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STUDY THE DIMENSIONAL AND COMFORT PROPERTIES OF SINGLE JERSEY KNITTED FABRIC MADE FROM TUCK AND MISS STITCH

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ABSTRACT

Loops are the main structural elements of knitting their shape and size influences the appearance and properties of knitted products even though other knitting and yarn parameters remain constant. In knitting industries, many derivatives of single jersey construction can be developed by combining different stitches for different reasons mainly; for design purpose, to give stability and to improve other physical properties. However, each stitch has its own effect on dimensional as well as comfort properties of a given knitted fabrics. This paper is focused on the effect of different stitch combinations mainly; knit, tuck and miss stitch on dimensional and comfort properties of single jersey derivative fabrics. Samples were knitted from 100% cotton yarn on circular knitting machines and the various dimensional and comfort properties were measured using relevant standards. From this investigation, it was found that the presence of tuck and float stitch in a given structure have significant effect on fabric drape ability, stretch and recovery, shrinkage, thickness, areal density, air permeability and low stress mechanical properties.

Key words: Tuck loop, Float loop, Bending rigidity, Shear rigidity, Compression, Surface property.

ADVISOR’S APPROVAL

ETHIOPIAN INSTITUTE OF TEXTILE AND FAHION TECHNLOHY (EiTEX)

POSTGRADUTE STUDIES AND PROJECT DEVELOPMENT OFFICE

This is to certify that the thesis entitled ‘‘Study the dimensional and comfort properties of single jersey knitted fabric made from tuck and miss stitch’’, submitted in partial fulfillment of the requirements for degree of Master’s with specialization in Textile Manufacturing, the Postgraduate Studies Program of the Ethiopian Institute of Textile and Fashion Technology, and has been carried out by Alemayehu Assefa ID.No 002/09, under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the institute.

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Name of advisor signature Date

APPROVAL

EXAMINERS APPROVAL SHEET I

EXAMINER APPROVAL SHEET II

DECLARATION

I hereby declare that the thesis entitled "Study the dimensional and comfort properties of single jersey knitted fabric made from tuck and miss stitch" is submitted in fulfillment for the degree of Master of Science in Textile Manufacturing is my own work and that all contributions from any other persons or sources are properly and duly cited. I further declare that the material has not been submitted either in whole or in part, for a degree that at this or any other university. In making this declaration, I understand and acknowledge any breaches in this declaration constitute academic misconduct, which may result in my expulsion from the program and/or exclusion from the award of the degree.

Name of Candidate: Alemayehu Assefa

Signature of candidate: --------------------

Date: --

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CHAPTER ONE
INTRODUCTION

1.1 Background and justification

The term knitting describes the technique of constructing textile structures by forming a continuous length of yarn into columns of vertically intermeshed loops. The term 'knitting' dates from the mid-sixteenth century, indicating that knitting probably evolved from sources such as the experience gained by knotting and Coptic knitting (Spencer, 2001).

Modern knitted fabrics range from very thin veil like structure to immensely strong rigid multi-layer multi-axial structures. This include every conceivable combination of properties in between these two extremes. In the daily life the using area of knitted fabrics is quite important. They are used not only as garments but also automotive interior and many other technical areas (K.Au, 2011).

Plain, rib, interlock and purl are the four basic wefts knitted structures from which all other weft-knitted structures can be derived." The physical and mechanical properties of these basic structures are different. Due to the structural difference, knitted fabrics are used in different applications (Hafsa Jamshaid, 2015). Different stitches and stitch combinations affect the properties of knitted fabric. The physical property of knitted fabric depend on loop structure, stich density, types of yarn ring, rotor, compact, type of raw material fiber, composition of yarn, twist level etc (Hafsa Jamshaid, 2015). Both the physical and mechanical properties of knitted fabrics are influenced by the structural parameters of the fabrics and relaxation/finishing process. Mainly stitch length and knit structure are the major factors that affect all the dimensional, comfort, handle and other properties. Single jersey plain knitted fabric is one of the popular knitted structures. It is the simplest and most economical weft knitted structure to produce (Hafsa Jamshaid, 2015).

A great many derivatives of single jersey construction can be developed by combining the three structural elements judiciously. The patterns of knit fabrics are designed by loops, tuck stitches, and float stitches and their combinations. Float stitch fabrics are narrower than equivalent knit fabrics because the wales are drawn closer together by the floats, thus reducing widthwise elasticity and improving fabric stability. Strength and comfort are very important criteria for any material especially for fabric. To increase the durability and dimensional stability strength plays a vital role.

A loop is a stitch exhibiting four binding or interlacement zones, two around the needle loop and two around the base. If however the two zones of interlacement around the base are done away with, then a new structural element, namely the tuck is formed. Furthermore, if all the four binding zones are removed then evidently a straight segment of yarn, namely the float would materialize. Thus, the three basic structural elements of a knitted fabric are loop, tuck and float (Delhi, 2012)

A tuck stitch is composed of a held loop, one or more tuck loops and knitted loops. Tuck loops reduce fabric length and length-wise elasticity because the higher yarn tension on the tuck loop causes then to rob yarn from adjacent knitted loops, making them smaller and providing greater stability and shape retention (D. J. Spencer ,2001).

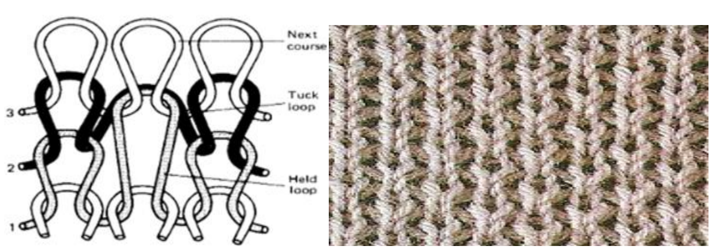


Figure 1 Tuck stitch

(Source: Spencer, D. J., 2001.knitting technology).

A miss stitch or float stich is composed of a held loop, one of more float loops and knitted loops. Miss stitch (float stitch) fabrics are narrower than equivalent all knit fabric because the wales are drawn closer together by the floats, and reducing width wise elasticity and improving fabric stability. (D. J. Spencer, 2001).

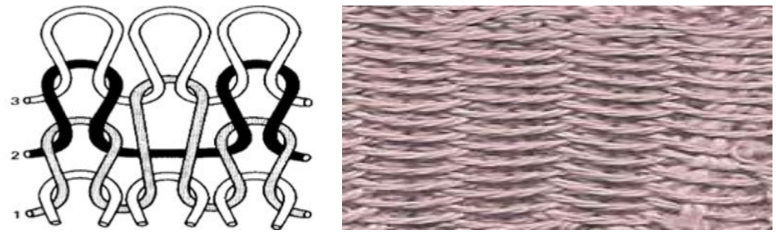


Figure 2 Miss Stitch

(Source: Spencer, D. J., 2001.-knitting technology).

1.2 Problem statement

In knitting industries, many derivatives of single jersey construction can be developed by knit, tuck, float stitches and their combinations for different reasons mainly for design purpose, to give stability and to improve some physical properties of knit fabrics. However, some factories technologists do not know the effect of tuck and miss stitches on dimensional and comfort properties of single jersey knitted fabric rather than improving its stability. This is due to the products are served for local markets and in local markets the orders are not coming with brief specifications rather the factory technologists producing their designs. However, the presence of different stitch combinations (knit, tuck and miss stitches) in a given knitted fabric structures will have their own effect on dimensional and comfort properties.

This study is focused on the effect of different stitch combinations mainly tuck and miss stitches incorporate with knit stitches on dimensional and comfort properties of some single jersey derivative fabrics.

1.3 Objectives

1.3.1 General objective:

- To study the effect of different stitch combination on dimensional and comfort properties of single jersey knitted fabrics.

1.3.2 Specific objectives:

- To identify the stitch type that significantly influences the dimensional properties of knitted fabrics
- To identify the stitch type that significantly influences the comfort properties of knitted fabrics
- To study the effect of tuck stitch on dimensional and comfort properties knitted fabrics
- To study the effect of float stitch on dimensional and comfort properties of knitted fabrics

1.4 Benefits and beneficiaries of the thesis

1.4.1 Benefits

- The benefits of this thesis work is satisfying the rapidly increasing demand of customers

1.4.2 Beneficiaries

- Any organization who are using knitted fabrics for apparel as well as technical applications.
- Industries that produce knitted fabrics of different designs
- Any customer who need knitted fabric with better aesthetic and functional performances
- Researchers and students in the future use the document as a reference

1.5 Scope of the study

For this thesis work, investigation was carried out on three different structures made from tuck stitch, miss stitch with knit stitches in equal proportion and fully knit stitch for comparison. The structures were produced using 30Ne 100% cotton yarn, on 24-gauge circular weft knitting machine. Fabric properties were tested at grey stage and only dimensional and comfort properties were tested due to time and money constraints.

In future researchers may extend the research work on different loop length and yarn count, raw material, machine gauge on different derivative structures at grey stage and finished stage.

CHAPTER TWO

LITERATURE REVIEW

2.1 Fabric properties affected by knit structures

In addition to knit structure, there are different factors, which affect the physical properties of weft knitted fabrics. Some of them are; yarn variables: such as; yarn strength, count, evenness, twist, finishing treatment etc. Machine variables: machine gauge, speed, needle timing, needle arrangement, knitting elements etc. Knitting variables: feeding type or input tension, fabric take down tension. State of a fabric: this is the state of knitted fabric in which it is obtained just after production from knitting machine. Dry relaxed state, fully relaxed state, and finished state (Ahmed Asif, Moshiur Rahman, Farial Islam Farha, 2015).

Akaydin in, 2016. Studied on the effect of tuck and miss loops on bursting strength weft knitted fabric. From his analysis, when the number of tuck loop increased bursting strength gradually decreased on (single pique, double pique, single lacoste, double lacoste) than all knit loop containing fabric (plain single jersey). It is also observed that fabric containing tuck loop has lower bursting strength than fabric containing miss loop (S.Uyanik, 2017) reported that; the effect of number of tuck stitch and its location on knitted fabrics properties. Their investigation showed that the number of tuck stitches and its position affect the bursting properties of knitted fabrics.

2.1.1 Dimensional properties

Previously most researches performed to find out the impact of different parameters on the knitted fabrics dimensional tests. But, limited numbers of research have been done to study the effect of loop shape on comfort, mechanical and dimensional properties of knitted fabrics.

To meet the demands of an increasingly discerning market, knitters have called for increased research in to the dimensional stability of knitted cotton goods. With the rising popularity of cotton, greater demands in terms of quality were required as the customer became more aware of the negative properties, e.g. shrinkage from laundering (S. C. Anand, K. S. M. Brown, L. G. Higgins, D. A. Holmes, M. E. Hall and D. Conrad., 2002). Yesmin, S. in 2014, studied the effect of stitch length on dimensional and mechanical properties of three different structures of knitted fabrics such as single jersey, single lactose and double pique. They found that when stitch length increased the dimensional stability of a fabric gradually deceases. Their investigation is only on the effect of stitch length.

According to Spencer, the properties of a knitted structure are largely determined by the interdependence of each stitch to its neighbors on either side and above and below it (D. J. Spencer 2001). The way that loops are intermeshed one another affects the knitted fabric dimensional properties.

Many researchers have reported the impact of different knit constructions on physical properties. They found that increasing the loop length and fiber diameter causes higher spirality. Previously many attempts were made to analyze the relationship between weft knitted fabrics dimensional properties and weight related properties which are influenced by the length of stitch in the fabrics.

