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Study on Moisture Behaviour of Weft Knitted Interlock Spacer Fabrics

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Abstract: Investigations on moisture absorption behaviour of double-layered spacer knitted fabrics enabled to anticipate the fabric's ability to absorb humidity and transmit to the next layer and evaporate to the environment. The main objective of this work is to investigate the influence of inlay yarn properties in the knitted structure on moisture absorption in weft knitted interlock spacer fabrics. The face and back fabric layers are knitted with cotton yarns and cotton/viscose/polyester yarns with varying linear densities are used in inlay. Box Benhken experimental design with quadratic model is used to execute the experiment with fifteen runs. The study established that the moisture transfer behaviour of the fabric is influenced by fibre nature, inlay yarn count and space between the two layers. The polyester inlay yarn showed higher moisture transfer behaviour when compared with cotton and viscose.
Key words: Interlock fabric, Overall Moisture Management Capacity (OMMC), inlay.

Introduction

Moisture transmission and thermal insulation properties of textiles have great influence on the comfort of the human body, which is balanced by perspiration both in vapour and liquid form. The moisture management of the clothing under changing humidity conditions is an important factor that influences the comfort of the wearer in practical use[1]. Clothing must assist the body's thermal control function under changing physical loads in such a way that the body's thermal and moisture level is balanced and a microclimate is created next to the skin[2]. The human body continuously produces heat during all the activities due to metabolic processes. With greater physical exertion, greater level of heat is generated by the body itself and the heat transfer through clothing is insufficient to compensate the body's energy balance. As a result the body begins to sweat in order to cool the body through evaporation of sweat on the skin[3].

A fabric that is perceived as comfortable should be able to transport moisture in both vapour and liquid form during body sweating. Prahsarn et al[4] and Yoon and Buckley[5] showed the importance of fabric construction variables on moisture transmission characteristics. When a fabric allows the transport of water vapour at a faster rate, it is said to be water vapour permeable[6,7]. Hygroscopic fibres, such as cotton, have higher water absorption levels and release water slowly. This retention of water increases the weight of the garment as well as impairs the heat dissipation from the skin and post–activity evaporative cooling[8]. Synthetic fibres such as polyester, polypropylene and polyamide are hydrophobic in nature and therefore they absorb less moisture.

Yi Li[9] studied air and water vapour transport properties that are mainly related to heat and moisture transfer characteristics of textiles. He described the mechanism of water vapour transmission such as diffusion, absorption, adsorption and forced convection. Wicking is another effective process to maintain the feel of comfort in sweating conditions. The clothing with high wicking properties is able to spread the sweat throughout the fabric and enables the moisture to evaporate quickly. During wetting, the liquid reaches the space between the fibres and causes a capillary pressure[10]. Saravana kumar and Sampath[11] studied the swelling of fibres and subsequent change in dimensional properties of rib knitted fabrics through artificial neural network.

In interlock knitted fabric, sweat secreted from the wearer's skin is absorbed by the inner layer and then transferred to the outer layer by diffusion for evaporation in the open air. In this research work, interlock fabrics are knitted with three different types of inlay yarns and their influence on the dynamics of water absorption was investigated.

Material and Methods

Face and back yarn:

Cotton spun yarn with a linear density of 30^s Ne is used for both face and back layers of interlock fabric. The average twist per inch of yarn is 26 and the twist direction is Z.

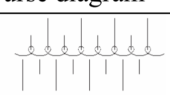
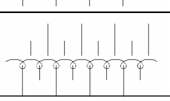
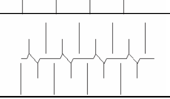
Inlay yarn:

Inlay yarns with three types of fibres such as cotton, polyester and viscose are used. Cotton yarns with three linear densities 20^s, 30^s and 40^sNe were used. Polyester and viscose filament yarns of 120, 180 and 300 deniers were used for fabric development.

Production of knitted fabric

All the experimental sample interlock fabrics are produced in imported circular knitting (Make: Pailung-XXI) machine which consisted of 18 gauge, 50 positive feeders and 30-inch diameter cylinder. The loop length and cam settings are kept constant for all the samples. The stitch diagram and yarn feed arrangements of the interlock fabric are given in Table 1.

Table 1 Fabric structure and materials

Course diagram	Material
1 	Cotton
2 	Cotton
3 	Cotton/Polyester/Viscose

Fabric Evaluation

The developed samples were measured for stitch length (mm), areal density (g/m^2) and fabric thickness (mm). The fabric structural and physical properties were evaluated according to ASTM standards ; aerial density (ASTM D 3776), thickness (ASTM D 1777), wales and courses per unit length (ASTM D 3887: 1996)and loop length (ASTM D 3887). The samples were tested for moisture management properties like wetting time of top & bottom (WTt, WTb), absorption rate of top & bottom (ARt&ARb), maximum wetted radius of top & bottom (MWRt&MWRb), spreading speed of top & bottom (SSt&SSb), accumulative one-way transport capacity index (AOTI) and overall moisture management capability (OMMC) according to the procedures of AATCC 195-2009 test method. .

