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Effect of environment temperature on fatigue properties of laminated leather

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1. Introduction

Various multicomponent polymeric products containing materials of different nature and properties are used in consumer goods. One kind of these composite materials are the soft polymeric laminates used f or clothing products exploited in aggressive environment. Usually such soft laminates are composed of the layers of leather or textile and microporous or hydrophilic film (membrane). Advanced soft polymeric laminates often combine a set of different properties, for example, water impact, temperature and chemical resistance, and simultaneously a high possible permeability of water vapour [1-5].

A cyclic load is a very critical loading mode for laminates, because under fatigue failure occurs as the initiation and growth of a crack at loads significant lower than ultimate strength of the material [6]. Multilayer laminates under fatigue loadings experience damage, consisting of a multiplicity of failure modes, such as matrix cracking, delamination and fibre breakage [7]. With the increasing number of loading cycles this results in a continuous decrease not only of the residual strength, but also of the elastic modulus. Consequently, the fatigue life of a multicomponent material can be determined by its loss in elasticity modulus, rather than catastrophic failure [7]. The clothing products undergo a multiplex cyclic deformation during wear. Frequent reason of threadbare of clothing products is the material cracking in the creases areas which appear during wear. On the other hand, similarly to other materials, advanced laminates age, suffer physical or chemical degradation, accumulate micromechanical damage and become weaker during exploitation. Poor fatigue performance can significantly reduce the strength of multilayer composites, decrease the life cycle and compromise safety [8]. Microscopic cracks, which emerge at the beginning of exploitation, grow later to macrostructural damage and cause failure [9].

The parameters, such as environment temperature, stress amplitude, mean stress level, frequency and etc., have a great influence on fatigue lifetime behaviour [1]. Temperature also has a significant effect on fatigue crack growth and creep effect at elevated temperatures playing a critical role in the behaviour of adhesively bonded laminates [10-12]. One of such adhesively bonded laminates is laminated leather used for clothing products [3].

The goal of this research is to investigate the influence of environment temperature at cyclic flexing on the mechanical properties of laminated leather and its separate layers.

2. Testing procedures

The laminated leather and the materials of its layers (the split leather and polyurethane (PU) *Permair* film (commercial grade product of "Porvair plc.", UK)) were used for the investigation. Their characteristics are presented in Table.

The laminated leather was obtained by the lamination of the film to the split leather surface by hot pressing using water-born polyurethane adhesive with acrylic hardener [3]. Such structure imitates the leather with natural grain (Fig. 1). Microporous PU film perfectly protects leather from different external effects. However such coating changes rheological behaviour of the leather, which is very important from the technological aspect [13].

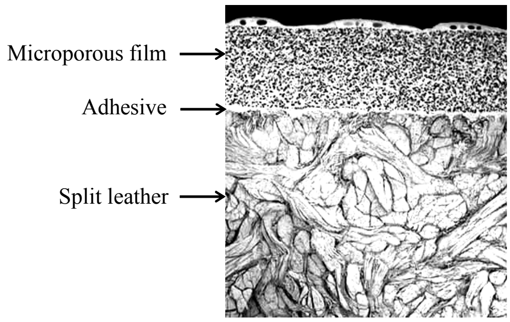


Fig. 1 Crossection of microporous PU film laminated leather [14]

Table 1

Characterization of the investigated materials

Sample	Material	Materials characterization
S	Split leather	Chrome-tanned bovine split leather 1.2 ± 0.1 mm of thickness grounded with acrylic leather ground STUCO in amount of 20 g/dm^2.
P	*Permair* film	Microporous polyurethane (PU) film 0.4 ± 0.05 mm of thickness; breathable film consists of interconnected pores with the diameter not higher than 5 μm.
L	Laminated leather	Soft polymeric laminates 1.5 ± 0.1 mm of thickness: microporous polyurethane membrane laminated to split leather surface by adhesive layer.

Test specimens for the flexing test were cut from the materials presented above in the shape of square of side 64 ± 1 mm. All specimens were conditioned in standardized atmosphere of 23 ± 2°C and relative humidity 50 ± 5% for the period no shorter than 48 h.

