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Effect of Repeated Loading on Compressional Rigidity of Highlofts

Abstract

Highloft textile materials are developed to replace non-recyclable foams for numerous end uses such as upholstery, mattresses, the automotive industry and many others. Better hygienic properties, recyclability and environmental friendliness are the main advantages of fibrous bulky materials when compared with foams. Nevertheless, the elastic properties of textile highlofts after repeated, long-term use and/or hot loading are still a weak point limiting their heavy-duty end-use, especially in the automotive industry. In the article, a method is suggested and tested to characterise the loss of compressional rigidity of bulky materials due to repeated loading during end-use. This method is used to evaluate the properties of fibrous highlofts developed with improved compressional properties.

Key words: *highlofts, perpendicular-laid, compressional rigidity, elastic recovery.*

Introduction

Highloft textiles [1, 2] are low density fibre network structures characterised by a high ratio of thickness to weight per unit area. Highloft battings have no more than 10% solids by volume, and are usually greater than 3 mm in thickness. Typical characteristics of highloft materials are thickness between 5 and 100 mm and 1 to 5% of solids.

The main end-use areas for highloft products are [2] furniture, mattress pads, sleeping bags, apparel insulation pads, filtration, the automotive industry and others. In many of the applications, highlofts are strained by loading, typically by long-term and/or repeated loading. Due to such loading, the bonds in the fabrics tend to break which leads to softening of the material, loss of compressional rigidity and finally to decrease of thickness, filling and thermal-insulating properties. The development of highlofts which are resistant to repeated loading is inspired by the possible replacement of non-recyclable foams.

There are various ways to improve the compressional properties of highloft materials. Perpendicular-laid fabrics [3-5] can serve as an example of achievements in this development effort. The better properties of these materials result from upright fibre positions. Recently introduced special fibres and ELK bi-component bonding fibres by the firm Teijin give more significant access to the improvement of highlofts [6].

Highlofts with improved properties were elaborated in the Department of Nonwovens of the Technical University of Liberec, in co-operation with Teijin, Japan. The properties of cross- and perpendicular-laid structures, with conventional matrix and bonding fibres, as well as of completely new Teijin-TUL inventions were tested and compared together with those of foams. The new technology and the test results will be published in a further publication. A new testing method was elaborated for the purpose of the above-mentioned tests carried out at our Department. The aim of this method was better characterisation of the compressional rigidity of different structures.

Various testing methods are used to test the compressional properties of both foams and fibrous filling materials. For instance, DIN 53577 describes a method to measure compressional rigidity by repeated compression up to 70% of original thickness using a dynamometer. The behaviour of materials is described by stress-strain curves in the loading and unloading processes. DIN 53572 lays down a procedure to measure elastic recovery of material after compression by 50, 70 or 90% at 23°C for 72 hours or at 70°C for 22 hours. Czech standard 645442 describes a method of measuring the change in thickness of the material after repeated loading by a high number (80,000) of loading cycles. Measurement of the load vs. thickness curves before and after repeated loading and their comparison is a method to characterise breakdown and softening of the material owing to repeated exertion. Many other methods and their modifications are described in standards for materials with specific end-uses.

The method elaborated by us, presented below, allow the obtaining of factors which are very useful for the comparison of compressional rigidity of various structures as in other used methods. The new method is a kind of compilation of the modified DIN 33557 and Czech standard methods.

Experimental

A method to test softening of bulky materials by repeated loading was developed and its parameters tested. The method comprises three steps:

Step 1
Load vs. thickness curves are measured according to DIN 53577. The curve in the fourth loading cycle is used as an initial characteristic of tested material.

Step 2
After having been submitted to the procedure in Step 1, the same samples are repeatedly loaded using a modified needle loom equipped with one solid and one reciprocating plate. The device is designed to process a number of samples at the same time. The number of loading cycles, the working frequency and the sample deformation in every loading cycle are optional test parameters.

Step 3
Load vs. thickness curves of the samples are measured identically as in step 1.

The difference between the load vs. thickness curves measured in steps 1 and 3 characterises the softening of the material. To characterise the softening as a

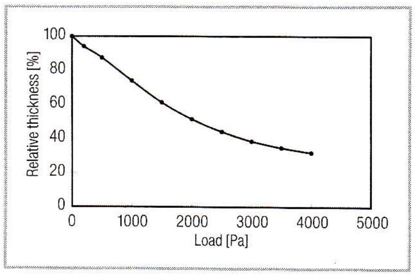

Figure 1. Relative thickness of the material (in percent of original thickness) vs. load.

function of a specific parameter of repeated loading, the quotient of corresponding values of the third and the first load vs. thickness curves is plotted against this parameter. The quotient is denoted as the softening value (SV):

$$SV = \frac{RTL}{RT} \cdot 100(\%)$$

where RTL is the relative thickness of the samples at a specific load <u>after</u> the sample was submitted to repeated loading (%), and RT is the relative thickness of the sample at the same load <u>before</u> the sample was submitted to repeated loading (%).

Thus, the compressional properties of materials showing SV=100 are not changed by repeated loading. The lower the value of SV, the more the material is softened.

