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Testing the car seats' comfort

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ABSTRACT

In this paper, four commonly used car seat covers, made from leather as well as from woven, knitted and 3D spacer fabrics are tested as sandwiched and separate layers to determine the effect of the lamination and layers on air and water vapor permeability. Different combinations of interlining materials are also tested to obtain the optimum comfortable car seat cover. This analysis gives us a real idea of which layer negatively affects the breathability of the car seat. The focus of this part of research was to identify the issues within the car seat material instead of factors like external cooling or the clothing of the driver. It was observed that the polyurethane (PU) foam and lamination significantly reduce the permeability of the car seats. The 3D spacer fabric shows the best top layer properties as compared to classical woven, leather or knitted car seat covers. The research shows how layers and lamination cause thermo-physiological discomfort of car seats.

Keywords
Comfort,
heat transfer,
car seat

1 Introduction

Car seats are meant to be safe, comfortable and durable. The comfort part is usually neglected because of complex structure of the seat and hesitation of experimenting new materials, as durability and safety are much more important for the car producers. During the last two decades, the demand of the customers forced the producers to prioritize the development of the car seat considering better ergonomics and breathability [1]. In this research the focus remains on the thermo-physiological comfort, neglecting the other factors like ergonomics, external cooling, etc.

Car seats do not only have to be designed for safety, they must also have ideal comfort properties. But seat comfort is much more than just passenger convenience. Scientific findings show that the performance of a driver over long distances significantly decreases if the car seats do not support posture and heat balance as required. This leads to exhaustion and loss of concentration, which, in extreme cases, could result in serious accidents [2, 3].

There are multiple factors which make up the comfort seat, but in this research we will keep the focus on the thermo-physiological comfort. From the physiological point of view, comfort of car seat has 4 phases [4]:

i. The first touch: This is the first warm-cool feeling which the driver gets on initial touch.

ii. The long-term comfort: The transfer of dry heat from driver through the car seat.

iii. Breathability of the material: The transfer of moisture and air through the car seat.

iv. Heavy perspiration: In the event of heavy perspiration (a car in the summer heat, stressful traffic situations) the ability to absorb perspiration without the seat feeling damp.

Liquid and moisture transfer in the textile materials includes [5-8]:

- diffusion,
- sorption,
- forced convection.

In this research, two classical ways are used to determine the breathability of the car seats. Moisture vapor transmission parameters are calculated by following different standard methods [9]:

i. The sweating guarded hot plate, skin model (ISO 11092)

ii. Air permeability by FX3300 (ISO7231)

The objective of this research is to analyze the thermo-physiological properties of car seat covers as sandwiches and separate layers and to find the optimum combination of layers for a better comfort performance.

In this research all the sandwiched car seats and each layer separately are obtained from the company MARTUR to determine the effect of each layer and the lamination.

2. Methodology

The experimental part of the research included different combination of car seats cover and the lining material including poly-urethane foam. The classical car seat is made of multiple layers as shown in Figure 1.

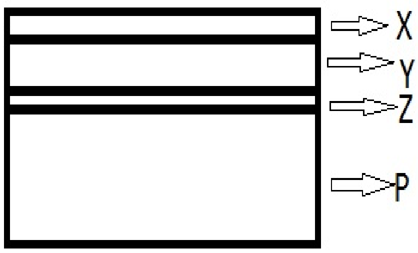

Figure 1. Layers of car seats

The layer details are listed below:
X is the upper fabric layer which is in contact with the person/driver
Y is the following layer made of thin polyurethane (PU) foam
Z is a thin porous polyester mesh (used to decrease friction during the sewing process)
P is a dense PU-foam (8 cm thick)

A set of samples was obtained from the company MARTUR (Turkey), which is a famous car seat cover producer in Europe. All these layers are obtained as sandwiched as well as single layers to identify the effect of lamination. The constructions of woven top layers are shown in Table 1.

Table 1. Car seat cover sandwich combinations

Car seat sandwich	Layer X	Layer Y	Layer Z	Layer P
1	Knitted	Perforated PU-foam, 5 mm	100% Polyester mesh 1.5 mm	8 cm PU foam
2	Woven	Perforated PU-foam, 5 mm	100% Polyester mesh 1.5 mm	8 cm PU foam
3	Leather	Perforated PU-foam, 5 mm	100% Polyester mesh 1.5 mm	8 cm PU foam
4	3D spacer fabric	Perforated PU-foam, 5 mm	100% Polyester mesh 1.5 mm	8 cm PU foam

As shown in Table 1, besides layer X, all other layers are identical. The properties of the layer X are shown in Table 2.

