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Air Permeability of Knitted fabrics made from Regenerated Cellulosic fibres

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Abstract:- The aim of this paper is to evaluate the air permeability property of the knitted structures made from viscose and modal yarns for sportswear. Viscose and modal yarns spun in different counts (Ne 30s, Ne 40s) with the same twist coefficient of α_e =3.3 were knitted as pique fabrics in the same production conditions with four tightness factors and air permeabililty property of fabrics were measured. Result indicate that air permeability is a function of the thickness, tightness factor and porosity of the knitted fabrics and for summer wear or sportswear modal pique structure could be used.

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

I. INTRODUCTION

Sportswear textiles belong to a category called sporttech, which is one of the mainstream technical textiles. This rising interest is due to a number of social factors that include increased leisure time, increased considerations of wellbeing and good health, growth of indoor and outdoor sports facilities and the ever-increasing pursuit of the adult population of activities outside the home or workplace. More healthy lifestyles are leading to greater sports participation, more sports have been invented and many old sports have become popular.

The active wear and sportswear sector of the textiles industry is extremely broad. It can range from specialist sports apparel worn by professional athletes, to sportswear worn by everyday consumers for its fashion value. In active and endurance sports, the performance of a sportswear is synonymous with its comfort characteristics. The wear comfort of sportswear is an important quality criterion that affects performance, efficiency and well-being. (e.g.[1]). Knitted fabrics are the preferred structures in sports wear in which demand for comfort is a key requirement. 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. Like other types of rayon, originally marketed as "artificial silk," modal is soft, smooth and breathes well. Its texture is similar to that of cotton or silk. It is cool to the touch and very absorbent due to the largest contact angle compared with viscose and excel.

A. Porosity

Heat and liquid sweat generation during sports 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.[2]). 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.[3]). Dias and Delkumburewatte, (e.g.[4]) 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. [5]). The most commonly used methods to evaluate the porosity of textile fabrics are: air permeability; geometrical modelling and image processing (e.g.[6]).

B. Air Permeability

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.[7], [8]). In outdoor clothing it is important to have air permeability as low as possible for achieving better wind protection (e.g.[9], [10]).

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.

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.[11]). 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. [12], [13], [14]).

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 modal knitted structures has not been researched systematically yet. In the present study, the effect of fabric tightness factor, fabric weight, fabric thickness and porosity on the air permeability of viscose and modal knitted fabric is determined and an attempt is been made to explore whether the natural hydrophilic properties of viscose and modal fibre could be used to enhance the comfort properties of sportswear fabrics improving the aesthetics.

II. MATERIALS AND METHODS

For the research, viscose and modal fibres made from a natural polymer – cellulose were selected as the basic material and the yarns were produced in two different yarn counts (Ne 30, Ne 40) with a twist coefficient of $\alpha_e = 3.3$.

A. Production of knitted fabric

A 24-gauge Single Jersey Circular Knitting Machine of 30-inch diameter of Mayer & Cie, Model: S4-3.2, Germany was used for manufacturing the samples. 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 of pique fabric 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 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 using Baker make J02 thickness tester as per ASTM – D 1777:197, IS:7702:1975 was used.
3) Air permeability : Air permeability was tested according to ASTM standard D737-1996 on the 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 equation (2):

$$K = \sqrt{T} / \ell \qquad (2)$$

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°C, 65% RH).The basic dimensional properties of both types of knitted fabrics are enumerated in (Table 1). It may be clear from the data in Table1 that thickness increases with the fabric tightness for both structures, but not linearly in the case of modal.

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 pique knitted fabrics the mass per square meter of the fabrics reduced from 160.6 g/m^2 to 85.40 g/m^2 i.e. by 46.82% (Table 1),

Table 1. Dimensional Properties of Viscose and Modal Pique Fabric

Fabric Code	Tightness factor, K	Thickness, mm	Weight, g/m^2
V1PT$_1$	1.64	0.740	160.6
V1PT$_2$	1.53	0.712	145.74
V1PT$_3$	1.43	0.716	128.76
V1PT$_4$	1.34	0.669	115.47
V2PT$_1$	1.42	0.628	107.98
V2PT$_2$	1.33	0.592	108.57
V2PT$_3$	1.24	0.580	88.35
V2PT$_4$	1.16	0.575	85.40
M1PT$_1$	1.64	0.641	151.16
M1PT$_2$	1.53	0.64	145.75
M1PT$_3$	1.43	0.658	129.66
M1PT$_4$	1.34	0.644	124.63
M2PT$_1$	1.42	0.575	114.64
M2PT$_2$	1.33	0.598	105.64
M2PT$_3$	1.24	0.557	97
M2PT$_4$	1.16	0.595	88.31

