ORIGINAL ARTICLES

INFLUENCE OF TOP COATED CLOTH FOR SITTING COMFORT OF AUTOMOTIVE SEAT

Toyonori NISHIMATSU , Hiromasa HAYAKAWA , Yoshio SHIMIZU , Masayoshi KAMIJOH
and Eiji TOBA

Shinshu University, 3-15-1 Tokida, Ueda-shi, Nagano, 386-8567, Japan

Abstract: A sitting comfort of seven automotive seats, whose top coated cloths were changed, and shape and structure of seats were the same, was evaluated by only human tactile sensation while sitting on these seats. The adjectives used for the sensory evaluation of seat comfort by the human tactile sensation were examined by factor analysis. As the result of factor analysis, the sitting comfort of driver's seats was evaluated by two adjectives "high-class" and "warm and smooth". The evaluated adjectives of top coated cloth, namely "hard", "smooth", "voluminous", "warm", "sporty", and "high-class" are closely related to same adjectives of the seat comfort. From the correlations between physical properties of top coated cloth and sensory evaluations for seat, it is found that the "sporty", the "high-class", the "warm", and the "smooth" feelings of seat are correlated to physical properties, namely surface friction and thermal character, of top coated cloths used in the surface of seat. And the body pressure on the back-rest has a negative correlation with "stiff at the cushion", the contact area on the back-rest has a positive correlation with "held by the cushion of seat and by the back-rest", and "stiff at the cushion and at the back-rest", and has a negative correlation with "smooth". It was found that the "hold" and the "stiff" feelings were judged by the contact area between the back-rest and the back of human body.

Keywords: *Sitting comfort, Top coated cloth, Automotive seat, Pressure distribution*

1. INTRODUCTION

As automotive seats are the significant man machine interface in automobiles, the importance of comfortable seat design is increasing as customer's expectations rise.

In the automotive seating industry, there has been a struggle to design the seat comfort in an objective method [1-8]. In the past, jury evaluations were performed after many seats were designed and many prototypes developed.

Unfortunately, these seats received poor results from subjective evaluations concerning comfort and many design changes were required.

If the correlation can be established between subjective and objective measurements, the task of designing a comfortable seat will be simplified.

It is important to establish the subjective words of judgment for the seat comfort and relate them to the objective measurement of pressure distribution between the seat and the occupant body.

In this paper, factor analysis was used to investigate the subjective words of sitting comfort for automotive seat whose top coated cloth was changed and structure and shape were the same.

The correlations between the subjective results of seat comfort and the physical properties of top coated cloths and between the subjective results of seat comfort and the pressure distribution were examined for seven seats in

automobiles by correlation analysis.

And it is investigated how the top coated cloth influences the sitting comfort of automotive seat.

2. EXPERIMENTAL

2.1. Subjective measurements

We selected same seven sporty seats on the market, whose characteristic, structure and shape were the same. The deflection of cushion pad of those seats was 32~34mm at 441N compression load and that of back-rest pad was 15~16mm at 147N compression load according to JASO B407.

Seven seats, whose top coated cloths were changed, and structure and shape were the same, were used in the subjective measurements. Details of each top coated cloth used in the surface of seat are shown in Table 1.

Hand of each top coated cloth of seven seats was judged by the Scheffe's method of paired comparison [9] using eight tactile adjectives, namely "hard", "smooth", "voluminous", "warm", "sporty", "elastic", "high-class", and "thermal and humid". Each cloth was first ranked for preference by 15 students. 21 pairs of test samples were randomized and presented that allowed the panel to touch only the surface of test samples on the board but not to see them for hand assessment.

