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Factors Affecting Air Permeability of Viscose & Excel Single Jersey Fabric

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Abstract:- This paper compares the porosity / compactness of the knitted structures made from viscose and excel yarns and evaluates the air permeability property for sportswear. In the experimental section, viscose and excel yarns spun in different counts (Ne 30, Ne 40) with the same twist coefficient of α_e = 3.3 were knitted as single jersey fabrics in the same production conditions with four tightness factors and air permeabililty property of fabrics were measured. The result showed that air permeability is a function of the thickness, tightness factor and porosity of the knitted fabrics and excel single jersey fabrics are considered preferred candidates for warmer climate sportswear, due to their higher air permeability.

Keywords:- Knitted fabric, Air permeability, Viscose, Excel, Porosity, Tightness factor

I. INTRODUCTION

Knitted structures are created by interloping the thread. Due to the three-dimensional curved shape of the basic unit – the loop, they are generally more porous and extensible than other textile structures. The appearance and performance properties of knitted structures differ mainly due to the differences in the material and structural parameters. The structure compactness which is described with loop modules and loop constants directly influences the performance, and the mechanical and comfort properties of knits. The compactness is expected to be closely connected to absorbency and air permeability of the structure. (e.g.[1]). As the possibilities to expand cotton fibre production are limited, there is considerable potential for a further increase in production of 'cellulosics' especially viscose rayon fibre. It is known that viscose is made from wood pulp, a naturally occurring, cellulose based raw material. As a result, it's properties are more similar to those of the natural cellulosic fibres, such as cotton fibre and has good comfort properties and excel is the third generation of man-made cellulosic fibre produced by an 'organic solvent spinning process'. It is designed to satisfy the need for a product that provides the comfort and luxury of a natural fibre, with the engineered finish of a man-made fibre. Efforts are being made to make a knitted fabric more comfortable by changing the fibres, yarn parameters like twist, count and finishing treatments, knitting parameters like stitch length, course per inch, wales per inch and fabric weight and post knitting finishes (e.g.[2]).

A.Porosity

Heat and liquid sweat generation during athletic activities must be transported out and dissipated to the atmosphere. A key property influencing such behaviors is porosity. The yarn diameter, knitting structure, course and wale density, yarn linear density, pore size and pore volume are the main factors affecting the porosity of knitted fabrics (e.g.[3]). It was determined that the loop length of a knitted jersey has more influence on porosity than the stitch density and the thickness (e.g.[4]). Dias and Delkumburewatte, (e.g.[5]) created a theoretical model to predict the porosity of a knitted structure and determined that porosity depended on fabric parameters and relaxation progression (e.g. [6]). The most commonly used methods to evaluate the porosity of textile fabrics are: air permeability; geometrical modelling and image processing (e.g.[7]).

B. Air Permeability

Generally, the air permeability of a fabric can influence its 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.

Air permeability is defined as the volume of air in millilitres 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 (e.g.[8], [9]).The ease or otherwise of passage of air is of importance for a number of fabric end uses such as industrial filters, tents, sailcloths, parachutes, raincoats, shirtings, downproof fabrics and airbags. In outdoor clothing it is important to have air permeability as low as possible for achieving better wind protection (e.g.[10], [11]).

It was noted that the stitch length, porosity and air permeability increase and the thermal retaining property decreases for dry relaxed cotton 1 x 1 rib knitted fabrics. Thermal properties and thermal behavior of cellulosic textile fabrics air permeability, porosity were investigated previously and found that air permeability and heat transfer through fabrics is closely related to both the capillary structure and surface characteristics of yarns (e.g.[12]). The effect of fibre composition and yarn type on the wickability, air permeability and thermal insulation of knitted fabrics was studied previously and found that the air permeability of fabrics decreases with the increase in cotton content. The air permeability of a fabric is affected by the fabrics material such as fibre fineness, structural properties such as shape and value of pores of the fabric and the yarn and fabric thickness. (e.g. [13], [14], [15]).

Most of the previous studies investigated the relationship between the air permeability and structural characteristics of plain knitted fabrics. The effect of the some of parameters on air permeability of viscose and excel knitted structures has not been researched systematically yet. Thus, the main purpose of this research was to study, the effect of fabric tightness factor, fabric weight, fabric thickness and porosity on the air permeability of viscose and excel knitted fabric and to explore whether the natural hydrophilic properties of viscose and excel fibre could be used to enhance the comfort properties of sportswear fabrics while at the same time improving the aesthetics.