According to Knapton's investigation, the magnitude of weft knitted fabric dimensional stability, not only depends on a combination of fibre characteristics, yarn factors, stitch length, knitting tension, washing and drying methods but also the fabric structure. The dimensional properties of plain, rib, half cardigan, interlock weft knitted structures made with wool were extensively investigated by Knapton. He studied on basic weft knitted structures and he found that each structure has different dimensional stability.

The dimensional changes of single jersey cotton weft knitted fabrics due to different yarn parameters and knitting parameters studied by (Kannan, 2014). Kannan studied the effect of yarn parameters like twist, yarn count on fabric properties and he found that yarn and knitting parameters affect the dimensional stability of fabrics.

The dimensional stability of knit fabrics is an important area of the knitting industry. Stitch length, yarn count, structure of fabric influence the dimensional stability of fabric. These various factors influence the dimensional stability as well as the bending length and drape co-efficient of the knitted fabrics investigated by (Islam, 2014).

a. Fabric width

Knit fabric structure and machine parameter has profound influence on the fabric width. The structure with tuck stitches is wider than the normal knit structures (Islam, 2014). According to Islam, Md. Azharul different, stitches have different physical and mechanical properties. He investigated the effect of fabric structure on the fabric width. He found that, the loop shape at the tuck stitch is distorted and has a wider base as the side wales are not pulled together.

Single Jersey fabric has high elasticity in width direction than the other fabrics which in turns change the dimension of the fabrics after fabric with washing. Ashif studied the effect of stitch length on the shrinkage properties of single jersey and double pique. Shrinkage of the fabrics fluctuates with changing the stitch length. Shrinkage percentages of double pique fabrics remain constant (Asif, 2013).

The spirality of fabric changed due to the change of stitch length and count variation (Rahman, 2015). It is clear that, the thickness of the single knitted fabric increases with the increase of tuck stitches percent in the structure and decreases with the increase of miss stitches percent in the structure. Fabric with tuck stitches is thicker than knit stitches due to accumulation of yarn in stitches at tucking places. Miss (float) stitch makes the fabric thinner than the tuck stitched one, as there is no yarn accumulation.

b. Shrinkage

Değirmenci and Çoruh, 2016. Studied performance and physical properties of single jersey, single lactose and double pique fabrics. They constructed single jersey fabrics only knit loops while single lactose and double pique fabrics are formed by both knit and tuck loops. Single jersey shows highest shrinkage in width direction on the contrary double pique fabric shows lowest shrinkage. Fabric shrinkage is a serious problem originating from dimensional changes in the fabric (Asif, 2013). The effect of knit structures on fabric shrinkage has not been investigated enough. They did not considering float stitch.

Both the physical and mechanical properties of knitted fabrics are influenced by the structural parameters of the fabrics and finishing process (Yesmin, 2014). He studied the effect of various factors such as; fiber characteristics, yarn parameters, machine parameters on dimensional characteristics of knitted fabrics.

c. Tightness factor

Tightness factor is the ratio of square root of yarn count in Tex by loop length in millimeter. Some literature says tightness factor is not only depends up on yarn count but also depends on knit structures (Mst. Sarmin Khatun Mohammad, Sohel Adnan, Bhuiyan Mahmuda Khatun, Afsana Munni, Mahfuza Pervin, 2016).

Those researchers together studied on the influence of knit structure (2x1 rib and 1x1rib) on tightness factor. According to their finding tightness factor of 2x1 rib is highest and 1x1 rib is lowest both for 30/2 Ne and 34/2 Ne. Like as stitch density, tightness factor also increase with yarn fineness, i.e. higher for 34/2 Ne yarn than 30/2 Ne yarn for all structures.

d. Curling behavior

One of the major problems knitted fabrics will curl on the edges when they are cut and laid free (Shohreh Minapoor, Saeed Ajeli and Hossein Hasani, 2015). That is due to the unbalanced loop structure and the yarn torque inside the fabric, which tends to recover the original shape of the yarn. Since the edges of a piece of fabric are free for movement, they are more likely to curl. The curling is one of the disadvantages of single knitted fabrics. It results in cutting, sewing, and linking problems (Shohreh Minapoor, Saeed Ajeli and Hossein Hasani, 2015). Since curling of the knitted goods can cause problems and waste production in sewing and finishing. Numerous studies have been undertaken to reduce this phenomenon in knitted fabrics. Doyle explained the curling behavior of plain knitted fabrics using a structural model of the knitted loop (Shohreh Minapoor, Saeed Ajeli and Hossein Hasani, 2015).They found that curling properties of knitted fabric highly dependent on knit structure and yarn twist.

Because of the dimensional instability of knitted loop construction, single jersey knitted fabrics suffers from various forms of dimensional distortion . Parmer reported that efforts are being made to make a knitted fabric more comfortable by changing the fibers, yarn parameters (twist, bulk, count and finish), knitting parameters (courses per inch, wales perinch, loop length and fabric weight) and post knitting finishes (enzyme and chemical).

The Single Jersey knitted fabric properties especially the dimensional and physical properties are mainly influenced by the constituent fibers, yarn properties, knitting machine variables, processing and finishing treatments (Sakthivel,2012). Sh. Minapoor, S. Ajeli, H. Hasani and M. Shanbeh studied on the effect of knit structure. Results showed that fabric structure and knit density have the most dominant effect on the fabric curling.

e. Thickness

Fabric thickness revealed that the effect of knit structure, relaxation processes and their interactions is highly significant, although knit structure has the greatest effect. (Nergiz Emirhanova, Yasemin Kavusturan, 2008).They studied on different types of fabrics (Milano, 2×2 Rib,2×2 cable, 1×1 Rib, 3×3 cable, half Milano, full cardigan, half cardigan, and single jersey fabrics ”links-links, lacoste, moss stitch, seed stitch, plain). According to their finding knit structure has greatest effect on fabric thickness.

Fabric with tuck stitches is thicker than knit stitches due to accumulation of yarn in stitches at tucking laces. Miss (float) stitch makes the fabric thinner than the tuck stitched one, as there is no yarn accumulation (El-Hady, 2016).The structure is done on rib and its knitted fabric derivatives not on single jersey fabrics.

f. Wales per inch, Course per inch

Emirhanova and Kavusturan, 2015 studied the effect of knit structures on Wales per inch, Course per inch and Gsm. Their finding showed that, Wales per inch, Course per inch, GSM of 2×2 Rib were higher than the 1×1 Rib and 2×1 Rib for both 30/2 Ne and 34/2 Ne. In addition WPI, CPI i.e. stitch density of 34/2 Ne is higher than 30/2 Ne but GSM of 34/2 Ne is lower than 30/2 Ne for different fabric structures.

g. Spirality

It is a major problem of knit fabrics, which is produced in circular knitting machines. Relaxation of torsional stresses cause dimensional distortions and instability in the knitted loop constructions. Ahmed Asif, Moshiur Rahman, Farial Islam Farha, 2015. Have analyzed the effect of machine gauge, yarn and fabric properties on the spirality of single jersey knit fabrics. There have been few researches regarding the effect of knit structures on the spirality of the fabric.

Ahmed Asif, Moshiur Rahman, Farial Islam Farha, 2015. Studied on the spirality percentage of various knitted construction. From their result, it is seen that with the increase of tuck loop in the knitted construction spirality decreases. Since the increase of tuck loop increases the density of the fabric, as a result the stability of the fabric increases (Ahmed Asif, Moshiur Rahman, Farial Islam Farha, 2015). Therefore, it is difficult for any force applied on high dense fabric to make it distorted. So double lacoste shows less spirality than single lacoste and single lacoste shows less spirality than plain jersey. Their investigation is only on tuck stitch structures.

h. Effect on Fabric Weight (Areal Density)

Knitted structures have pivotal influence on fabric areal density even if the processing parameters remain same. According to Asif, Rahman and Farha2015.

investigation with the increase of tuck loop in the fabric structure areal density is decreased in both grey and finished state.

2.1.2 Comfort

The demands from fabrics have changed with developments in textile technology and the rise of people's living standards. Now the requirement is not only style and durability, but also clothing comfort. Comfort, which is defined as a pleasant state of psychological and physical harmony between a human being and environment (Nilgün Özdil, 2006).The functional properties of knitted fabrics are related to low stress mechanical properties, such as bending, shear, and tensile. An increase in bending and shear parameters such as bending and shear rigidity, hysteresis of bending, and shear, result in a decrease in the drape structure of the fabric (R. Varadaraju, 2015). Clothing comfort includes three main considerations: psychological, sensorial and thermo physiological comfort (Oğlakcioğlu and Arzu, 2007). Knitted fabrics are preferred as clothing materials because of their outstanding comfort quality (R. Varadaraju, 2015)

Clothing comfort is closely related to thermal comfort. Various researchers Shoshani and Shaltiel noted that the thermal insulation increases while the density of fabric decreases. Oğlakcioğlu and Arzu studied the thermal conductivity of 1×1 rib and interlock structures of the cotton and polyester fabric samples. They explained by the amount of entrapped air in the fabric structure. The amount of fibre in the unit area increases and the amount of air layer decreases as the weight increases.

Nilgün Özdil, Arzu Marmaral, Serap Dönmez, 2007. Studied on the effect of yarn count on thermal resistances of the fabrics knitted with 20Ne, 30Ne and 40Ne yarns. The result shows that yarn count has significant effect on thermal resistant i.e. as the yarn gets finer the thermal resistance and thermal conductivity decrease. However, fabric tightness does not have an important effect on thermal resistance and thermal conductivity.

a. Air permeability

Air permeability, being a biophysical feature of textiles, determines the ability of air to flow through the fabric. Air permeability is often used in evaluating and comparing the “breathability” of various fabrics for end uses such as T- shirts, jackets, under wear and some outerwear garments, raincoats, tents, uniform shirting’s etc.

Airflow through textiles is mainly affected by the pore characteristics of the fabrics. The pore dimension and the distribution in a fabric is a function of fabric geometry (Züleyha Değirmenci & Ebru Çoruh ,2017). Construction parameters, such as fineness of yarns, density and the type of knitted structure affect the air permeability of a fabric. The distribution of air space influences a number of important fabric properties. The air permeability and the porosity of a knitted structure will influence its physical properties, such as the bulk density, moisture absorbency, mass transfer and thermal conductivity (Züleyha Değirmenci & Ebru Çoruh, 2017).

El-Hady and El-Baky in 2016, studied on the influence of pile weft knitted structures (fleece and plush) with different thickness and density on the functional properties of winter outerwear fabrics. There is a significant influence of the fabric structure on air permeability values (cm3/cm2/s). With higher fabric density and thickness both fleece and plush fabrics, have lower air permeability values. When the density and thickness of structures varied the permeability also varied.

All plush fabrics have higher thermal conductivity than fleece fabrics; this behavior is in a great extent influenced by the yarn characteristics, but also by the fabric structure (R.A.M. Abd El-Hady, R.A.A. Abd El-Baky, 2015). Thermal conductivity is depending on not only thickness and density but also fiber conductivity (100% polyester for plush structures while 80% polyester and 20% cotton for fleece structures). Yarn characteristics also play a significant role on thermal absorptivity. Moreover, the results showed that the surface characteristics of the fabric also have a great influence on the warm feeling.

Knitting technology has advanced considerably during the past two decades with the introduction of various knitted structures, use of new and modified yarns and design of versatile knitting equipment's. Knit fabrics provide outstanding comfort qualities and have long been preferred as fabrics in many kinds of clothing. Since knit fabrics are produced on different machines with different knit stitches and conditions to create different patterns and fabric types, we expect them to have different qualities.

Air permeability is an important factor in comfort of a fabric as it plays a role in transporting moisture vapor from the skin to the outside atmosphere. The assumption is that vapor travels mainly through fabric spaces by diffusion in air from one side of the fabric to the other.

