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Investigation of Stress Relaxation of Breathable-Coated Fabric for Clothing and Footwear

Abstract
The investigation of the stress relaxation process of a three-ply breathable-coated fabric, consisting of an outer polyester woven fabric, an insider polytetrafluoroethylene micropore film and a liner polyester knitted fabric, is presented. The tensile properties of these materials are also analysed. The stress relaxation curves of a breathable-coated fabric and an outer polyester woven fabric are determined in three directions, in warp, in weft and on the cross at a 45° angle, and the character of the relaxation process is also analysed. The break points of the stress relaxation process of the materials investigated are also determined. The comparison of the stress relaxation process of a breathable-coated fabric and breathable-coated leather is presented. The break point in the relaxation process is observable even in the system in which this is observable in at least one layer of the system.

Key words: *breathable-coated fabric, stress relaxation process.*

Introduction

Over the last decade, the new breathable-coated materials have been very widely used for manufacturing waterproof clothing. The main feature of these materials is that they include micropore films. Various micropore films have been used [1,2], but all of them have one characteristic property - they consist of interconnected micropores, the diameter of which is a hundred times smaller than the diameter of water drops (the diameter of water drops is not smaller than 200 μm), but a hundred times larger than a molecule of water vapour (which is usually smaller than 0.0003 μm). This structure allows the passage of perspiration vapour to the outside, and at the same time blocks the entry of rain and snow. The materials coated by this kind of film are called breathable-coated materials. Two kinds of such waterproof and breathable materials are used in clothing and footwear manufacturing: coated textile and coated leather. It must be noted that coated textile is used not only for clothing but also for footwear manufacture, and coated leather can be used not only for footwear but also for clothing manufacture.

During the manufacture of clothing and footwear, materials experience various long-lasting deformations, and the relaxation process in polymers of materials arises. Thus the investigation of stress relaxation is very important for predicting the behaviour of breathable-coated material. Plenty of various research works are known in which the relaxation of a given kind of polymeric material, yarns, fabrics, films or others, were investigated [3-9]. But in our case, the breathable-coated textile comprises two different nature polymeric materials, textile and microporous film, and the behaviour of this hybrid system during of relaxation is unknown. So, in this article the stress relaxation of a breathable-coated fabric (i.e. textile-film system) is investigated, and the comparison of the relaxation process of this system with the stress relaxation of breathable-coated leather (leather-film system) is presented.

Method of Investigation and Materials

The relaxation process of materials was investigated by the fixed elongation method, i.e. the test specimens were stretched up to 20% at a speed of 3.33%/s with a tensile testing machine, and left in this fixed elongation for 5000 s. The values of tension force were measured continuously. Standard strips of textile (5 cm width) were used for determining the tensile properties as well as for investigating relaxation. The breathable-coated three-ply fabric (Gore-Tex fabric [2]), consisting of an outer polyester woven fabric, an inner polytetrafluoroethylene film and a liner polyester knitted fabric, and the entire outer polyester woven fabric were used for investigation. The investigations of properties were carried out in three directions - in warp, in weft and on the cross at a 45° angle.

Experimental Results and Discussions

In the first stage of the experiment, the tensile properties of breathable-coated fabric and the outer polyester woven fabric were determined. The values of tensile properties of the breathable-coated fabric and the outer polyester woven fabric are presented in Table 1. The coefficient of variation of the tensile properties values presented is not higher than 4% for strength values, and no higher than 7% for elongation values.

