

Comparative Study of the Abrasion Resistance of Automobile Seat Covers

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Abstract

This work presents an experimental design for the evaluation of different types of behaviour of automobile seat cover fabrics after 10,000 rubs of abrasion. The fabrics used in this research were supplied from four different manufacturers which produce covers for many multinational car companies. The motivation behind this work is the demand from vehicle manufacturers for a high standard of abrasion resistance. The data collected are evaluated statistically using variance analyses and Fisher's multiple comparison test.

Key words: technical textile, automobile seat cover, variance analysis, Fisher's multiple comparison test.

Introduction

Along with the growth in the number of vehicles world wide, the amount of textile materials used in motor vehicles has increased [1]. As can be seen in **Figure 1**, the largest area of technical textile application is mobiltech [2].

The application areas of mobiltech include automobiles, shipping, railways and aerospace [4]. The automobile industry is the largest user of technical textiles, with about 20 kg in each of the 45 million or so cars made every year worldwide. It is estimated that over one million tonnes of textiles are consumed in this industry per annum [2]. **Table 1** shows an approximate breakdown of the textiles used in an average modern car.

The features required from the automotive textiles are gradually being raised as the competition amongst OEMs (Original Equipment Manufacturer) becomes even more intense [7]. Some of the most stringent performance requirements in the textile industry are enforced by vehicle manufacturers on their fabric suppliers [5]. Suppliers of automobile seating fabric should offer products of the highest standard of abrasion resistance [6]. Fibre type, fibre properties and fabric structure are known as the factors that affect abrasion. Polyester is considered to have good abrasion resistance. Acrylic and modacrylic have lower resistance while wool has moderate abrasion resistance [7]. Yarns of higher dtex/filament generally have better abrasion than yarns made from finer filaments. Highly textured yarns usually have slightly lower abrasion than yarns with a lower degree of texture. For this reason the yarns used for automotive seat covers are usually air texturized. In addition to these factors, abrasion results are usually slightly better when the fabric has been laminated

to polyurethane foam, compared to abrasion results carried out on a base fabric alone [8].

There have only been a small number of researches on abrasion properties. Ulku *et al.* (2003) examined the effect of chenille yarn properties and weaving construction on the abrasion resistance of upholstery fabric. Omeroglu and Ulku (2007) investigated the tensile strength, pilling and abrasion properties of plain woven fabrics made from 100% combed cotton ring and compact yarns. Koltysheva *et al.* (2004) constructed geometrical models to describe the abrasion resistance of flax/cotton two-layered fabrics. In the present study, we compare the abrasion performances of automobile seat covers produced using different techniques. The objective of this study is to compare different fabric types in terms of abrasion resistance but not to compare their resistance with a specific value. The importance of our work is to test seat cover fabrics in the form they are used in automobiles. We tried to attain seat covers applied in different types of automobiles from four major textile manufacturers in Turkey.

Table 1. Approximate breakdown of main textiles in an average modern car; Source: [5].

Kind of Textile	%
Carpets (including car mats)	33.3
Upholstery (seating fabric)	18.0
Pre- assembled interior components	14.0
Tyres	12.8
Safety belts	8.8
Airbags	3.7
Others	9.4
Total	100.0

In the following section, the experiment designed for this study is introduced. In section 3, to statistically analyse the difference between the abrasion resistances of different fabric types one way analyses of variance, and Fisher's multiple comparisons tests are conducted, employing the experiment data. Finally, the study is concluded by section 4.

Design of the experiment

The automobile seat cover fabrics used in the study were provided by major manufacturers in Turkey. The experiment

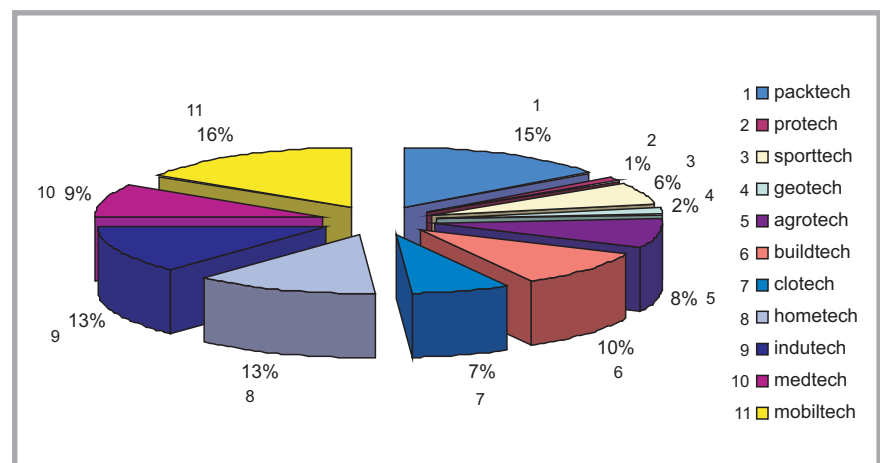


Figure 1. World end-use consumption of technical textiles in terms of application area. Source: [3].