The porosity of a knitted structure will influence its physical properties such as the bulk density, the moisture absorbency, the mass transfer and the thermal conductivity.

Airflow through textiles is mainly affected by the pore characteristics of the fabrics. It is quite clear that pore dimension and distribution is a function of the fabric geometry. The yarn diameter, surface formation techniques, number of loop count for knitted fabrics per unit area are the main factors affecting the porosity of textiles. The porosity of a fabric is connected with certain important features of it, such as air permeability, water permeability, dyeing properties etc.

Establishing a more complex theory to express air permeability related to all fabric parameters will have difficulties. To simplify the matter, certain important parameters such as the pore of the fabric were taken into account in the calculation of air permeability. Three factors are mainly considered that are related to the pores in fabrics. Cross-sectional area of each pore, depth of each pore or the thickness of the fabric and, the number of pores per unit area or the number of courses and wales per unit area. (Serin Mezarciöz* and R Tuğrul Oğulata, 2015).

Porosity

Heat and liquid sweat generation during athletic activities must be transported out and dissipated to the atmosphere. A key property influencing such behaviors is porosity. The yarn diameter, knitting structure, course and wale density, yarn linear density, pore size and pore volume are the main factors affecting the porosity of knitted fabrics (S.S.Bhattacharya and J.R.Ajmeri, 2013). It was determined that the loop length of a knitted jersey has more influence on porosity than the stitch density and the thickness.

b. Bending property

Nergiz Emirhanova, Yasemin Kavusturan, 2008. Studied on the effect of knit structure on bending rigidity. According to their finding wale wise and course wise bending rigidity revealed that the effect of knit structure is highly significant in washed fabrics. Milano is the most rigid fabric in wale way bending. Single jersey structures have lower wale way bending rigidity. Terry is the most rigid fabric in course way bending.

c. Stiffness property

It is clear that the yarn count is related with its diameter, and the diameter has a high impact on the flexural and torsional stiffness of the yarn (Shohreh Minapoor, Saeed Ajeli and Hossein Hasani, 2015). They studied about flexural and torsional rigidity by increasing the diameter of the yarn, its flexural and torsional rigidity increases and the force needs to curl the loops increases.

On the other hand, increasing the diameter of the yarn increases the contact surface between yarns in the fabric structures and will increase the friction and decrease the curling distance. According to their experimental results, yarn diameter increase lead to curling distance decrease. Minapoor, Ajeli and Hasani, 2015. Reported that; when the yarn diameter increases, the force required bending the loop and as a result, the stress in loop increases. However, they focus only on yarn diameter. They are not considering the effect of knit structures on stiffness property.

d. Drape property

Drape is defined as ‘the extent to which a fabric will deform when it is allowed to hang under its own weight’ some parameters, such as thickness, shear, mass per unit area and surface properties, significantly affect the drape behaviour (Araguacy Filgueiras, Raul Fangueiro& Filipe Soutinho, 2009).

It is also a secondary determinant of fabric mechanical properties and influenced by the low stress mechanical properties, like bending rigidity, formability, tensile & shears properties, and compressibility of the fabric (Pant, 2010).

The way in which a fabric drapes or hangs depends largely on its stiffness, i.e. its resistance to bending and its own weight. Fabric bending behaviour has been the focus of many investigations. A fabric’s bending characteristics contribute to differences in the way it conforms to the body.

The drape coefficient (F) is the most fundamental parameter for quantifying drape and the most widely used for textile materials. It is observed over a decade that the consumers prefer to wear light weight fabrics. At the same time, fabric comfort has gained priority over fabric durability.

Fabric drape is one of the most important properties of flexible material. It is also one of many factors that influence the aesthetic appearance of a fabric and has an outstanding effect on the formal beauty of the cloth. Drape is important for the selection and development of textile material for apparel industries. Chu et al. first did studies of drape, in 2008. When they established a measuring method for fabric drape using FRL drapemeter. They quantified the drapability of a fabric into a dimensionless value called "drape coefficient", which is defined as the percentage of the area from an angular ring of the fabric covered by a vertical projection of the draped fabric (Pattanayak, Author B K Behera & Ajit Kumar, 2008).

Filgueiras, Fangueiro and Soutinho, 2009. Studied on the influence of amount of functional fibres on the drape and flexibility behaviour of functional weft-knitted fabrics for sport clothing purposes. They studied the drape and flexibility of single jersey knitted fabrics made from different fibers (polyester, cotton acrylic, polyamide and viscose).

The amount of polyester bioactive fibres in the knitted fabrics also affects their drape behaviour and a direct relationship may be established; the increase in Bioactive fibres amount leads to a decrease in flexural rigidity in both the directions (Araguacy Filgueiras, Raul Fangueiro& Filipe Soutinho, 2009). From their finding the drape ability, flexibility or flexural rigidity significantly influenced by fiber stiffness. They are focused on fiber not on structure of fabrics.

Twist of yarn plays vital role in the hosiery yarn. The end applications of the knitted fabric are mainly depend upon the twist multiplier of Yarn (Kulkarni, 2015) (Kulkarni, 2015). He studied on the effect of twist multiplier in different loop length using ring and compact yarn on drape property of knitted fabric. Results show that twist multiplier value has significant effect on properties of knitted fabrics in the case of cotton ring and Cotton compact yarns not only this but also amount of fiber in case of blend yarn and loop length have their own effect on drape property. ‘’In the case of Polyester cotton twist multiplier of 3.94 Ring and compact yarn the twist multiplier 3.94 affected but 3.32 and 3.66 not affected because of content of polyester.’’ Variations in the twist multiplier and loop length after subjected to washing fabrics samples are softer. Therefore, washing and fabric construction has their own effect on drape property of knitted fabrics.

In general, many researches have been done on the effect of knitting parameters on some physical properties as it is mentioned above. Most of the researchers studied on the effect of yarn parameters mainly yarn count, types of raw material and yarn twist on mechanical and dimensional properties of knitted fabric. Few researches also done on the effect of knitting parameters mainly machine gauge, stitch density feeding and take down tension on fabric dimensional and comfort properties like shrinkage, spirality, bursting, pilling, air permeability etc.

Most of the research done on the effect of each stitches and structures on physical properties of a fabric. But, very few research have been done to observe the combine effect of stitch type on comfort and dimensional properties of knitted fabrics. This work focused on the combined effect of three different types of stitches (knit stitch, tuck with knit stitch and knit with miss stitch in equal proportion) on dimensional and comfort properties of single jersey knitted fabrics.

CHAPTER THREE

MATERIALS AND METHODS

This study examined the effects of different stich designs on dimensional and comfort properties of single jersey weft knitted fabric. Investigations were carried out on three different structures made from tuck stitch, miss stitch and knit stitches.

3.1 Materials

3.1.1 Knitting machine

Circular weft knitting machine equipped with different types of cams (knit, tuck and miss cams) was used. The machine parameters are shown in table 1.

Table 1 Machine Parameters

Machine speed (rpm)	Machine diameter	Feeding system	Truck level	Number of feeders	Needle type	Machine gauge
26	30”	Positive	Four	72	Latch	24

3.1.2 Yarn

All structures were produced from single type of yarn with parameters as shown in table 2.

Table 2 Yarn parameters

Yarn type	Tenacity (cN/tex)	Linear density(Ne)	Tpm	Uniformity (%)	Fiber type	Elongatio n (%)	Hairiness
Carded	9.02	30	960	26	100% cotton	5.6	5.46

3.2 Methodology

3.2.1 Sample production

Three different single jersey derivative structures made from tuck stitch, knit stitch and miss stitches in corporate with knit stitch were produced using 30Ne cotton yarn.

Except loop shape (knit stitch, tuck stitch and float loop), all other knitting and yarn variables like; loop length, yarn count, yarn twist, machine gauge, etc. remain same. All structures were single face structures. Since all other parameters were constant the only variable is loop shape i.e. tuck, knit and miss or float loop.

Table 3 Stitch designs produced

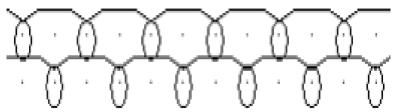
Number	Name of stitches	Stitch type
1.	Cross miss	Knit with miss
2.	Single pique	Knit with tuck
3.	Single jersey	Fully knit

In order to produce the above structures as it was mentioned above circular weft knitting machine equipped with knit cam, tuck cam and miss cam was used. Each structure needs different cam and needle arrangements. The repeat design, cam and needle arrangement of each structure has given below.

a. Cross miss structure

Cross miss, structure was produced by using two types of cams i.e. knit and miss cams equipped on circular knitting machine and latch needles with different butt positions. The repeat design, cam and needle arrangement of cross miss structure are shown next page.

i. Design repeat



ii. Feeders

Feed 1	Feed 2	Feed 3	Feed 4
Knit	Miss	Knit	Miss
Miss	Knit	Miss	Knit

iii. Cam order (two truck level)

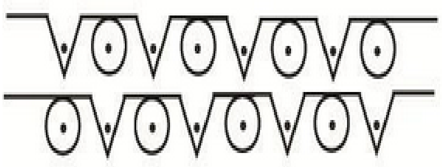
iv. Needle arrangement

Figure 3 Cam and needle arrangement of cross miss structure

b. Single pique structure

Single pique structure was produced by using two types of cams i.e. knit and tuck cams equipped on circular knitting machine and latch needles with different butt positions. The repeat design, cam and needle arrangement of single pique structure are shown next page.

i. Design repeat



ii. Feeders

Feed 1	Feed 2	Feed 3	Feed 4
Knit	Tuck	Knit	Tuck
Tuck	Knit	Tuck	Knit

iii. Cam order (two truck level)

iv. Needle arrangement

Figure 4 Cam and needle arrangement of single pique structure

c. Single jersey structure

For single jersey, structure was produced using knit cam with same butt position of needles.

Knit cam

Tuck cam

Miss cam

Figure 5 Different types of cams used to produce knit, tuck and miss stitches

3.2.2 Testing of dimensional and comfort properties of fabrics

After knitting, the various dimensional and comfort properties of knitted fabric samples were tested in accordance with the relevant standards. Fabrics used for this study were selected due to common commercial use in textile industry and they are common in clothing fabrics and commercially available. For example, single jersey, single pique and cross miss structures are used for outerwear, active wear, underwear etc.

On the machine, all structures have same wales and course per centimeters, because all structures are produced on same machines. Therefore, number of needles is equal to number of wales, since all structures were produced from same gauge of machine. In addition to these, all structures have same tightness factor because the loop length of all structure has no significant difference. However, out of the machine due to difference in loop structure each structure had different values. For example due to float yarn cross miss structure shown higher number of wales per centimeter.

Stitch Length

It is the length of yarn in mm for one loop. The loop value was measured by taking 70 Wales. Seventy wales are marked on the fabric surface and then the yarn for that particular place is unraveled, straightened and measured in millimeter by substituting the measured values in the formula, the loop length was measured. Results are shown in table 4.

$$\text{Loop Length (mm)} \ \frac{\text{Length of yarn}}{\text{Number of loops}} \ldots\ldots\ldots\ldots \ \text{equation}(1)$$

a. **Comfort property tests**

Air permeability

Air permeability was measured according to the ES ISO 9237 using Tester FX3300. Measurements of the fabric were carried out on seven samples for each structure and the average value expressed as $cm^3/cm^2/s$. Pre-conditioning of all fabrics were carried out in a conditioning chamber at 65 % relative humidity and 20°C for 24 hours. Results are shown in table 4.

Drape

The most widely accepted method of drape test, according to ISO 9073-9 uses is the drapemeter.

