EFFECT OF STITCHING TECHNIQUES ON SEAM STRENGTH AND ELONGATION OF A POLYESTER DOUBLE KNIT FABRIC

by

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I. INTRODUCTION

The total U.S. production of knitted fabrics for 1973 was 2,048 million pounds (3). Seventy-three percent, or 1,496 million pounds of this production figure were weft knits and of this, 707-762 pounds were double knits (3). In 1974, double knit production was expected to increase to 709,407 pounds (3), with a further prediction that knitted fabrics will pass wovens in apparel poundage for the first time in United States textile history (21).

A double knitted fabric can be manufactured in either of two ways: an interlock stitch or its variations can be used to produce a fabric somewhat ribbed-like in appearance or two fabrics can be knitted with two separate sets of needles incorporating occasional stitches that bind the two fabrics together (5,8).

Many factors have been influential in the popularity of knitted fabrics. Vanderhoff (20) stated that double knit fabrics, in general:

1. can be sewn as easily as most wovens
2. are economical as the large width of fashion fabric means less fabric required per garment
3. do not fray, sag, or bag
4. do not require a lining
5. do not stretch out of shape when worn
6. adjust to the shape of the body
7. pack well
8. travel well
9. resist wrinkles
10. recover well after wearing
11. are suitable for all reasons
12. are good for all figure types
13. have a large variety of designs suitable for every kind of wearing apparel and
14. have a low cost of maintenance because double knits can be laundered without losing their body or "new" look.

The aforementioned characteristics are positive, however, with the advent of double knitted fabrics, problems have also arisen. These include fit, needle cutting, stitches and thread. A description of these problems follows:

1. Fit -

Because knitted fabrics adjust and conform to the shape of the body, the garment pieces are initially cut to fit the body more closely (18).

2. Needle Cutting -

Knit fabrics are interlooped structures, not interwoven. Because of this interlooping, a broken yarn can cause a run, hole or both in the fabric. Ball point needles were developed to pierce the spaces between the loops rather than puncture the yarn thereby weakening the fabric (23, 26, 27, 30).

3 and 4. Stitches and Thread -

These two components should work together to provide a seam which will conform to the body, yet stretch when the human form is in action. A seam with optimum strength and greatest economy is valued for both the home sewer and industrialist (23, 33). If strength and/or stretch is not inherent in the seam, an opening of the seam will occur.

The problems stated relate directly to the seam appearance of the garment. Open or frayed seams will reduce consumer satisfaction because consumer satisfaction is often related to comfort and good appearance. This is increased when wrinkle resistance is high and a worn quality appearance is low (32). When seams are open or punctured due to needle damage, quality of the appearance is threatened and, depending upon the location of the open seam, comfort is questionable.

Wynn analysed stitching techniques for stretch denim which is a woven fabric (35). Coon (23) and Kyle (24) analysed strengths of seams in woven fabrics of various composition. However, seam strength of knit fabrics for apparel use has not been investigated in accordance with the American Society for Testing Materials' standards. Seam strengths of knit fabric for underwear was investigated in Germany (22), but the test method used was specifically considered invalid by ASTM.

The objectives of this research will be: 1) to evaluate the strength of straight seams in a moderate weight double knit by varying the following factors: composition of thread, type of needle, and type and length of stitch; 2) to evaluate the percentage of elongation of the various seam types before rupture; 3) to evaluate if the added thread used in some of the seams is correlated with added strength of the seams, which could determine the financial feasibility of strengthening seams.

RATIONALE

The seams in a knitted garment should have the properties of elongation and elasticity. Elongation is the ability to be stretched, extended, or lengthened (5). Elasticity is the ability of a stretched material to return immeidately to its original size (5). A combination of three factors is necessary to achieve this needle, thread, and stitch type. Elasticity may be established in a seam by 1) a thread which has a certain amount of elasticity, 2) by stretching the fabric slightly as the seam is sewn, and 3) by using an automatic stretch stitch on the sewing machine (10, 14, 18, 25). The amount that the home sewer should stretch the fabric as it was sewn was not agreed upon by several sources (10, 16, 18). Because of this dispute among the sources cited above, the fabric was not stretched as it was sewn. The two remaining methods of establishing elasticity in a seam were used in this thesis.

HYPOTHESES

1. The stretch stitch seam will not be the strongest of the seams used.

2. The overlock stitch seam will not have the greatest percent elongation.

3. The overlock stitch seam will not use the most thread.

4. There will be no significant difference in seams of the same stitch where the type of needle varied.

5. The seams with long staple fiber polyester thread will not be stronger than seams with short staple fiber polyester or polyester core, cotton wrapped threads.

6. The seams with a polyester core, cotton wrapped thread will not be the weakest.

DEFINITIONS

The following definitions are cited according to ASTM D-123-74a (36).

Breaking load - The maximum load (or force) applied to a specimen in a tensile test carried to rupture. It is commonly expressed in grams (kilograms) weight or in pounds weight.

Elongation - The increase in length of a specimen during a tensile test expressed units of length, for example, centimeters, inches, etc.

Elongation, percent - The increase in length of a specimen expressed as a percentage of the monimal gage length.

Elongation at the breaking load - Elongation corresponding to the maximum load.

Strength, bursting - The force required to rupture a fabric by distending it with force, applied at right angles to the plane of the fabric, under specified conditions.

Strength, tensile - The maximum tensile stress expressed in force per unit crossectional area of the unstrained specimen, for example, kilograms per square millimeter, pounds per square inch.

True tensile strength - The maximum tensile stress expressed in force per unit area of the specimen at the time of rupture.

The following definitions are cited according to their source.