(V: Viscose ; M: Modal; 1:Ne 30s; 2:Ne 40s; P: Pique structure; T: Tightness factor)

However, the corresponding reduction in terms of fabric thickness was from 0.740 mm to 0.575 mm, i.e., by 22.3 % . For Modal pique knitted fabrics the mass per square meter of the fabrics reduced from 151.16 g/m^2 to 88.31 g/m^2 i.e. by 41.58%. However, the corresponding reduction in terms of fabric thickness was from 0.658 mm to 0.557 mm, i.e., by 6.1 %. 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 modal pique fabrics.

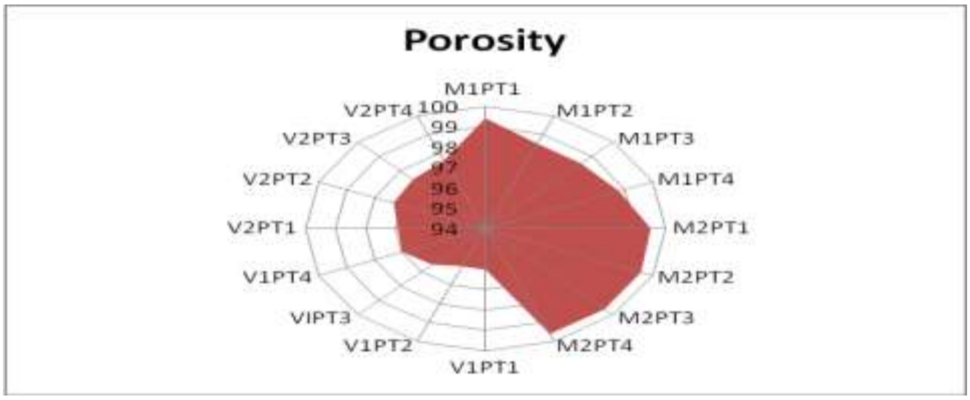

Figure1: The values of porosity for different variants of viscose and modal fabrics

B. Air permeability:

(Table 2) present the research results of air permeability. The range of values obtained is significant, ranging from 469.9 to 729.2 $cm^3/cm^2/s$ for viscose and 412.1 to 801.8 $cm^3/cm^2/s$ for modal fabrics. 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. 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 porosity of knitted fabrics.

Table 2. Air permeability results

Fabric Code	Air permeability $cm^3/cm^2/s$	
	Average	Standard Deviation (S)
$V1PT_1$	469.9	24.06681
$V1PT_2$	469.9	24.06681
$V1PT_3$	487.8	25.38941
$V1PT_4$	553.5	35.2018
$V2PT_1$	596.5	15.70739
$V2PT_2$	609.3	50.53063
$V2PT_3$	575.1	17.55278
$V2PT_4$	729.2	25.07677
$M1PT_1$	412.1	11.79878
$M1PT_2$	482.3	13.48291
$M1PT_3$	556.5	9.868581
$M1PT_4$	613.2	20.15385
$M2PT_1$	585.4	21.49522
$M2PT_2$	649.5	16.55462
$M2PT_3$	681.2	24.89444
$M2PT_4$	801.8	31.96456

(V: Viscose; M: Modal; 1:Ne 30s; 2:Ne 40s; P: Pique structure; T: Tightness factor)

From the (Tables 1), it 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 2 and 3). It shows that Viscose Pique Ne 30s (R= 0.9612) and Ne 40s (R= 0.6269) , Modal Pique Ne 30s (R= 0.46) and Ne 40s (R= 0.33) have negative correlation 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. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the fabric thickness range using the yarn counts Ne 30s in viscose pique structures.

