(REFEREED RESEARCH)

ANALYSIS OF THE FRICTION COEFFICIENT IN FABRICS MADE FROM NON-CONVENTIONAL BLENDS

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ABSTRACT

Most textile materials are used and touched by the human skin, in particular the hand. Traditionally, the quality and surface characteristics of apparel fabrics are evaluated by touching and feeling, leading to a subjective assessment. For this reason, the interaction with the human senses is an essential performance property. When touched by the human hand, friction is one of the first feelings and therefore friction coefficient is an important parameter. This paper describes a new patented laboratory instrument, which was investigated and designed at the University of Minho based on a different method of accessing friction coefficient of fabrics, as well as its fundamentals and working principle. This is followed by an experimental study, where a comparison between three different double-faced fabrics made with non-conventional fibre combinations was performed under controlled atmosphere. The tested materials are:

1) Polyester/Cotton – Soya fibre (PES/CO-SPF)

2) Polyester/Cotton – Corn fibre (PES/CO-PLA, Polylactic-acid)

3) Polyester/Cotton – Cotton (PES/CO-CO)

The results of the experimental work are analysed using various tools, including SPSS14.0® statistical package and commented in the light of the influence of the raw material in the friction properties of the fabrics.

Key Words: FRICTORQ, Friction coefficient, Handle, Polyester/Cotton, Soya fibre, Corn fibre.

ÖZET

Çoğu tekstil malzemesi, insan derisi ile etkileşim içindedir ve özellikle insanın eli ile temas halindedir. Geleneksel olarak, hazır giyimde kullanılan kumaşların kalite ve yüzey karakteristikleri öznel değerlendirmeye öncülük eden dokunma ve hissetme ile değerlendirilir. Bu nedenle, insanoğlunun duyuları ile olan etkileşim, gerekli bir performans özelliğidir. İnsan eli ile dokunulduğu zaman, sürtünme ilk histir ve bu yüzden sürtünme katsayısı önemli bir parametredir. Bu makale, Minho Universitesi'nde araştırılan ve tasarlanan, kumaşların sürtünme katsayısına ulaşmada değişik bir yöntem olma esasına dayanan, aynı zamanda temel özelliklerinin ve çalışma prensibinin anlatıldığı yeni bir patentli laboratuar aletini anlatmaktadır. Daha sonra, kontrollü atmosfer basıncı altında, geleneksel olmayan lif kombinasyonlarından elde edilmiş 3 farklı çift yüzlü kumaşların karşılaştırılması, deneysel çalışma olarak yapılmıştır. Test edilen materyaller:

Polyester/Pamuk – Soya lifi (PES/CO – SPF)

Polyester/Pamuk – Mısır lifi (PES/CO – PLA, Polilaktik asit)

Polyester/Pamuk – Pamuk (PES/CO – CO)

Deneysel çalışmanın sonuçları, SPSS14 istatistiksel paket programını da içeren çeşitli araçlar ile analiz edilmiştir ve kumaşların sürtünme özelliklerine hammaddelerin etkisi üzerine yorumlarda bulunulmuştur.

Anahtar Kelimeler: FRICTORQ, Sürtünme katsayısı, Tutum, Polyester/Pamuk, Soya lifi, Mısır lifi

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1. INTRODUCTION

Interaction with the human senses is an essential performance property (1, 2) as most textile materials are used near the skin, namely clothing, home furnishings and automotive fabrics. Friction coefficient is one of the factors contributing for the so-called parameter *fabric hand* and its importance justifies the number of contributions given in the past to this problem (3-7). More recently, novel laboratory equipment was proposed for a new method of friction coefficient assessment of fabrics, which is easy to use and is very precise. The development and validation of FRICTORQ (8) justifies an experimental work with a set of fabrics made from non-conventional fibre combinations. These new materials reflect the main fibre research of this century where new mixtures are used to reduce environmental impact, improve material performance and diversify the use of raw materials.

PLA (Polylactic-acid) is one of the new fibres used in the evaluated mixtures. Its main advantages are as follows: cotton look appearance; environmental friendly, based on a natural polymer thus biodegradable; high resistance to UV (9). When mixed with other fibres (10) PLA also shows a good performance, namely:

- Natural fibre hand;
- Wickability/breathability of natural fibres;
- Good performance qualities;
- Good flammability resistance;
- Excellent drapeability.

