An Investigation on the Air Permeability of Automobile Seat Cover Fabrics

Gülşah Pamuk, Ph.D. student
Prof. Dr. **Fatma Çeken**, dipl.eng*
Ege University, Tire Kutsan Vocation School
Tire-Izmir, Turkey
*Dokuz Eylul University, Textile Engineering Department
Bornova-Izmir, Turkey
e-mail: gulsah.pamuk@ege.edu.tr

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The level of interaction between passenger-drivers and vehicles has been increasing continuously from the date of transportation vehicles invention to today. Particularly in automobiles the seats have an important role for the comfort of the driver and the passengers. The components of a seat affect thermal comfort while the design of the seat has a big impact on anthropometric comfort. A considerable effort has been devoted to the seating comfort from the point of anthropometrics and ergonomics view. However, according to our literature research there has been no experimental study which measures the relative thermal comfort performances of automobile seat cover fabrics. In this study, air permeability of several automobile seat cover fabrics produced using different techniques are measured and then compared. The automobile seat cover fabrics produced using 7 different production techniques were provided by several important automobile seat fabric manufacturers in Turkey, and were tested in the form in which the fabrics were supposed to be used in vehicles.

Key words: *automobile seat cover fabrics, air permeability, one way analysis of variance*

1. Introduction

Automotive seats play an important role in improving the comfort and work of drivers and passengers [1]. There are two types of seating comfort. The first is anthropometric comfort related to the design of the seat, and the other is thermal comfort.

Much study in ergonomics and anthropometrics literature has been devoted to the seating comfort. Park et al (2000) developed a driving posture monitoring system (DPMS) consisting of a seat, computer, power motor and controller. The authors employed three-dimensional motion analysis system to obtain the postural angles of the segments for a comfortable driving postures of the subjects. In addition, anthropometric data for each subject were directly measured and used to investigate relationships among anthropometric characteristics (body segment lengths), preferred postural angles and seat adjustment level. Using the relationships, the authors discussed comfortable driving postures and seat adjustment levels according to gender [1]. Reed, Schneider and Ricci (1994) conducted a large body of literature review about automobile seat design recommendations on comfort parameters, including pressure distribution and vapor permeability, and support parameters defined with respect to seated posture. Reed et al. (1994), pointed out that particular attention was given to appropriate lumbar support configurations, and discussed the limitations of the basis for current design recommendations, and also explored the need for future study of postures and spine contours selected by drivers [2]. In the study by Kolich and Taboun (2004) a stepwise, multiple linear regression model was developed and validated. This model related seat interface pressure characteristics with occupant anthropometry, occupant demographics, and the perceptions of seat appearance to an overall, subjective comfort index derived from a survey with proven levels of reliability and validity [3].

Heat is transferred away from body surface by conduction, convection, radiation, and evaporation. At the interface between the sitting person and the seat, conduction and evaporation are the primary means of removing heat from the skin surface. Body heat and water vapor must be allowed to pass through the seat. Seat covers must not impede heat or water vapor transfer for thermal comfort [2]. The air permeability of a fabric shows how well it allows the passage of air through it [4]. A material that is permeable to air is, in general, permeable to water, in either its vapor or liquid phase. Thus, air permeability is closely related to moisture-vapor permeability and liquid-moisture transmission [5] having important influences on the fabric comfort behavior. This observation has been the motivation for the present work which measures the relative air permeability performances of automobile seat cover fabrics.

In the current study, we compare air permeability of several automobile seat cover fabrics produced using different techniques. In Section 2, the materials and methods used in the study are introduced. In Section 3, the differences among fabric types according to air permeability values are tested using one-way analysis of variance procedure, and multiple comparisons made by using the Fisher's the multiple comparisons method. In Section 4, the results of statistical tests are evaulated in detail.

