2017-12-09

COMPARATIVE STUDY OF MECHANICAL AND COMFORT PROPERTIES OF SINGLE JERSEY FABRICS KNITTED USING RING AND ROTOR SPUN YARN

MEKONNEN, SEBLEWORK

COMPARATIVE STUDY OF MECHANICAL AND COMFORT PROPERTIES OF SINGLE JERSEY FABRICS KNITTED USING RING AND ROTOR SPUN YARN

SEBLEWORK MEKONNEN BAYH

ETHIOPIAN INSTITUTE OF TEXTILE AND FASHION TECHNOLOGY

(EiTEX)
BAHIRDAR UNIVERSITY

Bahir Dar

June, 2017 G.C.

COMPARATIVE STUDY OF MECHANICAL AND COMFORT PROPERTIES OF SINGLE JERSEY FABRICS KNITTED RING AND ROTOR SPUN YARN

By

SEBLEWORK MEKONNEN BAYH

A Thesis Submitted to the

Ethiopian Institute of Textile and Fashion
Technology

Fulfillment of the Requirements for the Degree
of Master of Science

In

TEXTILE MANUFACTURING

Under the supervision of

Professor Dr. Kathirrvelu Subramanian

ETHIOPIAN INSTITUTE OF TEXTILE AND FASHION
TECHNOLOGY
BAHIR DAR UNIVERSITY

June, 2017 G.C.

ABSTRACT

This thesis which was an attempt to a comparative study of ring spun yarn and rotor spun yarn on the mechanical and comfort property of single jersey fabrics 28 Ne 100% cotton yarn were spun from the same carded slivers of the same mixing using ring spinning machine and rotor spinning machine of MAA garment industry. These yarns were separately knitted on a circular knitting machine to make two types of single jersey fabrics using the same knitting machine and parameters. The fabrics thus knitted were tested for their mechanical properties such as bursting strength, abrasion resistance and pilling resistance. They were also tested for their comfort properties such as air permeability, compressibility and surface friction, the results were studied and analyzed using ANOVA and the results shows that bursting strength of ring spun knitted fabric (6.82 bar) is greater than rotor spun knit (4.834 bar), as far as Abrasion resistance concerned ring spun yarn (1.32 %) have less weight loss than rotor spun yarn (3.03%) and ring spun yarns tends to pill more than rotor spun yarn. The fabrics knitted from rotor spun yarn (161cm^3/ cm^2 /s) have higher air permeability value than ring spun knitted fabric (134cm^3/ cm^2 /s). The fabrics knitted from ring spun yarn have higher roughness value than rotor spun yarn. So far as compression property is concerned the fabrics knitted from rotor spun yarn have higher compression value than ring spun yarn. It has been found that the yarn property and its structure has got significant influence on both the mechanical and comfort properties.

Advisor's approval

ETHIOPIAN INSTITUTE OF TEXTILE AND FASHION TECHNOLOGY (EiTEX)

POST GRADUATE OFFICE

This is to certify the thesis entitled ''Comparative study of mechanical and comfort properties of single jersey fabrics knitted using ring and rotor spun yarn'' submitted in partial fulfillment of the requirement of the degree of masters with specialization in textile manufacturing, the graduate program of the Ethiopian Institute of Textile and Fashion Technology, and has been carried out by SEBLEWORK MEKONNEN, ID No.MTM/R/007/08 under my supervision. Therefore I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the institute.

Professor Dr. Kathirrvelu Subramanian __________ ___________

Signature Date

Examiner's approval

ETHIOPIAN INSTITUTE OF TEXTILE AND FASHION TECHNOLOGY (EiTEX)

POST GRADUATE OFFICE

We, the undersigned, members of the board of examiners of final open defense by have read and evaluated her thesis entitled ''Comparative study of mechanical and comfort properties of single jersey fabrics knitted using ring and rotor spun yarn'', and examined the candidate. This is therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement for the degree of Master of Science in textile manufacturing.

____________________________	__________	___________
Name of the Chairperson	Signature	Date
____________________________	__________	___________
Name of the Internal Examiner	Signature	Date
____________________________	__________	___________
Name of the External Examiner	Signature	Date
____________________________	__________	___________
PG/ Graduate committee	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the post graduate studies office through the institute graduate committee of the candidate's program

Declaration

I hereby declare that the thesis is submitted in fulfillment of the master degree is my own work and that all contributions from any other persons or resources are properly and duly cited. I further declare that the material has not been submitted either in whole or in part, for a degree at this or any other university. In making this declaration, I understood and acknowledge any breaches in this declaration constitute academic miss conduct, which may result in my expulsion from the program and /or exclusion from the award of the degree.

Name ______________________________

Signature ___________________________

Date _______________________________

Acknowledgments

I would like to thank the almighty God for giving me the strength to end this thesis work. Next to God I thank my host institute, Ethiopian Institute of Textile and Fashion Technology [EiTEX] for supporting me financially and allowing me to get all laboratory facilities. The next great thank is for my advisor Professor katrrivalue for his meaningful cooperation and reliable guidance from start to the final. I am gratefully acknowledging Mr. Addisu Ferede (Scientific director of EiTEX) for his valuable encouragement and guidance throughout my progress. I would like to thank M/s Dereje for his guidance. I have glade to thank M/s MAA Garment and Textile Factory managers and operators for their unexpected help, support and cooperation in making this study successful. Without MAA it was not possible to accomplish and arrive at this result.

Thank You!

Seblework Mekonnen

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABREVASIONS

SFI =short fiber index

KES = Kawabata evaluation system

BD = Break draft

AR = Abrasion resistance

GSM = Gram per square meter

RPM = Revolution per meter

ASTM= American standard

U = Un evenness

TPI =Twist per inch

CVM = Coefficient of variation of mass

CHAPTER ONE

INTRODUCTION

1.1. Background

Knitting is a process of manufacturing a fabric by interloping of yarns. Knitting is the second most important method of fabric formation. Fabric can be formed by hand or machine knitting, but the basic principle remains exactly the same i.e. pulling a new loop through the old loop. The term knitting is used to describe the technique of constructing textile structures by forming continuous lengths of yarn in to vertically intermeshed loops. Knitted fabrics constitute horizontal row of loops termed as course and vertical columns of loops termed as wale. Knitted fabrics are popular for their shape fitting properties, softer handle, bulkier in nature with high extension. Knit fabric properties depend upon yarn properties and fabric construction. Fabric quality means different properties of finished fabric which depends on yarn properties and fabrics construction. The properties which are important for knitted fabric and maintained in the industries from grey stage to finished stage are GSM, dimensional stability, resistance of pilling and color fastness properties. Knitted fabrics are complex and dimensionally sensitive structures. Variations in material, structural, process and environmental parameters significantly affect the performances and comfort properties of knitted fabrics, as well as their qualities.

Yarns are the raw materials manipulated during knitting. There are different methods of yarn manufacturing such as ring spinning, rotor spinning, air jet spinning ,break spinning, friction spinning etc.

The properties of weft knitted fabrics depend up on the raw material, knitted structure, yarn structure and properties.

1.2. Justification

The various factors that can affect weft knitted fabric properties can be fiber causes, yarn causes and machine causes. The Yarn causes are bulkiness, spinning system, fiber arrangement; twist level, mechanical properties, twist direction, yarn count and doubling. Ring and Rotor spinning systems provide yarns with different structures and properties. Each system has its advantages and limitations in terms of technical feasibility and economic viability. Structural differences in the yarn play a large part in determining the behavior of the fabric type.

Knitted fabric properties such as mechanical and physical properties are affected by yarn. The major mechanical properties such as bursting strength, abrasion resistance and pilling resistance, major dimensional properties are fabric width, number of courses and wale per centimeter, fabric thickness, stitch length, fabric weight, tightness factor, loop shape, stitch density. The major comfort parameters are moisture absorbency, water and air permeability, draping coefficient and fabric handle. Effect of yarn spinning systems on physical properties of knitted fabrics had not been studied by different scholars so far.

With this thesis work, we are going to study the effect of ring and rotor spun yarns on the mechanical and comfort properties of single jersey weft knitted fabrics by carrying out proper testing and analysis of the produced sample fabrics. The mechanical and some comfort properties of single jersey weft knitted fabrics made from both cotton ring and open-end spun yarns investigated.

1.3. Statement of the problem

In today's world, knitting product is highly demanded for fashion and normal wearing. So, it is critical that studying the properties of different fabrics produced from yarns produced by rotor and ring spinning machines to decide best option of using yarns from rotor or ring spinning mill. It is observed that MAA garment industries are focusing on productivity rather than the quality i.e. when there is shortage of one type of yarn (ring) they tend to use alternative type of yarn (rotor) available there for same product on the process; which ultimately affects the properties as well as quality of fabric.