SPF (Soya Protein Fibre) is also another new fibre used in this work. It is made by a wet spinning process occurring after the extraction of spherical protein from soybean residue. One of the most attractive properties of SPF is the soft touch as well as a good moisture absorption giving fabrics better comfort properties when mixed with other fibres (11). Cotton (CO) is essentially made of cellulose which is a natural fibre being commonly used since it offers a high degree of comfort. For this reason it was used as a standard specimen fibre to compare the obtained results with the new fibres.

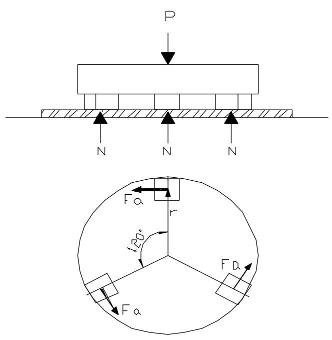

Figure 1. The FRICTORQ II model

Figure 2. FRICTORQ II laboratory prototype

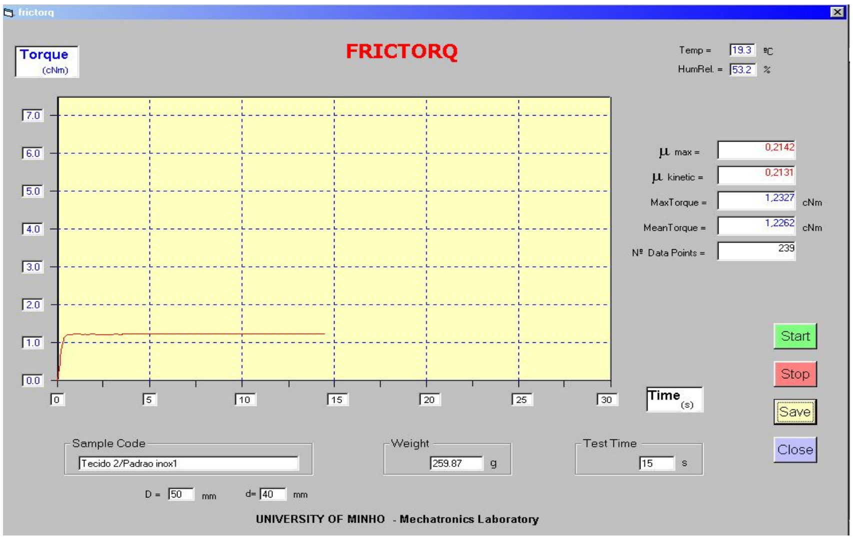

Figure 3. Graphical output representation of a typical fabric friction experiment

2. THE MODEL OF FRICTORQ

This model went through various development stages and some of the detected weaknesses suggested that a different approach could be explored (12, 13). Figure 1 is a schematic representation of the latest adopted model named FRICTORQ II. The laboratory prototype of the instrument is represented in figure 2.

For a more complete understanding, references (12, 14) present and discuss other models and design stage details for the development of the present prototype, including a fabric-to fabric initial proposal that is still valid and can easily be an alternative in this instrument.

The rotary action remains, but the contact is now restricted to 3 small special elements or feet, disposed at 120°. Providing a relative displacement of approximately 90°, it is assured that a new portion of fabric is always moved under the contact sensors. For this model, torque T is given by:

$$T = 3\,F_a\,r \qquad (1)$$

Being, by definition, friction force $F_a = \mu N$ and from figure 1, $N = P/3$, where P is the vertical load, the coefficient of friction μ is then expressed by:

$$\mu = \frac{T}{P \times r} \qquad (2)$$

being r the distance of F_a from the centre. Previous exploratory work led to the establishment of some design parameters, namely contact pressure and linear velocity in the geometric centre of each contact foot, the latter set to approximately 1,57 mm/s.

