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# Three-Dimensionally Knit Spacer Fabrics: A Review of Production Techniques and Applications

Shanna M. Bruer, Ph.D. Student
Professor Nancy Powell
Dr. Gary Smith, Associate Professor
NCSU College of Textiles

## ABSTRACT

*As the textile complex is faced with increasing competition, innovation and specialization have been employed by many machinery and product manufacturers to create a niche in the marketplace. In an effort to compete and appeal to the end-use market, products that go beyond the current range of performance and style have been developed. This paper will focus on the development of such specialized production through the use of knitted spacer fabrics. Basic knitting concepts will first be introduced followed by a review of literature on the history, technologies, advantages, disadvantages and potential end uses of knitted spacer fabrics.*

*Keywords: Spacer fabrics, knitting, automotive textiles, technical textiles*

## 1.0 INTRODUCTION

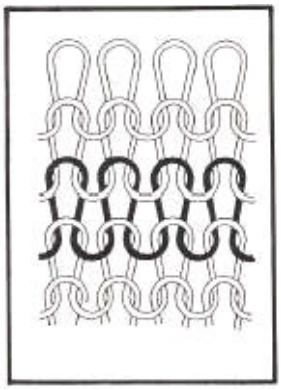
As control of the textile complex has shifted further downstream to the consumer, manufacturers have been faced with greater and more specialized demands. In order to compete and appeal to the end-use market, it is therefore important to offer products that go above and beyond the current range of performance and style offerings. One industry striving to meet such demands is the manufacturers of knitting machinery and knitted fabrics.

This paper will first introduce some necessary knitting concepts and then discuss the topic of spacer fabrics. Literature on the history, technologies, advantages, disadvantages and potential end uses of knitted spacer fabrics will then be presented to create a complete understanding of spacer fabric's purpose and means of production.

## 2.0 KNITTING FUNDAMENTALS

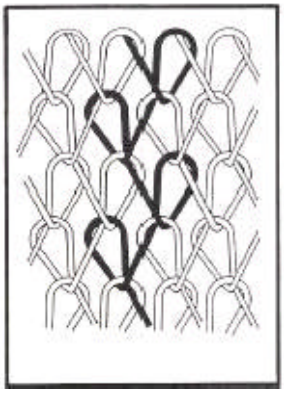
Simply stated, knitting is the interlooping of yarns to form a textile structure. There are two classifications of knits – weft and warp. Weft formations have yarns which are knit across the width of the fabric while warp formations have yarns being knitted along the length of the fabric (Spencer, 2001) (see Figures 2.0a and 2.0b).

**Figure 2.0a: Weft Knit Structure**



Source: Raz, 1987. Page 17

**Figure 2.0b: Warp Knit Structure**



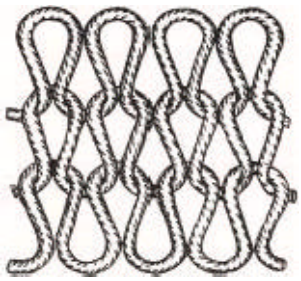
Source: Raz, 1987. Page 17

There are three primary loops, each having their own characteristics used to produce knit fabrics – the knit loop, the float loop and the tuck loop (Brown, 1973). In addition to having three primary loops there are three needles used in the production of knitted fabrics – the spring-bearded needle, the latch needle and the compound needle. The latch and compound needles, however, are more prevalent because of their efficiency and ability to increase productivity (Spencer, 1983).

## 2.1 Variations of Weft Knit Fabric Structures

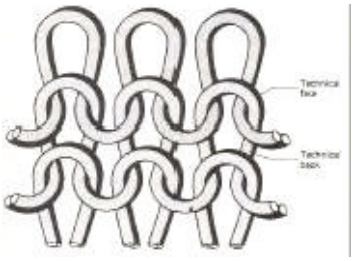
The three primary classifications of weft knit structures are the jersey (plain) structure and derivatives, rib fabric and derivatives and purl fabric and derivatives (Shinn, 1957; Smith, 1984; Smith, 2004). Jersey fabrics and their derivatives are single-sided structures and include fabrics such as plain jersey, feed stripe, pique, flat jacquard, fleece and plated jersey (Spencer, 2001; Smith, 2004). The two structures important for reference in this paper are the plain jersey fabric which is a single layer fabric in which the same yarn is being knit on the front and back of the fabric and a variation of the plain jersey called plated jersey (see Figures 2.1a and 2.1b).

