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Abstract

The use of super absorbent polymers (SAP) for moisture absorption and comfort is still unexplored. The aim of this work was to observe the application of super absorbent fibres in car seats for comfort purposes. In this research the efficiency of different SAP fibrous webs were determined under different moisture percentages to examine the sorption and desorption efficiency. A SAP fibrous web with low thickness and high moisture absorption were tested with a multilayer sandwich structure of a car seat cover to determine moisture absorption through the cover material. The standard Cup method was used to determine the moisture permeability of different car seat covers with a superabsorbent layer closed with impermeable polyurethane foam. It was observed that the SAP fibrous layers are very effective in absorbing and desorbing water vapour under extremely high and low moisture percentages. In extreme humid conditions (95%RH), 20g of the SAP layer absorbs nearly 70% of its weight in water vapour, reaching the maximum absorption capacity in 6 hours.

Key words: car seat, comfort, poly-urethane, moisture permeability, super absorbent fibres (SAF).

numbness, stiffness and so on [3, 4]. Discomfort could easily come from the bad structural biomechanical design of the seat [5]. In this research our focus was only to remove excess perspiration moisture from a car seat. In this research a unique way is used to remove moisture by using a superabsorbent. Fibres absorb water vapour due to their internal chemical compositions and structure. Most textile fibres have a certain degree of moisture absorption capacity (called hygroscopicity). Moisture absorption influences heat and moisture transfer processes. For example, a wool fiber can take up 38% of moisture relative to its own weight [6]. The aims of this work were as follows

- Application of super absorbent fibres (SAF) in car seats for comfort purposes.
- Determining the efficiency of SAF in humid conditions.
- Measuring experimentally the absorption and desorption of moisture to SAF under humid and dry conditions, respectively.

Thermal comfort

Comfort has become the main quality standard of cars. Comfort in a car is complicated process and includes different features like driving, behaviour, noise and ease of handling [5]. Car seats are one of the main features of vehicle comfort. Seats not only have a striking design or meet specific design standards for safety reasons, they must also have optimal parameters of comfort. Apart from ergonomic considerations, thermophysiological comfort is of significant impor-

tance. At present, the thermophysiological comfort of car seats can be acquired by a set of laboratory test apparatus. It is now feasible to improve and calculate the thermophysiological characteristics of car seats at the development stage by using a skin model and seat comfort tester [6,7].

It is known that strong discomfort sensation arises due to a small quantity of water in the microclimate between the person and the car seat [8-12]. It has been confirmed in numerous researches that either moisture from sweating or additional moisture creates clothing contact sensations, where the wetness of the microclimate, for any reason, causes a discomfort sensation [13-17].

There are four factors of car seats from a physiological point of view:

- The preliminary heat flow on first contact with the seat. Especially the feeling of warmth or cold in the first few minutes or even seconds after entering the car.
- The dry heat flow on lengthy journeys, i.e. the quantity of heat transferred by the seat
- The capability, termed “breathability”, to transfer any sweat away from the body. In so-called “normal sitting situations” there is no distinguishable sweating, however the human body constantly discharges moisture (insensible perspiration), which has to be carried away from the body.
- Contingent on heavy sweating (a vehicle in summer heat and stressful traffic situations), the ability to absorb perspiration without a damp feeling of the seat.

Introduction

Since yarns are assemblies of fibres, it becomes important to understand how the fibres are arranged in the yarn cross-section or, Hertzberg [1] describes comfort as the absence of discomfort. The term “seat comfort” is usually used to describe the temporary relief of the human body felt while sitting [2] Discomfort is primarily related to biomechanical factors (such as joint angles, muscle contractions, and pressure distribution) that produce feelings of pain, soreness,

