STUDIES ON FRICTIONAL BEHAVIOUR OF CHITOSAN-COATED FABRICS

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Abstract

Anti-microbial finishing has been an area of constant interest for processors. In this paper, we carried out studies into the frictional behaviour of the chitosan-coated fabrics. With the increase in chitosan concentration, a decrease in frictional constant values is observed. Test parameters such as normal load and area of contact are bound to affect the frictional values. With an increase in normal load, a decrease in frictional values is observed; and with an increase in the area of contact, a decrease in frictional values is observed.

Key words:

chitosan, friction, normal load, area of contact, wool

1. Introduction

Friction, in general, is defined as the resistance encountered when two bodies are brought into contact and allowed to slide against each other. A great deal of work on friction has been carried out in view of its importance. It was in 1699 that Amontons discovered the classical laws of friction [1]. These laws state that, (a) the frictional force F is proportional to the normal load N applied on the area of contact, the proportionality constant denoted by μ, and called the friction coefficient (μ = F/N), and (b) The frictional force is found to be independent of the area. Later, Bowden and Tabor [2,3] proposed the adhesion-shearing theory, according to which the junctions are formed at the points of real contact, which must be sheared in order for sliding to occur. Thus, the frictional force 'F' is obtained by the product of the true area of contact 'A' and the bulk specific shear strength of the junctions 'S', i.e.

$$F=AS \quad (1)$$

$$F=(N/P_Y)\,S \quad (2)$$

$$F=(S/P_Y)\,N \quad (3)$$

$$F=\mu N \quad (4)$$

where 'P_y' is the yield pressure of the material.

Frictional properties determine the physical and mechanical behaviour of a fabric as well as the subjective assessment of quality when it is handled. Fabric frictional properties and roughness are mostly felt subjectively. The nearest measure to this which can be assessed objectively is frictional force, experienced by a fabric against the same fabric.

Chemical treatments modify the surface characteristics, thereby affecting the frictional parameters. Antimicrobial finishing is an interesting area of the processing field, and has caught the attention of various researchers and industries. Chitosan has emerged as a good potential candidate for the anti-microbial finishing of textiles .

Chitosan, being a very abundant natural biopolymer, and because of its polycationic nature, finds various fields of applications such as water purification and drug delivery beads, apart from its application as a coating material in textiles. Chitosan-coated fabrics are well-known for their antibacterial and antifungal resistance. Some research on antimicrobial activity by varying parameters such as degree of deacetylation, molecular weight and chitosan concentration has been reported by various researchers [4-5]. However, limited studies have been carried out on characterising the fabric properties of chitosan-coated fabric [6-8]. Chitosan-coated fabrics exhibit different surface characteristics when compared with the uncoated fabrics. Studies on the surface characteristics of these fabrics will provide an insight into their suitability for apparel purposes. Fabric friction is one of the important properties that characterise the surface behaviour of fabrics.

The objectives of this paper are to characterise fabric friction as a function of varying chitosan concentration by a new frictional constant. Since the frictional properties of the fabric are also influenced by testing parameters such as speed, area and load, these were also taken into consideration while studying the frictional properties of chitosan-coated fabric.

2. Materials and Methods

2.1 Preparation of chitosan coated fabrics

Wool fabrics woven with 56 ends per inch and 56 picks per inch was selected for the study.The warp count and the weft count of the woven fabrics was 10 tex. Chitosan supplied by the Central Institute of Fisheries Technology (CIFT, Cochin) was used for this study. For the chitosan treatment, concentrations of 0.5%, 1% and 1.5% were prepared using 2% v/v acetic acid. The codes of the fabric based on the chitosan concentration are given in Table 1.

Table 1. Chitosan concentration used for the friction studies, along with their codes

Chitosan concentrations used in this study	
Fabric code	Chitosan concentration, %
C0	0
C1	0.5
C3	1
C4	1.5

The fabric was padded to 100% wet pick-up, and was dried at 100°C for 3 minutes. The fabric was then cured at 160ºC for 3 min., and was then washed with warm water for 30 min.

2.2 Friction measurement equipment

The equipment constructed was similar to that used by Ajayi [9]. The apparatus consists of a wooden platform with a smooth and uniform surface. At one end of the platform, a wooden clamp is provided to hold the fabric sample, which forms the fixed sample. At the other end, a frictionless pulley is mounted in the centre of a grooved rod, which is supported on both sides by metal bars, as shown in Figure 1.

