

Assessment of frictional properties of some woven fabrics

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Static and kinetic friction of some woven fabrics have been studied using different contact surfaces on the Instron tester with the help of a friction attachment. It is observed that air-jet texturing of weft yarns increases the frictional resistance of fabrics. The nature of the contact surfaces during the sliding action affects the frictional resistance considerably. Fabric-to-metal friction is less sensitive to the morphology and type of fabric. Variation of mesh size in monofilament fabrics affects the frictional resistance of these fabrics.

Keywords: Air-jet textured yarn, Frictional properties, Kinetic friction, Static friction, Tactile comfort, Woven fabrics

1 Introduction

Clothing comfort is generally classified into three broad categories, viz. thermal comfort, tactile comfort and aesthetic or psychological comfort. The thermal comfort is primarily related to the efficiency of heat dissipation from a clothed human body, the tactile comfort to the mechanical interaction between the clothing material and the human body and the aesthetic comfort to appearance. Fabric surface characteristics are important in determining the handle of the fabric and tactile comfort. The fabric surface is not homogeneous, smooth and featureless plane but has a number of ridges formed by yarns, arranged periodically in two dimensions and covered with a large number of fibres protruding out of yarn bulk. The surface fibres have a finite stiffness, tend to separate the fabric bulk from the skin, and act as the load transmitting media in low compressional load regions. Length and stiffness distributions of these surface fibres have a primary importance in tactile comfort. An important property of many textile material is their handle—an estimation of their feel between fingers and thumb. Therefore, the fabric handle depends on the sense of touch. One of the factors which influence this subjective judgement is undoubtedly the static and dynamic coefficient of friction between the cloth surface and the thumb or finger, although flexibility, thickness and other properties of the material are also involved when making such an assessment of cloth quality. In common with other manufactured goods, cloth can be specified with reference to a number of its physical properties, some of which will be more

important in some applications. Friction is considered to be one such property which has not yet received much attention, particularly in relation to handle or factors modifying handle.

The importance of sliding friction in clothing comfort is intuitively evident if we consider the words people used to describe 'feel' and 'aesthetics' of a fabric. Some of these words (e.g. clingy, greasy, mushy, oily, rough, scratchy, sheer, sticky, waxy, etc.) are related to the sliding behaviour of fabric and suggest the importance of frictional behaviour. The human hand is a sensitive instrument, capable of detecting small differences in fabric quality. The results of hand tests are expressed in such words as given above. It was found that while the descriptions such as smooth, harsh, etc. may be applied by handling the fabric, observers were very uncertain and divergent in judgement based on softly stroking a fabric laid flat on a table, i.e. when nothing but sliding friction could be appreciated. Sliding friction is of importance in deciding the aesthetic value. It is also important in other applications such as the writing surfaces of tracing cloth where the fabric should be of a certain roughness to offer due resistance to the steel pen-point.

In the present work, the frictional behaviour of the fabrics woven with cotton, cotton-filament composite and multifilament yarns (air-jet textured as well as untextured) in grey and finished states has been studied. The frictional behaviour of the woven fabrics of different mesh size produced with nylon monofilaments has also been studied.

1.1 Theory of Friction

During the last two decades, advances have been made in understanding the basic mechanism of friction. The adhesion theory of metallic friction has been extended to include high polymers and ceramic materials. The mode of deformation, real area of contact, and role of junction growth between the sliding surfaces have received attention. When one body slides over another under a normal load N , a finite force is resisting the motion; this force is termed as frictional force and is designated as F_s for static and F_k for kinetic conditions. The magnitude of the static frictional force generally exceeds the magnitude of kinetic frictional force. The latter is the force required to maintain sliding. Friction generally follows two basic laws which are referred to as Amonton's classical laws¹.

The friction of unlubricated surfaces arises due to two main factors. The first, which is usually the predominant factor, is the adhesion at the real area of contact. Such area is usually much smaller than and independent of the geometric area of the sliding body. Thus, the major component of friction between sliding solids is the force necessary to shear all the junctions. Consequently, if A is the true area of contact and S , the shear strength of the weaker material, the adhesion part of the friction may be written as:

$$F(\text{adhesion}) = A \times S$$

The second factor arises from the ploughing and grooving of the softer material by the harder material. It is denoted as deformation. Under conditions of negligible interaction between these two processes the total frictional force ' F ' may be expressed as:

$$F = F(\text{adhesion}) + F(\text{deformation}) \quad \dots (1)$$

since the frictional behaviour of metals can be approximated by the adhesion mechanism. If the contacting asperities deform plastically, as is generally observed in metal friction, the real area of contact is equal to the ratio of the normal load (N) and mean yield pressure (P) of the softer material.

$$A = N/P \quad \dots (2)$$

Consequently, the coefficient of friction (μ) is equal to the ratio of the shear strength and the yield pressure of the softer material.

$$\mu = F/N = S/P \quad \dots (3)$$

This relationship is considered as an over simplification in case of fabrics, since the shear strength and yield pressure in the contact region

may differ from those of the bulk materials². In the theory of fabric friction, the friction coefficient μ is believed to consist of two components, namely the adhesion term and ploughing term³.

$$\mu = \mu_a + \mu_p$$

In a loose structure such as fabric, the relative importance of these two terms varies with the type of surface in contact and with the applied load N . When the fabric is in contact with a surface of the same fabric, the surface fibres penetrate into the domain of the fibres of the contacting fabric and form a loose inter-fabric structure. The friction coefficient represents the energy lost in breaking this loose structure (or energy lost in shearing the inter-fabric structure), while resistance to this comes from the adhesion at contact points of fibres and the bending of fibres in the moving fabric surfaces.