II. MATERIALS AND METHODS

For the research, viscose and excel fibres made from a natural polymer – cellulose were selected as the basic material and the yarns were produced by using fibre length 38 mm and fineness 1.12 dtex in two different yarn counts (Ne 30, Ne 40) with a twist coefficient of $\alpha_e = 3.3$.

A.Knitting

The structure important for reference in this work are the plain jersey fabric which is single layer fabric in which the same yarn is being knit on the front. The fabric samples were knitted on Single Jersey Circular Knitting Machine of Mayer & Cie, Model : S4-3.2, Germany. By adjusting the stitch cams the rate of yarn feeding to knitting needles was adjusted. The amount of yarn feeding in one revolution was varied in order to produce fabrics with different loop length values (ℓ) : 2.7, 2.9, 3.1 and 3.3 mm to knit samples in four different tightness factor. Combining two fibres, two yarn counts, and four tightness levels, sixteen different samples were prepared in all.

B.Fabric Relaxation

Full relaxation was carried out of the samples by wet relaxing them in an automatic front loading machine followed by rinsing, spinning and tumble drying and finally conditioning for 24 hours in standard atmospheric condition as per Standard wash procedure - IS 1299:1984.

C.Fabric Testing

1) Fabric weight per unit area : Standard procedure for measuring GSM as per ASTM – D 3776-1996, IS:1964-2001 was followed using Mettler make measuring balance, model PB 602-5 capable of weighing to an accuracy of 0.1 gm.

2) Fabric thickness : The thickness of the fabric depends on the yarn count, knitted structure and relative closeness of the loops. The thickness of fabric samples was measured as the distance between the reference plate and parallel presser foot of the thickness tester under a load of 20 gm / cm^2. Standard procedure for measuring GSM using Baker make J02 thickness tester as per ASTM – D 1777:197, IS:7702:1975 was used.

3) Air permeability : Air permeability of the samples was tested according to ASTM standard D737-1996 on the apparatus Air Permeability Tester Model : MO21A (SDL Atlas). The measurements were performed at a constant pressure drop of 196 Pa (20 cm^2 test area). Measurements of the fabrics were carried out 10 times, and the average expressed as $cm^3/cm^2/s$ and standard deviations were calculated.

4) Porosity :The porosity was determined using construction parameters of the knit fabric (Benltoufa et al. 2007) using 'Eq. (1)'

$$\varepsilon = 1 - \frac{\Pi d^2 \ell c w}{2t}$$

Where:

t : sample's thickness (cm) ;

ℓ : elementary loop length (cm) ;

d : yarn diameter (cm) ;

c : number of Courses per cm ;
w: number of Wales per cm.
5) Fabric tightness factor : The tightness factor of the knitted fabrics was determined by the following equation :
$K = \sqrt{T} / \ell$
Where T is the yarn count in tex and ℓ is loop length in cm or mm.
To determine the statistical importance of the variations, correlation tests were applied.

III. RESULTS AND DISCUSSION

All tests were performed under standard atmospheric conditions (20^{o}C, 65% RH).The basic dimensional properties of both types of knitted fabrics are enumerated in (Table 1 and 2). Results showed that thickness increases with the fabric tightness for both structures, but not linearly.

A.Porosity

Porosity is one of the key properties influencing thermo-physiological comfort of the wearer. The thickness and mass per square meter of the fabrics reduces as the yarn becomes finer, which is quite obvious. For viscose single jersey knitted fabrics the mass per square meter of the fabrics reduced from 145.85 g/m^2 to 75.84 g/m^{2}i.e. by 48% (Table 1),

Table 1. Dimensional Properties of Viscose Single Jersey Fabric

Fabric Code	Tightness factor, K	Thickness, cm	Weight, g/m^2
$V1JT_1$	1.64	0.574	145.85
$V1JT_2$	1.53	0.564	133.02
$VIJT_3$	1.43	0.54	124.5
$V1JT_4$	1.34	0.526	103.73
$V2JT_1$	1.42	0.482	101.80
$V2JT_2$	1.33	0.494	93.71
$V2JT_3$	1.24	0.506	91.57
$V2JT_4$	1.16	0.448	75.84