This work is highly aimed to assess current quality effect of yarns from rotor and ring spinning on weft knitted fabrics for MAA garment textile factory. The main reason for selecting MAA garment industry for this work is that they use both the yarn types which are produced by themselves.

1.4. Objectives

General objectives: To study the effect of ring and rotor spun yarns on mechanical and comfort properties of single jersey knitted fabric

Specific Objectives:

- To study the effect of ring yarn on mechanical and comfort properties of single jersey weft knitted fabric.

- To study the effect of rotor yarn on mechanical and comfort properties of single jersey weft knitted fabric.
- To explore the comparison among ring and rotor spun yarns.
- To select the knitted fabric with better performance
- To create awareness and give knowledge to knitting factory technicians about the effects of spinning systems on knitted fabric properties.

1.5. Benefits and Beneficiaries

1.5.1. Benefits

- Scientific information will be obtained for Ethiopian textile and garment industries, researchers and textile institutes for their further interaction and work.
- More opportunities for the industries to compete at international market by avoiding fabric property variations

1.5.2. Beneficiaries

The major beneficiaries of this thesis work are the following;

- Customers
- Researchers
- Textile industries
- Textile Engineers
- Students
- Textile and Apparel institutes

1.6. Scope

This thesis work covers study the effects of ring and rotor spun yarns on mechanical properties such as Bursting, abrasion and pilling and comfort properties such as compression, air permeability, surface friction of single jersey knitted fabric. The knitted fabric samples are knitted using 28Ne yarn in grey state with single jersey structure.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Knitting is one of the methods most frequently used in fabric formation. Knitting is a process of fabric formation that involves the interloping of yarn in a series of connected loops by means of needles. Knitted fabrics have been extensively used in readymade apparel owing to their excellent mechanical and comfort properties (Salvia Rahman, 2010).

The last few years have witnessed growing interest in knitted fabrics due to their simple production techniques, low cost, high levels of clothing comfort and wide product range. Knitted fabrics are known to possess excellent comfort properties as they not only allow for stretching and ease of movement, but they also have good handling characteristics for the body. They also possess high extensibility under low load, allowing comfortable fit on any part pulled. Furthermore, they are also light weight and flexible. Knitted fabrics, especially ready-made knitted garments like shirts, underwear and lingerie are an important method of the textile sector (Md. Abdul, 2014). The reasons for their usage can be explained in various ways: Firstly, it has an elastic and light structure; secondly, single jersey fabrics are easily and quickly produced; thirdly they have a lighter weight and lower production cost, and finally, because of their smooth surface, they are convenient for printing Single jersey fabrics are generally used to make underwear and outerwear such as T-shirts. Compared to woven structures, knit fabrics can more easily deformed or stretched by compressing or elongating the individual stitches that from the fabric **(**MuhammetAkaydin,Yahya Can,2010).the physical and mechanical properties of knitted fabric can be changed due to use of various count of yarn, type of yarn (ring, rotor, and compact), quality of yarn, stitch length / loop length, structural geometry, fiber composition of yarn etc. such study was focused on the various stitch length effect of grey single jersey (Elias Khalil & Md. Solaiman, 2013)

Yarns produced using various spinning technologies not only differ from one another in respect of their structures, but also in their bulk, mechanical and surface properties. The properties of the fabrics produced from such yarns are affected by yarn properties, as well as by their fabric construction parameters (Kane, 2007).

2.2. Effect of ring and rotor spun yarn on mechanical property

2.2.1. Abrasion resistance

S. Mukereje and S. Chindila (1983) described that abrasion resistance is the most important mechanical characteristics of fabrics. The resistance of a fabric against the force of friction is known as the abrasion resistance. Abrasion is the physical destruction of fibers, yarns, and fabrics, resulting from the rubbing of a textile surface over another surface (Abdullah et al., 2006). Textile materials can be unserviceable because of several different factors and one of the most important causes is abrasion. Abrasion occurs during wearing, using, cleaning or washing process and this may distort the fabric, cause fibers or yarns to be pulled out or remove fiber ends from the surface (Hu, 2008; Kadolph, 2007). Abrasion ultimately results in the loss of performance characteristics, such as strength, but it also affects the appearance of the fabric (Nilgün Özdil1, GoncaÖzçelik Kayseri and Gamze SüpürenMengüc, 2008)

There are many factors, such as the yarn spinning system, fabric construction and finishing operation, which affect the abrasion resistance (S Mukereje E, ScChindila, 1983).

C. Canadan, U.B Nergis, and Y.Iridag(2000) studied on the performance of open end and ring spun yarn on weft knitted fabrics, the single jersey and lacoste fabrics were made from 30 Ne ring and rotor spun cotton yarn, each produced from the same fiber blend and concluded that ring spun knit is better abrasion resistant than rotor spun yarn.

Ramesh kumar C. et.al (2008) studied comparative studies on ring, rotor and vortex yarn knitted fabrics with 30 Ne single jersey Yarns from three different spinning systems were produced and the properties of yarns and knitted fabrics were studied and concluded that abrasion resistance of rotor spun yarn is better than ring spun yarn.

As we reviewed, different research works on abrasion resistance of ring and rotor spun yarn there is a conclusion difference between their works and also they did not report anything about single jersey weft knitted fabric that are made from 28 Ne.

2.2.2. Piling Resistance

Pilling is a fabric defect observed as small fiber balls or a group consisting of intervened fibers that are attached to the fabric surface by one or more fibers. Pills are small knots or balls of mixture of large number of small fibers accumulated at the surface of the fabric and entangled by the mild frictional action during processing or wearing (Rameshkumar C, 2008**)**.

There are many factors which affect the pilling resistances of knitted fabrics such as the yarn spinning system, fabric construction and finishing operation.

C.Canadan and L.Onal (2002) studied on dimensional, pilling and abrasion property of weft knitted fabric and the result show that both structural differences of yarns and fiber type play a large role in determining the property of knitted fabric. They concluded that fabrics knitted from open end spun yarns have a lower propensity to piling.

Peter V. Alston discussed the effect of yarn spinning system on pill resistance of polyester / cotton knit fabrics and have determined the effect of ring, rotor, and air-jet spinning on the pill resistance of jersey and interlock fabrics. The yarns produced by the three spinning systems have major structural differences that are expected to impact pill resistance. Ring spun yarn has real twist and good fiber orientation. Rotor spun yarn also has real twist but poorer fiber orientation, with fibers wrapped around the yarn core. Air-jet spun yarn does not have real twist and obtains integrity by wrapping fibers tightly around a core of parallel fibers. These wrapper fibers are more tightly held to the yarn than the wrapped fibers of the rotor spun yarn. The 2 1.09 tex (28 / 1 cc) yarns used to construct the jersey fabrics were prepared on a Rieter ring spinning frame, a Schlafhorst open-end frame, and a Murata air-jet spinning frame at a DuPont test facility. The 16.4 tex(36/ 1 cc) yarns used to construct the interlock fabrics were spun in commercial facilities. All yarns were made of a 50/ 50 blend of pill resistant

Dacron polyester and cotton. The results show that the ring spun fabric was slightly more pill resistant than the rotor spun fabric.

2.2.3. Bursting strength

For knitted fabric the bursting strength is very important because in weft knitted structure, there is only one set of yarn. Multi- directional bursting strength testing is an alternative criterion to judge the fabric strength because the force is applied perpendicular direction to the plane of the fabric to rupture the yarn at a week place (S Mukereje E, ScChindila, 1983)

S Mukereje E, ScChindila(1983)carried out a comparative study of open end spun yarn and ring spun yarn on single jersey weft knitted hosiery fabric using 20s nominal yarn count which was prepared from J34 cotton. All the fabric samples were produced in a circular knitting machine and concluded that the bursting strength of fabric samples in grey state is lower by 50% for fabric made from open end than for from ring. The work of rupture of rotor yarn (which is a product of strength and elongation) is much lower than that of ring spun yarn, which is reflected in the fabric bursting strength values.

2.3. Effect of ring and rotor yarn on comfort property

2.3.1. Air Permeability

Kotb (2011) and Saville (2000) defined air permeability as the volume of air in milliliters which is passed in one second through 100mm2 of the fabric at a pressure difference of 10mm head of water. The air permeability of a fabric is a measure of how well it allows the passage of air through it.