A special type of fabric holder, which resembles the one developed in [10], was designed from wood, where a fabric sample is held onto the leading edge of holder by a small metallic plate, which can be tightened or loosened with the help of screws and nuts. The metal plate carries a hook which is positioned at the centre of gravity of the holder. The face of the holder, which is in contact with the sample, is lined with a thin and smooth wood. The specifications of the fabric holder are as follows: length 36 mm; width 37mm; and weight 27g.

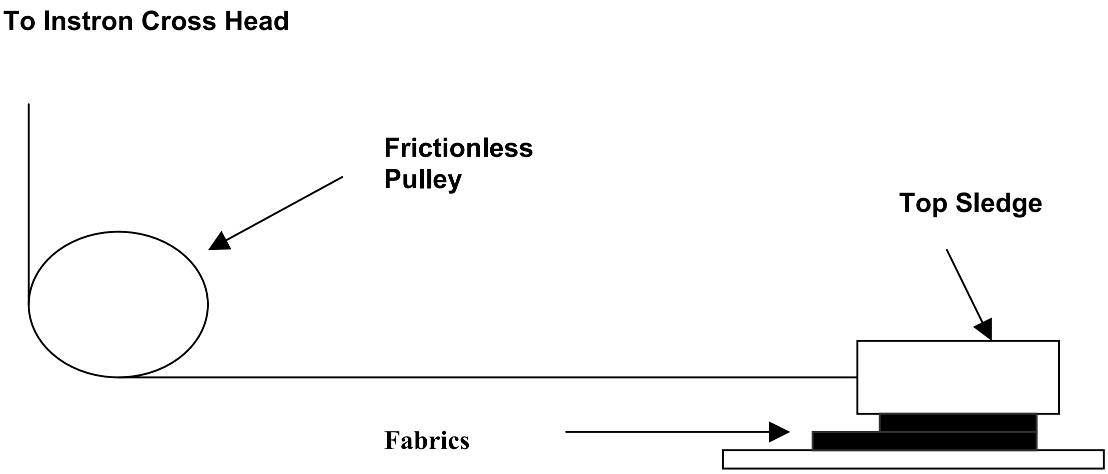

Figure 1. Frictional set-up used in Instron for testing friction

2.3 Measurement of friction

The equipment described was placed over the Instron platform and levelled. One holder with fabric on it was kept on the platform which formed the fixed fabric sample. Another holder with a fabric was then placed over the fixed fabric sample, so that the samples were in contact with each other. The area of contact depends upon the width of the fabric. Normal force from 27g-127g was then applied by placing the weights over the holder. The hook of the holder was connected to the moving crosshead of Instron by a string of non-extensible polypropylene filament. The initial tension of the string had an effect on the frictional force, and hence it is important to keep the string straight and fairly taut.

When the crosshead of Instron starts moving up, the tension builds up in the string. Once the friction overcomes the static friction, the holder starts moving so that relative sliding occurs between the fringes. The sliding motion is sticky-slippery in nature, which is governed by the fabric type and test conditions. One fabric holder can slide for any distance, depending on the length of sample size. In this study, the sliding distance was changed from 5-25 mm/min.

The maximum force at which sliding starts is termed as static frictional force (F_s). The dynamic frictional force (F_d) is calculated by averaging the peak values in the stick-slip force, for a sliding distance form 6mm to 12mm. The computer with Instron on-line performs the necessary calculations and prints the results & the friction profile.

In the case of textile fibres, Amontons' laws of friction fail, and hence the coefficient of friction μ is not a logical measure to characterise the frictional properties of fabrics [10-12]. Frictional properties are characterised using the friction index n and the frictional parameter C [9,14].
The relationship between friction force and normal load can be represented by the power relationship:

$$F/A = C\,(N/A)^n. \qquad (5)$$

where F is the friction force in Newtons, C is the friction parameter in Pa $^{(1-n)}$, N is the normal load applied in Newtons, A is the apparent area of contact in m^2, n is the friction index, and Pa is Pascals, which is given in Newtons / m^2.

