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The Effect of Washing Conditions on the Dimension and Mechanical Properties of Spandex Yarns

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세척조건이 스판덱스사의 길이와 기계적 성질에 미치는 영향

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Abstract

The durability of a stretch fabric is mainly related to the change in the dimension and mechanical properties of elastomeric fibers during wearing and washing. In this study, we examined the effects of washing temperature, presoaking time and the number of washing cycles on the change in length, tenacity, elongation at break, and permanent elongation after six repeated cycles of 300% extension and relaxation of spandex yarns with varying fineness and with a different rate of extension during heat-set. The spandex yarns continued to shrink as the wash temperature and the number of wash cycles increased. In addition, the finer spandex yarns decreased in length more than the thicker yarns. The increase in temperature and presoaking time tended to cause a slight decrease in the tenacity and elongation at break of the spandex yarns. Permanent elongation of the spandex yarns also increased as the temperature, presoaking time and the number of washing cycles increased. Moreover, an extended presoaking time followed by washing at 40°C like repeated washing cycles showed the great increase in the permanent elongation of spandex yarns. The thinner spandex yarn had a better elasticity than the thicker one, since the former had a lower permanent elongation percentage than the latter. Based on the DSC thermograms, the melting points of the spandex yarns after washing were almost the same as those of the spandex yarns before washing.

Key words: Spandex yarn, Washing condition, Change in length, Tenacity, Permanent elongation; 스판덱스사, 세척조건, 길이변화, 강도, 영구신장

I. Introduction

Today's consumers prefer apparel that fits well and offers more comfortable movement, so the demand is growing for more stretchable fabrics that contain elastomeric fibers. Rubber and spandex fibers are the main elastomeric fibers, but spandex blend fabrics predominate in apparel items. Spandex is used in smaller deniers and is lighter than rubber.

We frequently find spandex blend fabrics are deformed by the deterioration of their physical properties during actual wear and finally discard them. Spandex fiber is mostly made of segmented polyurethanes. The polymer chains of the spandex fiber consist of two distinct structural units, i.e., hard segments, whose Tg is above room temperature and are related to stronger intermolecular bonds, and soft segments, whose Tg is below room temperature and are related

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to elasticity. In general, the aliphatic polyethers of polyesters are used for soft segments, and the aromatic diisocyanates chain extended with small molecular diols or diamines are used for hard segments(Lee et al., 1997). These urethane, urea, ether or ester groups in polyurethane fibers are more easily hydolyzed or oxidated by chlorine bleach, high temperatures, and ultraviolet light than are ether or ester groups of polyamide or polyester fibers(KFS., 2001). There is not a great deal of research about spandex fabrics and spandex yarns in the aspect of the change in properties during using. Marmarali(2003) compared the dimensional and physical properties of cotton/spandex single jersey and cotton single jersey. He found that as the amount of spandex fibers in the fabrics increased, loop length remained nearly the same and the course and wale spacing decreased. Furthermore, the weights and thicknesses of spandex-containing fabrics were higher, air permeability, pilling grade and spirality were lower. Park et al.(1999, 2000) investigated the setting behavior of cotton/spandex knit fabrics with heat treatment. They found that fabrics treated with steam had a greater increase in the length of the spandex yarn than fabrics treated with hot water or dry heat. They also reported that the length of spandex yarn increased and tensile strength and elongation decreased as treatment temperature, time and fabric extension increased. These studies related to the fabric production process. Chung et al.(2005) evaluated the effect of laundering on the deformation of knitted spandex/cotton fabrics compared with the effect on knitted cotton fabrics. Knitted spandex/cotton fabrics have a lower angle of spirality than knitted cotton fabrics, and the angles of spirality of all the fabrics were decreased greatly during the first washing cycles. The knitted spandex/cotton fabric which expanded greatly during the heat-set had a lower elastic recovery rate and had worse surface appearance than that of knitted cotton fabrics.

In this study, we characterized the effect of washing conditions on the change in the breaking tenacity, the elongation at break, the length, and the permanent elongation at 300% extension of the polyether type spandex yarns. Moreover, the DSC thermograms of the spandex fibers were compared to confirm the change in crystals brought about by washing.

