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A Study of Finishing Conditions influencing Spandex Quality

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ABSTRACT

Spandex is a elastomeric fiber in which the-fiber-forming substance is a long chain polymer consisting of at least 85% segmented polyurethane.

In the polyurethanes there are the additional oxygen atoms in the main chains of the molecule. The effect of these oxygen atoms is to make the molecule flexible. From a physical point of view, elasicity and recovery from stretch are the most important properties of polyurethane, so its use had now expanded into many knitting industry.

In this paper, we wish to Test the effect of some finishing conditions on the quality of polyurethane.

I. INTRODUCTION

As the elastic fiber, polyurethane fiber in which contains 85% segmented polyurethane is generally used to make knitted works or elastic fabrics for its good taste of wear.

The strong points of this fiber are especially the properties of its elasticity and its recovery from stretch, and if the internal structure of this fiber is affected by some factors in the process of scouring, bleaching, dyeing and the other treatings, it is thought that not only the strong points of this fiber but also the strengh, the elongation and the fatigue of fiber should be influenced.

Therefore some factors which operate upon the Process of finishing were selected and were treated in this experiment, and from these results it was intended to examine the affection about the qualities of spandex, to induce some response equations.

II. MATERIALS AND THE EXAMINATION METHOD

1. Spandex fiber.
   The white TOYBO 140 was used.
2. PH solution.
   The buffer solution of PH 3.19, 4.4, 6.22, 8.0, 9.4, 10.4 is used by mixing CH_3 COOH, CH_3 COONa, KH_2PO_4, $Na_2B_4O_7$, Na_2CO_3.
3. The examination method
   The shrinkage, the strength, the elongation

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and the fatigue of spandex fiber which was treated at several levels of each conditions of temperatures 70, 80, 90, 100°C, of pH 3.19, 4.4, 6.22, 8.0, 9.4, 10.4 and of period of times 1.5, 3, 5 hours were measured in this experiment.

III. RESULTS AND DISCUSSIONS

1. The results of experiment.
   The data measured from the experimentals are presented in table 1-1 to table 1-4.

2. The arrangement of the experimental results.
   In order to find the relationship between the treated conditions and the properties of Spandex fiber with F-test method, the data in table 1 were rearranged, and the subtotal of each shrinkage, strength, elongation and fatigue are respectively calculated.
   Subsequently MANOVA(Multivariate Analysis of Variance) tables gained from above data are showed in table 2-1, 2-2, 2-3, 2-4. Wher $Y^{(1)}$, $Y^{(2)}$, $Y^{(3)}$, $Y^{(4)}$ are respectively the values of 70, 80, 90, 100°C and d. f. means degree of freedom.
   To illustrate one case of preparation methods of MANOVA table, for example, in case of $RXY^{(1)2}$ column in table 2-1 from row total Y value is obtained by;

$$Y^{(1)2} = \frac{(513.06)^2}{18} + \frac{(516.9)^2}{18} + \frac{(511.1)^2}{18} - \frac{(1541.06)^2}{54} = 0.9671704$$

   And $Y^{(1)}\ Y^{(2)}$ that is multiplied the value of 70°C and 80°C from the row totals.

$$Y^{(1)}Y^{(2)} = \frac{(513.06)(509.7)}{18} + \frac{(516.9)(510.2)}{18} + \frac{(511.1)(507.9)}{18} - \frac{(1541.06)(1527.8)}{54}$$

$$= 0.3479259$$

   And the other values are derived from this same method.

3. F-test method.
   For example at 70°C, M.S.E (Mean Square Errow) of the shrinkage from MANOVA table 2-1 is

$$\text{M.S.E} = \frac{\text{sum of square}}{\text{d.f}} = \frac{60.1066594}{36}$$

$$= 1.669629428$$

   And from the table 2-1, M.S. Sub-total is

$$\text{M.S.Sub-total} = \frac{4.3359481}{17} = 0.2550557706$$

   Hence the measured Value F_0 is

$$\frac{\text{M.S. Sub-total}}{\text{M.S.E.}} = 0.152961904$$

   and because F, from the F table, is F(17, 36) (0.99) = 2.5, the above measured value has no signification.
   Since $F_0 < F\ 0.99\ (17, 36)$, we may accept H_0 at the 1% level and conclude that we cannot say "at least one".
   Next, to examine the interaction of the row and the column,

$$\text{M.S.R. x C} = \frac{1.9140728}{10} = 0.19140728,$$

$$F = \frac{\text{M.S.R x C}}{\text{M.S.E}} = \frac{1.9140728}{1.669629428} = 0.1940728$$

   and compare with F(10, 36) (0.99) = 2.86 in the F table and above F_0, this result F_0 in not significant.
   But because above two F-tests are minor effects and the next two which relies on time and pH variation in 70°C, are main effects, these are the main view points of test.
   The shrinkage variation (row) according to time variation is $\text{M.S. Row} = \frac{0.9671704}{2}$

$$= 0.4835852,\ F_0 = 0.2896362462,$$

   and because F (2, 36) (0.99) = 5.25 in the F table, the above is not significant.
   The effect of shrinkage according to the