The friction parameter C and friction index n are interdependent, and hence it is not logical to make frictional comparisons among different fabrics using the friction parameter C. To overcome this difficulty, a simple friction factor R is defined that makes the frictional comparisons among the different possible fabrics [12].

$$R = C/n \qquad (6)$$

Friction parameters are derived from the friction force and normal load values (Eq. 5). Regression analysis was carried out using $\log_{10}$ (F/A) and $\log_{10}$ (N/A) values. The intercept and slope values were obtained from the regression analysis. The intercept represents the friction parameter C, and the slope represents the friction index n. The friction parameters C and n are then used to obtain the simple friction factor R.

Many studies on the frictional behaviour of textiles have shown the importance of the load. The results of these studies indicate that a normal load induces alteration in the nature of contact between the textile samples [13,14]. In our investigation into chitosan-treated wool fabrics, a load range of 27g-77g was considered sufficient to explore the effect of normal load on friction properties.

Only limited information is available in the literature on the effect of apparent area of contact on fabric frictional characteristics. One of the most informative studies is [15], which deals with the effect of apparent area of contact on dynamic friction between fabrics. Both the theoretical analysis and the experimental results clearly show that apparent contact area is important in fabric frictional characteristics. Three different areas of contact – 9.7 cm^2, 11.5 cm^2 and 13.3 cm^2 – were considered in this case to examine their effect on the frictional properties.

Speed is another frictional parameter that influences friction value. Preliminary trials at speeds of the order of 10, 100 and 500 mm/min for directly-driven fabric samples did not show any significant differences in the frictional force. In view of this, a constant speed of 5 mm/min was adopted for this study.

3. Results and discussion

The results of the frictional studies carried out on the fabrics are presented in Tables 2 and 3, from which it can be seen that the friction factor (R) of the chitosan-coated fabric decreases with the increase in concentration, irrespective of the testing parameter.

Table 2. Frictional parameter and frictional index values for fabrics

Area, cm^2	Fabric treatment coating, %	Friction parameter and friction index values		
		Fabric code	Average friction parameter C, [Pa (1-n)]	Average friction index, n
13.3	Control	AC0	0.9784	0.7563
	0.50%	AC1	0.9778	0.8863
	1%	AC2	0.8475	0.8634
	1.50%	AC3	0.7354	0.9378
11.5	Control	BC0	0.9678	0.8876
	0.50%	BC1	0.9354	0.8974
	1%	BC2	0.8863	0.8975
	1.50%	BC3	0.6234	0.9784
9.7	control	CC0	0.9367	0.9745
	0.50%	CC1	0.9012	0.9621
	1%	CC2	0.8633	0.9687
	1.50%	CC3	0.59	0.9921

The decrease in the friction constant is associated with the uniform coating with the increase in concentration of chitosan. This conforms with studies carried out on wool fabric coated with chitosan using the KES-F system and dual-finished textile materials[6,7]. Above 1.5% chitosan concentration, the viscosity of the polymer increases drastically, making it unfeasible to coat on the fabrics.

However, for a given chitosan concentration with changes in normal load and area of contact, the frictional parameters and the frictional index change. With the increase in normal load, the coefficient of friction decreases as given in Figures 2, 3 and 4. This is because as the normal force increases, the nature of contact between the fabrics is altered. At higher normal force, the fabrics present more uniform and constant area of contact. As a consequence, the new friction constant value decreases as the load increases.

Table 3. R values for fabric samples tested and measurement of improvement of fabric smoothness

Area(cm^2)	Fabric treatment coating, %	Fabric code	R	improvement= *(Ro -Rn)/Ro x 100*, %
13.3	Control	AC0	1.29	0
	0.50%	AC1	1.10	14.72
	1%	AC2	0.98	24.12
	1.50%	AC3	0.78	39.38
11.5	Control	BC0	1.09	0
	0.50%	BC1	1.04	4.40
	1%	BC2	0.98	9.43
	1.50%	BC3	0.63	41.56
9.7	Control	CC0	0.96	0
	0.50%	CC1	0.93	2.54
	1%	CC2	0.89	7.27
	1.50%	CC3	0.59	38.13

