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The Study of Fabric Performance for Car Seats

Študija učinkovitosti tkanin za avtomobilske sedeže

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Abstract

This paper deals with the investigation of the performance of car seat fabrics in terms of physiological comfort of sitting, specifically their water vapour resistance and air permeability. The current work presents an alternative approach to increasing the effectiveness of car seat fabrics through a combination of newly designed middle layer with forced convection achieved by a supplementary suction ventilation device. The supplementary device was designed to measure water vapour permeability by means of the sweating guarded hot plate (SGHP) system. It consists of two parts: a frame to grip a tested sample for measurements within the SGHP system and two suction ventilators which are arranged at one end of the mentioned frame in order to provide suction into the tested fabric plane during the SGHP test. The results of this investigation show that water vapour transport is increased by approximately 20% compared to the standard way of measurement by means of SGHP because of forced air flow in the plane of ribbed – channelled structure of the car seat middle layer. The findings of this study have a number of important implications for future practice. The combination of a car seat cover with channelled structure and forced air flow improves physiological comfort of sitting which is a key issue for both drivers and manufacturers. The suggested device for forced air flow convection in the plane of a car seat fabric has not yet been part of an actual car seat, however it is possible to use its principles in a smart car seat prototype.
Keywords: physiological comfort, air suction, channelled fabric structure

Izvleček

V prispevku je predstavljena raziskava učinkovitosti tkanin za avtomobilske sedeže z vidika fiziološkega udobja sedenja, zlasti upora prehodu vodne pare in zračne prepustnosti. Raziskava je alternativni pristop k povečanju učinkovitosti tkanin za avtomobilske sedeže s pomočjo kombinacije na novo oblikovanega srednjega sloja in prisilne konvekcije s sesalno ventilacijsko napravo. Dodatna naprava je bila zasnovana tudi za merjenje prepustnosti vodne pare na kožnem modelu. Ta je sestavljen iz dveh delov: okvirja za preskušanje vzorca in dveh sesalnih ventilatorjev, ki sta nameščena na eni strani okvirja kožnega modela za zagotavljanje sesanja skozi ravnino preskušane tkanine med izvajanjem preskusa. Rezultati preiskave so pokazali, da se je zaradi prisilnega pretoka zraka v ravnini rebraste (kanalizirane) strukture srednjega sloja tkanine za avtomobilski sedež prehod vodne pare v primerjavi s standardnim načinom merjenja s pomočjo kožnega modela povečal za približno 20 odstotkov. Ugotovitve te študije imajo številne pomembne posledice za nadaljnjo prakso. Kombinacija prekrivne tekstilije avtomobilskega sedeža s kanalizirano strukturo in prisilnega pretoka zraka skozi kanalizirano strukturo izboljša fiziološko udobje sedenja, kar je ključno vprašanje za voznike in izdelovalce. Predlagana naprava za prisilno konvekcijsko gibanje zraka v ravnini tkanine še ni bila vključena v dejanski avtomobilski sedež, vendar je mogoče te principe uporabiti pri prototipu pametnega avtomobilskega sedeža.
Ključne besede: fiziološko udobje, sesanje zraka, kanalizirana struktura tkanine