Table 1—1. Data Sheet of Shrinkage

Temp (°C)	pH	Shrinkage 1.5			3			5		
70	3.19	29.9	27.9	27.4	29.9	27.9	27.4	29.7	27.7	27.2
	4.4	27.02	29.02	29.52	30.0	28.0	27.5	27.4	27.9	30.0
	6.22	27.0	29.0	29.5	27.5	29.9	28.1	27.3	29.7	27.9
	8.0	27.9	27.4	30.2	29.0	29.5	30.1	27.8	27.3	30.1
	9.4	30.0	28.0	27.5	27.4	29.8	28.0	27.5	29.9	28.1
	10.4	27.6	28.1	30.1	27.3	29.7	29.9	27.4	28.8	29.4
80	3.19	29.0	29.3	26.6	27.6	27.1	29.9	28.9	29.2	26.5
	4.4	29.8	27.8	27.3	27.2	29.6	27.8	28.8	29.3	26.5
	6.22	27.4	29.8	28.0	26.8	28.8	29.3	27.3	29.7	27.9
	8.0	29.9	27.9	27.4	27.3	29.7	29.9	29.2	28.9	26.5
	9.4	27.2	27.7	29.7	27.2	29.6	27.8	28.8	29.3	26.5
	10.4	29.8	27.8	27.3	27.5	29.3	27.8	29.5	27.9	27.2
90	3.19	26.6	28.6	29.1	29.6	27.6	27.1	27.0	29.4	27.6
	4.4	29.5	27.5	27.0	27.0	29.4	27.6	27.4	26.9	29.7
	6.22	28.7	29.0	26.3	28.8	29.1	26.4	27.2	29.0	28.1
	8.0	27.1	29.5	27.7	27.6	27.1	29.9	28.6	28.9	26.2
	9.4	27.4	26.9	29.7	29.5	27.5	27.0	28.7	29.0	26.3
	10.4	26.6	28.6	29.1	27.3	27.0	29.7	29.0	26.6	28.4
100	3.19	26.9	26.5	30.3	27.4	26.9	29.7	27.08	26.78	29.48
	4.4	29.3	27.4	26.8	26.82	29.22	28.22	27.2	26.7	29.5
	6.22	26.8	29.2	27.4	28.48	28.78	26.08	26.62	29.02	28.02
	8.0	26.7	29.1	27.3	27.8	26.58	29.38	28.36	28.66	25.96
	9.4	29.2	27.2	26.7	27.22	29.22	26.72	27.04	26.45	29.32
	10.4	29.2	26.9	27.3	28.22	28.22	26.72	29.02	26.52	28.12

Table 1—2. Data Sheet of Strength

Temp (°C)	pH	Strength 1.5			3			5		
70	3.19	0.152	0.117	0.132	0.190	0.255	0.170	0.234	0.099	0.284
	4.4	0.222	0.187	0.202	0.188	0.192	0.154	0.203	0.168	0.173
	6.22	0.257	0.322	0.237	0.259	0.263	0.225	0.248	0.244	0.282
	8.0	0.230	0.234	0.196	0.224	0.228	0.190	0.239	0.243	0.205
	9.4	0.226	0.230	0.192	0.213	0.237	0.199	0.209	0.213	0.175
	10.4	0.233	0.229	0.267	0.245	0.249	0.211	0.139	0.135	0.173
80	3.19	0.129	0.149	0.109	0.269	0.273	0.235	0.227	0.247	0.207
	4.4	0.162	0.166	0.128	0.289	0.295	0.269	0.258	0.278	0.308
	6.22	0.138	0.303	0.318	0.260	0.264	0.236	0.299	0.295	0.333
	8.0	0.303	0.368	0.273	0.203	0.268	0.183	0.245	0.249	0.211
	9.4	0.107	0.272	0.187	0.276	0.280	0.242	0.228	0.224	0.262
	10.4	0.202	0.267	0.182	0.273	0.277	0.239	0.262	0.266	0.228
90	3.19	0.211	0.215	0.177	0.222	0.226	0.188	0.260	0.264	0.226
	4.4	0.183	0.258	0.173	0.155	0.320	0.235	0.246	0.250	0.212
	6.22	0.294	0.298	0.260	0.270	0.274	0.236	0.314	0.318	0.280
	8.0	0.290	0.294	0.256	0.227	0.231	0.193	0.234	0.238	0.200
	9.4	0.219	0.223	0.185	0.248	0.244	0.282	0.224	0.257	0.172
	10.4	0.260	0.280	0.240	0.270	0.274	0.236	0.210	0.214	0.176
100	3.19	0.179	0.183	0.145	0.259	0.263	0.225	0.242	0.245	0.212
	4.4	0.244	0.248	0.210	0.306	0.310	0.272	0.193	0.186	0.227
	6.22	0.280	0.284	0.246	0.312	0.316	0.278	0.346	0.342	0.380
	8.0	0.337	0.341	0.303	0.279	0.283	0.245	0.258	0.262	0.224
	9.4	0.230	0.234	0.196	0.234	0.230	0.220	0.253	0.257	0.219
	10.4	0.260	0.264	0.226	0.250	0.254	0.216	0.280	0.284	0.246

