A STUDY ON DIMENSIONAL AND MECHANICAL PROPERTIES OF VISCOSE / SPANDEX PLATED KNITTED FABRICS

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BONAFIDE CERTIFICATE

Certified that this project report titled **"A STUDY ON DIMENSIONAL AND MECHANICAL PROPERTIES OF VISCOSE / SPANDEX PLATED KNITTED FABRICS"** is the bonafide work of **Mr. KARTHIKEYAN.K** who carried out the research under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

16/6/05

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For the viva-voce examination held on ....25.6.05....

25.6.05

INTERNAL EXAMINER

EXTERNAL EXAMINER

ABSTRACT

An increase in need for woven and knitted garments with elastic properties for shape retention, fit and comfort has been gradually rising now a days. This is mainly due to the shift in consumer's preference from durability to comfort and fashion.

One of the main objectives of knitted garments is to provide enough comfort to the human body and required stretch to body movements however; the power of recovery in single jersey fabrics that have been stretched is generally inadequate. To rectify these drawbacks, spandex, an elastane is used along with the base yarn as in core-spun form or through plating during knitting, to impart a greater level of stretch and more dimensional recovery.

Viscose, well known for its highly soft and comfortable nature, luster and drapability is used as a base yarn. Spandex has satisfactory strength, good flexible property, adequate crease and wrinkle recovery where viscose lags. A viscose / spandex plated knitted fabric can be used widely in leisurewear, party wear and active wears due to its comfort, combined with good extensible and recovery property added with high luster and possibility of having vivid colors that gives an added bright look.

In this project, single jersey fabric's are produced from plain viscose yarn and using viscose yarn plated with spandex yarn on alternate feeds and all feeds. The study covers the testing of dimensional and mechanical properties of single jersey knitted fabric. The samples were obtained at three different loop length values representing a range of tight, medium, and loose fabrics. After the sample production, the fabrics are left for dry relaxation for two days at standard atmospheric conditions. After that,

grey state testing i.e., Wales per inch, courses per inch, fabric width, loop length and fabric thickness are all measured.

The samples are then subjected to Heat setting accordingly to their configurations and then washed and tumble dried to make it wet relaxed. The samples are now tested for dimensional and mechanical properties and they are being compared.

From the work it is found that, as the amount of spandex increases, loop length values remain the same and the Wales per inch values also remains the same, whereas the courses per inch increases linearly. Furthermore, because the spandex containing fabrics tend to be tighter, the weight and thickness of the fabrics are higher, but air permeability is lower. The abrasion resistance, bursting strength and pilling grade are found to be higher for spandex containing fabrics.

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LIST OF ABBREVIATIONS

WPI	-	Wales per Inch
CPI	-	Courses per Inch

CHAPTER 1

1. INTRODUCTION

1.1 OUTLINE OF PROJECT WORK

Fashion in clothing has always been a reflector of ranges in lifestyle and social and economic status. Feel good attitude is rapidly spreading. Today, the discerning consumer wants much more then just a garment, with the most luxurious look and superior comfort is an absolute need, spectrum of bright and vivid colors, comfortable to wear are consumers key purchase criteria. Durability is not given much importance in fashion trends. Due to the influence of fashion, the production of knitted goods has been expanded, with new fabric designs created with different fiber blends and knit structures.

Most RMG'S exported from India are of use and throw category and not wash and wear types, so viscose in spite of its poor wet strength satisfies all the above said requirements. The power of recovery in single jersey fabrics that have been stretched is generally inadequate, and therefore spandex is tried to impart a greater level of stretch and more dimensional recovery than can be achieved with viscose alone. The use of spandex has supposed to result in fabrics that fit better on the body like a second skin.

Textiles worn in direct contact with the skin must, especially with active wears, support the functions of the body. It should be comfort to the wearer defined by fit, elasticity in movement, tailored shape and feel. It should have better moisture absorbency and moisture regain. It should be dimensionally stable. It should have a high luster to give a value added look to the wearer. It should have at least the minimum strength.

The ongoing influence of casual clothing of lifestyle is boosting the popularity of spandex containing garment. Casual work attire becomes more popular; spandex allows these types of garments more comfort.

Viscose provides high moisture regain, very good thermal protection, good air permeability, very good softness, very good drape, antipilling etc. Additionally spandex provides a greater degree of wear ability, wrinkle recovery and crease retention where viscose lacks making it the perfect compliment to garments.

In this project, studies have been done on dimensional and mechanical properties of knitted fabrics of three varieties namely plain viscose fabric, half spandex plated viscose fabric, and all feeder spandex plated viscose fabric. Effect of spandex and its amount on knitted fabric is tested. The loop length and amount of spandex are used to determine the dimensions and properties of the knits.

1.2 NEED OF THE PROJECT

Today's clothing trend needs a perfect blend of comfort, fit, style, wrinkle resistance etc, so to make a garment in that fashion viscose and spandex combination is found to be best suit and this area is not potentially used. In this project this combination is tried and the performance is evaluated.

1.3 REVIEW OF THE LITERATURE

1.3.1 Garment Needs

Fashion, comfort, fit, extensibility are some of the key factors during purchase of a garment. Generally cotton is best preferred for its comfort and polyester for its durability. Viscose well known for its moisture absorbency, luster and comfort has its own market but with a small share due to its poor wet strength, in efficient crease recovery. So an ideal use of spandex will help the fabric in inheriting the advantages of both viscose and spandex in this case.

The garments made out of the fabrics consisting of spandex provide consistent shape, fit and comfort. These properties also help to develop the garments for "ready to wear". Because of the above properties, spandex fibers are found in light weight end uses especially in swim wear, sports wear, light weight support garments, ladies inner wear etc.,

Knitting is the process of making cloth with a single yarn or set of yarns moving in only one direction. Instead of two sets of yarns crossing each other as in weaving, the single knitting yarn is looped through itself to make a chain of stitches. These chains or rows are connected side by side to produce the knit cloth.

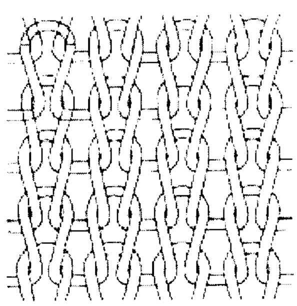
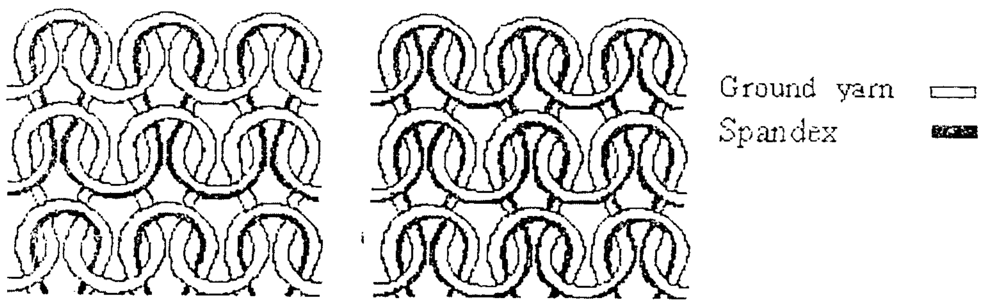


Figure 1.1 Knit fabric

1.3.2 Plated Fabrics

Daniels and Mc Intyre[1] (1995) define plated fabrics as "A fabric knitted from two yarns of different properties, both of which are used in the same loop whilst positioned one behind the other. The special feature of the fabric is that each loop exhibits the characteristics of one yarn on the face side and the characteristics of the other yarn on the reverse side".



(a) (b)

Figure 1.2 Loop diagrams of Viscose/Spandex Jersey Fabrics
(a) In alternating courses (half plating), (b) In every course (full plating).

In the plating process, two separate yarns are fed into the knitting machine at the same time. The two yarns are in the same loop, one behind the other. By varying the type of yarn interesting effects can be achieved. One yarn is face yarn and the other is backing yarn as explained by Billie j. collier and Phyllis[2] (2000).

Edward Menezes[3] (2002) explains that Lycra can be laid in between rows of knitting, or knitted into every stitch, the later producing superb fit and uniformity.

A.Mukhopadhyay et al[4] (2003) provides the experimental result as overall performance of Lycra blended fabrics is better than that of non-lycra cotton fabrics as the immediate recovery; resiliency and extension at peak load are higher, whereas delayed recovery and permanent set are lower for Lycra blended fabrics, irrespective of the direction of loading.

1.3.3 Properties of Viscose

Viscose rayon has a silk-like aesthetic with superb drape, feels and retains its rich colors. Its cellulosic base contributes many properties similar to those of cotton or other cellulosic fibers. Rayon is moisture absorbent (more so than cotton), breathable, comfort to wear, and easily dyed in vivid colors. It does not build up static electricity, soft to skin and has moderate dry strength and abrasion resistance, moderate resistance to acids and alkalis. Rayon will burn, but flame retardant finishes can be applied.

Viscose originates from regenerated cellulose sodium xanthate by wet spinning, with a tenacity varying between 1.8 to 2.4 grams per denier, with a extension at break varying from 16 to 20 %. Elastic recovery of viscose is poor compared to polyester and moreover equal to cotton. Viscose is made with a density of 1.52, mean refractive index value 1.534, moisture regain 11% and with a dry/wet strength of 50%. Crystallinity is moderate with good resistance to heat, light, mildew and moths compared to cotton and polyester as suggested by F.T. Word[5] (1947).

Grasim Technical Service Manual[6] (1984) contains that Cotton and other natural cellulosic fibers have little inherent elasticity. Viscose at 2 % extension has an elastic recovery of about 60 %. Reduced crytallinity of cellulose in viscose staple fiber renders the fiber more responsive to water penetration. It will absorb twice as much water vapor from air as cotton does. When soaked in water, viscose staple fiber swells double its original volume. Viscose begins to lose strength at 150 degree Celsius after prolonged heating. It gets charred at about 185 degree Celsius to 250 degree Celsius without melting.

It is also stated that crystalline areas decide modulus of elasticity, rigidity and tensile strength of the fiber, while the amorphous regions are responsible for flexibility, recovery, elongation and swelling. Therefore, low degree of crytallinity leads to low elasticity and wet strength in viscose fibers.

The molecular alignment and their degree of crystallinity is not as high as in cotton.

J.F.Clark and J.M.Preston[7] (1956) put forward to account the effects of temperature on wet viscose rayon as,

1. Swelling is a minimum between 50°C and 60° C
2. Breaking load starts to fall rapidly with rise of temperature above about 55° C
3. Breaking extension is a maximum between 50° C and 60° C
4. The rate of relaxation of stress in a stretched fiber increases sharply above about 55° C

These things have to be taken into account during dyeing or wet relaxing and laundering of viscose rayon fabrics.

1.3.4 Properties of Spandex

According to ISO 2076 or DIN 60001, elastane fibers "described by the generic name spandex" are synthetic fibers composed of linear macro-molecules with at least 85% by mass, being segmented polyurethane as illustrated by H.U.Bhonde[8] (2002).