(V: Viscose; 1:Ne 30s; 2:Ne 40s; J:Single Jersey structure; T: Tightness factor)

Table 2. Dimensional Properties of Excel Single Jersey Fabric

Fabric Code	Tightness factor, K	Thickness, cm	Weight, g/m^2
$E1JT_1$	1.64	0.54	136.78
$E1JT_2$	1.53	0.544	130.0
$EIJT_3$	1.43	0.5729	124.35
$E1JT_4$	1.34	0.554	108.96
$E2JT_1$	1.42	0.522	102.82
$E2JT_2$	1.33	0.494	86.06
$E2JT_3$	1.24	0.484	81.29
$E2JT_4$	1.16	0.5278	76.45

(E: Excel; 1:Ne 30s; 2:Ne 40s; J:Single Jersey structure; T: Tightness factor)

However, the corresponding reduction in terms of fabric thickness was from 0.574 mm to 0.448 mm, i.e., by 22% . For excel single jersey knitted fabrics the mass per square meter of the fabrics reduced from 136.78 g/m^2 to 76.45 g/m^{2}i.e. by 44.11%, however, the corresponding reduction in terms of fabric thickness was from 0.5729 mm to 0.484 mm, i.e., by 15.52% . This analysis bolsters the fact that when yarn is becoming finer, mass per square meter is reducing at a faster rate as compared to that of fabric thickness. Therefore, the porosity of the fabric increases. (Figure 1) shows the porosity of viscose and excel single jersey fabrics.

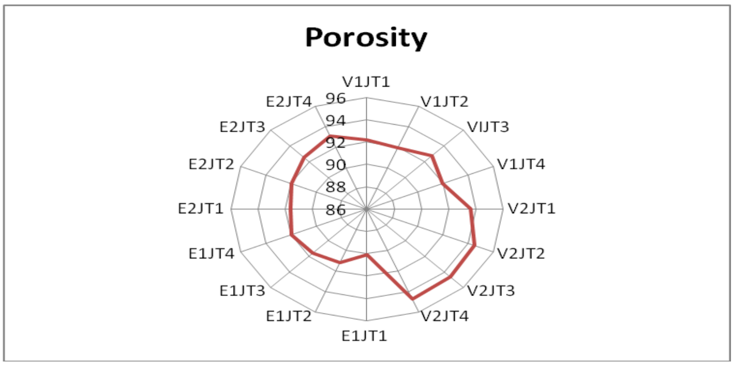

Figure1: The values of porosity for different variants of viscose and excel fabrics

B.Air permeability:

(Figure 2 and Table 3) present the research results of air permeability. The range of values obtained is significant, ranging from 287 to 690 $cm^3/cm^2/s$ for viscose single jersey fabric and from 331 to 725 $cm^3/cm^2/s$ for excel. The porosity determines the variation of air permeability. Fabrics having low porosity values shows the lowest value for air permeability. Increasing fabric tightness by machine setting decreased the air permeability in both fabrics. Coarser yarn produce fabrics with more intra-yarn air spaces but with fewer inter-yarn air spaces resulting in lower air permeability in the single jersey knitted fabrics. Air permeability increases for the fabrics made from finer yarns as expected. The lower thickness and mass per square meter also facilitate the passage of air through the fabric. The lower hairiness of the finer yarn may be another contributing factor towards the better air permeability. As the loop length increases, the air permeability value also increases.

Table 3. Air permeability results

Fabric Code	Air permeability $cm^3/cm^2/s$	
	Average	Standard Deviation (S)
$VIJT_1$	287.3	20.42
$VIJT_2$	368.14	7.71
$VIJT_3$	434.625	24.14
$VIJT_4$	529.56	17.78
$V2JT_1$	430.1	28.63
$V2JT_2$	587	6.39
$V2JT_3$	690	34.72
$V2JT_4$	662.6	56.76
E1J T_1	331	10.85
E2J T_2	437.1	21.34
E3J T_3	426.8	12.2
E4J T_4	449	32.11
E2J T_1	466.5	28.73
E2J T_2	598.8	20.44
E2J T_3	608.1	31.33
E2J T_4	725.1	27.56

(V: Viscose; E: Excel; 1:Ne 30s; 2:Ne 40s; J:Single Jersey structure; T: Tightness factor)