Table 1–3. Data Sheet of Elongation

Temp (°C)	pH	Item: Time (hr)	Elongation 1.5			3			5		
70	3.19		29.3	30.3	29.8	31.0	33.4	31.6	31.7	33.1	32.3
	4.4		33.9	31.9	31.4	29.4	31.8	30.0	31.8	34.2	32.4
	6.22		32.1	34.1	34.6	31.8	34.2	32.4	32.2	34.6	32.8
	8.0		31.8	34.2	32.4	31.3	30.8	30.2	31.8	31.1	33.9
	9.4		32.8	30.8	30.3	31.5	33.9	32.1	31.4	33.8	32.0
	10.4		34.4	32.4	31.9	31.9	34.3	32.5	30.7	33.1	31.3
80	3.19		31.4	29.4	28.9	31.4	33.8	32.0	31.9	31.4	34.2
	4.4		28.6	31.0	29.2	34.7	32.7	32.2	32.1	34.5	32.7
	6.22		33.8	31.8	31.3	31.1	33.5	31.7	33.7	33.2	36.0
	8.0		34.4	32.4	31.9	30.7	33.1	31.3	30.4	29.9	32.1
	9.4		33.4	31.4	30.9	31.4	32.8	32.0	32.3	31.8	34.6
	10.4		30.4	32.8	31.0	34.7	32.7	32.2	29.7	32.1	30.3
90	3.19		28.4	30.8	29.0	31.2	30.9	33.6	32.3	31.8	34.6
	4.4		31.0	33.4	31.6	33.4	33.7	31.0	31.7	32.0	29.3
	6.22		31.0	33.3	31.7	31.1	33.5	31.7	31.4	30.9	33.7
	8.0		33.9	31.9	31.4	32.2	34.6	32.8	32.0	31.5	34.3
	9.4		31.8	34.2	32.4	32.5	34.9	33.1	31.5	31.0	33.8
	10.4		32.0	34.4	32.6	34.6	34.9	35.6	32.5	30.5	30.0
100	3.19		31.0	33.4	31.6	34.7	32.7	32.2	32.0	34.4	32.6
	4.4		31.9	31.4	34.2	33.7	34.0	31.3	32.1	31.6	34.4
	6.22		31.0	32.4	34.6	32.5	32.0	34.8	34.1	34.4	31.7
	8.0		28.8	28.4	32.2	32.2	31.7	34.5	33.5	33.8	31.1
	9.4		31.8	29.8	29.3	32.8	35.2	33.4	32.7	35.1	33.3
	10.4		30.3	32.7	30.9	32.1	31.6	34.4	33.7	34.0	31.3