The sitting comfort of driver seat, whose top coated cloth

Table 1: Details of top coated cloth

No.	Cloth Construction	Thickness (mm)	Fiber Content	Yarn Count	Density
1	Leather				
2	Moquette	2.40	G: Polyester/Rayon W: Polyester/Rayon P: Polyester	30/2s 30/2s 22/2s	19.4 ends/cm 17.2 picks/cm 29.1 ends/cm
3	Double Rasche	1.30	P: Polyester	100d	45 courses/cm
4	Tricot	1.40	G: Polyester Front: Polyester Middle: Polyester Back: Polyester	100d 110d 110d 75d	25 wales/cm 73 courses/cm 46 wales/cm
5	Plain fabric	0.80	G: Polyester W: Polyester	200d, 300d 200d, 300d	56.3 ends/cm 26.4 picks/cm
6	Plain fabric	1.80	G: Polyester W: Polyester	150d/4F 20/2, 7, 2.8s	20.0 ends/cm 12.2 picks/cm
7	Jersey	1.30	W: Polyester	150d/2	44 courses/cm 28 wales/cm

P; Pile Yarn, G; Ground Yarn, W; Weft Yarn, F; Filament Number

was the same as used in the hand evaluation, was judged by the Scheffe's method of paired comparison [9] using twelve tactile adjectives. Twelve tactile adjectives — namely “hard”, “smooth”, “voluminous”, “warm”, “sporty”, “elastic”, “high-class”, “thermal and humid”, “held by the seat cushion”, “held by the back-rest”, “stiff at the cushion” and “stiff at the back-rest” — were chosen to represent the sitting comfort of seven seats. The judges sat as if they were driving as shown in Figure 1 without seeing the seat and they were 15 male students enrolled in textile courses at Shinshu University within the age range of 22-25 years.

Figure 1: Seat setting

The response of each judge was tested individually without limit in a quiet room maintained at 25°C and 50% relative humidity.

We used the Scheffe'-Haga method [9] of analyzing paired comparisons to calculate statistically the mean preference scores of seven cloths for each sensory adjective from the results of the paired comparisons. This method is used to determine whether the preference scores are

statistically different from each other and to generate the mean preference scores of samples, so the method applies to any case of consumer preference tests by paired comparison, such as testing of foods, hand lotions, etc.

We used factor analysis to study twelve adjectives defining seat comfort from calculated mean preference scores. Factor analysis also made it possible to determine if the correlations between each sensory adjective could be explained by the fact that each testing result was affected by one or more common factors.

2.2. Objective tests of top coated cloth

Cloth thickness was measured by a thickness gauge at a pressure of 4.9kPa. Tensile property(LT, WT, RT), bending property(B, 2HB), compression property(LC, WC, RC), and surface property(MIU,MMD) were measured by KES-FB testers(KATO TECH Co, LTD.,). Thermal character(qmax; warm/cool feeling evaluation, K; thermal conductivity, α ; heat keeping property) was measured by a THERMO LABO tester. Flexural rigidity was measured by a cantilever tester and computed according to JIS L 1096. Coefficient of dynamic friction was measured by an experimental friction measurement system described in JIS L 1096. And air permeability was measured by a Frazier permeometer according to JIS L 1096. Testing is done in a room maintained at a temperature of 25°C and 50% relative humidity.

2.3. Pressure measurement at person/seat interface

15 male judges sat as if they were driving and the response of each judge was tested individually in a quiet room maintained at 25°C and 50% relative humidity.

Body pressure and contact area between the seat and the occupant body were measured by the measurement system

Table 2: Mean preference values of each seat for six adjectives

Adjective	Seat 1	Seat 2	Seat 3	Seat 4	Seat 5	Seat 6	Seat 7
Hard	0.473	-0.418	-0.231	-0.319	0.341	0.154	0.000
Smooth	1.374	-0.275	-0.297	-0.121	0.275	-0.659	-0.297
Voluminous	-0.154	0.451	0.242	0.143	-0.418	-0.088	-0.176
Warm	-0.868	0.571	0.538	0.396	-0.495	0.000	-0.143
Sporty	-0.132	-0.286	-0.154	-0.055	0.341	0.165	0.121
Elastic	0.000	0.330	0.165	-0.033	-0.253	-0.044	-0.165
High-class	0.231	0.374	0.242	0.011	-0.374	-0.275	-0.209
Thermal and humid	-0.077	0.154	0.154	0.165	-0.077	-0.088	-0.231
Held by the cushion	-0.560	0.055	0.099	-0.077	0.022	0.363	0.099
Held by the back-rest	-0.857	0.154	0.242	0.011	-0.033	0.341	0.143
Stiff at the cushion	-0.099	-0.033	-0.022	0.000	0.088	0.066	0.000
Stiff at the back-rest	-0.264	0.066	0.022	0.055	-0.033	0.077	0.077

of the pressure distribution (BIGMAT-2000 by NITTA Co. Ltd.,) while evaluating the seat comfort.