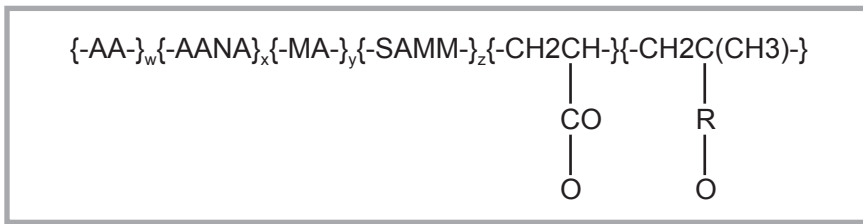


Figure 1. Chemical structure of SAF, where: -AA- = {CH₂CH(COOH)-} from acrylic acid -MA- = {CH₂CH(COOCH₃)-} from methyl acrylate, -AANA = {-CH₂CH(COONa)-} from acrylic acid and caustic soda, R = -COOCH₂CH(CH₃)-. The values of w, x, y and z depend on the amount of heat treatment received.

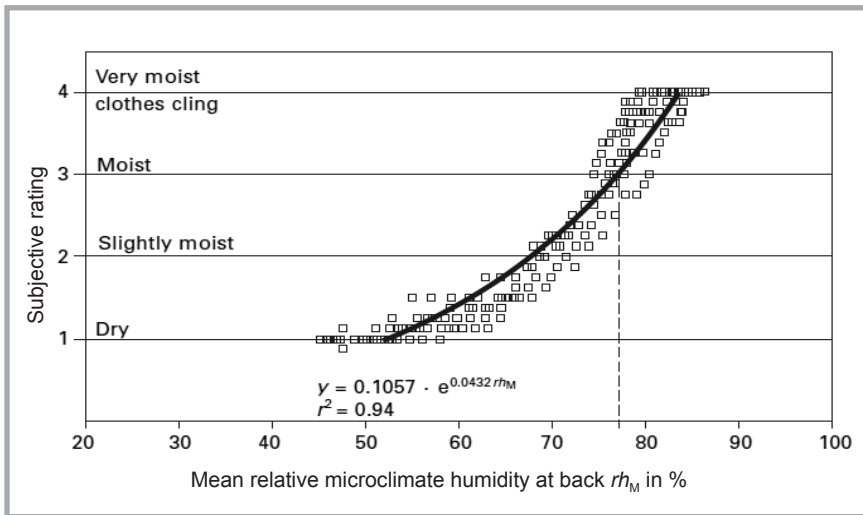


Figure 2. Subjective moisture sensation of human test subjects as a function of relative humidity in the microclimate between the skin and seat [10].

Super absorbent fibres (SAF)

Super absorbent fibres (SAF) or super absorbent fibrous material have been popular since the last decade to absorb and retain a high amount of liquids (nearly 300 times its own weight). The SAF used in this study was prepared from a cross-linked polymer consisting of three different monomers – acrylic acid (AA), methylacrylate (MA) and a small quantity of special acrylate/methylacrylate monomer (SAMM) – in which the acrylic acid is partially neutralised to the sodium salt of acrylic acid (AANA). The cross-links between polymer chains are formed as ester groups by a reaction between the acid groups in acrylic acid and the SAMM. The chemical structure of SAF is shown in **Figure 1**.

Moisture sensation

Water vapor transportation

The moisture sensation of a person is very significant for the observation of overall seat comfort. **Figure 2** reveals that a seated passenger can distinguish microclimate humidity between the skin and the seat [10].

To achieve a dry microclimate, the breathability of the seat for transferring sweat produced away from the body is critical. The human body continually discharges moisture called insensible sweating. Human body loses 30 grams of moisture per hour. As car seats cover a large area of the body, the seat has to accommodate a large part of perspiration produced, and thus a substantial quantity of moisture per hour. In order to maintain thermoregulation, the human body does not only produce insensible sweating but also sensible perspiration, as well as to cool down the core temperature of the human body through evaporation of sweat. Up to one liter/ hour of moisture can be produced during sports activity or hot surroundings [12].

For sensible perspiration, moisture is actively produced by sweat glands inside the human skin. However, the cooling effect desired can be acquired only from the evaporation of this moisture. This is the direct requirement from a vehicle seat, which has to permit this evaporation. Besides thermoregulation, the human body sweats further due to mental stress. This

stress driven sweating may be produced during car driving in tough traffic circumstances. Thus it is important that the seat delivers high vapour transport to permit the evaporation of perspiration for the majority of seating situations. The seats must have low water vapour resistance (i.e. high breathability). All parts of seats must be water vapour permeable as one single permeable layer may obstruct the transportation of water vapours [12].