Table 1–4. Data Sheet of Fatigue

Temp (°C)	pH	Item: Time (hr)	Fatigue 1.5			3			5			
70	3.19		39.85	37.85	37.35	37.05	35.05	34.55	37.35	35.35	34.85	A
			22.05	20.05	19.55	19.35	21.75	19.95	19.25	21.65	19.85	B
	4.4		36.35	34.35	33.85	35.2	33.2	32.7	34.15	33.65	36.45	A
			19.5	21.9	20.1	19.25	21.65	20.65	19.25	21.65	19.85	B
	6.22		33.12	35.52	33.72	33.3	35.7	33.4	34.75	34.25	34.95	A
			19.5	21.9	20.1	19.3	29.7	19.9	19.25	21.65	19.85	B
	8.0		34.75	37.15	35.35	35.9	33.9	33.4	35.75	35.05	38.05	A
			19.35	21.75	19.95	21.8	19.8	19.3	21.7	19.7	19.2	B
	9.4		38.3	36.3	35.8	34.05	36.45	34.65	35.0	34.5	57.3	A
			19.45	21.85	20.05	19.7	19.2	20.0	19.6	19.1	21.9	B
	10.4		24.0	36.4	34.6	34.4	33.9	36.7	33.75	33.25	36.05	A
			19.3	21.7	19.9	19.3	21.7	19.9	19.1	21.5	19.7	B
80	3.19		33.8	36.2	34.43	33.3	35.7	33.9	36.3	34.9	33.8	A
			19.15	21.55	19.75	19.25	21.65	19.85	19.2	21.6	19.8	B
	4.4		34.1	36.5	34.7	34.5	34.0	36.8	33.9	36.3	34.5	A
			19.15	21.55	19.75	19.6	19.1	21.9	19.25	26.65	19.85	B
	6.22		34.1	33.7	34.7	33.1	32.5	34.9	32.8	35.2	33.4	A
			19.2	21.6	19.8	19.15	21.55	19.75	19.2	21.6	19.8	B
	8.0		35.7	33.7	33.2	36.8	34.8	34.3	36.2	34.2	34.6	A
			19.2	21.6	19.8	19.15	21.55	19.75	19.3	21.7	19.9	B
	9.4		36.5	34.5	34.0	33.7	36.1	33.7	35.8	35.3	38.1	A
			19.1	21.5	19.7	21.7	19.7	19.2	19.3	21.7	19.09	B
	10.4		36.7	34.7	34.2	34.21	36.51	34.81	36.5	36.8	34.1	A
			19.15	21.55	20.55	19.15	21.55	22.55	19.7	19.1	23	B
90	3.19		37.5	39.9	38.5	33.6	36.0	34.2	38.1	40.5	38.7	A
			19.4	21.8	24.0	19.25	21.65	19.85	20.8	19.2	23.1	B
	4.4		33.4	35.8	34.0	33.2	35.6	33.8	36.8	37.1	35.4	A
			19.35	21.85	19.95	19.3	21.7	19.9	19.6	19	22.9	B
	6.22		33.3	35.7	33.9	33.7	36.1	34.3	36.5	34.5	34	A
			19.3	21.7	19.9	21.75	19.75	19.25	19.25	21.65	19.85	B
	8.0		33.9	36.3	34.5	36.5	34.5	34.0	37.75	35.75	35.25	A
			21.73	19.75	19.25	19.25	21.65	19.85	19.25	21.65	19.85	B
	9.4		36.1	38.5	36.1	36.8	34.8	34.3	35.1	37.5	35.7	A
			19.35	21.75	19.95	19.3	21.7	19.9	19.2	21.6	19.8	B
	10.4		36.2	38.6	36.8	34.6	37.0	35.2	33.85	36.25	34.45	A
			19.25	21.65	19.85	19.25	21.65	19.85	19.2	21.6	19.8	B
100	3.19		35.8	33.8	33.3	34.8	37.2	35.4	34.5	36.9	35.1	A
			19.15	21.55	19.75	19.25	21.65	19.65	19.4	21.8	20.0	B
	4.4		36.25	34.25	33.75	34.4	36.8	35.0	34.0	36.4	34.6	A
			19.15	21.55	19.75	21.7	19.7	19.2	19.25	21.65	19.85	B
	6.22		37.55	35.35	35.05	35.05	34.55	37.35	34.9	37.3	35.5	A
			19.25	21.65	19.85	19.2	21.6	19.8	19.2	21.6	19.8	B
	8.0		35.95	33.95	33.45	34.2	36.6	34.8	36.7	34.7	34.2	A
			19.15	21.55	19.75	19.2	21.6	19.8	21.7	19.7	19.2	B
	9.4		34.6	37.0	35.2	37.6	35.9	35.4	35.5	35.0	37.8	A
			19.2	21.6	19.8	19.25	21.65	19.65	19.25	21.65	19.85	B
	10.4		37.5	35.5	35.0	36.8	34.8	34.3	34.4	36.8	35.0	A
			19.3	21.7	19.7	19.2	21.6	19.8	21.6	19.6	19.1	B

Table 2—1. MANOVA Table of Shrinkage

Source	d. f	$\dot{Y}^{(1)2}$	$Y^{(2)2}$	$Y^{(3)2}$	$Y^{(4)2}$	$Y^{(1)}Y^{(2)}$	$Y^{(1)}Y^{(3)}$	$Y^{(1)}Y^{(4)}$	$Y^{(2)}Y^{(3)}$	$Y^{(2)}Y^{(4)}$	$Y^{(3)}Y^{(4)}$
Row	2	0. 9671704	0. 16. 5926	0. 0803704	0. 0978814	0. 3479259	−0. 1741482	0. 3015703	−0. 0198148	0. 0964813	−0. 068037
Column	5	1. 4547049	0. 6614771	0. 5742593	0. 3127482	0. 63682	0. 13397	−0. 2652518	0. 2274074	−0. 0860742	−0. 1684816
RXC	10	1. 9140728	0. 8663026	1. 0085184	56. 206652	1. 14718	0. 5963634	28. 6526963	0. 4231482	28. 5081855	27. 9560371
Subtotal	17	4. 3359481	1. 6903703	1. 6631481	56. 6172815	2. 2319259	0. 5561852	28. 6890148	0. 6307408	28. 5185926	27. 7195185
Error	36	60. 1066594	65. 32667	63. 94667	13. 4072065	−6. 49666	31. 49	−36. 952663	4. 84	−24. 742222	−9. 8246665
Total	53	64. 4426075	67. 0170371	65. 609815	70. 024488	−4. 3647407	32. 046182	−8. 2636481	5. 4707408	3. 7743704	17. 894852

