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Changes of Pulling-out Length and Shrinkage Ratio in Polyester/Spandex Power Net Warp Knitted Fabrics

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Abstract: Power net fabric is one of the highly extensible two-way fabrics. Power net structure shows special characteristics in the wearing of final functional clothes. This research evaluated effects of treatment temperature on proportional extensibility and shrinkage ratio of spandex at a given wale length. As treatment temperature increased, extensibility increased proportionally to the standard length of the sample and the shrinkage ratio in the direction of course and wale increased. The pulling-out length increased proportionally to the standard length of the sample. However it was affected by the effect of treatment time and temperature due to the thermal properties of spandex filament yarn.

Keywords: Power net, Shrinkage ratio of power net, Pulling-out length, Raschel warp knitting

Introduction

Each stitch in a course of warp knitting is made by a different yarn from a warp beam prepared by the warping process. The yarn is supplied by a guide bar which has a swinging motion and a shogging movement that form overlap and underlap paths. The amount of extension in warp knit is influenced by the type of yarn, construction, stitch density, finishing techniques, and so on. Raschel fabrics, including a power net fabric, belong to the warp-knit fabrics, and the principle of knitting in Raschel knits utilizing latch needles is very similar to that of knitting in tricot knits utilizing beard needles [1].

Power net is an elasticized warp knitting fabric used for foundation garments, panties, all in one, firm control body briefs, open bottom girdle, panty briefs and girdles, women's brassieres, lining, bathing suits, dance wear and costuming. Generally, nylon is used for the two-bar ground construction even though polyester is used for this experiment, and spandex is laid in by two other guide bars for the construction of power net fabric [2]. Power net fabric stretches both lengthwise and widthwise by at least 50 %. It remains springy when stretched due to the spandex component.

A Raschel warp knit machine is used to knit power net construction. Most laces and nets manufactured today are formed with Raschel knit method. Guide bars can carry a variety of yarns in a variety of patterns to form structures in the machine. The Raschel warp knit machine has one or two flat beds with two to seventy-eight guide bars. Power net has been knitted on the four-bar high performance Raschel machine. The four-bar Raschel machine is recognized as the simplest ideal power net machine for an efficient production of highly elastic fabrics for corsetry, swimsuits, and sportswear also made of elastane yarn [3].

One of the important performance characteristics of power net is the strongest open-effect structure. Strong two-way elasticity and functional characteristics are put to practical use for foundation garments [4].

The purpose of this paper to quantify the changes of pulling-out length and shrinkage ratio of spandex in the two-way power net structure as affected by treatment temperature, wet vs. dry treatment conditions, and the addition of firming and softening chemical agents.

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Experimental

Materials

The constituent materials of power net fabric are polyester and spandex yarns [5-10]. The important physical properties of power net fabric are extensibility and retractive force due to the use of spandex yarn. The power net fabric was manufactured using 210 denier spandex yarn and polyester yarn of 70 denier/24 filaments. Using the different warping machines, these yarns were supplied to the warp knitting machine.

The softening agent is a modified degenerated amino silicone applied at 3 *g/l*. The firming chemicals are 119B urethane, RS-MS urethane and MS urethane (Bokwang Chemical. Co.).

Process of Power Net Manufacturing

Figure 1 shows the manufacturing process of power net warp knitted fabric. Through the master chip manufacturing and filament spinning, polyester filament yarn (for guide bars ① and ②) and spandex yarn (guide bars ③ and ④) are prepared and these are rewound through polyester filament yarn warping and spandex yarn warping (Figure 2), respectively. Raschel four-bar power net construction and dyeing-finishing processes are the main processes for the final fabrics used in the manufacture of high extensibility and recovery apparels such as foundation garments, all in one, firm control body briefs.

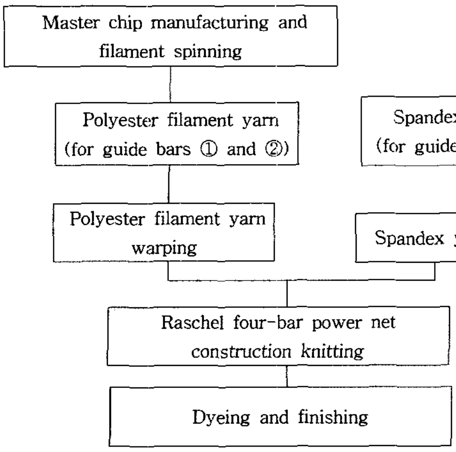

Figure 1. Power net manufacturing process.