comprises 7 types of commonly used automobile seat cover fabrics; flat woven, woven velour, circular knitted flat, circular knitted pile, warp knit flat, warp knit pol, and warp knit double bar raschel (DNBR). The reason why these types were selected for the experiment is that on a worldwide basis these fabric types are used for automobile seat covers [2].

For each type we obtained fabrics having different yarn counts, that is 5 flat woven, 7 woven velour, 3 circular knitted flat, 7 circular knitted pile, 3 warp knit flat, 2 warp knit pol and 1 DNBR. Six samples of each fabric were taken and tested. A total of 168 measurements were made. The observed abrasion values and changes in weight and thickness are recorded in **Table 2**. In this table, information on production techniques, raw materials and yarn counts of the fabrics are also given. In each row of this table, W_1 (T_1) indicates the average weight (thickness) of the six samples before the abrasion test, W_2 (T_2) the average weight (thickness) of the six samples after the abrasion test, and W (T) the average rate of weight (thickness) loss of the six samples after the abrasion test.

Martindale (using 12 kPa), Schopper and Taber are the three main test methods in use for abrasion resistance [8]. Many researchers prefer Martindale's multi direction action method and the use of wool as the abrading material [8]. In this study, we used a Nu-Martindale Abrasion and Pilling Tester in our tests. During the tests conducted with this apparatus, circular specimens were abraded under known pressure, and the fabric under test was abraded against a standard fabric [7].

Before starting the experiments, pretests were carried out to determine the number of rubs and composition of the abrading material. As a result of the pretests, it was seen that 5,000 rubs caused no abrasion. Thus, the experiments were carried out using 10,000 rubs. It must be noted that the objective of this study is to compare the different fabric types in terms of abrasion resistance, and not to compare their resistance with a specific value. Therefore, since abrasion occurred after 10,000 rubs and considering the fact that the fabric manufacturers apply less than 10,000 rubs, we accepted this rub amount as being sufficient. On the other hand, instead of the standard abradant (100% wool plain fabric), we used woven fabric comprising 55% polyester and 45%

Table 2. Specifications and abrasion test results of the automotive seat cover fabrics used in the experimental study.