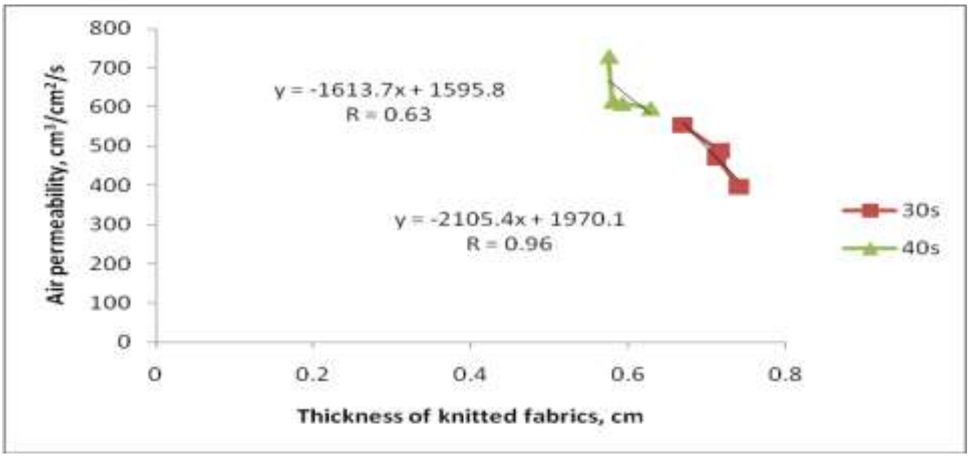

Figure 2: Air permeability in function of thickness of viscose pique knitted fabrics.

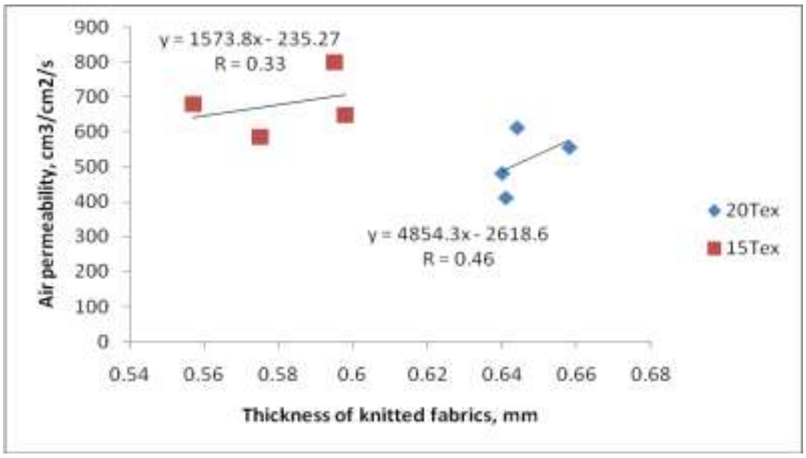

Figure 3: Air permeability in function of thickness of modal pique knitted fabrics.

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 4. and 5), where the estimated value of correlation index between air permeability and the tightness factor of knitted fabric is R = 0.98 for Ne 40s and 0.83 for Ne 30s for the viscose pique fabrics and 0.96 for Ne 40s and 0.99 for Ne 30s for the modal pique fabrics. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the tightness factor range using both the yarn counts and fibre types.

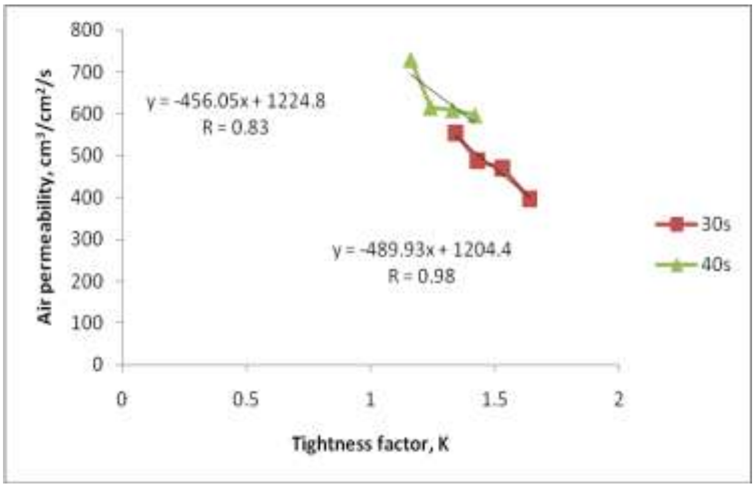

Figure 4: Air permeability in function of tightness factor of viscose pique knitted fabrics.

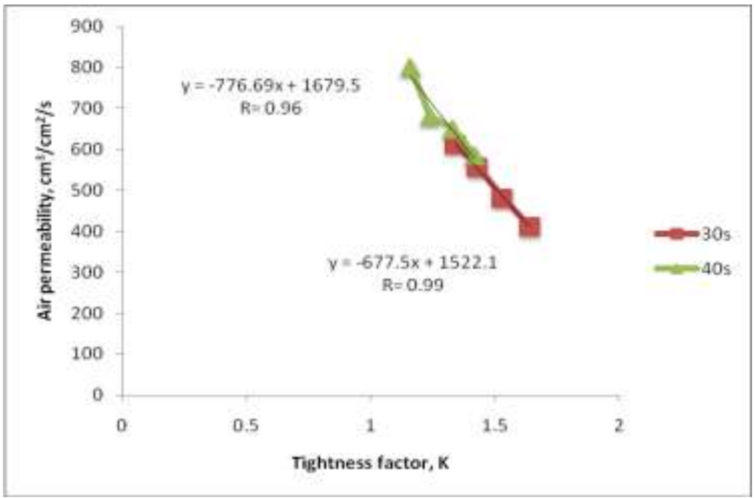

Figure 5: Air permeability in function of tightness factor of modal pique knitted fabrics.