He also narrates that elastane is insensitive to hydrolytic effects during normal washing and handling, and is unaffected by the use of normal solvents (e.g. perchloroethylene or benzene) during dry cleaning. Resistance to chlorinated water at concentrations of active chlorine typically found in swimming baths is good. Elastane yarns have good affinity for various classes of dyestuffs.

www.Dupont.com[9] informs that spandex belongs to the generic elastane classification of man-made fibers. It is segmented polyurethane composed of soft or flexible segments Bonded together with hard or rigid segments giving lasting elasticity. The highly resilient elongation is the result of the combination of these two segments. It can be stretched four to seven times its initial length, yet springs back to its original length once tension is released. While spandex appears to be a single continuous thread, it is in reality a bundle of tiny filaments.

The hard segment consists of polyurethane, which is cross-linked crystalline and polar. The hard segments provide mechanical stability and flexibility. The soft segment consists of polyol (polyester or polyether). These segments are easily deformed producing high extensions under low stress, which determines the high elongation. Few properties of spandex are high resilient, elongation, high modulus, good elastic recovery, mechanical stability and flexibility.

1.3.5 Loop Length, Shape and its Effects

Weft knitted structures has unique properties of form-fitting and elastic recovery based on the ability of knitted loops to change shape when subjected to tension. Unfortunately, dimensional changes can also occur during production, or washing and wearing.

Three basic laws governing the behavior of knitted structure are:

1. Loop length is the fundamental unit of weft knitted structure.
2. Loop shape determines the dimensions of the fabric, and this shape depends upon the yarn used and the treatment that the fabric has received.
3. The relationship between loop shape and loop length may be expressed in the form of simple equations.

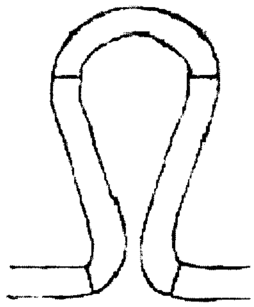


Figure 1.3 The Loop

Loop lengths combine in the form of course lengths and it is these that influence fabric dimensions and other properties, including weight. With the exacting demands of modern knitting technology, the need to maintain a constant loop length at one feed for long periods of time between one feed and another on the same machine, and between different machines knitting the same structure has become of major importance in the control of fabric quality.

The loop structure of a knit fabric changes as relaxation treatment progress. The contribution of the dry relaxation process to the dimensional stability of the fabrics is quite slow when compared to the laundering and tumble-drying treatments.

F.T.Pierce (1947)[10] derived the equations for length of yarn in one stitch and for weight per unit area,

i. Length of yarn L, in a unit cell: $L = 2p + w + 5.94d$
ii. Weight W, per unit area of cloth: $W = Lg/wp$

where

p = course spacing
w = wale spacing
g = weight per unit length of yarn
d = diameter of the yarn

P.J.Doyle[11] (1953) was the first to show that the total number of loops per square unit of fabric was independent of the yarn material, structure, and system of knitting and dependent only on loop length.

For Munden[12] (1959), a relaxed fabric has a definite configuration, and the fabric dimensions depend only on the stitch length and material. Therefore, fabric geometry has no relation to tightness and yarn physical properties.

Postle and Munden[13] (1967) theoretically and Knapton (1968) experimentally brought to light the influence of yarn diameter relative to stitch length, i.e., the tightness or cover factor, on the loop shape.

According to J.J.F. Knapton et al[14] (1968), W.E.Shinn (1955)[15] and W.Zurek et al[16] (1986), fabric thickness doesn't change with regard to stitch length.

Mohammed and Abou[15] (2001) studied that fabric dimensional properties and found that the length of yarn in a loop is the dominating fact in controlling fabric dimensions.

A. Bayazit Marmarali (2003)[16] studied the dimensional and physical properties of cotton/spandex single jersey fabrics and the results are compared with plain cotton knits. The loop length and the amount of spandex are used to determine the dimensions and properties of the knits. It is apparent that as amt of spandex increases, loop length remains nearly the same and the course and wale spacing values decrease. It is found that the amount of spandex and loop length influences the weight, thickness, air permeability, pilling and spirality.

D.L.Munden's[17] (1959) major assumption is that the knitted loop, being a geometrically determined shape, takes up its shape in space independently of the yarn's physical properties or the mechanisms governing loop formation. Thus twist, fiber quality, elastic rigidity, etc, must have no effect on fabric dimensional properties.

D.L. Munden[17] (1959) discussed the difficulties encountered in attempting to obtain relationship between the dimensions of knitted fabrics, the properties of the constituent yarns and the variable factors in knitting. It is suggested that the natural shape of the knitted loop is determined by minimum energy conditions, that the loop tends to this state on relaxation and that this shape is independent of the properties of the yarn or length of stitch. He found experimentally that the dimensional and weight properties of the knitted fabric in a relaxed state are determined uniquely by the length of yarn in the stitch and the width of a fabric in a relaxed state is dependent solely upon the length of yarn knitted into the course and is independent of the number of needles used to produce the fabric.

Nutting T. S. and Leaf G. A. V[18] (1963) suggested that the loop shape was largely dependent on the ratio F/G, where, F and G are the yarn's flexural and torsional rigidities, respectively, but they did not support this theoretical conclusion with specific experimental evidence.

T.Dias et al[19] (2002) investigated the tension build-up of the yarn on its way from the yarn package to the storage yarn feed wheel. The results show that the stitch length is largely affected by the winding tension to the storage yarn feed wheel.

Marie-Ange Bueno et al[20] (2004) studied that even if yarn physical properties and knitting process have a very small influence on fabric geometric characteristics relative to stitch length and fabric tightness, the effect must not be neglected on fabric roughness and thickness, i.e., the 3D loop shape. Even a very small change in loop shape can change fabric tactility and quality. After full relaxation, the loop shape depends on yarn characteristics, stitch length, and tensile stress wale wise due to the knitting process. It is also concluded that the yarn bending rigidity and interyarn friction co-efficient are very important for loop shape.

When bending rigidity decreases and the frictional co-efficient increases, tensile stress in the knitting process is more influential. Any modification of fiber fineness or yarn structure affects yarn bending rigidity and the therefore yarn behavior during fabric relaxation. The influence of these parameters on fabric tactility cannot be neglected.

1.3.6 Dimensional and Mechanical Properties

Knitted fabrics tend to change dimensions in width and length after being taken off the machine, even without yarn shrinkage, indicating a change of loop shape rather than of loop length. During knitting, the loop structure is subjected to a tension of approximately 15 – 25 grams per needle from sources such as the take down mechanism and, in the case of fabric machines, the width stretcher board. Unless the structure is allowed to relax from its strained and distorted state at some time during manufacture, the more favorable conditions for fabric relaxation provided during washing and wearing will result in a change in dimensions, leading to customer dissatisfaction.

In theory, knitted loops move towards a three – dimensional configuration of minimum energy as the strains caused during production are allowed to be dissipated so that eventually, like all mechanical structures, a knitted fabric will reach a stable state of equilibrium with its surroundings and will exhibit no further relaxation shrinkage.

Unfortunately, there are number of states which may be achieved by different relaxation conditions, such as dry relaxation, steaming, static soaking, washing with agitation, centrifuging, and tumble drying. These states are difficult to identify, define, and reproduce because friction and the mechanical properties of the fibers, yarn, and structure can create high internal restrictive forces and thus inhibit recovery. However, agitation of the knitted structure whilst it is freely immersed in water appears to provide the most suitable condition for relaxation to take place as it tends to overcome the frictional restraints imposed by the intermeshing of the structure.

A satisfactory relaxation technique applied during the finishing of fabric in continuous length form is the compacting or compressive shrinkage technique.

Fabric shrinkage is a serious problem for knitwear, originating from dimensional changes in the fabric, particularly stitches. It has become even more prevalent in recent years due to popularity of casual wear such as tights, pants, blouses and sports wear.

Shrinkage is a result of the combined effect of numerous factors such as relaxation, finishing, dyeing, and effects of machinery. The significance of this problem has been investigated by several researchers who focused mainly on the geometry and dimensional relations of knitted structures. Repeated laundering followed by tumble-drying helps the loops to approach their relaxed shape, which could be accepted as the minimum energy state. After loops reach their fully relaxed shape, the fabric becomes dimensionally stable with fewer tendencies to shrink.

Dutton[21] (1944) who published data from shrinkage tests made on knitted fabrics made the next important contribution to knitted fabric research. He suggests that it was necessary to create a satisfactory physical model of knitted fabric structure in order to explain the causes and effects of the dimensional changes observed.

Hazel M. Fletcher and S.Helen Roberts[22] (1952) studied the relationship of geometry of knit fabrics of staple rayon and nylon to shrinkage in laundering. In laundering tests, it was found that the various shrank or stretched less than 3% in the finished fabrics. It is also found that wale and course spacing of both the laundered gray and laundered finished fabrics followed parabolic curves. In unlaundered materials wale and course spacing curves are not of orderly pattern. Shrinkage in area increased with knitting stiffness for all of the gray fabrics and for the finished fabric viscose.

Hazel M.Fletcher and S.Helen Roberts[22] (1952) found that stitch length of plain, rib and interlock gray fabrics decreased as much as 4% in five launderings for the viscose and nylon. They also found that in the finished goods the viscose yarn in the plain and rib knit fabrics stretched between 2% and 3% in laundering, but in the interlock fabrics it neither shrank nor stretched.

Munden[17] (1959) studied the shrinkage problem of plain knits with respect to relaxation shrinkage, consolidation shrinkage, felting shrinkage. It is found that shrinkage is due to the fabric recovering from the wear and washing strains, i.e. the loop shape is retained from distorted state.

Moon Won[23] (1967) studied the structural change of the jersey loop upon yarn swelling is related to the amount of expected laundering shrinkage in cotton jersey fabric by introducing a 3 dimensional loop model. It is concluded that laundering and its parameters influence dimensional stability of knitted fabrics.

J.J.F. Knapton[14] (1968) studied the dimensional stability of knitted wool fabrics and found that the plain knitted structure is shown to be a rationally determinate structure only in the fully-relaxed state; in any other state, the nature of the knitted loop is dependent on the yarn's physical properties, mechanical processing, and the knitted variables. The fully relaxed state is only found after the fabrics have been thoroughly wetted-out, briefly hydro extracted, and tumble dried. Fabric thickness is shown to be independent of the loop length and dependent only on yarn diameter in the fully-relaxed state only.

The fabric dimensional properties are predictable if the loop length is known, involving certain constants whose values are established by empirical analysis.

J.J.F. Knapton et al[24] (1975) subjected cotton plain-jersey fabrics to mechanical relaxation techniques and chemical treatments and found that both treatments cause large linear-dimensional changes i.e., shrinkage leading to a fixed loop configuration. It is also evaluated that the geometrical fabric thickness and bulk density are significantly dependent on fabric tightness. He also concludes that the geometry of the completely relaxed fabric must be largely independent of the fiber, at least for hydrophilic fibers.