2. Material and method

This section comprises an experiment wherein 7 types of fabrics, commonly used for automobile seat covers, were tested for air permeability. The total number of samples was 28. The total number of samples combines 5 flat woven, 7 woven velour, 3 circular knitted flat, 7 circular knitted pile, 3 warp knit flat, 1 warp knit pol, and 1 warp knit double bar raschel (DNBR). All the fabrics, except for the woven velour, were in the three-laminated form.

The samples taken from the automobile seat cover fabrics were tested on Textest FX 3300 air permeability machine according to the ISO 9237 to determine air permeability of the fabrics. Ten air permeability measurements for each fabric type in total 280 measurements, were made. Information on

Tab.1a Flat woven automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Warp: 100% PES Weft: 100% PES	666 666	479.15	7.08	3.22	0.09
Warp: 100% PES Weft: 100% PES	655 916	427.71	13.54	3.35	0.11
Warp: 100% PES Weft1: 100% PES Weft2: 100% PES	655 907 638	434.72	17.01	3.27	0.04
Warp: 100% PES Weft: 100% PES	660 660	396.19	5.79	2.91	0.04
Warp: 100% PES Weft1: 100% PES Weft2: 100% PES	660 555 633	401.45	3.64	3.11	0.12

Tab.1b Woven velour automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
100%CO 65%PES 35%CV 100% PAC	591 667 555	479.15	3.48	3.22	0.06
65%PES 35%CV 65%PES 35%CV 30%WO 70%PES	591 667 625	427.71	7.13	3.35	0.06
65%PES 35%CV 65%PES 35%CV 30%WO 70%PES	591 591 492	434.72	7.60	3.27	0.03
65%PES 35%CV 65%PES 35%CV 100%PAC	738 1181 and 984 625	396.19	8.02	2.91	0.12
65%PES 35%CV 65%PES 35%CV 30%WO 70%PES	738 1181 and 984 625	401.45	7.33	3.11	0.06
65%PES 35%CV 65%PES 35%CV 100%PAC	591 667 625	432.06	9.04	2.12	0.03
65%PES 35%CV 65%PES 35%CV 100%PAC	738 1181 and 984 625	524.90	8.29	2.72	0.101

Tab.1c Circular knitted flat automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
100% PES	75	449.55	4.49	3.02	0.16
100% PES 100% PES	383 425	427.34	3.50	2.93	0.13
100% PES T 100% PES T	160 160 x 2	417.65	4.01	3.10	0.05

Tab.1d Circular knitted pile automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
100% PES 100% PES	165 165	526.82	36.37	3.10	0.12
100% PES 100% PES 100% PES	220 165 165	559.48	25.48	4.163	0.15
100% PES 100% PES	172 172	436.86	20.36	3.76	0.17
100% PES 100% PES 100% PES	200 167 167	506.86	30.15	3.30	0.09
100% PES 100% PES 100% PES	330 220 167	564.76	18.75	4.57	0.07
100% PES 100% PES 100% PES	220 167 167	500.35	23.48	3.81	0.10
100% PES 100% PES 100% PES	220 220 167	536.18	26.01	5.00	0.12

Tab.1e Warp knit flat automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
100% PES	111	336.96	3.25	2.89	0.24
100% PES 100% PES	166 111	379.70	4.03	2.95	0.13
100% PES	111	309.62	2.78	2.04	0.10

Tab.1f Pol automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
100% PES 100% PES 100% PES	99 165 77	562.92	9.09	4.44	0.17
100% PES 100% PES 100% PES	111 111 111	440.65	22.34	2.96	0.16

Tab.1g DNBR automobile seat fabrics used in the study

Material	**Yarn Count (dtex)**	**Weight (g/m^2)**		**Thickness (mm)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
100% PES 100% PES 100% PES	165 495 660	649.83	10.77	4.31	0.14

production techniques, raw materials and yarn counts of these fabrics are given in Tab.1. The last column of the table shows, each value obtained by averaging ten measurements from the air permeability test.