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1 Introduction

Automotive seating and its comfort has long been part of research efforts [1, 2]. A seat consists of three parts: a metal armature, foam injected in a matrix (cushion), and textile structures (fabric) which cover the foam and armature. There is approximately 3–5 kg of car seat cover fabrics used in each car [3]. Car seat covers are often composed of several layers of different materials, usually polyester fabric, leather or synthetic leather laminated to polyurethane foam, 3D knitted spacer or nonwoven fabric held by an adhesive. Each part of a car seat cover is characterized by different properties which affect both its durability and comfort in automotive seating. Recently, car producers put an increased emphasis on the heat, moisture and air transportation properties of their car seat covers to ensure good physiological comfort for drivers. In order to understand the process, the effect of a heated seat on thermal comfort during the initial warm-up period, an ergonomic evaluation of thermal comfort inside a car, the measurement of sweating and other factors have been investigated [2, 4, 5]. Moisture management behaviour, thermal properties and air transport of 3D warp knitted spacer fabric (3D spacer) and polyurethane foam (PU foam), which are commonly used as padding in car seat covers, have been examined [6–9]. Thermal properties of porous nonwoven materials were analysed as well [10]. Majority of researchers have reached the conclusion that the appropriate choice of the car seat cover middle layer can improve physiological comfort even in complex car seats including PU cushion, though they cannot agree on whether PU foam or 3D spacer is better as a car seat cover middle layer. One group of researchers prefer polyethylene terephthalate (PET) fibres for automotive applications (both for top and middle layer) due to their superior properties, such as high tenacity, resistance to abrasion, light, heat and chemical aging, UV resistance, dimensional stability, recyclability etc. [8, 11, 12]. The others are in favour of modified PU foam (in the middle layer) because of its excellent elasticity and very good recovery to compression [12]. The study comparing the quality of different types of seat cover paddings was carried out from the point of view of physiological properties and relaxation behaviour after static and dynamic loading [13]. The result of this study showed that warp knitted spacer fabrics demonstrated better recovery to compression, better thermal properties and better breathability compared to PU foam. Further research found out that fabrics using monofilament as spacer yarn generally had higher compression resistance compared to multifilament yarns [8, 14]. Automotive producers usually use several techniques of heating and cooling to enhance physiological comfort of car seats. Two basic ways of cooling the car seats are suction or ventilation through all layers of the car seat, i.e. through the metal armature, foam injected in a matrix (cushion), and textile cover [15, 17]. The main disadvantage of this idea is that the heat and moisture (due to driver's sweating) cannot be sufficiently transported from textile cover to the other side of the car seat mainly because of a non-porous seat cushion. Therefore, the possibility of improving heat and moisture transport using suction along (in the plane) the textile structure of the car seat cover was investigated.

2 Experimental

The current study focused on improving the moisture management and transportation (especially of water vapour) using air suction along the ribbed (channelled) structure of the car seat cover middle layer. The new equipment was designed to simulate the abovementioned process within SGHP. It is assumed that a uniform flow into the internal structure of a car seat cover can be useful in increasing the transportation properties of covers.

2.1 Materials

A set of fourteen car seat fabrics (combination of different fabric structures in the top layer: different weave, raw material and surface treatment: embossed, etc.) with a different structure in the middle layer (nonwoven, foam, 3D spacer) were analysed and compared in terms of their physiological behaviour. The effect of the arrangement of these layers on air permeability and moisture management of car seat fabrics was monitored. The sample 14 presented a newly designed car seat fabric to improve the management of water vapour transport due to its channelled structure. The fabric 14 consisted of two layers. Top layer was rips woven fabric, the second one was warp knitted spacer fabric. There were transversely oriented channels (in warp direction) with gaps of 5 mm between channels in the second layer of the sample 14, see sectional view in Table 3. The size of the channel was approximately 3.5 mm.

Basic characteristics of all tested car seat fabrics are shown in Tables 1–3. Before being tested, the samples had been conditioned for 24 hours. The measurements were carried out in an air-conditioned room under constant relative humidity of 65% and the temperature of 21°C.