S.Coban[25] (1989) states that, 34 days of open-width relaxation is necessary for a fully relaxed fabric.

Leticia Quaynor[26] (1999) investigated the deformation by laundering for single jersey and 1x 1 rib flat knit silk and cotton fabrics with yarn's of varying linear densities and fabric tightness. Statistical analysis of the experimental data reveal the effect of yarn type as well as linear density and tightness factor on the linear and area shrinkage behavior of silk as compared to cotton, thus informing that yarn type influences area shrinkage.

Q.H.Chen et al[27] (2000) states that differences in fabric dimensions can occur after relaxation as a consequence of different relaxed states. It is difficult to achieve complete relaxation.

D.L. Shah[28] (2001) says that knitted garments can be dimensionally stabilized by steam setting process. Knit garments are steamed to acquire desired shape and dimensional stability.

K.R.Keshkari[29] (2002) infers that it is essential to adjust feeding rate of yarns to be compatible with yarn count and fabric structure on circular knitting machines since the change of yarn feed length affects the dimensional properties of weft knitted fabrics.

Levant Onal and Cevza Candan[30] (2003) found that cotton and cotton/polyester blended weft knitted fabrics are prone to shrinkage during finishing processes and customer usage. It is found that the effect of various fabric characteristics on the shrinkage behavior of weft knits is as important as that of the fiber characteristics. It is found that yarn type and fiber blend have relatively more significant contribution to fabric shrinkage lengthwise than widthwise.

Even with the same knit type, shrinkage changes with both yarn type and fiber blend. Knit type and fabric tightness greatly influences fabric shrinkage.

Monica Szabo and Mircea Bucur[31] (2003) studied the dimensional stability of jersey cotton knitted structures and concluded that unbalanced structures influence the dimensional stability. Imbalances can be due to design of structures, or unbalanced yarn, or due to variation of stress in feeding or knit delivery or due to unsuitable relaxation process.

Yoon and Buckley[32] (1984) studied the parameters affecting air permeability and found that the physical and chemical nature of the fiber has little influence on air permeability and it is mainly dependent on fabric geometrical parameters namely thickness and porosity.

W.H.Rees[33] (1969) studied the air permeability of knitted fabrics and suggested through experiment that air permeability is dependent on the structure of the fabric and the yarn or fiber assembly, and is not dependent on the fiber type.

Li Long and Zhou Wei[34] (2004) observed that the conditions of test, structure of yarn, yarn content and property of fibers affect the pilling of worsted fabrics. Pilling is an undesirable phenomenon that affects the hand and the appearance of garments. The pill formation on fabric surface follows four stages,

- Fuzz forming
- Fuzz entanglement
- Pill forming
- Pill wear-off

Gmits and Mead[35] (1959) ranked the fibers according to their fuzz tendency from minimum to maximum for acetate, wool, PES, Viscose and PA (Nylon) fabrics.

Young - Seok Koo[36] (2004) states that yarn tension should be controlled in the best knitting conditions to reduce processing faults and to manufacture good quality knitted fabrics

1.3.7 Heat Setting and its Effects

R.Meredith[37] (1971) states that the ability of spandex yarns to be heat-set is of considerable technological importance. As a result of heat treatment, the amount of available stretch and power may be adjusted to suit a given application. Temperatures of 180° C or more are required to produce substantial amounts of set.

Wet relaxation generally reduces the degree of set induced by heat treatment. The strength of the spandex yarns begins to fall after heat-setting at 150°C, and the breaking extension rises rapidly for heat-setting temperatures greater than 180°C.

American dyestuff reporter writes[38] (1964) Heat setting is holding a fabric extended and heating it until it doesn't retract as much as previously. Physically, molecular slippage or break down has taken place in the spandex relieving the stress. Heat settability can be a help in over-coming the modulus disadvantage inherent in using bare spandex as compared to covered spandex.

A high set spandex has limitations but can have some advantages. If it is heat settable and has high modulus, when it is used bare in a fabric, these characteristics lead to:

a. Easy flat finishing and equalization of tension differentials.
b. Sheer fabrics from lighter yarns in constructions where hard fiber yarn must hold out the fabric.
c. High yield of fabric.
d. Fair power with bare spandex.

M.Y.Gudiyawar[39] (2003) subjected the synthetic fabrics to the process of heat setting before pulling them into the end use. The heat setting conditions like temperature, time and tension affect many mechanical properties of the fabric

CHAPTER 2

2. METHODOLOGY AND EXPERIMENTAL PLAN

2.1 Methodology

Procurement of Birla viscose staple fiber: 1.2 Denier, 40mm cut length, and 30 Denier spandex yarn.

↓

Spinning of 30's NE Viscose yarn at TPI=18.8, TM=3.4

↓

Waxing, clearing and winding the viscose yarn into 54 baby Cones of each 1.5 kg using schlafhorst Auto coner

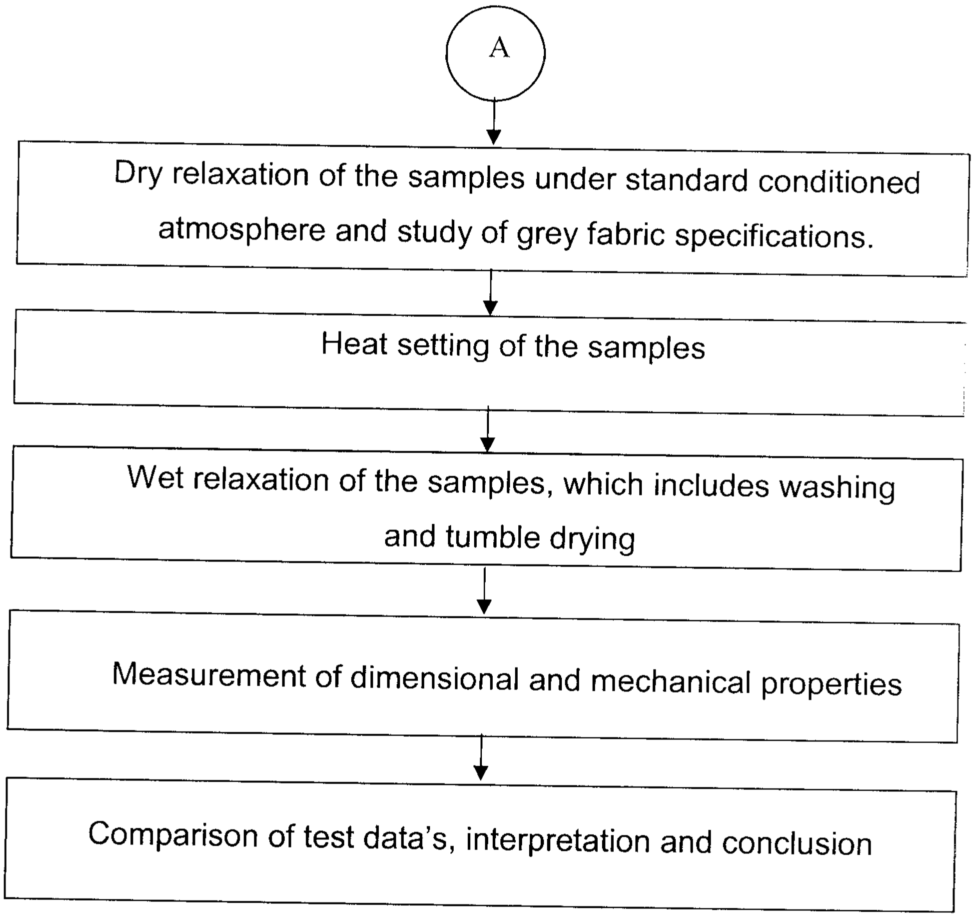
↓

Production of single jersey knitted fabrics at different loop lengths and at different constructions as

i. 100% viscose single jersey fabric
ii. viscose/spandex single jersey fabric with spandex in alternating courses
iii. viscose/spandex single jersey fabric with spandex in every course

↓

(A)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Dry relaxation of the samples under standard conditioned atmosphere and study of grey fabric specifications.
Heat setting of the samples
Wet relaxation of the samples, which includes washing and tumble drying
Measurement of dimensional and mechanical properties
Comparison of test data's, interpretation and conclusion

2.2 EXPERIMENTAL PLAN

In order to study the dimensional and mechanical properties of viscose /spandex plated knitted fabrics the following tasks were performed.

2.2.1 Fiber Details

Fiber	:	Birla Viscose Fiber
Denier	:	1.2
Cut length	:	40 mm
Origin	:	Cellulose regenerated from cellulose sodium xanthate by wet spinning

2.2.2 Yarn Details

30/1 NE Viscose yarn

30 Denier Spandex yarn

Characteristics of Viscose Yarn

COUNT REPORT	
Actual Count[NE]	29.98
Count C.V. %	0.90%
Actual Strength [LBS]	84.51
Lea Strength C.V. %	2.85%
C.S.P	2533

USTER UT4 RESULTS	
U%	9.9
CVM %	12.5
Thin [-50 %]	0.5
Thick [+50 %]	4.9
Neps [200 %]	37.9
Total IMP/KMTR	43.3
Hairiness Index	6.41
SH	1.69
Actual TPI/TPM	18.71 / 736
TM	3.4
Direction of Twist	Z
TPI C.V. %	1.20%

USTER CLASSIMATE 3 RESULTS	
Objectionable faults[A4+B4+C3+C4+D3+D4]	0.8
Long Thick faults[E+F+G]	0.5
long Thin faults[H1+H2+I1+I2]	11
Total faults[A1 To D4+E+F+G+H1,2+I1,2]	185.3

STS RESULTS	
Breaking Strength in Gms	297.2 / 304.2
Elongation %	13.86 / 13.72
Elongation C.V. %	8.46% / 9.01%
RKM	15.09 / 15.45
RKM C.V. %	7.62% / 7.70%

Characteristics of Spandex Yarn

Brand	Texlon
Grade	AA
Luster	Clear
Linear Density	30 Denier
Tenacity	8.0 CN/Tex
Elongation at Break %	608%
Elastic Recovery after 5 cycles 300% (%)	92.60%

2.2.3 Winding

It is the process of reversing yarn from the spin cops into cones of required amount and tension. The yarns from the spin cops are cleared for faults, waxed and wound on to 54 cones (baby cones) each weighing 300 grams using a schlafhorst auto coner winding machine.

2.2.4 Fabric Knitting

The fabric was knitted on a circular knitting machine.

Knitting Machine details

M/C Make	Fukahama Machinery co
M/C Type	SH-2XFA
M/C Year	APR 2003
Diameter	20"
Gauge	24
Total Needle Count	1500
Number of Feeders available	60
Number of Feeders used	54
Knitting speed	30 rpm
Yarn feeding system	Fukahama DG / 24V

Spandex Feeding

Tension	5 grams
Feed System	Memminger-IRO MER 2 System

The yarn is knitted into a plain viscose single jersey fabric, a half plated viscose / spandex single jersey fabric, and a full plated viscose / spandex single jersey fabric with varying loop length values to represent different tightness levels.