Over all moisture management capacity (OMMC) is an index indicating the capacity of the fabric to manage transport of liquid moisture, which includes three aspects:

1. Average moisture absorption rate at the bottom surface.
2. One-way liquid transport capacity.
3. Maximum moisture spreading speed on the bottom surface.

The OMMC is defined as:

OMMC = C_1 x ARb + C_2 x AOTI + C_3 X SS_b, (2)

where C_1, C_2, and C_3 are the weights of the index of the absorption rate (AR_b), the accumulative one-way transport index (AOTI) and the spreading speed (SS_b), respectively. Here, C_1=0.25, C_2=0.5 and C_3=0.25, and they can adjust with respect to end-of-use purposes. AOTI is the difference in the accumulative moisture content between the two surfaces of the fabric. AOTI reflects the one-way liquid transport capacity from the top (inner next to the skin) to the bottom (outer) surface of the fabric[12].

In this experiment, all specimens were washed, hydro extracted and dried. The samples were conditioned for 24hours in the standard atmosphere before testing.

Experimental design for optimization

The design of experiments for optimisation of air permeability and moisture transfer of interlock knitted fabric is formed by using Box Benhken design. The details are given in Table 2 and Table 3.

Table 2 Box benhken design for Process variables

Factors	-1 level	0 level	+1 level
Inlay yarn count	20Ne	30 Ne	40Ne
Areal density	360gsm	330gsm	300gsm
Inlay yarn composition	Cotton	Polyester	Viscose

Table 3 Three Factor Box-Behnken design of experiments with predicted response

Runs	Factors						Response
	Coded			Actual			Overall Moisture Management Capacity (OMMC)
	X1	X2	X3	X1 (Linear density)	X2 (Areal density in gm/m^2)	X3 (Composition)	
1	0	0	0	30Ne	330	Polyester	0.72
2	-1	-1	0	20Ne	360	Polyester	0.63
3	1	-1	0	40Ne	360	Polyester	0.61
4	-1	0	1	20Ne	330	Viscose	0.82
5	0	0	0	30Ne	330	Polyester	0.76
6	0	0	0	30Ne	330	Polyester	0.65
7	0	1	-1	30Ne	300	Cotton	0.84
8	0	-1	-1	30Ne	360	Cotton	0.72
9	-1	1	0	20Ne	300	Polyester	0.69
10	1	1	0	40Ne	300	Polyester	0.66
11	-1	0	-1	20Ne	330	Cotton	0.92
12	0	-1	1	30Ne	360	Viscose	0.63
13	1	0	-1	40Ne	330	Cotton	0.73
14	1	0	1	40Ne	330	Viscose	0.62
15	0	1	1	30Ne	300	Viscose	0.89

Results and Discussion

Effect of input variables on moisture transfer behaviour of fabric

The moisture transfer behaviour of fabric is studied with areal density, inlay yarn count and inlay fibre composition as input variables. The Figure 1 shows that the response and corresponding contour plots for Moisture transfer behaviour as a function of inlay yarn count and fabric areal density. A decrease in inlay yarn count with optimum fabric areal density yields maximum OMMC value of 0.73.

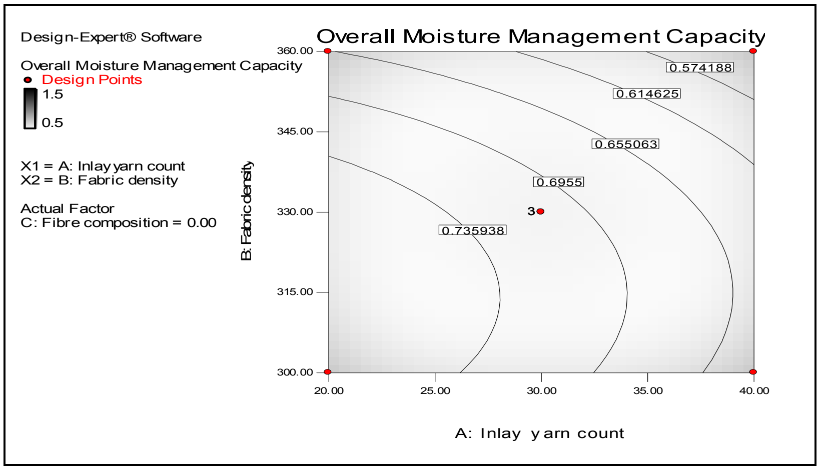


Figure 1. Response and contour plots for Moisture transfer behaviour for the function of in lay yarn count and fabric areal density

Figure 2 shows that the response and corresponding contour plots for moisture transfer behaviour as a function of lay yarn count and lay yarn fibre composition. A decreasing inlay yarn count with polyester fibre composition yields maximum OMMC value of 0.82.