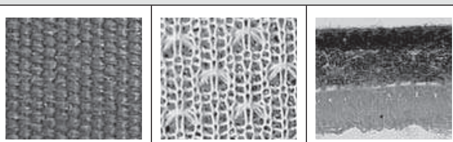
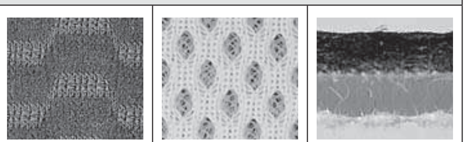
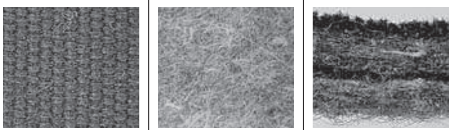
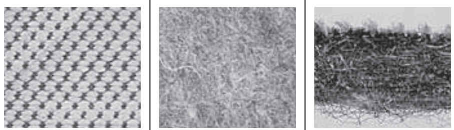
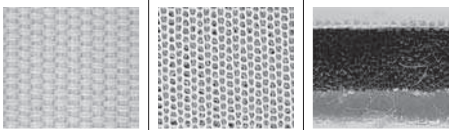
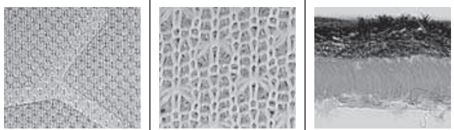
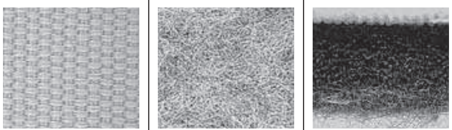
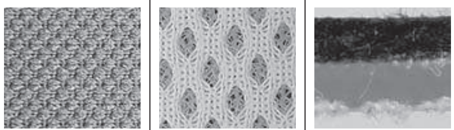
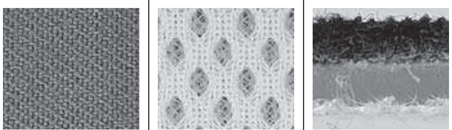
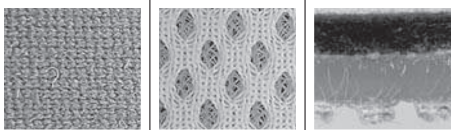
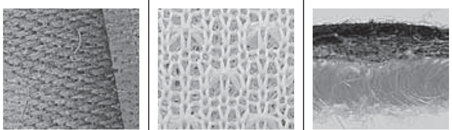
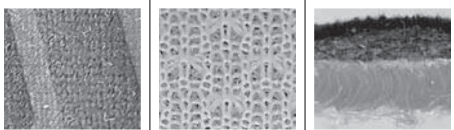
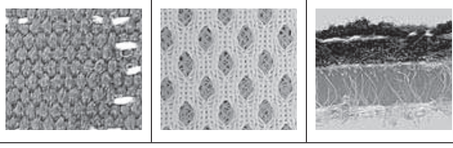
Table 1: Basic characteristics of tested car seat fabrics: structure and raw material

Sample	Structure/Top layer	Raw material			
		Foam	Nonwoven	3D spacer	Top
01	Weave/Uni rips hybrid	–	70% PES, 30%WO	100% PES	100% PES
02	Weave/Uni rips vlies	–	70% PES, 30%WO	–	100% PES
03	Weave/Uni rips	100% PU		100% PES	100% PES
04	Weave/Uni rips	100% PU	70% PES, 30%WO	–	100% PES
05	Weave/Clima hybrid	–	100% PES	100% PES	100% PES
06	Weave/Embossed hybrid	–	70% PES, 30%WO	100% PES	100% PES
07	Weave/Steppe hybrid	–	100% PES	100% PES	100% PES
08	Warp knit/Hybrid	–	100% PES	100% PES	100% PES
09	Warp knit/View embossed	–	70% PES, 30%WO	–	100% PES
10	Warp knit/View embossed hybrid	–	70% PES, 30%WO	100% PES	100% PES
11	Warp knit/View hybrid	–	100% PES	100% PES	100% PES
12	Warp knit/Suede hybrid	–	100% PES	100% PES	100% PES
13	Warp knit/Suede embossed hybrid	–	70% PES, 30%WO	100% PES	100% PES
14	Weave/Uni rips	–	–	100% PES	100% PES

Table 2: Basic characteristics of tested car seat fabrics: thickness, density, mass