**Figure 2.1a: Technical Face of Plain Jersey Fabric**



Source: Shinn, 1957. p. 10

**Figure 2.1b: Plated Jersey Fabric**

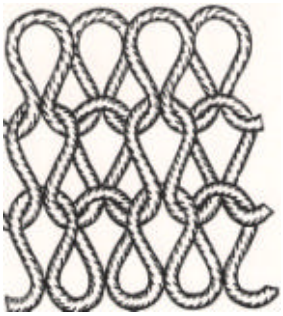


Source: Spencer, 2001. Pg. 57

Plated jersey has the same basic structure as single jersey, but it uses two yarns which are knitted at the same time under controlled tension so that one yarn is always on the designated side of the fabric (Spencer, 2001; Smith, 2004). It is still a single jersey fabric, but with two layers of yarns which may be used to manipulate the characteristics of the fabric to control such qualities as moisture transfer, comfort, hand and stretch.

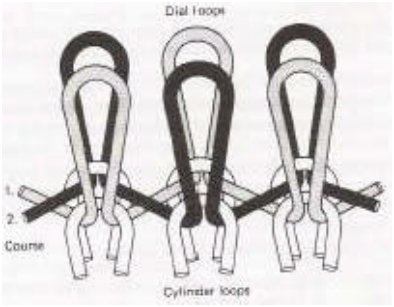
Rib fabrics and derivatives include 1x1 rib, cardigan, interlock, flat jacquard and double-faced fabrics (Spencer, 2004). The three structures important for later discussion of spacer fabrics are the 1x1 rib, interlock and double-faced fabrics (see Figure 2.1c and 2.1d).

**Figure 2.1c: 1x1 Rib Fabric**



Source: Shinn, 1975. Pg. 12.

**Figure 2.1d: Interlock Fabric**




Source: Spencer, 2001. Pg. 73

1x1 rib is a single layer fabric that has the same yarn knitting loops on both sides of the fabric. Interlock fabrics are a form of rib that use two sets of needles that knit back-to-back in an alternate sequence to create two sides of the fabric that are exactly in line with each other and hide the back of the loops on the inside of the structure and show identical face loops on both the front and the back of the fabric. The final product has the appearance of a plain jersey fabric on the front and back with the two yarns alternating sides of the fabric (Spencer, 2001; Smith, 2004). It should be noted that interlock fabric (like 1x1 rib and other stated fabrics) cannot be called spacer fabric because there is no separation of fabric layers.

Double-faced fabrics use two sets of needles that can be set between one another (rib gaiting as found in the 1x1 rib fabrics) or directly aligned with one another (interlock gaiting) to form a class of fabrics that can have the same or different types of yarns on both sides of the fabric. The yarns on both sides are held together by tuck loops (Spencer, 2001; Smith, 2004).

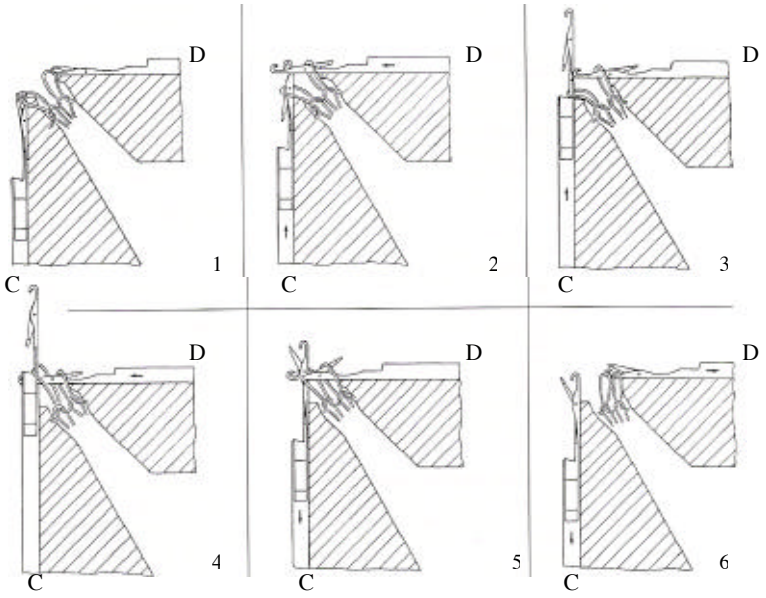
Purl fabric is the final classification in which there is also the possibility of making double-faced fabrics using the same idea presented with the rib fabrics. However, due to slow machine speed and low productivity they are not typically used for such production.

## 2.2 Weft Knitting Machines

There are two types of weft knitting machines – circular and flat. Circular machines can be classified in one of three categories – 1) single jersey machines which have one set of needles and make only jersey fabrics, 2) dial and cylinder machines which have two sets of needles and are capable of making jersey and rib fabrics, and 3) double cylinder purl machines which use double-ended latch needles and make purl fabrics (Iyer, et al, 1995; Spencer, 2001; Smith, 2004). The two primary forms of flat knitting machines are the V-bed machine, which is useful in the production of spacer fabrics and the flat purl machine which is nearly non-existent in today's applications (Raz, 1993; Smith, 2004). The V-bed has the potential for making both jersey and rib

fabrics, as well as their derivatives including double-faced fabrics. Figures 2.2a and 2.2b show and explain the knitting action associated with the dial and cylinder and v-bed knitting machines.

