

리브편 조직과 펄편 조직을 이용한 입체 니트 구조의 개발

최 원 석 · 이 연 희[†]
한양대학교 의류학과

Development of Three-Dimensional Knit Models through Rib & Purl Structures

Wonseok Choi and Youn Hee Lee[†]

Dept. of Clothing and Textiles, Hanyang University, Korea
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Abstract

Knit fabrics are created on diverse machines with diverse knit loops and conditions to make different patterns and fabric types¹⁾. Dimensional modifications of knit fabrics can also be achieved by numerous methods such as different knit-loop structures, different types of yarns, or different finishing processes including heat setting, steaming, chemical treatment et cetera. This research develops and explores sophisticated three-dimensional knit fabrics by combining the several different knit stitches including rib and purl. This study focuses on 3D knit models created on modern electronic weft (flat V-bed) knitting machines which have capability of individual needle selection. Several samples of the 3D knitted fabrics are also examined in this research. This research furthermore suggests new types of knitted fashion garment made by using the interesting physical effects.

Key words: knitting(편성), V-bed(V-베드), 3D structure(입체 니트 조직), geometric shape(기하학 구조).

I . Introduction

Numerous manufacturing techniques such as stitching, weaving, knitting and braiding are used to pro-

duce three-dimensional structures of fabrics²⁻⁴⁾. Three-dimensional structures can be more easily accomplished on knitted fabrics since knitted fabrics tend to have elasticity and flexibility which facilitate a formability and deformability of fabrics⁵⁾. Thus, knitting including

[†] 교신저자 E-mail : yiyhee@hanyang.ac.kr

- 1) Nergiz Emirhanova and Yasemin Kavusturan, "Effects of the Knit Structure on the Dimensional and Physical Properties of Winter Outerwear Knitted Fabrics," *Fibers and Textiles* Vol. 16 No. 2 (2008), p. 69.
- 2) Ryuta Kamiya, Bryan A. Cheeseman, Peter Popper and Tsu-Wei Chou, "Some Recent Advances in the Fabrication and Design of Three-dimensional Textile Performs: a Review," *Composites Science and Technology* Vol. 60 (2000), p. 34.
- 3) K. H. Leong, S. Ramakrishna, Z. M. Huang and G. A. Bibo, "The Potential of Knitting for Engineering Composites: a Review," *Composites* Vol. 31, (2000), p. 197.
- 4) A. P. Mouritz, M. K. Bannister, P. J. Falzon and K. H. Leong, "Review of Applications for Advanced Three-dimensional Fibre Textile Composites," *Composites* Vol. 30 (1999), p. 1445.

both warp knitting and weft knitting is ideally suited to the creation of 3D complex shapes. Knitting is capable of providing versatile ways of creating complicated three-dimensional structures. Weft flat knitting is specifically one of the most critical technologies to make intricate 3D models. A modern electronic flat knitting machine makes possible to develop three-dimensional complicated knit structures by using the technical features, which contain individual needle selection capabilities⁶⁾. A large number of 3D complex knit structures can be made by various knitting techniques including knit, tuck, float (or miss), loop transference, racking, and other techniques created on the automated flat knitting 2 machinery.

Among the numerous knit techniques, this study explores the combination of two different knitting structures that involve rib and purl (links-links) in order to create the 3D knit-loop models. By knitting together the rib and purl structures, which are the most common types of weft knitting, sophisticated three-dimensional knit-structural effects can be accomplished. On the vertical lines, a front loop is protruded, while a back loop is sunk. It creates a rib structure. On the horizontal lines, a back loop is protruded, while a front loop is sunk. It creates a purl structure. Hence, three-dimensional knit structures can be made by effectively utilizing the two structures. The three-dimensional knitted fabrics created on the modern weft-flat knitting machines have a number of advantages and can be used in various end uses. This study reviews various basic knit loops utilized to create weft knitted fabrics. This research also examines how the three-dimensional knit structures can be achieved using the two knit structures which contain rib and purl (links-links). This study additionally explores and develops several knit fashion garments made by the 3D knitted models. Moreover, this re-




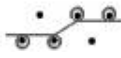


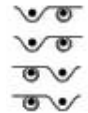



search discusses the potential benefits of the 3D knitted fabrics and further applications.