Sample	Thickness [mm]		Density [kg/m³]		Mass per unit area [g/m²]	
	Foam	Nonwoven	3D spacer	Foam	Nonwoven	3D spacer
01	–	5	5	–	230	335
02	–	5	–	–	230	–
03	8	–	5	43	–	335
04	8	5	–	43	230	–
05	–	2	3	–	100	250
06	–	5	5	–	230	335
07	–	2	3	–	100	250
08	–	2	3	–	100	250
09	–	5	–	–	230	–
10	–	5	5	–	230	335
11	–	2	3	–	100	250
12	–	2	3	–	100	250
13	–	5	5	–	230	335
14	–	–	5	–	–	–

Table 3: Structure images of tested samples: face view, back view and sectional view

Sample	Face/Back/Sectional view	Sample	Face/Back/ Sectional view
01		08	
02		09	
03		10	
04		11	
05		12	
06		13	
07		14	

2.2 Methods

The experiment was divided into three steps:

- Measurement of physiological properties according to standards: water vapour resistance of the tested samples according to EN 31092:1993 (ISO 11092) by Sweating Guarded Hotplate System 8.2 (SGHP), and measurement of air permeability according to EN ISO 9237:1995 by TEXTEST FX 3300;
- Design of supplementary equipment to simulate suction in the plane of ribbed middle layer structure of the car seat cover;
- Measurement of water vapour resistance by the above mentioned supplementary equipment within SGHP.

The results of the above mentioned methods have been compared and discussed in order to understand the real performance of tested materials. The average values of all tested parameters correspond to five measurements. The coefficients of variation for all tests do not exceed 10% and are therefore not statistically significant.

Measurement of physiological properties according to standard

Water vapour resistance

Thermal resistance Rct [m^2K/W] and water vapour resistance Ret [m^2Pa/W] of samples were investigated in accordance with the EN 31092:1993 (ISO 11092) standard by a Sweating Guarded Hotplate

System 8.2 (SGHP). The SGHP device is often referred to as 'skin model'. The test simulated the transfer processes of heat and moisture through material next to skin and measured the rate of transfer of heat or moisture in such processes. The standard defines the setting up of the following conditions: an air temperature of 35 °C and a relative humidity of 40% for measurement of water vapour resistance. The measurements were carried out under the air velocity of 1 m/s.

Air permeability

Air permeability of tested samples was carried out in accordance with the EN ISO 9237:1995 standard using a TEXTEST FX 3300 device.

Supplementary equipment for suction simulation in the plane of a car seat structure

To simulate suction in the plane of a car seat structure, a **supplementary** equipment has been designed by our team. This equipment consists of two parts. There is a frame to grip a tested sample for measurements within SGHP. The suction into the tested fabric plane is provided by two suction ventilators which are arranged at one end of the mentioned frame, Fig. 1 and 2. The suction speed can be set within the range of 0.8–1.2 m/s.

The measurement process with the help of supplementary equipment was as follows. First, the tested sample was fixed onto the frame by tapping on pins which were located on the sides of the frame, Fig. 1a, b. In case of the sample 14, channels in the middle layer were oriented in the direction of flowing air to support the transport of water vapour caused by sweating of the driver. The test sample filled the gap through which the air flew, and its thickness didn't exceed the height of the gap, Fig. 1c.

Second, the frame was put on a sweating hotplate within the SGHP system. Further, the speed of suction was set and water vapour resistance was then measured according to the standard procedure by SGHP, i.e. air velocity was set to 1 m/s, air temperature was set to 35 °C and relative humidity was 40%.

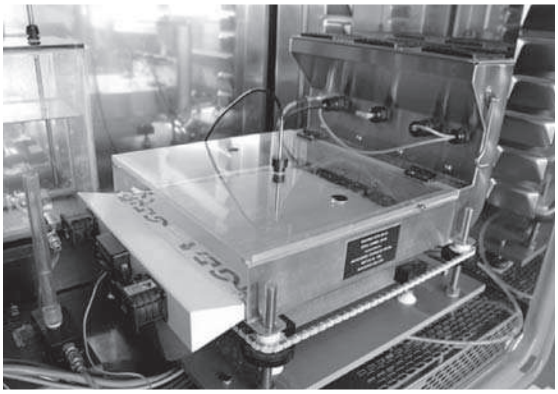


Figure 2: Water vapour resistance Ret measured using the supplementary equipment within SGHP

3 Results and discussion

3.1 Measurement of physiological properties according to standards

The results of water vapour resistance Ret [m^2Pa/W] and air permeability R [$l/min/100cm^2$] are shown in the Fig. 3 and 4.