Figure 3 represents a graphic display of an experiment showing the most relevant parameters. The shape of the graph is stable and nearly horizontal for the duration of the test. To compute dynamic or kinetic friction coefficient, the data of friction torque T, collected between t = 5 seconds and t = 20 seconds of the test is used.

As well as other well known methods, such as KES, this one is not covered by any standards. The contact surface is made of standard and commercially available steel needles of 1 mm diameter joint side by side in a square shape as it is seen in figure 1. Therefore this surface is well characterized and easily reproducible.

3. EXPERIMENTAL PROCEDURE

3.1 Characterization of the Tested Materials

The tested materials were three double-faced fabrics made from non-conventional fibre combinations listed as follows:

1) Polyester-Cotton – Soya fibre (PES/CO-SPF)
2) Polyester-Cotton – Corn fibre (PES/CO-PLA)
3) Polyester-Cotton – Cotton (PES/CO-CO)

These fabrics have a double face structure based on a satin weave as shown in figure 4 which represents the weave. This results in that each material is mainly in one of the fabric's face, for example in the PES/CO-SPF fabric the outer face presents the PES/CO as contact fibre material.

Table 1. Fabrics dimensional properties

Fabric	Properties						
	Thickness (mm)	Weight / unit area (g/m²)	Warp yarns /cm	Weft yarns/cm	Warp yarn (Ne)	Weft yarn OF (Ne)	Weft yarn IF (Ne)
Polyester/Cotton – Soya fibre (PES/CO-SPF)	0,444	143,0	75	34	50	30	40
Polyester/Cotton – Corn fibre (PES/CO-PLA)	0,406	140,1	75	34	50	30	40
Polyester/Cotton – Cotton (PES/CO-CO)	0,417	136,8	75	34	50	30	50

Table 2. Descriptive statistics for friction coefficient. IF-inner-face; OF-outer-face

Fabric ref.	N	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
					Lower boundary	Upper boundary		
PES/CO -SPF_IF	13	,205500	,0067417	,0018698	,201426	,209574	,1967	,2168
PES/CO -PLA_IF	13	,189838	,0041969	,0011640	,187302	,192375	,1851	,1971
PES/CO -CO_IF	13	,207169	,0035382	,0009813	,205031	,209307	,2027	,2133
PES/CO -SPF_OF	13	,207308	,0033175	,0009201	,205303	,209312	,2032	,2133
PES/CO -PLA_OF	13	,191477	,0025044	,0006946	,189964	,192990	,1864	,1962
PES/CO -CO_OF	13	,206200	,0023241	,0006446	,204796	,207604	,2029	,2107
Total	78	,201249	,0085277	,0009656	,199326	,203171	,1851	,2168