II. Theoretical Background

1. Knit Structures

A number of knit structures can be achieved by use of varied types of knit stitches. <Table 1> shows fundamental weft-knit structures and knit-loop notations. All knitted fabric structures can be created by knit, tuck and float (miss) loops which are basic stitches on weft knitting. A knit loop is formed when a needle receives a new yarn and knocks over the old loop. A tuck loop is achieved when a needle receives a new yarn, but does not knock over the old yarn which makes a held loop. A float loop or a miss loop is accomplished when a needle is presented a yarn but

<Table 1> Fundamental Weft-knit Structures and Knitting Notations

Loop Notation	Fabric Structure	Loop Notation	Fabric Structure
	Plain single jersey		1×1 rib
	Feed stripe		2×2 rib
	1×1 cross tuck		Half cardigan
	2×2 cross tuck		Full cardigan
	Satin stitch		Links-links

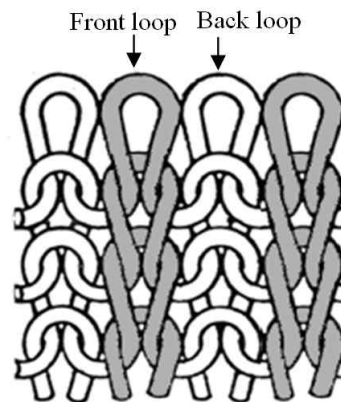
5) B. Gommers, I. Verpoest, and P. Van Houtte, "Analysis of Knitted Fabric Reinforced Composites: Part I. Fiber Orientation Distribution," *Composite* Vol. 29 (1998), p. 1579.

6) Md. Abounaim, Gerald Hoffmann, Olaf Diestel and Chokri Cherif, "Development of Flat Knitted Spacer Fabrics for Composites using Hybrid Yarns and Investigation of Two-dimensional Mechanical Properties," *Textile Research Journal* Vol. 79 No. 7 (2009), p. 597.

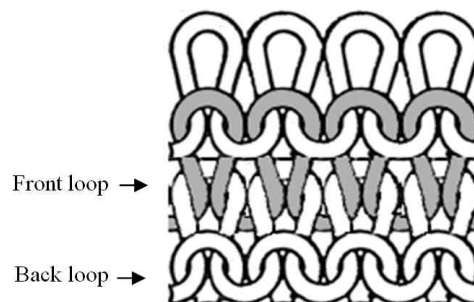
does not grasp it, thus it displays the missed yarn as a float on the back side of the held loop⁷⁾. In general, tuck and float stitches show the major routes for modifying knit structures to accomplish specific macroscopic properties in knitted fabrics⁸⁾. However, appropriate combination of knit loops also creates three-dimensional fabrics. A variety of shapes of knit structures can therefore be created by combining the three fundamental loops including knit, tuck and float (miss) as can be seen in <Table 1>. The combination of the three basic loops which are made on front and back needle beds or on a cylinder and a dial produce an assortment of knit structures including ribs, purls, cardigans, cross tucks, satins et cetera <Table 1>.

2. Rib & Purl Structures

Rib and purl structures are patterned knits which are composed of front and rear loops in the direction of wale or course. Rib structures can be produced by two sets of needles (a front bed and a back bed on a flat machine or a cylinder and a dial on a circular machine) being alternately set or gated between each other. <Fig. 1> illustrates face and back loop wales in a 1×1 rib. As can be seen in <Fig. 1>, rib structures have a vertical cord appearance since the face loops have a tendency to protrude in front of the back loops. Because of the properties of rib structures, rib structures have no curl and heavier fabrics than plain structures⁹⁾. Also, rib structures are elastic, form-fitting, and preserve warmth better than plain structures. On the other hand, purl structures are achieved by alternately knitting one or more courses on a front bed and a back bed. Hence, purl structures have a horizontal cord appearance because the reverse loops tend to protrude in front of the face loops.



<Fig. 1> 1×1 rib Structure.



<Fig. 2> Purl Structure.

Thus, the purl structures also have no curl and heavier fabrics than plain structures <Fig. 2>. Generally, double-bed machines are utilized to create rib and purl fabrics in the knitting industry.

