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EXPERIMENTAL STUDY ON THE FRICTION CHARACTERISTICS OF COTTON FABRICS WITH CLOTH TWILL 3/1 BEFORE AND AFTER FINISHING

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Abstract: *This research shows some of the functional characteristics of the cotton fabrics all in the same cloth twill 3/1 in different direction of the cloth and under different pressure. The measurements are conducted according to the standard BDS EN ISO 8295:2006 using μ-meter MXD-02 made by Labthink, China. The tester allows the determination of the static and the dynamic coefficients of friction (COF). The tests are performed for both fabric sides (face and reverse), in different fabric directions, and under different pressure (200, 300 and 400 g). The speed of sliding has been constant -100 mm/min. Formulas for frictional characteristics specialized for fabrics have been used for the precise determination of the fraction behavior of the textile products – friction index n, friction parameter C and friction factor R. The connection between the friction force and the normal pressure is transformed to logarithmic relation:*

$$\frac{F_i}{B} = C.\left(\frac{N_i}{B}\right)^n \rightarrow \log\left(\frac{F_i}{B}\right) = \log C + n.\log\left(\frac{N_i}{B}\right)$$

i=1, 2,…m; B – contact area (m^2); C – friction parameter [Pa^{1-n}]; n – friction index (without dimension); N – normal pressure [N]; F – friction force [N]; m – number of conducted examinations.

The friction index n and the friction parameter C are calculated from the coefficients of the linear regression equation. The friction parameter and the friction index are used for the determination of the friction factor R.

Conducted examinations show the influence of the pressure on the friction characteristics of fabrics with the same composition (cotton), but made from yarns with different linear densities. The values of the friction characteristics depend also on the changing of the actual contact area which varies in the different fabric directions. The actual contact area is growing with the increase of the pressure that leads to the increase of the coefficient of friction in neutral state (at rest) and the coefficient of friction when sliding.

Keywords: *cotton fabric, friction, friction characteristics*

1. INTRODUCTION

Friction in weaves is defined as the resistance a weave encounters when changing its position relative to another solid body which touches it. Textile friction occurs between two or more textile surface areas, between a textile surface area and metal parts of sewing machines or cutting machines, ironing irons, as well as the human body, friction of upholstery furniture and furniture without upholstery, etc.

The subjective feeling of rubbing weaves between the thumb and forefinger of a person is called touch. This feeling is mainly related to the mechanical interaction between clothing and the human body. Human fingers are a sensitive tool for detecting small differences in friction of weaves.

In the field of sewing technology, friction occurs when the fabrics are cut, multi-layered cutting and subsequent separation, friction occurs when sewing clothing with metal sewing machine parts, packing and storing ready-made garments, etc. The friction of cloth on the same cloth, fabric on another cloth, or cloth on hard objects has a significant effect on its qualities such as wear and tear, as well as consumer comfort.

Cotton fabrics are the most commonly used ones. The reason for this is their special quality - it regulates the body heat, it does not cause allergies, it absorbs sweat from the body, etc. Cotton fabrics are strong and with low elasticity, resistant to bases, highly resistant to organic solvents, almost insect-free, etc. For the production of denim clothing, cotton fabrics with twill twill 3/1 are mainly used. Technological trends have been imposed on sewing raw cloth clothing and subsequent finishing operations to respond to fashion trends in cowboy fashion. Separately, readymade denim clothing is made of raw denim clothing.

2. MAIN HEADING

The study for the here presented work was carried out with 100% cotton (P) fabrics, with 3/1 cloth twill. Textiles tested have different characteristics. They are produced in "Strumatex" Textile Works - Blagoevgrad. Their parameters are shown in Table 1a and Table 1b. In the following tables the items are marked with letter A and different initials.

With the purpose of determining the friction parameter, friction factor, and friction index, values established as coefficients of friction at rest and friction when slipping were used when with MXD-02 from Labthink, China (1). Force meter 1 measures the friction force that occurs when sleigh 2 slides onto platform 3, which in turn moves forcefully along guide rail 4 (Fig. 1). The force-change graph is displayed on screen 6. It also displays the calculated friction coefficient at rest, the coefficient of drag friction, the speed of the platform and the mass of the sleigh.

