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Effect of Twist Multipliers on Air Permeability of Single Jersey and 1 x 1 Rib Fabrics

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ABSTRACT

Different researchers have worked on air permeability of knitted fabrics in relation to yarn count, tightness factor, fabric structures, loop length and finishing process. But the study of twist multiplier effect on knitted fabrics air permeability properties received minimum attention. This paper focuses on effect of twist multiplier on air permeability property of single jersey and rib1x1 knitted fabrics. For this study three yarn twist levels namely 900 turns/m, 1050 turns/m and 1200 turns/m with respective twist multipliers (TM) of 3.6, 4.2 and 4.8 were used. The yarn count used for this research was 40Ne made of 100% cotton carded ring spun yarn. From the results, the air permeability of fabrics is affected by twist multipliers differently and the effect is significant as shown in this study briefly and clearly. For this study all yarn, spinning and knitting parameters and properties are kept constant for all of the three twist multipliers. The twist multiplier is the only factor studied in order to determine its effect on the two fabrics air permeability property.

Keywords: single jersey, 1x1 rib fabrics, air permeability, twist multiplier

1. Introduction

Knitting is the process of forming fabrics by interloping yarn in a series of connected loops using needles. Knit fabrics provide outstanding comfort qualities and have long been preferred in many types of clothing.

Knitted fabrics are known for their excellent comfort properties. They possess high extensibility under low load allowing comfortable fit on any part it is pulled onto. Due to the manner in which yarns and fabrics are constructed, a large proportion of the total volume occupied by a fabric is usually airspace (Serin (Mavruz) Mezarcioz, R.Tugrul Ogulata, 2010). Such knitted structures have a more open character when compared to other textile fabric structures, such as woven and braided. This character gives better air permeability for knitted fabrics as compared to other fabrics.

Permeability and porosity are strongly related to each other. If a fabric has very high porosity, it can be assumed that it is permeable (R. Ogulata R.T., Mavruz S., 2010).

Air permeability is 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 *(Saville 2000)*.

Air permeability of a fabric can affect fabrics comfort behaviours 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 vapour or the liquid phase. Thus, the moisture-vapour 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 (*S.S. Bhattacharya and J.R. Ajmer, 2013)*.

Air permeability is an important factor in the performance of such textile materials as gas filters, fabrics for air bags, clothing, mosquito netting, parachutes, sails, tents, and vacuum cleaners. In filtration, for example, efficiency is directly related to air permeability (*ASTM-D 737-2012*).

Air permeability has a decisive influence on utilization of fabric for some technical applications (filters, parachutes, and sails) and clothing application as well. Air permeability is a measured by the ease with which the air passes through the material (Ghada Ahmad Mohamad, 2015).

Air permeability also 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.

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. The effect of the loop length has more influence on porosity than the stitch density and the thickness. Increasing loop length, looser the structure and so the values of air permeability increases *(Bhattacharya and Ajmeri, 2013)*.

The researchers did not consider the effect of yarn twist on air permeability property of single jersey and rib1x1 knitted fabrics. This research is designed to study the effect of yarn twist level (multiplier) on knitted Air permeability property by collecting different data and samples.

2. Methodology

2.1. Methods

Cotton fiber is dominantly used for circular knitting machines in Ethiopia and its properties are identified for this study. The yarn parameters, excluding of yarn twist, were kept constant. Theair permeability offabricsproduced from three different twist multipliers of yarn with the same material and machine setting and parameters was studied.

The methods for this study are listed below.

- Produce yarn with different twist level with other yarn parameters kept constant
- Study yarn properties by carrying out yarn testing
- Produce knitted fabrics from the three different twist levels of yarn.
- Study the fabric air permeability property by carrying out testing
- Analyze the results obtained from testing

The data related to this research work is collected from MAA garment and textile factory, Kombolcha textile Share Company and from EiTEX laboratory (all are located in Ethiopia). Relevant data related to effect of yarn twist on knitted fabric properties include fiber properties, spinning machine parameters, yarn parameter, knitting machine parameters, knitted fabric articles, properties and test results are collected. The materials and equipment listed in table 1 were used to collect the data for this research work.