All the samples are conditioned in chamber at 65% relative humidity and 20°C temperature for 24 hours before measuring to relieve localized stresses caused by handling during preparation. There are three diameters of specimen (24cm for limp fabric, 30cm for medium fabric and 36cm for stiff fabric) that can be used. For this, work 30cm diameter specimen used.

To measure the areas involved, the whole paper ring was weighed and then the shadow part of the ring is cut away and weighed. The stiffer a fabric is, the larger is the area of its shadow compared with the unsupported area of the fabric. The paper is assumed to have constant mass per unit area so that the measured mass is proportional to area.

The drape coefficient can then be calculated using the following formula.

$$\text{Drape coefficent} = \frac{\text{mass of shaded area}}{\text{total mass of paper ring}} \text{ x } 100\ \% \text{ .... equation } (2)$$

The higher the drape coefficient the stiffer is the fabric. Seven specimens were used and the results are shown in table 4.

Fabric weight (GSM); this test was measured according to ISO3801.

Using Mettler make measuring balance ;It was measured by using a cutting device (round, area 100 cm^2); the fabric was cut and weighted in a weighting balance. Grams per square meter (GSM) of the fabric are measured. Seven samples are used for each structure and the results are shown in table 4.

Fabric thickness measurement.

A Digital thickness gauge (MESDAN, model: D-2000) was used to measure the thickness of the fabric samples in accordance to ASTM D1777-96. 100 KPa was used for the testing. Seven tests are performed for each fabric type, and results are shown in table 4.

Measurement of shear rigidity

The shear properties are measured on Kawabata KESFB-AUTO A-1 Shear Tester. Sample width 20 cm: Shearing angle 8.0 deg: Shearing weight 200 g. Average results are shown in table 8.

Measurement of bending rigidity

Bending rigidity of fabric samples was measured on the Kawabata (KESFB-AUTO A-2) pure bending tester. This measures the bending rigidity of the fabric in wale and course directions separately and then the average value is taken for analysis.

Sample size taken was 20cm x 5cm (wale wise and course wise separately) and maximum curvature was 2.5 per centimeter. Average results are shown in table 9.

Measurement of compressional properties

Compressional properties are measured on Kawabata Compression Tester (KESFB-AUTO A-3). The instrument gives linearity of compression, compressional energy and compressional resilience. The test parameters are velocity 50 sec/mm, processing rate standard, sample width 20 cm, and maximum load 50 gf/cm2. Average results are shown in table 11.

b. Dimensional property tests

There are different factors, which affect the dimensional property of knitted fabrics such as fiber type, finishing route, yarn linear density, fabric structure, twist level, etc. However, for this study only fabric structures (loop shape i.e. tuck knit and miss stitches) are considered.

The dimensional stability (shrinkage) test was measured according to ISO 6330. The test used a washing machine to wet out (swell) the fiber/fabric under tensionless conditions. For each three structures, six samples were prepared 65mm x 65mm and allowed for washing for one hour at 60 degree centigrade using standard detergent (soap 5g/l). Finally, the samples are dried using mini drying machine and the values are noted in table 12. Shrinkage percentage calculated using the following formula.

$$\text{Shrinkage \%} = \frac{(\text{length of fabric before wash}) - (\text{length of fabric after wash}) * 100}{(\text{length of fabric before wash})}$$

$$\ldots.\ \text{Equation (3)}$$

Extensibility (stretch and recovery) test

For this particular test, six samples were measured. This test was measured according to ASTMD2594Extensometer. Specimens ‘were prepared using a template size of 75mm x 85mm. After cutting samples were exposed for standard atmosphere for 24 hours. After transferring the specimen to the clamp of the tester, by adding 3 Kg load recommended for knitted fabric, the specimens were allowed to stretch and recover finally the results are measured and calculated.

CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Effect of different stitches on comfort and dimensional property

4.1.1 Effect of knit, tuck and miss stitches on comfort properties

Comfort is one of the most important properties in apparel products, therefore companies tend to focus on the comfort aspect nowadays. Since it is subjective, feeling it varies from person to person. There are various factors, which affect comfort properties of a given knitted fabrics. For this work, only the effect of different stitches knitted from 30Ne cotton yarns are discussed below. Except loop shape (knit, tuck and miss stitches) all are same (single face) structures or derivative of single face structures and all yarn and knitting parameters remained the same.

Table 4 Effect of knit, tuck and miss stitch on some comfort property

Structure	Sample code	Thickness in mm	Weight (g/m^2)	Loop length (mm)	Air permeability (cm^3/cm ^{2}/s)	Drape coefficient
Single jersey (30 Ne)	JD1	0.188	163	3.10	87.5	41.7
	JD2	0.189	163	2.99	88.7	40.2
	JD3	0.187	164	3.06	89.4	42.5
	JD4	0.188	163	3.09	88.6	41.8
	JD5	0.189	162	3.10	90.8	41.2
	JD6	0.187	163	3.08	88.1	41.8
	JD7	0.188	163	3.00	88.9	40.6
Average value		**0.188**	**163**	**3.06**	**88.8**	**41.04**
Single pique (30 Ne)	PD1	0.230	181	3.10	122	46.4
	PD2	0.226	180	3.08	121.5	46.5
	PD3	0.229	179	3.11	122	47.3
	PD4	0.228	181	3.09	120.8	45.9
	PD5	0.226	181	3.09	123	47.2
	PD6	0.230	180	3.10	121.7	46.5

	PD7	0.226	181	2.99	122	47.8
Average value		**0.227**	**180**	**3.08**	**122**	**46.8**
Cross miss (30 Ne)	CD1	0.248	170	3.08.	116	48.6
	CD2	0.259	170	2.98	117	49.6
	CD3	0.266	171	3.03	115.5	49
	CD4	0.274	170	3.10	116	50.4
	CD5	0.279	172	2.90	117	49.2
	CD6	0.251	170	3.00	116.5	50.3
	CD7	0.307	172	2.97	116	50.7
Average value		**0.269**	**170.7**	**3.01**	**116.3**	**49.12**

Table 5 One-way ANOVA test result analysis of different stitch designs

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Air permeability incm3/cm2/s	Between Groups	4394.667	2	2197.333	81.536	.000
	Within Groups	485.086	18	26.949		
	Total	4879.752	20			
Fabric thickness in mm	Between Groups	.023	2	.011	38.759	.000
	Within Groups	.005	18	.000		
	Total	.028	20			
Gram per square metre	Between Groups	1049.810	2	524.905	122.933	.000
	Within Groups	76.857	18	4.270		
	Total	1126.667	20			
Drape coefficient in %	Between Groups	211.407	2	105.703	25.729	.000
	Within Groups	73.951	18	4.108		
	Total	285.358	20			
Loop length	Between Groups	.019	2	.010	3.349	.058
	Within Groups	.051	18	.003		
	Total	.070	20			

The above table shown that the values of the different properties are significantly different. Except loop length all three stitches have significantly different values, therefore, multiple comparisons are done.

Table 6 Multiple comparisons of test results

LSD

Dependent Variable	(I) id no	(J) id no	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Air permeability incm3/cm2/s	1.0000	2.0000	-33.142857*	2.774847	.000	-38.97259	-27.31312
		3.0000	-27.428571*	2.774847	.000	-33.25831	-21.59884
	2.0000	1.0000	33.142857*	2.774847	.000	27.31312	38.97259
		3.0000	5.714286	2.774847	.054	-.11545	11.54402
	3.0000	1.0000	27.428571*	2.774847	.000	21.59884	33.25831
		2.0000	-5.714286	2.774847	.054	-11.54402	.11545
Fabric thickness in mm	1.0000	2.0000	-.0385714*	.0091869	.001	-.057872	-.019270
		3.0000	-.0808571*	.0091869	.000	-.100158	-.061556
	2.0000	1.0000	.0385714*	.0091869	.001	.019270	.057872
		3.0000	-.0422857*	.0091869	.000	-.061587	-.022985
	3.0000	1.0000	.0808571*	.0091869	.000	.061556	.100158
		2.0000	.0422857*	.0091869	.000	.022985	.061587
Gram per square metre	1.0000	2.0000	-17.2857143*	1.1045156	.000	-19.606215	-14.965213
		3.0000	-7.7142857*	1.1045156	.000	-10.034787	-5.393785
	2.0000	1.0000	17.2857143*	1.1045156	.000	14.965213	19.606215
		3.0000	9.5714286*	1.1045156	.000	7.250927	11.891930
	3.0000	1.0000	7.7142857*	1.1045156	.000	5.393785	10.034787
		2.0000	-9.5714286*	1.1045156	.000	-11.891930	-7.250927
Drape coefficient in %	1.0000	2.0000	-5.2571429*	1.0834354	.000	-7.533356	-2.980930
		3.0000	-7.5857143*	1.0834354	.000	-9.861928	-5.309501
	2.0000	1.0000	5.2571429*	1.0834354	.000	2.980930	7.533356
		3.0000	-2.3285714*	1.0834354	.045	-4.604785	-.052358
	3.0000	1.0000	7.5857143*	1.0834354	.000	5.309501	9.861928
		2.0000	2.3285714*	1.0834354	.045	.052358	4.604785

*. The mean difference is significant at the 0.05 level. 1. Single jersey 2. Single pique 3.Cross miss

4.1.1.2 Effect of knit, tuck and miss stitches on air permeability

Air permeability is an important factor in comfort of a fabric as it plays a role in transporting moisture vapours from the skin to the outside atmosphere. For this study the air permeability of single jersey, single pique and cross, miss structures (most commonly used for apparel products) are discussed below**.** The result shown that all the three structures have different air permeability value even though all other knitting and yarn parameters such as yarn count, loop length, machine gauge, etc. remained the same.

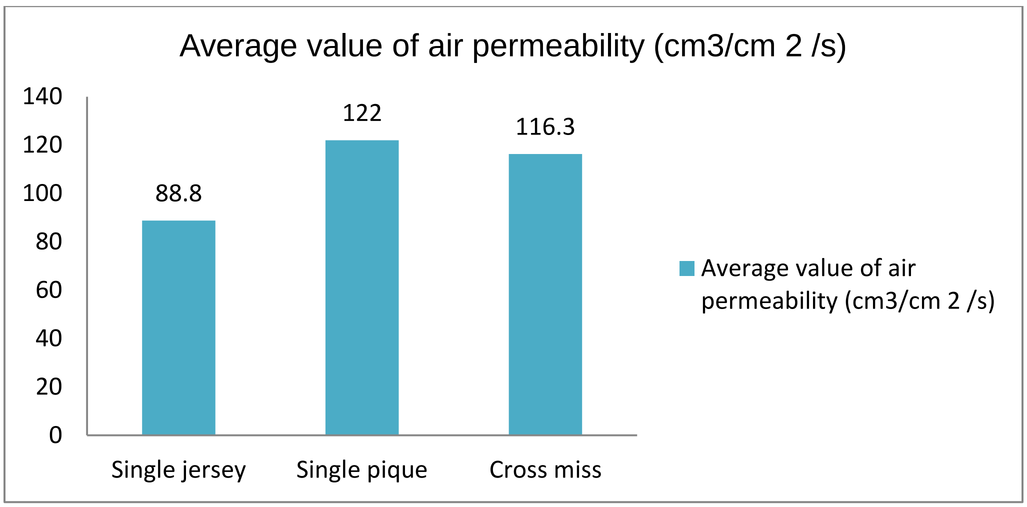


Figure 6 Air permeability value of different stitch designs

The range of values obtained from these three different types of structures are significant (from table 5), ranging from 88.8cm3/cm2/s for single jersey 122cm 3/cm2/s 116.3cm3/cm2/s single pique and cross miss respectively. The air permeability values obtained from single pique knit fabric is significantly higher than single jersey structures. This is due to that, the presence of tuck stitch. When amount of tuck stitch in a given fabric increases, the fabric becomes open and more porous.