Table 2—2. MANOVA Table of Strength

Source	d. f	$Y^{(1)2}$	$Y^{(2)2}$	$Y^{(3)2}$	$Y^{(4)2}$	$Y^{(1)}Y^{(2)}$	$Y^{(1)}Y^{(3)}$	$Y^{(1)}Y^{(4)}$	$Y^{(2)}Y^{(3)}$	$Y^{(2)}Y^{(4)}$	$Y^{(3)}Y^{(4)}$
Row	2	0. 000026 0354	0. 027776 592	0. 009615 5913	0. 003457 3334	0. 000451 926	0. 004329 2582	0. 000221 7775	0. 004730 37	0. 009440 4438	0. 005181 1108
Column	5	0. 02667 ‘447	0. 023213 202	0. 032276 147	0. 052353 333	0. 017536 869	0. 027398 704	0. 030935 777	0. 024143 593	0. 033260 443	0. 036597 443
RXC	10	0. 048027 055	0. 122879 632	0. 017725 521	0. 044598 667	0. 010748 853	0. 016300 519	0. 004935 892	0. 026712 63	0. 032710 893	0. 007516 224
Subtotal	17	0. 074720 537	0. 173869 426	0. 059617 259	0. 100409 333	0. 028737 648	0. 048028 482	0. 036089 444	0. 055586 593	0. 075411 778	0. 049294 778
Error	36	0. 022429 611	0. 002976 277	0. 025034 741	0. 014812	0. 007348 092	0. 012576 185	0. 027979 444	0. 015027 74	0. 025561 697	0. 006448 222
Total	53	0. 097150 148	0. 176845 703	0. 084652	0. 115221 333	0. 036085 74	0. 060604 666	0. 064068 888	0. 070614 333	0. 100973 444	0. 055743

Table 2–3. MANOVA Table of Elongation

Source	d. f	$Y^{(1)^2}$	$Y^{(2)^2}$	$Y^{(3)^2}$	$Y^{(4)^2}$	$Y^{(1)}Y^{(2)}$	$Y^{(1)}Y^{(3)}$	$Y^{(1)}Y^{(4)}$	$Y^{(2)}Y^{(3)}$	$Y^{(2)}Y^{(4)}$	$Y^{(3)}Y^{(4)}$
Row	2	2. 854444	13. 8503704	15. 5648148	25. 23	0. 1433334	−5. 466666	0. 725	8. 124074	18. 656	9. 9083334
Column	5	17. 3972	10. 165926	17. 8520371	11. 4172	10. 851111	5. 7205556	0. 6772	0. 8129629	2. 9266667	−11. 0916666
RXC	10	31. 796689	48. 6518518	36. 7174074	22. 8944666	12. 886666	19. 1333333	−6. 2572	19. 5592594	−20. 09666	−9. 4883334
Subtotal	17	52. 048333	72. 6681482	70. 1342593	59. 541666	23. 8811112	19. 3872223	−4. 895	28. 4962963	1. 486667	−10. 671666
Error	36	51. 54	120. 976667	63. 126666	120. 80333	34. 04	2. 01	5. 08	57. 29	136. 85	−4. 88
Total	53	103. 58833	193. 644815	133. 26093	180. 345	57. 921111	21. 397222	0. 185	85. 786296	138. 33666	−15. 551666

Table 2–4. MANOVA Table of Fatigue

Source	d. f	$Y^{(1)^2}$	$Y^{(2)^2}$	$Y^{(3)^2}$	$Y^{(4)^2}$	$Y^{(1)}Y^{(2)}$	$Y^{(1)}Y^{(3)}$	$Y^{(1)}Y^{(4)}$	$Y^{(2)}Y^{(3)}$	$Y^{(2)}Y^{(4)}$	$Y^{(3)}Y^{(4)}$
Row	2	3. 0948148	6. 984812	16. 58333	1. 6281481	2. 500741	6. 994442	−2. 413333	7. 613889	0. 29555	−4. 56666
Column	5	19. 069259	16. 5602569	44. 3352778	8. 27800915	−18. 058148	25. 39	2. 31222223	−12. 602777	−7. 666671	12. 14
RXC	10	37. 4000522	27. 6758436	38. 3260592	13. 7755095	25. 5952145	12. 9941692	−5. 3722781	32. 0169435	15. 3283453	−8. 22284
Subtotal	17	59. 564126	51. 2208926	99. 2446667	23. 6816667	10. 0379074	45. 3786112	−5. 4733888	27. 0280555	7. 9572233	−0. . 6495
Error	36	337. 98	95. 5301667	63. 2923812	157. 919166	37. 0713334	82. 8602592	122. 209259	−176. 92876	−15. 680334	−2. 035055
Total	53	397. 54413	146. 751059	162. 537048	181. 600833	47. 1092408	128. 238870	116. 735870	−149. 90070	−7. 7231111	−2. 684555