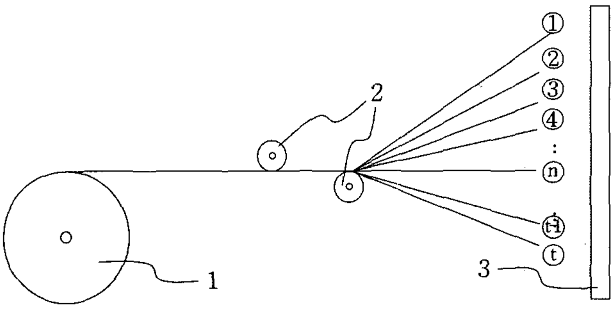

Figure 2. Warping process for the manufacturing of the power net fabrics; (1) warp beam, (2) end guide rollers, (3) side creel.

Warping from the Creel of the Spandex Bobbins

Warping process for spandex yarns is very sophisticated because of the extensibility of spandex. A special warping machine for spandex yarns is used in controlling yarn tension accurately. The optimum preliminary draft in warping depends on the design of the particular warping machine and the characteristics of the spandex used in knitting. In general, over the 200 denier yarn, a preliminary draft of 60-70 % is used. But under 100 denier, a preliminary draft of about 100 % is used. In this experiment, a preliminary draft of 80 % is used.

Polyester filament yarns were rewound at guide bars ① and ②, and subsequently, spandex filament yarns were rewound at guide bars ③ and ④. Figure 2 shows the warping process for the manufacturing of the power net fabrics.

A Four-bar Raschel Machine

The spandex yarn together with polyester yarn is used to make elastic power net fabrics by means of the warp knitting in the Raschel warp knitting machine. To provide spandex yarn on the knitting element of the four-bar Raschel machine, the spandex yarn on the bobbins must be warped to be prepared for sectional beam form. For the manufacture of corsetry, the power net constructions are primarily used, which are knitted on the four-bar Raschel machine.

Table 1. The specification of a four-bar Raschel machine

Working width (cm)	432
Total width (cm)	612
Gauges (needles/in)	24
Pattern drive	N-4 pattern discs
Machine drive	speed-regulated main drive
Take-up	change gear drive, vulcanized fabric take-up rollers
Knitting elements	latch needle, needle bar and tongue bar

Table 2. The details of a power net construction

Net connecting yarn density (threads/in)	35
Spandex warp yarn density (ends/in)	50
Tensile strength (N)	298
Tensile elongation (%)	283
Common notation for materials (spandex 210 d/polyester 70 d)	2170

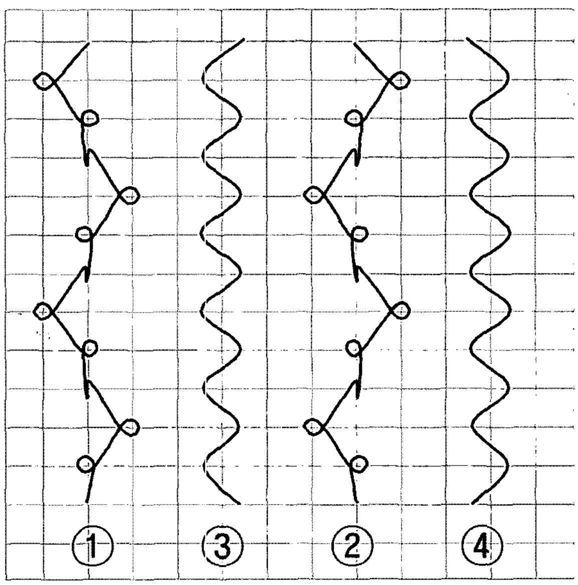

Figure 3. Guide bar movements for the power net construction.

The specification of the four-bar Raschel machine used in the experiments is shown in Table 1.

Power Net Construction

Specifications of the power net construction knitted in the experiments are given in Table 2. The swing and lapping movement of the spandex threads and the polyester threads for the power net construction can are shown in Figure 3.

