Shrinkproof Effect and Property of Shrinkproof-Finished Wool Knit

Myung-Ja Park† and Soo-Kyoung Kwak
Dept. of Clothing & Textiles, Hanyang University
(Received May 20, 2004 : Accepted November 13, 2004)

Abstract

The shrinkproof-finished wool fibers treated with resin coating and chlorination methods were used to find out an optimal shrinkproof finishing method keeping the quality properties of wool fabric to manufacturers. Shrinkage during repeated washing, electrostatic propensity, thermal resistance and pilling propensity of shrinkproof-finished wool knits, and analysis of finishing methods were measured. Upon the results from the surface examination of shrinkproof-finished wool fibers, the patterns of scale layer and degree of scale removal were subject to change according to the finishing processes. The shrink resistance was significantly enhanced on repeated washing of shrinkproof-finished knits, especially, chlorinated wool. Addition of strong physical force and alkali detergent applied in this washing experiment brought about superior effects with the low shrinkage rate although it was very severe washing conditions for wool fabrics. The results from the washing experiment implies that shrinkproof-finished knitted fabrics can be machine washed at individual households with other ordinary laundry. There was some changes and variation found in thermal resistance, electrostatic propensity, and pilling, however, it seems to be minor within standard limits. Therefore, shrinkproof-finished knitted fabrics did not bring serious changes to other physical properties comparing with original wool, which helps consumers handle wool knitted clothes more conveniently.

Key words : chlorination, electrostatic propensity, shrinkproof finish, thermal resistance, pilling.

Ⅰ. Introduction

Wool as a staple fiber obtained from nature is an ideal fabric material for the clothes; its low initial modulus makes wool very soft, warm, elastic, hygroscopic, water resistant and fire retardant. So, it is widely used as high-quality cloth fabrics from a winter coat to summer-wear, or from knitted innerwear to outerwear like sweater and jersey.[1)]

The surface of the wool fiber, cuticle, is made up of an epicuticle and a horny, nonfibrous layer of scales. The epicuticle is a thin, nonprotein membrane that covers the scales. This layer gives abrasion resistance and water repellency to the fiber, but is easily damaged by mechanical treatment. Under mechanical action, such as agitation, friction, and pressure in the presence of heat and moisture, the wool fiber

This work was supported by Hanyang University, Korea, made in the program year of 2001.

E-mail : mjapark@hanyang.ac.kr

[1] Norman Hollen, Jane Saddler, Anna L. Lanford and Sara J. Kadolph, *Textiles*, 6th ed.(NY: Macmillan Publishing Co., 1988), 44-56.

tends to move rootward and the edges of the scales interlock, thus preventing the fiber from returning to its original position in the fabric. The result is the shrinkage, or felting, of the cloth, which makes the laundering of wool more difficult.

Drycleaning is the recommended care procedure for wool fabric due to its tendency to felt and be degraded by alkaline laundry detergents.[2] However, washable wool is important in clothing that has easy-care characteristics to keep its original size with laundering. Therefore, treatments to prevent felting shrinkage have been studied, based on the principle of smoothing off the rough edges of the scales.[3-7]

Cockett et al.[8] carried out a research on the shrink-proof finishing method for wool fabrics and the degree of shrinkage by time. It was shown that as the time to process the fabric in a high concentrate solution was longer, the shrinkage decreased. The studies with respect to the shrink-proof finishing process mainly include new ways of shrink resistant process, wrinkle-prevention method for washed wool fabrics, and physical properties, dyeing or hand of shrink-proof finishing fabrics.[9,10]

With respect to such research on physical properties of knitted fabrics, Kim[11] determined the effect of knit structure and knit density(machine tightness factor) on the dimensional properties and K_{1-4} values of weft-knitted cotton fabrics for outerwear followed over eleven cycles of mechanical relaxation. Park et al.[12] studied on the dimensional stability of double-weft-knitted fabrics in connection with knit density and loop configurations. According to the results from aforementioned research, the knit structure and knitting conditions along with the fabric properties of raw yarn of knitted fabrics can have an impact on the dimensional properties and physical properties. However, various properties of washable wool are still not known. Therefore, the study is designed to determine the various properties of wool knits altered by shrinkproof finishing.