Sweat buffering

Entering a hot car in summer, the human body starts to perspire excessively. This additional quantity of sweat has to be buffered to maintain a dry microclimate. The dominant components for the buffering capacity are linings and seat covers. For an adequate buffering capacity, both water vapour transportation and absorbency of water vapours are very pertinent. As revealed by researcher [17], water vapour transportation is of significant importance for a seat cover.

The impact of water vapour transportation on water vapor buffering becomes smaller when studying whole car seats. The thickness of car seats serves as barrier against diffusion because of their thickness. Consequently water vapour absorbency evaluates the water vapor buffering capacity for whole car seats. The underneath covering and lining material must be hygroscopic for acquiring swift absorption.

Fundamentals of moisture vapour transmission

Moisture vapour transmits through fibrous materials by the following mechanisms:

1. Diffusion of water vapour through the air gaps between fibres.
2. Absorption, transmission and desorption of water vapour by fibres.
3. Adsorption and migration of water vapor along the surface of fibre.
4. Water vapour transportation by forced convection.

Investigation of scientific literature revealed the keen interest of researchers to solve the issue of reliable determination of vapour permeability properties of textile materials. It is pertinent to design fabric with the moisture transmission properties required. The selection of the experimental procedure is the most important concern monitored during the evaluation of moisture transmission properties of a fabric or clothing system.

Heat and moisture transfer through fabric is evaluated in two conditions:

1. Steady state.
2. Transient state.

Steady state experiments deliver reliable heat and mass transfer data for non-active cases, but they are unable to demonstrate heat and moisture transfer mechanisms in actual wearing situations [18]. A number of test conditions, designs of devices and approaches facilitate the fundamental understanding and comprehensive learning of the vapour permeability process [11].

The evaluation of moisture vapour transmission through fabric is slow and sensitive but a very effective process. Different standard methods utilised for evaluating the moisture vapour transmission properties of textile substrates are:

1. Evaporative dish method or control dish method (BS 7209).
2. Upright cup method or Gore cup method (ASTM E 96-66).
3. Inverted cup method and desiccant inverted cup method (ASTM F 2298).
4. Dynamic moisture permeable cell (ASTM F 2298).
5. Sweating guarded hot plate method, skin model (ISO 11092).
6. Sweating manikins.

Experimental part

In this research, different compositions of super absorbent fiber (SAF) and car seat covers (from Company Martur, Turkey) were obtained.

The 3 SAF compositions used in this research are shown in **Table 1**.

The car seat covers obtained from the Company Martur were made of different layers as shown in **Figure 3**.

Properties of the X layer is shown in **Table 2**.

Whereas Layer Y is a thin PU-foam layer with a thickness of 6mm and density of 300 g/m², Layer Z is a thin mesh of polyester with a thickness of 1mm and density of 50 g/m²: this layer is used to make the sewing process easier as PU-foam is rough, compressible and causes stoppage of the sewing machine.

Methodology

SAF is famous for absorbing and retaining a huge amount of liquid, but moisture absorption and desorption is still an undis-

covered property of SAF. In this research, firstly the absorption and desorption properties of the SAF layers were measured. Then the most efficient SAF was used in between rear carseat layers to observe the effect of superabsorbence in the carseat assembly. The measurement was performed by the Cup Method (ASTM E 96-66) for moisture permeability.

Absorption desorption isotherm

Isotherm was obtained by the desiccator method, where the specimen was put in a sealed container with different amounts of various saturated salt solutions until weight equilibrium could be assumed. Different salts were used to obtain the humidity level required in the sealed containers. Table III shows the relative humidity (RH%) obtained in different sealed containers at 20°C.