3. Variance analysis and multiple comparisons

Several hypotheses were testing in this section using the data given in Tab.1. Our aim was to determine if there is any difference among the fabric types according to air permeability values using one-way analysis of variance procedure. Selected value of significance level (α) for all the statistical tests in the study was 0.05. There were 7 different values (treatments) of each single factor (fabric) that we wished to compare. The average permeability, given in Tab.2, say y_{ij}, represented the jth observation taken under treatment i. $i = 1,2,\ldots,7$ represented fabric type namely flat woven, woven velour, circular knitted flat, circular knitted pile, warp knit flat, Pol, and DNBR. There was unequal number of observations for each treatment. The observations can be described using the one-way analysis of variance model,

$$y_{ij} = \mu + \tau_i + e_{ij} \quad \begin{cases} i = 1,2,\ldots,7 \\ j = 1,2,\ldots,n \end{cases} \qquad (1)$$

where μ is overall mean air permeability, τ_i is the effect of ith fabric type, ε_{ij} is a random error component [6]. In this one-way analysis of variance model, r_i denotes the number of observations at ith level of the factor. That is $r_1 = 5$, $r_2 = 7$, $r_3 = 3$, $r_4 = 7$, $r_5 = 3$, $r_6 = 2$, and $r_7 = 1$. The sum of r_i s gives total number of observations. Since the seven treatments were specifically chosen, this model is called the *fixed effects* model. In this situation we tested the hypotheses about the τ_i, and applied conclusions only to the factor levels considered. We were interested in testing the equality of the 7 treatment effects. The appropriate hypotheses were:

$$H_0: \tau_1 = \tau_2 = ... = \tau_l = 0 \text{ ;}$$
$$H_1: \tau_i \neq 0 \text{ for at least one } i \qquad (2)$$

If the null hypothesis is true, then we could conclude that fabric types did not significantly affect the mean air permeability. Minitab Release 13.20 statistical software package was used to conduct variance analyses. The analysis of variance results for one way classification fixed effects model is summarized in Tab.3, in the analysis of variance (ANOVA) table [7].

In the ANOVA table, *source*, indicates the source of variation, either from the factor, the interaction, or the error. The total is a sum of all the sources. *DF* shows the *degrees of freedom* from each source. *SS* is the *sum of squares* among groups (factor) and the sum of squares within the groups. *MS* (*mean squares*) are found by dividing the sum of squares with the degrees of freedom. *F* is calculated by dividing the factor MS with the error MS. This ratio can be compared against the critical *F* found in the table or the *P*-value is used to determine whether a factor is significant. *P* value is used to determine whether a factor is significant; typically to compare against an alpha value of 0.05. If the *P*-value is lower than 0.05, then the factor is significant [8].

According to the *P* value ($<\alpha$) in Tab.3, we can say that fabric types significantly affected air permeability. In Fig.1, main effects diagram for air permeability is given. As can be seen in Fig.1, the woven velour automobile seat cover fabrics used in the study offered minimum air permeability while warp knitted flat fabrics offered maximum.

In testing for equality of means in the one way classification model, we could either reject *Ho* or fail to do so. If *Ho* was rejected, we could conclude that at least two of the population means differed in value. Unfortunately, the analysis of variance procedure did not tell us which of the *k* population means might be