The various samples knitted are as shown in the table

Sample No.	Configuration	Loop length (mm)
1.	Plain viscose S.J fabric	2.7 mm
2.	Plain viscose S.J fabric	2.9 mm
3.	Plain viscose S.J fabric	3.1 mm
4.	Half plated viscose / spandex S.J fabric	2.7 mm
5.	Half plated viscose / spandex S.J fabric	2.9 mm
6.	Half plated viscose / spandex S.J fabric	3.1 mm
7.	Full plated viscose / spandex S.J fabric	2.7 mm
8.	Full plated viscose / spandex S.J fabric	2.9 mm
9.	Full plated viscose / spandex S.J fabric	3.1 mm

S.J Single jersey

2.2.5 Dry Relaxation

The knitted samples were relaxed in grey stage and conditioned in standard atmosphere. The standard atmosphere for testing textiles is, air maintained at a relative humidity of 65 ± 2% and at a temperature of 21 ± 1°C (70 ± 2 ° F) in a conditioning room for two days.

Reference

- ASTM: D 1776 90 (Re approved 1996)
- ISO 139

2.2.5.1 Study of Grey fabric specifications

2.2.5.1.1 Measurement of Wales and courses per inch

Fabric samples are taken and laid flat on a table. Creases and wrinkles are removed without distorting. On one side of the test specimen, with the help of pick glass or magnifying glass, the Wales per inch and courses per inch are counted. Five such readings are taken and the average is accounted.

Reference

- BS 5441 section Two: clause 8: 1988
- CAN CGSB 4.2: NO 7 M 88
- ASTM D 3887: 1996

2.2.5.1.2 Measurement of loop length

It is the length of yarn in mm for one loop.

$$\text{Loop length} = \frac{\text{Length of yarn in mm}}{\text{Known number of wale}} \quad (2.1)$$

The loop value is measured by taking 50 Wales. 50 Wales are marked on the fabric surface and then the yarn for that particular place is unraveled, straightened (not stretched) and measured in mm. by substituting the measured values in the above formula, the loop length is measured.

2.2.6 Heat Setting

The fabric is stretched to the required level and set permanently by passing through the heating and curing chamber, by maintaining the required temperature. This is done to relieve the knitting stresses and to permanently set the fabric at required levels.

2.2.6.1 Heat Setting Conditions

i. Plain viscose single jersey fabric

Stretch = Fabric Ideal Diameter + 3%
Temperature = 160 °C
Rpm = 6
Time = 4.8 sec

ii. Half plated fabric

Stretch = Fabric Ideal Diameter + 12%
Temperature = 190 °C
Rpm = 5
Time = 4.2 sec

iii. Full plated

Stretch = Fabric Ideal Diameter +18%
Temperature = 210 °C
Rpm = 3.3
Time = 3.3 sec

2.2.7 Wet Relaxation

The wet relaxing includes washing, tumble drying and then relaxing the fabric at atmospheric condition.

Washing Process Parameters

Machine : Ramsons-Drum type washing machine
Temp : Cold wash
Time : 10 min
Water level: 500 lit
Wetting agent: 35 % conc., 50 ml wetting oil.

Tumble Drying Process Parameters

Machine : Ramsons Tumble dryer
Time taken: 1hour 15 minutes
Temp : 95 °C
Start Temp: 60 °C

2.2.7.1 Fabric Specification after Wet Relaxation

The measurement of Wales per inch, Courses per inch and loop length of the fabric are done as before.

2.2.7.2 Measurement of Thickness

Thickness

Perpendicular distance between two reference plates exerting a pressure of 1 K Pa or less on textiles

Thickness is measured using a thickness meter. Thickness for the fabric is measured at five different places and the average value is noted.

Reference

- ISO 5084
- ASTM D 1777 96.

2.2.7.3 Measurement of Fabric Weight/ Unit Area (GSM)

Using a cutting device (round, area 100 cm^2), the fabric is cut and weighed in a weighing balance. GSM for the fabric is measured at five different places and the average value is noted.

Calculation

100 × sample weight = weight / square meter (grams) [GSM] → (2.2)

Reference

- ASTM D 3776 96.

2.2.7.4 Shrinkage test

Take the specimen in dimensions as 50 × 50 cm and mark 35 × 35 cm. The fabrics are then subjected to half washing cycle in a front loading [IFB] washing machine.

Washing parameters

Cycle	= B → D, D → F,
Temp	= 40 ° C,
Detergent	= ECE reference detergent – 2 table spoon.

The fabric is then spread out on a smooth and horizontal surface; wrinkles are removed by hand without stretching or distorting and flat dried. The final distances between the benchmarks are measured.

Calculate the percentage dimensional changes according to the following formulae,

$$\%\text{ dimensional change} = \frac{\text{After wash reading} - \text{Original reading}}{\text{Original reading}} \times 100\% \rightarrow (2.3)$$

The lengthwise, widthwise and area shrinkage are all calculated.

Reference

- ISO 5077 / 6330
- BS EN 25077 / 26330
- DIN EN 25077 / 26330

2.2.7.5 Determination of Abrasion Resistance

Instrument : Martindale abrasion tester

Make : M/s Ramesh machine works

Model : RC 11

Method : Constant Revolution method.

A circular specimen is cut using a template (3.8 cm Diameter) and weighed. It is mounted in a specimen holder and subjected to a definite load (200 grams). It is rubbed against an abrasion medium (silicon carbide paper-400 E4) in a translational movement tracing a lissajous figure, the specimen holder being additionally freely rotatable around its own axis perpendicular to the plane of the specimen

After 20 revolutions the specimen is taken out and weighed.

Formulae used for calculation:

1) $$\text{\% of weight loss} = \frac{[\text{Original weight} - \text{After weight loss}]}{\text{Original weight}} \times 100 \quad \rightarrow (2.4)$$

2) Fabric abrasion resistance= 100 - % of weight loss → (2.5)

Reference

- ASTM D 4966 89
- ISO 12947 2

2.2.7.6 Determination of Bursting Strength Value

Apparatus : Hydraulic diaphragm bursting tester
(Ramesh machine works RC 61)

Medium : Glycerine

Capacity : (0 10.6 & 0 28 Kg / cm^2) or
(0 150 & 0 400 P.S.I [lb / in^2])

Condition the test sample and place it over the diaphragm and then secure it by pushing down the clamp lever. Adjust the pointer to the zero position and inflate the diaphragm by moving the operating handle. While the diaphragm is inflating, take hold of the latch that is located to right of the operating handle. At the instant of the rupture of the specimen, swing the latch as far as it will go to bring the operating handle to neutral position.

Record the bursting strength value in pounds that is indicated by the red pointer. This is repeated for five times and the average is recorded.

Reference

- ASTM D 3786,
- CAN / CGSB 4.2 No. 11. 1 94,
- ISO 13938 1,
- BS EN ISO 13938 1.

2.2.7.7 Determination of Pilling Resistance

Equipment : Pill testing box ICI
(Ramesh machine works, RC 21)

Rotating speed : 60 rpm

Cut a specimen of 125 x 125 cm and mark the fabric length direction at the back. Sew 12 mm from the cut edges to form a tubular shape and insert them on a polyurethane tube using mounting jig. Apply self-adhesive PVC tape at cut ends to prevent yarns fraying during test.

Condition the samples. Clean the pill box and place four specimens in each box and close the lid. Set the pilling tester for 18,000 revolutions and switch on. When tester stops, cut the seams and remove the specimen from tube.

Evaluate the pilling grade using rate of appearance. This is done by mounting the specimens along with reference samples in viewing cabinet. Evaluate using a suitable light source and using ASTM reference scale.

Expression of results

Table 1	**Assessment**	**Interpretation**
Rating	Description	Points to be taken into consideration during assessment
5	No change	No visual change
4	Slight change	Slight surface fuzzing
3	Moderate change	The test specimen may exhibit either or both of the following : A. Moderate fuzzing. B. Isolated fully formed piles.
2	Significant change	Distinct fuzzing and / or pilling
1	Severe change	Dense fuzzing and / or pilling which covers the specimen

The average pilling grades are recorded.

Reference

- BS EN ISO 12945 1: 2001
- ISO 12945 SECTION – 1: 2000.

2.2.7.8 Measurement of Air Permeability

Principle

This method is based on the measuring of the rate of flow of air through a given area of fabric by a given pressure drop across the fabric.

Procedure

Take the conditioned specimen and mount a portion between the clamp and circular orifice with sufficient tension to eliminate wrinkles if any taking care to see that the fabric is not distorted in its own place. Start the vacuum cleaner to force the air through the fabric and adjust the rate of flow of air till the pressure drop of one centimeter water head across.

Note the rate of flow of air in cm^3 / s. This is repeated for five times and the average is accounted.

Calculation

Rate of flow of air (Or) Air permeability

$$[R] = \frac{r}{a} \text{ cm / s} \longrightarrow (2.6)$$

Where,

r = mean rate of flow of air in cm^3 / s,

a = area cm^2 of fabric under test.

Reference

- IS: 11056 – 1984.

All the testing procedures has followed

a) 10 cm side rule and

b) Diagonal rule.

CHAPTER 3

3. RESULTS, DISCUSSIONS AND CONCLUSION

3.1 RESULTS AND DISCUSSIONS

On each sample, the following test parameters are measured in dry relaxed conditions and after wet relaxation and the results are tabulated.

1. Courses per inch
2. Wales per inch
3. Loop length

Table 3.1 Effect of Loop Length and Plating on WPI at Dry Relaxation Stage

LOOP LENGTH MM (inch)	1/LOOP LENGTH(inch)	WPI (DRY RELAXED SAMPLE)		
		100% VISCOSE	HALF PLATED	FULL PLATED
3.1 (0.122)	8.2	30	40	43
2.9 (0.114)	8.8	30	40	43
2.7 (0.106)	9.4	30	40	43

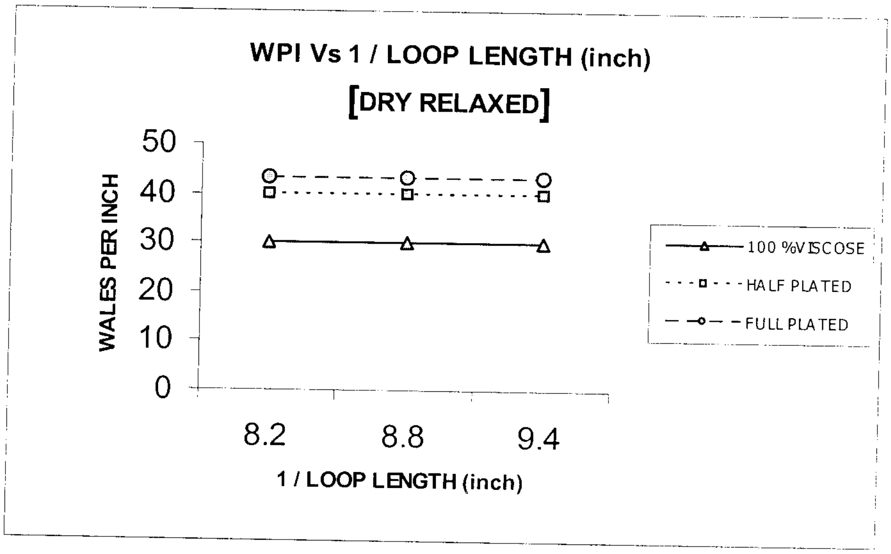

Figure 3.1 Effect of Loop Length and Plating on WPI at Dry Relaxation Stage

Table 3.1 and figure 3.1 shows that WPI values remain unaltered with varying loop lengths but WPI values increases due to plating effects. Regardless of loop length, for a particular plating level (amount of spandex) the WPI values stand same as a constant but when the plating level is increased (100% viscose – half plated – full plated), the fabrics get tighter due to the elasticity of spandex and the WPI values increases gradually. This results in tighter fabrics.