2 Materials and Methods

The description and construction details of woven fabrics studied for frictional properties are given in Table 1. These fabrics can be classified into the following four groups:

Group I: Cotton/polyester composite yarn woven fabrics (Fabric Nos 1-4). In these fabrics, warp is 100% cotton and weft is cotton/filament (89.5:10.5) composite yarn. A parent composite yarn was textured on an Eltex AT/HS machine at a texturing speed of 300 m/min using a HemaJet with T100 core at 500 kPa air pressure and 11.1% overfeed.

Fabric samples having parent composite yarn and air-textured composite yarn as weft were tested in grey as well as mill-finished form.

Group II: 100% cotton fabrics made from untextured and air-jet textured yarns (Fabric Nos 5-8). These fabrics have either untextured warp and weft or untextured warp and textured weft and were tested in both grey and finished (bleached) form. In textured yarn fabrics, cotton yarns were textured in the same way as the weft yarns of Group I fabrics.

Group III: Synthetic multifilament yarn woven fabrics (Fabric Nos 9-12). Fabrics 9 and 10 have polyester weft yarns while the fabrics 11 and 12 have nylon weft yarns. In each fabric, the warp is untextured polyester. Textured yarns for these fabrics were produced on an Eltex AT/HS machine at a texturing speed of 300 m/min using a HemaJet with T100 core at 900 kPa air pressure and 25% overfeed.

Group IV: Three nylon monofilament bolting fabrics (Fabric Nos 13-15) of different mesh size.

Table 1—Construction details of the woven fabrics studied for frictional properties

Fabric No.	Fabric description	Sett (threads/cm)		Linear density (tex)		Yarn crimp (%)		Fabric weight (g/m ²)
		Warp	Weft	Warp	Weft	Warp	Weft	
Group I								
1	Cotton warp and untextured cotton/filament composite yarn weft mill-finished fabric	17	44	59	16.4	15.0	4.0	188
2	Cotton warp and air-jet textured cotton/filament composite yarn weft mill-finished fabric	17	43	59	16.4	15.0	4.0	182
3	Cotton warp and untextured cotton/filament composite yarn weft grey fabric	17	39	59	15.9	13.0	2.0	186
4	Cotton warp and air-jet textured cotton/filament composite yarn weft grey fabric	17	39	59	16.0	14.0	2.0	191
Group II								
5	Cotton warp and untextured cotton weft bleached fabric	17	14	65.6	65.6	17.3	11.4	182
6	Cotton warp and air-jet textured cotton weft bleached fabric	17	14	65.6	65.6	17.7	12.5	207
7	Cotton warp and untextured cotton weft grey fabric	16	13	59	59	12.0	11.3	192
8	Cotton warp and air-jet textured cotton weft grey fabric	16	13	59	59	9.4	9.6	186
Group III								
9	Untextured polyester warp and untextured polyester weft fabric	41	20	11.1	24.2	5.5	2.4	76
10	Untextured polyester warp and air-jet textured polyester weft fabric	41	20	12.9	24.9	5.0	3.3	82
11	Untextured polyester warp and untextured nylon weft fabric	44	20	10.0	25.0	4.7	4.2	81
12	Untextured polyester warp and air-jet textured nylon weft fabric	44	20	13.1	24.9	4.7	4.3	84
Group IV								
13	Fine mesh nylon monofilament bolting fabric	82	79	2.8	2.3	4.6	3.0	36
14	Medium mesh nylon monofilament bolting fabric	50	47	2.3	2.7	2.9	2.8	23
15	Coarse mesh nylon monofilament bolting fabric	21	20	15.1	17.0	2.6	2.3	69

2.1 Measurement of Friction

The measurement of friction of various fabrics was carried out using a fabricated attachment which can be mounted on the Instron tensile tester as described earlier⁴ and three readings were taken on each fabric. From the Instron chart, the values of F_s and F_k were calculated and the ratios (F_s/N) and (F_k/N) were taken as the measures of static and kinetic friction. Frictional measurements were carried out in the following three ways:

- *Fabric-to-fabric*: to simulate the interaction between clothing items. In all fabrics, fabric-to-fabric friction was studied taking two samples of the same fabric.