The system consists of mats that are made up of thin flexible sensors to place on the seat cushion and the seat back for measuring the occupant body/seat interface pressures as shown in Figure 1. These measurements were recorded in real time for ten minutes.

And pressure distribution data were compared to the subjective interpretation of seat comfort.

3. RESULTS AND DISCUSSION

3.1. Subjective measurements

3.1.1. Top coated cloth

From the results of paired comparison, the mean preference scores of seven cloths for each sensory adjective were computed using the Scheffe'-Haga method [9].

As the result of the analysis of variance for the mean preference scores of eight sensory adjectives, the main effect for the mean preference scores of all adjectives was significant at 1% level and the combination effect was not significant at 1% level.

As the result, it was found that two adjectives "sporty" and "high-class" could be evaluated by the touch of top coated cloth on the board.

3.1.2. Seat

From the results of paired comparison, the mean preference scores of seven seats for each sensory adjective, computed using the Scheffe'-Haga method [9], were shown in Table 2.

From the result of the analysis of variance for the mean preference scores of each sensory adjective, the main effect for the mean preference scores of twelve adjectives was significant at 1% level and the combination effect was not

significant at 1% level.

As shown in Table 2, the seat No.2 was judged as highest-class, most warm, most elastic and softest, and the seat No.1 was judged as hard, not held by the cushion and by the back-rest, and pliable at the cushion and at the back-rest.

It was found that the top coated cloth of seat influenced each adjective of sitting comfort.

The mean preference scores of twelve adjectives as shown in Table 2 were examined by factor analysis to investigate the subjective words of the seat comfort.

Factor analysis makes it possible to discover if the correlations among sensory values can be explained by the fact that each testing result is affected by one or more common factors. We obtained the factor matrices using the principal factor solutions without repeated assumption of communality, which is the proportion of the test variance ascribed to the action of the common factors.

Communality ranges from 0 to 1, and the degree of the difference between communality and unity is explained by the experimental error or by the effect of a property that is only measured by a single test.

Table 3: Factor loading matrix

	Factor 1	Factor 2
Hard	0.746	-0.588
Smooth	0.099	-0.981
Voluminous	-0.954	0.265
Warm	-0.686	0.710
Sporty	0.963	0.240
Elastic	-0.936	0.054
High-class	-0.931	-0.348
Thermal and humid	-0.788	0.169
Held by the cushion	0.139	0.954
Held by the back-rest	-0.054	0.990
Stiff at the cushion	0.620	0.665
Stiff at the back-rest	-0.097	0.971
Proportion	0.47	0.45

Table 4: Correlation coefficients among adjectives of seat comfort.

	Hard	Smooth	Voluminous	Warm	Sporty	Elastic	High-class	Thermal & humid	Held by the cushion	Held by the back-rest	Stiff at the cushion	Stiff at the back-rest
Hard	1.000											
Smooth	0.636	1.000										
Voluminous	-0.865	-0.365	1.000									
Warm	-0.959	-0.756	0.840	1.000								
Sporty	0.568	-0.117	-0.864	-0.476	1.000							
Elastic	-0.647	-0.162	0.933	0.643	-0.905	1.000						
High-class	-0.464	0.242	0.797	0.379	-0.980	0.886	1.000					
Thermal and humid	-0.715	-0.173	0.804	0.727	-0.661	0.717	0.656	1.000				
Held by the cushion	-0.389	-0.949	0.132	0.559	0.345	-0.003	-0.435	-0.009	1.000			
Held by the back-rest	-0.600	-0.984	0.313	0.736	0.180	0.128	-0.276	0.182	0.964	1.000		
Stiff at the cushion	0.096	-0.559	-0.431	0.057	0.818	-0.540	-0.836	-0.228	0.733	0.628	1.000	
Stiff at the back-rest	-0.696	-0.971	0.355	0.759	0.127	0.110	-0.257	0.181	0.889	0.955	0.557	1.000

We rotated the factor axes so that the structure of the sensory test relations was indicated more clearly. The results of factor matrices rotated by the Varimax method [10] is shown in Table 3.