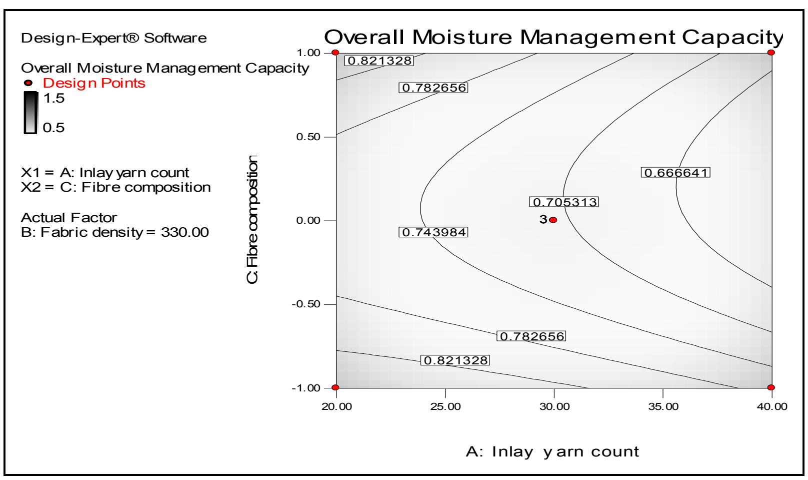


Figure 2. Response and contour plots for Moisture transfer behaviour for the function of in lay yarn count and in lay yarn fibre composition

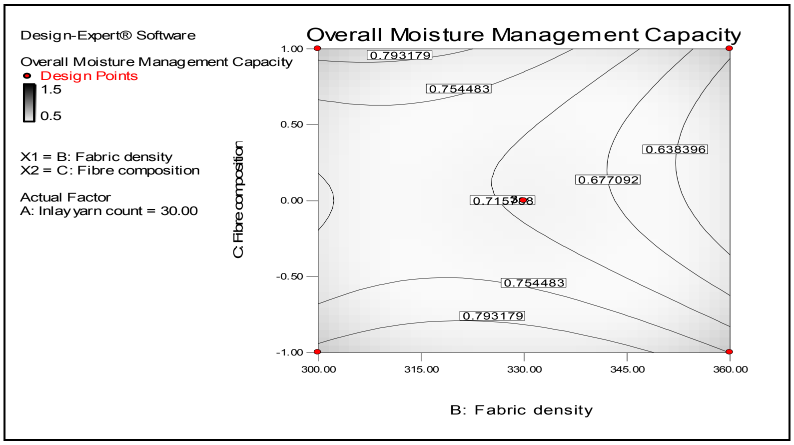


Figure 3. Response and contour plots for Moisture transfer behaviour for the function of fabric areal density and in lay yarn fibre composition

Figure 3 shows that the response and corresponding contour plots for Moisture transfer behaviour as a function of fabric areal density and lay yarn fibre composition. An optimum areal density with polyester fibre composition yields maximum OMMC value of 0.79. ANOVA for Response Surface Quadratic Model revealed that fabric density is the only significant parameter.

Development of prediction equations

The multiple regression equations are then developed by combining the process parameters for three different fibres with respect to its air permeability as well as OMMC. The equations obtained from that analysis are given in Table 4.

Table 4. Multiple Regression Equations for Prediction

Material	Experimental model for Overall Moisture Management Capacity (OMMC)
Cotton fabric	1.748 − 0.010*count − 0.002*areal density
Polyester fabric	1.014 − 0.001* count − 0.001* areal density
Viscose fabric	2.470 − 0.01*count − 0.004* areal density

Experimental Validation of the Model

The experimental model is validated by comparing the predicted values of air permeability and OMMC with the actual values of new samples developed for validation. Three samples are developed with varying input parameters and the parameter values shown in Table 5. The correlation co-efficient for air permeability is 0.98 and for OMMC is 0.97. This shows that the values are highly positively correlated.

Table 5 Validation of predicted and actual values

Types of fibre in fabric	Overall Moisture Management Capacity (OMMC)	
	Actual value	Predicted value
Cotton	0.65	0.64
Polyester	0.68	0.66
Viscose	0.81	0.77

Conclusions

The main conclusions drawn from the experiment performed are as follows:

- The overall moisture management capacity of the double knit structures mainly influenced by inlay yarn count and fibre composition of the inlay yarn i.e. as the inlay yarn count become coarser the OMMC value will increase. As per Prahsarn et al[4] the rate of moisture transfer in polyester is higher that of cotton and viscose fibres and the outcome of the research is justified .

- As compared with the contour analysis to the predicted regression model the maximum possible values of air permeability and OMMC for the selected process parameters are 249 ft3/ft2/min and 0.82, respectively.

- The study reveals that the inlay yarn made with viscose material shows better moisture absorption and transportation behaviour with 0.81 OMCC value.

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