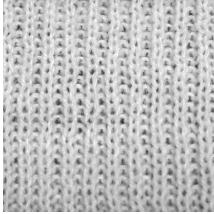
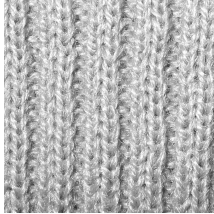
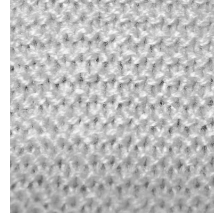
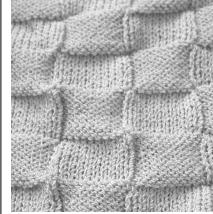
<Table 2> reveals various types of rib and purl (or links-links) structures. As can be seen in <Table 2>, rib structures can be produced in numerous shapes such as 1×1 rib, 2×2 rib, 3×3 rib, 3×2 rib, and other ribs by use of two needle beds. Links-links also makes assorted knit structures such as purl and other structures by double-ended latch needles or by loop

7) Wonseok Choi, "The Development of Specialized Knitted Structures in the Creation of Resist-dyed Fabrics and Garments" (Doctoral Dissertation, North Carolina State University, 2006), p. 10.

8) K. H. Leong, S. Ramakrishna, Z. M. Huang and G. A. Biboa, "The Potential of Knitting for Engineering Composites: a Review," *Composites* Vol. 31 (2000), p. 200.

9) D. David Spencer, *Knitting Technology, A Comprehensive Handbook and Practical Guide*, 3rd ed. (Cambridge: Woodhead Publishing Limited, 2001), p. 68.

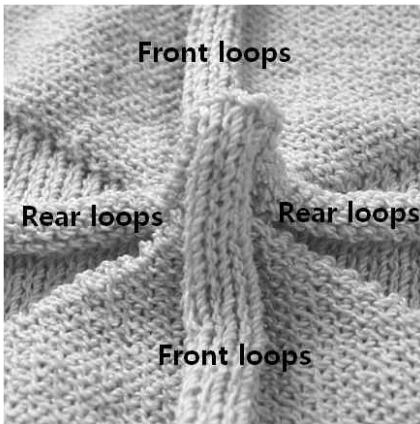
<Table 2> Various Types of Rib and Links-links Structures

Structure	1×1 Rib	2×2 Rib	Purl	Links-links
Figure				

transfer on two needle beds.

3. 3D Knit Models through Rib & Purl Structures

When a rib structure meets a purl structure at a portion of a fabric, specific 3D knit-structural effects occur. As shown in <Fig. 3>, when front loops in a vertical line meet rear loops in a horizontal line at a position of a knitted fabric, the two different loop structures tend to push up each other at the meeting position of the fabric. Dimensions of the three dimensional shapes can be varied according to the number of front or back loops.



<Fig. 3> 3D Knit Fabrics Created by Using Rib and Purl Structures.

Effectual use of the rib and purl structures thus creates numerous shapes of three-dimensional knit models. The rib and purl structures can be knitted on both flat knitting machines and circular knitting machines. However, the three-dimensional effects made by combining rib and purl structures require a loop-transfer action, which can only be performed on V-bed flat knitting machinery. It is because cams of V-bed flat knitting machinery can be changed after every course (even every stitch) and they are able to knit one or both beds easily¹⁰⁾. Therefore, all designs in this research are created on electronically-controlled V-bed flat machines which enable individual needle selection.

4. Potential Benefits and Application for 3D Knitted Fabrics

According to Mouritz et al.¹¹⁾, advantages of three-dimensional knitted fabrics over two-dimensional fabrics are as follows:

1. 3D knitted performs have better formability because they are more drapable.
2. 3D knitting can produce more complex near-net-shape (fully-fashioned-shape) performs.
3. Some types of 3D knitted composites have high impact damage tolerance and energy absorption (crash) properties.

10) E. A. Young, “Knitwear Manufacturers’ Use of Electronic V-bed Knitting Machines with Presser Foot” (Master’s Thesis, North Carolina State University, 1985), p. 28.

11) A. P. Mouritz, M. K. Bannister, P. J. Falzon and K. H. Leong, “Review of Applications for Advanced Three-dimensional Fibre Textile Composites,” *Composites* Vol. 30 (1999), p. 1457.

4. 3D knitted fabrics have the potential to greatly lower production costs by reducing the time needed to produce perform.

Three-dimensional knitted fabrics can be created in several styles such as sandwich, non-crimp, fully-fashioned shape, et cetera. Through the several knitting methods, 3D knitted fabrics have recently been utilized in numerous industries including apparel, home

furnishing, automotive textiles, geo textiles, medical textiles, aerospace textiles and other industries. This is due to numerous potential properties of 3D knitted fabrics such as better formability, high impact damage tolerance and energy absorption properties, greatly lower production cost et cetera. 3D knitted fabrics provide artificial design effects as well as can be seen in <Fig. 4>.



<Fig. 4> Knitwear by Using 3D Knit Models¹²⁾.