Two common factors were obtained as shown in Table 3. Factor 1 is related to “hard”, “voluminous”, “sporty”, “elastic”, and “high-class” and factor 2 is related to “smooth”, “warm”, “held by the cushion and by the back-rest” and “stiff at the back-rest”.

Table 4 shows the correlation coefficients among the adjectives of seat comfort.

As shown in Table 4, the adjective “high-class” is closely related to four adjectives “voluminous”, “sporty”, “elastic”, and “stiff at the cushion” and the adjective “smooth” is related to three adjectives “held by the cushion”, “held by the back-rest”, and “stiff at the back-rest” from the values of correlation coefficients.

Therefore, two factors “high-class” and “smooth and warm” were common and significant in evaluating the sitting comfort of car driver’s seat, whose top coated cloths

were changed, and structure and shape were the same.

The correlation coefficients between eight adjectives of “hand of top coated cloths” and twelve adjectives of seat comfort are illustrated in Table 5.

From the result of hypothesis testing of correlation coefficient [11] in Table 5, t values of the adjectives “hard”, “voluminous”, “warm”, and “high-class” were significant at 1% level and t value of “sporty” was significant at 5% level. When the correlation coefficient is 0.727 or 0.843, it is significant at 5% or 1% level.

As shown in Table 5, the adjectives of top coated cloth “hard”, “voluminous”, “warm”, “sporty”, and “high-class” are closely related to the same adjectives for seat comfort.

From this result, it was found that the seat comfort was expected by the hand of the top coated cloth used in the surface of the seat

3.2. Correlation of objective testing to sensory evaluations

Table 6 shows some values of measured physical properties (tensile, bending, compression, and surface

Table 5: Correlation coefficients among hand of cloth and seat comfort.

Seat comfort	Hand of top coated cloth used in surface of seat							
	Hard	Smooth	Voluminous	Warm	Sporty	Elastic	High-class	Thermal & humid
Hard	0.854	-0.065	-0.686	-0.931	0.837	-0.346	-0.664	0.230
Smooth	0.263	0.702	-0.030	-0.624	0.423	0.423	0.040	0.867
Voluminous	-0.882	0.272	0.927	0.934	-0.970	0.511	0.890	0.022
Warm	-0.773	-0.089	0.616	0.970	-0.872	0.162	0.610	-0.354
Sporty	0.826	-0.622	-0.979	-0.647	0.796	-0.769	-0.926	-0.425
Elastic	-0.750	0.319	0.941	0.791	-0.897	0.564	0.883	0.158
High-class	-0.767	0.701	0.960	0.560	-0.736	0.827	0.927	0.554
Thermal and humid	-0.702	0.455	0.738	0.810	-0.852	0.425	0.887	0.285
Held by the cushion	0.015	-0.854	-0.199	0.415	-0.215	-0.609	-0.260	-0.918
Held by the back-rest	-0.222	-0.697	-0.012	0.590	-0.386	-0.415	-0.062	-0.830
Stiff at the cushion	0.546	-0.782	-0.709	-0.126	0.334	-0.808	-0.628	-0.674
Stiff at the back-rest	-0.297	-0.636	0.022	0.603	-0.375	-0.336	-0.039	-0.821

Table 6: Physical properties of top coated cloth

Sample No.	Tensile property		Compression property		Surface MIU	Thermal property		Coefficient of dynamic friction	Air permeability (cc/cm ² /sec)
	LT	RT(%)	LC	RC(%)		qmax(W/cm ²)	α (%)		
1	0.846	43.2	0.071	55.5	0.559	0.179	50.6	0.406	0.00
2	0.653	49.0	0.177	45.5	0.488	0.071	60.0	0.410	1.77
3	0.636	48.7	0.161	46.6	0.560	0.087	59.0	0.407	31.86
4	0.571	49.9	0.139	48.7	0.561	0.066	60.9	0.369	1.74
5	0.819	51.0	0.133	57.2	0.291	0.110	59.0	0.318	5.85
6	0.661	47.2	0.149	44.8	0.445	0.039	58.8	0.384	14.53
7	0.669	46.1	0.121	55.6	0.623	0.069	59.6	0.353	30.96

properties, thermal character, coefficient of dynamic friction and air permeability) of each top coated cloth.