II. Experimental

1. Materials

Four spandex yarns with different levels of fineness- 20D, 40D, 70D, 140D- and other 20D spandex yarns which were separated from spandex blended, cotton plain jerseys were used. Detailed information about the yarns is given in Table 1. Spandex blended, cotton plain jersey was expanded to 5.2%(20D-knit-5.2%) or to 15.8%(20D-knit-15.8%) during heat-set.

Table 1. Characteristics of the spandex yarns

Type	Denier	Tenacity (g/d)	Elongation at break(%)
SP20	20	1.7	666
SP40	40	1.3	475
SP70	70	1.4	530
Sp140	140	1.4	790
20D-knit-5.2%	20	1.2	297
20D-knit-15.8%	20	0.3	183

2. Methods

1) Washing

The spandex yarns and the spandex blended, cotton single jerseys were washed in a domestic drum washing machine(WD-1005X) containing a 0.1% heavy duty detergent solution. The washing load was kept at 2 kg including dummy cloths. For washing, 20D, 40D, 70D and 140D fibers were wrapped in cotton fabric and tied at both ends according to KS K 0219. After washing, the samples were dried in a tumble drier at 65°C for 50 minutes. This laundering procedure was repeated up to thirty cycles.

2) Mechanical properties

The length of each yarn was measured in accordance with KS K 0219, and the percentage of the change in length for each sample was calculated as

$$\text{Length change (\%)} = 100\frac{B-A}{B},$$

where A is the distance between the data lines marked on the yarn before washing, and B is after washing.

Tensile strength and elongation at break of the yarns were measured using an Instron 1011 according to KS K0219 with a gauge length of 50±5mm and a crosshead speed of 500mm/min.

Permanent elongations of the yarns were measured with an Instron 1011 according to KS K0219, and the gauge length and crosshead speed were the same as for the measurement of tensile strength. The yarns were extended to 300% and released six times, and then in that position they were held for 30 seconds. This was followed by measuring the length in the Instron. Permanent elongation percentages were then calculated using the formula:

$$\text{Permanent elongation (\%)} = 100\frac{E-G}{G}$$

Here, G and E represent the gauge length and residual length.

3) Thermal analysis

The thermal properties of spandex yarns were characterized by DSC thermograms using Universal V4.1D TA. The weight of samples were 20mg and samples were heated at a rate of 10°C/min from 0°C to 300°C.

III. Results and Discussion

1. Change in Length

The dimension and the mechanical properties of an elastic fabric change as launderings progress. Because the length and mechanical properties of the spandex yarns which are contained in an elastic fabric change as launderings progress. The effects of the various laundering conditions on the length and mechanical properties of the spandex yarns were studied.

<Fig. 1(a)> shows the change in length of spandex yarns which were washed at different washing temperatures. In this figure, the "-" change in length rates denotes shrinkage. When the washing temperature increased, the length of every spandex yarn decreased substantially. The thinner yarn shrank more than the thicker yarn, so the 20D spandex yarn shrank most and the 140D yarn shrank least at all temperatures. The shrinkage rate of the thinner yarn was greater than that of the thicker yarn, because a larger surface area of the thinner yarn was exposed to the washing solution than was the thicker yarns. The shrink rate of the thinner yarns was more pronounced between 20°C and 40°C and less pronounced between 40°C and 60°C. The shrink rate of the thicker yarns, on the other hand, tended to be less pronounced at the lower temperatures and more dramatic at the higher tem-

