Investigation of differential stretching properties of single jersey knitted fabrics on air permeability

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***Abstract*: In this study, air permeability of single jersey was investigated with variable stretching conditions in wales direction namely 10%, 20%, 30% and 40%. Types of yarn used for the study included ring spun yarn, rotor yarn and core and cover spun yarn with the count of 40 Ne. The loop length of the knit were kept at 0.35 cm, 0.40cm and 0.45 cm. Three types of relaxation treatment have been given to the fabrics namely dry relaxed, wet relaxed and fully relaxed treatments. Based on the experiments, it is observed that irrespective of loop length and fabric relaxation treatment ,all the knitted single jersey fabrics except core spun structure showed gradual reduction in the air permeability value as function of increase in the stretch. In the case of core spun (Cotton/Spandex) structure, the inverse behavior on air permeability was found which is attributed to its high elasticity as compared to other types of yarns.It is further understood that the progressive stretch% on single jersey knitted fabric has strong impact on air permeability in respect of all the samples tested. The fabric samples produced from the yarns of three different spinning systems i.e; ring yarn, rotor yarn and core &cover yarn differ in its air permeability value .The loop length and types of relaxation treatment also influences the air permeability of the single jersey knitted fabrics. It is further understood that the interaction affects the said parameters which have bearing on the air permeability to a large extend. Among all samples, knitted fabric made out of core spun system exhibit comparatively the lowest permeability.**

***Keywords*: Single jersey knitted fabric, Air permeability, Dry, wet, fully relaxed, differential stretching.**

Introduction

Single jerseys knitted structures are the primary material for intimate clothing as well for the sport wearing. The main expectation of such clothing is to provide higher level of comfort to the human being .Milenkovic.L et al (1999) stated that earlier days comfort was a subjective analysis and it is recognized by the experience of individual, but in recent years it is presumed that the comfort depends upon the fabric thickness and air flow within the fabric. These are the major factors that affect the heat transfer through the fabric. According to Dubrovski, P.D (2004) physical properties such as air permeability, water permeability, and thermal resistance change with respect to the fabric construction pattern. Marmarali et al (2009) reported that the parameters of thermal conductivity, thermal resistance, thermal absorptivity and air permeability are significantly affected by tightness factor of the knitted fabric. According to Mukhopadhyay and Ishtiaque (2013), yarns packing density, inter-yarn porosity and fabric thickness strongly influence the thermo-physiological properties of the knitted fabric. Most of the knitted fabrics have been produced with ring spun yarn and rotor yarn. Kane.C.D. et al (2007) proved that knitted fabric produced from rotor yarn showed improved physical properties as compared to the fabrics made from other yarn varieties. Loop length is considered as one of the important structural variable,which affects the knitted fabric properties. Marmarali (2003) reported that there is a positive correlation between the air permeability with loop length of the knitted fabric. He also confirmed that this trend will not change irrespective of yarn structure. As stated by Pavko-Cuden et al (2013), incorporation of elastane fibres within the knitted structure is becoming popular towards the production of compact knitted structure and have confirmed that the physic-mechanical properties will be affected by incorporation of elastane fibre into the basic structure. In general, air permeability of knitted fabric will affect the comfort of the wearer, and hence the measure of this behaviour is considered as important an analysisof the performance of the fabrics. Most of the time, the air permeability is measured on the fabric without stretching, but while wearing the cloth the fabric will be stretched either in wales wise or coarse wise. The degree of stretching affects the air permeability property of the fabric. In the present work , air permeability of the single jersey fabrics are measured under differential stretching condition in width wise by changing the process variables such as relaxation treatment, loop length and yarn structure .To impart the differential stretching condition ,a stretching device has been designed and fabricated and incorporated with the air permeability tester.

Materials and methods

Three different types of yarn structures namely ring yarn,compact yarn and core spun yarn have been produced from various spinning system with the linear density of 20 tex. The technical specifications with regard to various functional propereties are given in Table 1.