Double creases in the specimens are generated periodically by means of a relevant apparatus until they survive a specified number of flexure cycles. The test was performed according to the standard LST ISO 5423:1992. The apparatus consists of pairs of V-shaped clamps suitably mounted so that the axes of each pair are in the same straight line. The fatigue test was carried out using ”VAMP” flexing machine (“Pegasil/ZIPOR”, Portugal) with the aim to evaluate the occurrence of cracking in the area of greater flexion which forms arises during the use of footwear (Fig. 2).

Fig. 2 Fixation of the samples in flexing machine

One of the clamps is reciprocating at the frequency of 90 ± 9 cycles/min. (number of cycles $N_C = 10^5$). The equipment is placed inside a cold chamber so with the possibility to adjust the test temperature till −25°C. The testing temperature was changed from 20± 2°C to −20°± 2°C.

During testing, each test piece folds with an inward crease symmetrically across it, surrounded by a diamond of four outward creases. The tensile properties were investigated with 10 mm width strips which were cut only from that area. Mechanical properties of the samples were determined under tension by means of universal testing machine FP-10/1 (Germany). All the tensile tests were carried out with a strain rate of 100±10 mm/min under controlled temperature of 23 ± 2°C and relative humidity of 50 ± 5%. The engineering stress σ is defined as the ratio of the load to the area. The tensile strength was recorded as the ultimate stress at fracture. As the final result mean values of no less than 10 test results was assumed.

3. Results and discussion

As it is known, temperature is very important parameter of the fatigue life of polymers and composites. Polymeric clothing products during wear undergo fatigue at relatively not high positive and not low negative temperature of the environment.

The influence of environment temperature on tensile strength and elasticity modulus of laminated leather and its separate layers at break are presented in Fig. 3 and Fig. 4. All test pieces survived 10^5 flexure cycles.

It was observed that tensile strength of the split leather decreases marginally. Mechanical properties of tanned leather in great deal depend on the leather structure, topographical zone, from which the sample was cut, the nature and size of defects, therefore great variation of the obtained results is typical for these materials.

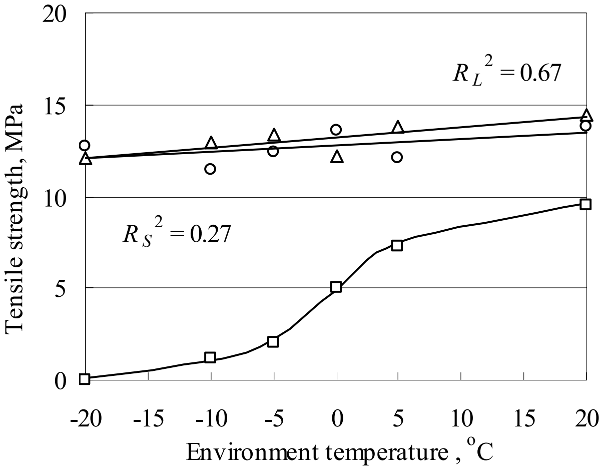


Fig. 3 Influence of environment temperature on tensile strength of laminated leather and its layers: Δ – laminated leather (L), ○ – grounded split leather (S), □ – PU film (P)

The experimental results showed that the dependencies of mechanical properties of laminated and split leathers after flexing in various conditions are similar, but differ from the analogous properties of elastomeric PU film.

