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Form Durability of Clothing Laminates from the Standpoint of Maintenance Procedures

Abstract
To improve the aesthics 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 ones) which cause deformation and wear. In order to better analyze the issue of maintenance procedures on the quality of laminates made from adhesives, this paper is limited to describing the influence of the 5th procedure - delicate washing + ironing - on the value of F - the index of separation force. The experiments proved that maintenance procedures do not cause significant changes in the adhesive strength of the analyzed laminates.

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

Introduction

In recent years, customers have become increasingly interested in products made of natural fibres (flax and hemp), which have many beneficial features for health and wellbeing, such as good moisture absorption, anti-bacterial properties, are non-allergenic and are not susceptible to static electricity [1 - 3]. The main disadvantage of linen fabrics is their high crumpling level, which limits their use for certain elements of clothing, such as jackets. During the production process, various methods to reduce crumpling are applied, but they do not guarantee appropriate shape durability of the individual elements [4 - 6].

To improve the aesthetics of the clothing, special insert materials are used during production [7 - 9]. These are usually woven, knitted or unwoven fabrics, with a layer of thermoplastic adhesive. The type of insert depends on the properties of the upper material, the designation of the product, as well as the elements which need to be reinforced (e.g. collar, front, sleeve cuffs, facings of the jacket).

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.

In order to better analyse the issue of maintenance procedures on the quality of laminates made from adhesives, this paper is limited to describing the influence of the 5th procedure (M_{pr}-5) – delicate washing + ironing – on the value of F – the index of separation force, depending on the mass of applied adhesive (m), D_l – direction of layers and D_c – direction of swathes' cutting.

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, and
- 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.*

Fabric type	Weave	Area mass, g/m²	Composition	Number of threads of warp/weft, number of threads/dm	Mass of the warp/weft, tex
Linen-cotton mix B	Plain weave	210	warp - 52.8% linen	260	50
			weft - 46% cotton /1.2% of surface PU	180	50/2.5

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

Insert symbol	Density /dm		Area mass, g/m²	Amount of applied adhesive, g/m²	Type of polymer
	vertical	horizontal			
PA - 12	120	110	72.0	Paste = 12.0	copolyamide
PA - 16	120	110	76.0	Paste = 16.0	copolyamide
PA - 20	120	110	80.0	Paste = 20.0	copolyamide
Pp -13 'double spot'	120	110	73.0	Paste = 6.0 Powder = 7.0	modified polyethylene, low pressure + copolyamide

Preparing the laminates for experiments

Three variants of the laminates were prepared for experiments (Figure 1), with the following D_l 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 predefined adhesion parameters: T = 140 °C, t = 13 s and p = 3.5 N/cm^2. Next, the laminates prepared in this way were cut into swathes, in three directions based on the warp of the top fabric, that is, Dc = 0, 45, 90°, according to the requirements for setting the separation force [11].

Maintenance procedures – M_{pr} (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.

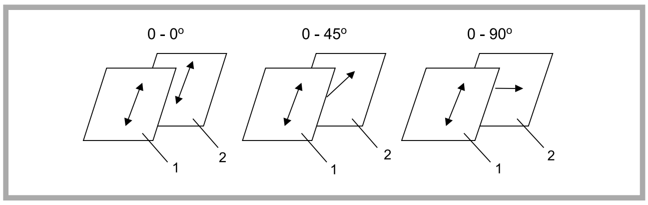

Figure 1. Various placement of layers in the package: 1 – upper fabric, 2 – textile insert, ↔ – direction of the warp.

The final treatment of the swathes included ironing on a stationary, flat press under pre-defined conditions, i.e. T = 140 °C, t = 13 s, p = 3.5 N/cm^2.

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 5th maintenance procedure (M_{pr} – 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 3^3 and 2^3 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).*

Factor	Unit of measure	Code	Central value	Unit of variation
Glue mass m	g/m^2	X_1	16	4
Layers' placement direction D_l	°	X_2	45	45
Cutting direction D_c	°	X_3	45	45

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

Factor	Unit of measure	Code	Central value	Unit of variation
Layers' placement direction D_l	°	X_1	45	45
Cutting direction D_c	°	X_2	45	45

***Table 5.** Influence of the maintenance procedures M_{pr} on selected mechanical features of analysed laminates B(PA), depending on the mass of glue m in g/m^2, direction of layers in the package D_l in deg and the direction of cutting the swath D_c in deg.*

Analysed feature	Regression equations for laminate B(PA)	R
	M_{pr} - 0	
Separation force F_0	$F_0 = 0.8844 – 0.1007X_1 – 0.0016X_2 – 0.0007X_3 + 0.0038X_1^2 + 0.00005X_1X_2 + 0.000004X_2^2 + 0.000002X_1X_3 + 0.000007X_2X_3 + 0.000003X_3^2$	0.99
	M_{pr} - 5	
Separation force F_5	$F_5= 0.8692 – 0.1054X_1 – 0.0006X_2 – 0.00029X_3 + 0.0041X_1^2+ – 0.000007X_1X_2 + 0.000008X_2^2 – 0.00003X_1X_3 + + 0.0000006X_2X_3 + 0.000006X_3^2$	0.99