Therefore, the study was designed to analyze the impact of shrinkproof finishing methods for wool fabrics on the shrinkage effects of knitted fabrics and change in physical properties. To do so, various shrink-proof finished wool were prepared and the shrinkage rates due to repeated washing, electrostatic propensity, thermal resis-

---

2 Norman Hollen, Jane Saddler, Anna L. Lanford and Sara J. Kadolph, *Op. cit.*

3 P. K. Banerjee and T. S. Alaiban, "Geometry and dimensional properties of plain loops made of rotor spun cotton yarns, part i: outline of problem and experimental approach," *Text. Res. J.* Vol. 58, (1988), 123-127.

4 E. A. Ney, R. Peake and N. Regos, "Wool reactive polyurethanes: a method for shrink resistant, permanent press wool," *Textile Chemist and Colorist* Vol. 8, No. 10 (1976), 40-45.

5 K. J. Dodd, C. M. Carr and K. Byrne, "Ultraviolet radiation curing treatments for shrink-resistant wool fabric," *Text. Res. J.* Vol. 68 (1999), 10-16.

6 G. N. Freeland and G. B. Guise, "Soft handle shrink-resist for wool fabrics," *Proc. Int. Wool Text. Res. Conf.* IV-401 (1990).

7 K. R. F. Cockett and D. M. Lewis, "Shrink resist finishing of wool knits," *Textile Chemist and Colorist* Vol. 10, No. 11 (1978), 33-35.

8 K. R. F. Cockett and D. M. Lewis, *Op. cit.*

9 K. R. F. Cockett and D. M. Lewis, *Op. cit.*

10 E. A. Ney, R. Peake and N. Regos, *Op. cit.*, (1976), 40-45.

11 Young-Li Kim, " Studies on dimensional properties of cotton weft-knitted fabrics for outerwear," *J. of the Korean Society of Clothing & Textiles* Vol. 21, No. 1 (1977), 170-181.

12 Shin W. Park, Jai S. Ahn, Bok C Kang and Ho H. Cho, "Studies on the mechanical properties and hand of double weft-knitted fabrics," *J. of the Korean Fiber Society* Vol. 32, No. 3 (1994), 198-203.

tance and pilling propensity depending on finishing methods were measured. Based on these, this study will find out an optimal shrinkproof finishing method with shrink-proof effects and excellent physical properties while keeping the quality properties of wool fabric to manufacturers and help consumers handle wool knitted clothes more conveniently.

Ⅱ. Experimental

1. Materials

Wool shrinkproof-finished yarns were used for the manufacturing of test knitted fabrics. Three kinds of finished yarns were modified by resin coating to mask the scales, combining of resin-coating & softening, and chlorination to dissolve the scales (2/48's). Its types and characteristics are summarized in 〈Table 1〉.

2. Knitting Method

The test fabrics were knitted by a weft knitting machine (SHIMA SEIKI SES124 S) with 48-inch width, 12 gages, and all needle knitting structure (0×0 rib, presented in Fig. 1) under the same knitting conditions with gauge loop 5.4 mm long and degree of knit density.

3. Examination of Fiber Surface

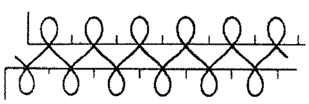
The wool shrinkproof-finished yarn is considered to have different scale formats of fabric surface depending on finishing processes. Therefore, a SEM, scanning electron microscope, (JSM-6330F, JEOL Korea) is introduced to observe the fiber surface at a magnification of 1,000 times.