S.S.Bhattacharya[1], J.R.Ajmeri[2] (2013) described that the air permeability of a fabric can influence its comfort behaviors in several ways. In the first case, a material that is permeable to air is, in general, likely to be permeable to water in either the vapor or the liquid phase. Thus, the moisture-vapor permeability and the liquid-moisture transmission are normally related to air permeability. In the second case, the thermal resistance of a fabric is strongly dependent on the enclosed still air, and this factor is in turn influenced by the fabric structure.

Bhattacharya, Ajmeri(2013) reported that air permeability has a direct relationship with the count of the yarn. Increase in yarn fineness and more open structure of the knitted fabric improved air permeability. Air permeability, is a function of knitted fabric thickness, tightness factor and porosity. Air permeability showed a negative correlation with fabric thickness and tightness factor. Tightness factor can be used for fabric air permeability forecasting. The high correlation between the permeability to air and tightness factor confirms that. Porosity is affected by yarn number or yarn count number. Air permeability is an important factor in comfort of a fabric as it plays a role in transporting moisture vapors from the skin to the outside atmosphere. Modal single jersey fabrics are considered preferred candidates for warmer climate sportswear, due to their higher air permeability.

The researchers did not consider the effect of spinning system on permeability property of single jersey weft knitted fabric, and also no research had been done on the effect of ring and rotor spun yarn on air permeability property of single jersey weft knitted fabric so far.

2.3.3. Surface Property

Surface properties of textile materials are important for all textile products in many situations from production to performance of final product. When clothing fabric is the subject, these properties affect consumer preference for a garment or a fabric. For fabrics which are directly in contact with the skin, fabric handle and tactile properties are especially important in connection with clothing comfort. The physical interaction between fabric and skin is always subjected to a complex mechanical load and the distribution of this load on contact areas of skin is assessed subjectively. Thus, surface properties have always examined for years because of having considerable importance for clothing fabrics in both of technological fields and subjective perception. Fabric friction is affected by a lot of factors, such as type of fiber, type of blend, blend proportion, yarn structure, fabric structure, crimp, compressibility etc.(VildanSülara, ErenÖner& Ayşe Okur, 2016)

Any surface is generally composed of three components in accordance with wavelength or frequency. The low, medium and high frequency range variations are called form, waviness, and roughness respectively (Sara sghari, 2014).

2.3.4. Compression Property

A fabric that compresses easily is likely to be judged as soft, possessing a low modulus or highly compressible. Compression is also fundamentally important in determining how a fabric will perform when subjected to a wide range of complex deformations. In surgical compression, the softness of fabric is important for two main reasons: The fabric should give rise to minimal skin irritation during prolonged wear and, while maximizing the chances for the patient, comply with the extended plastic surgery recovery period (G. Manonmali, 2014).

The compressibility of a fabric mainly depends on yarn packing density and yarn spacing in the fabric. Compressibility provides a feeling of bulkiness and spongy property in the fabric. Compressibility has some correlation with the thickness of the fabric; the higher the thickness, the higher the compressibility.

G. Manonmani (2014) studied on the effect of ring and compact cotton spun yarn characteristics on physical and comfort properties of knitted fabric and for this research work, the cotton yarn of 40s Ne count was selected from three spinning systems, namely Ring spinning, Sussen Elite and Com4 spinning systems, the result shows that compression resilience of compact spun yarn knitted fabrics made of both Sussen Elite and Com4 yarn exhibited higher values than ring spun yarn knitted fabrics in single jersey, rib and Interlock fabrics. This may be attributed to better fiber integrity and yarn packing density of compact spun yarns. However, the compression energy was found to be lowest for ring spun yarn knitted fabrics when compared to compact spun yarn knitted fabrics. The compression energy of all kind of knitted fabrics was higher when fabric thickness, stitch density and fabric aerial density increase.

The researchers did not report about the comparative effect of ring and rotor spun yarns on compression property of single jersey knitted fabrics.

CHAPTER THREE

MATERIAL AND METHOD

3.1. Material

The materials and equipment types, specifications, parameters and properties are described as follows one by one.

Yarn samples: 28 Ne 100% cotton yarns from ring spinning and rotor spinning machines.

Fabric: single jersey weft knitted grey fabrics knitted from ring and rotor spun yarns with the same count

The equipment listed in Table 3.1 is used to collect the data required for this research work. The data are to be collected from.MAA Garment and textiles, Mekele, Ethiopia.

Table 3.1 Equipment and material

Name of equipment	Type of the test	Location
Uster tester-5	Evenness	EiTEX
Cutting dies	Abrasion, piling, bursting	EiTEX
Kawabata automatic surface tester	Surface property	EiTEX
Kawabata Automatic compression tester	Compression property	EiTEX
Air permeability	Air permeability	EiTEX

3.1.1 Fiber Properties

Fiber properties included in this study are used for the production of knitted fabrics to make a comparative study of ring and rotor spun yarn on comfort and mechanical properties of single jersey knitted fabric. These fiber properties are provided to indicate that the yarns for this study are produced from these fiber properties and without variation ring and rotor spun yarn. Cotton fiber is used in this study for it is the dominant raw material in textile factories especially in Ethiopia

Table 3.2 Fiber parameters

Type	Origin	Trash %	Nep	SFI	Staple length (mm)	Micronire
Cotton	Awash	4.06	300	12.5	12.5	4.2

3.1.2. Spinning machine parameters

The spinning machine parameters used in this work are related to ring spinning and rotor spinning machine on which the yarns are spun the following are the data about ring frame machine (Table 3.3) and rotor spinning (Table 3.4) which used to produce ring and rotor spun yarn.

Table 3.3 Ring spinning machine parameter

Machine type	Rieter G33
Material	Carded 100% cotton
Twist	900
Twists factor	3.6
Rpm	1600
Traveler	25
Spacer	3.0(white)
Break draft	1.1(69T)

Table 3.4 Rotor spinning machine parameter

Process parameter	Rotor spinning
Delivery speed	153
Total draft	200
Sliver hank	0.148
Rotor	T331BD
Rotor speed	120,000rpm
Opening roller	8000rpm
Yarn count	28Ne

3.1.3. Yarn parameter

Table 3.5 gives the details of the yarn specification or parameters of both the yarns used for the fabric sampling.

Table 3.5 Yarn specification

Count	Yarn type	U%	CVM	Thin-50%	Thick+50%	Neps+200%	TIP
28Ne	ring	13.94	17.88	36.8	671.8	317.2	1025.08
	rotor	9.21	11.7	1	52.6	315	63.4

3.1.4. Knitting machine parameter

The fabrics for this study were produced in MAA Garment and Textile factory on circular knitting machine details are given in table 3.6.

Table 3.6 knitting machine parameter

Speed (rpm)	Adjusted loop length(mm)	Number of needles	Gauge	Needle type	Number of feeders	Number of cam track	Machine diameter (inch)
20	3.21	2976	28	Latch	108	4	34

3.1.5 Knitted fabric parameters

The knitted fabric parameters are shown in Table 3.7

Table3.7 knitted fabric parameters

Fabric type	Gsm	Width	Loop length	count
Single jersey	145	110*2	2.85	28

3.2. Methods

This research were designed to study the comparative effect of ring and rotor spun yarn on mechanical and comfort properties of single jersey weft knitted fabric by collecting relevant data and samples. These fabric properties are supposed to be studied for the fabrics which were produced from two different yarns produced with the same material, machine settings and parameters.

3.2.1. Mechanical property tests

3.2.1.1 Abrasion resistance

Martindale abrasion fabric Tester was used to test the abrasion resistance of the fabrics according to ASTM D 3886 standard. It uses the principles of two simple harmonic motions working at right angles. The knitted sample is cut into 40mm diameter and subjected to a load of 200gms weight. The loss in weight of the samples was calculated after the visual examination of the tested fabrics.

$$AR\% = \frac{\text{Original weight} - \text{Weight loss}}{\text{Original weight}} \times 100$$

Where AR - Abrasion Resistance.

Figure 3. 1 Abrasion resistance tester

3.2.1.2 Pilling resistance

Pills are small knots or balls of mixture of large number of small fibers accumulated at the surface of the fabric and entangled by the mild frictional action during processing or wearing. Fabrics was tested by Martindale pilling tester. Pills are soft, firmly held balls of fibers on the surface of the material. A piece of fabric measuring 127X127mm was stitched so as to be a firm fit when placed round a rubber tube of 152mm long, 32mm outside diameter and 3mm thick. The box is then rotated at 60 rpm for 5 hours. The extent of pilling was assessed visually by comparison with the standards ASTM D 4970.

Figure 3. 2 Pilling tester

3.2.1.3 Bursting strength

The bursting strength of the single jersey knitted fabrics that made from ring and rotor spun yarn was tested with the Bursting Strength Tester according to ASTM D 3786 standards. The test was carried out at ten different places per sample. The reading is noted in kg/cm^2.