Table 3.2 Effect of Loop Length and Plating on WPI at Wet Relaxation Stage

LOOP LENGTH MM (inch)	1/LOOP LENGTH(inch)	WPI (WET RELAXED SAMPLE)		
		100% VISCOSE	HALF PLATED	FULL PLATED
3.1 (0.122)	8.2	37	40	54
2.9 (0.114)	8.8	37	40	54
2.7 (0.106)	9.4	37	40	54

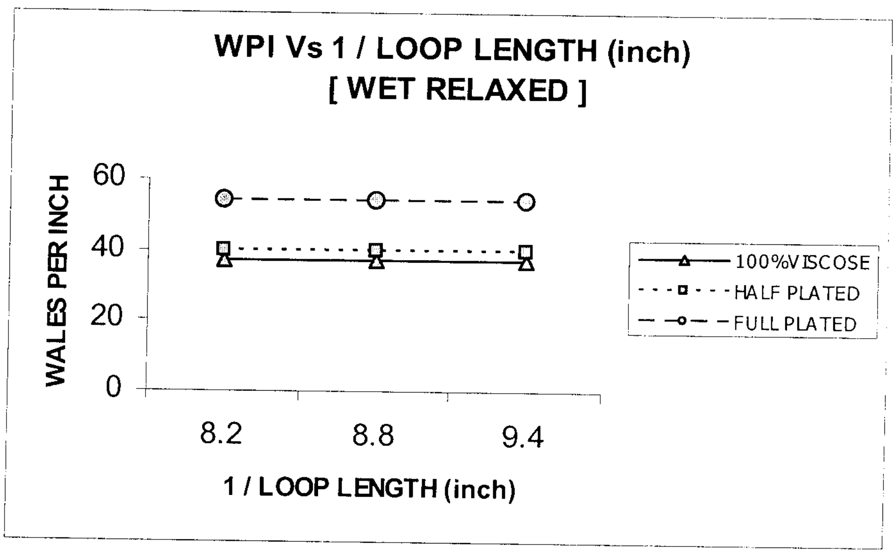

Figure 3.2 Effect of Loop Length and Plating on WPI at Wet Relaxation Stage

Table 3.2 and figure 3.2 shows that the WPI values are fairly high after wet relaxation and an important factor to be considered is the different loop lengths have same WPI and increase in plating levels increases WPI, same as in the case of dry relaxed samples. Compared to dry relaxed results (table 3.1 and figure 3.1) the wet relaxed samples have higher WPI values inferring that wet relaxation further increases the fabric tightness.

Wale spacing values of all samples decrease while relaxation progresses. The variation in WPI with loop length is nil and significant in different plating levels.

Table 3.3 Effect of Loop Length and Plating on CPI at Dry Relaxation Stage

LOOP LENGTH MM (inch)	1/LOOP LENGTH(inch)	CPI (DRY RELAXED SAMPLE)		
		100% VISCOSE	HALF PLATED	FULL PLATED
3.1 (0.122)	8.2	35	50.6	72
2.9 (0.114)	8.8	42	54.2	71
2.7 (0.106)	9.4	47.8	60	73.2

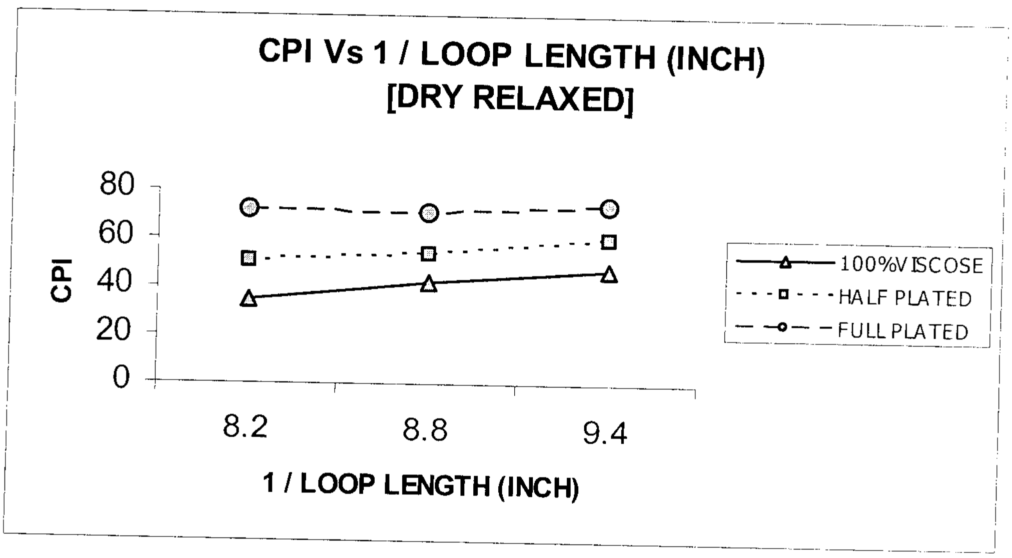

Figure 3.3 Effect of Loop Length and Plating on CPI at Dry Relaxation Stage

Table 3.3 and figure 3.3 shows that CPI values for dry relaxation samples vary linearly with loop lengths. The CPI values decreases with increase in loop length. When the plating levels (amount of spandex) are increased the CPI values gradually increases.

The regression equations for 100% viscose, half plated and full plated samples are, y = 6.4x + 28.8, y = 4.7x + 45.53, and y = 0.6x + 70.86 respectively and the regression co-efficient for 100% viscose is r = 0.99, half plated is r = 0.98, and full plated is r = 0.29, stating that there is a strong correlation between loop length and CPI in 100% viscose and half plated samples, whereas the correlation is poor in full plated.

Table 3.4 Effect of Loop Length and Plating on CPI at Wet Relaxed Condition

LOOP LENGTH MM (inch)	1/LOOP LENGTH(inch)	CPI (WET RELAXED SAMPLE)		
		100% VISCOSE	HALF PLATED	FULL PLATED
3.1 (0.122)	8.2	36	64	82
2.9 (0.114)	8.8	42	70	88
2.7 (0.106)	9.4	45	76	96

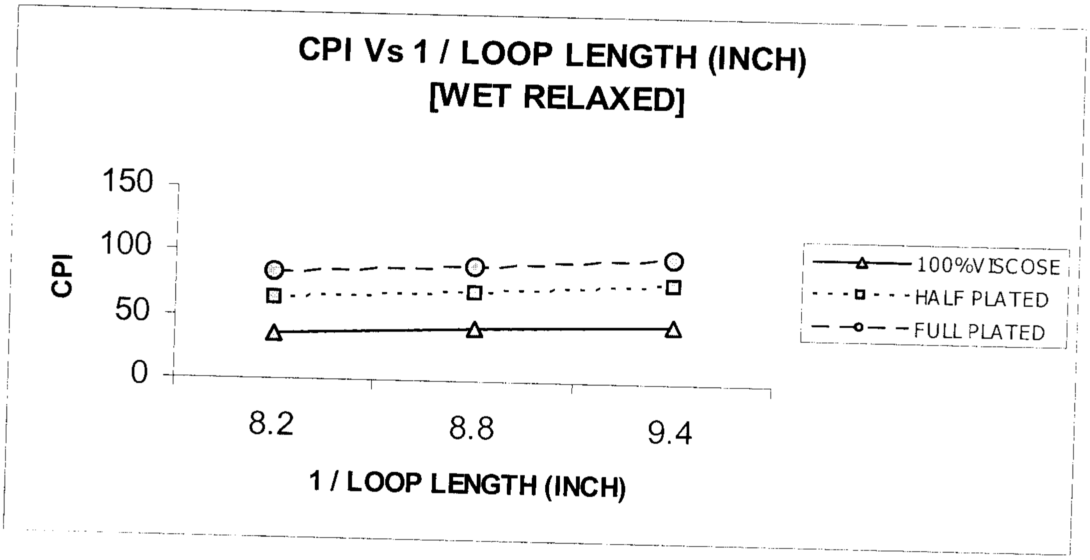

Figure 3.4 Effect of Loop Length and Plating on CPI at Wet Relaxed Condition

Table 3.4 and figure 3.4 shows that CPI values at wet relaxation stage also vary linearly with loop lengths. The CPI values increases with decrease in loop length, also when the plating levels increases the CPI values gradually increase.

The regression equations for 100% viscose, half plated and full plated samples are, $y = 4.5x + 32$, $y = 6x + 58$, and $y = 7x + 74.66$ respectively, and the regression co-efficient for 100% viscose is $r = 0.96$, half plated is $r = 1$, and full plated is $r = 0.99$, stating that there is a very strong correlation between loop length and CPI in case of all the three configurations 100% viscose, half plated samples, and full plated.

Table 3.5 Effect of Loop Length and Plating on Stitch Density at Dry Relaxed Condition

LOOP LENGTH MM (inch)	1/LOOP LENGTH^2 (inch)	STITCH DENSITY (DRY RELAXED)		
		100% VISCOSE	HALF PLATED	FULL PLATED
3.1 (0.122)	67.13	1050	2024	3096
2.9 (0.114)	76.71	1260	2168	3053
2.7 (0.106)	88.49	1434	2400	3147.6

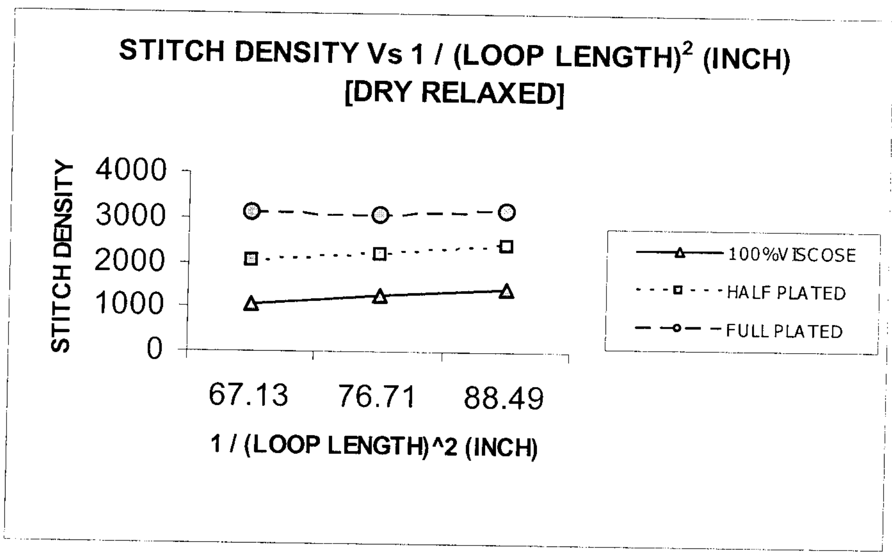

Figure 3.5 Effect of Loop Length and Plating on Stitch Density at Dry Relaxed Condition

Table 3.5 and figure 3.5 shows that the stitch density values of dry relaxed samples vary linearly with loop length. Since the increase in plating level increases the fabric tightness and so the stitch density also increases.