Table 1. Equipment

S/r No.	Name of equipment	Tests	Located in
1	Atlas twist Tester	Twist	MAA
2	Atlas Count Tester	Linear desity of yarn	MAA
3	Uster tester-5	U%, CVM, Thin, Thick, Nep	MAA
4	Cutting Dies	GSM, Abrasion, Pilling, Bursting,	MAA, EiTEX
5	Air permeability tester (FX3300)	Air permeability	EiTEX
6	Tensile tester for yarn	Yarn tensile strength	EiTEX

2.2. Properties and specifications of materials

2.2.1. Fiber Properties

Cotton fiber was used in this study because it is the dominant raw material in textile factories especially in Ethiopia. The test was done by randomly taking samples from five different bales and the average results are shown in Table 2.

Table 2. Fiber properties

Properties						
Type	**Origin**	**Staple length**	**Short fiber index**	**Nep**	**Trash %**	**Micronaire**
Cotton (100%)	Indian	30.6	10.4	207.4	3.58	3.78

2.2.2. Spinning Machine Parameters

The spinning machine parameters included in this work are related to ring spinning machine. In MAA garment and textile factory there are ten ring frame machine of which five for combed yarn and five for carded yarn.The following lists of data are about ring frame machine which used to produce the yarns with it for the yarn property analysis and sample fabric production.

- Material: carded, 100% cotton
- Twist: 900, 1050 and 1200
- Twist Factor: 3.6, 4.2 and 4.8
- RPM: 16000
- Traveler: 25
- Spacer: 3.0 (White)
- Break Draft: 1.19 (69T)

From this ring frame machine and spinning parameters only the twist level and twist multipliers are the factors designed to be studied its effect on air permeability property but the others are kept constant. The three twist levels with the respective twist multipliers are produced with the same machine settings and parameters. This research is designed to study the effect of twist multiplier on air permeability property of the two fabrics.

2.2.3. Yarn Parameters

This work is designed to study the effect of yarn twist on knitted fabric properties by testing the yarn and fabric sample using Zweigle Uster Tester standard and are used for analysis of the yarn properties related to twist effect. The data collected from MAA during yarn production with different twist levels are indicated below in Table 3.

Table 3. Yarn specifications

Machine type	Machine number	Twist (1/m)	Ne	U%	CVM	Thin_50 %	Thick+50 %	Neps+200 %
Ring frame	07	900	40	13.97	17.90	38.8	612.8	844
		1050	40	13.88	17.83	31.6	646.8	827.8
		1200	40	13.53	17.37	24.4	557.6	791.6

2.2.4. Produced Fabric Parameters

The fabrics produced to study the air permeability are of two different articles. These are single jersey and rib1x1 knitted fabrics of which produced from three different twist levels. The sample fabrics were produced with one roll and the required sample sizes are taken as per ASTM different designation for different tests. The fabrics were produced with the machine parameter as shown in Table 4.

Table 4. Fabric specifications

M/c type	Machine number	Speed (rpm)	Machine Diameter (inch)	Number of needles	Gauge	Needle type	Number of feeder	Number of cam track	Type of structure
MAYER & CIE	60	20	34	2976	28	Latch	108	4	Single jersey
	99		30	1404	15		62	2	Rib(1x1)

3. Experimental Determination of Air Permeability

Air permeability property of single jersey and rib1x1 knitted fabricswas determined by using ASTM D 737-2012. The Fabrics sampled were single jersey and rib 1x1 and tested in thelaboratory using FX3300 air permeability tester. The test results are recorded for ten specimens for each twist multiplier and recorded in Table 5.

Table 5. Air permeability test records of knitted fabrics produced from different TM

Fabric type	Sample number	Air permeability ($cm^3/cm^2/s$) in ten tests for each sample										Average
		1	2	3	4	5	6	7	8	9	10	
Single jersey	Sj1	250	252	241	245	240	240	245	245	253	248	245.9
	Sj2	283	307	308	288	279	304	293	295	304	299	296
	Sj3	325	352	348	343	333	340	327	335	336	339	337.8
Rib 1x1	R1	291	277	273	305	294	309	289	278	296	279	289.1
	R2	324	330	318	330	341	332	327	335	332	325	329.4
	R3	357	359	338	391	354	372	368	359	384	379	366.1

4. Effect of Yarn Twist multiplier on Air Permeability of Knitted Fabrics

Air permeability of knitted fabrics was studied on single jersey and rib1x1 produced from 900turns/m (3.6 TM), 1050turns/m (4.2 TM) and 1200turns/m (4.8 TM) of yarns and the fabrics were named Sj1, Sj2 and Sj3 for single jerseys, R1, R2 and R3 for rib1x1 knitted fabricsrespectively. Both single jersey and rib1x1 knitted fabrics were produced from these three twist multipliers (TM). As shown in table 5, the air permeability of knitted fabrics was affected by twist level in which it increases as twist multiplier increases. As shown in Figures 1 and 2, the air permeability of single jersey is lower than rib. This is because rib1x1 is more stable fabric from shrinkage as compared to single jersey and air is applied at face and reverse stitches equally. The other reason for the two fabrics different air permeability is rib fabrics have high resistance to robbing back of yarn during knitting. This resistance helps the needles to obtain long yarn during knitting. As shown in Figure 1 the difference between low and medium twist level and that of medium and higher level twist of knitted fabrics air permeability is uniform.