<Fig. 5> 3D Knit Chair¹³⁾.

5. Yarns and Machines

In order to make more effective three-dimensional knit models, 100% wool or wool blends such as a wool crepe (80% wool and 20% rayon) are utilized in this research. Wool, a natural protein fiber, has commonly been used to produce knitwear because of its softness, elasticity, resiliency, cohesiveness and heat retention^{14,15)}. Elasticity, cohesiveness and flexibility of wool specifically permit more efficient three-dimensional knit models. Knit structures are actually dependent on yarn's physical properties. Yarns with good drape such as silk would not be appropriate to create 3D knit models. Therefore, it is significant to choose appropriate yarns to create effective 3D knit fabrics. Unique 3D fabric designs can moreover be created by use of felting properties of wool.

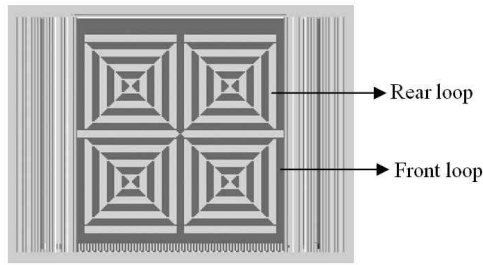
Computerized flat knitting machines facilitate a large number of intricate 3D knit structures as the electronic knitting machines have greater flexibility in loop structure combinations and patterning by means of individual needle selection. In this research, a Shima Seiki 7-gauge V-bed flat knitting machine is used to make knitted fabrics with the three-dimensional knit structures. Although actual knit fabrics have three-dimensional shapes, knit-loop structures are shown

12) "3D Knit Dresses Let You Dress like a Transformer," in Gizmodiva [magazine online] (5 November, 2008 [Retrieved 22 July, 2009]); available from World Wide Web@http://www.gizmodiva.com/fashion/3d_knit_dresses_let_you_dress_like_a_transformer.php.

13) "Think - 3D Knit," in Steelcase, (December, 2007 [Retrieved July 27, 2009]); available from World Wide Web@<http://store.steelcase.com/go/products/detail/E0/>.

14) Seong-Ryun Kim, *Clothing Materials*, 3rd ed. (Gyounggi: Gyomunsa, 2000), p. 89.

15) Sara Kadolph, *Textiles*, 10th ed. (New Jersey: Pearson Education Inc., 2007), p. 71.



<Fig. 6> A 3D Knit Design Created on the Shima Seiki SDS-ONE® CAD System.

as a two dimensional design on a computer-aided design (CAD) screen (see Fig. 6). Prior to actual knitting, a Shima Seiki SDS-ONE® computer design system is exploited to create a 3D knit design. <Fig. 6> shows a 3D knit design created on the Shima Seiki SDS-ONE® CAD system, which is an all-in-one knit design system that enables all stages of product production including planning, design, evaluation and production of knitted fabrics and garments. The state-of-the-art CAD controlled machines result in higher-speed, lower cost, and larger-volume textile production¹⁶⁾.

III. Creation of 3D Knitted Fabrics and Garments

In this research, several different types of three-dimensional knit fabrics by use of rib and purl structures are created <Table 3>. As shown in <Table 3>, an assortment of three-dimensional loop models is accomplished according to positions that rib structures meet purl structures.

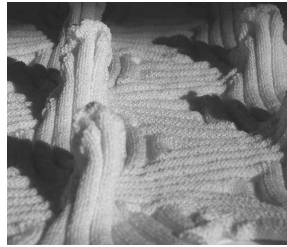
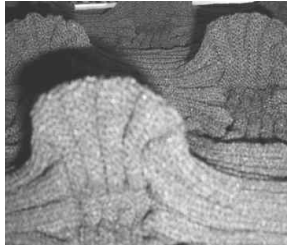
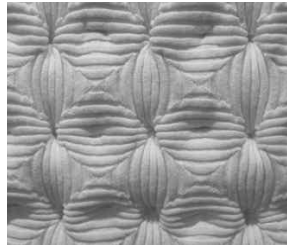
Based on the three-dimensional knit samples, three pieces of knit garments are created.

The creating process of the garments is as follows:

First, three-dimensional knit fabrics are created on a 7 gauge computerized flat-knitting machine which is capable of loop transference by using latch needles with a transfer spring. Three dimensional knitted fabrics are produced through basic knit techniques including rib and purl structures. By knitting together the rib and purl structures, specific 3D knit-structural effects are achieved. It also makes interesting distorted fabric-edge lines and special geometric models. After knitting, binding-off process is performed on the knitted fabrics by linking machines. Binding off is the process that consecutively passes each loop over the adjacent stitch from the edge¹⁷⁾.

