Improvements in Compressional Properties of Highlofts

Oldrich Jirsak, Tomas Burian, Pavlina Sasková

Technical University of Liberec, Department of Nonwovens
Halkova 6, 461 17 Liberec, Czech Republic
Tel: +420-48-5353233 Fax:+420-48-5353244
E-mail: OLDRICH_JIRSAK@VSLIB.CZ

Abstract
One new type of matrix fibres and two types of bi-component bonding fibres of the Teijin Company, Japan have been tested as raw material for manufacturing highloft textile materials. The fabrics obtained were compared with those made of commonly used fibres. Simultaneously, the properties of cross-laid and perpendicular-laid fabrics made of the fibres mentioned above were compared with those of polyurethane foam. Significant improvements in the compressional properties of fibrous highlofts were achieved by using the newly developed Japanese fibres, due to the perpendicular orientation of these fibres in comparison with conventional cross-laid fabrics. The contributions of the new fibre materials together with the upright fibre position in highlofts proved that the resulting compressional properties of fabrics are close to those of polyurethane foams. This opens up more opportunity for the utilisation of fibrous highlofts in specific products, and allows us to exploit their advantages.

Key words: *nonwovens, highlofts, perpendicular laid, compressional properties.*

Introduction

The main end-use areas for highloft products are [1] furniture, bedspreads, comforters/quilts, mattress pads, pillows, sleeping bags, apparel insulation pads, filtration, crafts, home sewing, toys, decorations, roofing and building insulations, healthcare, geotextiles, cleaning & polishing materials inter alia.

In the automotive industry, parts of car interiors are produced by moulding highlofts which contain thermoplastic adhesives. Significant effort has been devoted to developing a fibrous replacement for polyurethane foam in car seats. Polyurethane foam has some problems such as difficulties in handling chemicals used during its manufacture, non-recyclability, poor hygienic properties due to low hygroscopicity & air permeability, as well as discharge of toxic gases when burning. On the other hand, the use of textiles as substitutes for polyurethane foam has been limited by their incompatibilities with respect to some properties such as elasticity and compressional recovery after loading, whether at low or at high temperature.

In effort to improve the compressional characteristics of highlofts, both new structures of textile materials and new special base and bonding fibres were developed. Voluminous fibre materials made of fibres situated upright towards the plane of the fabric [1] can serve as an example. The principle of their production is shown in Figure 1. A carded web containing base and bonding fibres is formed by using the perpendicular lapper into a voluminous fibre layer. The material is reinforced in a thermobonding through-air oven. The considerably improved properties of perpendicular-laid highlofts have been described in a number of papers [2-4]. The new special fibres from the Teijin firm [5] are another example of an effort to improve the properties of fibrous highlofts.

It is the aim of this paper to study the properties of highloft materials produced

- by perpendicular - vs. cross-layering, and
- of conventional fibres vs. the new special Teijin fibres.

The authors believe that the positive contributions to properties obtained by both perpendicular layering and by the use of new fibres would combine.

Experimental

Two series of voluminous fabrics (cross-laid thermobonded and perpendicular-laid thermobonded) of fibre blends containing 70% matrix fibres and 30% bonding fibres were produced.

The basic properties of the fabrics obtained were as follows:

- Area density: 30-32 kg/m^2
- Area weight: 800-1100 g/m^2
- Thickness: 26.5-35 mm.

Polyurethane foam with the following properties was used in our experiments as comparative material:

- Density: 30 kg/m^2
- Area weight: 1000 g/m^2
- Thickness: 33 mm.

The highloft fabrics were produced of the following staple fibres:

Matrix fibres:

1. PET 13 dtex, 64 mm, hollow, Teijin denoted as JAP,
2. PET 6.7 dtex, 65 mm, conventional denoted as PES.

New bonding fibres:

1. PET 6.6dtex, 51 mm, Low melting point, Teijin denoted as P
2. PET 6.6dtex, 51 mm, High melting point, Teijin denoted as V
3. Conventional bico PET/coPES 5.3 dtex, 55 mm denoted as W.

The bonding fibres differ in the bonding temperatures recommended by producers. The characteristics of the fabrics prepared are presented in Table 1.