Decrease in loop length increases the fabric tightness thereby increasing the stitch density values. The regression equations for 100% viscose, half plated and full plated are y = 192x + 864, y = 188x +1821.3, and y = 25.8x +3047.3 respectively, and the regression co-efficient are r =.99,r = .98 and r=.29 respectively showing that the correlation between loop length and stitch density is stronger in 100% viscose and half plated and it is poor in full plated.

Table 3.6 Effect of Loop Length and Plating on Stitch Density at Wet Relaxed Condition

LOOP LENGTH MM (inch)	1/LOOP LENGTH^2 (inch)	STITCH DENSITY (WET RELAXED)		
		100% VISCOSE	HALF PLATED	FULL PLATED
3.1 (0.122)	67.13	1332	2560	4428
2.9 (0.114)	76.71	1554	2800	4752
2.7 (0.106)	88.49	1665	3040	5184

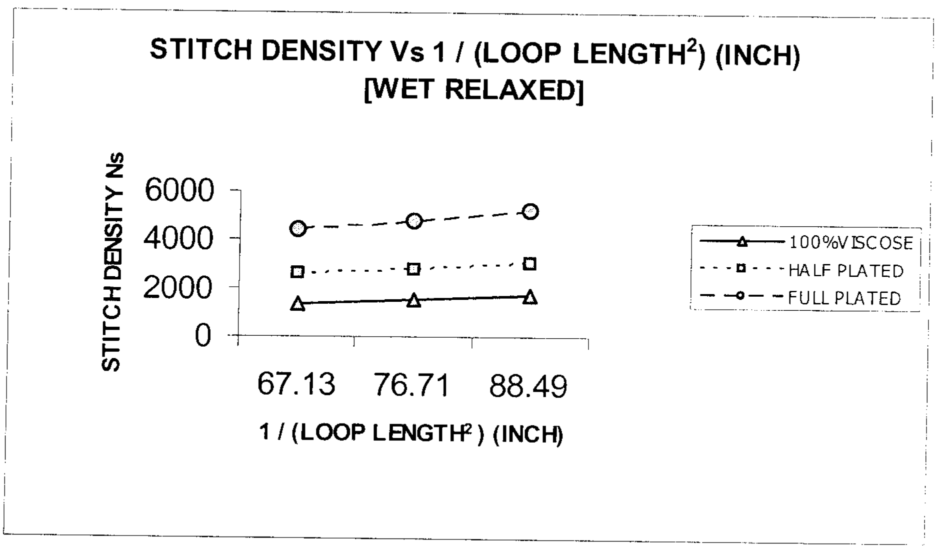

Figure 3.6 Effect of Loop Length and Plating on Stitch Density at Wet Relaxed Condition

Table 3.6 and figure 3.6 shows that the stitch density vary linearly with loop length, increase in loop length decreases stitch density since the fabric gets looser, where as increase in plating increases fabric tightness thereby increasing the stitch density.

Regression equations for 100% viscose, half plated and full plated are y = 166.5x + 1184, y = 240x +2320, and y = 378x +4032 respectively, and the regression co-efficient are r=.96.66, r=1.0 and r=.99 respectively, showing that correlation between loop length and stitch density is quiet very strong.

The wet relaxed samples are further subjected to the following tests to experiment the dimensional and mechanical properties and the results are tabulated and discussed.

Table 3.7 Shrinkage Behaviors of the Knits in Length Directions for Varying Loop Length and Plating Level

FABRIC TYPE	LOOP LENGTH	LENGTHWISE SHRINKAGE (%)
100% VISCOSE	2.7 2.9 3.1	0 -0.5 -0.9
HALF PLATED VISCOSE / SPANDEX	2.7 2.9 3.1	-4.7 -4.5 -3.8
FULL PLATED VISCOSE / SPANDEX	2.7 2.9 3.1	3.2 2.7 2.67

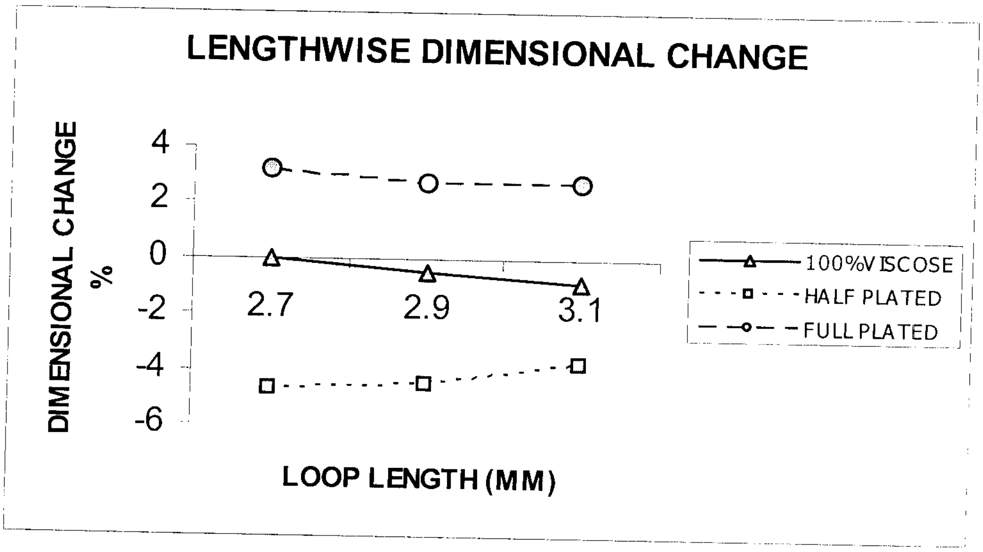

Figure 3.7 Shrinkage Behaviors of the Knits in Length Directions for Varying Loop Length and Plating Level

From the above table and figure it's found that lengthwise shrinkage levels vary linearly with loop length and also different plating levels have different lengthwise shrinkage value.

The result of experiments were statistically computed and the regression equation for the lengthwise shrinkage of 100% viscose fabric, half plated and full plated are y = -0.45x + 0.433, y = 0.45x - 5.23 and y = -0.265x + 3.38 respectively and the regression analysis clearly shows that the correlation between loop length and shrinkage are quite strong for 100% viscose and half plated (co-efficient for 100% viscose, r = 0.99 and for half plated is r = 0.90) and average for full plated (r = 0.79).

The full plated samples show a positive dimensional change in lengthwise. They elongate in lengthwise where as for 100% viscose the shrinkage is approximately nil. For half plated the shrinkage is high in negative side. The length of half plated samples (for all loop lengths) has shrunk.

The shrinkage amount of each knit structure has a different value and each loop length value exhibit different shrinkage level.

Table 3.8 Shrinkage Behaviors of the Knits in Width Directions for Varying Loop Length and Plating Level

FABRIC TYPE	LOOP LENGTH	WIDTHWISE SHRINKAGE (%)
100% VISCOSE	2.7 2.9 3.1	0 0.2 0.4
HALF PLATED VISCOSE / SPANDEX	2.7 2.9 3.1	3.8 2.4 1.6
FULL PLATED VISCOSE / SPANDEX	2.7 2.9 3.1	2.1 1.9 2.3

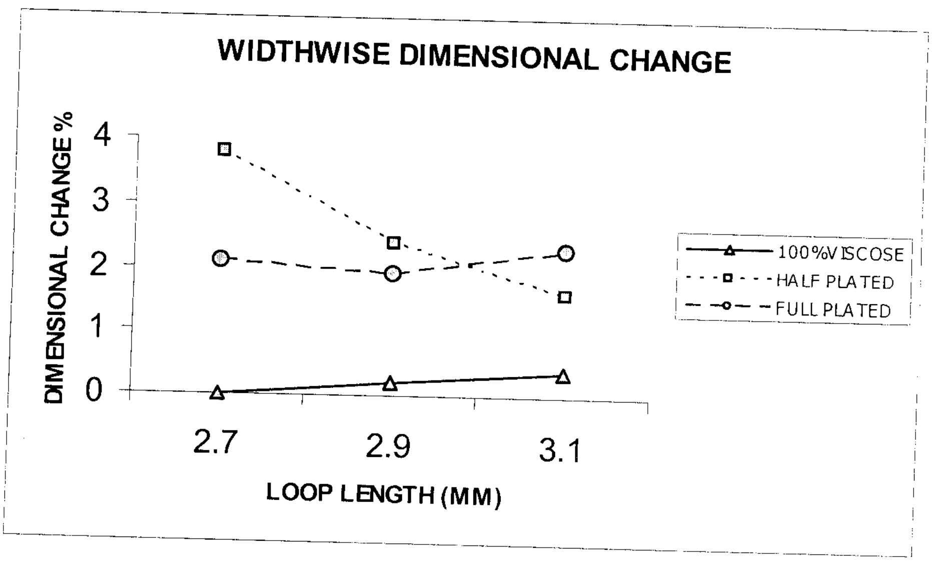

Figure 3.8 Shrinkage Behaviors of the Knits in Width Directions for Varying Loop Length and Plating Level

The above table and figure shows that the widthwise shrinkage levels also vary linearly with loop length and also different plating levels have different width wise shrinkage value.

The result of experiments were statistically computed and the regression equation for 100% viscose fabric, half plated and full plated are $y = 0.2x - 0.2$, $y = -1.1x + 4.8$ and $y = 0.1x + 1.9$ respectively, and the regression analysis clearly shows that the correlation co efficient between loop length and shrinkage are quite strong for 100% viscose and half plated (co-efficient for 100% viscose, r = 1 and for half plated is r = 0.97) and poor for full plated (r = 0.25).

All the samples showed only a positive shrinkage (i.e. elongation) in widthwise irrespective of loop length value and plating levels.