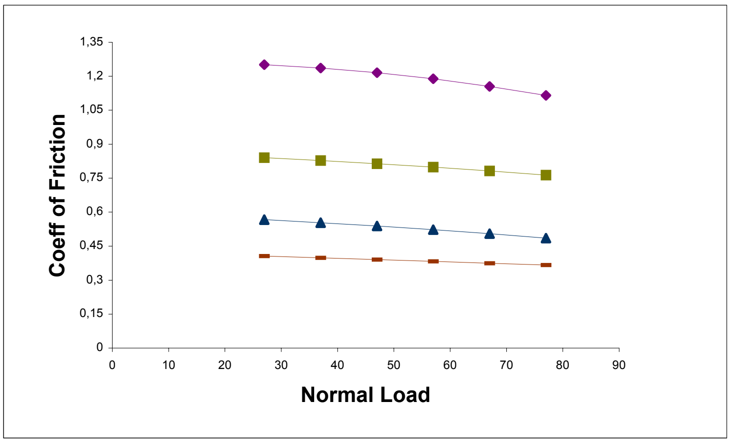

Figure 2a. Coefficient of friction of fabrics as a function of normal load at an area of 13.3 cm^2

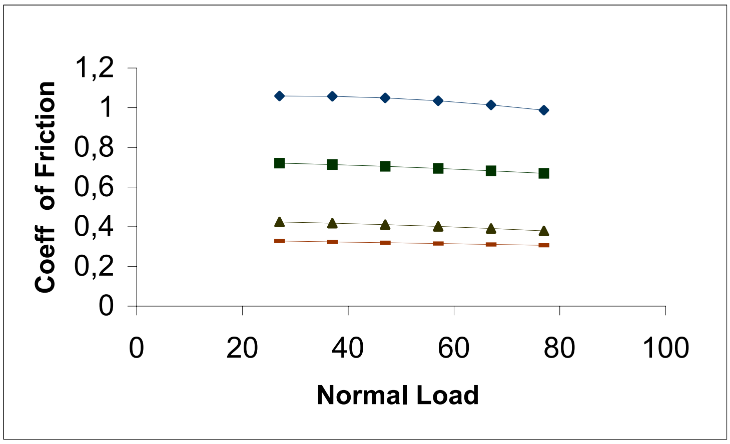

Figure 2b. Coefficient of friction of fabrics as a function of normal load at an area of 11.5 cm^2

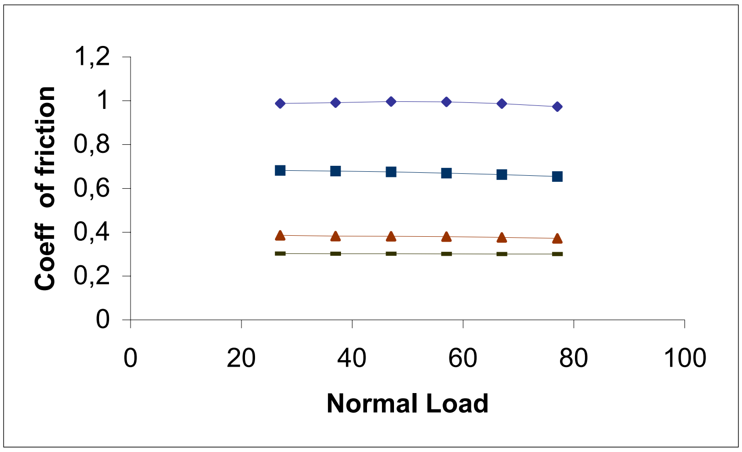

Figure 2c. Coefficient of friction of fabrics as a function of normal load at an area of 9.7 cm^2

From Table 3, it can be observed that the frictional constant value increases with the increase in the area of the fabrics' contact. This is attributed to the increase in the number of contact points which are to be sheared to start sliding, creating a higher value of the frictional constant.

The percentage improvement in smoothness is given in Table 3, from which it can be seen that the smoothness of the fabric increases with the coating concentration; the improvement is notably high for 1.5% concentration. This is attributed to uniform film formation on the fabric, as discussed earlier.

4. Conclusions

On the basis of these studies, we observe that coating with chitosan leads to the formation of a uniform film on the surface of the fabric, leading to low frictional values. With the increase in chitosan concentration, a more uniform coating is formed on the surface of the fabrics, thereby reducing frictional values. The parameters of normal load and area of contact have a significant effect on the fabric friction.

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