Double Knit - Fabrics knitted with two sets of needles producing an interknitted double layered fabric (5).

Overlock Stitch - Created in 1963, this stitch was the first overlock stitch to be sewn on an household sewing machine. It consists of a zig zag stitch with a straight stitch inserted between the peaks of the zig zag stitch. This straight stitch enabled the stitch to be sewn so that it will overcast the edge of the fabric at the same time that the seam is sewn (25).

Stretch Stitch - This stitch was established in 1960 and the stitching mechanics consist of two straight stitches in the forward direction and one straight stitch in the reverse direction (25).

II. REVIEW OF LITERATURE

HISTORY

Knitted fabric is defined as a fabric structure composed of a series of interloopings from one or more yarns (13). The actual construction of knitted fabric can be made by crocheting, netting, knotting, tatting, and knitting (13).

The process of knitting has existed for centuries. Primitive man accomplished the task of knitting by knotting together grasses to construct baskets, nets, or mast (18); French revolutionaries such as Charles Dickens' Madame Defarge, in A Tale of Two Cities, might have kept knitted chronicles which resembled military code books of today; modern man advanced knitting technology to the extent that knitted good production will surpass that of wovens for the first time in textile history (21).

The oldest knitted fabric known to exist was found by Yale University and the French Academy of Inscriptions and Letters at Dura-Europas (Syria). It was dated circa 256 A.D., and believed to have been fabricated by the nomadic peoples of North Africa because the pattern of the cloth, the Crossed Eastern Stitch, was made by these peoples. The North Africans were the first known to have worked on frames with their knitting (18).

Heavy woolen socks, dated between the fourth century B.C. and third century A.D., were found in Egyptian tombs (18). The Victoria and Albert Museum contains knitted socks which date from the fourth to fifth century. Knitted fragments have also been exhumed from Viking entombments (16). The Ashmolean Museum of

Eastern Art at Oxford has a piece of ninth century Spanish altar cloth of the Arab Crossed Eastern Stitch pattern (18).

Prior to the sixteenth century, knitting was popular in Italy and Spain (1). The practice of knitting in the Shetland Isles was said to have been established by sailors of the Spanish Armada. The shipwrecked sailors on Fair Isle taught knitting to the inhabitants. The craft was imported from those islands to Scotland and England (1). In 1887, the most accomplished knitters were recognized as the Germans and the Polish. The Turkish scarlet fezes were also knitted. Hand knitting was considered a "universal" craft (1). The oldest known guild of stocking knitters, Fiacre Knitting Guild, was founded in Paris in 1557 (1,15).

Knitting was a hand process until 1589 when William Lee, a clergyman of Nottingham, England, invented the first knitting machine (5). City Records of Nottingham stated the local knitting of stockings in 1519 (15). Lee's machine was a flatbed type with springbeard needles and a gauge of eight loops per inch of width (18). Cloth was produced at a rate ten times the speed of hand knitting (5). Since the machine was originally designed to manufacture hosiery, the mesh produced was too coarse to be used for that purpose. By 1608 Lee's knitting machines had been improved so a finer gauge of twenty loops per inch was obtained. That same year, William Lee presented silk hosiery to Queen Elizabeth I (18). However, a patent was never granted to Lee because of the potential replacement of hand knitting, and subsequent unemployment that could result from his invention (18).

Modern knitting machines operate on Lee's basic principles. Knitting machines designed today for use by one person are practically unchanged from Lee's original design (18).

Jedediah Strutt of Derbyshire, England invented a machine which would produce ribbing in knitted cloth in 1758. It was known as the Derby Rib Hosiery Frame (18) and was also used to manufacture the first machine made lace by dropping stitches to produce a patterned effect (13).

Improvements in knitting machines became frequent and enabled more competition between hand knit and machine knit fabrics. The rotary frame and the warp frame were invented by the close of the eighteenth century (18), and the circular knitting machine was invented by Marc Brunel in 1816. Further modifications were made on the circular knitting machine in 1845 by Peter Claussen.

The needle hook on the knitting machine usually was a barbed hook. In 1847, Matthew Townsend patented the latch needle which featured a hook which was opened and closed by a swinging latch (18). At the beginning of the nineteenth century, men's and women's knitted underwear was produced (15).

William Cotton patented a highly mechanized knitting machine in England in 1864 (4). It's refinements were numerous, however, Cotton's principles are utilized in modern knitting machines. These knitting machines produce full-fashioned garments (18). Full fashioned garments are completely produced on a flat knitting machine. The garment is shaped to the form of the body not by cutting and stitching, but by the addition or deletion of stitches (13). The addition or deletion of stitches causes an overlapping of two or more loops which produce marks in the form of slight holes. These marks are recognized in a garment where the sleeve joins the upper bodice.

PRESENT STATUS OF KNITS

Many problems with knitted fabrics had to be overcome in production before consumers were satisfied with the articles produced. Knited fabrics are only as strong as their weakest link because of the interloopings of the yarn (18). The properties of natural fibers were well liked by consumers, but strength was lacking in the knitted garments which were produced (18). Man made fibers were developed. However, the knitted fabrics were uncomfortable to the wearer due to the wet, clammy feeling that the man made fibers evoked (5). Texturizing of the man made fibers was developed to simulate the qualities of natural fibers (5), especially wool. Texturizing alters the surface charcteristics of the man made fiber. It also creates space between the fibers of the yarn thereby adding a warm quality instead of a cold clammy feeling to the finished garment. Spun texturized polyester (21) gives the visual impression of a fine worsted with the ease of care of a polyester, and is especially used in men's tailored apparel.