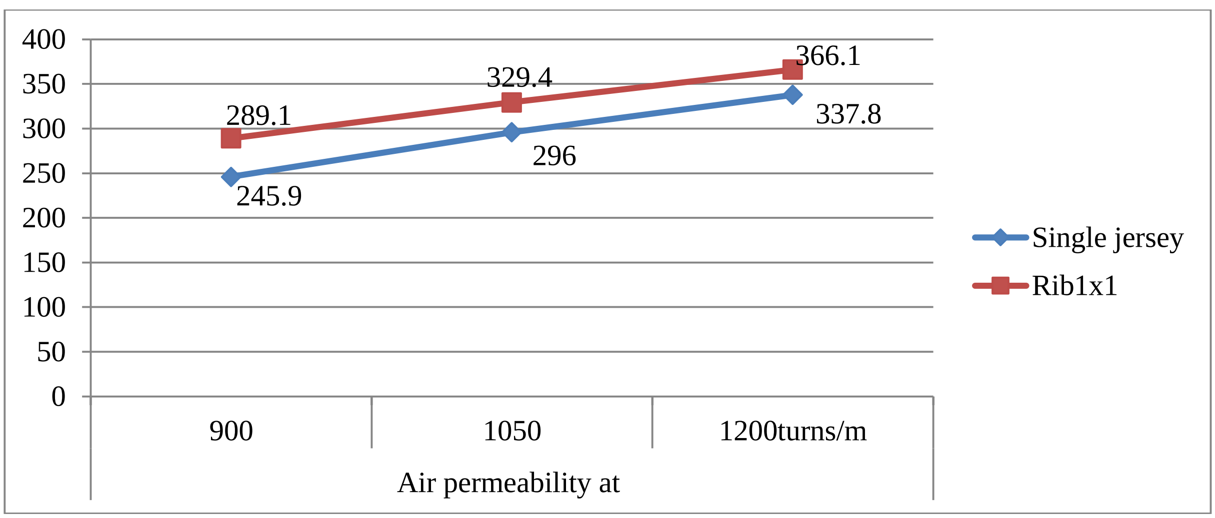

Figure 1. Effect of TM on air permeability of knitted fabrics

The air permeability of knitted fabrics was affected differently for single jersey and rib knitted fabrics. As shown in Figure 1,as the twist level increases the air permeability of knitted fabrics from lower level of twist to higher level of twist within the same structures i.e. either within single jersey or rib1x1. The permeability is higher in rib1x1 as shown in the Table 5 and Figure 1. This is due to the air pressure is applied in both the face and back of loops equally across the courses. Both technically face and reverse stitches are available in rib1x1in one side which increases the air permeability of the fabric. In single jersey the test was done in the technical face of the knitted fabric only which lowers the filtration capacity of single jersey relative to rib fabrics.

Knitted fabrics produced from lower level of twist are suitable for insulation because of its greater bulkiness nature whereas knitted fabrics produced from higher twist levels are suitable for filtration due to compacted and clearer surfaces are achieved in both single jersey and rib fabrics.The single jersey and rib1x1 knitted fabrics number of samples tested, mean of the air permeability, standard deviation and standard error are shown in the Table 6 (descriptive table) with the respective twist level (multiplier) as 900turns/m (3.6 TM), 1050turns/m (4.2 TM) and 1200turns/m (4.8 TM).