(Figure 6 and 7) shows the influence of the fabric porosity on air permeability. Better correlation observed in case of viscose fabrics compared to modal pique fabrics. Previous research also showed that air permeability of fabrics was mainly affected by the porosity of the fabrics.

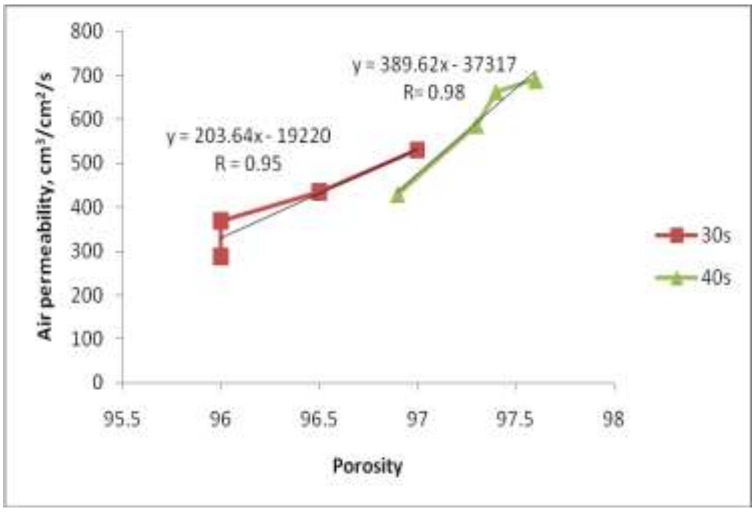

Figure 6: The relation between air permeability and surface porosity for viscose pique knitted fabrics.

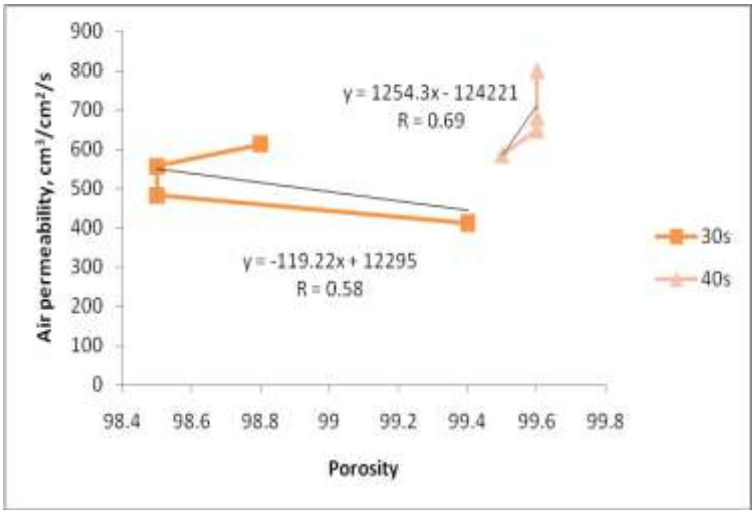

Figure 7: The relation between air permeability and surface porosity for modal pique knitted fabrics.

The results (expressed as means/standard deviation) of all assays were compared using ANOVA in order to investigate the effect of fibre type and yarn count on air permeability. ANOVA for air permeability indicated that there was not much impact of fibre type and yarn count on air permeability. Together, fibre type and yarn count accounted for only 57.76% of the variance in air permeability.

Table 3.: ANOVA Test for Fibre type and Yarn Count

Source	Dependent variable	Sum of Squares	Df	Mean Square	F	Sig.
Fibre Type	Air permeability	5285	1	5285.3	1.01	0.333
Yarn Count	Air permeability	87438	1	87438.5	16.76	0.001
Error		67822	13	5217.1		
Total		160546	15			

IV. CONCLUSION

We may see from the above test results 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 a good indicator of how a textile material will behave towards heat-loss as a thermo-physiological property. The higher air permeability rate the quickest heat-loss obtained from a textile material. For summer wear or sportswear modal pique structure could be used as it is characterized by higher air permeability, creating a cool feeling to the wearer by allowing more cold air to penetrate through to bring the heat away from the body and accelerate the sweat evaporation at the skin and fabric surface.

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