Table 3.9 Arial Shrinkage Behaviors of the Knits for Varying Loop Length and Plating Level

FABRIC TYPE	LOOP LENGTH	ARIAL SHRINKAGE (%)
100% VISCOSE	2.7	0
	2.9	-0.3
	3.1	-0.5
HALF PLATED VISCOSE / SPANDEX	2.7	-1.1
	2.9	-2.2
	3.1	-2.3
FULL PLATED VISCOSE / SPANDEX	2.7	5.4
	2.9	4.6
	3.1	5

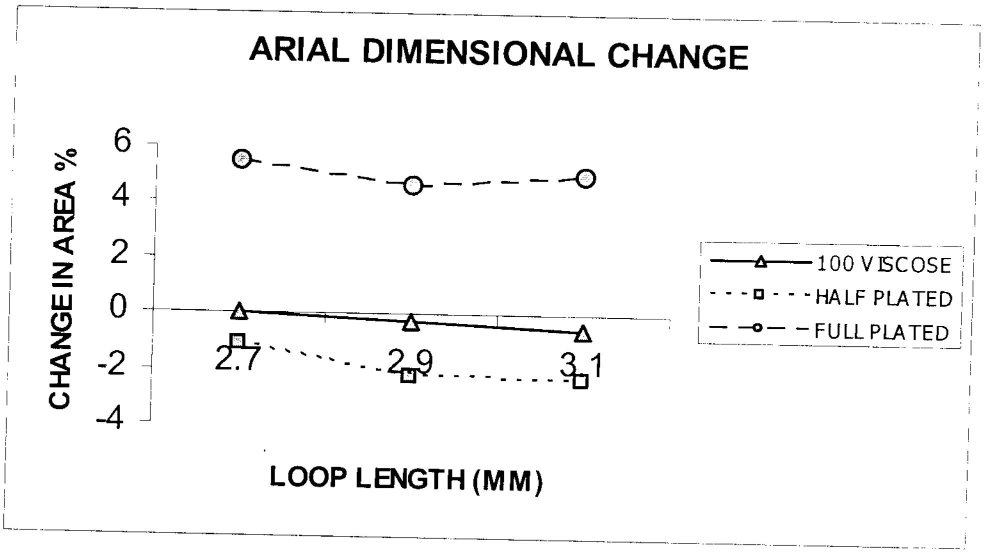

Figure 3.9 Arial Shrinkage Behaviors of the Knits for Varying Loop Length and Plating Level

From the table 3.9 and figure 3.9 it's found that Arial shrinkage levels also vary linearly with loop length and also different plating levels have different Arial shrinkage value.

The regression equation for 100% viscose fabric, half plated and full plated are $y = -0.25x + 0.23$, $y = -0.6x - 0.66$ and $y = -0.2x + 5.4$ respectively, and the regression co-efficient are $r = 0.98$, $r = 0.81$, and $r = 0.25$ for 100% viscose, half plated and full plated respectively.

Obviously here also the correlation between the shrinkage and loop length for 100 % viscose and half plated is quite good and poor for full plated.

The 100% viscose samples and half plated samples show a negative dimensional change (shrinkage) and full plated shows positive dimensional change (elongation).

Table 3.10 Effect of Loop Length and Plating on Abrasion Resistance

LOOP LENGTH (MM)	ABRASION RESISTANCE (%)		
	100% VISCOSE	HALF PLATED	FULL PLATED
2.7	93.26	98.58	99.18
2.9	92.85	97.72	99.13
3.1	92.01	96.93	99.07

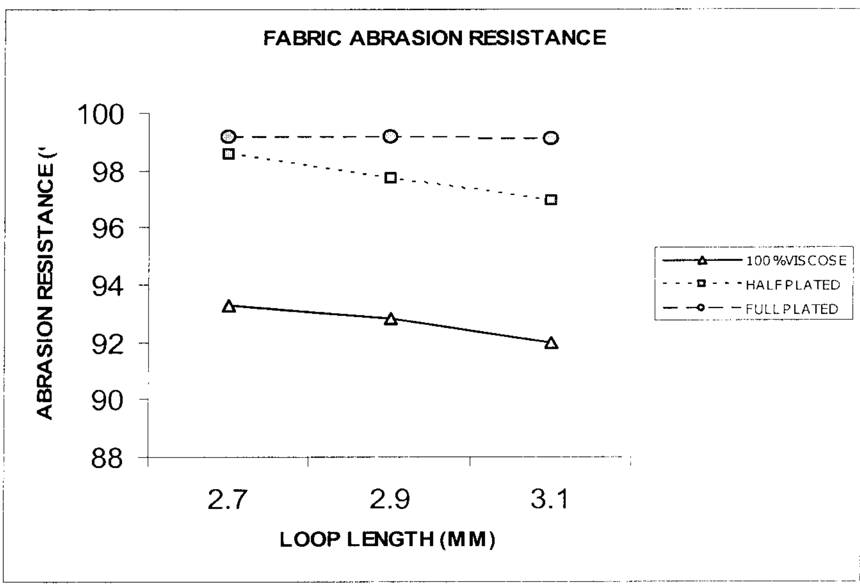

Figure 3.10 Effect of Loop Length and Plating on Abrasion Resistance

Table 3.10 and figure 3.10 shows that the abrasion resistance of the samples varies linearly with loop length. Increase in loop length values reduces the fabric tightness and so the abrasion resistance whereas increase in plating level increase fabric tightness and thereby the abrasion resistance.

The regression equation for the 100% viscose fabric, half plated and full plated are $y = -0.625x + 93.95$, $y = -0.825x + 99.39$ and $y = -0.055x + 99.23$ respectively, and the regression co-efficient are $r = 0.96$, $r = 0.99$, and $r = 0.99$ for 100% viscose, half plated and full plated respectively showing that the correlation between loop length and abrasion resistance are very strong.

Influence of loop length value on abrasion resistance is indirectly proportional and influence of plating (amount of spandex) is directly proportional. Lower loop length value and the full plated sample provide the best abrasion resistance sample.

Table 3.11 Effect of Loop Length and Plating on Bursting Strength

LOOP LENGTH (MM)	BURSTING STRENGTH (lb/inch^2)		
	100% VISCOSE	HALF PLATED	FULL PLATED
2.7	48	55	72
2.9	45	51.5	69
3.1	40	50.5	65

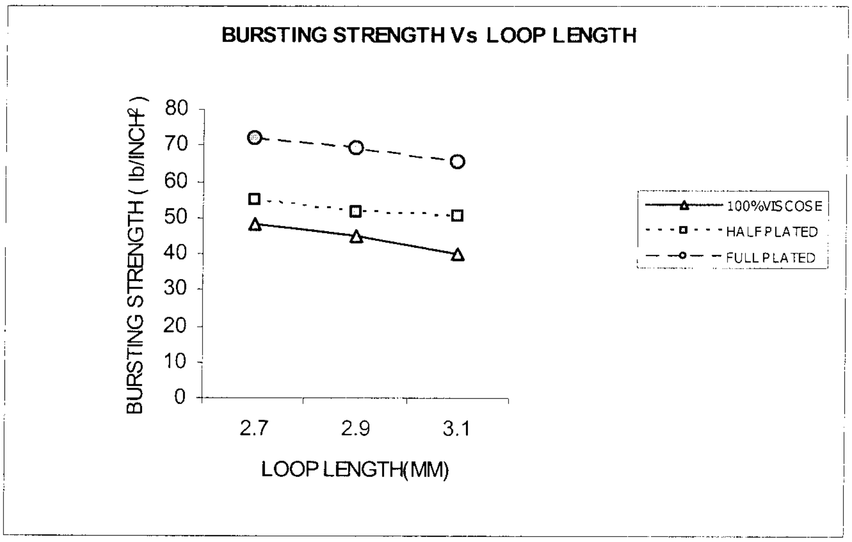

Figure 3.11 Effect of Loop Length and Plating on Bursting Strength

Table 3.11 and figure 3.11 shows that the bursting strength of the samples varies linearly with loop length. Increase in loop length values reduces the fabric tightness and so the bursting strength whereas increase in plating level increase fabric tightness and thereby the bursting strength.

The regression equation of 100% viscose fabric, half plated and full plated are $y = -4x + 52.33$, $y = -2.25x + 56.83$ and $y = -3.5x + 75.66$ respectively, and the regression co-efficient are $r = 0.97$, $r = 0.90$ and $r = 0.99$ for 100% viscose, half plated and full plated respectively showing that the correlation between loop length and bursting strength are very strong.

Influence of loop length value on bursting strength is indirectly proportional and influence of plating (amount of spandex) is directly proportional. Lower loop length value and the full plated sample provide the best bursting strength sample.

Table 3.12 Effect of Loop Length and Plating on Air Permeability

LOOP LENGTH(MM)	AIR PERMEABILITY(Cm/s)		
	100% VISCOSE	HALF PLATED	FULL PLATED
2.7	8.55	3.31	0.72
2.9	11.04	4.79	1.34
3.1	13.33	5.87	1.73

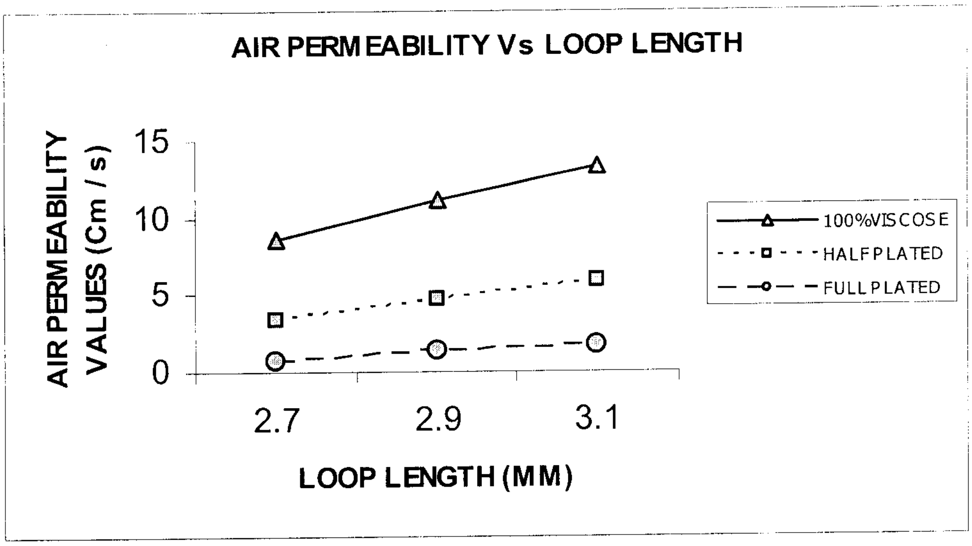

Figure 3.12 Effect of Loop Length and Plating on Air Permeability

The table and figure shows that the air permeability increases with loop length and varies linearly. Increase in loop length decreases fabric tightness which in turn increases the air permeability. It is also inferred that the increase in spandex amount decreases air permeability, since the tightness of the fabric increases.

The regression equation for 100% viscose fabric, half plated and full plated are y = 2.39x +6.19, y = 1.28x + 2.09 and y = 0.50x + 0.25 respectively, and the regression co-efficient are r = 0.99, r = 0.99 and r = 0.98 for 100% viscose, half plated and full plated respectively indicating that the correlation between loop length and air permeability is very strong.