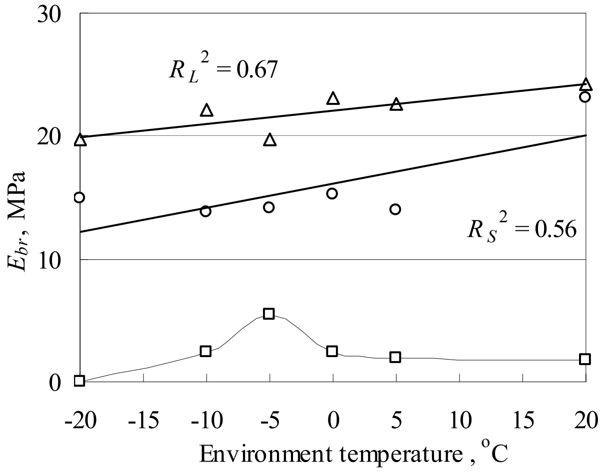


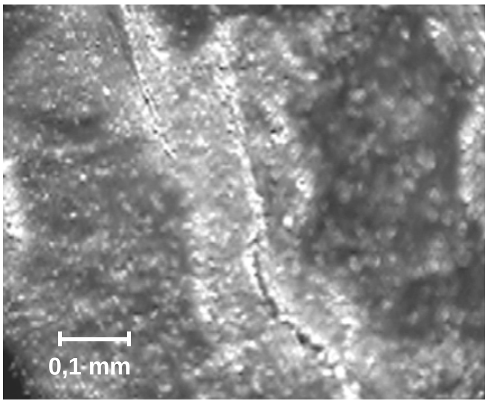
Fig. 4 Influence of environment temperature on elasticity modulus at break of the investigated materials: Δ – PU film (P), ○ – grounded split leather (S), □ – laminated leather (L)

It was observed that at fatigue loading the environment temperature has a great influence on mechanical properties of elastomeric PU coating film. As can be seen from Fig. 3, tensile strength of PU film reduces twice when the environment temperature decreases from 20°C to 0°C. Some samples (about 40%) fractured when flexing at -10°C and all the samples – at -20°C. It was established that the tensile strength of PU film and the environment temperature at flexing can be described by the following dependence ($R^2 = 0.9$):

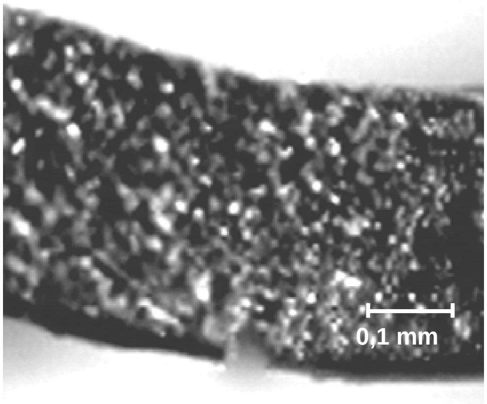
$$\sigma = 3.68arctg\left(\frac{T}{5.8}\right) + 4.9 \quad (1)$$

where σ is tensile strength, MPa, T is environment temperature, °C.

Microscopical analysis showed that the defects on the surface of microporous PU film samples appear at much higher temperatures (Fig. 5, a). It was determined that the depth of surface cracks is even about 13% – 16% of the overall thickness of cross-section of microporous PU film when flexing the test pieces at 0°C temperature (Fig. 6, b).



a

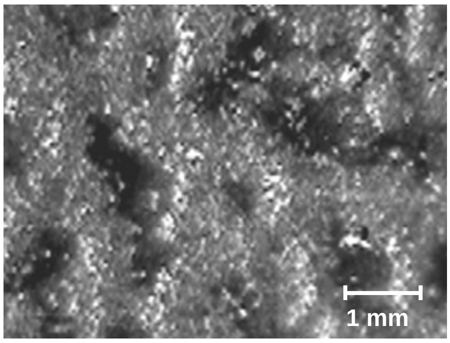


b

Fig. 5 The defects of microporous PU film samples flexed at 0°C ($N_C = 10^5$): a – surface, b – cross-section of crack

In the case of laminated leather its tensile strength and elasticity modulus at break reduces about 20% when environment temperature of fatigue loading decreases from 20 ± 2°C to −20 ± 2°C (Fig. 3 and 4). When the temperature is higher than 0°C, the defects on laminated leather surface were not observed even by microscope (Fig. 6, a). The defects on laminated leather surface become clearly visible when the temperature falls to ≤ -10 °C (Fig. 6, b). The depth of surface cracks varies from 65 % to 75% of the thickness of microporous PU film of the laminates (Fig. 6, c).

It is well known that the phenomena of self heating arises in polymeric materials under cyclic loading and is very important for fatigue limit of the polymers [9, 10]. Self-heating in the laminate depends on the nature and structure of all its layers and their interface.