Testing methods

Three tests have been carried out using the fabrics prepared. The following properties were measured:

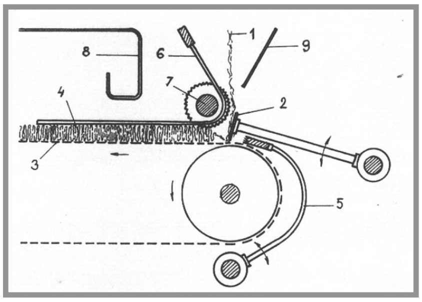

Figure 1. *Vibrating perpendicular lapper: 1 - carded web, 2 - forming comb, 3 - conveyor belt of thermobonding chamber, 4 - perpendicular laid fibre layer, 5 - presser bar, 6 - wire grid, 7 - hold-back roller, 8 - cover of thermobonding chamber.*

__Table 1.__ The characteristics of the fabrics prepared. Note: The PES matrix fibre was not processed together with the V bonding fibre, as the PES fibre was damaged (having shrunk) due to the high bonding temperature.

No	Materials		Layering	Bonding temperature, °C	Denoted as
	Matrix fibres	Bonding fibres			
1	JAP	V	cross	210	JAP-V C
2	JAP	P	cross	190	JAP-P C
3	PES	P	cross	190	PES-P C
4	JAP	W	cross	170	JAP-W C
5	PES	W	cross	170	PES-W C
6	JAP	V	perpendicular	210	JAP-V P
7	JAP	P	perpendicular	190	JAP-P C
8	PES	P	perpendicular	190	PES-P P
9	JAP	W	perpendicular	170	PES-W P
10	PES	W	perpendicular	170	PES-W P
Polyurethane foam					PUR

A. Compressional rigidity (see step 1).
B. Softening value of materials due to repeated loading (see steps 1 to 4).
C. Elastic recovery after heat and compression.

The way in which the A and B tests were carried out, and the advantages which could be achieved by such a procedure, have been described in [6] in more detail. The tests mentioned above were carried out in the steps described below.

Step 1: The compression curves were measured using a dynamometer within the load limit of 0-50 kPa. Two layers of the samples of dimensions 0.1×0.1 m were submitted to repeated loading at the velocity of 1 mm/s. The curve of the fourth compression cycle was recorded to avoid errors connected with initial conditions. The curves are shown in Figures 2, 4 and 6.

Step 2: The samples tested in step 1 were submitted to repeated loading in 25,000 loading cycles. In every cycle, the materials were compressed by 75% of their original thickness (up to 25% of original thickness). Frequency of loading: 200/min.

Step 3: The same samples (after having been submitted to repeated loading in step 2) were tested on a dynamometer using the same process as in step 1. Again, relative thickness as a function of load was recorded in the fourth loading cycle. For the calculation of relative thickness, the original thickness of the sample (before loading in the steps 1 and 2) was taken as 100%. The curves are shown in Figures 2, 5 and 7.

Step 4: The corresponding compressional curves measured before and after repeated loading in step 2 were compared, and the 'softening value' of materials in repeated loading was calculated as follows:
Softening value:

$$(SV) = T'_{rel} / T_{rel} \cdot 100\%$$

where

$$T_{rel} = T(\sigma) / T_0 \cdot 100\%$$

$$T'_{rel} = T'(\sigma) / T_0 \cdot 100\%$$

T_{rel} - relative thickness on the compressional curve in step 1,
T'_{rel} - relative thickness of materials in step 3,
T_0 - original thickness of the samples before loading in step 1.

The values of the softening value as a function of load are shown in Figures 8 and 9. The comparison of cross-laid and perpendicular laid fabrics is shown in Figures 10 (a - e). In each figure, the