By 1971, knits accounted for 42% of all fabrication used in apparel fabrics (9). Knits lost some of their popularity because of over-importation, a disappointment with women's knitted apparel because of "sameness" of goods, and a disappointment with the quality of men's apparel due to snagging and pilling (21).

Solutions for the abovementioned problems included an emphasis on yarn dyed double knits and spun filament fabric for both men and women, but especially in men's tailored wear (21). Both of these solutions tended to make knits appear as wovens. The favorable characteristics of knits are important, however, and these qualities should be maintained (9).

FUTURE OF KNITS

Knitted goods are expected to reach a proportionate balance with woven fabrics by the middle 1970's (21). This production balance is expected when the novelty of knitted fabrics decreases (9).

The greatest increase in production is expected in menswear (21), specifically slacks, sport jackets, suits, and tailored shirts (9).

In addition to the traditionally established markets for knits (women's and men's apparel and piece goods), many new markets will be investigated (21). These will include childrens' wear, home furnishings, automotive upholstery and outerwear.

Slacks for children are a potential market for knitted fabrics. The activities of children vary from passive to active. Their garments must be able to meet their needs accordingly. Because the abrasion resistance of some knits is high, this is a market that merits further investigation (21).

Knits in home furnishings have a good prospectus because of their inherent elastic qualities (21). Knitted upholstery fabric with a high density could conform to the curves of the furniture with ease due to the elastic construction, and be highly durable. Automotive upholstery could also be of a knitted construction. Diverse patterns can be created in knitted fabrics adding variation in design to the interiors of automobiles.

FACTORS CONTRIBUTING TO KNIT FABRIC EXPANSION

The expanded market production of knitted fabrics is due to a variety of factors. First, knitted fabrics have a production rate of three times the rate of woven production. The time of concept of design to retail outlets is generally six months for woven goods, and sixty days for knitted goods (9). As a result of the speed of production, a variety of patterns can be manufactured at a greater speed. Secondly, the speed of production is also increased due to the width of the fabric. As the width of the woven fabric increases, the rate of production decreases. This is not true in knit fabric production. Width variation does not deter the rate of production (5). Third, since knits have greater width than most wovens, less fabric is required per garment. This becomes a factor in the reduction of production costs. However, finer yarn was required and this added to the cost of production. The number of plants which produce double knits have increased from less than 100 in the 1960's to over 10,000 in 1971 (18). Major woven fabric producers became major knitted fabric producers (9).

The advanced technology of knitting machines and knitting techniques have been pertinent factors in the future marketing of knitted goods (5). Electronically controlled knitting machines enable wide flexibility of patterns with different patterns employed in the production process within twenty seconds (18). The technology of knitting machines have evolved to the stage of acceptability of non-traditional fibers, such as aluminum, tungsten, and stainless steel in combination with advanced knitting techniques, as weft insertion in a warp structure. These variation of patterns and textures add to the variety of knitted goods available for both the home sewer and the apparel manufacturer (18).

KNITS AND THE HOME SEWER

Polyester double knits expanded the home sewing market. The textile industry changed its method of marketing knitted goods (7). Numerous educational literature concerning the home sewing of knits were published (4,6,10). McCall's National Piece Goods Sales Survey of 1968 stated that the home sewer bought $1.76 billion worth of retail fabrics (18). By 1970, knits represented 25-30% of retail fabric sales with future expectations at 40-50% (7). A fashion which existed in ready-to-wear garments could now exist in home sewing with little or no time lapse due to changed marketing techniques of the knitting mills (7).

Knitting Times conducted a survey of home sewing operations of 75 knit cloth mills in 1972 (17). Nineteen percent of the knitting mills participating in the survey manufactured fabrics specifically for the home sewer. The remaining 81% sold the same fabric to the home sewer as was sold to the apparel manufacturer. This fabric usually represented overruns (an overproduction), or fabrics that were of inferior quality for the apparel maker (17). The volume for home sewing fabrics increased from 10% in 1971 to 13% in 1972 for the 81% of the mills that sold to both home sewer and apparel manufacturer (17). Forty-two of the seventy-five mills surveyed have established separate sales and merchandizing departments for fabrics designated for the home sewer (17).

As the volume of knits increased, the amount of information regarding the sewing of knits increased also. Retail stores developed courses in "how-to-sew with knits" (18). New stores selling only knits, (for exampe, "Stretch and Sew" franchise") were established (18).

The retail establishments promoted their knitted goods and then taught the consumer how to construct garments.

The pattern companies also produced instructional aids for the sewers of knitted fabrics. Vogue-Butterick published a Sewing Series which consisted of approximately ten booklets. Each of the booklets dealt with a specific type of garment or fabric and included a unit on knits (16). Simplicity published a pamphlet concerned with the construction procedures involved in sewing a knit (6).

The pattern companies also recognized that conventional patterns often allowed too great an amount of fabric in areas of garments that required a closeness of fit if the garment was constructed from a knitted fabric. Patterns were developed specifically for knits of varying stretch (16). The fabric was chosen by using a guide on the back of the pattern envelope which showed the varying amounts of stretch that were suitable for the pattern.

NEEDLES

The selection of the size of needle used in sewing knitted fabrics was based on the same principle as for woven fabrics. The size of the needle was determined by the weight of the fabric (14). Needles used should have a ball point because the point will push the threads of the fabric aside instead of damaging them as is done by regular needles (16).

Skipped stitches and snagging of the fabric are the problems which usually arise from an unsatisfactory needle. Skipped stitches result from 1) using too fine a needle for the weight of the fabric (10), 2) a bent needle (18) or 3) a needle which has become coated with a film from the fabric (18). The latter condition occurs because the finish used on the fabric reacts with the heat caused by the moving needle (18).