Fabric Type	Material	Yarn Count. dtex	W_1 , g	W_2 , g	W, %	T_1 , mm	T_2 , mm	T, %
Flat Woven	Warp: %100 PES T. Weft: %100 PES T.	666 666	0.499	0.4988	0.040	3.06	2.91	4.846
	Warp: %100 PES T. Weft: %100 PES T.	655 916	0.4481	0.4494	-0.290	3.27	3.22	1.529
	Warp: %100 PES T. Weft1: %100 PES T. Weft2: %100 PES T.	655 907 638	0.4528	0.4559	-0.685	3.19	3.06	4.204
	Warp: %100 PES T. Weft: %100 PES T.	660 660	0.4326	0.4308	0.416	2.75	2.70	2.117
	Warp: %100 PES T. Weft1: %100 PES T. Weft2: %100 PES T.	660 555 633	0.451	0.4489	0.466	3.08	2.96	4.058
Woven Velour	Weft: %100CO Ground: %65PES %35CV Pile: %100 PAC	591 667 555	0.4729	0.4306	8.945	2.09	1.87	10.53
	Weft: %65PES %35CV Ground: %65PES %35CV Pile: %30WO %70PES	591 667 625	0.5607	0.5361	4.387	2.66	2.59	2.511
	Weft: %65PES %35CV Ground: %65PES %35CV Pile: %30WO %70PES	591 591 492	0.6729	0.6334	5.870	2.95	2.75	6.722
	Weft: %65PES %35CV Ground: %65PES %35CV Pile: %100PAC	738 1181 and 984 625	0.7051	0.6564	6.907	2.67	1.85	30.69
	Weft: %65PES %35CV Ground: %65PES %35CV Pile: %30WO %70PES	738 1181 and 984 625	0.7633	0.7303	4.323	3.62	2.29	36.70
	Weft: %65PES %35CV Ground: %65PES %35CV Pile: %100PAC	591 667 625	0.5478	0.4692	14.348	2.55	2.25	11.89
	Weft: %65PES %35CV Ground: %65PES %35CV Pile: %100PAC	738 1181 and 984 625	0.6989	0.6551	6.267	3.05	1.90	37.71
Circular Knitted Flat	%100 PES T.	75	0.4863	0.4898	-0.720	3.01	2.94	2.433
	1. %100 PES 2. %100 PES	383 425	0.4433	0.4454	-0.474	2.93	2.84	3.240
	Ground: %100 PES T. Pile: %100 PES T.	160 160 x 2	0.4406	0.4427	-0.477	3.25	3.11	4.158
Circular Knitted Pile	Ground: %100 PES Pile: %100 PES T.	165 165	0.5384	0.5385	-0.019	3.96	3.30	16.59
	Ground: %100 PES T. Pile 1: %100 PES T. Pile 2: %100 PES T.	220 165 165	0.5689	0.571	-0.369	3.80	3.47	8.688
	Ground: %100 PES T. Pile: %100 PES T.	172 172	0.4704	0.4719	-0.319	3.87	3.32	14.10
	Ground: %100 PES T. Pile 1: %100 PES T. Pile 2: %100 PES T.	200 167 167	0.564	0.5641	-0.018	3.51	2.95	16.00
	Ground: %100 PES T. Pile 1: %100 PES T. Pile 2: %100 PES T. Pile 3: %100 PES T.	330 220 220 167	0.6162	0.6179	-0.276	4.52	3.94	12.80
	Ground: %100 PES T. Pile 1: %100 PES T. Pile 2: %100 PES T.	220 167 167	0.5209	0.5257	-0.921	3.61	2.89	19.97
	Ground: %100 PES T. Pile 1: %100 PES T. Pile 2: %100 PES T.	220 220 167	0.5472	0.5763	-5.318	4.97	4.41	11.33
	%100 PES	111	0.3557	0.3544	0.365	2.67	2.63	1.496
Warp knit flat	1: %100 PES T. 2: %100 PES T.	166 111	0.4101	0.4124	-0.561	2.99	2.83	5.240
	%100 PES T.	111	0.3419	0.3426	-0.205	2.09	2.06	1.553
	Ground: %100 PES Pile 1: %100 PES T. Pile 2: %100 PES T.	99 165 77	0.5862	0.5871	-0.154	4.65	4.49	3.513
Pol	Ground: %100 PES T. Pile 1: %100 PES T. Pile 2: %100 PES T.	111 111 111	0.4667	0.4689	-0.471	2.96	2.69	9.231
	Ground: %100 PES Pile 1: %100 PES Pile 2: %100 PES	165 495 660	0.6603	0.6565	0.575	4.21	3.28	22.04
	Ground: %100 PES Pile 1: %100 PES Pile 2: %100 PES	165 495 660	0.6603	0.6565	0.575	4.21	3.28	22.04

wool twill, which is thought to be more abrasive. A special 14 kPa weight was produced and used instead of the standard weight, which gives a pressure of 12 kPa.

From each fabric type, six specimens of 38 mm diameter each were cut using an appropriate cutter. All the fabrics, except woven velour, were in the three-laminated form. In other words, the tests were applied to the fabrics in the form they are used in an automobile. Before starting the abrasion, each specimen's weight and thickness were measured. The specimens were then mounted in the specimen holders, with a circle of standard foam behind the fabric being tested. After 10,000 rubs, to examine the difference in weight and thickness, those of the abraded specimens were measured again.

In **Table 2**, some weight values (after abrasion) are higher than before. Since the automobile fabric is stronger than the abrasive fabric, the automobile fabric makes the abrasive fabric abrade and gain pills on itself.

Analysis of the data

In this section, our aim is to determine if there is any difference among the fabric types with respect to abrasion resistance. For this reason, to test several hypotheses using the data given in **Table 2**, the one-way analysis of variance procedure is employed. The value of significance level (α) selected for all statistical tests in the study is 0.05. We have 7 different levels (treatments) of a single factor (fabric) that we wish to compare. The average rate of weight loss (thickness), given in **Table 2**, y_{ij} , represented by the j^{th} observation taken under treatment i . $i = 1, 2, \dots, 7$ represents the fabric type, namely flat woven, woven velour, circular knitted flat, circular knitted pile, warp knit flat, Pol, and DNBR. There is an unequal number of observations at each level. We may describe the observations by the one-way analysis of variance model,

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

where μ is the overall mean rate of weight loss (thickness), τ_i is the effect of i^{th} fabric type, e_{ij} is the random error component. In this one-way analysis of variance model, r_i denotes the number of observations at i^{th} 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

the total number of observations. We are interested in testing the equality of the 7 level effects. The appropriate hypotheses are

$$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = 0; \\ H_1 : \text{at least two of the means are not equal.}$$

If the null hypothesis is not true, then we can conclude that the means are not all equal. In this case, we still do not know which of the means are equal and which are different. To see the individual differences we apply Fisher's multiple comparison test, a test of $H_0 = \mu_i = \mu_j$ $H_1 = \mu_i \neq \mu_j$ for all $i \neq j$. A Minitab Release 13.20 statistical software package was used for conducting variance analyses and Fisher's multiple comparison tests.

