

## Study on physiological comfort of fabrics made up of structurally modified friction-spun yarns: Part II – Liquid transmission

K V P Singh & A Chatterjee

Department of Textile Technology, National Institute of Technology, Jalandhar 144 027, India  
and

A Das<sup>a</sup>

Department of Textile Technology, Indian Institute of Technology, New Delhi 110 016, India

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Dref III friction-spun yarn has been structurally modified using polyester filament fibre as core, viscose staple fibre as secondary core and water soluble poly (vinyl alcohol) as sheath. The yarn is then treated with hot water to wash out PVA in the sheath, leaving the twistless viscose staple fibres on the surface. Effect of sheath fibre proportion, fibre fineness and yarn fineness on physiological comfort related properties affecting the liquid transmission behaviour, such as wickability and water absorbency, has been studied. It is observed that the structural modification of yarn influences the liquid transmission behaviour of fabric. All the three factors studied significantly affect the liquid transmission behaviour of the fabric.

**Keywords:** Friction-spun yarn, Polyester, Viscose, Water absorbency, Wicking

### 1 Introduction

As per the global scenario, physiological comfort is very basic and necessary property of the fabric. The fabrics with higher level of comfort values have a tremendous scope from the point of view of comfort in the garment industry. The comfort has been an inherent feature of the knitted textiles. To further increase the softness in knitted fabric, twistless yarns are used. As compared with that of conventional spun yarns, their strength largely depends on the amount of twist but it has the disadvantage of imparting a harsh feel to the fabric<sup>1</sup>. Once the twistless yarn has been assembled in a fabric structure, the compacting forces created by the fabric structure itself hold the systems together<sup>2</sup>. Hence, it is quite possible to produce a twistless knitted fabric with improved parameters of physiological comfort, which can be beneficial for apparels.

Among the modern high technologies for producing spun yarns, friction spinning has some advantages over the others due to lower production cost. But its main disadvantage is the harsh feel due to the wrapper fibres of the sheath<sup>1</sup>. In order to increase the comfort-related properties of friction-spun yarn,

Merati and Okamura<sup>3</sup> used hollow yarn. They succeeded in getting the enhanced comfort with hollow yarn but they were unable to minimize the harsh feel<sup>4</sup> in fabric. Das and Ishtiaque<sup>2</sup> used twistless friction-spun yarns in weft to improve the comfort characteristics of fabrics. However, there is still a need to improve comfort characteristics of friction-spun yarn with minimum harsh feel. The present work was therefore undertaken with an objective to prepare twistless friction-spun yarn with minimum harsh feel and enhanced physiological comfort-related properties.

Physiological comfort evaluation (*f*) includes study of fabric behaviour with respect to 'vapour' and 'liquid' transmission properties at constant atmospheric conditions and constraints. 'Vapour transmission' [*f* (*a*, *b*, *c*)] includes air permeability (*a*), water vapour permeability (*b*), and thermal conductivity (*c*). 'Liquid transmission' [*f* (*d*, *e*)] includes wicking (*d*) and water absorbency (*e*).

The knitted fabric developed from the modified friction-spun yarn can be used for the specific apparels. These fabrics demand higher physiological comfort-related properties, viz. air permeability, wicking, thermal conductivity, water vapour permeability and water absorbency. A detailed study has already been reported<sup>5</sup> on the moisture vapour

<sup>a</sup>To whom all the correspondence should be addressed.  
E-mail: apurba@textile.iitd.ernet.in/ apurba65@gmail.com

transmission of the fabrics. This paper is focused only on liquid transmission properties, i.e. wicking and water absorbency. An attempt has also been made to develop regression equations of the above- mentioned properties to reproduce and predict the results.

## 2 Materials and Methods

Sample details and methodology adopted have already been discussed in earlier paper<sup>5</sup>.

As reported earlier<sup>5</sup> polyester filament fibre was used as a core, viscose staple fibre as a secondary core and PVA (poly vinyl alcohol) as a sheath (Fig.1). DREF-III spinning machine was employed to produce the series of yarns at constant yarn delivery speed of 200 m/min and spinning drum speed of 3500 rpm.

### 2.1 Test Procedure

Even after the removal of PVA, the fabric is not affected because compacting forces created by the fabric structure itself hold the system together<sup>6</sup> and also polyester multifilament core provides the strength to the yarn. These knitted fabrics were then tested for comfort properties related with liquid transmission properties i.e. wicking and water absorbency.

After the washing is complete, the fabric was dried and kept for conditioning for 24 h before testing. Conditioning is done at  $65\% \pm 2\%$  relative humidity and  $27^{\circ}\text{C} \pm 2^{\circ}\text{C}$  temperature [ASTM D1776- 90(96)]. After that the prepared knitted samples were tested for wicking (BS: 3424) and water absorbency (BS: 3449).