After binding-off process, snap fasteners are attached on each edge portion of the knitted fabrics. Each knitted fabrics can be freely connected and removed by the snap fasteners, and it makes a number of design






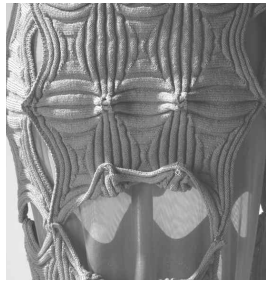
<Table 3> Three-dimensional Knit Shapes by Use of Rib and Purl Structures

Structure	Rib & Purl 1	Rib & Purl 2	Rib & Purl 3
Figure			

16) Ryuta Kamiya, Bryan A. Cheeseman, Peter Popper and Tsu-Wei Chou, "Some Recent Advances in the Fabrication and Design of Three-dimensional Textile Performs: a Review," *Composites Science and Technology* Vol. 60 (2000), pp. 33.

17) Shima Seiki, "Shima Seiki Instruction Manual - Shimatronic WholeGarment® Machine SWG-V," (Wakayama, Japan, 2004): pp. 1-4.

〈Table 4〉 Fashion Garments

	Work 1	Work 2	Work 3
Design			
Machine	7 gauge flat knitting machine	7 gauge flat knitting machine	7 gauge flat knitting machine
Structure	Combination of rib & purl	Combination of rib & purl	Combination of rib & purl
Detail Image			
Explanation	Effective use of rib and purl structures create sophisticated 3D shapes as well as interesting distorted outlines. In addition, meeting positions of rib and purl structures, various types of 3D knit shapes are created.		

patterns. A sheer dress which can be used in inner wear is created by a cut-and-sew process. Finally, the three-dimensional knitted fabrics are suitably fastened and connected by the snap fasteners on the sheer dress. The three-dimensional geometric shapes and distorted edge-line movements provide a new type of repeating images on the sheer dress. 〈Table 4〉 depicts three pieces of garments created with the 3D knitted fabrics.

IV. Conclusion

This research explores three-dimensional knit-shaped fabrics made by effectively combining rib and purl structures. Rib and purl structures can be combined on the modern V-bed flat knitting machines which allow individual loop transferences.

Rib and purl structures have characteristics as

follows:

1. When front and rear loops are knitted in a vertical line, front loop is protruded and a rear loop is sunk. This creates rib structures.

2. When front and rear loops are knitted in a horizontal line, rear loop is protruded and a front loop is sunk. This creates purl structures.

By using the two characteristics of rib and purl structures, numerous types of three-dimensional knit models are accomplished. The combination of rib and purl structures also creates interesting geometric shapes which comprise distorted outline effects. According to the positions that rib structures meet purl structures, various types of three-dimensional knitted structures can be accomplished. Additionally, this research shows that the dimensions of 3D shapes are different according to the number of loops for rib and purl structures. Based on the three-dimensional knit models, three pieces of knitwear are created in this research.

3D knitted fabrics have a number of advantages such as better formability and drapability, high impact damage tolerance and energy absorption properties, greatly lower 'production cost and others. The potential benefits of 3D knit models allow the 3D model to be utilized in apparel, upholstery, automotive, medical, and aerospace industries.

국문초록

편성물은 여러 가지 형태의 편성 조직을 얻기 위해서 횡편기나 환편기 등의 다양한 니트 편기를 이용하여 다양한 형태의 니트 편환과 조건에 의해서 편성을 하게 된다. 입체적인 형태의 니트 편지는 각기 다른 니트 편환 조직의 병용, 다양한 편사의 이용, 또는 여러 가지 가공공정 등을 거쳐서 얻을 수 있다. 본 연구는 컴퓨터화된 자동 횡편기를 이용하여 편성에 있어서 기본이 되는 조직인 리브편과 펠편의 편성조직을 효과적으로 혼합 편성하여 새로운 형태의 입체 니트구조를 갖는 편지를 개발하는데 그 목적이 있다. 이러한 입체 니트조직을

바탕으로 하여 몇 가지 다른 형태의 입체구조를 갖는 편성물을 개발하고, 새로운 형태의 니트 패션 의복을 제작한다. 또한 리브편과 펠편에 의한 입체 편성조직의 원리와 특성 등에 대하여 논한다.

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