Snagging occurs from a blunt or burred needle (16).

THREADS

There have been three types of thread available for sewing with polyester double knit fabrics. The types are: 100% short staple fiber (40mm in length) polyester thread, 100% long staple (80-160mm in length), polyester thread, and corespun, a cotton covered polyester thread containing 25-40% cotton. The choice of thread type was determined by the fiber content of the fabric. For example, a man made fiber fabric should be sewn with a man made fiber thread (14).

STITCHES

As previously stated, the seams in a knitted garment should have the properties of elongation and elasticity. A combination of three factors is necessary: needle, thread, and stitch type. Elasticity may be established in a seam by 1) a thread which has a certain amount of elasticity, 2) by stretching the fabric slightly as the seam is sewn, and 3) by using an automatic stretch stitch on the sewing machine (10,14,18,25).

The final method of adding elasticity to a seam included the actual stitch used. There was found to be no one absolute automatic stitch designed for a knitted fabric (10,16,18,25). Therefore, for this study three automatic stitches were chosen on the basis of the number of times mentioned in the literature, and the capabilities of a home sewing machine.

The stitches chosen were the straight stitch, zig zag stitch, stretch or triple stitch, and overlock stitch. The straight stitch can be used in the construciton of a knitted seam (10,16,18,25).

III. PROCEDURE

PHYSICAL CHARACTERISTICS OF SAMPLES

Federal Standard 751, type SSa-1 seam samples (37) with correct tension were constructed on a moderate weight 100% polyester double knit purchased on the open market. The fabric weight, wale and course count were determined according to ASTM D-231-62. The fabric weight was 291g/yd with a wale and course count of 21 x 27 respectively. The range was 20-21 wales per inch for the wale direction and 26-27 courses per inch for the course direction. The samples were constructed on an Elnasuper Sewing machine model no. 62C K428168. Sample size was determined according to ASTM D-23162: 4.25 ± o.1 in (100 ± 1mm) wide and 5.0 ± 0.1 in. (127 ± 1mm) long, with the wale direction parallel to the direction for which thr breaking load was required. A line 2.14 in. (37mm) was drawn from the edge of the specimen, running the full length of the specimen. This line was parallel to the lengthwise yarns and served as a stitching guide as the seam must be centered in the plate of the ball burst attachment of the tensile testing machine. A pre-test was used to ensure correct operation of the tensile tester.

The factors involved in the seam construction were thread, needle and stitch. The chart below (Table 1) shows the variables involved in three three catagories.

TABLE 1. VARIABLE CODING

CODE	CATEGORY
	Thread
M	long staple fiber polyester
P	short staple fiber polyester
PC	corespun
	Needle
BP	ball point
CP	conventional point
	Stitch
STR	straight stitch
OV	overlock stitch
SS	stretch stitch
ZZ	zig zag stitch

DESCRIPTION OF STITCHES

The straight stitch had 13 stitches per inch (10, 16, 18).

The overlock stitch was a stitch developed in 1963 by the Elna Company to simulate an industrial overlock stitch on a home sewing machine (25). To obtain this stitch, the selection dial was set on "A", the elnadisc used the number 149, the stitch width was number 4, and the stitch length was "A".

The stretch stitch was used because it was the stitch that many of the sewing machine manufacturers (White, Phaff, Sears, Singer) recommended for use with knitted fabrics. To achieve this stitch on the Elnasuper, the selection dial was set at "A", the elnadisc used was number 149, the stitch width was 0 (zero), and the stitch length was "A". This stitch was sewn with a needle movement of two straight stitches forward and one stitch in reverse. This 2 forward 1 back pattern continued throughout the stitching of the seam (25).

The zig zag stitch recommended for knits was narrow (10, 16, 18, 25). To establish this stitch, the selection dial was set at 1, no elnadisc was used, the stitch width was 1, and the stitch length was 3/4 - 1 (25).

SAMPLING PLAN

The following treatment combinations were obtained;

P/BP/STR	P/CP/STR	PC/BP/STR	PC/CP/STR	M/BP/STR	M/CP/STR
P/BP/OV	P/CP/OV	PC/BP/OV	PC/CP/OV	M/BP/OV	M/CP/OV
P/BP/TS	P/CP/TS	PC/BP/TS	PC/CP/TS	M/BP/TS	M/CP/TS
P/BP/ZZ	P/CP/ZZ	PC/BP/ZZ	PC/CP/ZZ	M/BP/ZZ	M/CP/ZZ

Ten samples were constructed in each of the treatment combinations in accordance with ASTM D-231-62, for a total of 240 samples.

PHYSICAL TESTS

The strength of the seam was evaluated using ASTM D-231-62 and ASTM D-1683-68. The specimens were gripped in the plate of the tensile testing machine. The instrument used for testing was the Scott CRE (constant rate-of-specimen-extension) Tester. With this machine, the rate of increase of specimen length was uniform with time, and the load-measuring mechanism moved a negligible distance with increasing load, meeting ASTM D-76-67. The following formula was used to calculate seam strength:

$$\frac{\text{Final measurement X WR}}{\dfrac{\text{chart speed}}{\text{crosshead speed}}} = \text{strength in kg}$$

Final measurement = measurement, in units, determined from the chart of the CRE

WR = the number of Kilograms equalling I unit for the working range that was used in the operation of the CRE

Chart speed = the speed at which the chart moved, in centimeters/min.

Crosshead speed = the speed at which the crosshead moved, in centimeters/min.