Table 3. Anova results

(I) Samples PES/CO	(J) Samples PES/CO	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower boundary	Upper boundary
PES/CO -SPF_IF	PES/CO -PLA_IF	,0156615(*)	,0015873	,000	,010230	,021093
	PES/CO -CO_IF	-,0016692	,0015873	,952	-,007101	,003762
	PES/CO -SPF_OF	-,0018077	,0015873	,934	-,007239	,003624
	PES/CO -PLA_OF	,0140231(*)	,0015873	,000	,008592	,019455
	PES/CO -CO_OF	-,0007000	,0015873	,999	-,006132	,004732
PES/CO -PLA_IF	PES/CO -SPF_IF	-,0156615(*)	,0015873	,000	-,021093	-,010230
	PES/CO -CO_IF	-,0173308(*)	,0015873	,000	-,022762	-,011899
	PES/CO -SPF_OF	-,0174692(*)	,0015873	,000	-,022901	-,012038
	PES/CO -PLA_OF	-,0016385	,0015873	,956	-,007070	,003793
	PES/CO -CO_OF	-,0163615(*)	,0015873	,000	-,021793	-,010930
PES/CO -CO_IF	PES/CO -SPF_IF	,0016692	,0015873	,952	-,003762	,007101
	PES/CO -PLA_IF	,0173308(*)	,0015873	,000	,011899	,022762
	PES/CO -SPF_OF	-,0001385	,0015873	1,000	-,005570	,005293
	PES/CO -PLA_OF	,0156923(*)	,0015873	,000	,010261	,021124
	PES/CO -CO_OF	,0009692	,0015873	,996	-,004462	,006401
PES/CO -SPF_OF	PES/CO -SPF_IF	,0018077	,0015873	,934	-,003624	,007239
	PES/CO -PLA_IF	,0174692(*)	,0015873	,000	,012038	,022901
	PES/CO -CO_IF	,0001385	,0015873	1,000	-,005293	,005570
	PES/CO -PLA_OF	,0158308(*)	,0015873	,000	,010399	,021262
	PES/CO -CO_OF	,0011077	,0015873	,992	-,004324	,006539
PES/CO -PLA_OF	PES/CO -SPF_IF	-,0140231(*)	,0015873	,000	-,019455	-,008592
	PES/CO -PLA_IF	,0016385	,0015873	,956	-,003793	,007070
	PES/CO -CO_IF	-,0156923(*)	,0015873	,000	-,021124	-,010261
	PES/CO -SPF_OF	-,0158308(*)	,0015873	,000	-,021262	-,010399
	PES/CO -CO_OF	-,0147231(*)	,0015873	,000	-,020155	-,009292
PES/CO -CO_OF	PES/CO -SPF_IF	,0007000	,0015873	,999	-,004732	,006132
	PES/CO -PLA_IF	,0163615(*)	,0015873	,000	,010930	,021793
	PES/CO -CO_IF	-,0009692	,0015873	,996	-,006401	,004462
	PES/CO -SPF_OF	-,0011077	,0015873	,992	-,006539	,004324
	PES/CO -PLA_OF	,0147231(*)	,0015873	,000	,009292	,020155

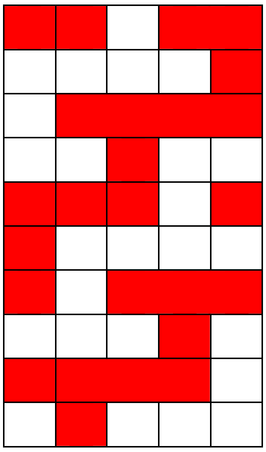

Figure 4. Satin fabric weave

Table 1 presents the dimensional properties of the fabrics used in the experimental process, being OF for outer face and IF for inner face.

Polyester-Cotton (PES/CO) is a mixture of polyester with a small percentage of cotton (85% PES, 15% CO), showing good anti-static and hygroscopic properties.

Corn fibre (PLA – Polylactic Acid) is composed of at least 85% by weight of lactic acid ester units derived from naturally occurring sugars (15). Its use is not yet widespread but the fact of being an ecological fibre represents an important factor for its use in blends.

Soya fibre (SPF), such as the corn fibre, is natural and ecological, with a moisture absorbing capacity greater than cotton, at a competitive price.

3.2 Methodology

The FRICTORQ II instrument was used to test the outer-face (OF) and inner-face (IF) surfaces of the mentioned materials. Samples were prepared and cut in circles of 130 mm diametre and tested under a conditioned atmosphere of 20 ± 2 ºC and 65 ± 2 % RH.

4. RESULTS AND DISCUSSION

After collecting the data obtained during the tests carried out using Frictorq testing apparatus, a statistical package SPSS14.0® was used in order to analyse the influence of the different materials in the friction coefficient. The obtained results are represented in the box plot of figure 5 and table 2 lists the corresponding statistical descriptives.