Comparison of weight change values after the abrasion test

In this section we will test the hypotheses given above for the mean rate of change in weight. **Table 3** is an ANOVA table obtained by using weight change data attained after the abrasion test.

According to the P value ($< \alpha$) in this table, we can say that there is a significant difference between the fabric types in the rate of weight change after the abrasion test. In **Figure 2**, a main effects diagram for the rate of weight change is given.

As can be seen in this figure, woven velour fabric has the highest rate of change in weight, while circular knitted pile has the lowest change.

All possible pairwise comparisons are evaluated by Fisher's multiple comparison test, and multiple comparisons of the fabric types are given in **Table 4**. In this table, each cell gives the value of the "column level mean" minus the "row level mean" according to the confidence intervals. If an interval is zero, then the difference is not significant. In other words, we do not find a significant difference between the means of levels represented by the columns and rows.

When we make a pairwise comparison using the confidence intervals given in

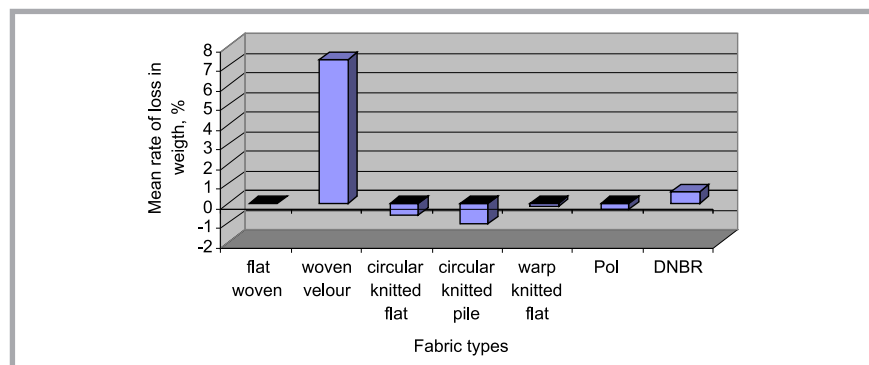


Figure 2. Main effects diagram for the rate of weight change after the abrasion test.

Table 3. ANOVA table for rate of weight change after the abrasion test.

Source	DF	SS	MS	F	P
Fabric type	6	319.35	53.23	11.59	0.000
Error (within fabric types)	21	96.42	4.59		
Total	27	415.78			

Table 4. Fisher's pairwise comparisons of weight change

Fabric type	Flat woven	Woven velour	Circular knitted flat	Circular knitted pile	Warp knit flat	Pol
Woven velour	-9.913 -4.693					
Circular knitted flat	-0.709 3.801	4.774 10.925				
Circular knitted pile	-1.586 3.633	5.944 10.709	-2.598 3.553			
Warp knit flat	-3.132 3.378	4.350 10.502	-4.062 3.216	-3.976 2.175		
Pol	-3.427 4.031	4.031 11.178	-4.313 3.824	-4.295 2.852	-3.890 4.247	
DNBR	-5.468 4.297	1.953 11.482	-6.278 4.014	-6.374 3.155	-5.855 4.438	-6.346 4.571

Table 4 (see page 59), we see that there is a significant difference between the means of woven velour and the other fabric types, although a significant difference does not exist among all other types. It is clear that, in each of the comparisons, the mean rate of weight loss of woven velour fabric is greater than that of other types.

Comparison of thickness change values after the abrasion test

The analysis of variance for testing the hypotheses given above is summarised in **Table 5**. Since P value $< \alpha$, we reject H_0 and conclude that fabric type significantly affects the mean rate of thickness loss. In **Figure 3**, mean effects of the treatments can be clearly seen.

In this figure, we can see that DNBR has the largest change in thickness. Fisher's multiple comparison method was used for pairwise comparison, results of which are shown in **Table 6**.

This table shows that there is a significant difference between woven velour and flat woven, flat woven and circular knitted flat, woven velour and circular knitted flat, woven velour and warp knit flat in terms of the mean change in thickness. Also the percentage of mean thickness change of woven velour is greater than that of flat woven, circular knitted flat and warp knitted flat.