***Table 6.** Influence of the maintenance procedures M_{pr} on selected mechanical features of analysed laminate B(Pp), depending on the direction of layers in the package D_l in deg and the direction of cutting the swath D_c in deg.*

Analysed feature	Regression equations for laminate B(Pp)	R
	M_{pr} - 0	
Separation force F_0	$F_0 = 0.319306 + 0.000972X_1 – 0.000472X_2 – 0.0000028X_1^2 + – 0.0000031X_1X_2 – 0.0000004X_2^2$	0.98
	M_{pr} - 5	
Separation force F_5	$F_5 = 0.290972 – 0.000120X_1 + 0.000231X_2 + 0.000008230X_1^2 + – 0.000005556X_1X_2 – 0.000000412X_2^2$	0.95

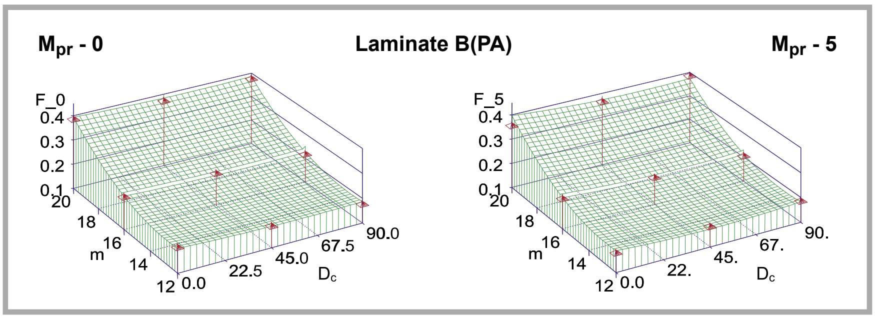

Figure 2.a. *Influence of maintenance procedures M_{pr}-5 on the value of separation force indicator F in daN of the B(PA) laminate, depending on glue mass m in g/m^2 and the swathes' cutting direction D_c in deg (for D_l = 45°)*

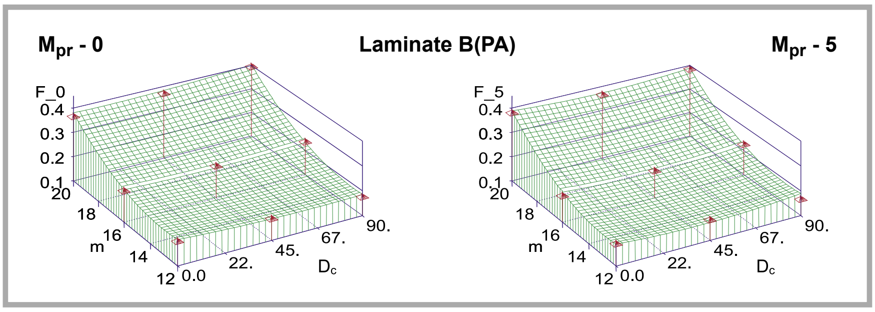

Figure 2.b. *Influence of maintenance procedures M_{pr}-5 on the value of separation force indicator F in daN of the B(PA) laminate, depending on glue mass m in g/m^2 and the layers' direction D_l in deg of swathes (for D_c = 45°).*

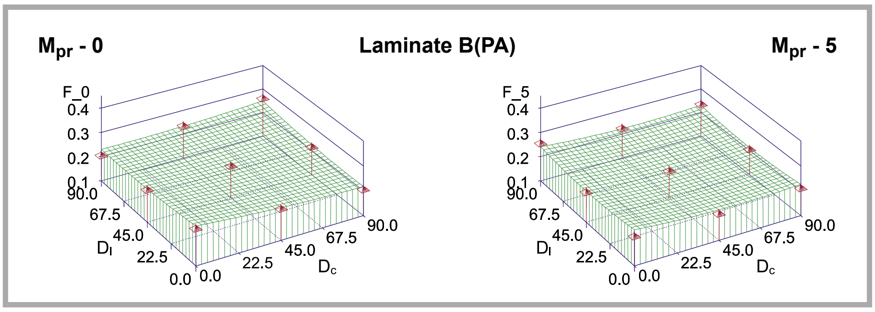

Figure 3.a. *Influence of maintenance procedures M_{pr}-5 on the value of separation force indicator F in daN, depending on the layers' direction D_l in deg and the swathes' cutting direction D_c in deg for laminate B(PA).*