Figure3. 3 Bursting strength tester

3.2.3. Comfort property test

3.2.3.1Compression property

The KES-FB3 measures properties of compression and thickness. These properties are not dependent on direction so measurements in the warp and fill directions are not needed. The instrument applies a force up to 50 gf/cm^2 to a 2 cm^{2}circular area at a constant velocity and measures the thickness with respect to the force per area applied. The device takes measurements during the compression process and the recovery process. Important properties of this instrument include compressibility, compression resilience, and thickness. The tests were done under standard testing conditions - temperature: 21 ± 1 °C and relatively humidity: 65 ± 2%.

Figure3.4 Compression tester

3.2.3.2 Surface property

The KES-FB4 measures properties of friction and geometric roughness of the surface of textiles in both the warp and filling direction. The sample is pulled tight by applying a tension load of 20 gf/cm for a standard test. The surface friction is then measured with a set of 10 parallel piano wires with a diameter of 0.5 mm. These wires are pressed against the fabric with a force of 50 gf by a dead weight. The sample is then moved between 2 cm intervals at a constant velocity while the contactor of piano wires is kept stationary in order to record a measurement of resistance. A similar procedure is used to measure the surface roughness but the difference is that the contactor is made of only one piano wire. The contact is pressed against the fabric with a force of 10gf and the device records the vertical movements of the probe.

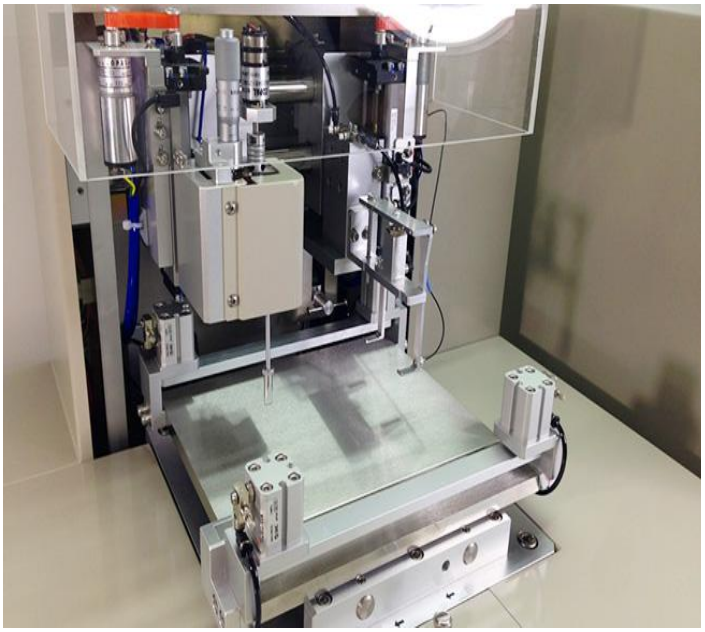

Figure 3.5 surface property tester

3.2.3.3 Air Permeability

FX 3300 Air Permeability Tester III is used for fast, simple, and accurate determination of the air permeability of flat materials ranging from dense, coated fabrics to open paper making felts. The instrument operates automatically and digitally in accordance with AFNOR G 07-111, ASTM D 737, standards. The specimen was clamped over the test head opening by pressing down the clamping lever which automatically starts the suction pump. The preselected test pressure was automatically set and maintained, and after a few seconds the air permeability of the test specimen is digitally displayed in the pre-selected unit of measure. By pressing down the clamping lever a second time the test specimen is released and the suction pump is shutoff. The air flow through the test specimen is measured with a variable orifice. The air permeability of the test specimen is determined from the pressure drop across this orifice, and is digitally displayed in the selected unit of measure for direct reading.

Figure 3. 6FX 3300 Air permeability tester

3.2.4. Data analysis

3.2.4.1. Fabric property analysis

Test data will be analyzed by using one-way Analysis of Variance (ANOVA) using SPSS software. One-way ANOVA examines equality of population means for a quantitative out- come and a single categorical explanatory variable with any number of levels. The term one- way, also called one-factor, indicates that there is a single explanatory variable ("treatment") with two or more levels, and only one level of treatment is applied at any time for a given subject. We have two hypothesis: first hypothesis is there is no difference in mean values of the properties of fabric (bursting strength, abrasion resistance, pilling resistance, air permeability and surface property) when there is change in spinning system. The second hypothesis is that there is mean difference between values of properties of fabric (bursting strength, abrasion resistance, pilling resistance, air permeability and surface property) when there is a change in spinning system. To determine whether any of the differences between the means are statistically significant, compare the sig. value (p-value) to significance level to assess the null hypothesis. The null hypothesis states that the population means are all equal. Usually, a significance level (denoted as α or alpha) of 0.05 works well. A significance level of 0.05 indicates a 5% risk of concluding that a difference exists when there is no actual difference. P values = the probability that the observed result was obtained by chance. P-value ≤ α: the differences between some of the means are statistically significant. If the p-value is less than or equal to the significance level, you reject the null hypothesis and conclude that not all of population means are equal. P-value > α: the differences between the means are not statistically significant. If one-way ANOVA p-value is less than significance level, it's to mean that some of the group means are different, but not which pairs of groups. Use the grouping information table and tests for differences of means to determine whether the mean difference between specific pairs of groups are statistically significant and to estimate by how much they are different by Using multiple comparisons to assess differences in group means. An F ratio is calculated - variance between the groups divided by the variance within the groups. Large F ratio means more variability between groups than within each group. The values of the F-statistic tend to fall around 1.0 when the null hypothesis is true and are bigger when the alternative is true So if we can compute the sampling distribution of the F statistic under the null hypothesis, then we will have a useful statistic for distinguishing the null from the alternative hypotheses, where large values of f argue for rejection of null hypothesis

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

4.1.1. Determination of Mechanical properties

Knitted fabrics were subjected to friction, pressure, stretch and other body movement related forces. The ability of knitted fabric to withstand different forces is determined by its mechanical properties. The knitted fabrics mechanical properties include bursting strength, abrasion and pilling resistance, extension and its recovery, In this study, mechanical properties such as bursting strength, abrasion resistance and pilling resistance are studied on both single jersey knitted fabrics by using ring and rotor spun yarn.

4.1.1.1. Bursting strength

Bursting strength is the distending force, which is applied at right angle to the plane of the fabric under specified conditions, which will result in rupture of knitted fabrics. This force is distributed to all parts of the knitted apparel (ASTM D 3786-01). The force is in the form of pressure applied hydraulically. The results are obtained by performing proper tests as per ASTM D3786-01termed as standard test method for hydraulic bursting strength of textile fabrics – diaphragm bursting strength test method and digital bursting strength tester is used. The knitted fabric samples for this test are single jersey knitted fabrics produced from ring and rotor spun yarns and the results are shown in Table 4.1 below.

Table4.1 Bursting strength of knitted fabrics tested by diaphragm bursting taste

Fabric type	Sample no	Bursting strength (bar)									
		1	2	3	4	5	6	7	8	9	10
Single jersey	Ring yarn	6.27	6.81	6.75	6.65	7.33	6.75	6.81	7.13	6.92	6.80
	Rotor yarn	4.63	4.74	5.18	5.13	4.70	4.92	5.02	4.74	4.59	4.69

4.1.1.2. Abrasion resistance

Abrasion is the wearing a way of any part of a textile material by rubbing against another surface (ASTM D4966-98). This is due to the friction between the cloth and other materials when we sit, work, wear, sleep etc. This determines the service time of the fabric for specific application. The specimens were tested as directed in ASTM D4966-98 with option 3 to determine the mass loss as the difference between the masses before and after abrasion. This loss may be expressed as a percentage of the before abrasion mass. The differences in the two weights (i.e. fabric before and after abrasion was calculated and finally the percentage of abrasion loss) were derived and the results are shown below in Table 4.2.

$$AR\% = \frac{\text{Original weight} - \text{Weight loss}}{\text{Original weight}} \times 100$$

Table4.2 weight loss %

Fabric type	Sample no	weight loss%					
			1	2	3	4	5
Single jersey	Ring yarn	Before(mg)	10.4	9.59	10.2	9.02	10.7
		After (mg)	10.2	9.49	10.1	8.92	10.6
		Weight loss %	2.23	1.03	1.21	1.07	1.06
	Rotor yarn	Before (mg)	10.2	10.2	9.65	9.32	10.2
		After (mg)	9.84	9.87	9.36	9.04	9.92
		Weight loss %	3.11	3.08	2.98	2.96	3.02

4.1.1.3. Piling property

Pills are bunches or balls of tangled fibers, which are held to the surface of a fabric by one or more fibers. Fuzz is tangled fiber ends that protrude from the surface of a yarn or fabric (ASTM D4970). This pills/fuzz can be formed by friction of apparel with other fabrics or materials.