Figure 2 shows the result of body pressure distributions between the back-rest of seat and human back and between the cushion and human buttocks.

Figure 2: Body pressure distribution between back-rest of seat and human back, and between cushion and human buttocks.

As shown in Figure 2, it is found that the pressure was highest at the hucklebone on the seat cushion.

Table 7 shows the measured body pressures and contact areas between each seat and occupant body.

Table 7: Body pressure and contact area between each seat and occupant body

Sample No.	Contact area (cm ²)		Body pressure (kPa)	
	Back-rest	Cushion	Back-rest	Cushion
1	1021.9	1555.4	29.3	40.4
2	1227.0	1677.3	26.7	41.7
3	1188.8	1575.1	26.7	49.3
4	1195.8	1580.2	26.1	51.4
5	1227.8	1542.9	23.3	41.0
6	1215.0	1574.3	24.1	41.4
7	1193.9	1667.5	27.9	44.1

Figure 3 shows the relation between the mean preference scores of adjective “high-class” and measured coefficient of dynamic friction.

Figure 3: Relation between the adjective “high-class” and coefficient of dynamic friction.

As in Figure 3, it is found that the relation between the adjective “high-class” and physical property (coefficient of dynamic friction) was linear and the correlation coefficient was 0.862.

From the result of hypothesis testing of correlation coefficient between “high-class” and coefficient of dynamic friction, t value was significant at 1% level.

Table 8 shows the correlation coefficients between the physical properties of each top coated cloth obtained from each measurement method and each mean preference score of twelve adjectives of seat comfort.

From the result of hypothesis testing of correlation coefficient in Table 8, the adjective “sporty” has a positive correlation with tensile property (LT), bending property (B) and surface property (MMD), and has a negative correlation with surface property (MIU), thermal conductivity (K) and coefficient of dynamic friction.

The adjective “high-class” has a positive correlation with surface property (MIU), thermal conductivity (K) and coefficient of dynamic friction, and has a negative

correlation with variation of coefficient of friction (MMD). And we see that the “sporty” feeling has a negative correlation with the “high-class” feeling from Table 4.

The adjective “warm” has a positive correlation with coefficient of dynamic friction and heat keeping property (α), and has a negative correlation with warm/cool feeling evaluation (qmax).

The adjective “smooth” has a positive correlation with warm/cool feeling evaluation (qmax), and has a negative correlation with α . And the “warm” feeling has a negative correlation with the “smooth” feeling from Table 4.

From the correlations between physical properties of top coated cloth and sensory evaluations for seat comfort, it is found that the “sporty”, the “high-class”, the “warm”, and the “smooth” feelings of seat are correlated to physical properties, namely surface friction and thermal character of top coated cloths of seat.

Table 9 shows the correlation coefficients between the body pressure at the cushion and the back-rest obtained from the measurement system of pressure distribution and each

Table 8: Correlation coefficients between physical properties and of cloth and seat comfort

	LT	WT	RT	LC	WC	RC	B	2HB	MIU	MMD
Hard	0.745	0.157	-0.560	-0.696	-0.591	0.553	0.711	0.665	-0.561	0.639
Smooth	0.121	0.205	-0.595	-0.733	-0.573	0.314	0.186	0.306	-0.038	-0.082
Voluminous	-0.783	-0.271	0.363	0.724	0.742	-0.712	-0.697	-0.606	0.813	-0.742
Warm	-0.574	-0.306	0.617	0.742	0.672	-0.663	-0.581	-0.581	0.476	-0.503
Sporty	0.823	0.032	0.061	-0.463	-0.476	0.490	0.803	0.582	-0.896	0.865
Elastic	-0.656	-0.329	0.242	0.663	0.749	-0.757	-0.525	-0.401	0.781	-0.643
High-class	-0.733	-0.066	-0.088	0.341	0.387	-0.519	-0.624	-0.461	0.800	-0.825
Thermal and humid	-0.470	-0.567	0.517	0.259	0.487	-0.828	-0.418	-0.329	0.517	-0.616
Held by the cushion	0.177	-0.284	0.584	0.604	0.496	-0.270	0.111	-0.028	-0.210	0.369
Held by the back-rest	-0.030	-0.256	0.649	0.661	0.512	-0.364	-0.096	-0.206	-0.090	0.142
Stiff at the cushion	0.676	-0.383	0.575	-0.072	0.013	-0.020	0.622	0.489	-0.728	0.771
Stiff at the back-rest	-0.202	-0.144	0.656	0.671	0.498	-0.252	-0.237	-0.325	0.017	0.033