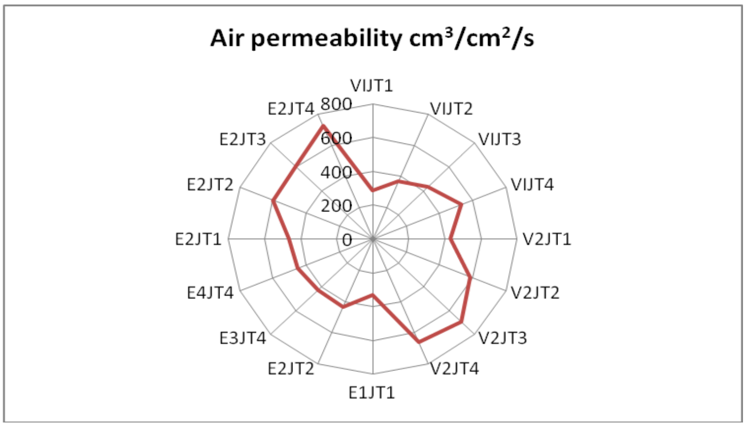

Figure 2: Air permeability of different variants of viscose and excel fabrics

A close look at the (Tables 1 and 2) reveals that as for the same yarn linear density the thickness was increased by increasing the fabric tightness. Thicker yarns increased thickness in both fabrics. The barrierability of knitted fabrics to the air as fabrics thickness function, is presented in (Figure 3 and 4). It shows that in both viscose and excel yarns single jersey knitted with Ne 30s (R= 0.98 and 0.61) gives good and low correlation while for Ne 40s (R= 0.19 and 0.014), there was no correlation observed between air permeability and thickness. This was expected to some extent as air has to travel a more complex path and faces higher frictional forces during its passage through the fabric.

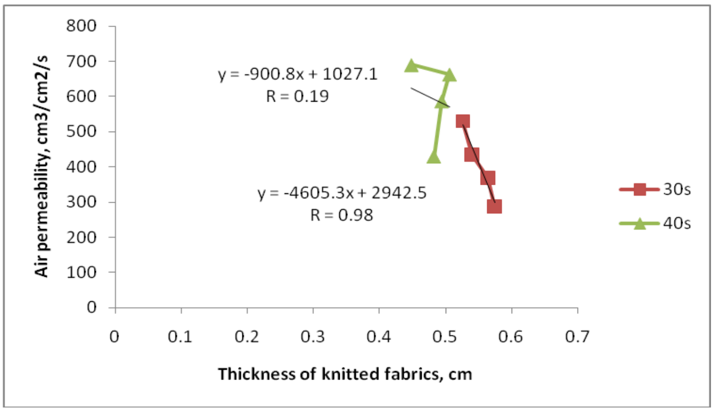

Figure 3: Air permeability in function of thickness of viscose single jersey knitted fabrics.

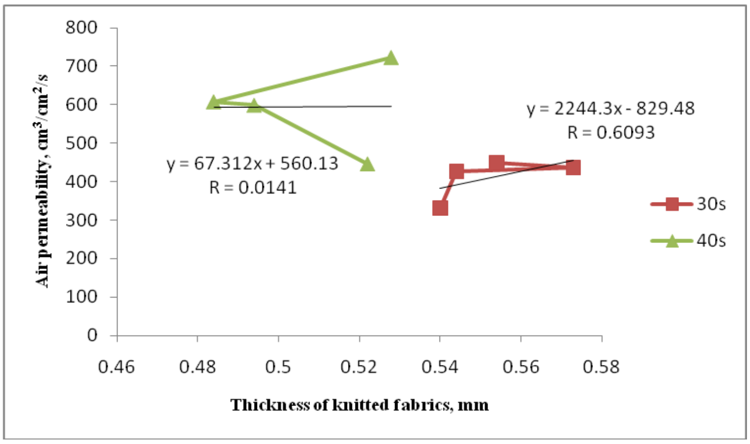

Figure 4: Air permeability in function of thickness of excel single jersey knitted fabrics.

Air permeability is inversely related with fabric tightness; it decreased with increase of compactness and decrease of air space. It must be emphasized that tightness factor correlates more with air permeability than knitted fabric thickness. This is documented by the test results and statistical analysis presented in (Figure 5 and 6), where the estimated value of correlation index between air permeability and the tightness factor of knitted fabric is R = 0.95 for Ne 40s and 0.99 for Ne 30s for viscose single jersey knitted fabrics and R = 0.95 for Ne 40s and 0.89 for Ne 30s for excel single jersey knitted fabrics which demonstrate that the dependence between those parameters exists and is very strong. The tightness factor can be changed through alteration of the loop length or linear density or through alteration of both these parameters. The correlation between the characteristics presented allows to maintain that when the tightness factor of the knit is known, it is possible to predict the potential air permeability of such a construction.