4. Measurement of Dimensional Stability

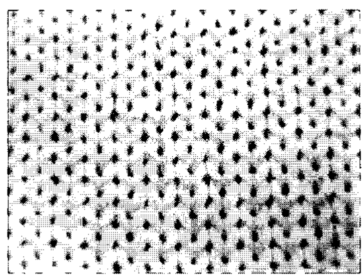
The specimens were prepared in size of $50\times50\ cm^2$ and the evaluation was performed by the washing method (KS C 9608). The washer, which is the rotating drum-type washing machine (TROM WD-R100C, LG Electronics) was under the same washing conditions of general cloths. The washing was carried out for 40 minutes at 30℃ temperature with commercial all-purpose

〈Table 1〉 Characteristics of the Shrinkproof-Finished Wool Yarns

No.	Code	Finishing Method	Thickness of Yarn	Commercial Name
1	Org	Original	2/48's	Normal Wool
2	Res	Resin Coating	2/48's	Super Wash Wool
3	R+S	Resin Coating & Silicone Softening Finish	2/48's	Ultra Wash Wool
4	Chl	Chlorination, Silicone Softening Finish & Crimp Finish	2/48's	Magic Luster Wool



(a) 0×0 Rib Stitch



(b) The Knitted Fabric

〈Fig. 1〉 Structure of All Needle Knitting.

detergent with a regular washing course. The time spent for washing, rinse, and spin-drying was an hour and 20 minutes. In each cycle, shrinkage of the length, width, and area of specimens were calculated.

5. Methods of Property Evaluation

1) Electrostatic Propensity

On the basis of Korean Industrial Standard(KS K 0555, KS K 055544), the charged surface or nylon standard friction fabric specimen was rubbed with the friction voltmeter (RET-20N, Daiei Trading), and the measurement of friction voltage was conducted for 60 seconds from the start of friction. Half life measurement was carried out through a Static Honestmeter (Static Honestmeter Type H-0110, Shishido Electrostatic Co., Ltd.). The half-life through which the static electricity is cut down by half was measured for 60 seconds.

2) Thermal Resistance

The thermal insulation tester (ASTM TYPE, Eiwa Denshikeiki) was used to measure the level of thermal insulation based on the constant temperature method (KS K 0560). The following equation was applied to calculate the warmth in percentage:

$$\text{Thermal Insulation Rate (\%)} = \left(1 - \frac{a_2}{a_1}\right) \times 100$$

where,

a_1 = radiant heat in cal/cm^2/sec or w/hour when no specimen is on the heating plate

a_2 = radiant heat in cal/cm^2/sec or w/hour when a specimen is on the heating plate

3) Pilling Propensity

Pilling test was carried out by the pilling tester (IWS VIEWING CABINET MODEL 120, James H. Heal & Co. Ltd.) based on the ICI box method (KS K 0503, ASTM D 3514), and evaluated in accordance with American Society for Testing and Materials (ASTM) Standard (ASTM D 3514) Pilling Rating Standards presented in 〈Table 2〉.

〈Table 2〉 Pilling Rating Standard

Scale	Evaluation
5	No Pilling
4	Slight Pilling
3	Moderate Pilling
2	Severe Pilling
1	Very Severe Pilling