Table 1a. Parameters of the tested cotton textiles

№	Item		Characteristics	
			Width	Specific weighting area
			mm	g/m^2
1.	Kiparis ready	A11	1510	247
2.	Kiparis raw	A12	1610	212
3.	Boro ready	A21	1510	282
4.	Boro raw	A22	1610	268
5.	Boby ready	A31	1510	261
6.	Boby raw	A32	1600	254

Table 1b. Parameters of the tested cotton textiles

№	Item	Characteristics			
		Linear density		Thickness	
		base	weft	base	weft
		tex	tex	no. threads/dm	no. threads/dm
1	A11	40	50	386	180
2	A12	40	50	355	178
3	A21	36	60	384	200
4	A22	40	60	355	200
5	A31	36	60	386	182
6	A32	36	60	355	176

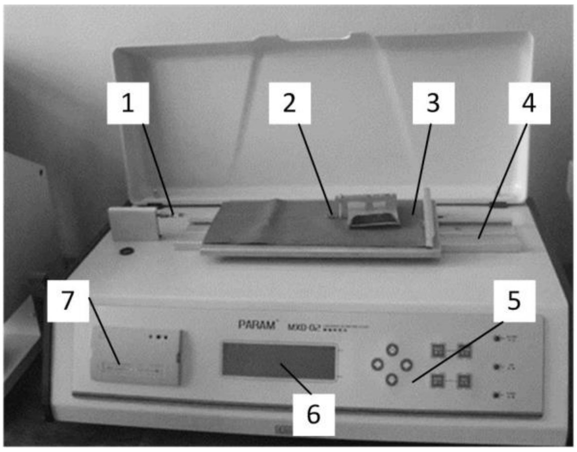

Figure 1. General appearance of device MXD-02

Force meter 1 measures the friction force that occurs when sleigh 2 slides onto platform 3, which in turn moves forcefully along guide rail 4 (Fig. 1). The force-change graph is displayed on screen 6. It also displays the calculated friction coefficient at rest, the coefficient of drag friction, the speed of the platform and the mass of the sleigh. The tester allows work to be performed based on different standards, as the hereby tests have been carried out according to BDS, ISO 8295: 2006.

Friction is done weave in weave, in different directions of the weaves on the face side of the two layers. Parameters and choice of standard are set by control panel 5. One layer of test weave is placed on the mobile platform 2 so that the direction of the base threads coincides with the direction of movement of the platform.

The second layer engages the sleigh in a selected direction - on a base, weft, and wreath. The friction coefficient at rest μ_0 is determined by the force taken into account in the test. At this point, the metal thread linking the force meter and the sleigh is stretched, then starts sliding on the platform. The instrument calculates the mean value of the studied coefficient of friction at sliding μ, as well as the mean deviation of μ_0 and μ. The numeric values visible on the screen can be printed with mini printer 7.

The results obtained for μ_0 and μ are shown in Table 2.

The literary study shows that there are no significant differences in frictional force [1, 4] in experiments with low sliding speeds of 10 to 500 mm / min. The main factor affecting the friction characteristics of the fabric is the weaves actual contact surface area of friction [2]. When in comes to the insignificant influence of the movement speed of friction surfaces relative to one another, the present study is carried out at a constant speed of 100 mm / min. Apart from this, most of the seamless manufacturing operations are at relatively slow speeds.

The relationship between friction force and normal load [2] is subject to logarithmic dependence:

$$\frac{F_i}{B} = C.\left(\frac{N_i}{B}\right)^n \text{ or } \log\left(\frac{F_i}{B}\right) = \log C + n.\log\left(\frac{N_i}{B}\right) \quad (1)$$

i=1, 2,…m; B – contact surface area [m^2]; C – friction parameter (measured in [Pa^{1-n}]); n – friction index (no measurement); N – regular pressure [N]; F – friction force [N]; m – number of experimental observations.

Table 2. Coefficient of friction at rest and when sliding

Item	Sleigh weight	Coefficient of friction at rest		
	g	BFS-BFS	BFS-SFS	BFS-VFS
A11	200	0,959	0,918	0,787
	300	1,061	1,001	0,912
	400	1,177	1,073	1,101
A12	200	0,827	0,819	0,800
	300	0,905	0,933	0,936
	400	1,022	0,983	1,064
A21	200	0,861	0,938	0,880
	300	0,981	0,972	0,997
	400	1,121	1,120	1,155
A22	200	0,875	0,833	0,770
	300	1,033	0,921	0,934
	400	1,135	1,035	1,082
A31	200	0,880	0,816	0,752
	300	1,034	0,971	0,934
	400	1,191	1,102	1,108
A32	200	0,866	0,863	0,757
	300	0,965	0,968	0,915
	400	1,101	1,065	1,044
Item	Sleigh weight	Coefficient of friction when sliding		
	g	BFS-BFS	BFS-SFS	BFS-VFS
A11	200	0,744	0,658	0,641
	300	0,959	0,844	0,787
	400	1,096	1,031	1,000
A12	200	0,639	0,540	0,682
	300	0,795	0,722	0,850
	400	0,938	0,890	0,993
A21	200	0,738	0,661	0,665
	300	0,890	0,849	0,867
	400	1,100	1,000	1,056
A22	200	0,700	0,572	0,583
	300	0,861	0,771	0,778
	400	1,029	0,916	0,955
A31	200	0,682	0,605	0,566
	300	0,882	0,783	0,759
	400	1,060	0,944	0,942
A32	200	0,686	0,631	0,537
	300	0,823	0,802	0,745
	400	0,979	0,949	0,920