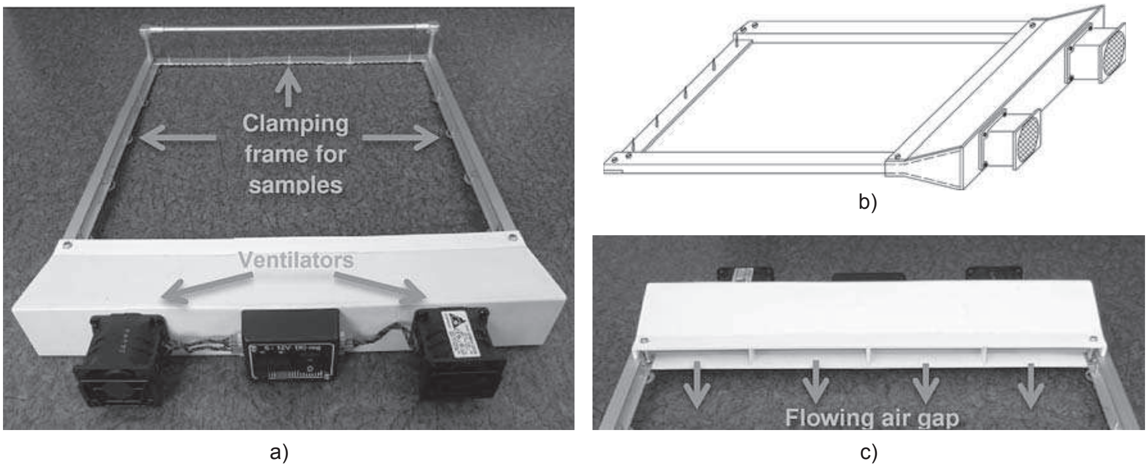


Figure 1: Supplementary equipment to simulate suction in the plane structure of a car seat cover