The seams were sewn with the use of a stitching guideline, as previously stated. The overlock seam was sewn one quarter inch from the edge of the specimen. The specimens were sewn seam type by seam type which eliminated constant resetting of the dials on the sewing machine. A new and previously unused needle was used for each category to eliminate any build up of finish or lint on the needle which could cause a skippage of stitches. The bobbin case was cleaned after each category was sewn to remove all lint which could impair the mechanical action of the sewing machine.

The seams were then opened flat and centered in the plates of the ball burst attachment on the CRE. Strength and elongation tests were then performed.

The elongation of the seams were determined by the following formula:

$$\frac{\frac{\text{Measurement}}{\text{chart speed}}}{\text{crosshead speed}} \times 100 = \%\text{ of elongation}$$

Measurement = the measurement, in units, determined from the chart of the CRE. One division on the chart equals .25 cm.

Chart speed = the speed at which the chart moved, in centimeters/min.

Crosshead speed = the speed at which the crosshead moved, in centimeters/min.

The elongation and strength of the seams were determined using the above mentioned formulae. The 240 specimens were evaluated with the average elongation and strength recorded for each category.

The cost of the thread per seam type was determined by the construction of two seams of each type: straight, overlock, stretch, and zig zag. These seams were then taken apart, the thread was measured, and an average of the two thread amounts taken. More than two samples for each type was determined unfeasible. Difference in the amount of thread used between two samples of the same type was negligible.

Statistical analyses of the seam strengths and elongation were performed using analysis of variance. The level of significance was .05. Correlation coefficients were calculated to determine the amount of thread used and seam strength.

IV. DISCUSSION OF RESULTS

The seams in a knitted garment should have the properties of elongation, elasticity, and strength. A combination of three factors is necessary to achieve this: needle, thread, and stitch type.

This study involved the construction of straight seams in a polyester double knit fabric and subsequent analysis of the strength and elongation of the seams with a variation of needle, thread, and stitch. Two types of needles, three types of thread and four types of stitches were the variables applied to the straight seam.

PHYSICAL CHARACTERISTICS OF THE FABRIC

The fabric used was a 100 percent polyester double knit fabric. The weight was 291 grams per square yard. The wale count was 21 wales per inch, and the course count was 27 courses per inch. The mean width of the fabric was 1.6 meters. The denier of the yarn, tensile strength and elongation of the fabric were evaluated. Physical characteristics of this fabric are shown in Table 1.

TABLE 1. PHYSICAL CHARACTERISTICS OF THE POLYESTER DOUBLE KNIT.

Weight	
per square yard	291 grams
Width	1.6 meters
Yarn Weight	116 denier
Thread Count	
Wales	21 per inch
Courses	27 per inch
Bursting Strength	
original	33.28 kilograms
Elongation	184.5 percent
Yarns	textured, crimped
Fabric Color	deep purple

As can be seen from Table I, the fabric used in this study was a moderate to heavy weight fabric. The yarns had been both texturized and crimped giving a soft, bulky hand. The original (control) bursting strength of the fabric was 33.28 kg and the fabric showed a high elongation of 184.5 percent.

The fiber content of the fabric was determined by optical and chemical analyses. Longitudinal analysis of the fiber showed that the fiber was in the classification of a synthetic rather than a natural fiber. Further optical analyses were not performed. The fiber was chemically analyzed in various solvents. No effect occurred with nine of the ten solvents tested. Disassociation of the fiber occurred with meta-cresol as a solvent. Meta-cresol is the solvent which is known to dissolve polyester. Table 2 shows the various solvents that were used and their specific effect on the fiber.

TABLE 2. THE EFFECT OF VARIOUS CHEMICAL SOLVENTS ON THE FABRIC.

Solvent	Chemical Formulas	Effect
Acetone	CH_3COCH_3	NS
20% Hydrochloric acid	HCl	NS
Sodium hydrochlorite	$NaOCl$	NS
Xylene	$C_6H_4(CH_3)_2$	NS
70% Ammonium thiocyanate	NH_4SCN	NS
Butyrolactone	$CH_2CH_2CH_2COO$	NS
N,N- Dimethyl formamide	$HCON(CH_3)_2$	NS
75% Sulfuric Acid	H_2SO_4	NS
90% Phenol	C_6H_5OH	NS
Meta-cresol	$CH_3C_6H_4OH$	Soluble

NS denotes non-soluble.

BURSTING STRENGTH OF THE SEAM

The bursting strength of the seam was dependent upon the interaction of the variables, of needle, thread and stitch. Mean values for these variables are shown in Appendix A.

As can be seen in Table 3, the most highly significant variable was the stitch type at the .01 level of significance. The interaction between stitch and thread was significant at the .01 level of significance. The effect of thread and stitch by needle were both significant at the .05 level of significance.

TABLE 3. ANALYSIS OF VARIANCE OF BURSTING STRENGTH

FIRST ORDER INTERACTIONS			
Source of variation	df	F ratio	Significance level
Stitch	3	1852.12	.001
Needle	1	0.86	NS
Thread	2	5.17	.05
SECOND ORDER INTERACTIONS			
Stitch by Needle	3	5.08	.05
Stitch by Thread	6	6.89	.01
Needle by Thread	2	3.10	NS

NS denotes not significant.

The first order interaction of needle type was not significant. For the second order interactions, needle by thread was not significant at the 0.05 level. That the interaction of stitch by needle was significant when needle was not significant in the first order interaction presented an interesting fact. This occurrence may have been caused by the overshadowing effect of the stitch variable on the needle variable. This would also explain why the interaction of needle by thread was not significant since it can be seen from the first order interaction that thread alone produced an F value of 5.17 compared with the F value of 1852.12 for the stitch variable.