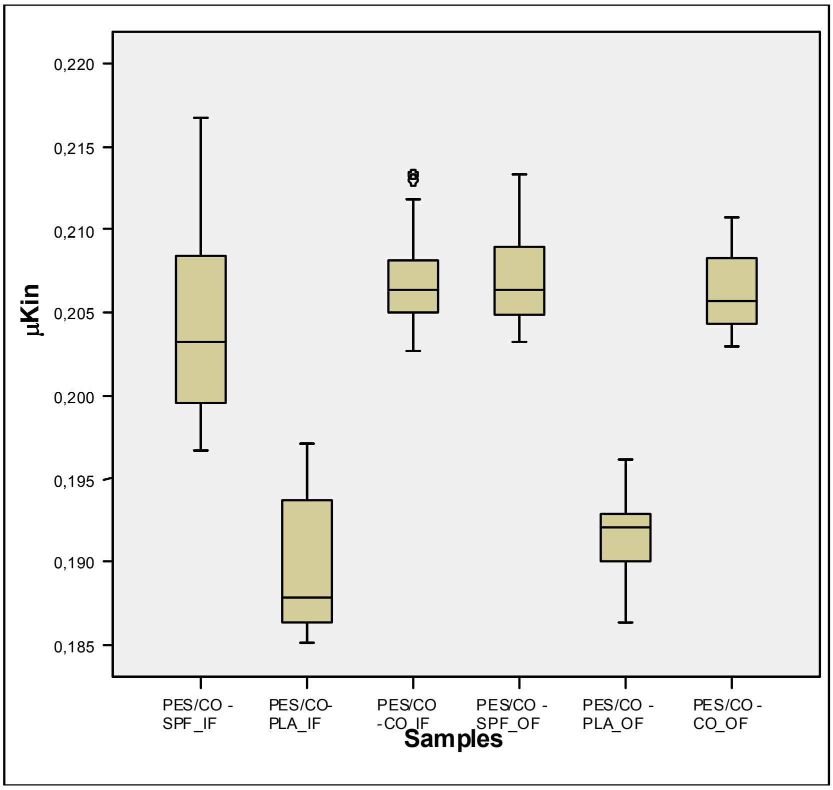

Figure 5. Box plot

Table 4. Scheffe results

Samples PES/CO	N	Subset for alpha = .05	
		1	2
PES/CO -PLA_IF	13	,189838	
PES/CO -PLA_OF	13	,191477	
PES/CO -SPF_IF	13		,205500
PES/CO -CO_OF	13		,206200
PES/CO -CO_IF	13		,207169
PES/CO -SPF_OF	13		,207308
Sig.		,956	,934

These results show that SPF, PLA and PES/CO fibre have higher amplitude values than those obtained when the main contact fiber is CO. However, when testing the OF, meaning PES/CO as the main contact fibre, the obtained amplitude is slightly smaller. This means that this fabrics (produced with PLA or SPF) exhibit higher surface irregularity. Although all fabrics have exactly the same weaving structure, this outcome can be explained by the fibre production process, particularly by the fibre cross-section, since the wet spinning process causes an irregular fibre cross-section.

Regarding the mean values obtained for fabric friction coefficients (in terms of kinetic coefficients, μ_{kin}), the lower values were obtained when testing fabrics with PLA fibre regardless of the tested fabric face, showing that PLA fibre has the strongest influence on the friction properties, lowering the friction coefficient. Behera refers in his study (6) that friction coefficient is related to the thougness of the fabrics which is also in agreement with our conclusion that fabrics with thougher fibres, such as PLA, exhibit low friction coefficient.

In order to analyse the obtained results a multiple comparison analysis (ANOVA) and Scheffe test (mean for groups in homogeneous subsets) were carried out. The obtained results are listed in tables 3 and 4, respectively.

In table 3, asterisk (*) means that the mean difference is significant at the 0,05 level. As it can be seen, it happens, for example, when comparing PES/CO-SPF_IF with PES/CO-PLA_IF and PES/CO-SPF_IF with PES/CO-PLA_OF.

As shown in table 4, when statistically comparing the values obtained for these trials, two different clusters appear: The first one is formed by PES/CO-PLA fabric while the other groups the fabrics containing PES/CO-SPF and PES/CO-CO. These results show that there are two different behaviours related to friction coefficient. The second cluster, with fabrics containing SPF and CO, shows no statistical difference between these two fabrics as to their friction properties.

The obtained results show that there are two different groups in this study. The first is the one containing PLA fibre while the second one groups the fabrics containing SPF and CO, meaning that there is no statistical difference between these two fabrics as to the friction properties.

5. CONCLUSIONS

Polyester-Cotton – Soya (PES/CO-SPF) fibre and Polyester-Cotton – Cotton (PES/CO-CO) fibre blended fabrics give comparatively higher surface friction coefficient and surface smoothness compared to Polyester-Cotton – Corn (PES/CO-PLA) fibre blended fabric. The experiments carried out in order to assess the differences between the new non-conventional materials also show that the friction coefficient is different between fabric surfaces mainly covered by SFP or PLA fibres, independently of the tested faces IF or OF.