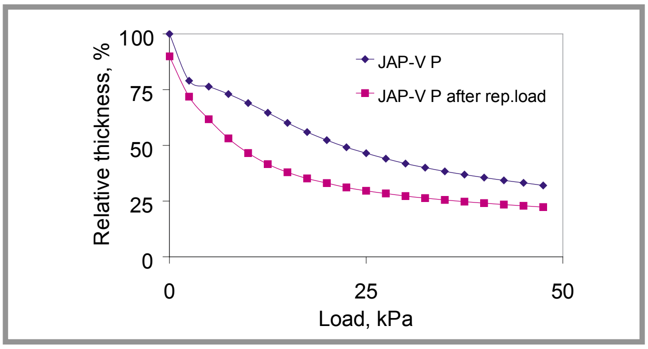

__Figure 2.__ Load vs. thickness curves of material before and after repeated loading.

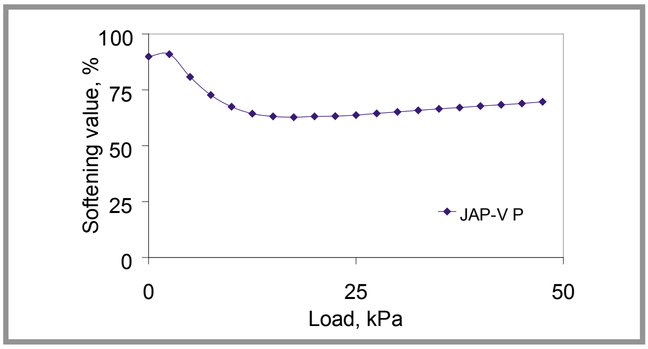

__Figure 3.__ Softening of material due to repeated loading.

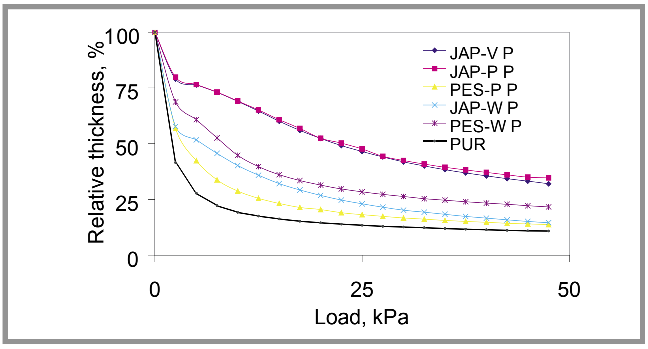

__Figure 4.__ Load vs. thickness curves of perpendicular laid materials and foam before repeated loading.

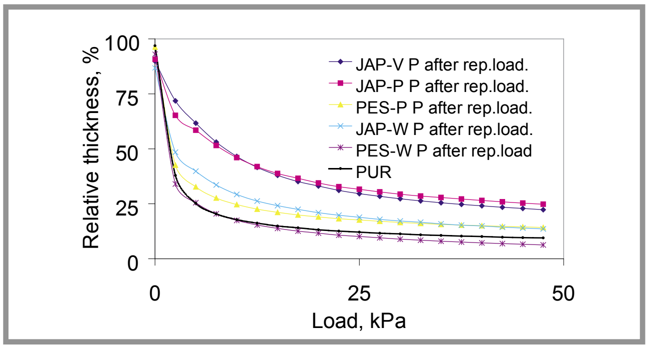

__Figure 5.__ Load vs. thickness curves of perpendicular laid materials and foam after repeated loading.

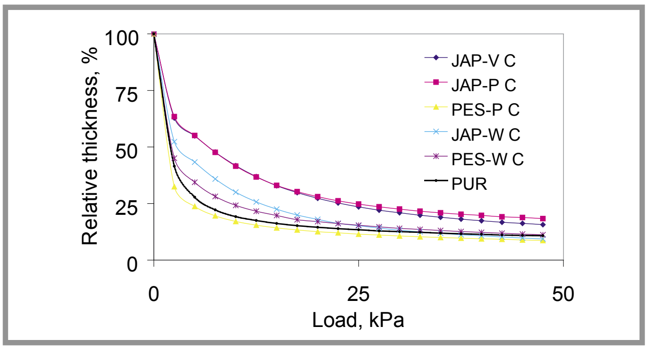

Figure 6. *Load vs. thickness curves of cross-laid materials and foam before repeated loading.*

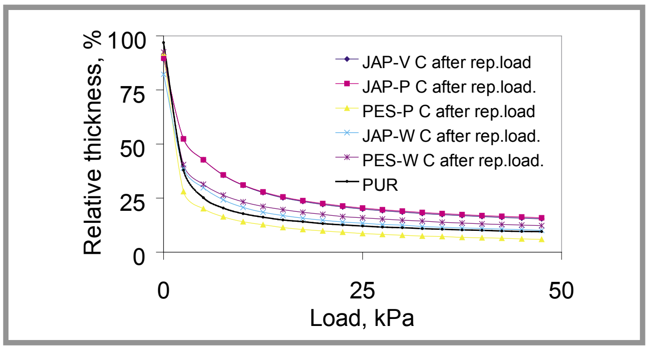

Figure 7. *Load vs. thickness curves of cross-laid materials and foam after repeated loading.*

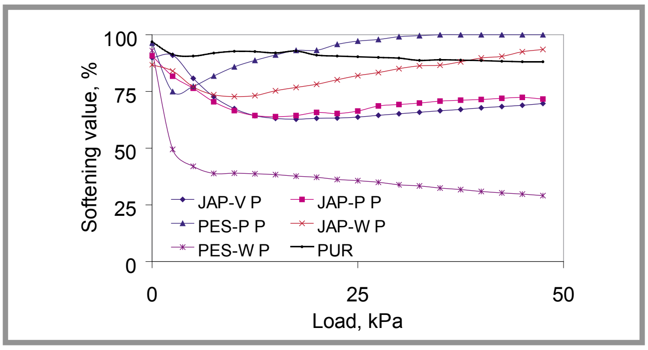

Figure 8. *Softening of perpendicular laid materials and foam due to repeated loading.*