#### 2.1.1 Wicking

For measuring wicking rate in knitted samples, capillary method was used. To determine the capillary rise in the samples, specimen of each sample was cut with  $12 \times 1$  inch dimension. The strip fabric was then suspended vertically with its lower edge in a reservoir of distilled water. The rate of the leading edge of water was then monitored. To detect the position of the water line, a dye was added to water. The measured height of rise in a given time (5 min) was taken as a direct indication of wicking of the test fabrics.

#### 2.1.2 Water Absorption

To measure the absorption of water in fabrics, circular specimens of area  $45.36 \text{ cm}^2$  were used. Four identical specimens from each fabric sample were tested. Samples were conditioned, weighed, uniformly wetted out in water and then left over

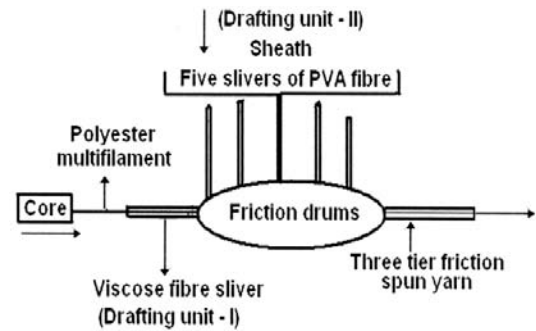


Fig. 1– Schematic diagram of production of three tier friction-spun yarn

Table 1— Actual and coded values of factors in three factor-three level Box-Behnken design

Factor	Low actual value	High actual value	Low coded value	High coded value
Fibre fineness ( $X_1$ ), den	1.3	1.7	-1	1
Yarn fineness ( $X_2$ ), tex	32.81	59.05	-1	1
Proportion of sheath ( $X_3$ ), %	10	15	-1	1

Table 2— Responses in three factor-three level Box-Behnken design

Response	No. of observation	Minimum value	Maximum value
Water absorbency ( $Y_1$ ), %	17	128.01	140.5
Wicking height in 5 min ( $Y_2$ ), cm	17	4.7	8.5

night sandwiched between two wet sponges. After 24 h, the mass of water freely absorbed by each sample was recorded and water absorbency was calculated using the following relationship:

$$\text{Water absorbency (\%)} = \frac{\text{Mass of water absorbed}}{\text{Original mass}} \times 100$$

### 2.2 Design of Experiment

Three level factorial Box-Behnken design was used for designing the experiments optimally and to create respective response surfaces (Tables 1 and 2). As each response is a linear function of independent variables, the approximating function is first - order model<sup>7</sup>, as shown below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_k X_k + \epsilon$$

The surface represented by  $Y = f(X_1, X_2, X_3)$  is known as 'response surface'. To know the interaction effect of variables, quadratic model was used. After the evaluation of responses of respective samples in the design, further analyses were performed for the development of a model to get the desired regression equations, both linear and quadratic (Table 3).

### 3 Results and Discussion

#### 3.1 Influence of Yarn Modification on Wicking

##### 3.1.1 Effect of Fibre Fineness

The effect of fibre fineness on wicking characteristics of fabrics is shown in Figs 2(a) and (b). It is evident that as the fibre becomes coarser the fabric wicking increases. The reason may be attributed to the higher bending rigidity of coarser fibres<sup>8</sup> and decrease in number of fibres in yarn cross-section. This results in increase in yarn bulkiness<sup>3,9</sup>. The availability of more pore space within the yarn structure leads to increase in wicking<sup>10</sup>.

##### 3.1.2 Effect of Sheath Content

The impact of sheath content on wicking characteristics of fabrics is given in Figs 2(b) and (c). It is observed that as the proportion of sheath fibres increases, the fabric wicking increases. The reason may be attributed to the increase in openness of fabric<sup>10</sup> and yarn bulkiness after sheath removal, resulting in availability of more air spaces in the yarn structure<sup>9</sup>. Moreover, parallel arrangement of fibres creates proper channeling within the yarn, leading to increase in wicking<sup>2,11,12</sup>.

##### 3.1.3 Effect of Yarn Fineness

Figures 2(a) and (c) show the effects of yarn fineness on wicking characteristics of fabrics. It is observed that with the increase in yarn coarseness the fabric wicking initially increases and then decreases. As the yarn becomes coarser, initially the size of the pores increases due to the decrease in compactness of

yarn structure<sup>9,13</sup> and increase in bulkiness of yarn, thereby increasing the availability of air spaces in yarn structure. This leads to increase in wicking<sup>10,12</sup>. But after certain point, the pore structure becomes more open which reduces the rate of water travel through the pores.