Tab.2 Airpermability and correlation coefficients of the seat fabrics

	Material	**Yarn Count (dtex)**	**Air Permeability (mm/S)**	**Existence of autocorrelation within the groups**
Flat Woven Fabrics	Warp: 100% PES Weft: 100% PES	666 666	238,7	Not exist
	Warp: 100% PES Weft: 100% PES	655 916	559,7	Not exist
	Warp: 100% PES. Weft1: 100% PES Weft2: 100% PES	655 907 638	402,5	Not exist
	Warp: 100% PES weft: 100% PES	660 660	307,4	Not exist
	Warp: 100% PES Weft1: 100% PES Weft2: 100% PES	660 555 633	243,4	Not exist
Woven Velour	100%CO 65%PES 35%CV 100% PAC	591 667 555	223	Not exist
	65%PES 35%CV 65%PES 35%CV 30%WO 70%PES	591 667 625	77,5	Not exist
	65%PES 35%CV 65%PES 35%CV 30%WO 70%PES	591 591 492	69,2	Not exist
	65%PES 35%CV 65%PES 35%CV 100%PAC	738 1181 and 984 625	15,03	Not exist
	65%PES 35%CV 65%PES 35%CV 30%WO 70%PES	738 1181 and 984 625	16,21	Not exist
	65%PES 35%CV 65%PES 35%CV 100%PAC	591 667 625	130,7	Not exist
	65%PES 35%CV 65%PES 35%CV 100%PAC	738 1181 and 984 625	13,15	Not exist
Circular Knitted Flat Fabrics	100% PES	75	811,6	Not exist
	100% PES 100% PES	383 425	700,2	Not exist
	100% PES T 100% PES T	160 160 x 2	1154,1	Not exist
Circular Knitted Pile Fabrics	100% PES 100% PES	165 165	834,4	Not exist
	100% PES 100% PES 100% PES	220 165 165	420,2	Not exist
	100% PES 100% PES	172 172	697,5	Not exist
	100% PES 100% PES 100% PES	200 167 167	669,3	Not exist
	100% PES 100% PES 100% PES	330 220 167	582,2	Not exist
	100% PES 100% PES 100% PES	220 167 167	634,9	Not exist
	100% PES 100% PES 100% PES	220 220 167	320,2	Not exist
Warp Knit Flat Fabrics	100% PES	111	1084	Not exist
	100% PES 100% PES	166 111	708,2	Not exist
	100% PES	111	966,1	Not exist

regarded as being different from the others [7]. Therefore, were applied the Fisher's multiple comparison tests, to determine which of the seven population means might be regarded as being different from the others. In this test, the starting hypotheses were H_0:$\mu_i = \mu_j$; for all $i \neq j$. All the possible paired comparisons were evaluated in Minitab Release 13.20 statistical software package, and the multiple comparisons of the fabric types are given in Tab.4.

The Fisher's multiple comparison method was used in ANOVA to create confidence intervals for all the paired differences between the factor level means while controlling the individual error rate to the level specified. The Fisher's method, then used the individual error rate and number of comparisons to calculate the simultaneous confidence level for all confidence intervals. This simultaneous confidence level was the probability that all confidence intervals contained the true difference [8].

	Material	**Yarn Count (dtex)**	**Air Permeability (mm/S)**	**Existence of autocorrelation within the groups**
Pol Fabrics	100% PES 100% PES 100% PES	99 165 77	753,8	Not exist
	100% PES 100% PES 100% PES	111 111 111	603,2	Not exist
DNBR Fabrics	100% PES 100% PES 100% PES	165 495 660	898,4	Not exist