Table 3. Results of F-Test

Item	Sub item	Table value	Comparison	Statistic value	Judgement
Shrinkage $Y^{(1)}$	Sub total	2.5	>	0.153	Not significant
	R * C	2.86	>	0.115	〃
	Row	5.25	>	0.290	〃
	column	3.58	>	0.174	〃
$Y^{(2)}$	Sub total	2.5	>	0.052	〃
	R * C	2.86	>	0.048	〃
	Row	5.25	>	0.045	〃
	Column	3.58	>	0.073	〃
$Y^{(3)}$	Sub total	2.5	>	0.055	〃
	R * C	2.86	>	0.057	〃
	Row	5.25	>	0.023	〃
	Column	3.58	>	0.065	〃
$Y^{(4)}$	Sub total	2.5	<	8.943	Significant
	R * C	2.86	<	15.092	Very significant
	Row	5.25	>	0.131	Not significant
	column	3.58	>	0.168	〃
Strength $Y^{(1)}$	Sub total	2.5	<	7.055	Significant.
	R * C	2.86	<	7.708	〃
	Row	5.25	>	0.021	Not significant
	Column	3.58	<	8.560	Significant
$Y^{(2)}$	Sub total	2.5	<	123.710	Very significnt
	R * C	2.86	<	148.631	〃
	Row	5.25	<	167.98	〃
	Column	3.58	<	56.155	〃
$Y^{(3)}$	Sub total	2.5	>	5.043	Significant
	R * C	2.86	<	2.549	Not significant
	Row	5.25	<	6.914	Significant
	Column	3.58	<	9.283	〃
$Y^{(4)}$	Sub total	2.5	<	14.355	Very significant
	R * C	2.86	<	10.840	〃
	Row	5.25	>	4.201	Not signignificant
	Column	3.58	<	25.449	Very significant
Elongation $Y^{(1)}$	Sub total	2.5	>	2.139	Not significant
	R * C	2.86	>	2.221	〃
	Row	5.25	>	0.997	〃
	Column	3.58	>	2.430	〃
$Y^{(2)}$	Sob total	2.5	>	1.272	〃
	R * C	2.86	>	1.448	〃
	Row	5.25	>	2.061	〃
	Column	3.58	>	0.605	〃
$Y^{(3)}$	Sub total	2.5	>	2.353	〃
	R * C	2.86	>	2.094	〃
	Row	5.25	>	4.438	〃
	Column	3.58	>	2.036	〃
$Y^{(4)}$	Sub total	2.5	>	1.044	〃
	R * C	2.86	>	0.682	〃
	Row	5.25	>	3.759	〃
	Column	3.58	>	0.680	〃
Fatigue $Y^{(1)}$	Sub total	2.5	>	0.373	〃
	R * C	2.86	>	0.398	〃
	Row	5.25	>	0.165	〃
	Column	3.58	>	0.406	〃
$Y^{(2)}$	Sub total	2.5	>	1.135	〃
	R * C	2.86	>	1.043	〃
	Row	5.25	>	1.316	〃
	Column	3.58	>	1.248	〃
$Y^{(3)}$	Sub total	2.5	<	3.321	〃
	R * C	2.86	>	2.180	〃
	Row	5.25	>	4.716	〃
	Column	3.58	<	5.043	Significant
$Y^{(4)}$	Sub total	2.5	>	0.318	Not significant
	R * C	2.86	>	2.593	〃
	Row	5.25	>	0.186	〃
	Column	3.58	>	0.377	〃

pH variation is

$$\text{M.S. Column} = \frac{1.4547049}{5} = 0.29094098$$

$F_0 = 0.1742548228$,

and because F (5.36) (0.99) = 3.58 in the F table, the above F_0 is not significant.

By using the above method, the results to examine F-test for total experimental values are reported in table 3.

4. The preparation of response equation.

To prepare the response equation is derived from table 4. In this table A, B and C means respectively temp., pH, period of time. For the complication of this table pH range is 3.19, 6.22, 10.4 and temp. range is 80°C, 90°C, 100°C, time range is 1.5, 3, 5 hours. And L, M, H are designated from the low value sequencely. To arrange the table 4, the coefficients of response equation are calculated at the final column in table 5, and the calculated response equations are showed in table 6.

We described briefly the procedures of testing for shrinkage. For strength, elongation and fatigue, we used the same procedures as described for shrinkage.

The procedures of calculation in the response equation are complicated and thus for the questions to this, the data is provided by the author of this paper.

5. Discussion.

Searching the major factors which may affect the quality of Spandex fiber, the variation of pH, time and Temperature affects only the strength of Spandex and does not affect of the other properties. And to calculate the a.b.c values about each factor in the response equation, in case of low these values are -1, in case of high these values are +1 and then the average values of yield to each condition are obtained.