The specimens were tested as directed by ASTM in Test Method D4970 termed as Standard Test Method for Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Martindale pilling Tester is used to assessing the pilling resistance. The materials or products sampled are single jersey knitted fabrics and laboratory sampling method is used. The fabric is in its raw state or tested before washing subjected for 100 movements. The rating standard is used for rating of individual specimens for pilling. Ratings of each individual specimen for pilling, the average rating of the specimens from each laboratory sampling unit, and the average are reported in Table 4.3-4below.

Table 4.3 Pilling test result for single jersey knitted fabric produced from ring spun yarn

	Single jersey ring spun yarn				
	Day 1		Day 2		
	Operator 1	Operator 2	Operator 1	Operator 2	Movement
Rating	1.5	1.5	1.5	1.5	100
	1.5	1.5	1.5	1.5	
	1.5	2.0	1.5	2.0	
	2.0	1.5	2.0	1.5	
	1.5	2.0	1.0	1.5	
Average	1.6	1.7	1.5	1.6	
Total average	1.6				

Table 4.4 Pilling test result for single jersey knitted fabric produced from Rotor spun yarn

	Single jersey rotor spun yarn				
	Day 1		Day 2		
	Operator 1	Operator 2	Operator 1	Operator 2	Movement
Rating	3.5	2.5	3.0	3.0	100
	3.0	2.5	3.0	2.5	
	3.0	3.0	3.5	2.5	
	3.5	3.0	3.0	3.0	
	3.5	2.5	2.5	3.5	
Average	3.3	2.7	3	2.9	
Total average	3.0				

4.1.2. Determination of Comfort properties

Knitted fabrics are selected for their comfort properties as they allow free body movement, permeable to air and water, soft hand feel because of their low twist of yarn, smooth appearance as they are bulk in nature and flexibility. Knitted fabrics comfort can be characterized by air permeability, wicking rate, moisture absorption, drape coefficient, thermal conductivity, bending resistance and stiffness. In this study, air permeability property of the two fabrics will be determined and discussed in detail

4.1.2.1. Air permeability

Air permeability is defined as the volume of air in milliliters which is passed in one second through 100mm^2 of the fabric at a pressure difference of 10mm head of water. The air permeability of a fabric is a measure of how well it allows the passage of air through it (ASTM D737-04). Air permeability can be used to provide an indication of the breathability of weather resistant and rainproof fabrics, or of coated fabrics in general, and to detect changes during the manufacturing process.

It is determined in accordance with ASTM Test Method D737-04. The materials or products sampled are single jersey knitted fabrics and laboratory sampling method using FX3300 air permeability tester. The results are indicated in Table 4.5. The test was carried out at ten different places per sample as per ASTM standard D737. The reading was noted in cm^3/cm^2/s.

Table 4.5 Air permeability single jersey made from ring and rotor spun yarn

Fabric type	Sample no	Air permeability $Cm^3/cm^2/s$									
		1	2	3	4	5	6	7	8	9	10
Single jersey	Ring yarn	141	139	140	129	132	127	122	128	135	147
	Rotor yarn	163	151	180	168	155	152	140	180	151	170

4.1.2.3. Compression

The knitted fabric samples for this test are single jersey knitted fabrics produced from ring and rotor spun yarns the test was carried out on Kawabata KES-FB3 compression tester and the results are shown in Table 4.6 below.

Table 4.6Test record for compression

Fabric type	Sample no	Compression %									
		1	2	3	4	5	6	7	8	9	10
Single jersey	Ring yarn	4.12	4.22	4.16	4.09	4.20	4.25	4.08	4.13	4.20	4.13
	Rotor yarn	6.91	6.82	6.99	6.92	6.94	6.86	6.99	6.92	6.84	6.99

4.1.2.4 Surface property

The knitted fabric samples for this test are single jersey knitted fabrics produced from ring and rotor spun yarns the test was carried out on Kawabata KES-FB4 surface tester and the results are shown in Table 4.7 below.

Table 4.7 Test record for surface roughness

Fabric type	Sample no	Surface roughness µm									
		1	2	3	4	5	6	7	8	9	10
Single jersey	Ring yarn	2.2	1.99	2.27	2.34	2.27	2.3	1.94	2.25	2.29	2.31
	Rotor yarn	1.05	0.94	1.32	1.03	1.91	1.32	1.09	1.28	1.23	1.29

4.2 Discussion

The study focuses on Comparative Study of Mechanical and Comfort Properties of Single Jersey Fabrics knitted using ring and rotor spun yarn and the analysis was done to compare the two fabric properties. Properties such as mechanical and comfort are proposed to be studied. e. From this property the analysis was done on the properties such as bursting strength, abrasion and pilling resistance air permeability surface and compression properties. For the analysis, one way ANOVA in SPSS and MS Excel are used

4.2.1 Mechanical properties

4.2.1.1 Bursting strength

The bursting strength of single jersey weft knitted fabrics made out of ring and rotor spun yarns were studied and as shown in Figure 4.1 the test result for bursting strength greater for ring spun kitted fabric (6.822 bar) than rotor spun yarns (4.834 bar) Table 4.8 indicating that the mean difference between the two fabrics are statistically different and highly significant It is confirmed with ANOVA analysis that p value is less than 0.05 at 95% confidence level, indicating significant differences in bursting strength of ring and rotor spun yarn. Knitted fabric from ring spun yarns have higher bursting strength than rotor spun yarn due to the fact that the work of rupture of rotor yarn (which is a product of strength and Elongation) is much lower than that of ring spun yarn and rotor spun yarn is less strong than comparable ring spun yarn. This is because of the straight, parallel arrangement of fibers and denser packing of fibers in ring spun yarn which contrast with the higher number of disoriented folded fibers in rotor spun yarn.

Table 4.8 Analysis of variance for bursting strength

		Sum of Squares	Df	Mean Square	F	Sig.
Bursting strength*fabric type	Between Groups (combined)	19.761	1	19.761	319.064	.000
	Within groups	1.115	18	.062		
	Total	20.876	19			

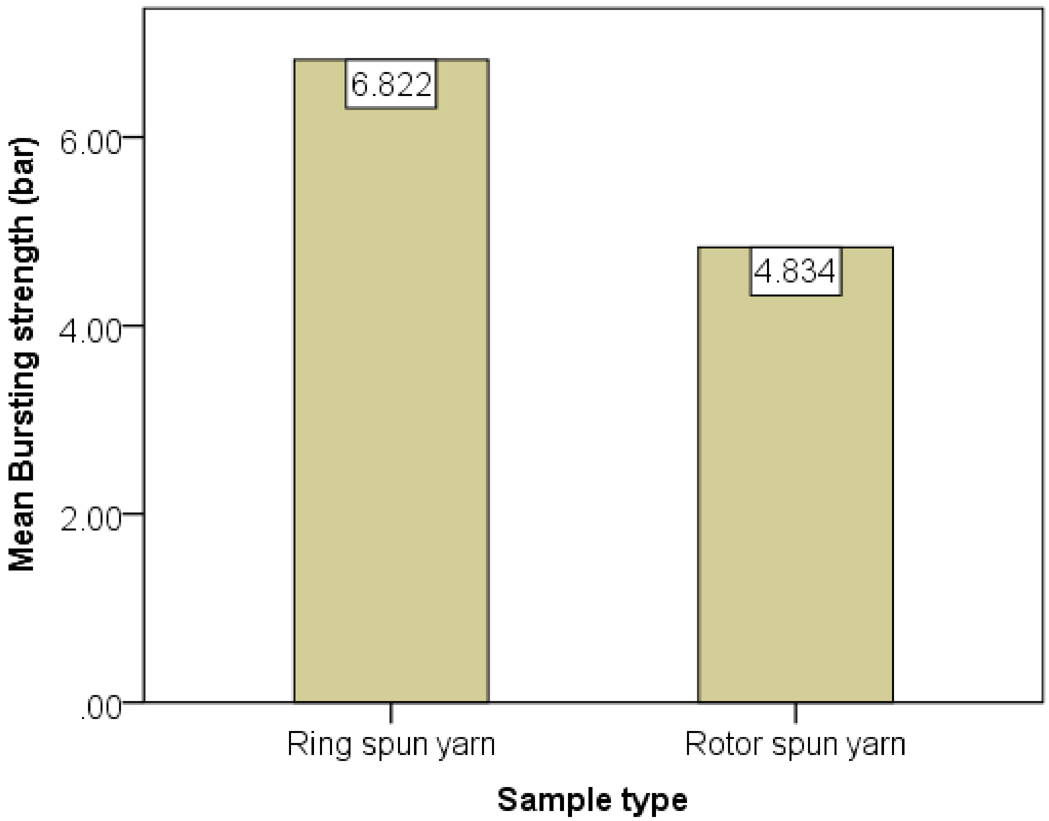

Figure 4.1Mean bursting strength value of ring and rotor spun knit single jersey fabric

4.2.1.2 Pilling property

The extent of pilling is assessed visually by comparison with the arbitrary standards. Pilling characteristics of single jersey weft knitted fabrics made out of ring and rotor spun yarns were studied and their piling grads are given in Figure 4.2. Rotor spun yarn knitted fabric showed 3-4 scale pilling grades as compared to Ring spun yarn. The piling grads of the samples shows that the fabrics knitted from Rotor spun yarns better than the knit from Ring spun yarn this maybe because ring spun yarns are more hairy than rotor spun yarn, which may allow easy exposure of raised fiber ends to abrading force.