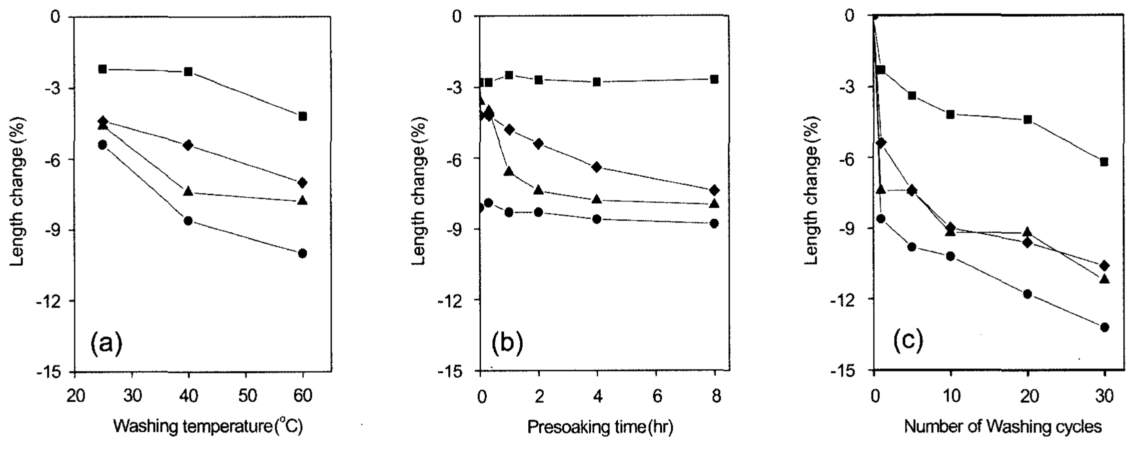


Fig. 1. Effects of washing temperature(a), soaking time(b) and the number of washing cycles(c) on the length change.

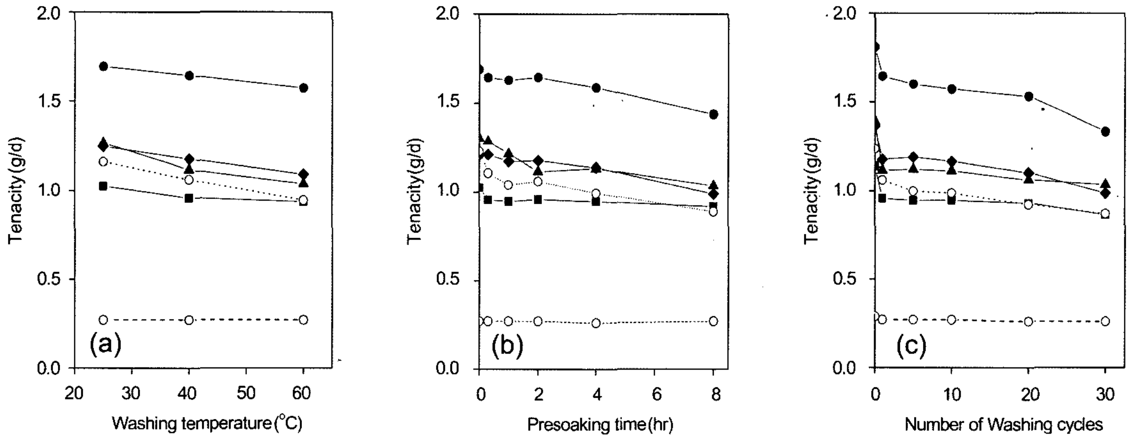
peratures. In other words thinner yarns shrank more at lower temperatures, whereas, thicker yarns tended to shrink more at higher temperatures. <Fig. 1(b)> plots the change in length of spandex yarns against presoaking time. Spandex yarns were presoaked for 0~ 8hours at 40°C followed by being washed at the same temperature using regular wash cycle. The influence of the presoaking time was less pronounced in 20D and 140D.

140D shrank about 2.7% after 8 hours presoaking at 40°C, so the shrinkage seemed to arise from the mechanical forces of the washing procedure. 20D shrank to its greatest shrinkable length during the first 30minutes of presoaking. 40D reached at its state of equilibrium after 4hours and 70D shrank gradually during the 8hours of presoaking.

The change in length of the spandex yarn is plotted against the washing cycles in (Fig. 1(c)). All the fibers shrank greatest amount during the first washing, but they shrank gradually through the 30 wash cycles. We found that mechanical forces during washing and drying cycles are a more important factor than presoaking time for the shrinkage of spandex yarns. This can be attributed more to the input of energy by agitation and drying, which leads to the transformation of the molecules in the amorphous region by removing the stress between molecules.

2. Tenacity and Elongation at Break

The tenacity after washing for the spandex bare yarns and for the spandex yarns which were isolated from the spandex containing cotton plain-knit is shown in (Fig. 2). The tenacity of the spandex yarn tended to decrease as the washing temperature increased(Fig. 2(a)). However, the rate of decrease in the tenacity was less distinctive than the rate of shrinkage, as the washing temperature increased. Though the 40D differed less from the 70D, the thinner yarns had higher tenacity. This is because the weaker points break first, and the thicker yarns have greater number of weak points. 20D-knit-15.8% and 20D-knit-5.2% were isolated from the knitted fabrics, which were the same fineness as 20D and were expanded 15.8% and 5.2% respectively during heat-set. Comparing the tenacity of the three, 20D-knit-15.8% was the weakest, 20D was the strongest, and 20D-knit-5.2% was between the two. The tenacity of 20D-knit-15.8% was especially low. The spandex yarn, which was contained in a fabric and extended large amount during heat-set, would probably break easily in the fabric and cause the fabric to lose elasticity. This was corroborated by Park et al.(1999) who found that the extension rate of the spandex yarn had the more significant effect than treatment temperature and time on the setting behavior. <Fig. 2(b)>