As the same manner cross miss structures highly permeable than single jersey fabrics this is due to the presence of held loop, which makes the fabric open than normal knitted loop structures also more permeable than single jersey due to the presence of held loop which makes the loop tighten and porous . However, the air permeability value of single pique structure is not significantly higher than cross miss structures. This is due to that, like single pique, cross miss structure has held loop, which makes the fabric open and permeable.

4.1.1.3 Effect of knit, tuck and miss stitches on fabric thickness

As seen in figure 7 thickness of cross miss fabric is significantly higher than single pique and single jersey fabric structures. This is due to the presence of the float stitch having missed (float) yarn floating freely on the reverse side of the held loop, which increases the fabric thickness by providing additional yarn, which is not intermeshed through the old loop. This is the reason cross miss structure is thicker than single pique and single jersey structures. Single pique also thicker than single jersey due to tucked yarn over the held loop, which increases fabric thickness than normal knitted loop.

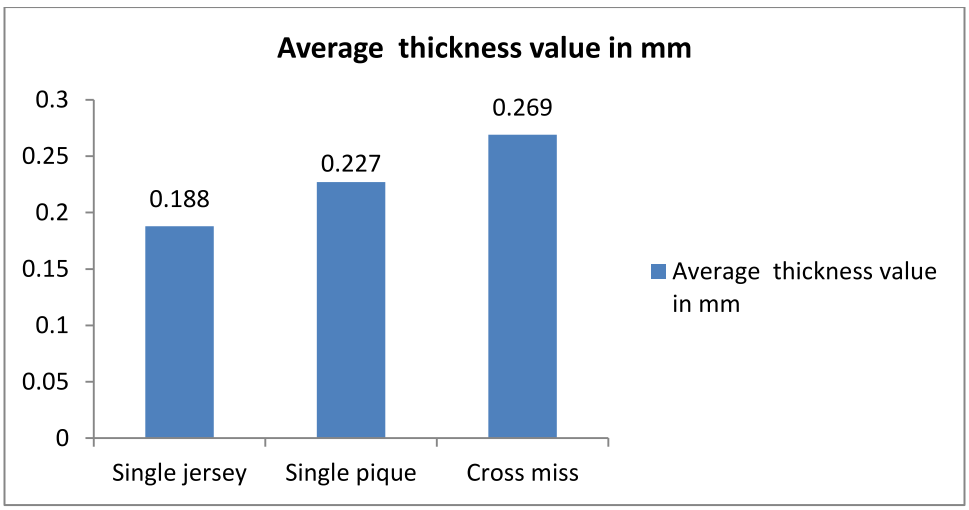


Figure 7 Thickness values of different stitch designs

4.1.1.4 Effect of knit, tuck and miss stitches and thickness on air permeability

It is known that, fabric thickness has indirect correlation with air permeability i.e. when fabric thickness increase air permeably decreases and the reverse is true. However, this test result did not show this correlation. Sometimes thick fabric might be highly permeable than thin fabric. This is due to, the difference in stitch designs (the way of loop arrangement and loop shape).

Table 7 Relationship between fabric thickness and air permeability

Structure	Thickness in mm	Air permeability(cm3/cm 2 /s)
Single jersey	0.188	88.8
Single pique	0.227	122
Cross miss	0.269	116.3

From the result, cross miss structure is thicker than single jersey and single pique fabrics. This is the presence of float yarn, which is not knitted rather, float on the back of held loop and provide additional thickness. However cross miss structures is highly permeable than single jersey due to the presence of held loop, which makes the fabric open and porous than normal knitted loop. In general, we can conclude that on knitted fabric air permeability highly influenced by loop arrangement or loop shape and always might not have an indirect relation with fabric thickness.

4.1.1.5 Effect of knit, tuck and miss stitches on fabric weight (areal density)

Test results shown that knit, tuck and miss stitches have crucial influence on fabric areal density even if other processing parameters remain same.

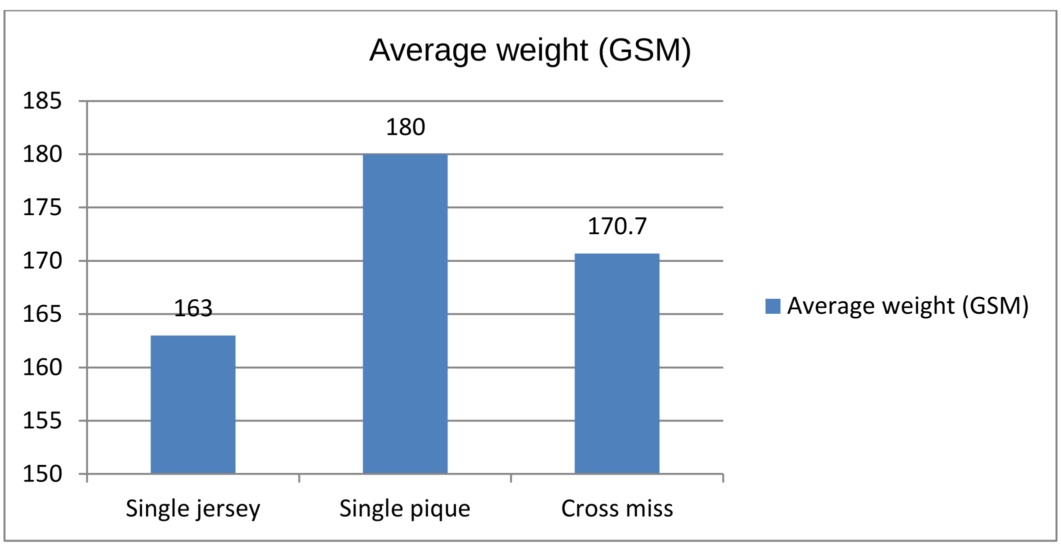


Figure 8 Effect of knit, tuck and miss stitches on fabric weight (areal density)

From figure 8 it can be observed that the weight of a fabric with tuck loops is significantly heavier than fabric having knit loops due to accumulation of yarn at the tucking place. Therefore, single pique has higher areal density than cross miss and single jersey structures. On the same manner due to the presences of float yarn wales are drawn closer together by the floats, and make the fabric narrower more stable than knit stitch. Therefore, cross miss structure has higher GSM value than single jersey structures.

4.1.1.6 Effect of knit, tuck and miss stitches on drapability

Drape is an essential parameter to decide both appearance and handle of fabrics. The following test result shown that the drape ability of a knitted fabric is significantly influenced by loop structure even other knitting parameters remain same.

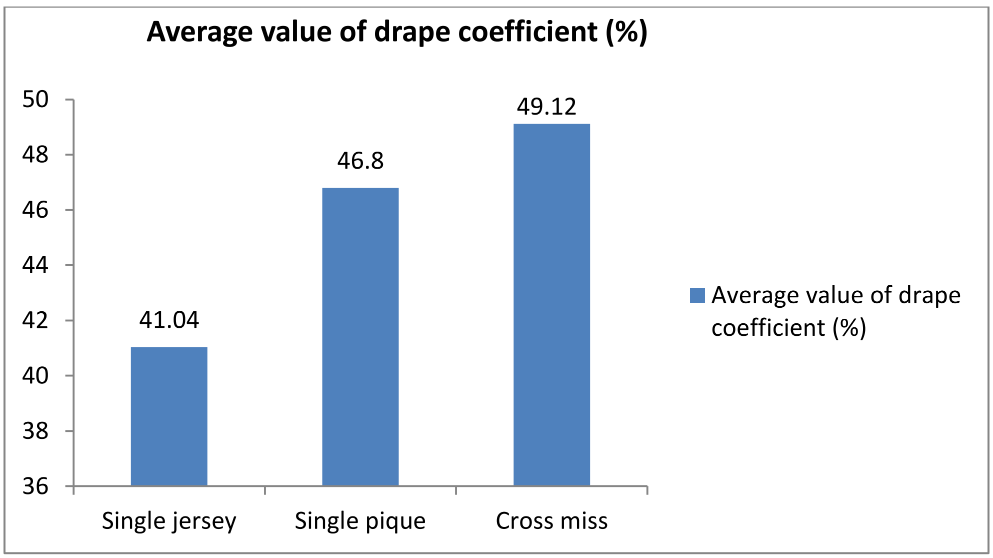


Figure 9 Drape coefficient value of different stitch designs

Figure 9 shown that cross miss structures has higher drape coefficient value than single jersey and single pique structures. This is due to the presence of floating yarn (float stitch) that connects adjacent wales close to each other. This provides greater fabric stability and less flexible than single jersey and single pique structures. The higher the drape coefficient the stiffer is the fabric. On the same manner, the drape coefficient value of single pique structure is significantly higher than single jersey. However, the drape coefficient value of cross miss structure is not significantly higher than single pique. On single pique, structure there is higher number of tuck loop, which makes the fabric stable. This is due to, the higher yarn tension on the tuck loop causes yarn robbing from adjacent knitted loops, making them smaller and providing greater stability than normal knit structures. Like float stitch, the presence of tuck stitch provides greater fabric stability on a given knitted fabric compared to knitted stitch. In general, all structures have good drape coefficient because their drape coefficient values found between (30- 85%).

4.1.1.7 Effect of knit, tuck and miss stitches and areal density on drapeability

Drape is the term used to describe the way a fabric hangs under its own weight but according to this study, fabric weight has lesser role on fabric drape ability. As it was mentioned above single pique, structure has higher areal density than single jersey and cross miss structure but lower drape coefficient value than cross miss structure. This is due to the difference in loop shape and its arrangement, which makes the fabric stable. The following figure shown that fabric drapeability and fabric weight.

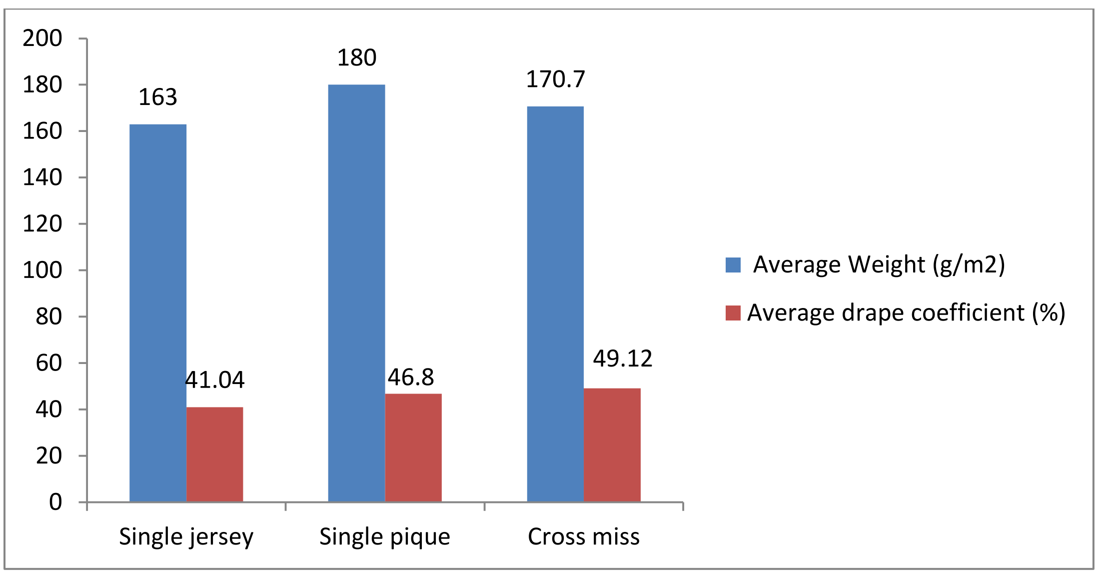


Figure 10 Effect of different stitches and areal density on drapeability

Therefore, drapeability or flexibility of a given knitted structure is not only depend on fabric weight rather the way of loop arrangement and loop shape also affect drape ability of knitted fabric.