(Figure 7 and 8) shows the influence of the fabric porosity on air permeability. Poor correlation observed in case of viscose single jersey fabrics while high correlation was obtained in excel single jersey fabrics. Previous research also showed that air permeability of fabrics was mainly affected by the porosity of the fabrics.

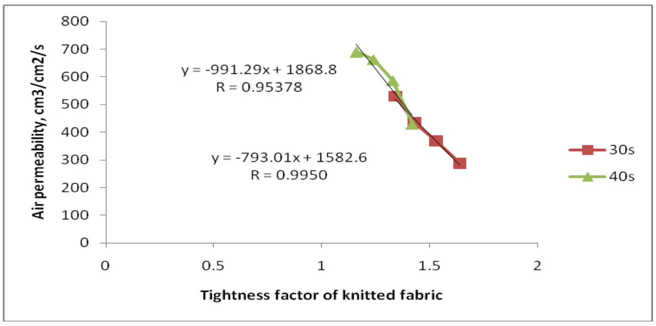

Figure 5: Air permeability in function of tightness factor of viscose single jersey knitted fabrics.

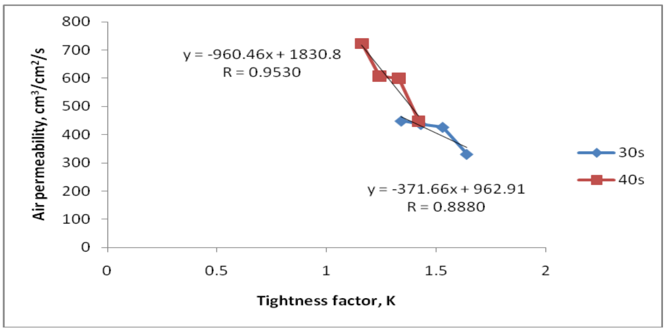

Figure 6: Air permeability in function of tightness factor of excel single jersey knitted fabrics.

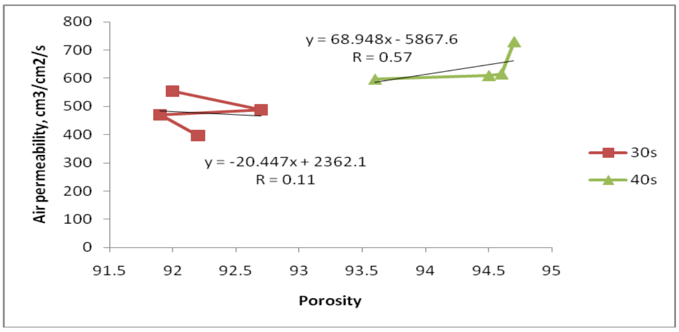

Figure 7: The relation between air permeability and surface porosity for viscose single jersey knitted fabrics.

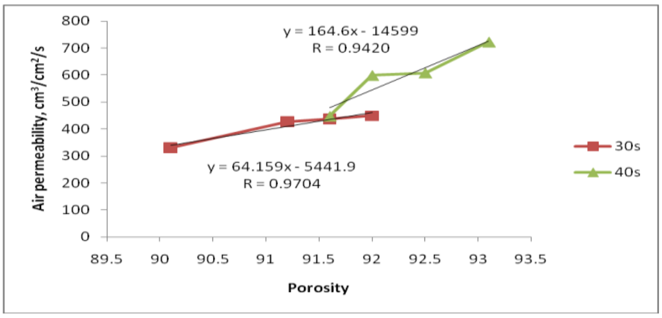

Figure 8: The relation between air permeability and surface porosity for excel single jersey knitted fabrics.

IV. CONCLUSION

As a result of research, it is seen that the air permeability of fabric knitted with Ne 40s is determined higher. 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. Air permeability is an important factor in comfort of a fabric as it plays a role in transporting moisture vapours from the skin to the outside atmosphere. Excel single jersey fabrics are considered preferred candidates for warmer climate sportswear, due to their higher air permeability.

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