- *Fabric-to-leather*: to simulate the interaction between clothing and skin. The goat skin was used to approximate the human skin after consulting the skin experts at AIIMS, Delhi. The main reasons for the use of goat skin were its softness which closely approximates the human skin, elasticity and thickness. The rubber backing to leather was given, because of the fact that immediately after skin surface there is a soft material in the human body.

- *Fabric-to-metal*: as a representative of fabric movement on hard surface.

3 Results and Discussion

The values of fabric-to-fabric, fabric-to-leather

and fabric-to-metal friction for all the fabrics are given in Table 2.

3.1 Fabric-to-Fabric Friction

Fabrics 2 and 4 having textured composite yarn as weft show high (F/N) values compared to fabrics 1 and 3 having untextured composite yarn as weft in Group I. Textured fabrics show high (F/N) value because of high surface hairiness and loops which are caused by texturing process. When two such fabrics are placed together, the interlocking of surface fibres will take place. Therefore, high energy is required to shear these interface structures. Fabrics 1 and 2, being mill finished, show comparatively high values than their grey counterparts, because the finishing treatment removes the natural wax on the cotton material which acts as a lubricant in the grey state.

Fabrics 6 and 8 having textured weft yarn show high (F/N) value than the fabrics 5 and 7 in Group II because of the interlocking phenomenon explained above. The finishing treatment causes increase in friction value of textured and untextured yarn woven fabrics.

In fabrics 9 and 10 and fabrics 11 and 12 of Group III, the fabrics having textured polyester weft (fabric 10) and textured nylon weft (fabric 12) show high (F/N) value. This is again due to surface loop interlocking and more surface roughness. Further, nylon weft yarn fabrics show lower frictional value than the polyester weft fabrics be-

cause of the lower shear and bending moduli of nylon.

Among the nylon monofilament fabrics, the fabric 13 having highest ends and picks densities shows maximum (F/N) value, because the mesh size reduces with the increase in warp and weft densities and offers more surface resistance to the flow of fabric. Thus, the frictional value increases as the mesh size reduces. The reduced specific surface area of the fabric made of higher linear density yarns will also lower the friction values in case of fabric 15.

In all the cases, the static friction is higher than the kinetic friction.

3.2 Fabric-to-Leather Friction

Fabric-to-leather friction follows the same trend as in the case of fabric-to-fabric, for both static and kinetic friction, but the values are higher than the fabric-to-fabric friction values. This may be due to the fact that when two dissimilar materials are in surface contact, ploughing takes place and at the same time, because of the difference in shear characteristics, the uniform distribution of load can not take place. This results in a complex situation where both adhesion and ploughing contribute to frictional characteristics. Due to its low modulus, the leather deforms around the yarns in fabrics, to a larger extent, and this contributes to increase in the frictional values.

3.3 Fabric-to-Metal Friction

Fabric-to-metal friction also follows the same

Table 2—Frictional properties of textured and monofilament fabrics

Fabric No.	Fabric-to-Fabric		Fabric-to-Leather		Fabric-to-Metal	
	$(F/N)_s$	$(F/N)_k$	$(F/N)_s$	$(F/N)_k$	$(F/N)_s$	$(F/N)_k$
1	0.817	0.548	0.887	0.750	0.281	0.272
2	0.868	0.592	0.892	0.773	0.299	0.276
3	0.695	0.486	0.798	0.684	0.262	0.259
4	0.813	0.525	0.826	0.692	0.277	0.268
5	0.813	0.566	0.927	0.747	0.277	0.270
6	1.152	0.823	0.968	0.781	0.309	0.296
7	0.722	0.492	0.743	0.659	0.246	0.242
8	0.816	0.543	0.776	0.663	0.261	0.259
9	0.342	0.293	0.569	0.545	0.208	0.204
10	0.473	0.385	0.694	0.625	0.226	0.216
11	0.274	0.247	0.563	0.543	0.194	0.193
12	0.361	0.332	0.663	0.623	0.222	0.216
13	0.375	0.349	0.642	0.575	0.250	0.244
14	0.358	0.276	0.618	0.564	0.298	0.283
15	0.292	0.260	0.406	0.397	0.229	0.225

trend but the values are much lower than those of fabric-to-leather and fabric-to-fabric friction. Basically, in this case, there is no deformation of the upper surface over the fabric and no interlocking of surfaces takes place. Since the smooth and polished surface of aluminium was used, it did not interact with the fabric structurally. But at the given pressure, it flattened out the yarns and hence caused the more area of contact, which, in turn, reduced the frictional value. However, the difference in the frictional values of different fabrics is not as much as in case of fabric-to-fabric and fabric-to-metal friction.

4 Conclusions

Static friction is always higher than kinetic friction. Air-jet texturing increases the frictional resistance of fabrics. The nature of the contact sur-

faces during the sliding action affects the frictional resistance considerably. Deformation of leather surface over the contact point has significant effect on kinetic frictional resistance. Fabric-to-metal friction is less sensitive to the morphology and type of fabric. Variation of mesh size in monofilament fabrics affects the frictional resistance of these fabrics.

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