**Figure 2.2a: Knitting Action of Dial and Cylinder Knitting Machines**




**Needle Positions of Dial and Cylinder Knitting Machine**

Position 1: Base Position.

Position 2: Clearing of dial needle for opening dial needle latches

Position 3: Dial needle in holding-down position

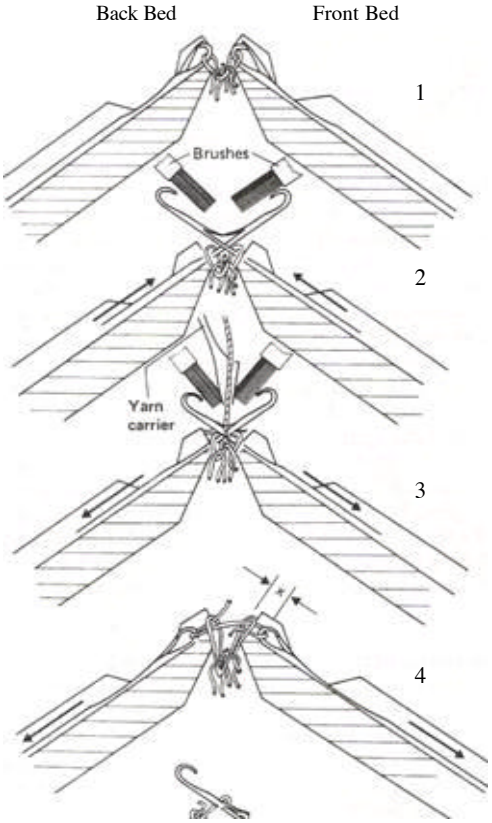
Position 4: Cylinder needle in forwarding position

Position 5: Dial needle in receiving position

Position 6: Transition position of needles to following knitting feeder

Source: Iyer, Mammel & Schach (1995). Pg. 149

**Figure 2.2b: Knitting Action of V-Bed Machine**




Position 1: The rest position. The tops of the heads of the needles are level with the edge of the knock-over bits.

Position 2: Clearing. The needle butts are lifted until the latches clear the old loops

Position 3: Yarn Feeding. Yarn is fed to the needles as they begin to descend.

Position 4: Knocking –over. The new loops are drawn through the old loops, thus completing the cycle.

Source: Spencer (2001). Pg. 212

## 2.3 Weft Knitting Notation

In order to fully understand the structures to be discussed, it is necessary to introduce the concept of notation. The two methods of notating weft stitches used in this paper are the graphic and diagrammatic techniques. The graphic method uses pictures or photographs to illustrate the fabric structure and is used in Figures 2.1a-c to depict basic weft knit structures. Figure 2.3 shows the diagrammatic method which is often more useful. The dots represent needles, while the lines represent the path of the yarns. The type of machine being used can be identified by the number of needles (i.e. dots) per course (one set per course being jersey while two sets per course indicate rib or interlock fabric created on dial and cylinder or v-bed machines), the way the needles are arranged and the notation used.

## 2.4 Warp Knitting Classifications and Machines

Warp knit structures have yarns that knit parallel to the length of the fabric and can be classified in three ways (Raz, 1987; Reisfeld, 1966; Smith, 2001). The first method of classification is the machine used in production – Tricot or Raschel. The Tricot machine makes fabrics that are less complicated, finer in gauge and more rapidly produced, while the Raschel machine has the ability to make more complex structures, but is considerably slower in production speed (Reisfeld, 1966; Spencer, 2001; Smith, 2001). It is important to mention that as gauge is increased, finer yarn is used and it is more likely that production flaws will occur (Smith, 2001).

The second means of classification is the number of bars or sets of yarns used in production. With the addition of bars, fabrics become more expensive, more stable, denser and more versatile (Smith, 1984). Typically a Tricot machine uses 2-6 bars (i.e., making a 2-bar fabric, 3-bar fabric, 4-bar fabric, etc.). Sub-categories of Tricot fabrics include traditional solid fabrics (also called standard full set fabrics) such as Locknit or Full Tricot, Openwork fabrics or Laid-in fabrics (Raz, 1987; Spencer, 2001). Raschel machines found in industry vary significantly, but for spacer fabrics discussed in this paper will range from 5-8 bars (Smith, 2001). Further sub-classification of Raschel fabrics can be broken down into solids, lace, open-work, mesh, laid-in and spacer fabrics (Raz, 1987; Spencer, 2001; Smith, 2001). It will be noted that even though production of one bar fabrics is possible, it is not common because they are weak and unstable, but such structures can be used to produce fabric structures that are components of warp knit spacer fabrics.

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