Ⅲ. Results and Discussion

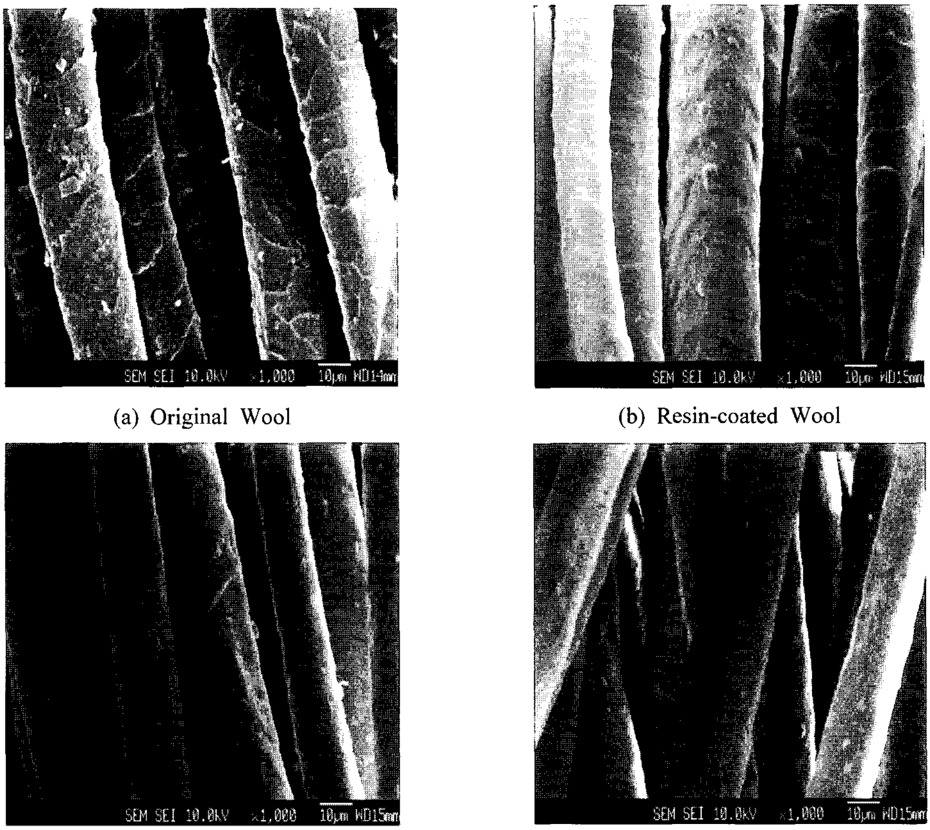
1. Changes of Scale Structure

From the observation of the scale patterns and of degree of scale removal depending on the shrinkproof finish types with the SEM, the scale layers were clearly displayed on the surface of original wool yarn shown in 〈Fig. 2(a)〉. In regard to the resin-coated wool yarn, which was processed with shrinkproof finish, the scale layers were covered with resin showing the scale less clearly than the original wool yarn presented in 〈Fig. 2(b)〉. The scale layers of resin-coating & softening were less clearly in 〈Fig. 2(c)〉. As for chlorinated wool fiber shown in 〈Fig. 2(d)〉, its surface had no friction and the layers of scale were not found; so it seems that it was dissolved most.

From the results, we examined the changes in shapes of the scale layer of the wool fiber through the resin coating and chlorination. It is considered that the fiber of the knitted fabrics, which are made of shrinkproof-finished yarn would greatly influence the changes in the shrink effect of the knitted fabrics depending on the modification of the scale layer and the level of removal. Chlorinated wool fiber is thought to be the optimal material for producing wool inner wear since the removal of the scale layer strengthens the shrink-proof effect and effectively reduce injuries caused by skin-irritation.

2. Effect of Dimensional Stability

The shrink resistance of knitted fabrics while washing was evaluated by measuring the fabric shrinkage rates in both horizontal and vertical



(a) Original Wool

(b) Resin-coated Wool

(c) Resin-coated & Softening Wool

(d) Chlorinated Wool

〈Fig. 2〉 SEM Photograph of Fiber Surface (1,000).

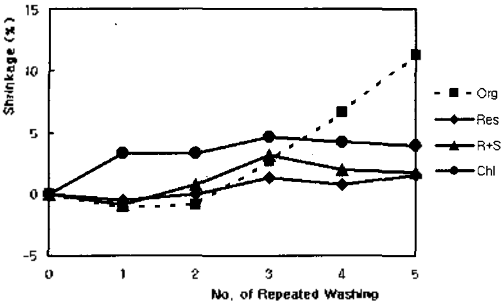
directions and the dimensions before and after repeated washing of the knitted fabrics shown in 〈Fig. 3〉.