Summary and conclusions

In this research, we are interested in how the abrasion resistance varies among 7 different types of automobile seat cover fabrics. The samples were exposed to 10,000 rubs of abrasion. It was decided that a variety of samples were to be tested for each fabric type. The fabrics were supplied by major manufacturers in Turkey and tested in the form they are used in automobiles. The main aim was to compare the different fabric types in terms of abrasion resistance, but not to compare their resistance with a specific value. To the best of our knowledge, there is no previously published experimental study that tried to compare the abrasion performances of automobile seat covers produced using different production techniques.

The pairwise comparison showed that there are significant differences between woven velour and other fabric types in terms of the change in weight and thick-

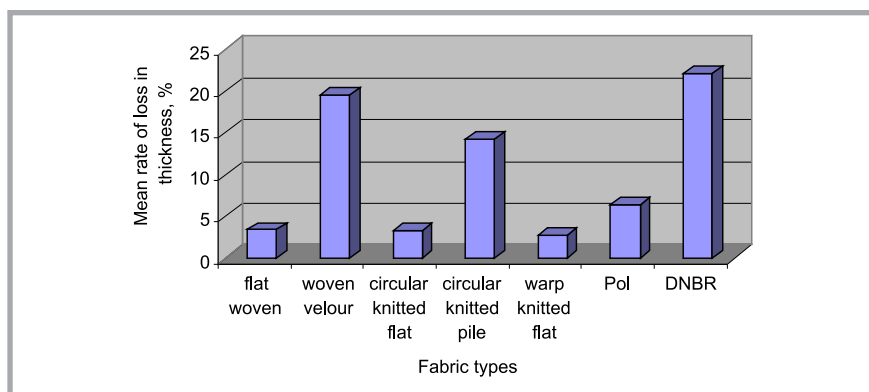


Figure 3. Main effects diagram for rate of thickness change after the abrasion test.

Table 5. ANOVA Table for rate of thickness change after the abrasion test.

Source	DF	SS	MS	F	P
Fabric type	6	1421.8	237.0	3.41	0.017
Error (within fabric types)	21	1461.2	69.6		
Total	27	2883.0			

Table 6. Fisher's pairwise comparisons for thickness change.

Fabric type	Flat woven	Woven velour	Circular knitted flat	Circular knitted pile	Warp knit flat	Pol
Woven velour	-26.34 -6.03					
Circular knitted flat	-12.60 12.74	4.29 28.23				
Circular knitted pile	-21.02 -0.70	-3.95 14.60	-22.91 1.04			
Warp knit flat	-12.08 13.26	4.80 28.75	-13.65 14.68	-0.53 23.42		
Pol	-17.54 11.50	-0.75 27.07	-18.93 12.74	-6.07 21.75	-19.45 12.23	
DNBR	-37.70 0.31	-21.06 16.04	-38.80 1.27	-26.38 1071	-39.31 0.75	-36.92 5.58

ness. In each of the comparisons, the mean rate of thickness loss of woven velour fabric, which is not laminated, is greater than that of the other fabric types. This result is in agreement with the notes given in [8]. Moreover, as mentioned above, it was noted in [8] that abrasion results are usually slightly better when the fabric has been laminated with polyurethane foam compared to abrasion results carried out on a base fabric alone. On the other hand, in this research less abrasion resistance was obtained for the woven velour fabrics. This result is consistent with [7], in which it was pointed out that fabrics made from acrylic, wool and viscose yarns have less abrasion resistance than those made from polyester. The piles of woven velour can be abraded more easily, and thus the loss of weight can be more than that of flat fabric types.

However, attention needs to be drawn to another important point. When **Table 2** is examined, it is seen that the weight change percentage of some of the fabrics

is minus - in other words the weight of some fabrics before abrasion is smaller than the weight measured after 10,000 rubs of abrasion. The reason for this unexpected phenomenon is that the abrasion fabric abraded more intensive than the abraded automobile fabric tested and that particles of the abrasion fabric were rubbed into the test material increasing its weight. This result also highlights how resistant these fabrics are.

Furthermore, the thickness loss of woven velour fabric is a bit under higher than that of other types. This kind of fabric has a pile structure, and at the end of the test, some piles were left on the fabric surface as a result of abrasion.

Finally, this study provides automobile seating fabric manufacturers and academic researchers with the abrasion performances of seating fabrics, as well as an example of designing such an experiment and statistically analysing the abrasion data collected.

Acknowledgment

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