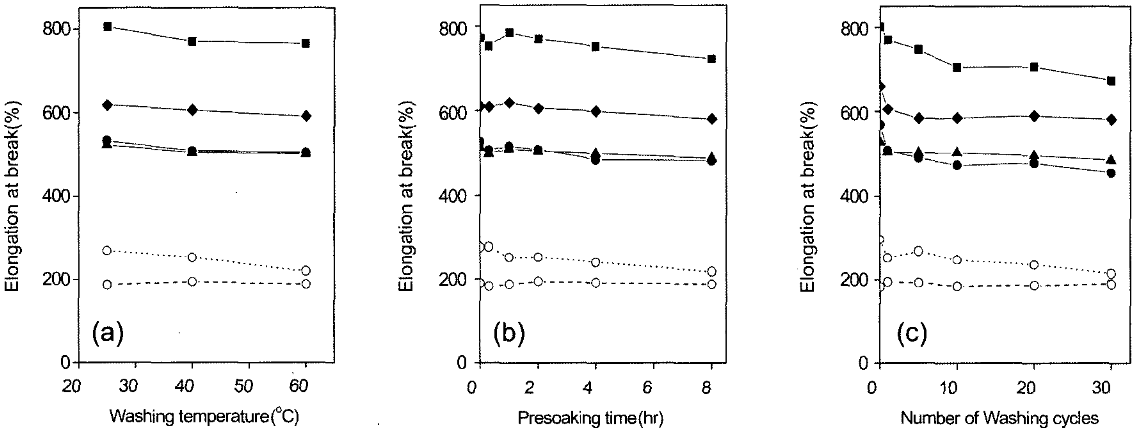
-●- 20D, -▲- 40D, -◆- 70D, -■- 140D, ···○··· 20D-knit-5.2%, --○-- 20D-knit-15.8%

Fig. 2. Effects of washing temperature(a), presoaking time(b) and the number of washing cycles(b) on the tenacity of spandex yarns

shows the change in the tenacity of spandex yarns against presoaking time. As the presoaking time increased, the tenacity of the spandex yarns decreased slightly. Especially, the spandex yarns which had lower tenacity showed less change in their tenacity as the presoaking time increased. The tenacity decreased sharply during the first washing(Fig. 2(c)). Though 20D and 20D-knit-5.2% lost a little amount of its tenacity, most spandex yarns changed little in their tenacity with the subsequent washings at 40°C. The elongation at break of the spandex yarns after washing is shown in <Fig. 3>. The elongation at break of the spandex yarns tended to be different from the tenacity of the yarns. The elongation at break decreased in the

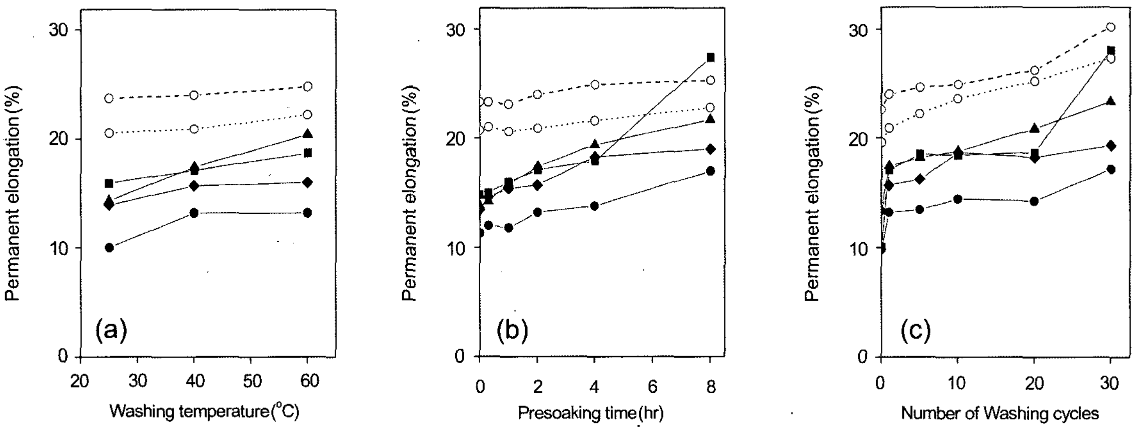
Table 2. Tenacity and strength of spandex yarns

