user of the garments, the most important thing is that the products retain their aesthetic properties both before and after maintenance procedures.

Key words: clothing laminates, polymers, adhesive joints, maintenance procedures.

Research methodology

Material for experiments
The following fabrics were used as objects for experiments:
- fabric for suits, produced by the Flax Products Enterprise from Żyrardów, Poland,
- experimentally developed insert materials, made by Clothing Inserts Enterprise ‘Camela’ S.A. from Wałbrzych, Poland (Table 1 and 2).

Various amounts of thermoplastic adhesive – copolyamide – were applied, from 12 to 20 g/m², to the inserts marked as PA. The insert marked as Pp was treated with thermoplastic adhesive, the so-called ‘double spot’, to the amount of 13 g/m². This adhesive consists of two polymer types.

Table 1. Fabric characteristics.

<table>
<thead>
<tr>
<th>Fabric type</th>
<th>Weave</th>
<th>Area mass, g/m²</th>
<th>Composition</th>
<th>Number of threads of warp/weft, number of threads/dm</th>
<th>Mass of the warp/weft, tex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linen-cotton mix B</td>
<td>Plain weave</td>
<td>210</td>
<td>warp - 52.8% linen, weft - 46% cotton</td>
<td>260</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 2. Characteristics of the knitted clothing inserts; Composition - polyester/viscose 44 dtex/40 tex; Number of polymer points - CP46.

<table>
<thead>
<tr>
<th>Insert symbol</th>
<th>Density/dm</th>
<th>Area mass, g/m²</th>
<th>Amount of applied adhesive, g/m²</th>
<th>Type of polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA - 12</td>
<td>120</td>
<td>110</td>
<td>Paste = 12.0</td>
<td>copolyamide</td>
</tr>
<tr>
<td>PA - 16</td>
<td>120</td>
<td>110</td>
<td>Paste = 16.0</td>
<td>copolyamide</td>
</tr>
<tr>
<td>PA - 20</td>
<td>120</td>
<td>110</td>
<td>Paste = 20.0</td>
<td>copolyamide</td>
</tr>
<tr>
<td>Pp - 13 ‘double spot’</td>
<td>120</td>
<td>110</td>
<td>Paste = 6.0 Powder = 7.0</td>
<td>modified polyethylene, low pressure + copolyamide</td>
</tr>
</tbody>
</table>
Preparing the laminates for experiments

Three variants of the laminates were prepared for experiments (Figure 1), with the following Di of the individual layers:

1. 0 - 0°, warp – warp
2. 0 - 45°, warp – angle
3. 0 - 90°, warp – weft.

In each of the variants, the upper fabric is placed in the same direction as the warp, that is, at a 0° angle. The textile inserts were placed in three directions: on the warp 0°, on the bias 45° and on the weft 90°. The adhesion process was executed on a plate press with the following pre-defined adhesion parameters: T = 140 °C, t = 13 s, p = 3.5 N/cm².

The said procedures were repeated five times. After each repetition, the value of F – the separation force indicator – was determined.

Results

In order to determine the influence of the maintenance procedures Mpr(5) on the separation force’s index of clothing laminates used to produce men’s jackets, the following experiments were carried out (Tables 3 and 4). The experiments were conducted according to a programme developed on the basis of a tri- and bi-factor plan of the 3² and 2³ type [13, 14]. Before using the standard experiment plans, the factors were coded according to the following rule:

coded value = [(physical value) – (central value)] / (unit of variation)

The estimates of regression functions, which describe the relations between the

Table 3. Ranges of factors’ variation for laminate B(PA).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unit of measure</th>
<th>Code</th>
<th>Central value</th>
<th>Unit of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glue mass m</td>
<td>g/m²</td>
<td>X₁</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Layers’ placement direction D₀</td>
<td></td>
<td>X₂</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Cutting direction D₁</td>
<td></td>
<td>X₃</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 4. Ranges of factors’ variation for laminate B(Pp).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unit of measure</th>
<th>Code</th>
<th>Central value</th>
<th>Unit of variation</th>
</tr>
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<tr>
<td>Layers’ placement direction D₀</td>
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<td>X₁</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Cutting direction D₁</td>
<td></td>
<td>X₂</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 5. Influence of the maintenance procedures Mpr on selected mechanical features of analysed laminates B(PA), depending on the mass of glue m in g/m², direction of layers in the package D₁ in deg and the direction of cutting the swath D₂ in deg.

<table>
<thead>
<tr>
<th>Analyzed feature</th>
<th>Regression equations for laminate B(PA)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mpr = 0</td>
<td>F₀ = 0.8844 – 0.1007X₁ – 0.0016X₂ – 0.0007X₃ + 0.0038X₂X₃ + 0.00005X₃X₁ + 0.0000004X₂² + 0.000002X₃X₁ + 0.000007X₂X₁ + 0.0000003X₂²</td>
<td>0.99</td>
</tr>
<tr>
<td>Mpr = 5</td>
<td>F₀ = 0.8692 – 0.1054X₁ – 0.0006X₂ – 0.00029X₃ + 0.0041X₂X₃ + 0.0000007X₃X₁ + 0.0000003X₂² + 0.0000006X₃X₁</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 6. Influence of the maintenance procedures Mpr on selected mechanical features of analysed laminate B(Pp), depending on the direction of layers in the package D₁ in deg and the direction of cutting the swath D₂ in deg.