Table 4. Design of Response Equation (Shrinkage)

1	LLL	29.0	29.3	26.6
C	LLM	27.6	27.1	29.9
c^2	LLH	28.9	29.2	26.5
b	LML	27.4	29.8	28.0
b c	LMM	26.8	28.8	29.3
b c^2	LMH	27.3	29.7	27.9
b^2	LHL	29.8	27.8	27.3
b^2 c	LHM	27.5	29.3	27.8
b^2 c^2	LHH	29.5	27.9	27.2
a	MLL	26.6	28.6	29.1
a c	MLM	29.6	27.6	27.1
a c^2	MLH	27 0	29.4	27.6
a b	MML	28.7	29.0	26.3
a b c	MMM	28.8	29.1	26.4
a b c^2	MMH	27.2	29.0	28.1
a b^2	MHL	26.6	28.6	29.1
a b^2c	MHM	27.3	27.0	29.7
a b^2c^2	MHH	29 0	26.6	28.4
a^2	HLL	26.9	26.5	30.3
a^2c	HLM	27.4	26.9	29.7
a^2c^2	HLH	27.08	26.78	29.48
a^2b	HML	26.8	29.2	27.4
a^2b c	HMM	28.48	28.78	26.08
a^2b c^2	HMH	26.62	29.02	28 02
a^2b^2	HHL	29.2	26.9	27.3
a^2b^2c	HHM	28.22	28.22	26.72
$a^2b^2c^2$	HHH	29.02	26.52	28.12
	↑ A	↑ B	↑ C	

Table 5. Prepareing of Coefficient of Response Equation (Shrinkage)

Cell	T	A	B	C	D_1	CNT	D_2	S. S	COEF	A′	B′	C′
1	84.9	254.1	763.2	2272.36	81	28.053827	1	63748.39	28.053827	28.039259	28.00864	27.866417
c	84.6	255.0	757.5	−1.04	27	−0.0385185	2	0.02	−0.019259	0.0177785	−0.156	−27.740865
c^2	84.6	254.1	751.66	0.76	27	0.028148	6	0.003565	0.00469136	−0.0483951	0.014	27.73644
b	85.2	252.6	−0.9	−1.12	27	−0.0414815	2	0.023229	−0.02074	−0.19111111	−27.97790	−27.889131
bc	84.9	252.6	−0.3	0.62	9	0.068	4	0.010677	0.0172	0.026	0.2277	27.83896
b c^2	84.9	252.3	0.16	2.3	9	0.25	12	0.04898	0.021296	0.007	0.0092591	−27.81031
b^2	84.9	251.04	0.9	−1.64	9	−0.182	6	0.049807	−0.03037	0.0029632	28.06530839	27.70642
b^2 c	84.6	250.40	−0.3	−1.82	9	−0.202	12	0.0306703	−0.0168518	0.0088	−0.296	−28.01919
b^2 c^2	84.6	250.22	0.16	−0.38	9	−0.042	36	0.007705	−0.011728	0.00259191	−0.232	28.04142
a	84.3	−0.3	0	−11.54	27	−0.427407	2	2.466138	−0.2137037	−28.049136	−28.08765	−27.994195
a c	84.3	−0.3	−0.3	1.06	9	0.117	4	0.0312109	0.0294	0.0420363	0.198	27.984161
a c^2	84.0	−0.3	−0.82	−0.74	9	−0.082	12	0.0050704	−0.00685185	0.02919753	−0.0003707	−28.07753
a b	84.0	−0.3	0	−0.82	9	−0.091	4	0.01867	−0.0227	0.20685185	28.0783	28.087279
a b c	84.3	0.3	0	0.62	3	0.206	8	0.016016	0.02583	0.04638	−0.23231	−28.085401
a b c^2	84.3	−0.3	0.62	1.7	3	0.56	24	0.040138	0.02361	−0.025463	−0.0070677	28.065894
a b^2	84.3	−0.36	0	2.26	9	0.251	12	0.0472926	0.0209259	0.0059875	−28.094875	−27.96752
a b^2 c	84.0	0.26	0.6	−0.62	3	−0.206	36	0.005338	−0.00861	0.0043518	0.313055	28.100214
a b^2 c^2	84.0	0.26	1.7	−0.98	3	−0.326	12	0.00444563	−0.004537	−0.001080198	−0.028981	−28.148358
a^2	83.7	0.3	−1.8	−0.14	27	−0.005185	6	0.0001209	−0.000864	28.097036	27.95531	28.336417
a^2 c	84.0	0.3	−0.3	−0.14	9	−0.015	12	0.0001815	−0.001296	−0.0338881	−0.236	−28.424198
a^2 c^2	83.34	0.3	0.46	1.66	9	0.184	36	0.0085049	0.0051235	0.00216049	−0.012	28.626419
a^2 b	83.4	−0.3	0	−0.22	9	−0.024	12	0.00044815	−0.002037	−0.2794	−28.10401	−28.485798
a^2 b c	83.34	−0.3	−1.2	0.62	3	0.206	24	0.005338	0.00861	−0.05083	0.0886108	28.535885
a^2 b c^2	83.66	0.3	−0.62	0.5	3	0.16	72	0.0011574	0.0023148	0.0336111	−0.003796	−28.74997
a^2 b^2	83.4	−0.96	0	−0.74	9	−0.082	36	0.00169012	−0.002284	0.0068518	28.16697	28.41642
a^2 b^2 c	83.16	0.38	0.6	1.78	3	0.593	72	0.0146685	0.0082407	−0.01694	−0.14416	−28.28502
a^2 b^2 c^2	83.66	0.74	−0.98	−2.18	3	−0.726	216	0.00007469	−0.00336478	−0.02212959	0.0186111	28.47390