As seen from Table 1, the difference between the analogous properties of the bre-

Table 1. *The values of tensile properties of breathable-coated fabric and outer polyester woven fabric.*

Material	Strength, N	Elongation, %
Breathable-coated fabric:		
in warp	1070	31.8
in weft	834	33.7
on the cross at 45° angle	658	55.2
Outer polyester woven fabric:		
in warp	1022	28.0
in weft	768	27.0
on the cross at 45° angle	392	38.2

athable-coated fabric and the outer polyester woven fabric is observed markedly only for properties measured on the cross at a 45° angle. Thus, it is possible to state that the tensile properties of breathable-coated fabric in warp and weft mainly depend on the outer polyester woven fabric properties as well as the insider polytetrafluoroethylene film. The liner polyester knitted fabric has a trivial influence on those properties. This presumption was confirmed by the analysis of the strips tested and the tensile curves. The breakage of the breathable-coated fabric in warp and weft is observed when the outer layer (polyester woven fabric) breaks. The insider layer (film) breaks at this moment also, but the liner layer (knitted polyester fabric) remain unbroken. The breakage of the liner polyester knitted fabric is observed only when elongation is secured at approximately 120%, although the strength is considerably lower at this moment. So, according to the standard of the determination of tensile strength using the strip method (ISO 13934-1:1999), the strength and elongation is measured at the highest strength moment, i.e. when the outer polyester woven fabric breaks. Only the tensile properties of the breathable-coated fabric on the cross at a 45° angle are considerably higher than the analogous properties of the outer polyester woven fabric. It is thus possible to state that the tensile properties of breathable-coated fabric depend on the outer polyester woven fabric and inner film, and the liner polyester knitted fabric does not influence that fact.

For the manufacture of clothing and footwear, the relaxation properties are also very important . The stress relaxation curves of the breathable-coated fabric and the outer polyester woven fabric are presented in Figure 1. One can see from Figure 1, that the stress relaxation curves of a breathable-coated fabric and an outer polyester woven fabric in warp and weft are different despite the similar tensile properties, and they are similar to the cross at a 45° angle despite different tensile properties (Table 1). It is also observed that the relaxation curves in weft and warp of an outer polyester woven fabric have higher strength values than that of the breathable-coated fabric. The coefficient of variation at each experimental point of the relaxation curves is no higher than 4%.

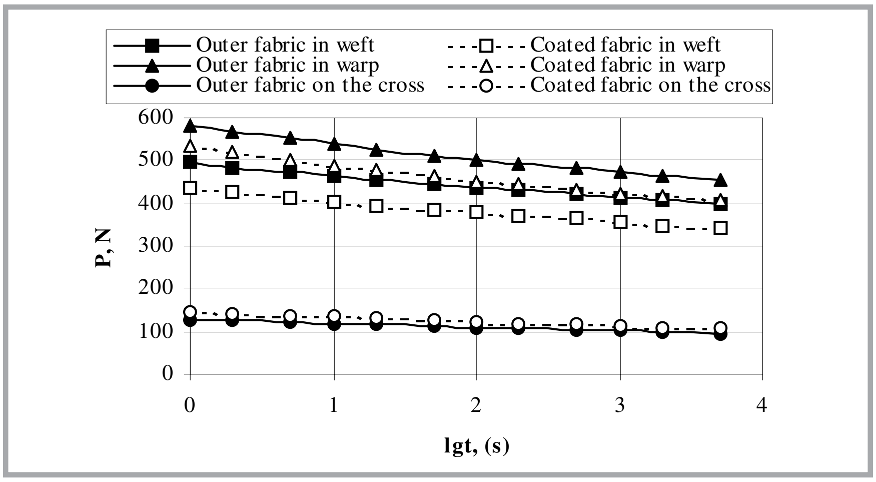

Figure 1. Stress relaxation curves of the breathable-coated fabric and the outer polyester woven fabric.

The relative relaxation curves are mostly used for comparing such different relaxation curves . In this case, the strength at the initial point (the initial point P_0 is the point when $t=0$) is equated to 100%, and the values of others points are calculated as percentage relation with the value of the initial point $(P/P_0)\times 100$. This relation characterises the slope of relaxation. On the other hand, the slope of curve of relaxation characterises the rate of relaxation (the rate is higher if the curve is more vertical). The relative relaxation curves are presented in Figure 2.

From Figure 2 it is evident that the values of P/P_0 of the relaxation curves of the outer polyester woven fabric in all three cases are higher than that of the breathable-coated fabric. So, it can be stated that the different character of the relaxation process in the breathable-coated fabric and the outer polyester woven fabric diverges in various directions (in warp, in weft or on the cross at a 45° angle) of the materials investigated.