Measurement of the Shrinkage Ratio of Power Net

The shrinkage ratio of power net (R) was measured by the following equation; l_0 is the initial length of the power net in

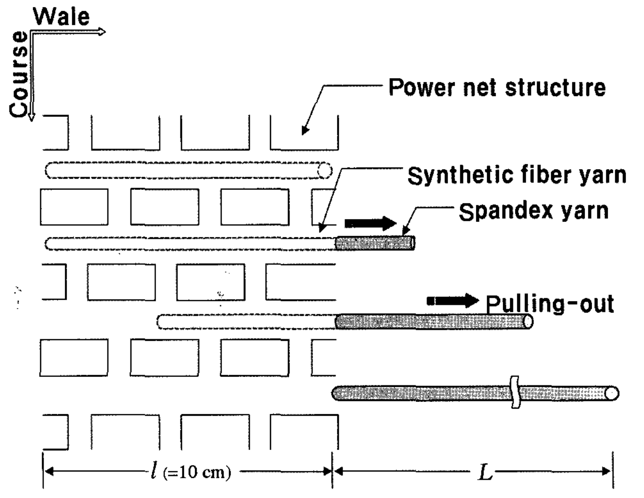

Figure 4. Measurement of the pulling-out length of spandex yarn in the power net fabric.

the direction of wale or course and Δl_o is the difference between the initial length and the shrunk length of the power net in the direction of wale or course.

$$\frac{\Delta l_o}{l_o} \times 100 = R \text{ (shrinkage ratio)}$$

Measurement of the Pulling-out Length of Spandex

The pulling-out length of spandex yarn in power net fabric was measured by stretching spandex yarn of a given length in the direction of wale from the knitted fabrics as illustrated in Figure 4. The given length in the power net warp knitted fabric, l is 10 cm and L is the pulling-out length of spandex yarn in power net fabric.

Results and Discussion

Tensile Curves of Spandex Yarn and Power Net Fabrics

Figure 5 shows the tensile curves of the spandex filament yarn used in manufacturing power net warp knitting in the experiments. The breaking strength was about 2.55 N and breaking elongation was about 770 %.

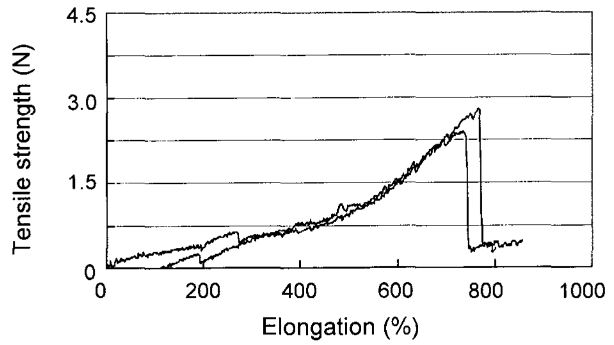

Figure 5. Tensile curves of the untreated spandex yarn.

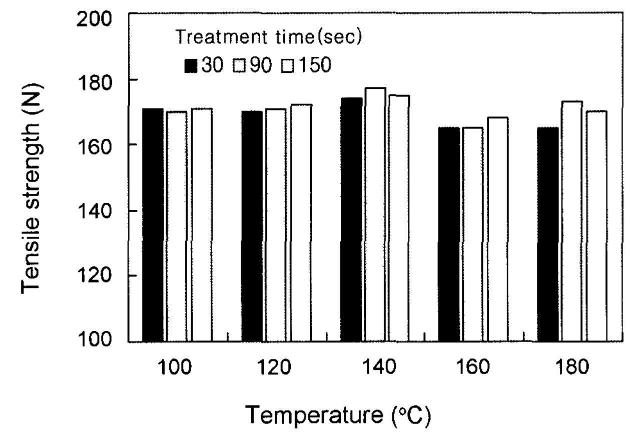

Figure 6. Breaking strength of the power net fabric manufactured by the polyester and spandex filament yarn.

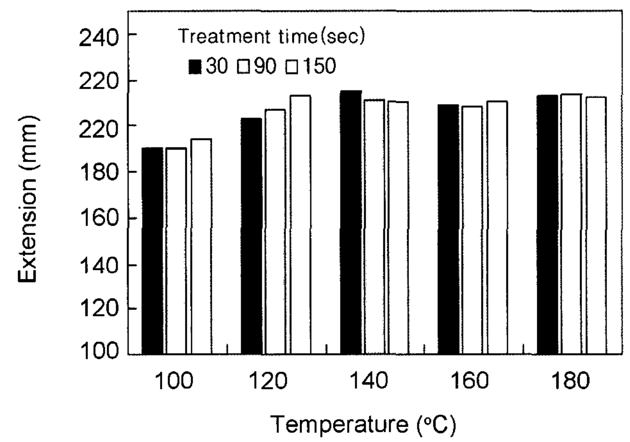

Figure 7. Changes of breaking elongation of the power net warp knitted fabric at different times and temperatures.