The specimens were pre dried at 7% RH prior to the absorption/desorption isotherm experiment. The specimens were weighed after every 4 days to a maximum of 12 days. Each container contained 4 samples: A, B, C and P (PU-foam). Each set of containers (5 containers with different percentages of the humidity level) were opened after 4, 8 and 12 days, respectively; a total of 15 containers were used in lab conditions of temperature 20°C. Weighing the samples after different days gave us information whether the material was still absorbing moisture, and if there was no difference in moisture gain from the last set of measurements (4 days and 8 days), then it was considered as the maximum moisture absorbed by the sample.

Table 1. SAF properties.

	Composition	Structure	Areal weight, g/m ²	Thickness, mm
A	Polyester staple fiber	Needle felt, non-woven	570	5.4
B	Fluff pulp	Bi component fiber	130	1.6
C	Polyester staple fiber	Super absorbent yarn netting, laminated with PES weave	115	1

Table 2. Top woven layer of car seat.

Woven pattern	Raw material	Warp density	Weft density	Cross section	Density, g/m ²	Yarn number	Filament number	Texture type
1x1 plain weave	100% Polyester	24	17	round	160	300	96	Air twisted yarn

$$\text{Moisture amount change \%} = \frac{(\text{New weight of sample} - \text{original sample weight})}{\text{original sample weight}} * 100$$

Equation (1).

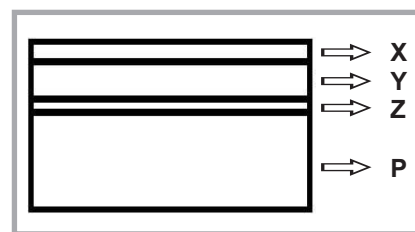


Figure 3. Layers of carseat, where: X is the top fabric layer which touches the person/driver; Y is the second layer made of thin poly-urethane foam, Z is thin porous polyester mesh, P is 5 cm thick PU-foam.

Climate chamber measurement

The absorption and desorption of samples were also tested in a climate chamber where the temperature was set as 20°C and the RH changed from 7% to 95%. The absorption and desorption of the specimen are calculated by **Equation (1)**.

Each sample was weighed inside the chamber after every 1 hour. This experiment gave valuable information regarding the time and efficiency of absorption and desorption of specimens. The experiment was repeated 3 times.

Standard upright cup method

The standard upright cup method or Gore cup method (ASTM E 96-66) was used to analyse the overall loss of water from the reservoir. A car seat cover material with a classic layer structure of X,Y, Z and P was first analysed and then an SAF layer was inserted between layers X and Y to determine the effect of the SAF layer on the moisture resistance of the complete sandwich material. Layer P was a thick PU-foam and is well-known for being

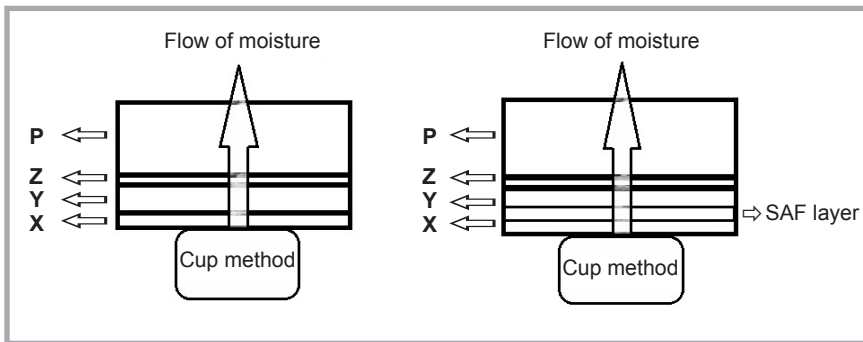


Figure 4. Visual illustration of specimen layers during testing.

impermeable and acts as a moisture barrier from the reverse side of the sandwich material. The PU-foam protects the SAF so as not to absorb moisture from the chamber environment; hence the results of the Cup method were precise as the flow of moisture was only from the top Layer "X". A visual illustration of the samples is shown in *Figure 4*.