Table 4 presents the thread codes that have been used to explain the matrices of the variable interaction. This table has also been used with the matrices analyzing the percent of elongation.

TABLE 4. CODE FOR THREAD VARIABLE

Thread	Code Number
Long staple fiber polyester	T1
Short staple fiber polyester	T2
Polyester core, cotton wrapped	T3

The interaction between stitch and needle with bursting strength at the .05 level of significance is shown in Table 5.

TABLE 5. MEAN BURSTING STRENGTH OF STITCH BY NEEDLE.

Needle	Stitch			
	Straight	Overlock	Stretch	Zig Zag
Ball point	48 kg*	100 kg(NS)	120 kg(NS)	156 kg(NS)
Coventional point	43 kg(NS)	100 kg(NS)	121 kg(NS)	164 kg*

NS denotes not significant.

* significant at the .05 level.

The stitch and needle combination which resulted in the weakest seam was a straight stitch used with a conventional point needle. The strongest seam was a zig zag stitch and a conventional point needle. The weakening effect of the conventional point needle tended to decrease with the use of multiple stitches.

The main effects of stitch and thread are presented in Table 6. The level of significance was .01

TABLE 6. MEAN BURSTING STRENGTH OF STITCH BY THREAD.

	Stitch			
	Straight	Overlock	Stretch	Zig Zag
T1	46 kg	97 kg	118 kg	166 kg**
T2	44 kg	101 kg	126 kg**	163 kg**
T3	45 kg	102 kg	118 kg	150 kg

LSD = 6.66

** significant at the .01 level.

The bursting strength data related to thread type and stitch type showed that the polyester core, cotton wrapped thread (T3) did not perform as well as the other two types of thread used (i.e. Long staple fiber polyester (T1), short staple fiber polyester (T2)). In addition, the highest bursting strength results were obtained with the zig zag stitch and long staple fiber polyester thread (T1), and with the stretch stitch and zig zag stitch with short staple fiber polyester thread (T2). It can also be seen that the straight stitch had the lowest bursting strength with each of the thread types (46 kg (T1), 44 kg (T2), 45 kg (T3)). The bursting strengths obtained when the overlock stitch was used with each of the thread types were slightly higher than those obtained with the straight stitch but not as high as those with either the stretch or zig zag stitch.

The stretch stitch produced varying bursting strengths with the different threads. For example, T1 withstood 118 kg of force while T2 had a bursting strength of 126 kg. With the overlock stitch, the highest bursting strengths were achieved with each of the thread types. T1 had a bursting strength of 166 kg compared with 163 kg for T2 and 150 kg for T3.

The interaction between needle and thread bursting strength is shown in Table 7.

TABLE 7. MEAN BURSTING STRENGTH OF NEEDLE BY THREAD.

	Needle	
	Ballpoint	Conventional point
T1	108 kg	106 kg
T2	108 kg	109 kg
T3	102 kg	106 kg

The mean bursting strength related with needle and thread type was not significant and is seen by the lack of variation in the force required to rupture the seams.

ELONGATION OF THE SEAMS

The percent of elongation of the seams was dependent upon the interaction of the three variables needle, thread, and stitch. Mean values for these variables are presented in Appendix B.

As shown by Table 7, the most highly significant variable is the stitch type which was significant at the .001 level. All of the interactions between the variables were not large enough for consideration. These interactions are presented in Tables 9, 10, and 11. It can be seen from the data that the effect of one variable, i.e. stitch type, was consistent when interacted with the other variables.

TABLE 8. ANALYSIS OF VARIANCE OF PERCENT OF ELONGATION.

Source of Variation	df	F ratio	Significance level
FIRST ORDER INTERACTIONS			
Stitch	3	1737.30	.001
Needle	1	2.10	NS
Thread	2	4.18	NS
SECOND ORDER INTERAACTIONS			
Stitch by Needle	3	4.60	.05
Stitch by Thread	6	3.29	NS
Needle by Thread	2	0.73	NS

NS denotes not significant.

The first order interactions of both needle and thread were not significant. For the second order interactions, stitch by thread and needle by thread were not significant at the 0.05 level. The interaction of stitch by needle was significant at the 0.5 level. The stitch variable overshadowed the effect of needle in the second order interaction. However the overshadowing effect of the stitch variable was not exhibited in the second order interaction of stitch and thread.

TABLE 9. MEAN PERCENT ELONGATION OF STITCH BY NEEDLE.

	Stitch			
Needle	Straight	Overlock	Stretch	Zig Zag
Ball point	108%	201%*	159%	178%
Conventional point	107%	195%	157%	182%*

* Significant at the .05 level.

The interaction of the straight stitch with both ball point and conventional point needle showed no significant difference. This was also the case with the stretch stitch and the ball point and conventional needle. The zig zag stitch by conventional needle produced a higher percent of elongation than when this stitch was used with the ball point needle. However, the stitch and needle combination which resulted in the highest percent of elongation was the overlock stitch used with the ball point needle. The overlock stitch used with the conventional point needle had a larger percent of elongation than the other stitch and needle combinations, but when this stitch was used with the ball point needle, the best results were obtained.

Because the original percent of elongation of the fabric was 184.5 percent, one can observe that the straight, stretch, and zig zag stitches inhibit the fabric from elongating to its fullest potential. The overlock stitch, however, allows the fabric to elongate not only to its fullest capacity, but to the percent of elongation of 201 and 195 percent as seen in Table 9.