However, Figures 6 and 7 show the tensile strength and extension of the power net fabric manufactured by the polyester and spandex filament yarn, respectively; breaking strength and breaking extension were ~170 N and 200 %, respectively.

Figure 6 illustrates the changes of physical properties of the knitted fabric over time as treatment temperature rises to 180 °C. Tensile strength is highest at 140 °C.

Figure 7 illustrates the tensile elongation of the power net fabric manufactured from polyester and spandex filament yarn. The breaking elongation increases with time and temperature, but the influence is on the ebb when the temperature rises to 140 °C due to changes in physical properties by the heat treatment.

Effect of Treatment Time and Temperature on the Shrinkage Ratio of the Power Net Fabric

Figures 8 and 9 show the effects of treatment time and temperature on the shrinkage ratio of the power net in each

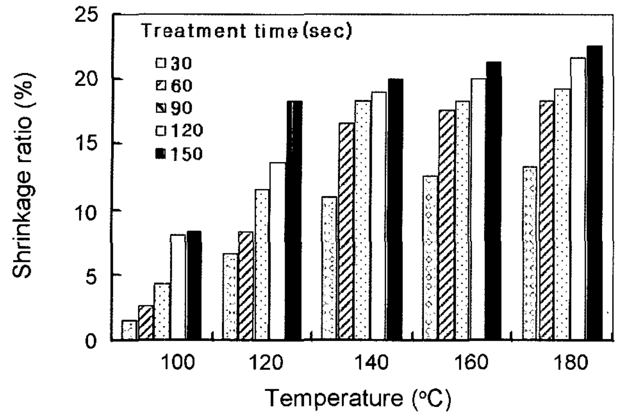

Figure 8. Shrinkage of the polyester/spandex power net fabric in the direction of wale.

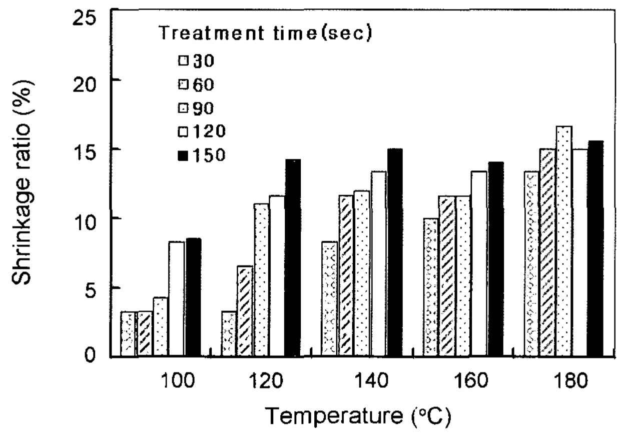

Figure 9. Shrinkage of the polyester/spandex power net fabric in the direction of course.

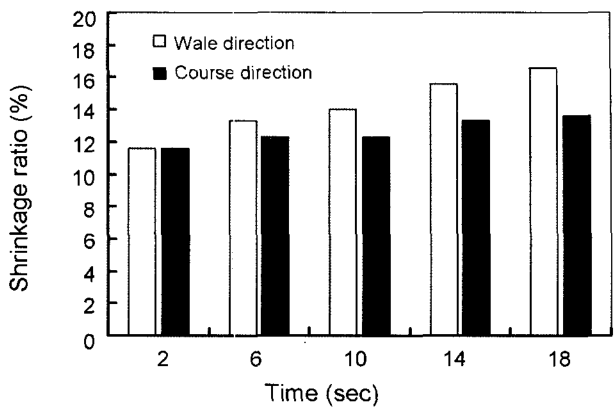

Figure 10. Shrinkage ratio of the polyester/spandex power net fabric under wet heat treatment.

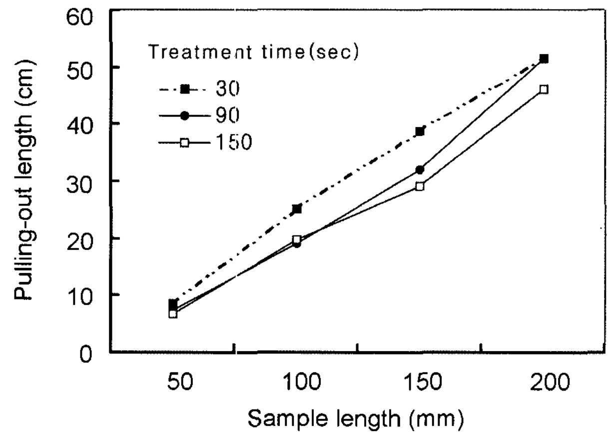

Figure 11. Effect of standard sample length on the pulling-out length of the spandex filament yarn treated by dry heat at 100 °C.

direction of wale and course with treatment by dry heat.