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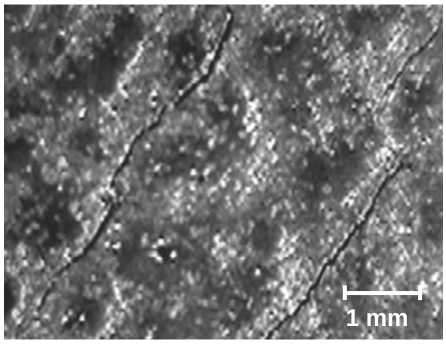

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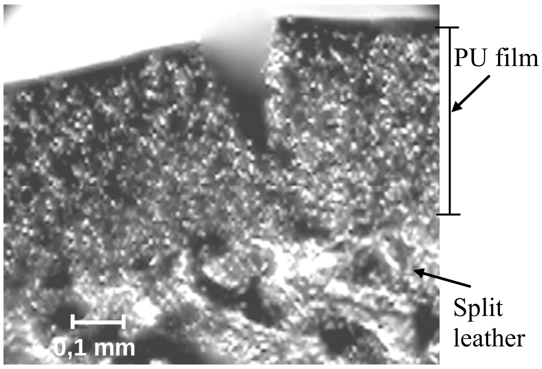

c

Fig. 6 Undamaged surface of laminated leather samples flexed at +20°C (a) and the surface creaks when laminated leather samples were flexed at -10°C: b – surface, c – cross-section of crack ($N_C = 10^5$)

The reason of such differences of laminated leather and PU film can be the different heating intensities of the material during the process of flexing. The self-heating is different for a separate PU film and a multilayer laminate.

4. Conclusions

The environment temperature has a great influence on tensile strength and deformability of separate microporous PU film.

The influence of environment temperature on analogous characteristics of laminated leather is not so high but is also significant. On the other hand the surface crack of laminated leather can influence on waterproof properties.

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D. Milašienė

VARGINIMO APLINKOS TEMPERATŪROS ĮTAKA LAMINUOTOS ODOS MECHANINĖMS SAVYBĖMS

R e z i u m ė

Straipsnyje pateikiami varginimo lankstant aplinkos temperatūros įtakos laminuotos odos ir atskirų jos sluoksnių (skeltinės odos ir mikroporingos poliuretaninės (PU) *Permair* plėvelės) mechaninėms tempimo savybėms (stipriui ir tamprumo moduliui) tyrimo rezultatai. Tiriamųjų medžiagų bandiniai buvo varginami keičiant aplinkos temperatūrą nuo 20 ± 2°C iki –20 ± 2°C (lankstymo ciklų skaičius $N_C = 10^5$). Gautos tirtų odų mechaninių savybių rodiklių priklausomybės nuo aplinkos temperatūros yra panašios ir visiškai skiriasi nuo analogiškų mikroporingosios plėvelės savybių. Laminuotos odos paviršiaus defektai tampa aiškiai matomi esant gana žemai lankstymo aplinkos temperatūrai (≤ -10°C).

D. Milašienė

EFFECT OF FATIGUE ENVIRONMENT TEMPERATURE ON THE MECHANICAL PROPERTIES OF LAMINATED LEATHER

S u m m a r y

In this study the influence of environment temperature on the mechanical properties (tensile strength and elasticity modulus at break) of laminated leather and its layers (split leather and microporous polyurethane (PU) *Permair* film) under fatigue flexing have been investigated. The testing was carried out by changing the temperature from 20 ± 2°C to –20 ± 2°C (number of cycles $N_C = 10^5$). The experimental results showed that the character of the dependences of tensile strength and elasticity modulus at break on temperature of fatigue environment of both leathers is similar and significantly differ from characters of analogous dependences of microporous PU film. The defects on the surface of laminated leather become clearly visible when the temperature falls to ≤ -10°C.

Д. Милашене

ВЛИЯНИЕ ТЕМПЕРАТУРЫ ОКРУЖАЮЩЕЙ СРЕДЫ ПРИ УСТАЛОСТНЫХ ИСПЫТАНИЯХ НА МЕХАНИЧЕСКИЕ СВОЙСТВА ЛАМИНИРОВАННОЙ КОЖИ

Р е з ю м е

В статье приведены результаты исследования влияния окружающей среды и усталостных испытаний на изгибание на механические свойства (прочность на разрыв и модуль упругости) ламинированной кожи и отдельных её слоёв (кожаного спилка и микропористой полиуретановой (PU) *Permair* плёнки). Испытания проводились в интервале температуры от +20 ± 2°C до –20 ± 2°C (число циклов $N_C = 10^5$). Определено, что зависимости механических характеристик обеих кожаных материалов от температуры окружной среды являются близкими и сильно отличаются от аналогических зависимостей микропористой PU плёнки. Видимые дефекты на поверхности ламинированной кожи появляются при температуре ≤ -10°C.

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