Reasons for methodology used

The absorption isotherm technique using salt is a very common method to measure the amount of moisture absorbed by the material over a long time. The experiment time is relatively high and human touch during measurement of the weight can cause error. To compensate for this, a climate chamber was used to compare the results of absorption and desorption. Finally the sandwich layers were tested using the Cup-method to avoid any external load on the sample, and finally the moisture permitted through the complete sandwich layers could be obtained.

Results and discussion

The specimen was put in a sealed container with different amounts of various saturated salt solutions until weight equilibrium could be assumed. 4 samples were placed in each container with 5 different salt solutions and tested after 4, 8 and 12 days; therefore a total of 15 containers were used for this experiment.

Table 3. Salt solution and RH% in closed containers.

	Salt solution	RH%
1	Distilled water	100
2	Pottasium chloride	85.1
3	Sodium bromide	59.1
4	Pottasium carbonate	43.2
5	Lithium chloride	11.3

Different salts, as shown in *Table 3*, were used to obtain the humidity level required in the sealed containers. *Figure 5* shows the percentage gain of moisture with respect to time.

It is observed that the SAF's absorbed nearly 70% moisture in relation to their weight at 100% RH. Specimen "A" showed the highest rate of moisture gain measured after 12 days. There was no difference between the measurement taken after 8 days and 12 days of testing, and results observed after 12 days can be considered as the maximum moisture absorbed by the sample. The process of testing the samples with different salts providing different humidity levels is quite slow but provides accurate results.

The PU-foam sample gained less than 2% moisture after 12 days.

The absorption and desorption of samples were also tested in the climate chamber, where the temperature was set as 20°C and the RH varied from 7% to 95%. The experiment was repeated 3 times, with the average value shown in the figure below. *Figure 6* shows the rate of absorption and desorption of samples.

Specimen A was inserted in between the car seat sandwich layers, as shown in *Figure 3*, to test the water vapour permeability cup method (ASTM E 96-66). The car seat was covered by PU-foam, which is impermeable to moisture. The presence of the superabsorbent helped in the absorption of moisture through the top layer of the fabric and caused a decrease in the water level in the cup.

The superabsorbent layer was pre-dried at 35% RH, which is the average ambient humidity inside a car. The layer is then inserted in between the car seat layer, as shown in *Figure 3*.

As shown in *Figure 7*, it was observed that the material became highly breathable for the first 4 hours of testing, and after that it was still much better than the original sample's breathability. The experiment was repeated 3 times, with average values shown in the graph. The results show a significant difference in moisture transport when a superabsorbent is used.

Conclusions

The following is concluded from this research

- The superabsorbent material is efficient to absorb and desorb water vapour, and a 50% and higher rate of absorption can be easily achieved under extreme humidity.
- The fast sorption and desorption process can be repeated multiple times, showing potential use for the comfort of car seat covering.
- The use of superabsorbent causes a significant change in the moisture permeability from the top layer of the original seat cover.
- The use of a superabsorbent can be a cheap method in future to increase the comfort of car seats without the use of expensive ventilation systems.
- The research was an initial work to observe the utilization of an superabsorbent in carseat. This is a novel work and further research will be done regarding the life time of the SAF in carseats.

Acknowledgement

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Future works

The use of SAF is still unexplored for the carseat, and the future testing of SAF with different assemblies of carseats will be undertaken as well as the performance under load examined. The life time study of SAF is also an interesting research area to explore.

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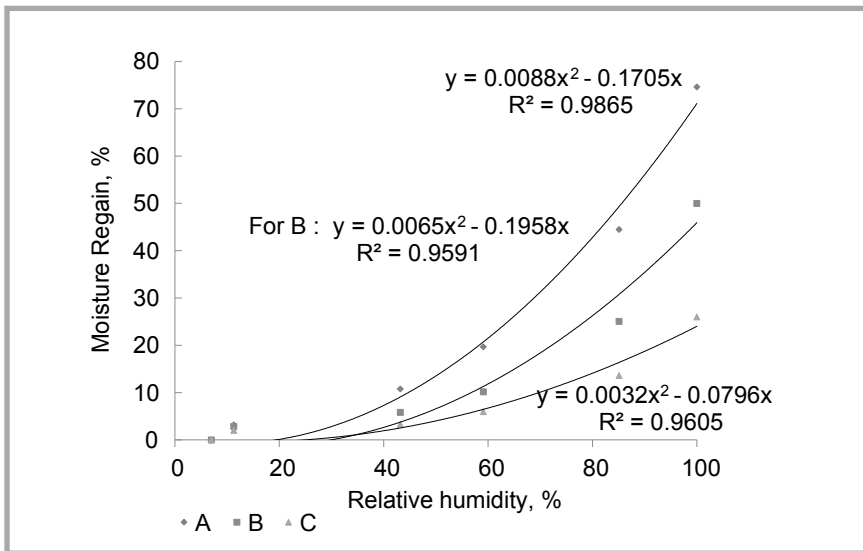