These figures illustrate that the values of shrinkage ratio of the direction of wale are higher than those of the direction of course.

As treatment temperature increases from 100 °C to 140 °C for various treatment times such as 30, 60, 90, 120 and 150 sec., respectively, the shrinkage ratio of the power net also increases by about 10 %. It increases in about 4 % at 120 °C, and increases about 2 % at 140 °C. At treatment temperature of 180 °C, the shrinkage ratio of the power net increases by about 6 %. In power net industry the heat setting is very important because power net fabric stretches lengthwise and widthwise at least 50 % in either direction. Therefore these results of experiments for the effects of treatment time on the shrinkage ratio of the power net may be applicable to the control of characteristics of the final products. The tendency of the results is very similar to the fact that polyester and spandex yarns are shrunk according to the treatment time.

Figure 10 shows the effects of treatment time on the shrinkage ratio of the power net under wet heat treatment in the direction of wale and course, respectively. The shrinkage ratio increases with longer treatment time and the increasing ratio in wale direction is higher than that of course direction. These results can be explained as the role of spandex filament yarn in the power net structure. The wale is composed of a spandex yarn core covered by a polyester yarn. Therefore as the treatment time is lengthened, the shrinkage ratio in wale direction increases more than that in the course direction.

Effect of Treatment Time and Temperature on the Pulling-out Length of Spandex yarn

Figure 11 shows the effect of the standard sample length on the pulling-out length of the spandex filament yarn in a power net at various treatment times. The power net sample was treated by dry heat at 100 °C. Pulling-out length increased proportionally to the standard length of the sample. But the increasing rate of the pulling-out length tends to decrease according to the treatment time. This figure also indicates that the frictional force between polyester and spandex yarn increases with sample length, suggesting that the rigidity of

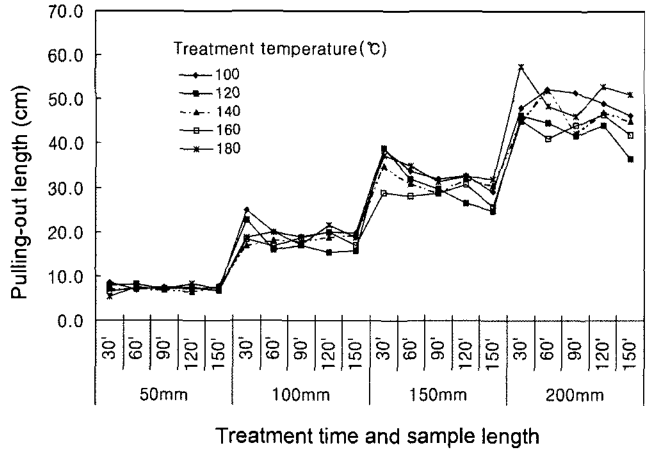

Figure 12. Effect of treatment temperature, treatment time and standard sample length on the pulling-out length of the spandex filament yarn.

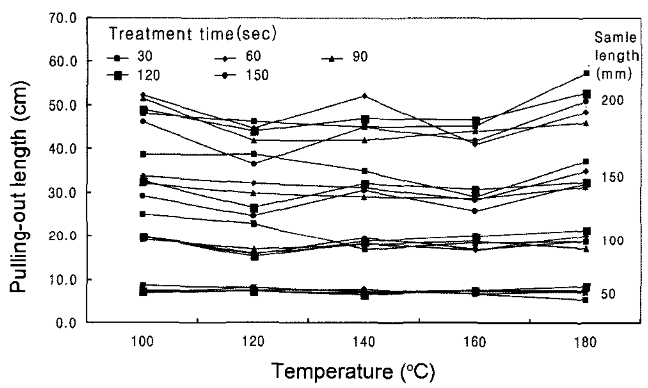

Figure 13. Effect of treatment temperature and standard sample length on the pulling-out length of the spandex filament yarn.

spandex yarn increases with treatment time.