	qmax	α	k	Thickness	Flexural rigidity	Air Permeability	Coefficient of dynamic friction
Hard	0.585	-0.610	-0.394	-0.542	0.515	-0.202	-0.399
Smooth	0.967	-0.941	0.360	-0.337	0.025	-0.421	0.070
Voluminous	-0.272	0.358	0.640	0.765	-0.557	0.009	0.744
Warm	-0.776	0.802	0.289	0.525	-0.399	0.251	0.807
Sporty	-0.212	0.134	-0.822	-0.659	0.673	0.082	-0.885
Elastic	-0.032	0.169	0.734	0.810	-0.406	-0.074	0.864
High-class	0.358	-0.262	0.902	0.569	-0.578	-0.105	0.862
Thermal and humid	-0.110	0.203	0.675	0.378	-0.330	-0.245	0.486
Held by the cushion	-0.913	0.901	-0.511	0.212	0.253	0.393	-0.214
Held by the back-rest	-0.930	0.915	-0.327	0.244	0.081	0.450	-0.148
Stiff at the cushion	-0.620	0.612	-0.701	-0.310	0.688	0.044	-0.736
Stiff at the back-rest	-0.969	0.944	-0.320	0.299	-0.045	0.380	-0.185

Table 9: Correlation coefficients between body pressure and seat comfort, and between contact area and seat comfort

	Contact area		Body pressure	
	Back-rest	Cushion	Back-rest	Cushion
Hard	-0.544	-0.591	-0.037	-0.636
Smooth	-0.863	-0.426	0.493	-0.332
Voluminous	0.193	0.497	0.264	0.422
Warm	0.633	0.456	-0.143	0.622
Sporty	0.306	-0.382	-0.651	-0.263
Elastic	0.007	0.419	0.329	0.136
High-class	-0.371	0.283	0.645	0.190
Thermal and humid	0.198	-0.014	-0.040	0.574
Held by the cushion	0.871	0.269	-0.664	0.110
Held by the back-rest	0.912	0.363	-0.574	0.311
Stiff at the cushion	0.753	-0.213	-0.938	-0.073
Stiff at the back-rest	0.905	0.514	-0.467	0.375

mean preference score of twelve adjectives of seat comfort.

From the result of hypothesis testing of correlation coefficient in Table 9, the body pressure on the back-rest has a negative correlation with the adjective “stiff at the cushion”.

The contact area on the back-rest has a positive correlation with the adjectives “held by the cushion of seat and by the back-rest”, and “stiff at the cushion and at the back-rest”, and has a negative correlation with “smooth”.

It was found that the “hold” and the “stiff” feelings were judged by the contact area between the back-rest and the back of human body.

4.CONCLUSION

It was investigated the relations between the tactual values of sitting comfort for the driver’s seat and the body pressure distribution, and between the tactual values and the physical properties of top coated cloths used in each seat by correlation analysis and factor analysis.

(1) The sitting comfort of driver’s seats, whose top coated cloths were changed and structure and shape were the same, was evaluated by two adjectives “high-class” and “warm and smooth”.

(2) The adjectives of top coated cloth, “hard”, “voluminous”, “warm”, “sporty”, and “high-class”, are closely related to the same adjectives of seat. From this result, it was found that the seat comfort was expected by the hand of the top coated cloth used in the surface of the seat.

(3) From the correlations between physical properties of top coated cloth and sensory evaluations for seat, it is found that the “sporty”, the “high-class”, the “warm”, and the “smooth” feelings of seat are correlated to physical properties, namely surface friction and thermal character of top coated cloths

used in the surface of seat.

(4) The body pressure on the back-rest has a negative correlation with “stiff at the cushion”. The contact area on the back-rest has a positive correlation with “held by the cushion of seat and by the back-rest”, and “stiff at the cushion and at the back-rest”, and has a negative correlation with “smooth”. It was found that the “hold” and the “stiff” feelings were judged by the contact area between the back-rest and the back of human body.

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