#### 3.2 Influence of Yarn Modification on Water Absorbency

##### 3.2.1 Effect of Fibre Fineness

The impact of fibre fineness on water absorbency of fabrics is given in Figs 3(a) and (b). It is evident from figures that the water absorbency increases as the fibres become coarser. The reason may be attributed to the higher bending rigidity of coarser fibres<sup>6,7</sup> and decrease in number of fibres in yarn cross-section. This results in increase in yarn bulkiness<sup>3,8</sup>. The availability of higher pore volume in yarn structure also leads to increase in water absorbency<sup>10</sup>.

##### 3.2.2 Effect of Sheath Content

Figures 3(b) and (c) show the effects of sheath content on water absorbency of fabrics. It is observed that with the increase in sheath content the fabric water absorbency increases. The reason may be attributed to the increase in openness of fabric<sup>9</sup> and yarn bulkiness after sheath removal, resulting in availability of more air spaces in yarn structure, which then leads to increase in water absorbency<sup>13</sup>.

##### 3.2.3 Effect of Yarn Fineness

The effects of yarn fineness on water absorbency of fabrics are given in Figs 3(a) and (c). It is clear from figures that with the increase in yarn coarseness the water absorbency of fabric initially increases and then decreases. The reason may be attributed to the decrease in compactness of yarn structure<sup>13</sup> and increase in bulkiness of yarn, thus increasing the availability of air spaces in yarn structure which leads to increase in water absorbency<sup>14, 15</sup>.

Table 3—Regression equations

Response	Linear regression equation	Quadratic regression equation	$R^2$
Wicking ( $Y_1$ )	$-8.11 + 7.25 X_1 + 0.0001 X_2 + 0.3 X_3$	$-9.70 + 5.58 X_1 + 0.09 X_2 + 0.41 X_3 + 0.93 X_1^2 - 0.002 X_2^2 - 0.01 X_3^2 - 0.01 X_1 X_2 - 0.05 X_1 X_3 + 0.009 X_2 X_3$	0.96
Water absorbency ( $Y_2$ )	$83.68 + 24.80 X_1 + 0.03 X_2 + 0.94 X_3$	$61.8 + 56.35 X_1 - 0.11 X_2 + 1.26 X_3 - 14.68 X_1^2 - 0.004 X_2^2 - 0.11 X_3^2 + 0.09 X_1 X_2 + 0.65 X_1 X_3 + 0.032 X_2 X_3$	0.94

$X_1$  = Fibre fineness,  $X_2$  = Yarn fineness, and  $X_3$  = Sheath.