Yarn	20D	40D	70D	140D	20D-knit-5.2%	20D-knit-15.8%
Tenacity(g/D)	1.64	1.12	1.18	0.96	1.06	0.27
Strength(gf)	32.87	44.66	82.36	134.24	21.25	5.35



-●- 20D, -▲- 40D, -◆- 70D, -■- 140D, ···○··· 20D-knit-5.2%, --○-- 20D-knit-15.8%

Fig. 3. Effects of washing temperature(a), presoaking time(b) and the number of washing cycles(c) on the elongation of spandex yarns



-●- 20D, -▲- 40D, -◆- 70D, -■- 140D, ···○··· 20D-knit-5.2%, --○-- 20D-knit-15.8%

Fig. 4. Effects of washing temperature(a), presoaking time(b) and the number of washing cycles(c) on the permanent elongation of spandex yarns

following order 140D>70D>40D, 20D≫20D-knit-15.8%>20D-knit-5.2%. In this study, we used a constant rate of extension tester to measure the tenacity and elongation. Thicker yarns needed more strength to break(Table 2), so the thicker yarns elongated more at break. Heat treatment of the spandex yarns influenced elongation more than it did tenacity. The larger extension during heat-set seemed to get rid of many intermolecular bonds, 20D-knit-15.8% became weaker and more elongated than 20D-knit-5.2%. When washing temperature, presoaking time and the number of washing cycles increased, elongation at break of all the spandex yarns remained nearly the same. This pattern was similar to that of the decreasing of tenacity under different washing conditions.

3. Permanent Elongation

Spandex yarns are used for stretchable fabrics due to their highly elastic recovery. Permanent elongation is a useful index for the elasticity of the yarn. Even small amounts, in the preceding section the spandex fiber lost of its tenacity and elongation at break after washing. We confirmed the change in the permanent elongation of the spandex fiber after extending it to 300% six times. These results are shown in <Fig. 4>. Except for the spandex yarns from the knitted fabrics, thinner yarns had lower permanent elongation under most conditions. Heat-set had a great influence on the permanent elongation of the spandex yarns. The yarns which were treated with both heat and tension had higher permanent elongation than the yarns which were untreated. In addition, the yarn which was treated with higher tension had higher permanent elongation. The permanent elongation of 20D before washing was 9.8%, but that of 20D-knit-5.2% and 20D-knit-15.8% were 19.6% and 22.6% respectively, even though they all have the same fineness. The permanent elongations of every spandex yarn before washing was about 10%, and that increased as the washing temperature, presoaking time and number of washing cycles increased. The increase rate in the permanent elongation of the spandex yarns washed at temperatures from 25°C to 40°C was higher than which was washed at temperatures from 40°C to 60°C(Fig.

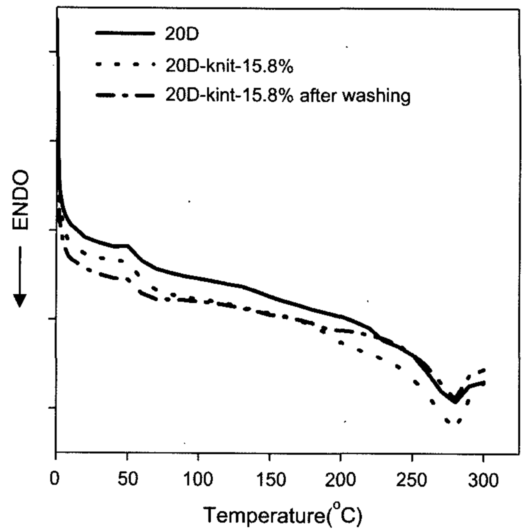


Fig. 5. DSC thermograms of spandex yarns

2(a)). The longer presoaking time at 40°C had greater effect on the permanent elongation of the spandex yarns. Our results show that spandex yarns should be washed at room temperature, and that if they are washed at 40°C, the presoaking time should be shortened.