The investigation results of the relaxation curve break point (the point at which the relaxation process intensity is changed) confirm this. The relaxation break point for various polymeric materials (fibres, yarns, fabrics, films, etc.) in references is noted [3,4,9]. This break point characte-

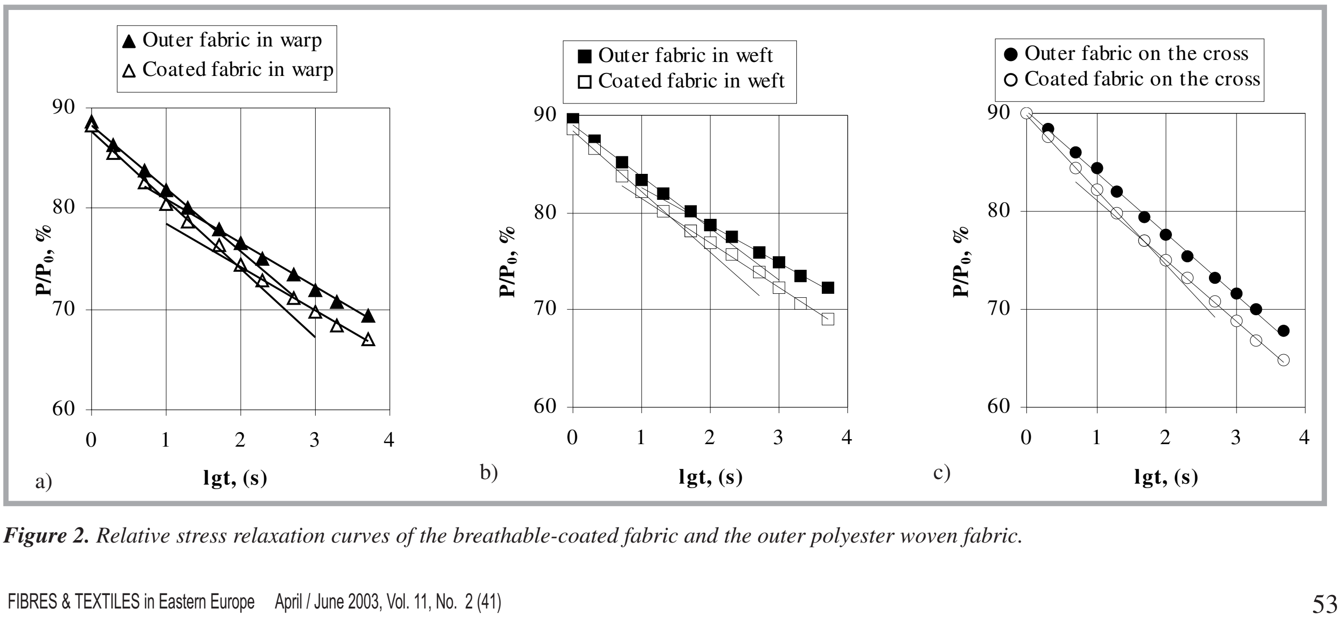

Figure 2. Relative stress relaxation curves of the breathable-coated fabric and the outer polyester woven fabric.

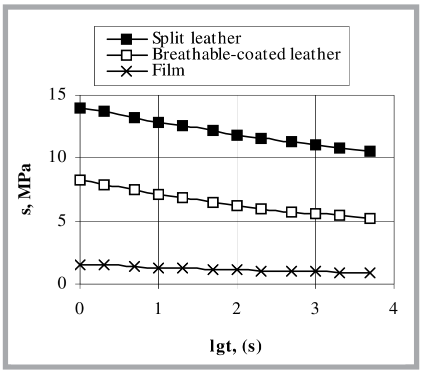

Figure 3. *Stress relaxation curves of split leather, breathable-coated leather and film.*