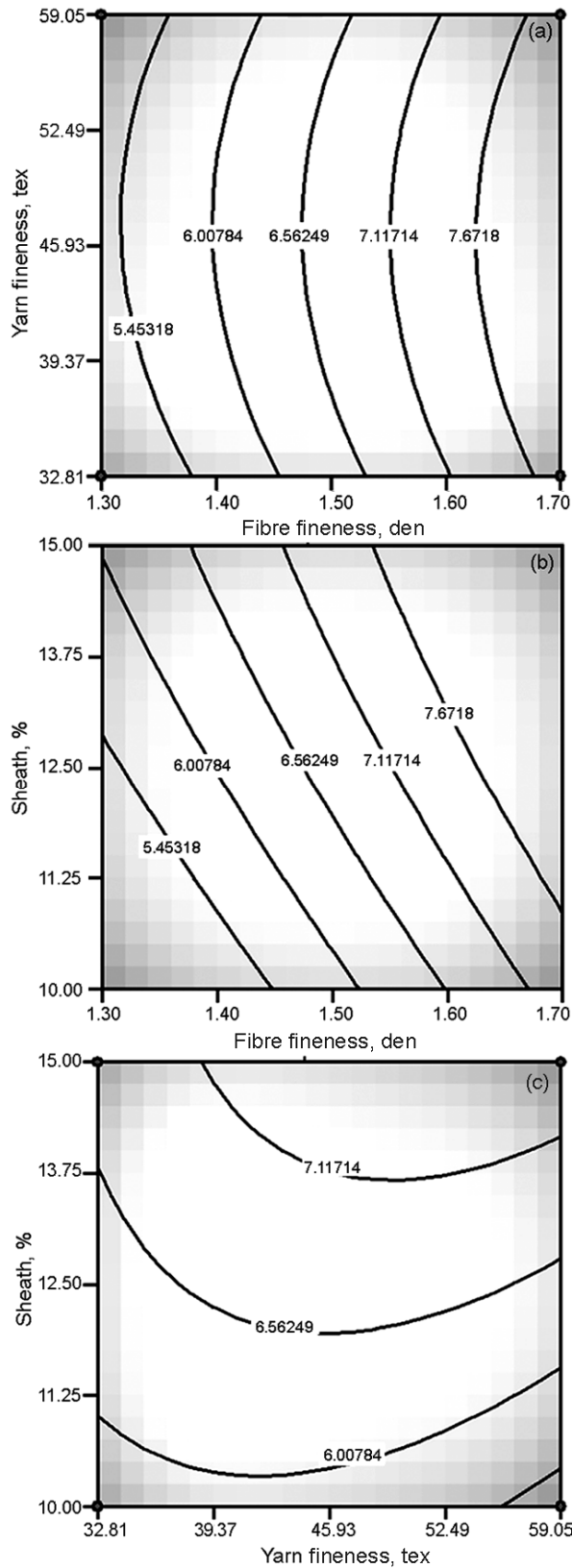


Fig. 2– Influence of yarn modification on wicking at constant (a) sheath %, (b) yarn fineness, and (c) fibre fineness

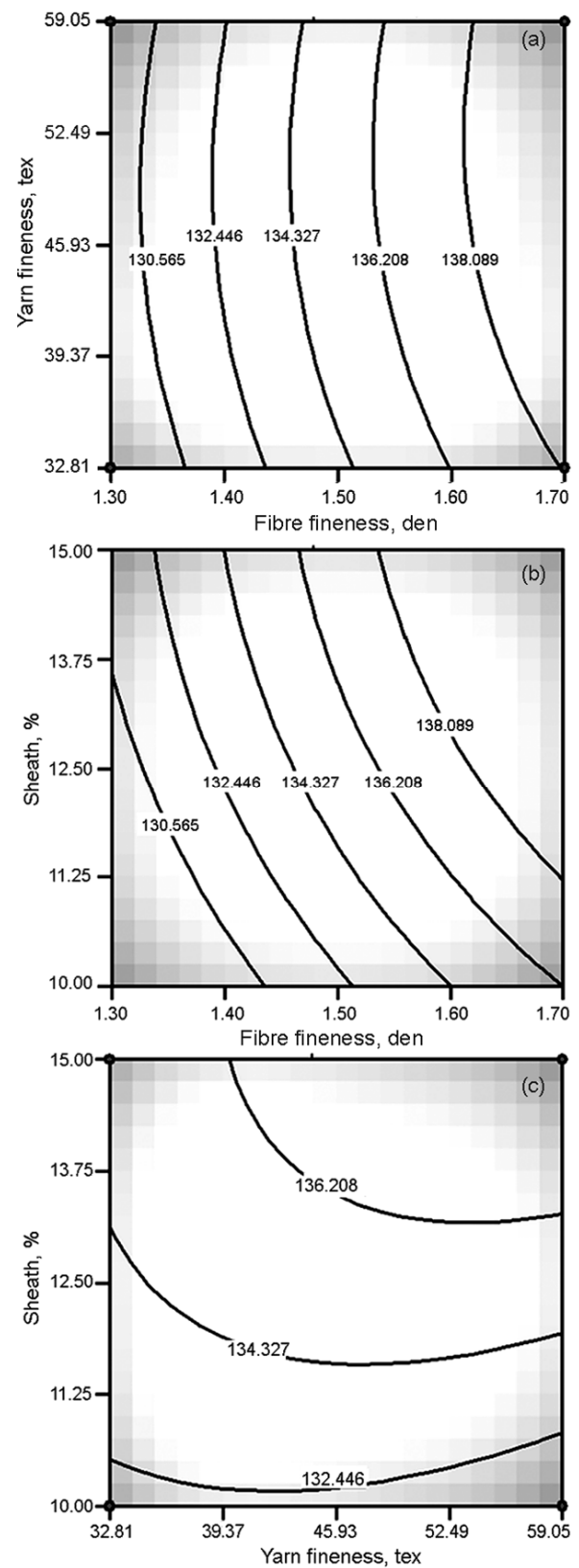


Fig. 3– Influence of yarn modification on water absorbency at constant (a) sheath %, (b) yarn fineness, and (c) fibre fineness

#### 4 Conclusions

With the increase in coarseness of fibre, the fabric wicking and absorbency increase. As the proportion of sheath fibres increases the fabric wicking and absorbency also increase. But in case of yarn fineness, as the yarn coarseness increases, the fabric wicking and absorbency initially increase and then decrease. The objective of the polyester multifilament is to act as a backbone of the twistless yarn. Moreover, it has a positive influence on wicking but negative influence on water absorbency. The crux of the matter is 'modification of friction-spun yarn enhances liquid transmission properties as per the desirability for specific end use'. Significant effect of proportion of sheath fibres, fibre fineness and yarn fineness is observed on liquid transmission behaviour.

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