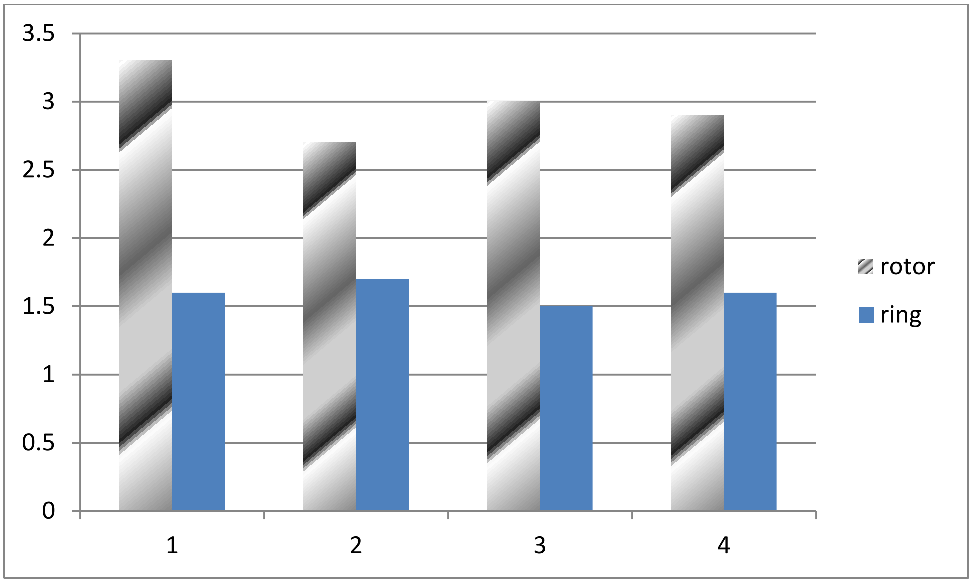

Figure 4.2 piling resistance

4.2.1.3 Abrasion resistance

The abrasion resistance of single jersey weft knitted fabrics made out of ring and rotor spun yarns were studied as shown in Figure 4.2 the test result for mean weight loss % for ring spun kitted fabric (1.32) less than rotor spun yarns (3.03) and Table 4.9 shows that the mean difference between the two fabrics are statistically different and highly significant It is confirmed with ANOVA analysis that p value is less than 0.05 at 95% confidence level, indicating significant differences in abrasion resistance of ring and rotor spun yarn. The fabrics knitted from rotor spun yarn have higher weight loss value than ring spun yarn, perhaps because the wrapping fibers gradually break due to the abrasive forces, facilitating the removal of loose fibers from the yarn structure.

Table 4.9 Analysis of variance of abrasion resistance of ring and rotor spun yarn

	Sum of Squares	Df	Mean Square	F	Sig.
Abrasion Between Groups (combined)	7.327	1	7.327	25.229	.001
strength*fabric Within groups	2.323	8	.290		
type Total	9.651	9			

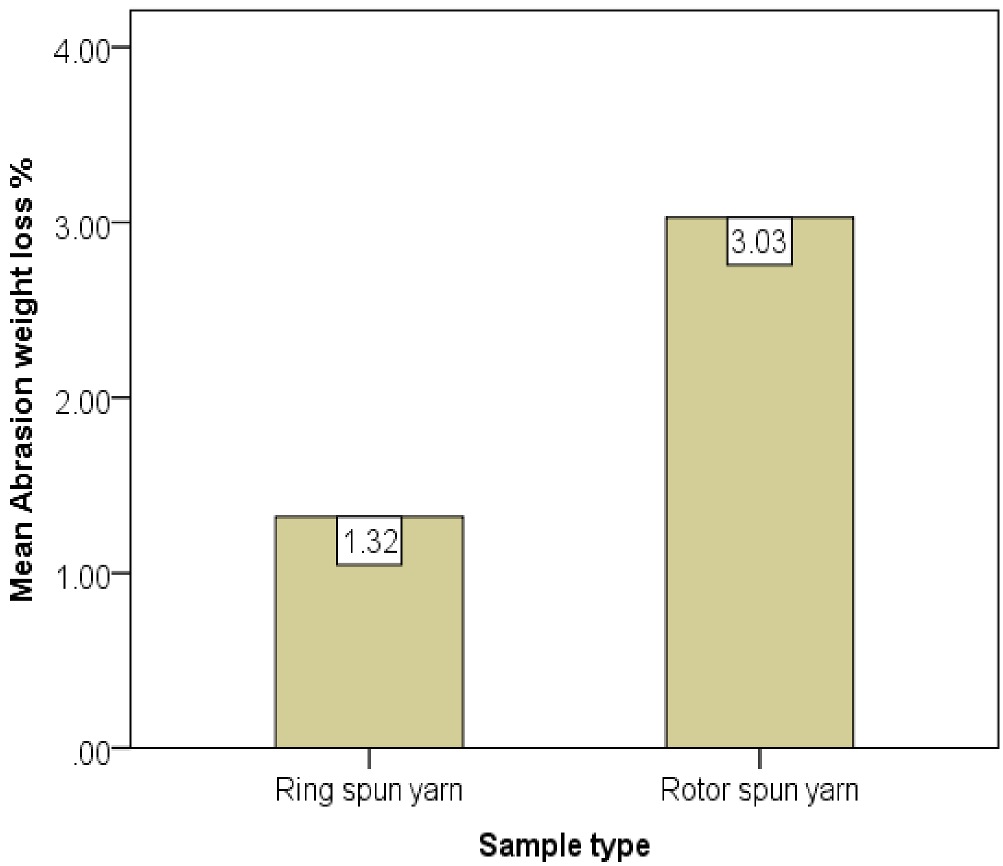

Figure 4.3 Mean weight loss % ring and rotor spun yarn single jersey knitted fabric

4.2.2 Comfort properties

4.2.2.1 Air permeability

The Air permeability of single jersey weft knitted fabrics made out of ring and rotor spun yarns were studied. as shown in Figure 4.3 the test result for air permeability greater for rotor spun kitted fabric (161 $Cm^3/cm^2/s$) than spun yarns (134 $Cm^3/cm^2/s$) and Table 4.10 shows that the mean difference between .2.the two fabrics are statistically different and highly significant It is confirmed with ANOVA analysis that p value is less than 0.05 at 95% confidence level, indicating significant differences in air permeability of ring and rotor spun yarn. The fabrics knitted from rotor spun yarn have higher air permeability value than ring spun yarn due to fiber in rotor yarn are less packed than ring yarn, Rotor yarns known to be bulkier than ring yarn across the cross-section.