Table 1: physical properties of various yarn structures

Yarn properties	properties of different spun yarns		
	Ring	**Rotor**	**Core spun yarn**
Yarn count in Ne	40s	40s	40s
Fibre type	Cotton	Cotton	Cotton as sheath and spandex as core
Strength in lbs	81	85	65
RKM value (grams/tex)	18.00	19.8	---
Elongation %	4.40	5.30	---
Direction of Twist	Z	Z	Z
TPI	22.71	22.43	---
Total imperfections/km	62	43	54
Hairiness	4.30	3.73	3.75
Spandex type / Count	Nil	Nil	Elaspan / 40 Denier

Using the above category of yarns, single jersey knitted fabrics have been produced with the three different loop length such as 0.35cm,0.4cm and 0.45 cm. The machine settings to produce the single jercey yarn using the cirucular knitting machine are as follows:

Table 2: Machine specification and settings

Machine make	MAYER & CIE
Machine Diameter	34 Inches
Number of Needles	2976
Gauge	28
Type of needle	Latch
Number of feeder	110

These fabric were further sbjected to dry relaxation,wet relaxation and fully relaxation treatement as per the following procedure.

Relaxation Treatment of Fabric Samples

In dry relaxation (DRS),the knitted fabric samples were kept flat in a tension free mode for 48 hours in a standard testing atmospheric conditions, Saville (1999).In wet relaxation(WRS) ,the knitted samples were treated in the water bath containing 5%(V/V)wetting agent at a temperature of 37°C and it is allowed to relax with mild agitation for 24 hours. Finally the wet samples were hydro-extracted for a minute and laid on a flat surface for 48 hours. In the case of fully relaxation treatment (FRS), fabric samples were subjected to five repeated cycle of wash and dry treatment on the fabrics to attain its dimensional equilibrium state; (Knapton et al; 1970). These treatments were carried out with the help of a standard fully automatic washing machine and tumble dryer. Finally,wet samples were hydro-extracted for a minute and laid on a flat surface for 48 hours.

Automatic fabric stretching machine

An automatic fabric stretching machine was fabricated with the support of MAG testing firm, Coimbatore and interfaced along with the air permeability tester to quantify the air permeability of knitted sample under differential stretching condition. This stretching unit has a provision to create the variable stretching condition on the fabric during testing (Fig.1).

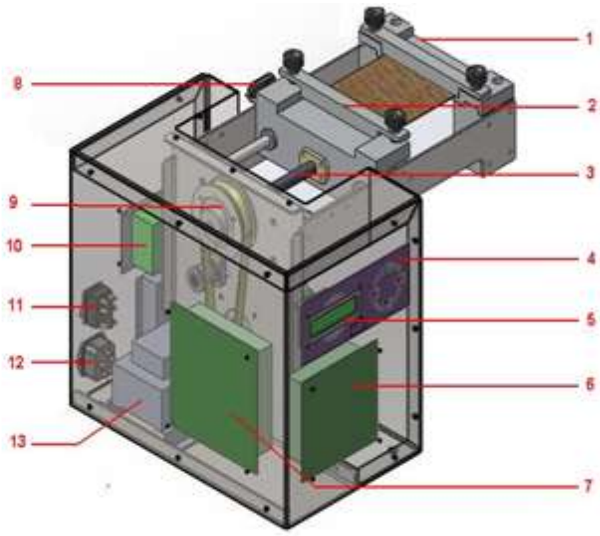


Fig.1 Automated fabric stretching device

The specifications of each part of air permeability tester having fabric stretching device interfaced are as under:

Sl.No	Name of the part		Sl.No	Name of the part
1	Fixed carriage		8	Proximity sensor
2	Moving carriage		9	Timing pulley
3	Screw rod		10	Stepped motor drive
4	Keypad		11	ON / OFF rocker switch
5	Display		12	Power socket
6	CPU board		13	Transformer
7	Input and Output board		-	--------------

Details of the parameters set during stretching are as follows:

Table3. Technical specifications of automated fabric stretching device

Sl. No.	Items	Particulars
1.	Carriage movement speed	18 to 100 mmpm
2.	Stretch length	1 to 75 mm or 1 to 75 %
3.	Test specimen size	10 cm x 10 cm
4.	Control system	Micro-controller based control circuitry
5.	Power supply	Single phase 220 Volts AC @ 50 Hz
6.	Power consumption	50 Watts
7.	Physical Dimensions	Size (WDH) : 400 x 310 x 280 mm
8.	Weight	15 kg

The air permeability tests of the single knit fabric samples were carried outas per the test procedure recommended by ASTM D737-2012 by using MAG air permeability tester with the head area of 10 cm^2 and pressure difference 100 Pa between two fabric surfaces.