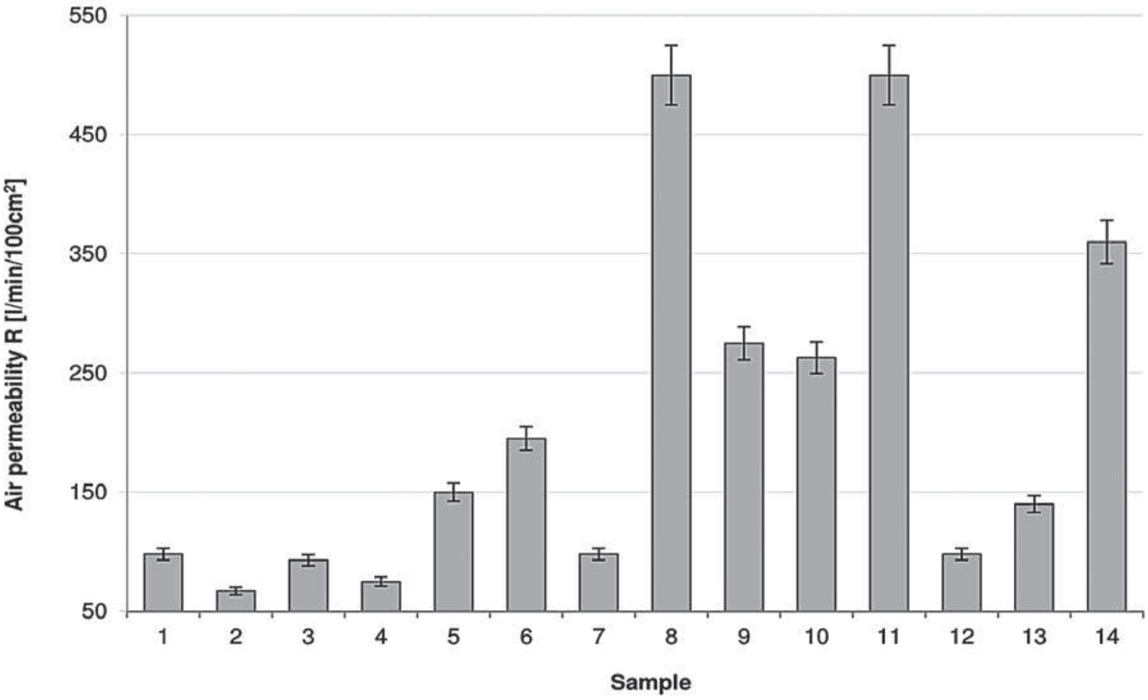


Figure 3: Water vapour resistance Ret of the measured samples

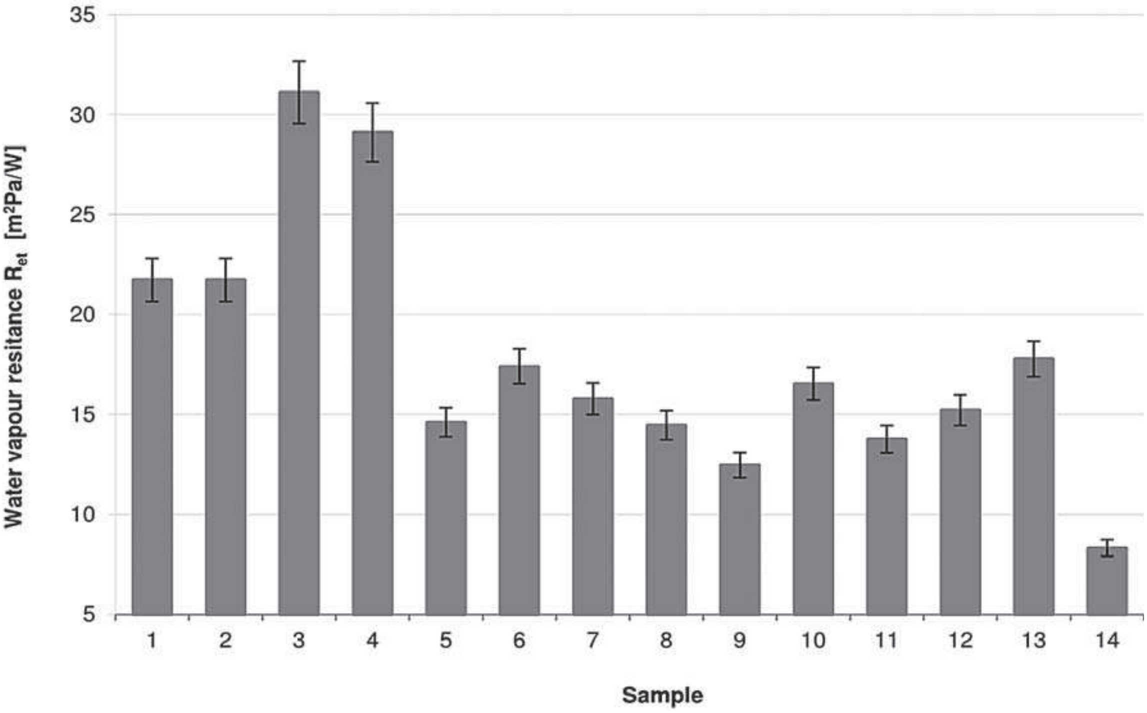


Figure 4: Air permeability R of the measured samples

The newly designed fabric 14 with the ribbed structure in the middle layer presented the best results. Further, the sandwiches 11, 8 and 9 also showed very satisfactory results of transporting air and water vapour. These results are likely to be related to the middle layer in the form of 3D spacer and nonwoven.