TABLE 10. MEAN PERCENT ELONGATION OF STITCH BY THREAD

	Stitch			
	Straight	Overlock	Stretch	Zag Zag
T1	108%	194%	156%	181%
T2	107%	200%	160%	184%
T3	107%	200%	157%	176%

The percentages expressed in the above table are not significant at the 0.05 level. As can be seen by the interaction of stitch and thread, the straight stitch interacting with threads T1, T2, and T3 produced the lowest percentage of elongation. The stretch stitch produced a higher percent of elongation when used with the short staple fiber polyester thread (T2), but this percentage was not significantly higher than when the stretch stitch was used with T1 or T3. The zig zag stich produced a greater amount of elongation that the stretch or straight stitches with the polyester core, cotton wrapped thread (T3) having the lowest percentage of elongation when used with these stitches. The straight, stretch, and zig zag stitches in combination with all of the thread types were less than the original percent of elongation of the fabric. Therefore, it can be stated that these stitches inhibited the full elongation of the fabric.

The overlock stitch used in combination with all of the threads showed the greatest amount of elongation. When this stitch was used with T2 and T3, the largest percentage of elongation was obtained.

TABLE II. MEAN PERCENT ELONGATION OF NEEDLE BY THREAD

	Needle	
	Ball point	Conventional point
T1	161%	158%
T2	163%	162%
T3	160%	160%

The second order interaction of needle and thread was not significant at the 0.05 level. The combination with the lowest percent of elongation was the long staple fiber polyester thread (T1) used with a conventional point needle. The thread type which yielded the highest percent of elongation was the short staple fiber polyester thread (T2) used with either the ball point or conventional point needle. The polyester core, cotton wrapped thread (T3) did not vary in the percent of elongation exhibited with either needle type.

Pearson's correlation coefficient was performed on the data on seam strength and the amount of thread used per seam type. Table 12 shows the amount of thread used per seam type. A negative correlation coefficient of 0.33 was found. These data showed that with increased strength of a seam there was a decrease in the amount of thread used.

TABLE 12. THREAD USED PER SEAM TYPE.

Seam Type	Amount of Thread Used
Straight	44.45 cm
Overlock	161.92 cm
Stretch	119.05 cm
Zig Zag	103.17 cm

The straight stitch seam was the weakest seam as in Tables 5 and 6. These two tables also showed that the strongest seam was the zig zag seam. The data in Table 12 indicated that the zig zag stitch seam did not use the greatest amount of thread.

V. SUMMARY AND RECOMMENDATIONS

The objectives of this research were: 1) to evaluate the strength of straight seams in a moderate weight double knit by varying the following factors: composition of thread, type of needle, and type and length of stitch; 2) to evaluate the percentage of elongation of the various seam types before rupture; and 3) to correlate added thread used in some of the seams with added strength of the seams. This factor could determine the financial feasibility of strengtheing seams.

The data from this study showed that the strength and elongation of seams in a knitted fabric are influended by the type of stitch used. The seam with the lowest percentage of elongation and also the weakest seam was the seam using the straight stitch. The greatest amount of strength was found in the seam with a zig zag stitch. The seam producing the highest percentage of elongation was the overlock stitch seam.

The results of this study indicated that to obtain the strongest seam, the choice of thread was dependent upon the stitch type. Both the long and short staple fiber polyester thread exhibited the greater amount of strength when used in the zig zag seam as compared with the polyester core, cotton wrapped thread. The thread type did not yield any effect in the percentage of elongation in the overlock stitch seam. Variations in percentages of elongation occurred in both the zig zag stitch and stretch stitch seam. In this analysis, the short staple fiber polyester thread generally produced a seam of greater elongation.

This study showed that the effect of needle was minimal in reference to both strength and elongation. The stitch type was the dominant variable in the evaluation of the seams.

Pearson's correlation coefficient was performed to compare the amount of thread used in the seams with their strength. A negative correlation coefficient of 0.33 was found. As strength increased, the amount of thread decreased. Also, as the amount of thread increased, the strength decreased. It should, therefore, financially feasible to strengthen the seam.

REJECTED HYPOTHESES

The following hypotheses were rejected:

1. The overlock stitch seam will not have the greatest percent elongation.

2. The overlock stitch seam will not use the most thread.

3. The seams with long staple fiber polyester thread will not be stronger than seams with short staple fiber polyester or polyester core, cotton wrapped threads.

4. The seams with a polyester core, cotton wrapped thread will not be the weakest.

ACCEPTED HYPOTHESES

The following hypotheses were accepted:

1. The stretch stitch seam will not be the strongest seam.

2. There will be no significant difference in seams of the same stitch where the type of needle varied.

RECOMMENDATIONS FOR FURTHER STUDY

1. Physical tests could be performed to determine the seam strength in relation to abrasion resistance, wear, and tear strength.

2. This study could be repeated with the variation of the grainline of the seams.

3. The effects of laundering procedures on durability and strength of seams could be investigaed.

4. This study could be repeated with the variation of different knitted structures i.e. single knit, interlock knit, and tricot knit.