Air permeability testing

Finally the fabrics were tested using air permeability tester to measure the air permeability of these fabric in a differential stretching condition. To test the air permeability parameter of the unstretched fabric and stretched fabric ,the knitted samples were prepared with the dimension of 10 cm X 10 cm placed above the cylindrical air blow head with the support of automatic stretching device tested under normal condition as well as stretched condition . The initial setting of monometer reading was set to zero. Both the normal samples and stretched samples (stretch % of 10%, 20%, 30% and 40%)were tested subsequently . The rotometer reading was noted, while the monometer reading reaches to the value of 1.0 which is equal to the pressure difference of 10 mm head of water.

Results and Discussions

Samples under varied stretch conditions were tested for air permeability and the results are discussed below:

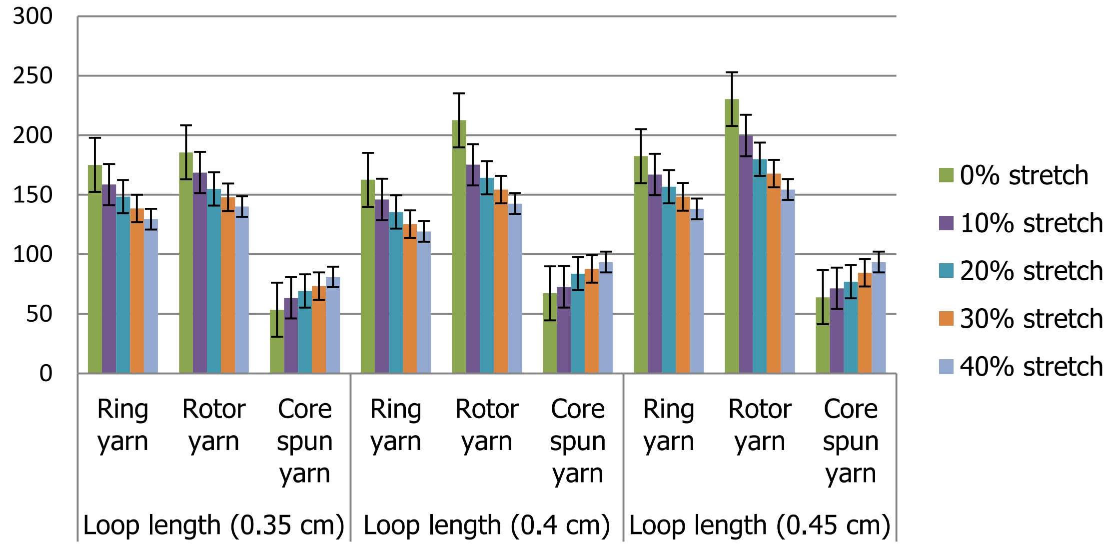
Effect of Yarn Structure on Air Permeability of Single Jersey Dry Relaxed Fabrics

Three different types of cotton yarns have been knitted through the circular knitting machine in three different loop length variations. After knitting, all the produced circular knitted jersey fabric samples were subjected to dry relaxation treatment in a controlled environment. The samples were tested under modified air permeability tester under normal condition and stretched condition (width wise) to measure the influence of fabric stretch, yarn loop length and yarn structure on air permeability behavior of the fabric.The stretch gradient during testing was between the ranges of 0 % to 40 %. The results are given in Table 4.and graphically is shown in Fig.2.