4.1.1.8 Effect of different stitch designs (knit, tuck and miss stitches) on low stress mechanical properties.

Shear properties

Table 8 Average shear property values of different stitch designs.

Shear properties						
Structure	G, (gf/cm.deg)		2HG, (gf.cm/cm) at 0.5^0		$2HG5^0$, (gf.cm/cm)	
	Wale	Course	Wale	Course	Wale	Course
Jersey	0.28	0.27	0.925	0.82	1.28	1.08
Pique	0.39	0.34	1.02	0.89	1.13	1.193
Cross miss	0.26	0.30	0.890	0.905	1.04	1.04

Shear Rigidity (G)

Compared to single jersey and cross miss structures single pique fabric has high shear rigidity value in wale and course direction. This is due to the presence of tucked yarn over the knitted loop. This increases GSM value , the contact area of loops, increase in the number of fibers in the fabric cross-section, increase in the inter yarn and inter fiber frictional forces all these increase in shear rigidity (G) value of single pique. Relatively cross miss fabric has high shear rigidity value than single jersey fabric. This is due to floating yarns, which increase slipperiness at loop intersections and GSM of a fabric.

The shear rigidity (G) is higher in wale direction than in course direction. This is due to the loop arrangement (tucked yarns over the knitted loops and floating yarns). The increase in GSM reduces air gaps in the structure which increases the interyarn and inter fiber friction. This contributes for the increase in shear rigidity (G). Sometimes GSM might not affect porosity because; it depends on the types of fabric construction (types of loop and its arrangement).

Shear stress (2HG)

Shear stress (2HG) reflects the ability to recover after shearing at 0.5° shear angle. The result shown that, single pique fabric has high shear stress value in wale direction than single jersey and cross miss fabrics. This is due to the tuck loop, which reduces wale wise stretch ability of fabric. The greater value of the shear stress, the worse will be the recovery ability of the fabric. Some literature says, fabric have similar shear stress value, suggesting similar recovery ability after shearing deformation.

Except cross miss structures, the shear rigidity value in wale direction is larger than the shear rigidity value in course direction this is due to that, the course direction is easily extend /stretch/ than the wale direction. The shear stress of wale direction is smaller than shear stress of course**;** this indicates that the wale direction had better ability to withstand external stress. This is due to loop shape and its geometry, which is easily, extends in course direction than wale direction.

Bending

Table 9 Average bending property values of different stitch designs.

Structure	**Bending properties**			
	B, (gf.cm2/cm)		2HB, (gf.cm2/cm)	
	Wale	course	Wale	course
Jersey	0.02	0.0355	0.0185	0.0405
Pique	0.0559	0.0836	0.0568	0.065
Cross miss	0.0585	0.0544	0.606	0.0558

Bending Rigidity

From the above result, single jersey fabric has lower bending rigidity (B) and lower bending moment (2HB) value. This indicates single jersey fabric has better flexibility and elastic recovery value than cross miss and single pique structures. This is due to that, the shape of loop (normal loop), which can easily stretch and recover compared to fabrics having tuck loop, held loop and float loop.

Comparatively, cross miss, structure has higher bending rigidity value in wale direction than single pique and single jersey structures. This is due to floating yarns or float loop, which connect adjacent wales close together and make the fabric more stable. The increase in fabric GSM, and decrease in porosity gives an increase in bending rigidity.

Cross-miss and single pique fabric has higher bending rigidity value than single jersey due to, the way of loop arrangement and its shape. These increase the number of fibers in the fabric cross section, increase in the interyarn and inter fiber frictional forces. The Bending rigidity (BR) is higher in course direction than in wale direction. This is due to the geometry of knit structure (difference in intermeshing) of a loop increases the inter yarn and inter fiber friction. This contributes for the increase in bending rigidity (BR).

The variation in recoverability value in wale and course direction is due to the difference in loop shape or loop arrangement. Compared to cross miss single pique has less width wise recoverability value but higher length wise recoverability value. It is known that a fabric with lower bending rigidity (B) and lower bending moment (2HB) indicates better fabrics flexibility and elastic recovery. The larger B is, the harder the object is.

In general, cross miss structure has higher (2HB) value in wale direction and less (2HB) value in course direction than single pique structures. This is due to float and tuck stitch that influences the bending and recoverability property in course direction.

Surface property

Table 10 Average surface property value of different stitch designs

Surface properties				
Parameters	Direction	Jersey	Pique	Cross miss
MIU coefficient of friction	Wale	0.196	0.177	0.124
	Course	0.134	0.187	0.1425
MMD mean deviation of friction	Wale	0.0196	0.0177	0.0124
	Course	0.0134	0.0187	0.01425
SMD, µm geometrical roughness	Wale	1.96	1.77	1.24
	Course	1.34	1.875	1.425

Note; (MIU) related with slipperiness and non-slipperiness, larger value indicates less slippery. MMD is related with smoothness, and roughness, SMD indicates the surface physical roughness.

Single jersey fabric has large and lower coefficient of friction and geometrical roughness in wale and course direction respectively than cross miss and single pique fabrics. This is due to the geometry (shape) of the loop i.e. knit stitch which makes the fabric less slippery. On the other hand, cross miss structure has lower coefficient of friction. This is due to that, the presence of float stitch, which provides slippery touch to handle than fabrics having tuck and knit stitch.

Cross miss, structure has lower MMD value (smoother) than single jersey and single pique structures. This is due to floating yarns or float stitch, which provides smoother surface mainly on the back of fabrics. Cross miss, structure also has lower geometrical roughness value. This indicates cross miss structure has more even in wale direction than single pique and single jersey. Single jersey structure has lower geometrical roughness value in course direction, due to the shape of knitted stich, which gives smoother touch (appearance). Compared to single jersey and cross miss structures single pique structure has large SMD or less even/uniform/ appearance in course direction, because of tuck loop over the knitted stitch. This stich might not uniformly tuck over the held loop in course direction.

Compression

The result of compression properties includes compression energy (WC) which was measured at 50 gf/cm2 pressure and compression resilience (RC).

Table 11 Average compression value of different stitch designs

Compression properties			
Parameters	Jersey	Pique	Cross miss
LC (-) linearity of compression	0.196	0.201	0.183
WC (gf*cm/cm2)	0.304	0.286	0.402
RC (%)	78	73	81
T(mm)	0.188	0.227	0.269

LC (Linearity of Compression), WC (Work of Compression), RC (Recoverability of Compression).

WC indicates fabric bulkiness with higher value denotes bulkier feature. RC indicates the ability of fabric to recover under compression deformation.

From the above table, single pique fabric had better linearity of compression and lower compression energy (less bulkier) than cross miss and single jersey. This is due to the presence of tuck stitch and held loop; these give higher yarn tension on the tuck loop providing greater stability and shape retention.

Compared to cross miss structures, single jersey fabric is hard to compress due to, knitted loop, which gives high compression resistance than float loop and knitted loop (which are found in cross miss structure). Cross miss, structure has smoother surface and easier to compress than single jersey and single pique. This is due to the presences of float stitch, floats on the back of held loop, which provides bulkiness and smoother feel to touch. In addition to this, float stitch also gives better recoverability of compression or better resiliency. Compared to single pique, single jersey fabric has better recoverability after compression deformation. Due to the difference of loop shape and configuration, i.e. knitted loop can easily compress and recover than tuck and held loop.

4.2. Effect of knit, tuck and miss stitches on dimensional properties

It is known that weft knitted fabrics tend to undergo large changes in dimensions mainly after washing. The change in magnitude also different on different stitch designs. A large number of factors are responsible for causing these undesirable effects in knitted fabrics; these are all associated with the yarn and knitting variables but for this work, only effect of stitch designs was investigated. The shrinkage value of different stitch designs is given next page.

Table 12 Shrinkage value of different stitch designs

Structure	Sample code	Sample size	length of fabrics in (mm) after washed		Shrinkage value (mm)	
			Length wise	Width wise	Length wise	Width wise
Single jersey (30 Ne)	JD1	65mm x 65mm	6.3	6.8	-0.2	+0.3
	JD2		6.2	6.7	-0.3	+0.2
	JD3		6	7	-0.5	+0.5
	JD4		6.1	6.9	-0.4	+0.4
	JD5		6.2	6.7	-0.3	+0.2
	JD6		6	6.8	-0.5	+0.3
Average value			**6.13**	**6.81**	**-0.36**	**0.31**
Single pique (30 Ne)	PD1	65mm x 65mm	5.9	6.4	-0.6	-0.1
	PD2		6.1	6.3	-0.4	-0.2
	PD3		5.9	6.1	-0.6	-0.4
	PD4		6.1	6.2	-0.4	-0.3
	PD5		6.3	6.4	-0.2	-0.1
	PD6		6.2	6.3	-0.3	-0.2
Average value			**6.08**	**6.28**	**- 0.42**	**-0.22**
Cross miss (30 Ne)	CD1	65mm x	5.7	6.2	-0.8	-0.3
	CD2		5.8	6.3	-0.7	-0.2

	CD3	65mm	6	6.1	-0.5	-0.4
	CD4		5.7	6.4	-0.8	-0.1
	CD5		5.8	6.2	-0.7	-0.3
	CD6		6	6.3	-0.5	-0.2
Average value			**5.83**	**6.25**	**-0.67**	**-0.25**

Table 13 One-way ANOVA shrinkage test result analysis of different stitch designs

ANOVA

Test direction		Sum of Squares	df	Mean Square	F	Sig.
length wise	Between Groups	.310	2	.155	7.881	.005
	Within Groups	.295	15	.020		
	Total	.605	17			
width wise	Between Groups	1.213	2	.607	47.478	.000
	Within Groups	.192	15	.013		
	Total	1.405	17			

Table 14 Multiple comparisons of shrinkage values

ANOVA

Dependent Variable: shrinkage

LSD

Test direction	(I) sample no	(J) sample no	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
length wise	1.00	2.00	.05000	.08097	.546	-.1226	.2226
		3.00	.30000*	.08097	.002	.1274	.4726
	2.00	1.00	-.05000	.08097	.546	-.2226	.1226
		3.00	.25000*	.08097	.008	.0774	.4226
	3.00	1.00	-.30000*	.08097	.002	-.4726	-.1274
		2.00	-.25000*	.08097	.008	-.4226	-.0774
width wise	1.00	2.00	.53333*	.06526	.000	.3942	.6724
		3.00	.56667*	.06526	.000	.4276	.7058
	2.00	1.00	-.53333*	.06526	.000	-.6724	-.3942
		3.00	.03333	.06526	.617	-.1058	.1724
	3.00	1.00	-.56667*	.06526	.000	-.7058	-.4276
		2.00	-.03333	.06526	.617	-.1724	.1058

*.The mean difference is significant at the 0.05 level. Note; 1. Single jersey 2. Single pique 3.Cross miss

4.2.1 Effect of knit, tuck and miss stitches on fabric shrinkage

Shrinkage is the process in which a fabric becomes smaller than its original size, mainly after washing. Cotton fabrics are highly susceptible on shrinking and creasing after washing. Shrinkage can be negative or positive as it was shown above and this expressed (shrinkage) by means of a minus sign (-) or increased (extension) by means of a plus sign. There are two types of shrinkage occurs during washing 1) Length wise 2) Width wise shrinkage. For this work, both width wise and lengthwise shrinkage analyzed. Finally, the mean changes in dimensions in both the length and width directions calculated. The following figure shown that the average shrinkage value of different stitch designs.