Table 4.10 Analysis of variance of Air permeability

	Sum of Squares	Df	Mean Square	F	Sig.
Air permeability Between Groups (combined)	3645.000	1	3645.000	30.488	.000
strength*fabric type Within groups	2152.000	18	119.556		
Total	5797.000	19			

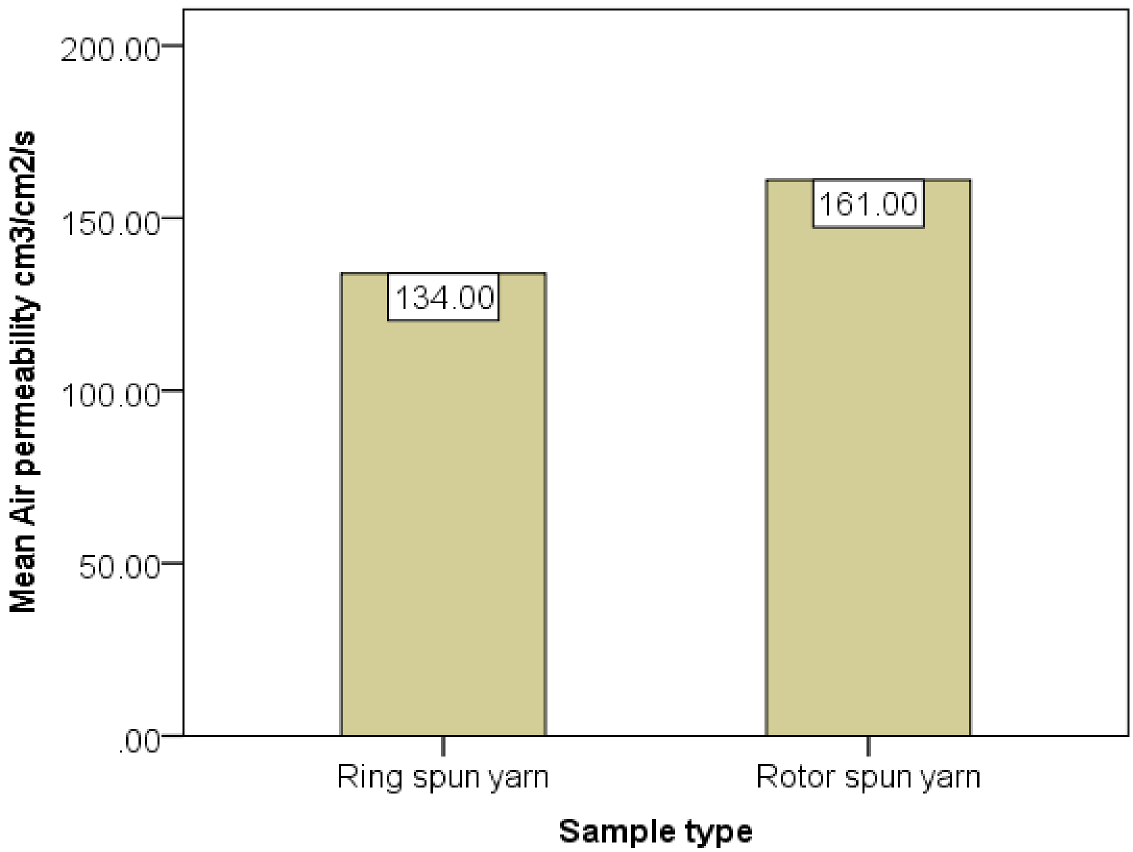

Figure 4.4 Mean air permeability of ring and rotor spun yarn of single jersey knitted fabrics

4.2.2.2 Compression property

Compression property of single jersey weft knitted fabrics made out of ring and rotor spun yarns were studied. As shown in Figure 4.4 the test result for compressibility greater for rotor spun kitted fabric (4.158 %) than spun yarns (6.90%) and Table 4.11 shows that the mean difference between the two fabrics are statistically different and highly significant It is confirmed with ANOVA analysis that p value is less than 0.05 at 95% confidence level, indicating significant differences in compression property of ring and rotor spun yarn. The fabrics knitted from rotor spun yarn have higher compression value than ring spun yarn; the value of compression is closer to 1 it is difficult to compress so fabrics knitted from ring yarn is difficult to compress than rotor spun yarn due to the fact that The compressibility of a fabric mainly depends on yarn packing density and yarn spacing in the fabric. Compressibility provides a feeling of bulkiness and spongy property in the fabric .

Table 4.11Analysis of variance for Compression property

		Sum of Squares	Df	Mean Square	F	Sig.
Compression (combined) *fabric type	Between Groups	19.069	1	19.069	45.400	.000
	Within groups	3.360	8	.420		
	Total	22.429	9			

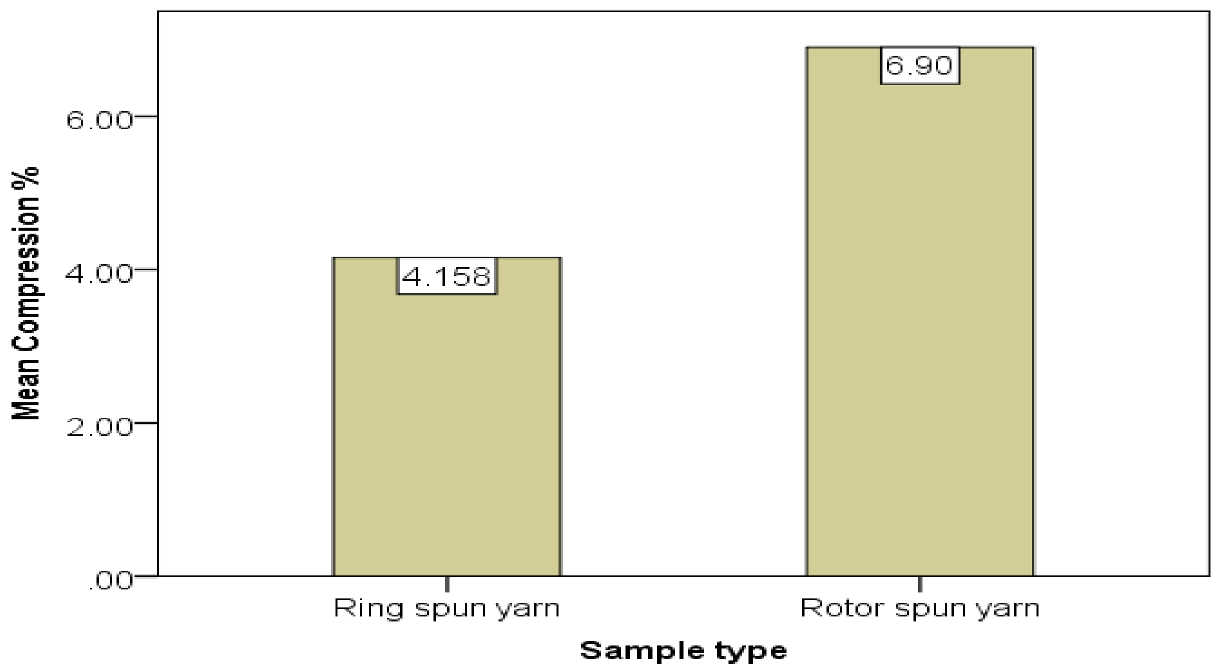

Figure 4.5 Mean compression value

4.2.2.3 Surface property

Surface roughness property of single jersey weft knitted fabrics made out of ring and rotor spun yarns were studied. As shown in Figure 4.5 the test result for surface roughness greater for ring spun kitted fabric (2.215 µm) than rotor spun yarns (1.245 µm) and Table 4.12 shows that the mean difference between the two fabrics are statistically different and highly significant It is confirmed with ANOVA analysis that p value is less than 0.05 at 95% confidence level, indicating significant differences in roughness of ring and rotor spun yarn. The fabrics knitted from ring spun yarn have higher roughness value than rotor spun yarn due to the fact that ring yarns are more compact than the rotor yarns.

Table 4.12 analysis of variance for surface roughness

		Sum of Squares	Df	Mean Square	F	Sig.
Surface Roughness *fabric type	Between Groups (combined)	2.350	1	2.357	20.125	.002
	Within groups	.934	8	.117		
	Total	3.285	9			