Abbreviations used in Table 2: BFS – base face side; WFS – weft face side; SFS – skew face side. The angle in the vertical direction is 45 °. The same abbreviations are used in the following tables and graphs in the text bel.

The studies of Apurba Das and team on textile materials blend cotton and polyester (C/ PE) in a different ratio, indicate that the logarithmic dependence approximates to a linear one [4].

For each of the tested textiles five tests were made. *Log* (F_i/B) and *log* (N_i/B) are determined in different directions and in change of pressure. Normal pressure changes. Further weight is added to the mass of the sleigh which is 200g. The mass of the test sample mounted on the sleigh is not taken into account as it is negligibly low.

The tests were carried out at an average air temperature of 22°C and an average humidity of 70%. The determination of the two parameters - friction index n and friction parameter C is performed by calculating $lg(F_i/B)$ and $lg(N_i/B)$ after calculation of normal Ni forces and friction forces F_i.

A linear regression equation of the type:

$$y=a+x.b \qquad (2)$$

$x= lg(N_i/B); \quad y= lg(F_i/B); \quad a=lgC; \quad b=n.$

Frictional parameter C and frictional index n serve to determine the frictional factor R, also called compound coefficient of friction or correlation coefficient of friction [3] whose value is determined by the dependence:

$$R = \frac{C}{n} \qquad (3)$$

Table 3a. Friction values at rest

Item	Direction of the textile	Friction characteristics at rest		
		index n	parameter C	factor R
		-	Pa^{1-n}	Pa^{1-n}
A11	BFS-BFS	1,292	0,306	0,237
	BFS-SFS	1,224	0,328	0,268
	BFS-VFS	1,476	0,110	0,075
A12	BFS-BFS	1,300	0,[illegible]5	0,196
	BFS-SFS	1,267	0,291	0,230
	BFS-VFS	1,410	0,843	0,598
A21	BFS-BFS	1,377	0,149	0,237
	BFS-SFS	1,245	0,355	0,285
	BFS-VFS	1,387	0,128	0,092
A22	BFS-BFS	1,378	0,202	0,237
	BFS-SFS	1,309	0,248	0,189
	BFS-VFS	1,490	0,084	0,056
A31	BFS-BFS	1,434	0,163	0,237
	BFS-SFS	1,433	0,130	0,091
	BFS-VFS	1,558	0,037	0,024
A32	BFS-BFS	1,341	0,233	0,237
	BFS-SFS	1,302	0,265	0,204
	BFS-VFS	1,464	0,130	0,089

Table 3b. Friction values when sliding

Item	Direction of the textile	Friction characteristics when sliding		
		index n	parameter C	factor R
		-	Pa^{1-n}	Pa^{1-n}
A11	BFS-BFS	1,563	0,083	0,351
	BFS-SFS	1,646	0,053	0,032
	BFS-VFS	1,633	0,110	0,067
A12	BFS-BFS	1,553	0,074	0,377
	BFS-SFS	1,721	0,034	0,020
	BFS-VFS	1,542	0,845	0,548
A21	BFS-BFS	1,568	0,0[illegible]	0,338
	BFS-SFS	1,599	0,064	0,040
	BFS-VFS	1,666	0,128	0,077
A22	BFS-BFS	1,553	0,081	0,342
	BFS-SFS	1,683	0,040	0,024
	BFS-VFS	1,712	0,084	0,049
A31	BFS-BFS	1,636	0,057	0,241
	BFS-SFS	1,641	0,050	0,030
	BFS-VFS	1,734	0,032	0,018
A32	BFS-BFS	1,509	0,094	0,397
	BFS-SFS	1,589	0,050	0,031
	BFS-VFS	1,779	0,130	0,073

The results of research on friction parameter, friction factor, and friction index for friction at rest and friction when slipping were shown in Table 3.