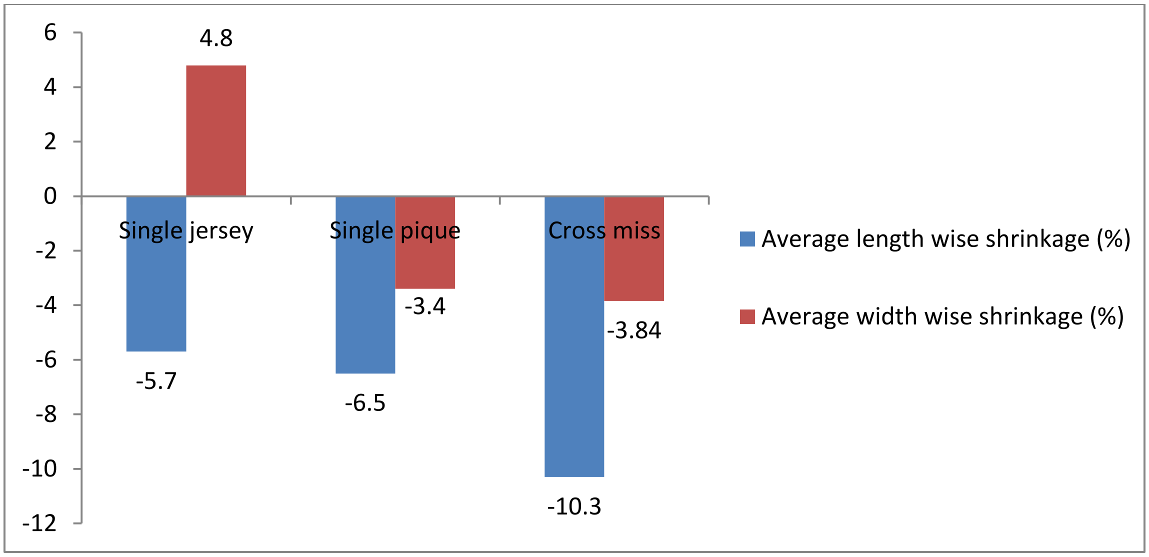


Figure 11 Average shrinkage values of different stitch designs

The results obtained for the dimensional stability tests were different for the three stitch designs, due to the distinct nature of each loop shape or structure. Moreover, there was considerable amount of change within the structure i.e. in length and width direction. The lengthwise shrinkage of single pique is higher than single jersey but statistically (from ANOVA table 14) not significant. This is due to the properties of knit stitch that reduce its height when immersed in water to reduce its internal stress i.e. it reduce height and increase its width. That is why knit stitch sometimes has positive shrinkage in width direction. The tuck stitch also reduces fabric length by pull down the held loop to reduce the high yarn tension imposed on it.

Single jersey structure shows positive and negative shrinkage in width and lengthwise direction respectively. The unbalanced nature of the loop structure causes the fabric to be more susceptible to distortion (change) as it was shown above. It is known that the shape of the loop before washing and after washing is different in different stitches, also the magnitude of change of loop shape and size different. After washing the loop reduce its height and become wider. Consequently, the fabric shows high dimensional instability in both directions.

Cross miss structures has high lengthwise shrinkage than single pique and single jersey. This is due to high yarn tension variation on float and held loop and due to swelling of fibers on float yarn. These provide more variation on length and width wise relaxation. Float yarn caused shrinkage in both course and wale wise of knitted fabrics due to drawn closer together loops by the floats. Sometimes yarn overlapping caused release in course wise and shrinkage in wale (length) wise.

In all stitch designs, there is high percentage of lengthwise shrinkage. This is fact that after washing (wet relaxed state) loops becoming shorter and wider Therefore, all three-stitch designs were vulnerable to length shrinkage. Normally shrinkage is acceptable less than 5%. The width wise shrinkage of all structures was within the acceptable limit.

This shows that any dimensional changes (shrinkage) that occurred during washing and drying treatments caused due to changes in loop shape rather than yarn or loop length shrinkage. Loop shape (knit, tuck and miss) stitches have important influence on the dimensional stability of the knitted fabric.

In general, after washing the length of knitted loops become smaller or larger and the fabric will shrink positively or negatively in the width and length direction. However, the magnitude of the change (shrinkage) highly depend on the shape of the loop which constituent a fabric.

4.2.2 Effect of knit, tuck and miss stitches on fabric extensibility (stretch recovery)

Once a knitted structure has been stretched in use, a fabric should contract or recover to its original dimension. The following table shown that, the stretch and recoverability value of different stitch designs.

Table 15 Extensibility (stretch recovery) values of knit, tuck and miss stitches

Structure	Sample code	Extensibility (%)		Recovery (%)	
		Width wise	Length wise	Width wise	Length wise
Single jersey (30 Ne)	JD1	75	32	33	13.6
	JD2	74	31	33.4	12.9
	JD3	76	32.6	33	12.6
	JD4	75	30	31.5	13
	JD5	76	32	32	14.1
	JD6	76	31	32.6	13.4
Average value		**75.33**	**31.4**	**32.4**	**13.2**
Single pique (30 Ne)	PD1	60	23	21.6	11.7
	PD2	59.5	22	22.3	10.6
	PD3	60	24	23	10.4
	PD4	61.5	23.8	24	12.3
	PD5	60.6	23	22.5	13
	PD6	62	23.7	25	10
Average value		**60.5**	**23.11**	**23.0**	**11.3**
Cross miss (30 Ne)	CD1	21	29	12	12.9
	CD2	22.4	30	11.5	13
	CD3	23	28	11	12
	CD4	23	28.7	10.8	13
	CD5	21.5	29	11	13
	CD6	22	28	10.7	12.5
Average value		**22.15**	**28.78**	**11.2**	**12.7**

Table 16 One-way ANOVA extensibility test analysis of different stitch designs

ANOVA

Extensibility

Test direction		Sum of Squares	df	Mean Square	F	Sig.
Length wise	Between Groups	209.214	2	104.607	156.963	.000
	Within Groups	9.997	15	.666		
	Total	219.211	17			
Width wise	Between Groups	9047.881	2	4523.941	6000.805	.000
	Within Groups	11.308	15	.754		
	Total	9059.189	17			

Table 17 Multiple comparisons of extensibility values

ANOVA

Dependent Variable: Extensibility

LSD

Test direction	(I) Sample number	(J) Sample number	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Length wise	1.00	2.00	8.18333*	.47133	.000	7.1787	9.1879
		3.00	2.65000*	.47133	.000	1.6454	3.6546
	2.00	1.00	-8.18333*	.47133	.000	-9.1879	-7.1787
		3.00	-5.53333*	.47133	.000	-6.5379	-4.5287
	3.00	1.00	-2.65000*	.47133	.000	-3.6546	-1.6454
		2.00	5.53333*	.47133	.000	4.5287	6.5379
Width wise	1.00	2.00	14.73333*	.50129	.000	13.6648	15.8018
		3.00	53.18333*	.50129	.000	52.1148	54.2518
	2.00	1.00	-14.73333*	.50129	.000	-15.8018	-13.6648
		3.00	38.45000*	.50129	.000	37.3815	39.5185
	3.00	1.00	-53.18333*	.50129	.000	-54.2518	-52.1148
		2.00	-38.45000*	.50129	.000	-39.5185	-37.3815

*. The mean difference is significant at the 0.05 level. Note; 1. Single jersey 2. Single pique 3.Cross miss

Table 18 One-way ANOVA recovery test analysis of different stitch designs

Recovery

Test direction		Sum of Squares	df	Mean Square	F	Sig.
Length wise	Between Groups	11.964	2	5.982	9.607	.002
	Within Groups	9.340	15	.623		
	Total	21.304	17			
Width wise	Between Groups	1381.701	2	690.851	907.819	.000
	Within Groups	11.415	15	.761		
	Total	1393.116	17			

Table 19 Multiple Comparisons of recovery values

Dependent Variable: Recovery

LSD

Test direction	(I) Sample number	(J) Sample number	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Length wise	1.00	2.00	1.93333*	.45558	.001	.9623	2.9044
		3.00	.53333	.45558	.260	-.4377	1.5044
	2.00	1.00	-1.93333*	.45558	.001	-2.9044	-.9623
		3.00	-1.40000*	.45558	.008	-2.3711	-.4289
	3.00	1.00	-.53333	.45558	.260	-1.5044	.4377
		2.00	1.40000*	.45558	.008	.4289	2.3711
Width wise	1.00	2.00	9.51667*	.50365	.000	8.4432	10.5902
		3.00	21.41667*	.50365	.000	20.3432	22.4902
	2.00	1.00	-9.51667*	.50365	.000	-10.5902	-8.4432
		3.00	11.90000*	.50365	.000	10.8265	12.9735
	3.00	1.00	-21.41667*	.50365	.000	-22.4902	-20.3432
		2.00	-11.90000*	.50365	.000	-12.9735	-10.8265

*. The mean difference is significant at the 0.05 level. Note; 1. Single jersey 2. Single pique 3.Cross miss

This study shown that, knit, tuck and miss stitches have a significant influence on wale and course way extensibility (stretch and recovery value) even though other knitting parameters remain same. The difference on stretch and recoverability value is not only between structures but also within the structures i.e. in course and wale wise direction. The following figure shows the effect of knit, tuck and miss stitches on fabric extensibility (stretch recovery) property.

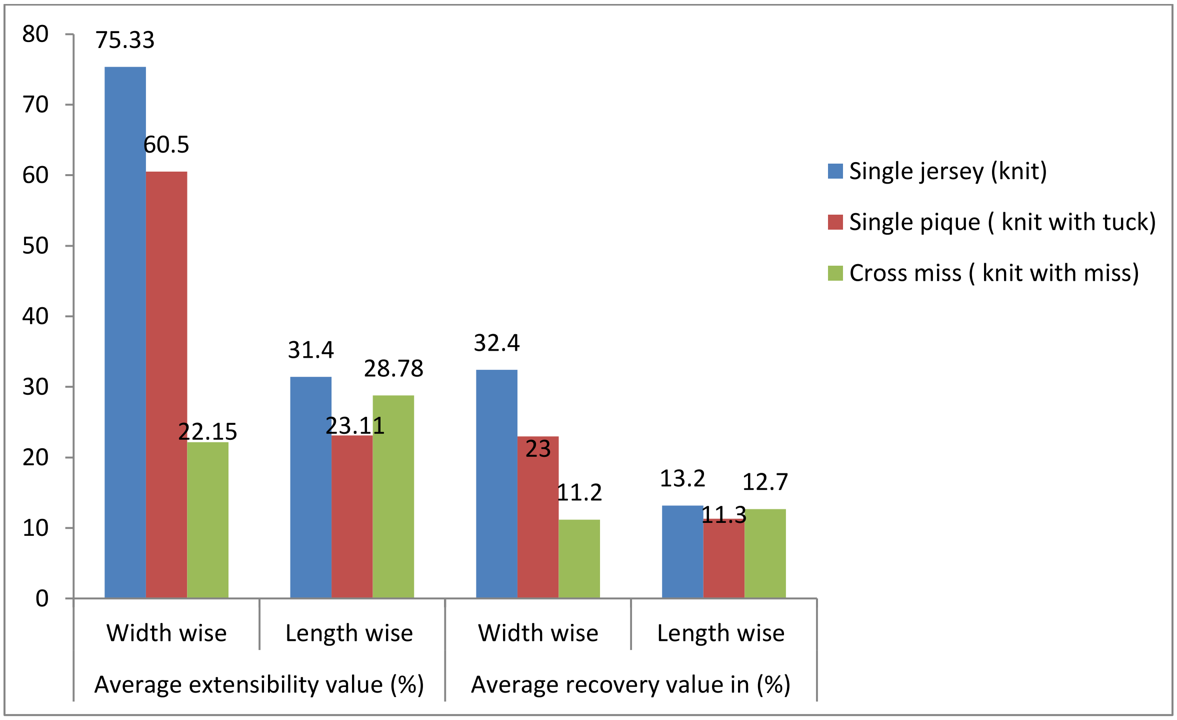


Figure 12 Extensibility (stretch recovery) values of different stitch designs

Stretch properties

It was shown that, single jersey structure in both directions has higher extensibility and recovery values than single pique and cross miss structures. This is due to the geometry or shape of knitted loop and its arrangement, which makes the fabric highly extensible and recoverable in both direction, than other loop structures (tuck and float stitches). The lengthwise recovery values of single jersey structure were not significantly higher than cross miss structures. This is due to the distinct nature of float stitch, which resists widthwise elasticity and lengthwise recovery.