As shown in 〈Fig. 3(a)〉, the widthwise shrinkage rate of original wool continuously increases as washing cycles were repeated, but the shrinkproof-finished knitted fabric reached the equilibrium at the third washing. Superior shrink resistance was found at less than 5% for all washing rounds. For the shrinkproof-finished knit, there was a little difference among materials. The chlorination process showed the best shrink resistance followed by the resin/softening process and resin-finished process in order. The resin/softening-finished knit and chlorinated knit were a little loosened at the first and second washing cycles. However, it started shrinking from the third.

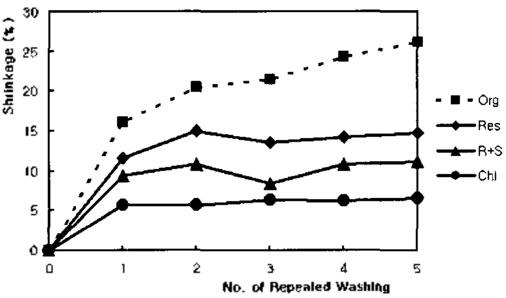
On the other hand, as seen in 〈Fig. 3(b)〉, the shrinkage rate difference was identified more drastically in the warp direction than the course direction, and the first washing cycle generated the highest shrinkage rate. For all the shrinkproof-finished knitted fabrics, the shrinkage was deemed to discontinue at the washing cycle of washing. While original wool (non-finished yarn) shrinkage by repeated washing, the shrinkage of shrinkproof-finished knitted wool did not change much from ones shown in the first and second washing. Among shrinkproof-finished knits, Chlorinated wool showed the lowest shrinkage rate with 6.6%.

As found in 〈Fig. 3(c)〉, the area shrinkage rate of the shrinkproof-finished knitted fabrics were similar to the shrinkage rate at the lengthwise, and the shrinkage rates differed in the type of shrinkproof finishing processes. Chlorinated wool was 10.3%, the lowest, followed by R+S (12.8%) and Res (16.2%). The shrinkproof-finished yarn material showed the highest shrinkage rate on the first washing, and reached the even point after the second round. However, those knitted fabrics in non-finished yarn kept shrinking (34.6 %) as washing was repeated.

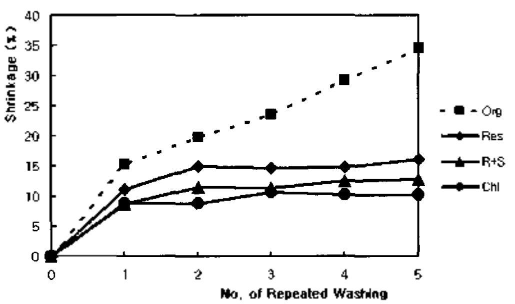
From the results above, the shrinkproof effects



(a) Widthwise



(b) Lengthwise



(c) Dimension

〈Fig. 3〉 Shrinkage of Shrinkproof-Finished Wool by Repeated Washing.

of shrinkproof-finished knitted fabrics were all good enough. Especially, the direct removal of scale will bring more effective results than the resin-coating process, which prevents scale from being activated. Therefore, the scale-dissolution by chlorination process is regarded to be appropriate for the manufacturing of inner wear easy to be exposed to washing.

Besides, since the shrink-proof finished knitted fabric showed lower shrinkage rate even in harsh washing conditions (machine washing in hot alkali detergent solution for a long agitation process period), it is considered that it could be machine-washed at home with other laundry. Particularly, it is expected to bring more enhanced shrink-proof effects in using a general wool washing method (hand laundered in low temperature of neutral detergent solution with less agitation). Thus, it is considered to help consumers easily care wool wear.

3. Electrostatic Propensity

The original wool fiber is known to have no electrostatic problems. In order to see whether the shrinkproof finishing process causes the change in electrostatic propensity or not, measurement on half-life and friction voltage was carried out. When fibers are rubbed each other, static electricity is generated. A half-life is the time taken to reduce the electrostatic amount by half at that moment.