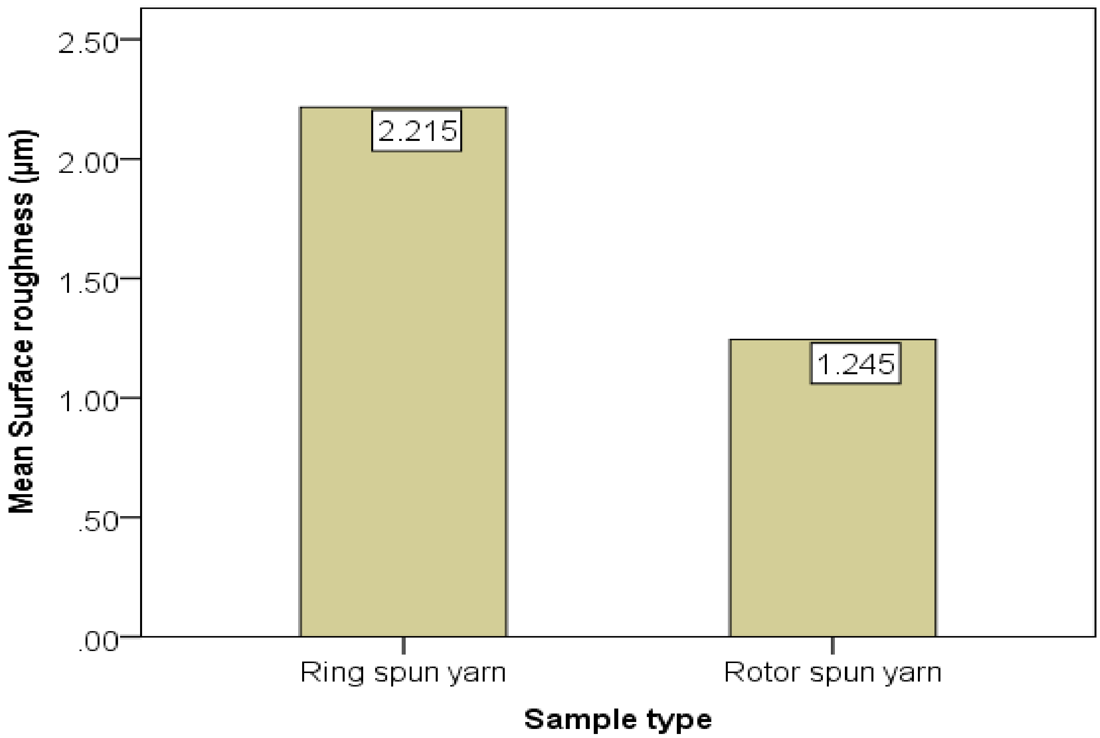

Figure 4.6 Mean roughness value of ring and rotor spun knitted fabrics

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Mechanical and comfort Properties of Single Jersey Fabrics knitted using ring and rotor spun yarn were studied. The properties studied in this thesis include some of the mechanical and comfort properties. Mechanical properties such as bursting strength, abrasion and pilling resistances were studied to compare the results of the two yarns namely ring and rotor spun yarns. The bursting strength of open end spun yarns tends to be weaker, which results in lower bursting strength. And because of the hairiness of ring spun yarns tend to pill more. As far as abrasion resistance is concerned, ring spun fabrics perform slightly better than open end spun yarns. In general the mechanical properties improved with higher twist since the constituent fibers bound to the body of the yarn that increases the internal interaction force between fibers of the yarn.

Comfort properties such as surface, air permeability and compression properties were studied and the results of the two yarn types was significantly influencing. The fabrics knitted from rotor spun yarn have higher air permeability value than ring spun yarn due to fiber in rotor yarn are less packed than ring yarn, The fabrics knitted from rotor spun yarn have higher roughness value than ring spun yarn. Finally, So far as a compression property is concerned the fabrics knitted from ring spun yarn have higher compression value than rotor spun yarn.

5.2 Recommendation

Depending on the type of knitted fabrics applications, the properties to be employed in the yarns as well as in the fabrics will be different. The MAA garment and textile factory produces knitted fabrics for apparel application especially for shirts and under wears.

From this study, we have found that the yarn structure and property (ring/rotor spun yarn) has got a strong influence on both the mechanical and comfort properties of the single jersey knitted fabrics. Mechanical and comfort properties are crucially important properties. From mechanical properties higher bursting strength, abrasion and pilling resistances are preferred and these can be achieved from ring spun knitted fabric except pilling. Air permeability, compressibility and surface friction are the main comfort properties and it is usually preferred with high permeability and easily compressibility level. High air permeability and compressibility can be obtained from rotor spun knitted fabric. Therefore, it is recommended that the mill technologists need to select the yarn type based on the desirable characteristics of the single knitted fabrics and as per the end use requirements. It is also recommended not to mix these yarns unless otherwise it is desirable as per the design requirements

REFERENCES

Akaydin, M., & Can, Y. (2010). Pilling Performance and Abrasion Characteristics of Selected Basic Weft Knitted Fabrics. *FIBRES & TEXTILES in Eastern Europe*, *18*(2), 51-54. Retrieved from http://www.fibtex.lodz.pl/2010/2/51.pdf

Alston, P. V. (1992). Effect of Yarn Spinning System on Pill Resistance of Polyester/Cotton Knit Fabrics. *Textile Research Journal*, *62*(2), 105-108. doi:10.1177/004051759206200208

Bhattacharya, S. S., &Ajmeeri, A. R. (2013). Investigation of Air Permeability of Cotton & Modal Knitted Fabrics. *International Journal of Engineering Research and Development* , *6*(12), 1-6. Retrieved from http://www.ijerd.com/paper/vol6-issue12/A06120106.pdf

Burnip, M. S., &Saha, M. N. (1973). 12—The Dimensional Properties of Plain-Knitted Cotton Fabrics Made From Open-End-Spun Yarn. *The Journal of The Textile Institute*, *64*(3), 153-169. doi:10.1080/00405007308630426

Candan, C., Nergis, U., &Iridağ, Y. (2000). Performance of Open-End and Ring Spun Yarns in Weft Knitted Fabrics. *Textile Research Journal*, *70*(2), 177-181. doi:10.1177/004051750007000215

Candan, C., &Önal, L. (2002). Dimensional, Pilling, and Abrasion Properties of Weft Knits Made from Open-End and Ring Spun Yarns. *Textile Research Journal*, *72*(2), 164-169. doi:10.1177/004051750207200213

Characteristics of jersey | URBANARA UK. (n.d.).

Hannan, M. A., Islam, M. M., & Sheikh, S. (2014). EffectOf Yarn Count & Stitch Length on Shrinkage, Gsm And Spirality Of Single Jersey Cotton Knit Fabric. *European Scientific Journal*, *10*(36), 188-199. Retrieved from eujournal.org/index.php/esj/article/download/4897/4675

Kane, C., Patil, U., &Sudhakar, P. (2007). Studies on the Influence of Knit Structure and Stitch Length on Ring and Compact Yarn Single Jersey Fabric Properties. *Textile Research Journal*, *77*(8), 572-582. doi:10.1177/0040517507078023

Khalil, E., &Solaiman, M. (2014). Effect of Stitch Length on Physical and Mechanical Properties of Single Jersey Cotton Knitted Fabric. *International Journal of Science and Research*, *3*(9), 593-596. https://www.academia.edu/8270336/Effect_of_Stitch_Length_on_Physical_and_Mechanical_Properties_of_Single_Jersey_Cotton_Knitted_Fabric

Lord, P., Mohamed, M., &Ajgaonkar, D. (1974). The Performance of Open-End, Twistless, and Ring Yarns in Weft Knitted Fabrics. *Textile Research Journal*, *44*(6), 405-414. doi:10.1177/004051757404400601

Manonmani, G., Vigneswaran, C., Chandrasekaran, K., &Ramachandran, T. (2013). Effect of Ring and Compact Cotton Spun Yarn characteristics on Physical and Comfort Properties of Knitted Fabrics. *Research Journal of Textile and Apparel*, *17*(3), 68-82. doi:10.1108/rjta-17-03-2013-b008

Mukherjee, S., &Chindalia, S. C. (1983). Comparative Performance of Open-end Spun Yarn and Ring-spun Yarn In Single Jersey Weft-knitted Hosiery Fabric. *Indian Journal of Fibre& Textile Research*, *8*(83), 121-124.

Prakash, C., &Ramakrishnan, G. (2013). Study of Thermal Properties of Bamboo/Cotton Blended Single Jersey Knitted Fabrics. *Arabian Journal for Science and Engineering*, *39*(3), 2289-2294. doi:10.1007/s13369-013-0758-z

Rahman, S., &Smirithi, S. A. (2015). Investigation on the Changes of Areal Density of Knit Fabric with Stitch Length Variation on the Increment of TuckLoop Percentages. *Journal of Polymer and Textile Engineering*, *2*(3), 1-4. Retrieved from http://www.iosrjournals.org/iosr-jpte/papers/Vol2-issue3/A0230104.pdf

Ramachandran, T., Manonmani, G., &Vigneswaran, C. (2010). Thermal behavior of ring and compact spun yarn single jersey, rib and interlock knitted fabrics. *Indian Journal of Fibre& Textile Research*, *35*, 250-257.

Rameshkumar, C.,Anandakumar, P.,Senthilnathan, P.,Jeevitha, R.,&Anbumani, N. (2008). COMPARITIVE STUDIES ON RING ROTOR AND VORTEX YARN KNITTED FABRICS. *AUTEX Research Journal*, *8*(4), 100-105.

Zdil, N., Zelik, G., &Spren, G. (2012). Analysis of Abrasion Characteristics in Textiles. *Abrasion Resistance of Materials*. doi:10.5772/29784