Table 4.Effect of spinning systems on air permeability of single jersey fabrics at Dry relaxed condition

Yarn type	Type of Relaxation	Loop length	Air Permeability in $cm^3/cm^2/sec$				
			Stretch %				
			0%	10%	20%	30%	40%
Ring yarn	Dry	0.35	175.03	158.53	148.44	138.5	129.5
Rotor yarn			185.53	168.63	154.91	147.84	140.1
Core Spun yarn			53.4	63.4	69.14	73.32	81.02
Ring yarn		0.40	162.64	146.03	135.56	125.32	119.22
Rotor yarn			212.56	175.24	164.17	154.42	142.62
Core Spun yarn			67.23	72.7	83.84	87.8	93.45
Ring yarn		0.43	182.5	167.04	156.64	148.3	138.15
Rotor yarn			230.34	199.75	179.95	167.66	154.4
Core Spun yarn			63.89	71.45	76.92	84.62	93.47

Fig.2.Effects of Loop length ,yarn strcture and stretch % on air permeability of single jersey knitted fabric



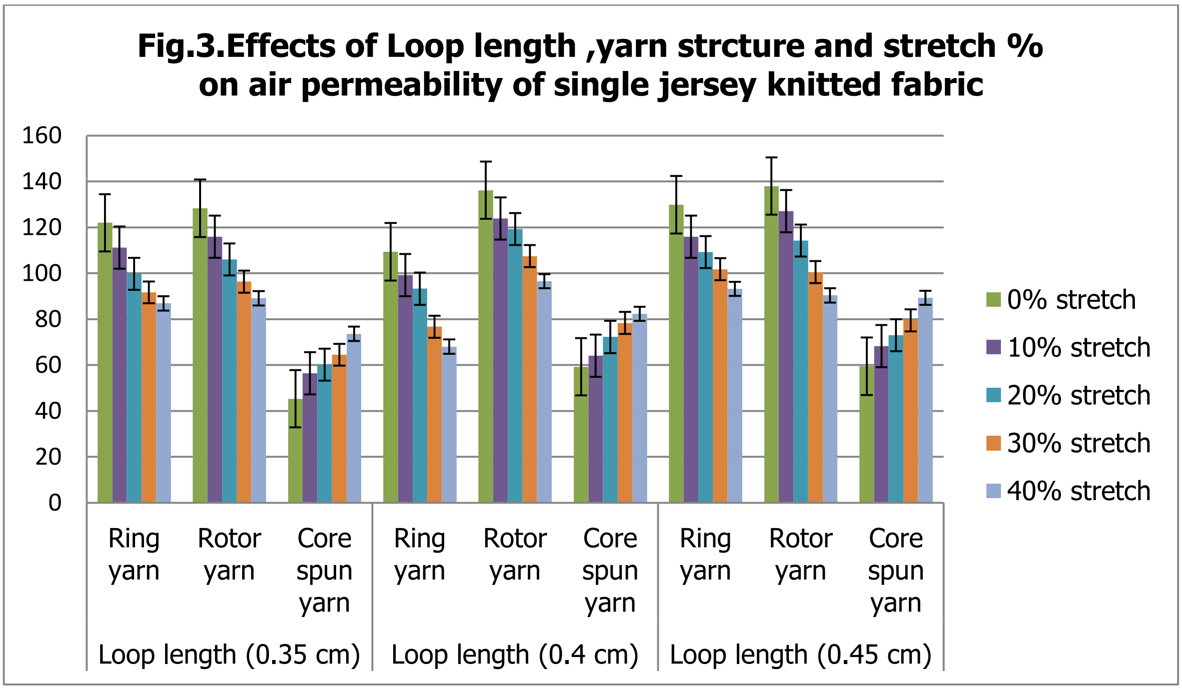
Dry relaxed compact spun yarn knitted samples exhibit highest air permeability values for all three loop length variables in both un-stretched and stretched conditions. It may be attributed to the low yarn hairiness therby more possibilities for air penetration inside the fabric structure. The ring yarn samples gave second highest air permeability values similar to the compact spun yarn. The lower values of air permeablity as comapred to the fabric made out of compact yarn may be due to yarn hairyness. The core spun samples are found with least air permeability values in all the stretched and un-stretched samples. It may be ponted out that the contribution of elastane yarn inside the structure limits the air flow inside the structure. Further to this, all the fabrics were shown higher air permeability value during its un-stretched condition than the stretched stage. It is also found that the reduction in air permeability follows linear variation with respect to percentage of stretch.Further to this, the larger loop length structure yields higher air permeability parameter.