Influence of loop length values on air permeability is directly proportional and influence by spandex is indirectly proportional. Higher loop length and 100% viscose (nil spandex amounts) provide the best air permeable sample. Air permeability is lowest for full plating viscose / spandex fabrics and greater for 100 % viscose sample, because tightness of the fabrics increases with spandex. The difference between the air permeability values of these two samples is consistently higher. The variation in air permeability values of samples knitted from different loop length is also high, higher loop length has high air permeability and vice versa.

Table 3.13 Effect of Loop Length and Plating on Pilling Grade

LOOP LENGTH(MM)	PILLING GRADE		
	100% VISCOSE	HALF PLATED	FULL PLATED
2.7	1	2	3-4
2.9	1	2-3	4
3.1	1-2	2	3-4

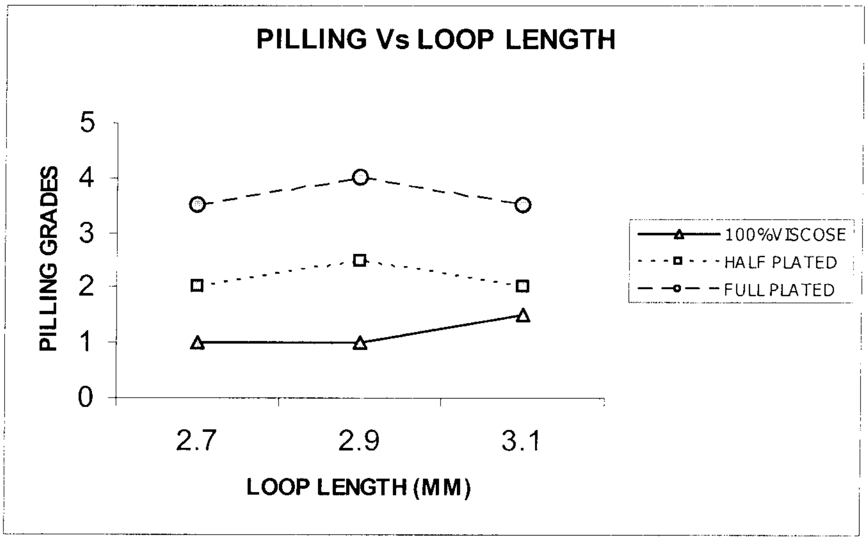

Figure 3.13 Effect of Loop Length and Plating on Pilling Grade

From the above table and figure it's found that pilling values changes with loop length and with amount of spandex. The pilling grades of tight samples are better than looser once. Therefore as the amount of spandex increases the tendency of pilling decreases.

Table 3.14 Effect of Loop Length and Plating on Thickness

FABRIC TYPE	LOOP LENGTH	THICKNESS (MM)
100% VISCOSE	2.7	0.42
	2.9	0.44
	3.1	0.48
HALF PLATED VISCOSE / SPANDEX	2.7	0.65
	2.9	0.7
	3.1	0.72
FULL PLATED VISCOSE / SPANDEX	2.7	0.79
	2.9	0.83
	3.1	0.91

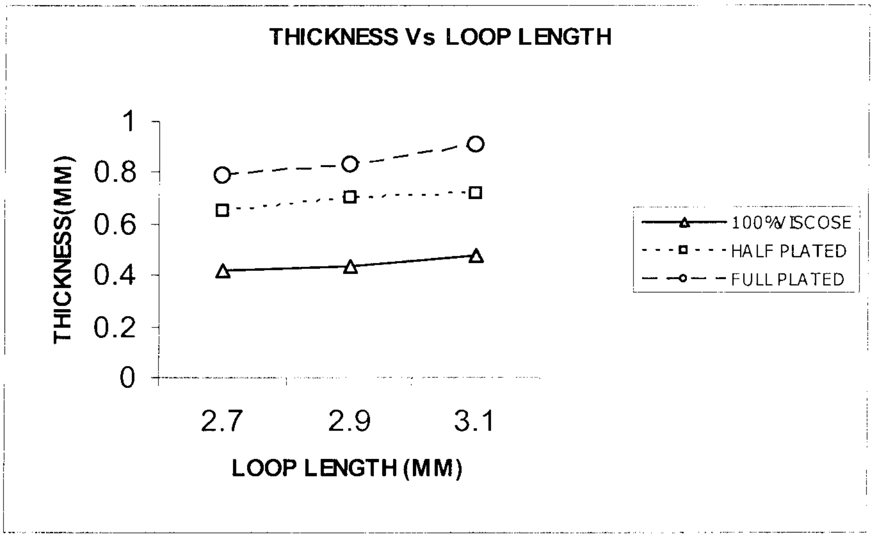

Figure 3.14 Effect of Loop Length and Plating on Thickness

Table 3.14 and figure 3.14 shows that thickness of the samples varies linearly with loop length. Both increase in loop length and plating level increases thickness.

The regression equations of 100% viscose, half plated and full plated are Y= 0.03x + 0.38, y = 0.03x + 0.62 and y = 0.06x + 0.72 respectively and their regression co-efficient are r = 0.96, 0.94, 0.96 respectively this shows that correlation between loop length are very strong.

Table 3.15 Effect of Loop Length and Plating on Fabric Weight (GSM)

LOOP LENGTH(MM)	WEIGHT PER UNIT AREA (GRAMS) [GSM]		
	100% VISCOSE	HALF PLATED	FULL PLATED
2.7	144.03	280.8	460.96
2.9	128.1	279.2	455.56
3.1	119.63	267.4	438.93

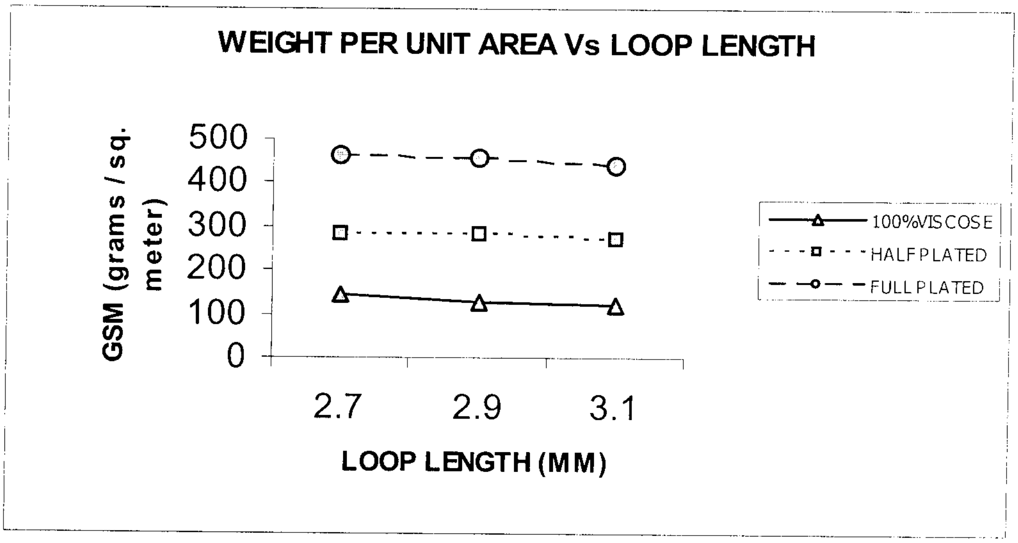

Figure 3.15 Effect of Loop Length and Plating on Fabric Weight (GSM)

Table 3.15 and figure 3.15 shows that the weight of the samples varies linearly with loop length. Increase in loop length values reduces the fabric tightness and so the weight, whereas increase in plating level increase fabric tightness and thereby the weight.

The regression equation for the 100% viscose fabric, half plated and full plated are y = -12.2x + 154.99, y = -6.7x + 289.2 and y = 11.015x + 473.85 respectively, and the regression co-efficient are r = 0.96, r = 0.83, and r = 0.92 for 100% viscose, half plated and full plated respectively showing that the correlation between loop length and weight are very strong.

Influence of loop length value on weight is indirectly proportional and influence of plating (amount of spandex) is directly proportional.

3.2 RESULTS AND DISCUSSIONS - SUMMARY

1. 100 % VISCOSE

a Wales per inch remains unchanged with loop length

b Courses per inch decreases with increase in loop length and it follows a linear equation as follows,

CPI = 4.5 (1 / LOOP LENGTH (inch)) + 32 [After Wet Relaxation]

c Stitch Density also decreases with increase in loop length and it follows a linear equation as follows, [After Wet Relaxation]

STITCH DENSITY = 166.5 (1 / LOOP LENGTH^2 (inch)) + 1184.

d The shrinkage (length wise, width wise & Arial) is between ± 1.

e With increase in loop length the Abrasion resistance, Bursting Strength and Weight decreases whereas Air permeability, Pilling Grade, and Thickness increases.

2. HALF PLATED

a Wales per inch remains unchanged with loop length

b Courses per inch decreases with increase in loop length and it follows a linear equation as follows,

CPI = 6 (1 / LOOP LENGTH (inch)) + 58 [After Wet Relaxation]

c Stitch Density also decreases with increase in loop length and it follows a linear equation as follows, [After Wet Relaxation]

STITCH DENSITY = 240 (1 / LOOP LENGTH^2 (inch)) + 2320.

d The shrinkage (length wise, width wise and Arial) is very high in this type of fabric and it is between ± 5.

e With increase in loop length the Abrasion resistance, Bursting Strength and Weight decreases whereas Air permeability and Thickness increases. The Pilling Grade remains almost the same.

3. FULL PLATED

a Wales per inch remains unchanged with loop length

b Courses per inch decreases with increase in loop length and it follows a linear equation as follows,

CPI = 7 (1 / LOOP LENGTH (inch)) + 74.66 [After Wet Relaxation]

c Stitch Density also decreases with increase in loop length and it follows a linear equation as follows, [After Wet Relaxation]

STITCH DENSITY = 378 (1 / LOOP LENGTH^2 (inch)) + 4032.

d The shrinkage (length wise, width wise and Arial) is very high in this type of fabric and it is between ± 5.

e With increase in loop length the Abrasion resistance, Bursting Strength and Weight decreases whereas Air permeability and Thickness increases. The Pilling Grade remains almost the same.

Increase in Plating Level [Amount of spandex] increases Wales per inch, Courses per inch, Stitch Density, Abrasion Resistance, Bursting Strength, Pilling Grades, Thickness and Weight & decreases Air Permeability.

3.3 CONCLUSION

The lower Loop Length Full Plated viscose / Spandex knitted fabric is found to be better in many way except air permeability. The Shrinkage of these fabrics is also within the tolerable limits (±5 %). The Full Plating of Spandex on viscose enhanced the properties and this fabric can be better used for active wears, casual wears etc. New applications can also be explored to use this fabric because of its satisfactory results which will lead to increased use of viscose fibers as an alternative to cotton.

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