Table 6. Descriptive of air permeability of single jersey and rib1x1 knitted fabrics from different twist multipliers (generated from one-way ANOVA-SPSS)

		N	Mean	Std. Deviation	Std. Error
Air permeability of single jersey (cm3/cm2/s)	900	10	245.9000	4.77144	1.50886
	1050	10	296.0000	10.18714	3.22146
	1200	10	337.8000	8.52187	2.69485
Air permeability of rib knitted (cm3/cm2/s)	900	10	289.1000	12.26966	3.88001
	1050	10	329.4000	6.36309	2.01219
	1200	10	366.1000	15.86366	5.01653

Table 7. Multiple Comparisons of air permeability property of single jersey and rib1x1 knitted fabrics Tukey HSD

Dependent Variable	(I) Knitted fabrics produced from 900, 1050 &1200turns/m twist level	(J) Knitted fabrics produced from 900, 1050 &1200turns/m twist level	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Air permeability of single jersey (cm3/cm2/s)	900 (3.6 TM)	1050	-50.10000*	3.64387	.000	-59.1347	-41.0653
		1200	-91.90000*	3.64387	.000	-100.9347	-82.8653
	1050 (4.2 TM)	900	50.10000*	3.64387	.000	41.0653	59.1347
		1200	-41.80000*	3.64387	.000	-50.8347	-32.7653
	1200 (4.8 TM)	900	91.90000*	3.64387	.000	82.8653	100.9347

		1050	41.80000*	3.64387	.000	32.7653	50.8347
Air permeability of rib knitted (cm3/cm2/s)	900 (3.6 TM)	1050	-40.30000*	5.43255	.000	-53.7696	-26.8304
		1200	-77.00000*	5.43255	.000	-90.4696	-63.5304
	1050 (4.2 TM)	900	40.30000*	5.43255	.000	26.8304	53.7696
		1200	-36.70000*	5.43255	.000	-50.1696	-23.2304
	1200 (4.8 TM)	900	77.00000*	5.43255	.000	63.5304	90.4696
		1050	36.70000*	5.43255	.000	23.2304	50.1696

*. The mean difference is significant at the 0.05 level.

Air permeability property of both single jersey and rib1x1 knitted fabrics has significant mean difference at different twist levels (TM) which is shown in the ANOVA multiple comparisons Table (Table 7).
As shown in ANOVA table below, twist level or multiplier has significant effect on airpermeability of both single jersey and rib1x1 knitted fabrics.

The analysis was done by using ONE WAY ANOVA and gives significant value for each fabrics in which for single jersey F = 318.900 and Sig. (P) = 0.000 and for rib1x1 F = 100.522 and Sig. (P) 0.000.

The ANOVA table shows below that the result is due to the effect of twist multiplier in which mean square between groups is greater than mean square within groups.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Air permeability of single jersey (cm3/cm2/s)	Between Groups	42342.867	2	21171.433	318.900	.000
	Within Groups	1792.500	27	66.389		
	Total	44135.367	29			
Air permeability of rib knitted (cm3/cm2/s)	Between Groups	29666.600	2	14833.300	100.522	.000
	Within Groups	3984.200	27	147.563		
	Total	33650.800	29			

Knitted fabrics require low twist level but the ranges of this low twist level of yarn vary for different yarn count, structures and processibility. As twist multiplier increases the yarn bulkiness reduces since the constituent fibers bind to the body of the yarn compactly. The openness size in the fabric will not be changed but the opened spaces become clearer with high twist multipliers since the yarn hairiness become reduced to a high extent. This clearer surface on knitted fabric due to high twist level brings high permeable knitted fabrics. In general as twist level changes to higher level short and protruding fibers tend to bound to the body of yarn and the yarn become compacted and clearer.

Due to this, obstacles to air permeability in the fabric will be reduced to a high extent and more air can pass through the fabric in unit time. So, knitting technologist has to consider the level of yarn twist since it has significant mean difference which inturn shows its significant effect on knitted fabric's air permeability property. This is because of the twist level has an effect on yarn hairiness. With increased twist multipliers the yarn hairiness reduced for it is compacted and bound to the body of the yarn rather than protruding (but up to limited range of twist). This inturn insures the perfect porosity of the fabrics that allows the passage of air through it more easily. This is practical when other yarn properties, machine and processing parameters constantly controlled i.e. only twist level or twist multiplier vary.

5. Conclusion

The initial hypothesis of this research was one that the yarn twist multipliers have an effect on air permeability property of single jersey and rib1x1 knitted fabrics. The result of this research shows similar alternative hypothesis result to the null hypothesis by which the twist multiplier (TM) significantly affects the air permeability property of single jersey and rib1x1 knitted fabrics.

The air permeability of knitted fabrics is affected not only by yarn linear density, fabric tightness factor, loop length, stitch density and type of knitted structures but also by twist multipliers of yarn.

Air permeability property is vital for applications requiring ventilation and porosity.

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