Figure 5. Moisture absorption with respect to time.

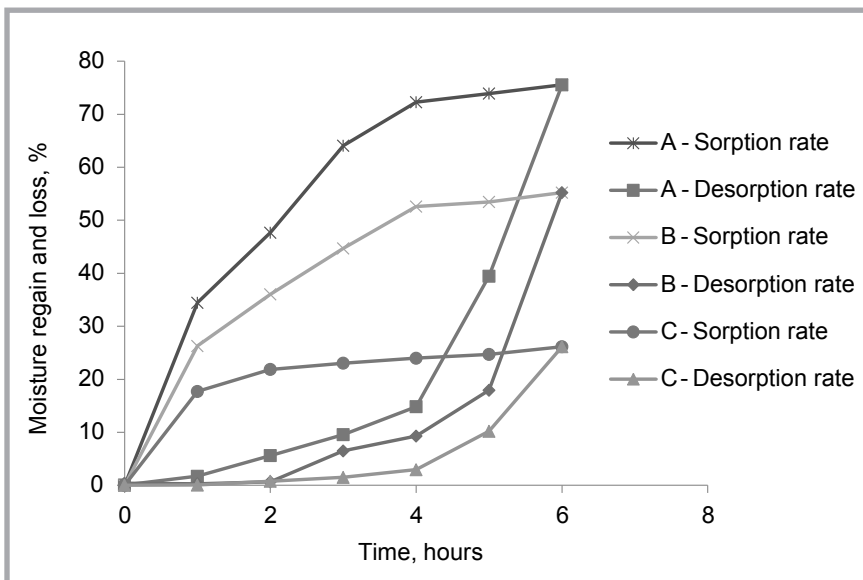


Figure 6. Rate of absorption and desorption.

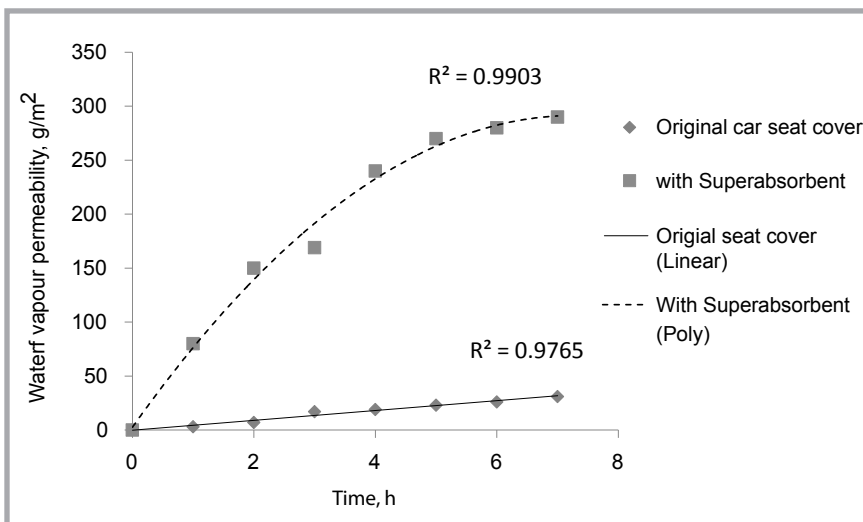


Figure 7. Effect of superabsorbent on water vapor permeability.

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