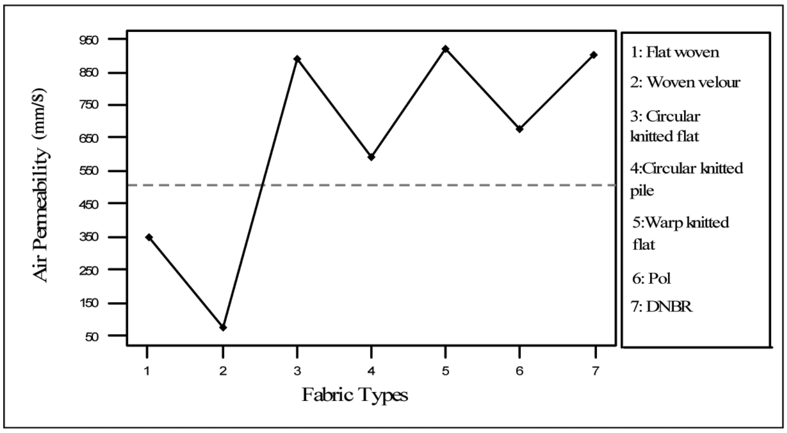

Fig.1 Main effect diagram for air permeability tested samples

Tab.3 ANOVA table for air permeability

Source	**DF (Degrees of Freedom)**	**SS (Sum of Squares)**	**MS (Mean Square)**	**F (F_0)**	**P**
Fabric type	k-1=7-1=**6**	$\sum_{i=i}^{k}\frac{T_i.^2}{n_i}-\frac{T..^2}{N}=SS_{Tr}$ =2624262	$\frac{SS_{Tr}}{k-1}$ =437377	$\frac{MS_{Tr}}{MS_E}$ =18,88	0,000
Error (within fabric types)	N-k=28-7=**21**	$SS_E = SS_{Tot} - SS_{Tr}$ = 486457	$\frac{SS_E}{N-k}$ =23165		
Total	N-1=28-1=**27**	$\sum_{i=1}^{k}\sum_{j=1}^{n_i}Y_{ij}^2-\frac{T..^2}{N}=SS_{Tot}$ =3110720			

Tab.4 Fisher's paired comparisons for air permeability

Fabric type	**Flat woven**	**Woven velour**	**Circular knitted flat**	**Circular knitted pile**	**Warp knit flat**	**Pol**
Woven velour	87 458					
Circular knitted flat	-769 -307	-1029 -592				
Circular knitted pile	-429 -58	-685 -347	76 513			
Warp knit flat	-800 -338	-1060 -623	-289* 228	-544 -107		
Pol	-593 -63	-854 -347	-79* 499	-338* 169	-48* 530	
DNBR	-895 -201	-1159 -482	-375* 356	-643* 34	-345* 387	-608* 168

In Tab.4, estimated confidence intervals on the difference between mean air permeabilities ($\mu_1 - \mu_2$) of two fabrics are given. While computing the intervals given in this table, "column level mean" were represented by μ_1, and "row level mean" by μ_2. For instance, in the woven velour-flat woven cell, the estimated confidence interval was [87, 458]. Here, 87 and 458 were lower and upper limits of the interval, respectively. This interval was estimated for the difference between the flat woven mean and the woven velour mean. If the both values in the bracket were '+' or '-', we would certainly infer that $\mu_1 > \mu_2$ or $\mu_1 < \mu_2$, respectively. There was a significant difference between the mean air permeabilities of the fabrics. But, if the first value was '-' and the second value was '+', there was no significant difference between the means.

When we make a paired comparison using the confidence intervals given in Tab. 4, we can see that there are no significant differences between the mean air permeabilities of the fabrics marked by a star. For instance, there is no significant difference between the mean air permeability of the warp knit flat and that of the circular knitted flat. But there are significant differences between the mean air permeabilities of the fabrics not marked by stars. That is, the mean air permeability of flat woven is higher than that of the woven velour but lower than that of the circular knitted flat. In each of the comparisons, the mean air permeability of the woven velour fabric is smaller than those of others. Besides that, flat woven fabric's mean air permeability is smaller than all the fabrics except woven velour.

4. Conclusion

The objective of this study is to examine the air permeability performances of different automobile seat cover fabrics in order to improve the thermal comfort of automobiles. The automobile seat cover fabrics produced employing 7 different production techniques were provided by the several major automobile seat fabric manufacturers in Turkey, and were tested in the form in which the fabrics will be used in vehicles. Air permeability performances of the seat cover fabrics were compared using the one way analysis of variance using the test data, and the individual differences among the factors were assessed using Fisher's multiple comparison test. The results showed that, while there were significant differences among mean air permeabilites of some types of fabrics, the difference in the mean air permeabilites of the others were insignificant. Although, in each of the comparisons, the mean air permeability of the woven velour fabric was smaller than those of others, obviously there was no fabric exibited mean air permeability higher than that of all the other fabrics.

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