<table>
<thead>
<tr>
<th>Analyzed feature</th>
<th>Regression equations for laminate B(Pp)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mpr = 0</td>
<td>F₀ = 0.319306 + 0.000972X₁ – 0.00472X₂ – 0.0000028X₁X₂ + 0.0000031X₃X₁ + 0.0000004X₂²</td>
<td>0.98</td>
</tr>
<tr>
<td>Mpr = 5</td>
<td>F₀ = 0.290972 – 0.000102X₁ – 0.000231X₂ + 0.00000823X₂X₃ + 0.00000055X₃X₁ – 0.00000041X₂²</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Figure 1. Various placement of layers in the package: 1 – upper fabric, 2 – textile insert, ↔ – direction of the warp.

The final treatment of the swatches including ironing on a stationary, flat press under pre-defined conditions, i.e. T = 140 °C, t = 13 s, p = 3.5 N/cm².

Maintenance procedures – Mpr (delicate washing in water + ironing)

To preserve the ecological properties of linen garments, delicate washing in water was carried out during the process of maintenance.

Delicate washing in cold water is the method used to clean garments marked as ‘do not wash’ on their tags. This method allows dirt to be removed by washing in water containing special, biologically active products (which are biodegradable and do not contain phosphates), specially designated for cold washing. They offer a high degree of dirt removal, with a more delicate and shorter process, at the same time preventing the crumpling of fabric and changes in its dimensions [12].

For the basic washing process, 140 ml of Lanadol Active was used; and to the second rinse 150 ml of Lanadol Apret was added. The washing was done at a temperature of 24 °C, and the rinsing at 18 °C. The total duration of the process amounted to 28 minutes 20 seconds.

To remove the liquid, a 2-phase drying process was applied, consisting of:

- preliminarily drying the garment in a heating chamber, at a temperature of 50 °C, to the remaining 20% of moisture,
- final drying in natural conditions, for 5 hours.
analysed factors and features, were carried out with the use of SAS software.

After taking the value of regression coefficients for laminates B(PA) into account, regression equations were obtained for the second degree of dependence of the $F$ factor on the mass of glue PA, direction of layers $D_l$, and the direction of cutting swathes $D_c$ before and after the maintenance procedures $M_{pr}$ (Table 5 see page 98). For the B(Pp) laminate, regression equations were also obtained for the second degree of dependence of the $F$ factor on the direction of layers $D_l$, and the direction of cutting swathes $D_c$ before and after the maintenance procedures (Table 6 see page 98).

Those models adequately describe the gluing process, which is proven by the high values of the correlation coefficient $R$. This proves the connections between the analysed factors, and the features used to evaluate the laminates' properties. The resulting dependencies were used to determine the surface of replies (Figures 2 & 4) which illustrate the influence of the variable factors: – glue mass PA, $D_l$ the direction of layers' placement in the package, and the swathes' cutting direction $D_c$ – on the value of $F$, the separation force of laminates B(PA) before and after maintenance procedures $M_{pr}$.

The dependence analysis (see Figure 2.a, 2.b and 3.a) of the separation force of laminates B(PA) from the glue mass PA, layers' direction $D_l$ and swathes' cutting direction $D_c$ shows the important influence of the amount of applied thermoplastic polymer, which melts and merges with the surface structures of the fabric and knitted fabric during the adhesion process.

Figure 2.a and 2.b shows that an increase in the amount of applied polymer PA(12-20) causes a growth of the separation force of fabric packages: by 84 - 125% before the maintenance procedures, and by 95–120% after the maintenance procedures. The growth is independent of the direction of layers, or of swathes’ cutting. This proves that various glue inserts can be applied to the upper fabric, depending on its properties.

Comparing Figures 3.a and 3.b, it was noticed that despite the smaller glue amount, the laminate B(Pp-13) is characterised by larger separation force than B(PA-16). This means that the insert with a double spot of adhesive offers an appropriate quality of adhesion ($F \geq 3$ N/cm), with a smaller amount of glue being used, regardless of the influence of subsequent maintenance procedures.

As a result of the research, it was noted that maintenance procedures $M_{pr}$ do not cause significant changes in the
Form durability of the laminates analysed (Figure 4). The values of separation force obtained are close to the initial values (the average increase by 4%, decrease by 8.6%). This shows that the form stability obtained as a result of adhesion was not damaged after the tests. It can be stated that after five consecutive Mpr procedures entailing washing in water, there is no change in the initial values of the package, and that washing in water is a gentle dirt-removing process, suitable for all the packages, regardless of the amount and type of applied polymer.

The research also proved that after the maintenance procedures, the mutual placement of layers in analysed samples did not influence the values of separation force in the various directions of swathes’ cutting, both for the B(PA) and B(Pp) laminate.

## Conclusions

The results of the experiments carried out in the course of this study can be summarised in the following conclusions:

1. Mathematical models for the influence of adhesive fastening on the value of separation force indicator and the bending stiffness of laminates were obtained, which allow changes in laminates’ properties to be forecast, depending on the mass of applied glue, layers’ direction and swathes’ cutting direction.

2. We established the influence of maintenance procedures Mpr – delicate washing in water and ironing – on the shape durability of laminates. The experiments proved that maintenance procedures do not cause significant changes in the shape durability of the analysed laminates.
3. The use of garment inserts with a ‘double spot’ of adhesive allows satisfactory values to be obtained of the laminates’ separation force with a much smaller amount of applied adhesive than in the case of inserts with PA adhesive.

References

The Textile Network area covers the following fields:
- MED-TEXTILES: textiles for medical treatment,
- ECO-TEXTILES: textiles safe for human health,
- ENVIRO-TEXTILES: textiles, which protect against physical, chemical and biological hazards.

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The ECO-TEXTILES group covers research works and studies aimed at protecting human (skin, respiratory and thermo-regulating systems), and against the negative effects of textile fabrics.

The ENVIRO-TEXTILES group comprises textile fabrics protecting humans against the harmful effects of external factors (electromagnetic and electrostatic fields, UV and IR radiation, microorganisms).

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