From the half-life of the shrinkproof-finished wool yarn knitted fabrics shown in 〈Table 3〉, the time spent for original knitted fabrics to reach the half-life can be summarized as follows: the original wool (10 sec) shows the highest, followed by the resin coating & softening process (19 sec), chlorinated process (36 sec) and resin coating process (40 sec) in order. The wool finishing process makes all half-life increase, and the time taken for the wool finished knitted fabrics to reach to the half-life is effected by the finishing process type. The increase of half-life seems to be caused by the softening finishing process implemented right after the shrinkproof finishing. And, it was found that the half-life increased due to only the resin finishing or the increase of the finishing time. However, the time taken for all to come to the half-life was less than 60 seconds, indicating that there was no issue found in regard to electrostatic propensity.

With respect to the friction voltage occurring when the fabric was rubbed with others, as shown in ⟨Fig. 4⟩. Friction voltage of shrinkproof finished wool knit, the highest friction voltage was found on the original wool, followed by the resin finishing, resin/softening finishing, and chlorinated finishing in sequence. However, all the friction voltages revealed less than 3,000V making a conclusion that there was no issue arisen related to shrink-proof finishing process likewise the results of half-life testing mentioned before.

4. Thermal Resistance

One of the most essential functions of the clothes is to keep body warmth, so this thermal resistance feature is one of the primary features in cloth fabrics. Wool is known to have excellent thermal resistance. The change in thermal resistance caused by the shrinkproof finishing process was measured.

As found in ⟨Fig. 5⟩, thermal resistance of shrinkproof-finished wool knit, original wool knit (41.2%) showed a little higher thermal resistance ratio than shrinkproof-finished wool knit. There was little difference among resin finished wool (32.3%), resin/softening wool (30.7 %), and chlorinated wool (33.3%) in terms of the thermal resistance rate.

It seemed that the shrink-proof finishing process did not make any difference in thermal resistance. In other words, all of them showed lower thermal resistance after the finishing process, but the finishing type did not have any impact on thermal resistance.

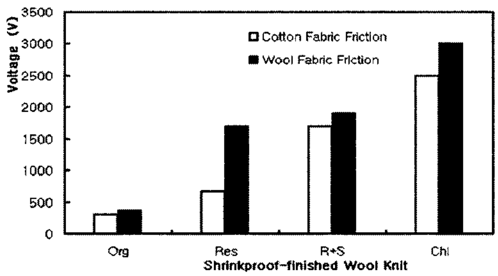
Fabric-specific heat conductivity is critical for the thermal resistance of cloth fabrics. However, once the fiber is spun as yarn or knitted fabric, thermal resistance is going to be considerably influenced by the amount of air, that is, air content. Therefore, it can be concluded that when the shrinkproof finishing process is performed, the reduction of thermal resistance appears since the air layer with low heat conductivity rate is decreased as the scale layer is reduced.

5. Pilling Propensity

Wool fabrics are subjected to pilling because they generally have fuzzy surfaces. Pills do not tend to accumulate to distressing proportions because they break off due to the weakness of the

⟨Table 3⟩ A Half-Life in Electrostatic Propensity of Shrinkproof-Finished Wool Knit (Unit: s)

Sample Code	Half-life
Org	10.05
Res	40.25
R+S	19.35
Chl	36.21



⟨Fig. 4⟩ Friction Voltage in Electrostatic Propensity of Shrinkproof-Finished Wool Knit.

⟨Fig. 5⟩ Thermal Resistance of Shrinkproof-Finished Wool Knit.

〈Table 4〉 Pilling Rating Standard of Shrinkproof-Finished Wool Knit

Sample	Org	Res	R+S	Chl
Scale	4.1	4.9	4.9	5

* Unit: Scale 1(very severe pilling) - 5(no pilling).

wool fiber. More pilling occurs on fabrics composed of fine wool fibers than on fabrics composed of medium wool fibers, but the pills are easy to remove. Pilling is about forming minute fiber fuzzy pills on the fabric surface when some fibers are pulled out of fabric or yarn and entangled with intact fibers and stuck on the surface. The wool fabric is known for a good fabric having no pilling even when rubbed or washed.