4. Thermal Property

An experiment was conducted to examine the effect of washing on the thermal property of 20D spandex yarns. The DSC thermograms for heat-set and washing of 20D are compared in <Fig. 5>. The endotherm peak temperatures of 20D, 20D-knit-15.8%, and 20D-knit-15.8% after washing were the same. Baik and Kim (2005) studied the thermal properties of segmented block copolyetherester elastomers which had PBT, PTT, PBN as a hard segment and PTMG as part of the soft segment. They found that melting temperature was a function of hard segment length for all the copolymers examined. Hu & Koberstein(1994) and Lee et al.(1999) reported that the degree of crystallinity in the elastomers was related to the hard segment content rather than to the hard segment length. The area of the peak for 20D-knit-15.8% was a little larger than that for 20D. This may be explained by heat-set. Heat treatment of a spandex fiber increases the regularity of hard domains and the area of the peak in a DSC thermogram(Lee et al., 1997).

IV. Conclusions

The influence of washing conditions on the change in length and in the mechanical properties of spandex yarns has been examined. Effects of washing temperature, presoaking time and the number of washing cycles have been evaluated in terms of tenacity, elongation at break, and permanent elongation after six times 300% extension, and the results were supplemented with DSC thermograms. It is clear from these experiments that the length and mechanical properties of spandex yarns are influenced by the washing conditions, the fineness of the yarns, and the history of the heat treatment.

All spandex yarns shrink gradually as the wash temperature and the number of wash cycle increases. However, the finer spandex yarns shrink more than the thicker yarns. These results may be related to the relaxation of the soft segments in a spandex yarn by the input of energy, such as heat and vigorous mechanical agitation. Though, tenacity and elongation at break of the spandex yarns change little during laundering cycles, permanent elongation changes significantly. The fine denier spandex yarn has a lower permanent elongation percentage than do the thicker yarns. The crystals in the spandex yarns may not have been affected by washing since there was no significant change between the melting points in the DSC thermogram and the tenacity of the spandex yarns before washing and after washing. This experiment has shown that we can reduce deterioration of spandex yarns by washing at the temperature of 25°C and shortening the presoaking time. An elastic fabric which is woven with fine spandex yarns and heat-set with a smaller amount of extension will most probably keep its elasticity longer.

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요 약

탄성직물의 내구성은 탄성직물에 포함된 스판덱스사의 성질변화가 큰 영향을 미친다. 그러므로 본 연구에서는 세탁조건이 스판덱스사의 길이, 강도와 신도, 300% 신장 후의 영구탄성 변화에 미치는 영향을 조사하였다. 시료로는 굵기가 다른 스판덱스사와 heat-set 시 신장률이 다른 편성물을 가정용 드럼세탁기에서 세탁온도, 세탁 전 침지시간과 세탁횟수를 달리하여 세탁한 후, 편성물로부터 스판덱스사를 분리하여 기계적 성질을 측정하였다. 스판덱스사의 길이는 세탁온도가 높아지거나, 40°C에서 세탁횟수가 증가하면 계속 감소하였으나 세탁 전 침지시간에 따른 영향은 비교적 적었다. 섬유가 가늘수록 길이 수축률이 크며 세척 조건변화에 따른 수축률이 크게 증가하였다. 스판덱스사의 강도와 신도는 반복 세척 시의 감소가 뚜렷하였으며, heat-set 시에는 강도와 신도도 크게 감소하였고, heat-set 시에 가해준 신장률이 클수록 감소가 더 컸다. 한편 스판덱스사의 영구변형률은 세탁온도가 높으며, 침지시간이 길고, 세탁횟수가 많을 때 현저히 높았다. 대체적으로 굵은 스판덱스사의 영구변형률이 크며, 140D는 30회 세척 후에 28.0%의 영구변형이 일어났다. Heat-set로 스판덱스사의 영구변형은 늘어나며, heat-set 시에 신장률이 큰 스판덱스사의 영구변형이 더 많았다. DSC 열분석 곡선에서 스판덱스 섬유는 반복 세탁과 heat-set 여부와 관계없이 동일한 융해온도를 나타내었으며, 이로부터 스판덱스 섬유의 hard segment 분자쇄 길이는 세탁 또는 heat-set 후에도 변화가 없는 것으로 보여진다.