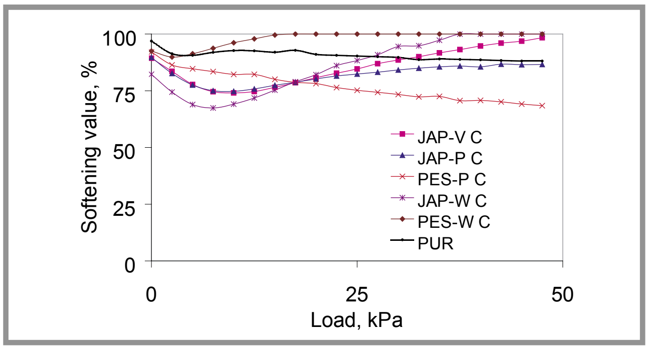

Figure 9. *Softening of cross-laid materials and foam due to repeated loading.*

compression curves of both cross-laid and perpendicular-laid materials before and after repeated loading are presented. The elastic recovery after heat and compression was carried out according to the DIN 53272 German standard. The samples were compressed between two metal plates to 50% of their original thickness and placed in a chamber at 70°C for 22 hours. Then the samples were released from the plates and allowed to recover at laboratory temperature for 24 hours. The elastic recovery ER was calculated from the original and final thickness as:

$$ER = t_2 / t_0 \,.\, 100\%$$

where t_2 and t_0 is thickness of material after and before the described procedure. The results are shown in Table 2.

Test Results

The thickness vs. load curves (Figures 4-7) show that the JAP matrix fibres and both V and P bonding fibres are very well suited to increase compressional resistance and elastic recovery after repeated loading of the voluminous fabrics. The properties are significantly better than those of fabrics made of the JAP-W, PES-P and PES-W blends, no matter whether cross-laid or perpendicular-laid fabrics are produced. The softening values of textiles made of JAP and V or P fibres show medium level; nevertheless their compressional rigidity after repeated loading is still the best.

When comparing cross-laid and perpendicular-laid fabrics made of various fibre blends (Figures 10 a – e), perpendicular-laid materials show significantly higher compressional rigidity than cross-laid ones. In most the cases, the compressional rigidity of perpendicular-laid fabrics after repeated loading is higher than that of cross-laid fabrics before repeated loading. The material made of the PES-W blend is the exception.

Generally, the softening value of perpendicular-laid textiles is lower than that of the cross-laid ones. This can be explained by the lower tensile properties of the perpendicular-laid fabrics which are more damaged during repeated loading. The strength of perpendicular laid fabrics is often improved when using a light reinforcing backing combined with the fabrics during production process.

The materials made of JAP-P and JAP-V blends also show excellent elastic recovery after the hot-pressing process (Table 2). Perpendicular-laid textiles show higher values of elastic recovery (0 to 10 per cent in specific cases) than cross-laid ones.

Conclusions

The results of the experiments carried out lead to the conclusion that all the measured properties of the fabrics examined are better when compared with the remaining variants, when

- JAP matrix fibres are used in blends with bonding fibres of the V or P type, and
- the fabrics with perpendicular-laid structures are produced.

Especially good results can be achieved if JAP and V & P fibres are processed into perpendicular-laid fabrics.

Use of the combination of Teijin special fibres with the STRUTO technology will bring a significant step forward in the development of highloft textiles. The fabrics show improved elastic fabric recovery after repeated loading and heating. In this respect, they are closer to the properties of foam than conventional fibrous highlofts.