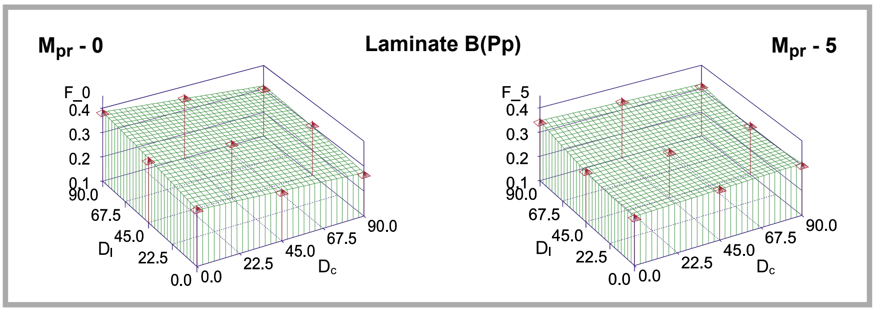

Figure 3.b. *Influence of maintenance procedures M_{pr}-5 on the value of separation force indicator F in daN, depending on the layers' direction D_l in deg and the swathes' cutting direction D_c in deg for laminate B(Pp).* ***Source:*** *own research.*

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

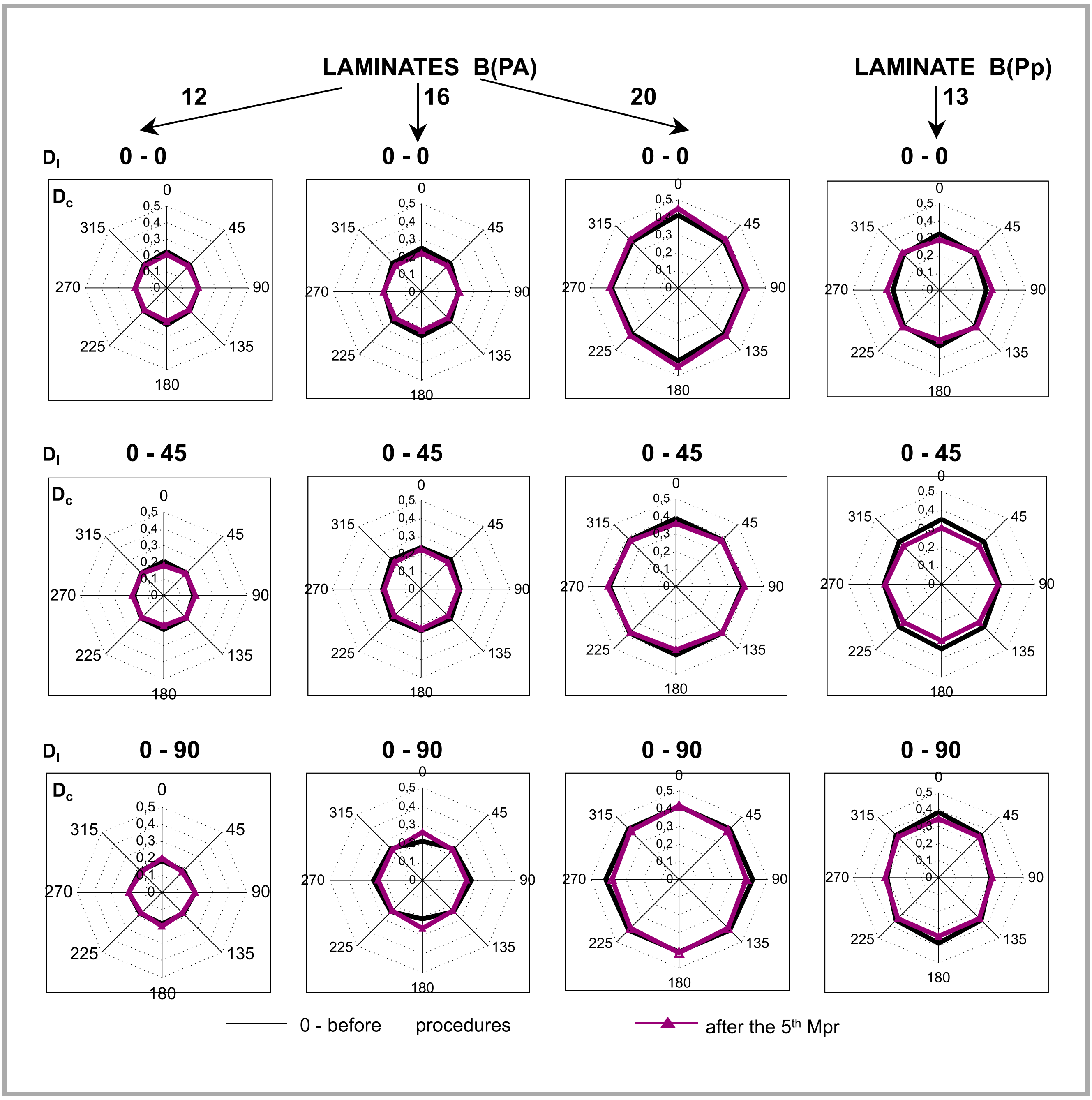

***Figure 4.** Influence of maintenance procedures M_{pr}-5 on the value of separation force indicator F in daN of laminates B, depending on the glue mass in g/m2, direction of the layers D_l in deg and swathes' cutting direction D_c in deg for two types of glue (PA and Pp).*

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 M_{pr} 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.

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