Table 2. Properties of car seat cover layers

Layer X	Material	Thickness (mm)	Areal mass (g/m^2)
1	Knitted, 100% polyester	5.1	245
2	Woven, 2/1 twill, 100% polyester	5.2	230
3	Natural leather, porous	4.8	297
4	3D spacer fabric, warp knitted	5.4	280

3. Results

Car seats are made of multiple layers and each layer has unique importance for the comfort, durability or lifetime of the car seat. The top layer is mostly made permeable to air and moisture, while the bottom and middle layers made up from PU-foam are known for being impermeable to moisture or air. But PU-foams are easy to use, cheap to produce, durable and long-living, so they are an essential part of the car seat. For this research all material types mentioned in Table 1 are tested for air and moisture permeability. Table 3 shows the air permeability of each layer of the car seat cover separately. It was measured by a device FX 3300 according to the standard ISO 7231.

Table 3. Air permeability of each layer separately

Air permeability ($L/m^2/s$) ± standard deviation				
Car seat sandwich	Layer X	Layer Y	Layer Z	Layer P
1	3200 ± 86	780 ± 60	9400 ± 420	14 ± 2
2	2400 ± 72			
3	1260 ± 41			
4	4900 ± 52			

All these layers are attached together using a copolymer polyamide powder. This is a very economical way, and the majority of the car seat cover producers use this technique. To see the effect of the lamination on the air permeability, the sandwiched car seat (already received as laminated by the producer) which is a combination of layers X, Y and Z was tested by the device FX 3300 (Table 4).

Table 4. Air permeability of laminated and non-laminated car seat's cover

Air permeability (L/m^2/s) ± standard deviation		
Car seat sandwich	Layer X + Y + Z by lamination	Layer X + Y + Z without lamination
1	220 ± 8	510 ± 12
2	180 ± 7	407 ± 18
3	120 ± 4	310 ± 14
4	310 ± 5	620 ± 22

These results clearly show that the lamination (to stick each layer together) significantly affects the air permeability of the car seat cover, as the lamination closes the pores of the woven or knitted textile layer and blocks the flow of air. The lamination is mostly a polymeric material which melts to connect the two layers.

Figure 2 shows the percentage change for the air permeability of the car seat cover after lamination. It is more than 50% of change and the highest was recorded for the leather material.

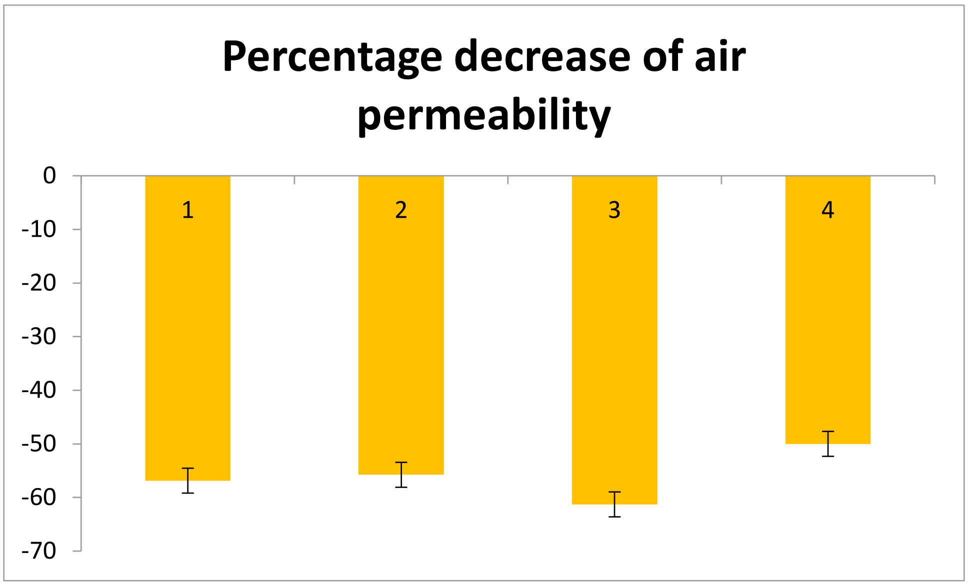

Figure 2. Percentage change of air permeability

The set of sample was also tested for the water vapor resistance with the machine Atlas Sweating Guarded Hot Plate (SGHP using standard ISO 11092. Each experiment is repeated 5 times for mean value.

To measure the water vapor permeability, the device Sweating Guarded Hot Plate was used according to standard ISO11092. Each sample was tested for 5 times. It is visible from Table 5 that the layer 4, i.e. the 3D spacer fabric, is very permeable to water vapor, followed by the knitted fabric, the woven fabric and finally leather.