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APPENDIX

APPENDIX A

MEAN VALUES OF BURSTING STRENGTH

FIRST ORDER INTERACTIONS

Variable	Mean Value Kilograms
Stitch	
Straight	45.34
Overlock	99.99
Stretch	120.92
Zig Zag	159.90
Needle	
Ball point	106.02
Conventional point	107.05
Thread	
Long staple fiber polyester	107.02
Short staple fiber polyester	108.44
Polyester core, cotton wrapped	104.15

SECOND ORDER INTERACTIONS

Variable	Mean Value Kilograms
Stitch x Needle	
Straight x ball point	47.64
Straight x conventional point	43.05
Overlock x ballpoint	99.86
Overlock x conventional point	100.12
Stretch x ball point	120.50
Stretch x conventional point	121.36
Zig zag x ball point	156.11
Zig zag x conventional point	163.69

Stitch x Thread	
Straight x long staple fiber polyester	46.35
Straight x short staple fiber polyester	44.40
Straight x polyester core, cotton wrapped	45.27
Overlock x long staple fiber polyester	96.93
Overlock x short staple fiber polyester	100.80
Overlock x polyester core, cotton wrapped	102.23
Stretch x short staple fiber polyester	118.42
Stretch x short staple fiber polyester	166.39
Stretch x polyester core, cotton wrapped	162.79
Zig zag x long staple fiber polyester	166.39
Zig zag x short staple fiber polyester	162.79
Zag zag x polyester core, cotton wrapped	150.50
Needle x Thread	
Ball point x long staple fiber polyester	108.25
Ball point x short staple fiber polyester	107.81
Ball point x polyester core, cotton wrapped	102.01
Conventional point x long staple fiber polyester	105.79
Conventional point x short staple fiber polyester	109.07
Conventional point x polyester core, cotton wrapped	106.30

APPENDIX B

MEANS VALUES OF THE PERCENT ELONGATION

FIRST ORDER INTERACTIONS

Variable	Mean Value Percent
Stitch	
Straight	107.34
Overlock	197.90
Stretch	157.96
Zig Zag	180.23
Needle	
Ball point	161.54
Conventional point	160.17
Thread	
Long staple fiber polyester	159.68
Short staple fiber polyester	162.77
Polyester core, cotton wrapped	160.12

SECOND ORDER INTERACTIONS

Variable	Mean Value Percent
Stitch x Needle	
Straight x ball point	107.89
Straight x conventional point	106.78
Overlock x ball point	201.05
Overlock x conventional point	194.76
Stretch x ball point	158.79
Stretch x conventional point	157.13
Zig zag x ball point	178.43
Zig zag x conventional point	182.03

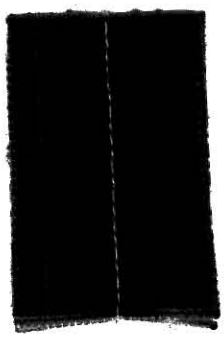
Stitch x Thread	
Straight x long staple fiber polyester	107.89
Straight x short staple fiver polyester	106.64
Straight x polyester core, cotton wrapped	107.47
Overlock x long staple fiber polyester	193.90
Overlock x short staple fiber polyester	199.59
Overlock x polyester core, cotton wrapped	200.21
Stretch x long staple fiber polyester	156.02
Stretch x short staple fiber polyester	160.58
Stretch x polyester core, cotton wrapped	157.26
Zig zag x long staple fiber polyester	180.92
Zig zag x short staple fiber polyester	184.24
Zig zag x polyester core, cotton wrapped	175.52
Needle x Thread	
Ball point x long staple fiber polyester	161.04
Ball point x short staple fiber polyester	163.49
Ball point x polyester core, cotton wrapped	160.08
Conventional point x long staple fiber polyester	158.33
Conventional point x short staple fiber polyester	162.04
Conventional point x polyester core, cotton wrapped	160.15

THIS BOOK CONTAINS NUMEROUS PAGES THAT CONTAIN SWATCHES OF FABRIC THAT ARE ILLEGIBLE DUE TO INABILITY TO SCAN THE TEXTURE OF THE FABRIC.

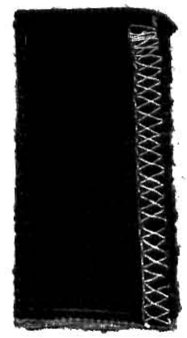
THIS IS AS RECEIVED FROM THE CUSTOMER.

Plate 1

Sample Seams

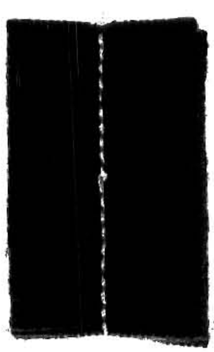


Straight Stitch

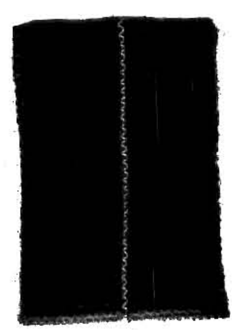


Overlock Stitch

Stretch Stitch



Zig Zag Stitch



EFFECT OF STITCHING TECHNIQUES ON SEAM STRENGTH
AND ELONGATION OF A POLYESTER DOUBLE KNIT FABRIC

by

SUSAN ANNE THORLEY

B.S., Baldwin-Wallace College, 1974

AN ABSTRACT OF A MASTER'S THESIS

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1976

ABSTRACT

The seams in a knitted garment should have the properties of elongation, elasticity, and strength. A combination of three factors is necessary to achieve this: needle, thread, and stitch type.

This study involved the construction of straight seams in a polyester double knit fabric and subsequent analysis of strength and elongation of the seams with a variation of needle, thread, and stitch. Two types of needles, three types of thread and four types of stitches were the variables applied to the straight seam. The seams were tested by using a constant rate-of-extension tensile tester with a ball burst attachment.

An analysis of variance was performed with the resulting data. Thread type was found to be a signigicant variable at the .05 level in both strength and elongation. However, the effect of stitch was significant at the .001 level with both strength and elongation data.

Pearson's correlation coefficient was performed comparing the amount of thread used with the strength of the seam. It was found that a negative correlation existed. Therefore, with increasing strength of a seam there was a decrease in the amount of thread used.