Table 6. Response Equation

1) Shrinkage

$$\hat{Y} = 27.9 - 27.7c + 27.7c^2 - 27.9b + 27.8bc - 27.8bc^2 + 27.7b^2 - 28.0b^2c + 28.0b^2c^2 - 28.0a + 28.0ac - 28.1ac^2 + 28.1ab - 28.1abc + 28.1abc^2 - 28.0ab^2 + 28.1ab^2c - 28.1ab^2c^2 + 28.3a^2 - 28.4a^2c + 28.6a^2c^2 - 28.5a^2b + 28.5a^2bc - 2.87a^2bc^2 + 28.4a^2b^2 - 28.3a^2b^2c + 28.5a^2b^2c^2$$

2) Strength

$$\hat{Y} = 0.2 - 0.2c + 0.2c^2 - 0.4b + 0.3bc - 0.3bc^2 + 0.2b^2 - 0.2b^2c + 0.1b^2c^2 - 0.2a + 0.2ac - 0.2ac^2 + 0.3ab - 0.3abc + 0.3abc^2 - 0.2ab^2 + 0.2ab^2c - 0.1ab^2c^2 + 0.2a^2 - 0.2a^2c + 0.1a^2c^2 - 0.3a^2b + 0.3a^2bc - 0.2a^2bc^2 + 0.2a^2b^2 - 0.2a^2b^2c - 0.1a^2b^2c^2$$

3) Elongation

$$\hat{Y} = 32.7 - 32.2c + 30.2c^2 - 33.6b + 33.3bc - 32.5bc^2 + 32.7b^2 - 33.2b^2c + 34.7b^2c^2 - 31.0a + 33.2ac - 32.7ac^2 + 32.7ab - 32.8abc + 32.0abc^2 - 33.3ab^2 + 30.9ab^2c - 26.4ab^2c^2 + 29.3a^2 - 32.2a^2c + 32.1a^2c^2 - 33.8a^2b + 32.4a^2bc - 30.6a^2bc^2 + 33.3a^2b^2 - 30.6a^2b^2c + 22.7a^2b^2c^2$$

4) Fatigue

$$\hat{Y} = 15.8 - 15.9c + 17.1c^2 - 15.1b + 14.8bc - 15.0bc^2 + 15.5b - 16.0b^2c + 13.6b^2c^2 - 16.6a + 16.7ac - 18.0ac^2 + 14.4ab - 14.2abc + 13.4abc^2 - 18.5ab^2 + 15.6ab^2c - 16.6ab^2c^2 + 17.5a^2 - 15.7a^2c + 14.0a^2c^2 - 13.1a^2b + 12.4a^2bc - 15.8a^2bc^2 + 13.5a^2b^2 - 13.8a^2b^2c + 17.4a^2b^2c^2$$

IV. CONCLUSION.

1. The finishing conditions of Spandex fiber affect the strength but does not affect nearly shrinkage, elongation and fatigue.
2. Response equation is obtained as table 6.

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요 약

스판덱스 섬유는 신축성 섬유로서 착용감이 좋기 때문에 스포츠웨어나 편물에 많이 이용되고 있으며 화학적으로 폴리아미드 조성과 비슷하나 주 사슬속에 산소원자를 포함하고 있어서 유연하며 융점이 낮다.

스판덱스 섬유에 대한 연구동향은 구조에 관한것,[1] 물성에 관한것,[2] 편성에 관한것,[3] 염색가공에 관한것,[4-7] 등으로 대별할 수 있으나 가공조건에 따른 물성변화를 검토한 것은 별무하다.

따라서 스판덱스 섬유의 가공시와 유사한 조건을 부여하고, 영향을 미칠 것으로 예상되는 인자 즉 강도, 신도, 수축율, 피로도에 대한 통계적 검정[8]을 통하여 영향력을 확인했고, 반응 방정식을 유도했다.

이 보문은 본 학회지 Vol. 9, №1에 게재한 "스판덱스 섬유의 염색조건이 섬유품질에 미치는 영향"을 정리 영문 번역한 것이다.