Table 5. Water vapor permeability of each layer separately

Water vapor permeability (m^2Pa/W) ± standard deviation				
Car seat sandwich	Layer X	Layer Y	Layer Z	Layer P
1	5.56 ± 0.89	12.6 ± 1.5	2.2 ± 0.5	(not permeable)
2	6.37 ± 0.97			
3	12.2 ± 1.23			
4	4.2 ± 0.56			

Similarly as for the air permeability test, the water vapor permeability test was also performed for sandwiches (X + Y + Z) with laminated and non-laminated layers to see the effect of lamination on water vapor permeability (Table 6). The results show that lamination significantly decreases the water vapor permeability by approximately 30-70%.

Table 6. Water vapor permeability of laminated and non-laminated cover

Water vapor permeability (m^2Pa/W) ± standard deviation		
Car seat sandwich	Layer X + Y + Z by lamination	Layer X + Y + Z without lamination
1	19.5 ± 0.9	15.2 ± 1.2
2	22.7 ± 0.7	17.1 ± 1.7
3	27.4 ± 0.3	19.4 ± 1.3
4	15.3 ± 0.4	12.6 ± 2.7

The standard rating for comfortable water vapor resistance values is shown in Table 7.

Table 7. Water vapor resistance and comfort grading

Water vapour resistance (m^2Pa/W)	Performance
0-6	Extremely breathable
6-13	Very Breathable, comfortable at moderate activity rate
13-20	Satisfactory but uncomfortable at high activity rate
20-30	Unsatisfactory
30+	Uncomfortable and short tolerance time

There are multiple interlining materials (Layer Y) available in the market that differ in properties and thickness. The research was further extended to see the effect of different interlining on the car seat cover. In this part the most permeable top layer X, which was the 3D spacer fabric, was taken to measure the effect of interlining on the overall performance of the car seat cover. From the previous experiment, we know that that lamination causes more than 50% decrease of air and water vapor permeability, so this test was performed with the lamination.

Table 8 shows the thickness of different interlinings which are commonly used in car seats. It is easily seen that 3D spacer fabric shows minimum thermal resistance, water vapor resistance and the highest air permeability; both these factors plays a significant role for the thermal comfort of the car seat

The top layer X used in this experiment is the most permeable one, i.e. a 3D-spacer fabric with an air permeability of (4900 ± 52) $L/m^2/s$, combined with different interlining materials (Table 9).

Table 8. Thickness of interlinings

Samples	Interlining materials (layer Y)
1	3.6 mm PU-foam
2	5.6 mm PU-foam
3	6.7 mm PU-foam
4	8.5 mm PU-foam
5	3D spacer 3.6
6	3D spacer 4.8 mm
7	3D spacer 6.5 mm
8	Non-woven felt 4.5 mm
9	Non-woven felt 8.5 mm

Table 9. Air permeability of car seat covers with different interlining materials

Air permeability (L/m^2/s) ± standard deviation		
Samples	**Interlining materials (layer Y)**	**Sandwich layers (X+Y)**
1	450 ± 22	425 ± 21
2	430 ± 18	398 ± 12
3	408 ± 19	375 ± 17
4	380 ± 20	345 ± 14
5	4100 ± 36	3700 ± 72
6	3900 ± 39	3450 ± 32
7	3500 ± 32	3321 ± 28
8	650 ± 12	620 ± 9
9	625 ± 18	589 ± 11

It is visible that by using the 3D spacer as the interlining significantly improves the breathability of the car seat. But overall there is a significant decrease in air permeability when interlining (Layer Y).

In the car seat cover materials, the air permeability and water vapor resistance show very similar trend and performance, and the effect of the interlining materials can be easily predicted.

5. Conclusion

It can be concluded from our research that highly permeable top layers alone cannot improve the overall breathability of the car seat. The problem zone for the breathability will always be the PU-foam and the lamination. The focus should be to use a breathable layer with improvement to the lamination and the PU-foam for better permeability. The car seat comfort should be evaluated considering overall car seat, not just the top layer. There was a significant 50% decrease in breathability due to lamination.

In this research different car seat materials are compared amongst which the 3D spacer fabric shows a great improvement for the car seat thermal comfort. Using 3D spacer fabric can reduce the number of layers of car seat cover, as higher numbers of layers negatively affect the thermal comfort of the car seat. The high thickness variety of 3D spacer fabrics gives the opportunity to use them as car seat covers as well as cushion part of the car seat.

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