Both mentioned layers are very permeable compared to PU foam and their thickness and weight are appropriately set.

3.2 Measurement of water vapour resistance by means of supplementary suction equipment

To support the performance of water vapour transport inside the car seat fabric, the suction in the plane of the fabric was used during measurement using SGHP. Both measurements, with suction created by ventilators, and without suction (Fig. 1 and 2), were carried out and results were compared to each other.

The car seat fabrics 14 and 3 were tested by the supplementary equipment (to simulate suction) within SGHP because these fabrics presented materials with the best and the worst results. The rest of the sample group was not investigated due to the high time demands of the suggested measurement. The fabric 14 presented the best material in terms of the above mentioned measurements according to the SGHP standard (Fig. 3 and 4) unlike the commonly used car seat fabric 3 (PU foam in the middle layer) which exhibited air and water vapour impermeability. The purpose of the measurement was to determine whether forced air flow in the sample plane (e.g. the fabric 14 with high permeability or e.g. the fabric 3 – impermeable) would affect the efficiency of heat and humidity transport. To ensure forced convection in the plane of tested fabrics (especially along the channels of the fabric 14), the membrane was laminated to both top and bottom side of the tested sample. The Ret (according to classical way of SGHP) of the used membrane was about 6.

These results (Fig. 5) support the idea of improving water vapour transport of car seat fabric using the plane suction. Water vapour resistance of the tested fabric 14 decreased by approximately 20%. No increase in the ability of water vapour transport was detected for the sample 3.

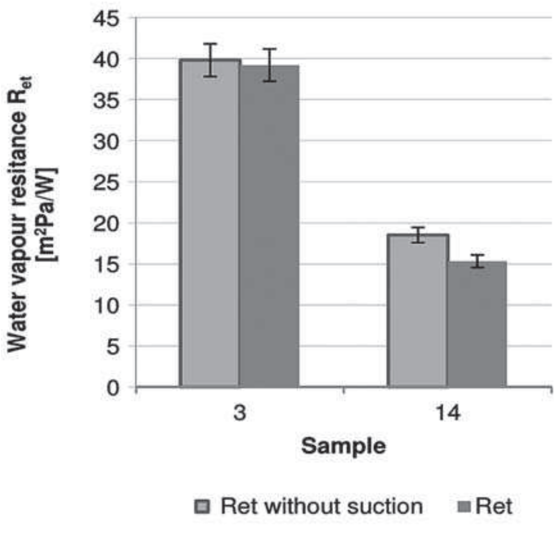


Figure 5: The water vapour resistance Ret measured using the supplementary suction equipment within SGHP

4 Conclusion

Thermo-physiological comfort is not just a pleasant feeling during sitting but most of all it improves the performance and concentration of drivers. The Department of Clothing Technology at the Technical University of Liberec has long been investing in the research to improve comfort through various inventions. Although some research has been carried out on the topic of physiological comfort and performance of the car seat fabrics, the recommended value of heat and moisture transport properties, which the car seat fabrics should reach, has not been determined yet. Generally, transport performance of car seat fabrics increases with the level of air permeability (degree of porosity). Unfortunately, the impermeable seat cushion degrades the transport properties of even the best permeable car seat materials. Therefore, the options to improve heat and moisture transport through suction along (in the plane of) the textile structure of a car seat cover were investigated in this paper.

Further, the present study was designed to determine the effect of air suction along the ribbed (channelled) structure of the middle layer of a car seat cover to improve water vapour transport. For that reason a new equipment was designed and used within the SGHP system. One of the more significant findings to emerge from this study is that suction in the plane of the car seat cover increases water vapour permeability significantly (by about 20%). A key strength of our research is the combination of the forced convection in the plane with ribbed structure. The principle of the suggested supplementary equipment (forced suction in the plane of the car seat fabrics) can be part of active car seats to help with the heat and water vapour transport.

Further studies need to be carried out in order to validate the above mentioned fact to other structures of car seat covers (with PU foam, nonwoven fabric or their combination).

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