As indicated in the 〈Table 4〉, pilling rating standard of shrinkproof-finished wool knit, under the pilling category, all testing materials showed level fourth or fifth that is almost pilling free status. Especially, there was none of pilling found on the shrinkproof-finished wool knit. It is considered that the strength of wool fabrics was low so that the piling, if any, was easily rubbed out to drop. Furthermore, the decrease of scale layers due to the shrinkproof finishing process prevents the pill from forming to improve the pilling related quality.

Ⅳ. Conclusion

The shrinkproof-finished wool fibers treated with resin coating and chlorination methods were used to find out an optimal shrinkproof finishing method keeping the quality properties of wool fabric to manufacturers. Shrinkage during repeated washing, electrostatic propensity, thermal resistance and pilling of shrinkproof finished wool knits, and analysis of finishing methods were measured.

Upon the results from the surface examination of shrinkproof-finished wool fibers, the patterns of scale layer and degree of scale removal were subject to change according to the finishing processes, and the shrink resistance was significantly enhanced when repeatedly washing shrinkproof-finished knits. Addition of strong physical force and alkali detergent applied in this washing experiment brought about superior effects with the low shrinkage rate although it was very severe washing conditions for wool fabrics. The results from the washing experiment implies that shrinkproof-finished knitted fabrics can be machine-washed at individual households with other ordinary laundry. Also there was some changes and variation found in thermal resistance, electrostatic propensity, and pilling, however, it seems to be minor within standard limits. Therefore, shrinkproof finished knitted fabrics did not bring serious changes to other physical properties comparing with original wool.

Such research results are expected to help consumers handle wool knits more conveniently. In regard to manufacturers of knitted wool fabrics, this study presents the manufacturing conditions where knit products can be produced with the optimal physical properties suited for the end-use. So, it is anticipated to manufacture knitted products in more advanced and diverse ways by the use of differentiated cloth fabrics like shrinkproof-finished fabrics.

The materials used in this study are restrained to the structure of all needle knitting (0×0 rib). This implies that when there is a need to apply the research results to other knitting structure nits, a careful consideration must be exercised. Any preceeding studies are recommended to focus on properties of materials differentiated with a variety of knitting structure.

References

Banerjee, P. K. and Alaiban, T. S. 1988. "Geometry and Dimensional Properties of Plain Loops Made of Rotor Spun Cotton Yarns, Part I: Outline of Problem and Experimental Approach," *Text. Res. J.* Vol. 58.

Cockett, K. R. F. and Lewis, D. M. 1978. "Shrink Resist Finishing of Wool Knits," *Textile*

Chemist and Colorist Vol. 10.

Dodd, K. J., Carr, C. M. and Byrne, K. 1999. "Ultraviolet Radiation Curing Treatments for Shrink-resistant Wool Fabric," *Text. Res. J.* Vol. 68.

Freeland, G. N. and Guise, G. B. 1990. "Soft handle Shrink-Resist for Wool Fabrics," *Proc. Int. Wool Text. Res. Conf.* IV-401.

Hollen, Norman, Saddler, Jane, Lanford, Anna L. and Kadolph, Sara J. 1988. *Textiles*, 6th ed NY: Macmillan Publishing Co.

Ney, E. A., Peake, R. and Regos, N. 1976. "Wool Reactive Polyurethanes: A Method For Shrink Resistant, Permanent Press Wool," *Textile Chemist and Colorist* Vol. 8.

Park, Shin-W., Ahn, Jai-S., Kang, Bok-C and Cho, Ho H. 1994. "Studies on the mechanical Properties and hand of Double Weft-knitted Fabrics," *J. of the Korean Fiber Society* Vol. 32.

Kim, Young-Li. 1977. "Studies on Dimensional Properties of Cotton Weft-knitted Fabrics for Outerwear," *J. of the Korean Society of Clothing & Textiles* Vol. 21.