Figure 12 shows the effect of treatment temperature, treatment time and standard sample length on the pulling-out length of the spandex filament yarn in a power net. This integrated figure also shows that the pulling-out length increases proportionally to the standard length of the sample as shown in Figure 11. The effects of treatment temperature and treatment time on the pulling-out length are very complicated, but the rate of increase in pulling-out length tends to decrease according to the treatment time at all treatment temperatures. This phenomenon also explains the effect of the increase of the rigidity of spandex yarn when the treatment time increases as in the case of the treatment temperature of 100 °C. The effect of treatment temperature is not clear in this figure, so another treatment temperature axis figure is necessary for clarity.

Figure 13 shows the effect of treatment temperature on the pulling-out length. The effect of treatment temperature is not insignificant but the deviation of the data increases with standard sample length. This indicates that the pulling-out length remains invariant and fabric length shortens, even though heat treatment is applied.

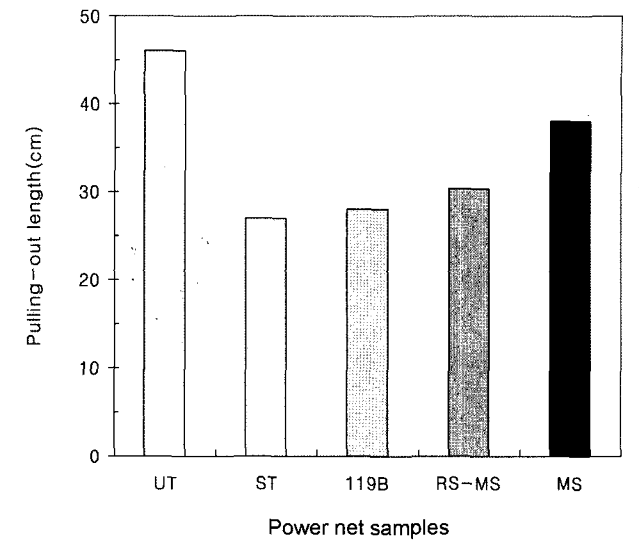

Figure 14. Effect of the softening agent and firming agent on the pulling-out length of spandex yarn in the case of standard sample length of 200 mm.

Shortening the Pulling-out Length of Spandex yarn by the Treatment of Softening Agent

When a softening agent is used, the pulling-out length decreases rapidly with the amount of softening agent. This phenomenon causes a pulling-out problem in a power net of elasticized warp knitting fabrics used for foundation garments, firm control body briefs and dance wear. These clothes need to grip strongly without the spandex yarn pulling-out to prevent weakening of the grip and an inferior appearance of the pulled-out spandex yarn tail. So it is necessary to use chemicals to grip the spandex yarn firmly in the polyester coverings when a softening agent is used.

Figure 14 shows the effect of the softening agent and firming agent on the pulling-out length of spandex yarn. The softening agent is a modified degenerated amino silicone applied at 3 *g/l*.

The value of pulling-out length at the standard sample length of 200 mm without the softening agent is lowered to about 58 % when the softening agent is applied, but this value increases when the firming chemicals are added. Treatment temperature and treatment time are 40 °C and 10 min., respectively. In using a softening agent in power net warp knitted fabrics to improve flexibility, the chemicals are beneficial to improve the pulling-out length.

When the firming chemicals were added, the values of pulling-out length increased from 26.8 to 27.5, 30.3 and 38.0 cm, respectively. Therefore these firming chemicals are useful in reducing the pulling-out problem caused by the softening agent treatment.

Conclusions

Power net is an elasticized warp knitting fabric used for foundation garments, panties, all in one, firm control body briefs, open bottom girdle, panty briefs and girdles, women's brassieres, lining, bathing suits, dance wear and costuming. One of the important characteristics of power net is the strong open-effect structure. Not only strong two-way elasticity but also functional characteristics are required for foundation garments nowadays. Through the experiments for the changes of pulling-out length of spandex and shrinkage ratio by the treatment of dry heat, the following results were obtained. The power net fabric was manufactured by using the 70 denier/24 filaments polyester yarn and the 210 denier spandex filament yarn in the needle gage of 24. As treatment temperature increased, the shrinkage ratio of the direction of course and wale also increased. Treatment time also affected the shrinkage ratio. The values of shrinkage ratio in the direction of wale were higher than those in the direction of course. The pulling-out length increased proportionally to the standard length of the sample. However it was affected by the effect of treatment time and temperature due to the thermal properties of spandex filament yarn. The firming chemicals were useful in reducing the pulling-out problem. When the firming chemicals are added, the values of pulling-out length increased from 26.8 to 38.0 cm.

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