Effect of Yarn Structure on Air Permeability of Single Jersey Wet Relaxed Fabrics

Similar to the dry relaxed single jersey fabric, the wet relaxed fabrics have been produced and it air permeability was analysed in similar way to the previous case. The results are tabulated in Table 5 and graphically shown in Fig.4.

Table 5.Effect of spinning systems on air permeability of single jersey fabrics at WRS

Yarn type	Type of Relaxation	Loop length	Air Permeability in $cm^3/cm^2/sec$				
			Stretch %				
			0%	10%	20%	30%	40%
Ring yarn	Wet	0.35	122.01	111.2	99.8	91.66	86.9
Rotor yarn			128.32	115.86	106.04	96.37	89.1
Core Spun yarn			45.3	56.42	60.2	64.5	73.6
Ring yarn		0.40	109.36	99.19	93.3	76.73	68.05
Rotor yarn			136.17	123.88	119.24	107.45	96.56
Core Spun yarn			59.24	64.06	72.25	78.35	82.31
Ring yarn		0.43	129.85	115.9	109.27	101.75	93.24
Rotor yarn			138	127.11	114.23	100.51	90.36
Core Spun yarn			59.48	68.33	72.97	79.51	89.33



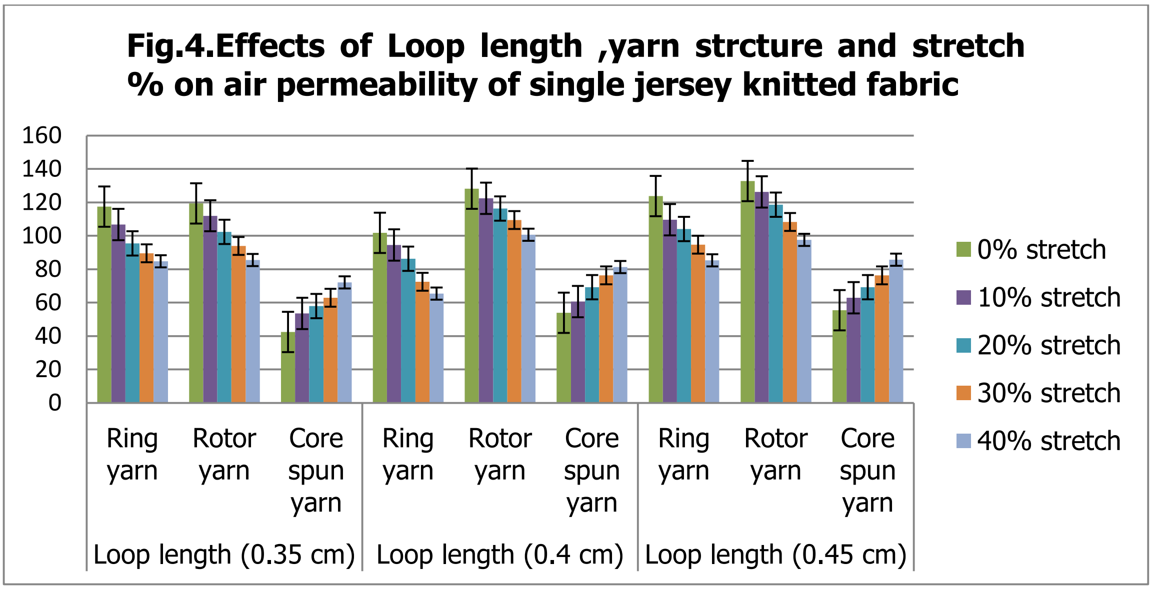
The air permeability value of wet relaxed samples reduced in the range of 35% to 48% when compared with the wet relaxed samples to dry relaxed samples in all samples. This may be ponted out that the wet relaxed knitted fabrics possess closer structure due to its higher relaxation effect. All the other behaviours of wet relaxed samples were similar to dry relaxed samples. Further, hairiness of theyarn in the knitted fabric samples may not significantly be a contributing factor for decreasing the air permeability under wet relaxed conditions.