Compared to cross miss structures, single pique has higher width wise extensibility and recovery values but lower lengthwise extensibility and recovery value. This is the fact that, tuck loops reduce fabric length and length-wise elasticity because the higher yarn tension on the tuck and held loops causes them to rob yarn from adjacent knitted loops, making them smaller. Therefore, fabric width is increased because tuck loops pull the held loops downwards. This provides extra yarn available for width wise extensibility and recovery.

The width extensibility and recovery of cross miss structure is relatively lower than single pique and single jersey structures. This is because of floating yarns, which connect the adjacent wales closer together, and reducing width wise elasticity and improving fabric stability. Float yarn reduced course wise elasticity and increased wale wise elasticity of knitted fabrics; however, overlapping of yarn reduced elasticity in both directions. The stretch value in course direction is mainly influenced by yarn floating rather than loop overlapping. However, wale wise stretch ability influenced by both yarn floating and loops overlapping.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Knit, tuck and miss stitch can be combined to produce different stitch designs. In this study, it was shown that, almost, each stitch has significant effect on dimensional, comfort and/ low stress mechanical properties even other knitting and yarn parameters remain same.

From this investigation, it was found that the presence of tuck stitch in a given structure increase air permeability, areal density, width wise extensibility lengthwise shrinkage. The tuck stitch also gives moderate drape ability, thickness and reduces lengthwise stretch ability. Tuck stitch also has significant effect on low stress mechanical properties. It gives high shear rigidity, shear stress, bending rigidity in course direction. It also reduces fabric compressibility.

Float stitch has significant effect on fabric drape ability, width wise extensibility, fabric weight, lengthwise shrinkage, thickness and areal density. Compared to single jersey and single pique it has lower width wise extensibility and recovery. Float stitch also gives high bending rigidity, bulkiness and smoother fabric surface.

Knit stitch has no significant effect on fabric air permeability, areal density, thickness and bending rigidity. However, it has higher drape ability, extensibility and recovery values than tuck and miss stitches. It has positive shrinkage in width direction due to the change of knitted stitch after washing.

In all stitch designs, there is high percentage of lengthwise shrinkage. The fact that after washing (wet relaxed state) loops becoming wider and shorter. Therefore, the length of knitted loops become smaller or larger and the fabric will shrink positively or negatively in the width and length direction. However, width wise shrinkage of all structures is within the acceptable limit.

In general, tuck and miss stitches increase fabric stability and knit stitch increase fabric flexibility and extensibility. Each stitch has also significant influence on bending, shear, surface and compressional properties.

5.2 Recommendation

From this work, it was observed that the dimensional and comfort properties of single jersey derivative fabrics are highly influenced by loop structure with other knitting and yarn parameters are kept unchanged.

Therefore, understanding the effect of different stitches and their combination even on same structures has become vital. Since using different stitches and their combination in a given knit structure can positively or negatively affect the knitted fabric properties.

- Manufactures who are producing different stitch designs should know the effect of different stitches and their combination in a given fabric properties.
- Selection of stitch designs even on the same structures should be based on their end use application.
- Since this work was carried out on single jersey, researchers and students in the future can experiment on different knit structures and their combinations.

REFERENCE

Ahmed Asif, Moshiur Rahman, Farial Islam Farha, 2015. Effect of Knitted Structure on the Properties of Knitted Fabric. International Journal of Science and Research.

Anon., March 2016. Effect of Stitch Type on Air Permeability of Summer Outerwear Knitted Fabrics. International Journal of Advance Research in Science and Engineering.

Araguacy Filgueiras, Raul Fangueiro& Filipe Soutinho, 2009. Drape behaviour of functional knitted fabrics for sport clothing. Indian Journal of Fibre & Textile Research .

Asif, A., 2013. Effect of Knitted structure on the properties of knitted fabric. nternational Journal of Science and Research (IJSR).

Coruh, E., 2015. Optimization Bursting Strength and Weight of Plain Knitted Fabrics by Design Expert Analysis Method. Journal of Engineered Fibers and Fabrics.

Değirmenci, 2016. Comparison of The Performance and Physical Properties of Plain, Pique, Double-Pique And Fleeced Knitted Fabrics. TEKSTL ve KONFEKS.

NPTEL.[Online] Available at: http://nptel.ac.in/courses/116102008/3# [Accessed 26 December 2017].

Edin Fatkić, 2012. Fibres and Textiles in Eastern Europe 2011, Vol. 19, No. 5.

Emdadul Haque, M. S. A., 2016,. Effect of Stitch Lengths and Yarn Counts on Areal Density and Drape Behaviour of Different Weft Knitted Single Jersey Structures. American Journal of Applied Scientific Research.

Fatkić, E., 2012. Influence of Knitting Parameters on the Mechanical Properties of Plain Jersey Weft Knitted Fabrics. Fibres & Textiles in Eastern Europe 2011, Vol. 19, No. 5.

Hadidy, A., 2015. Mathematical model to predict the geometrical and physical properties of bleached cotton plain single jersey knitted fabric. Jornal of Textile.

Hady, 2016. Effect of Stitch Type on Air Perpeability of Summer Outerwear Knitted Fabrics. International Journal of Advance Research in Science and Engineering.

Hafsa Jamshaid, R. M. N., 2015. End Use Performance Characterization of Unconventional Knitted Fabrics. Fibers and Polymers 2015, Vol.16, No.11, 2477-2490.

Hannan, M. A., 2014. Effect of Yarn Count and Stitch Length on Shirinkage,Gsm,And Spirality of Single Jersey Cotton Knitt Fabric. Europian Sceintific Journal.

Haque, E., 2016. Effect of Stitch Lengths and Yarn Counts on Areal Density and Drape Behaviour of Different Weft Knitted Single Jersey Structures. American Journal of Applied Scientific Research.

History of knitting, ,2017. http://www.historyofclothing.com/making-clothing/history-of-knitting/. [Online] [Accessed 2017].

Islam, M. A., 2014. Effect of Wale Wise Increaseing of Tuck And Miss Loops on Bursting Strength of Single Jersy Knitted Fabic At Grey State. IJRET:.

Jamshaid, H., 2015. End Use Performance Characterization of Unconventional Knitted Fabrics. Fibers and Polymers 2015, Vol.16, No.11, 2477-2490.

Kannan, M., 2014. Effect of Yarn Count and Stitch Length on Shirinkage, Gsm,Spirality of Single Jersey Knit Fabric. Europian Sceintific Journal, Volum 10.

Kayseri & Kirtayu, 2015. Predicting the Pilling Tendency of the. Interlock Knitted Fabrics by Regression Analysis.

Kulkarni, S. R., 2015. Effect of TM and Loop Length on Drape Coefficient of Single Jersey Knitted Fabrics. International Journal of Advanced Research in Engineering and Technology (IJARET).

Mikučionienė, D., 2010. The Influence of Knitting Structure on Mechanical Properties. Materials Science.

Mst. Sarmin Khatun Mohammad, Sohel Adnan, Bhuiyan Mahmuda Khatun, Afsana Munni, Mahfuza Pervin, 2016. Effect of Fabric Structures and Yarn Fineness on the Properties. IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE).

Nergiz Emirhanova, Yasemin Kavusturan, 2008. Effects of Knit Structure on the Dimensional and Physical Properties of Winter Outerwear Knitted Fabrics. Fibres and Textiles in Eastern Europe.

Nilgün Özdil, A. M. S. D. K., 2006. Effect of yarn properties on thermal comfort of knitted fabrics. International Journal of Thermal Sciences 46 (2007) 1318–1322.

Oğlakcioğlu, N. & Arzu , M., 2007. Thermal Comfort Properties of Some Knitted Structures. Fibres & Textiles in Eastern Europe Vol. 15.

Pattanayak, Author B K Behera & Ajit Kumar, 2008. Measurement and modeling of drape using digital image processing. Indian Journal of Fibre & Textile Research, Volume Vol. 33, pp. 230-238.

Pratihar, P., 2013. Static and Dynamics Drape of Fabric: an Emerging Arena of Fabric Evaluation. International Journal of Engineering Research and Applications.

R. Varadaraju, S. J. P., 2015. Prediction of Certain Low Stress Mechanical Properties of Journal of Engineered Fibers and Fabrics. Journal of Engineered Fibers and Fabrics.

R.A.M. Abd El-Hady, R.A.A. Abd El-Baky, 2015. The Influence of Pile Weft Knitted Structures on the Functional Properties of Winter Outerwear Fabrics. Journal of American Science.

Rahman, S., ,2015. Investigation on the Changes of Areal Density of Knit Fabric with Stitch Length Variation on the Increment of Tuck Loop Percentages. Journal of Polymer and Textile Engineering.

Rashed & Md. Mahamudu, I., ,2014. Effect of Tuck Loop In Bursting Strength of Single Jersey Knitted Fabrics. International Journal of Research in Engineering and Technology.

S. C. Anand, K. S. M. Brown, L. G. Higgins, D. A. Holmes, M. E. Hall and D. Conrad., 2002. Effect of Laundering on the Dimensional Stability and Distortion of Knitted Fabrics. AUTEX Research Journal, No 2,, Volume Vol. 2.

S.S.Bhattacharya and J.R.Ajmeri, 2013. Factors Affecting Air Permeability of Viscose & Excel Single Jersey Fabric. International Journal of Engineering Research and Development.

S.Uyanik, Jan 2017. The effect of knit structures with tuck stitches on fabric properties and pilling resistance. Journal of Textile Institute.

Serin Mezarciöz* and R Tuğrul Oğulata, 2015. Modelling of Porosity in Knitted Fabrics. Journal of Fashion Technology & Textile Engineering.

Shohreh Minapoor, Saeed Ajeli and Hossein Hasani, 2015. Investigation into the Curling Intensity of Polyester/Cotton Single Jersey Weft Knitted Fabric Using Finite Element Method. Journal of Textiles and Polymers, Vol. 3, No. 2.

Sitotaw, D. B., 2017. An Investigation on the Dependency of Bursting Strength of Knitted Fabrics on Knit Structures. Industrial Engineering & Management.

Spencer, D. J., 2001. knitting technology.

Theaker, J., 2006. http://knitty.com/ISSUEspring06/FEAThistory101.html. [Online] [Accessed 2017].

Yesmin, S., 2014. Effect of Stitch Length and Fabric Constructions on Dimensional and Mechanical Properties of Knitted Fabrics. World Applied Sciences Journal .

Züleyha Değirmenci & Ebru Çoruh, 2017. The Influences of Loop Length and Raw Material on Bursting Strength Air Permeability Characteristics of Single Jersey Knitted Fabrics. Journal of Engineered Fibers and Fabrics Volume 12.