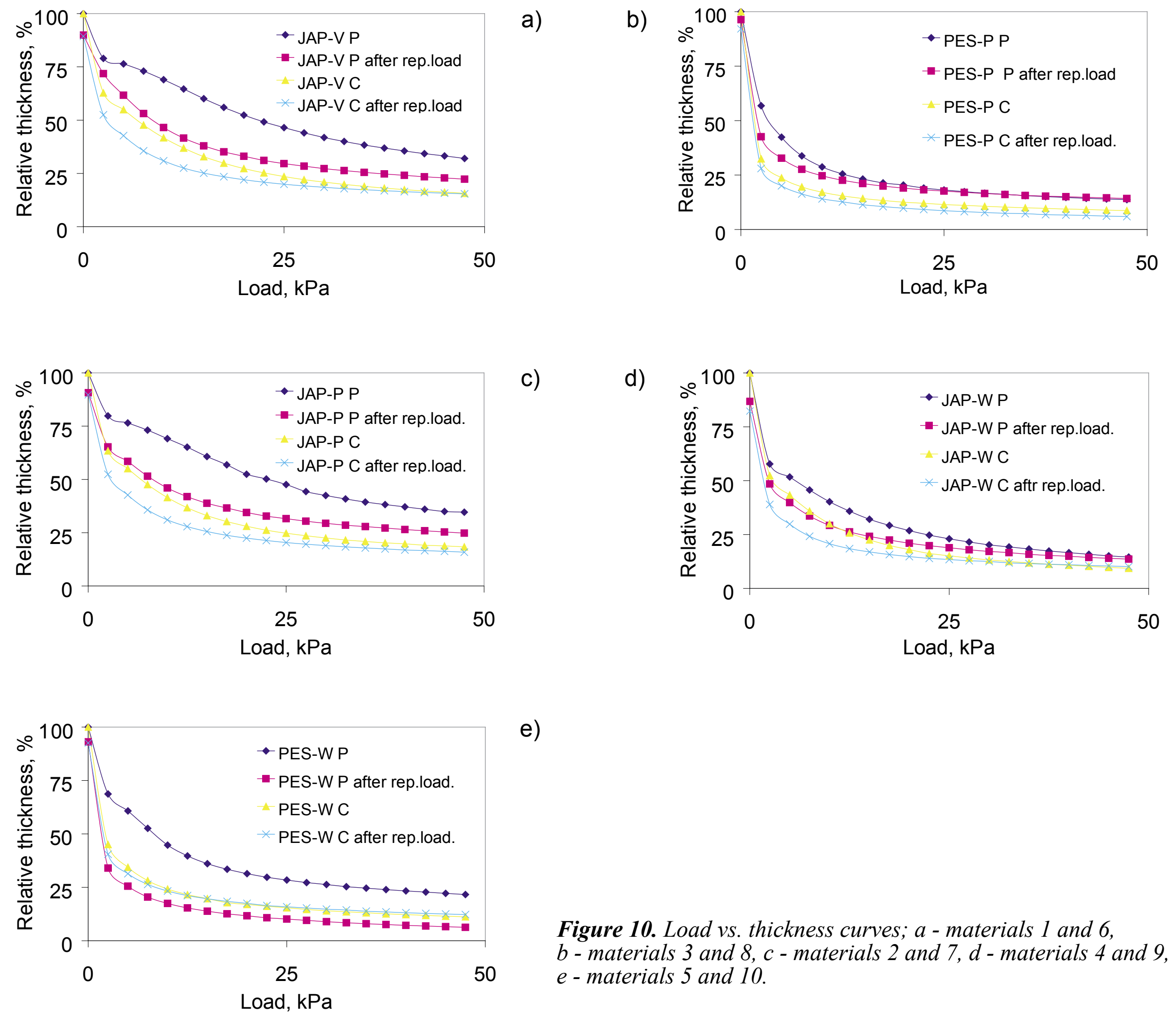

Figure 10. *Load vs. thickness curves; a - materials 1 and 6, b - materials 3 and 8, c - materials 2 and 7, d - materials 4 and 9, e - materials 5 and 10.*

Table 2. *Elastic recovery of materials after 50% compression 22 hours 70°C (V - 210°C, P - 190°C, W - Wellbond, t - average values of 4 measurements, % - average values of 2 samples, t_0 - original thickness of sample, t_1 - thickness after heat pressing 22 hours, t_2 - thickness after 46 hours recovery).*

Denotation	t_0, mm	t_1, mm (22 hours)	t_1, % of t_0	t_2, mm (46 hours)	t_2, % of t_0
PUR	29.4	28.2	95.92	28.3	96.25
	29.3	28.0		28.1	
JAP-V C	30.75	21.125	65.95	22.375	70.60
	33.25	21.0		22.75	
JAP-P C	31.75	19.0	58.60	20.5	61.95
	33.75	19.375		20.0	
JAP-W C	32.75	18.625	56.25	19.875	59.30
	31.5	17.5		18.25	
PES-P C	23.75	15.5	64.65	17.0	71.20
	26.5	17.75		18.75	
PES-W C	28.75	15.125	51.95	16.5	55.60
	29.75	15.25		16.0	
JAP-V P	29.0	19.875	67.60	20.75	73.30
	28.5	19.0		20.25	
JAP-P P	29.0	20.875	71.37	21.75	71.45
	29.5	20.875		20.05	
JAP-W P	31.5	18.32	58.15	18.75	60.12
	32.25	18.75		19.40	
PES-P P	34.75	25.750	72.75	27.25	77.05
	35.0	25.0		26.5	
PES-W P	30.75	16.5	52.75	17.5	55.75
	31.125	16.125		17.0	

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