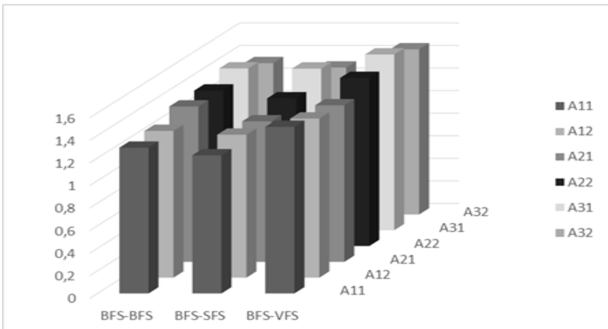

Figure 2. Influence of test direction on friction index n at rest

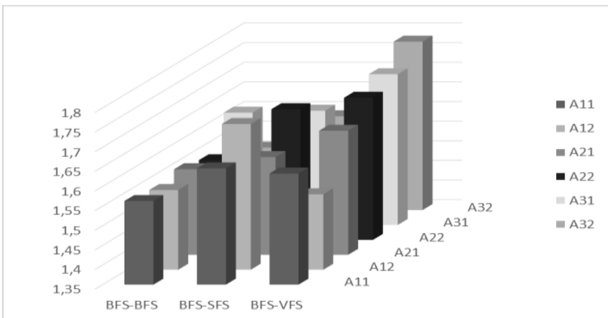

Figure 3. Influence of test direction on friction index n when sliding

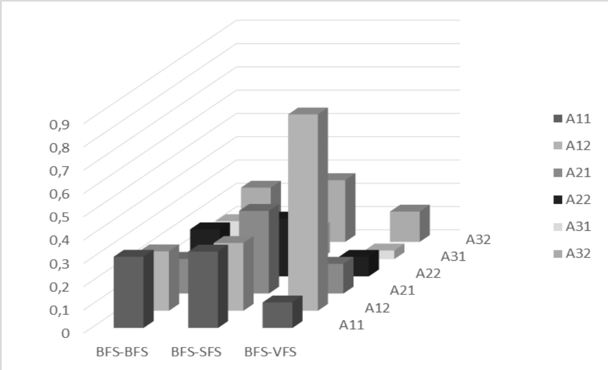

Figure 4. Influence of test direction on friction parameter *C* at rest

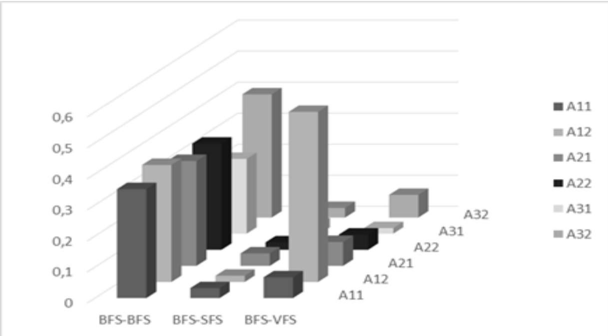

Figure 5. Influence of test direction on friction parameter *C* on sliding

Figures 2-5 visualize the experimental results for the friction index and friction factor, depending on the direct.

3. CONCLUSION

The conducted studies show the influence of pressure on the friction characteristics of weaves of the same composition, with the same weave, but with different thickness of the base and weft threads. Different values of frictional characteristics depend on the change in actual contact area, which varies in different directions. The actual contact area increases as the pressure increases, resulting in an increase in the coefficient of friction at rest and the coefficient of friction when sliding.

The friction index in the highest at face-facing direction for one layer and weft-facing direction for the other layer, both in the friction at rest and in the friction when sliding. In this direction - base face side - weft face front, the actual contact area increases due to increased contact areas of the base and weft threads of the two layers.

For articles A21 and A31, which are of the same thickness of the threads on base and weft sides but with different density of the weft threads, a difference in friction characteristics is also noted which is also due to the different real contact area of the friction surfaces.

Larger values for friction coefficients, both at rest and when sliding, are observed for finished fabrics than with raw cloth. In the raw cloth, the base and weft densities are lower than on the finished cloth, and hence the difference in the real size of the finished and the raw cloth.

The experimental results obtained here can serve as a basis for other scientific studies related to the fabrication of so-called "smart" garments, which use the friction of the layers of weave to produce electrical current. Additionally, the results obtained can serve as a basis for setting up textile machines. For the power analysis of machines in the sewing industry, these experimental results can also be used for their coefficients of friction when sliding and at rest.

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