A perpendicular-laid through-air bonded highloft material was tested using this method. The material was produced of 80% polyester staple fibres 6.7 dtex, 65 mm, and 20% bi-component core/sheath polyester/co-polyester fibres 2.2 dtex, 30 mm.

Basic properties of material were: area weight 500 g/m^2, thickness 31 mm, density ca. 16 kg/m^3. The load vs.

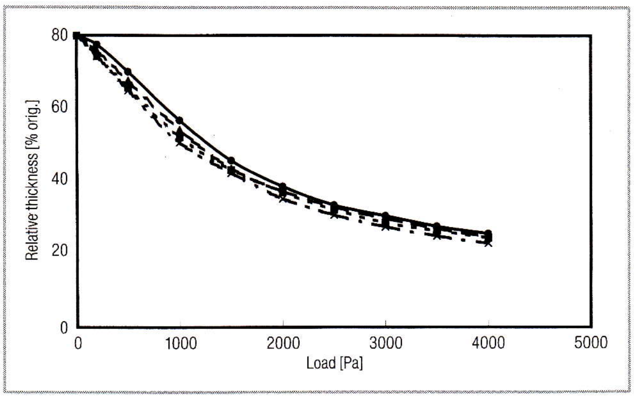

Figure 2. Relative thickness of the material (in percent of original thickness) vs. load after repeated loading in step 2 by 50% of thickness. ● - 1000 loading cycles, ▲ - 10000 cycles, ■ - 25000 cycles, x - 50000 cycles

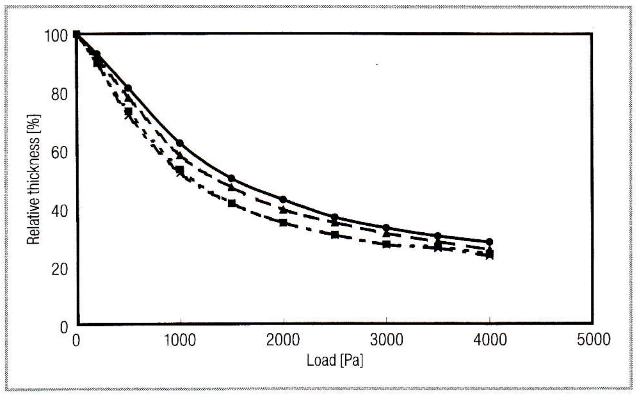

Figure 3. Relative thickness of the material (in percent of original thickness) vs. load after repeated loading in step 2 by 75% of thickness. ●- 1000 loading cycles, ▲ - 10000 cycles, ■ - 25000 cycles, x - 50000 cycles

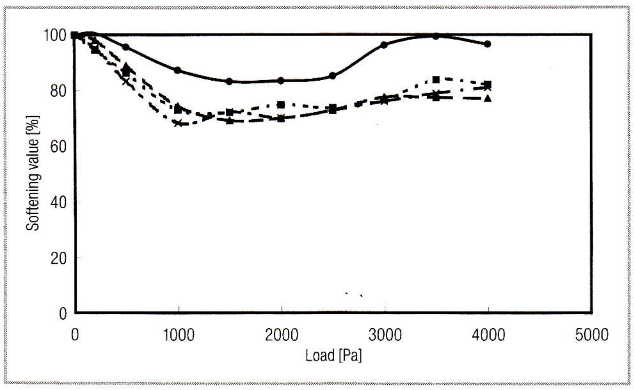

Figure 4. Softening value as a function of load after repeated loading in step 2 by 50% of thickness. ● - 1000 loading cycles, ▲ - 10000 cycles, ■ - 25000 cycles, x - 50000 cycles

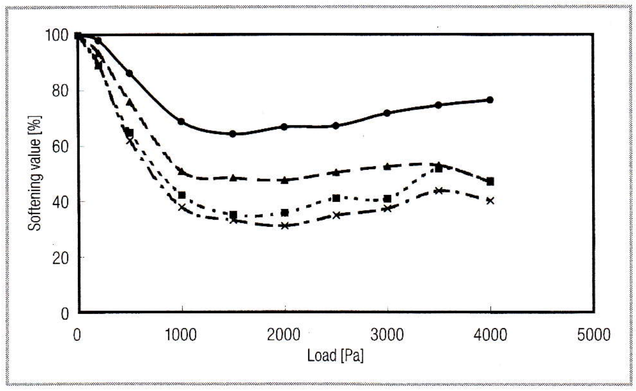

Figure 5. Softening value as a function of load after repeated loading in step 2 by 75% of thickness. ● - 1000 loading cycles, ▲ - 10000 cycles, ■ - 25000 cycles, x -50000 cycles