As we wanted to compare the non-conventional blends with a standard material, such as Cotton, we have tested three sets of fabrics: In these fabrics the friction behaviour is similar only for those made of PES/CO-SPF and PES/CO–CO, meaning that soya protein fibre shows similar surface characteristics to the cotton fibre. This conclusion shows that further research on this SPF material could be a "*good bet*" for this new century.

PES/CO-PLA fabric presents the lower friction coefficient and is clearly different from all the other fabrics used in this study, showing a higher surface roughness, indicating a worse touch performance when compared with the other two studied blends.

Concerning the FRICTORQ apparatus performance, this has demonstrated to be a good tool to assess and differentiate friction in fabrics. Also this equipment shows no influence from external factors, meaning user interferences as well as the tested material. This can easily be observed in the present study in which the obtained values range depends only on the tested material.

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REFERENCES

1. Kawabata, S., M. Niwa and F. Wang, 1994, "Objective Hand Measurement of Nonwoven Fabrics", *Textile Research Journal*, Vol. 64, No. 10.
2. Gupta, B.S. and Y. E. El Mogahzy, 1991, "Friction in Fibrous Materials", *Textile Research Journal,* pp 547-555.
3. Kawabata, S., 1980, "The Standardisation and Analysis of Hand Evaluation", *2nd. Ed., Textile Machine Society of Japan*.
4. Nosek, S., 1993, "Problems of Friction in Textile Processes", *International Conference Textile Science 93*, TU Liberec, Czech Republic.
5. Bueno, M. A., M. Renner and B. Durand, 1998, "Tribological Measurement of the State of Surface Fabrics by a Contact and a Non contact Method", *Proceedings of the Conference Mechatronics'98*, pp 703-708, Sweden.
6. Behera, B. K., 2007, "Comfort and Handle Behaviour of Linen Blended Fabrics", *AUTEX Research Journal*, Vol. 7, No 1, pp 33-47.
7. Ramkumar, S. S., A. S.Umrani, D. C. Shelly, R. W. Tock, S. Parameswaran and M. L. Smith, 2004, "Study of the Effect of Sliding Velocity on the Frictional Properties of Nonwoven Fabric Substrates", *Wear*, Vol. 256, Issues 3-4, pp 221-225.
8. Lima, M. and L. Hes, 2002, Inventors/authors, Portuguese Patent Nº 102790, Title: "Método e Aparelho para a Determinação do Coeficiente de Atrito de Materias Sólidos Planos (*Method and Instrument for the Measurement of the Coefficient of Friction in Flat Solid Materials*)", Date: 12th June 2002.
9. Ingeo™ Fibers (www.ingeofibers.com, on-line accessed in 2006).
10. Fabric link (www.fabriclink.com/university/planfiber.cfm, on-line accessed in 2007).
11. Harvest SPF Textile co., Ltd (www.spftex.com, on-line accessed in 2006).
12. Lima, M., L. Hes, R. Vasconcelos and J. Martins, 2005, "FRICTORQ, Accessing Fabric Friction with a Novel Fabric Surface Tester", *AUTEX Research Journal*, Vol. 5, No 4, pp 194-201.
13. Lima, M., L. Hes, R. Vasconcelos and J. Martins, 2005, "FRICTORQ, a Novel Fabric Surface Tester: A Progress Report", *Journal of Textile Engineering, The Textile Machinery Society of Japan*, Vol. 51, No 3/4 (2005), pp 40-46.
14. Lima, M., L. F. Silva, R. Vasconcelos, J. Martins and L. Hes, 2005, "FRICTORQ, Tribómetro para Avaliação Objectiva de Superfícies Têxteis", Actas do III Congresso Ibérico de Tribologia – IBERTRIB'2005 (CD-ROM), Escola de Engenharia da Universidade do Minho, Guimarães, 16-17 de Junho, 2005.
15. Fibersource (www.fibersource.com/f-tutor/pla.htm, on-line accessed in 2006).

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