Effect of Yarn Structure on Air Permeability of Single Jersey Fully Relaxed Fabrics

The fully relaxed fabrics werer analysed with regard to air permeability. The results are tabulated in Table 6 and graphically shown in Fig.4.

Table6. Effect of spinning systems on air permeability of single jersey fabrics at FRS

Yarn type	Type of Relaxation	Loop length	Air Permeability in cm^3/cm^2.sec				
			Stretch %				
			0%	10%	20%	30%	40%
Ring yarn	Dry	0.35	117.5	106.76	95.5	89.52	84.65
Rotor yarn			119.3	111.98	102.33	93.9	85.46
Core Spun yarn			42.4	53.52	57.84	62.88	72.11
Ring yarn		0.40	101.8	94.54	86.32	72.5	65.38
Rotor yarn			128.14	122.48	116.36	109.38	100.62
Core Spun yarn			53.83	60.53	69.12	76.24	81.22
Ring yarn		0.43	123.7	109.64	104.1	94.62	85.34
Rotor yarn			132.7	126.25	118.62	108.18	97.6
Core Spun yarn			55.5	62.94	69.12	76.36	85.62



The air permeability value of fully relaxed samples reduced in the range of 45% to 55% when compared to the fully relaxed samples to dry relaxed samples in all the samples. This may be attributed to fully relax knitted fabric possessing close structure among all the other mode of relaxed fabrics due to its highest relaxation effect. All the other behaviors of fully relaxed samples were similar to those of dry and wet relaxed samples.

Analysis of variance

An Anova was performed to determine the significant difference due to process variables on air permeability of the samples and the results were given in Table 7. Here the factors such as types of relaxation treatment, yarn structure, loop legth and stretch percentage significantly differ with its air permeability values are concerned ($p<-0.05$). It is also understood that their interaction effects also differ significantly.

Table 7.Tests of Between-Subjects Effects

Dependent Variable: airpermeability

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	150188.724a	10	15018.872	47.888	.000
Intercept	1504764.170	1	1504764.170	4797.930	.000
relaxation	47753.490	2	23876.745	76.131	.000
Looplength	3295.033	2	1647.516	5.253	.006
Yarntype	92999.303	2	46499.652	148.264	.000
stretch	6140.898	4	1535.225	4.895	.001
Error	38889.842	124	313.628		
Total	1693842.737	135			
Corrected Total	189078.566	134			

a. R Squared = .794 (Adjusted R Squared = .778)

To analyse whether is there any significant difference in the means of air permeability of pair of variables selected for this study such as of loop length, yarn structure, types of relaxation and percentage of stretch, the Post-hoc test was carried out. It shows that loop length 0.35 cm and 0.45 cm samples differ significantly each other in their mean value of air permeability value ($p<-0.05$). Similarly, when compared to yarn structures, all the three structured samples differ significantly each other in their mean of air permeability value ($p<-0.05$),dry relaxed samples differ significantly with fully relaxed samples ($p<-0.05$)and relaxation treatment expect 0%,30% and 40% stretched samples differ significantly with other set of samples

Conclusions

Single jersey knitted fabric samples were produced by varying relaxation treatment ,yarn structure,loop length and its differential stretch percentage using circular weft knitting machine.It is found that irrespective of loop length and fabric relaxation treatment ,all the knitted single jersey fabrics except core spun structure showed gradual reduction in its air permeability value as the stretch progressed. In the case of core spun (Cotton/Spandex) structure, the reverse behavior on air permeability was found due to its elastomeric nature.It is further pointed out that the incremental stretch% on knitted fabric has strong impact on air permeability of all the samples tested. The fabric samples produced from the yarns of three different spinning systems such as ring yarn, rotor yarn and core and cover yarn differ in its air permeability value .The loop length and types of relaxation treatment also influences the air permeability value of the single jersey knitted fabrics.It is also found that the interaction effects of all the said parameters have also influence on the air permeability value to a larger extend. Among all the samples of knitted fabrics, fabrics made out of core spun yarn exhibited comparatively the lowest permeability.

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