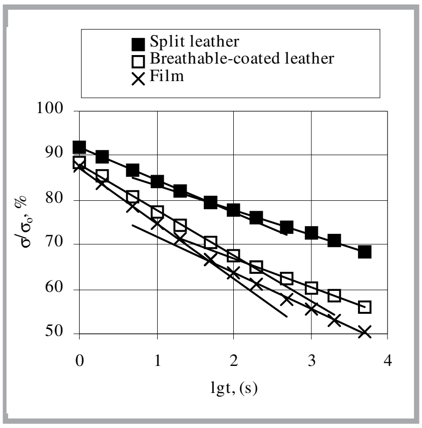

Figure 4. *Relative stress relaxation curves of split leather, breathable-coated leather and film.*

rises the behaviour of the material during relaxation. The coefficient of determination (R^2) can be used to determine this point. In this case, if the coefficients of determination of both linear equations describing the two parts of relaxation in the expected break point area are highest, the point which is common to both equations can be named the relaxation break point. In the case of the regressive equation determination of stress relaxation of the outer polyester woven fabric in weft, for example, without the break point, the R^2=0.9908, while in the case of describing this one in two regressive equations with the break point in *lgt*=2, the coefficients of determination are higher (R_1^2=0.9945 and R_2^2=0.9993). This supports the existence of a relaxation break point. When describing this one in other points, the coefficients of determination are slightly lower (R_1^2=0.9941 and R_2^2=0.9981 with break point at *lgt*=1.7; R_1^2=0.9942 and R_2^2=0.9993 at *lgt*=2.3).

Figure 2 shows that the *lgt* values of the break point of relaxation curves for both materials in warp and in weft, and the breathable-coated fabric on the cross at a 45° angle are 1.7-2.0, i.e. *t*=50-100 s, whereas the break point of the relaxation curve of polyester woven fabric on the cross at a 45° angle is negligible. So, it is possible to state that the break point in the breathable-coated fabric on the cross at a 45° angle is observable only thanks to the influence of the film.

The following hypothesis has been made: in the hybrid system consisting of a few layers, the break point of stress relaxation is observable even if this is observable in at least one layer of the system. The same dependencies are observed in reference [9], where the break points are determined in the relaxation curves of polyethylene fibre unidirectional composites, but are not observable for matrix material used for composite material manufacture. The observable break points are also higher for hybrid (polyethylene-carbon) composites in which the polyethylene fibre constitutes a higher quantity. This phenomenon in reference [9] is explained by a rearrangement or reorientation at the viscoelastic interface of two different polymers, but it can also be explained by the presented hypothesis. The experimental data presented in reference [9] supports this hypothesis also.

The investigations of stress relaxation of breathable-coated leather, which is used for a similar purpose as a breathable-coated fabric, were carried out for comparison and confirmation of the hypothesis. The stress relaxation curves of split leather, breathable-coated leather and film are presented in Figures 3 and 4.

One can see from Figure 4 that the break point in relaxation of breathable-coated leather (*lgt*=2.3) and film (*lgt*=1.7) is more readily observable than that one of split leather (*lgt*=1.7) where it is negligible. This also supports the presented hypothesis about the observability of the relaxation break point in a multilayered system if this one is observable in at least one layer of the system. It can also be noted that the film considerably decreases the stress relaxation values of split leather (Figure 3), and the rate of relaxation of breathable-coated leather is also higher (the curve of relaxation is more vertical) than that of split leather (Figure 4), i.e. in the breathable-coated fabric case also (Figure 2). So, it can be maintained that a breathable film decreases the stresses during the relaxation in coated materials, and increases the relaxation rate.

Conclusions

The stress relaxation process of the breathable-coated fabric depends on the properties of both fabric and film. The relaxation curves of the breathable-coated fabric and the outer polyester woven fabric in both warp and weft are different, despite the similar tensile properties, and are similar to the cross at a 45° angle despite different tensile properties. The breathable film decreases the stresses during relaxation in coated material, and increases the stress relaxation rate. The break point in the stress relaxation process is observable even in the system in which this is observable in at least one layer of the system. The investigations presented can be applied to behaviour prediction of the materials investigated in clothing and footwear manufacture and wearing.

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