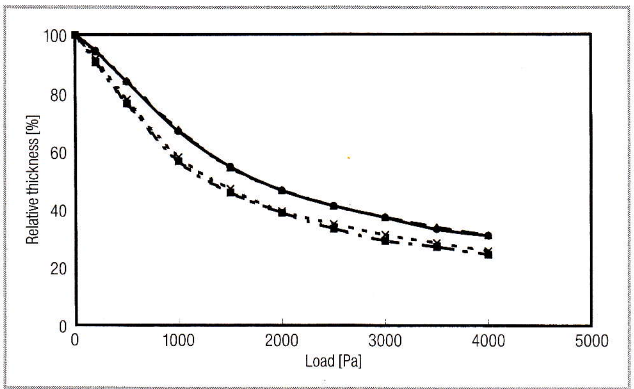

Figure 6: Influence of frequency during repeated loading in step 2; relative thickness vs. load. ● - compressed by 50%, frequency 200/min, ▲ - 50%, 20/min, ■ - 75%, 200/min, x -75%, 20/min

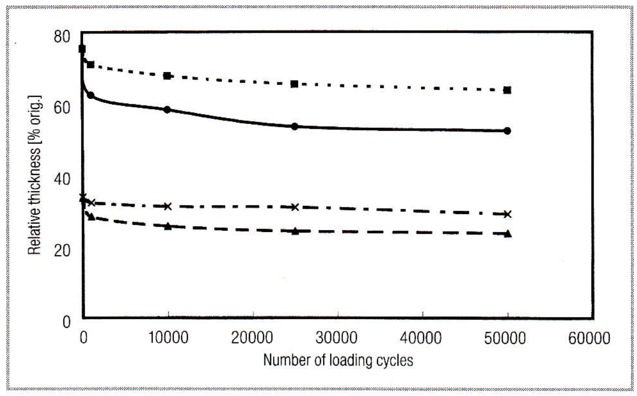

Figure 7. Dependence of relative thickness on number of loading cycles (measured at a load of 1000 and 4000 Pa). ■ - repeatedly loaded by 50%, measured at 1000 Pa, ● - 75%, 1000 Pa, x - 50%, 4000 Pa, ▲ - 75%, 4000 Pa

thickness curve of tested material is shown in Figure 1. The thickness on the y-axis is expressed as relative thickness in percent of original thickness. This makes it possible to compare the compressional behaviour of materials of different original thickness.

The same compressional curves of the material after having been submitted to repeated loading are shown in Figure 2 (repeated compression by 50% of original thickness), and in Figure 3 (repeated compression by 75% of original thickness). Various loading cycles were applied: 1000, 10000, 25000 and 50000 cycles. The softening values of the material were calculated as described above for the various loading cycles. The results are shown in Figures 4 and 5. The effect of loading frequency (200/min and 20/min) during repeated loading was evaluated. The comparison of results is shown in Figure 6. The relative thickness of the samples submitted to repeated loading when compressed by 1000 and 4000 Pa is plotted against the number of loading cycles is shown in Figure 7.

Discussion

The load vs. thickness curves (Figure 2) show a slight softening of the material with an increasing number of loading cycles. In this case, the material was deformed by 50 per cent of its original thickness in every loading cycle. If the material is compressed by 75 per cent (Figure 3), the compressional curves show more significant softening. Considering the effect of the number of loading cycles in Figure 3, it appears that the behaviour of the material is the same after 25000 and 50000 loading cycles.

The thickness and appearance of the samples did not change considerably during repeated loading. In some cases, the thickness of highlofts even increased to a small extent after repeated loading. The results show that the testing demonstrates important characteristics of highlofts when these are repeatedly compressed by 75 per cent 25000 times.

The softening values of studied material, depending on the deformation in repeated loading (50 and 75 per cent) and on the number of loading cycles, are shown in Figures 4 and 5. The material appears softened mainly when loaded by 1000-3000 Pa. At higher loads the SV increases. This can be explained by a different deformation mechanism at low and high compressions and corresponding fabric densities. At low density, the compressional resistance is influenced mainly by breaking fibre-to-fibre adhesive bonds during repeated loading. At high fabric densities, the compressional resistance increases due to the increasing number of fibre-to-fibre contacts. The possible effect of the frequency of repeated loading was tested. The materials were repeatedly loaded at 20 and 200 strokes per minute.

The results show a negligible effect of testing frequency. The frequency of 200 strokes per minute makes the time of testing fairly reasonable. 25000 strokes are applied in 125 minutes. Beside this, ten to twenty samples can be loaded at the same time using the device. The effect of the number of loading cycles and that of the sample deformation in every cycle on the relative thickness measured at 1000 and 4000 Pa is shown in Figure 7. Again, only a small difference between 25000 and 50000 cycles appears under all the testing conditions.

Conclusions

The method of evaluating compressional properties at bulky material was tested using a perpendicular-laid fibrous highloft fabric. Repeated loading does not cause changes in the thickness of the fabric. On the contrary, the structure of through-air bonded fabrics can be damaged, and the compressional rigidity decreases due to breaking adhesive bonds. The following parameters of the testing procedure were found to be suitable for testing fibrous highlofts; repeated loading in 25000 cycles; compression by 75 per cent in every loading cycle; loading frequency 200 strokes per minute. The softening value is derived from compressional curves measured before and after repeated loading. ❑

Acknowledgement

This work was carried out with the support of research project No. J11/98:244100001.

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❑ ***Received 03.09.2001 Reviewed: 09.01.2001***