IOP Conference Series: Materials Science and Engineering

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To cite this article: M Abu-Rous *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **254** 142001

IOP Conf. Series: Materials Science and Engineering **254** (2017) 142001 doi:10.1088/1757-899X/254/14/142001

A new physical method to assess handle properties of fabrics made from wood-based fibers

M Abu-Rous[1], E Liftinger[1], J Innerlohinger[1], B Malengier[2] and S Vasile[3]

[1.] Lenzing AG, Werkstrasse 2, 4860 Lenzing, Austria
[2.] Ghent Univ., Faculty of Engineering. and Architecture, Department of Materials, Textiles and Chemical Eng., Centre for Textile Science and Eng., Belgium
[3.] Univ. College Ghent, Faculty of Science and Technology, Department of Textiles, Fashion and Wood Technologies, Belgium

Email: m.aburous@lenzing.com

Abstract. In this work, the handfeel of fabrics made of wood-based fibers such as viscose, modal and Lyocell was investigated in relation to cotton fabrics applying the Tissue Softness Analyzer (TSA) method in comparison to other classical methods. Two different construction groups of textile were investigated. The validity of TSA in assessing textile softness of these constructions was tested. TSA results were compared to human hand evaluation as well as to classical physical measurements like drape coefficient, ring pull-through and Handle-o-meter, as well as a newer device, the Fabric Touch Tester (FTT). Physical methods as well as human hand assessments mostly agreed on the softest and smoothest range, but showed different rankings in the harder/rougher side fabrics. TSA ranking of softness and smoothness corresponded to the rankings by other physical methods as well as with human hand feel for the basic textile constructions.

1. Introduction

Various approaches to assess fabric handfeel by physical methods have been developed in the last 50 years such as Kawabata, ring pull-through, Handle-o-meter, drape coefficient etc. [1, 2]. The classical physical approach simulates the hand by applying a physical force such as squeezing, bending, shearing etc. on the fabric to receive an equivalent physical response.

A new approach to assess fabric handfeel is offered by the Tissue Softness Analyzer (TSA), which was developed by Emtec Electronic GmbH. The handfeel can be evaluated by measuring the sonic waves generated by applying a friction on the fabric. The method is well established in the quality control in the hygiene tissue sector [3, 4]. Recently, this method is beginning to claim its place in nonwovens and textile sectors [5]. The rotating part of the TSA generates noise while moving over the fabric surface, which is captured by the microphone and analyzed into its amplitude signals. In the resulting sonic spectrum, the signal peak at 750Hz is a measure for the fabric vibration under the rotating part and should correlate with fabric smoothness, while the peak at 6500Hz occurs through the vibration on the rotating part itself while moving above the fabric surface and is considered as a measure for the softness of surface fibers. The lower the generated noise, the smoother resp. softer is the fabric (figure1). A handfeel value (HF) calculated on the basis of the TS values and the fabric weight and thickness. The used HF calculation algorithm is given

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in the device settings and it has been developed based on experience from the hygiene tissue sector. It was included into this work only for orientation.

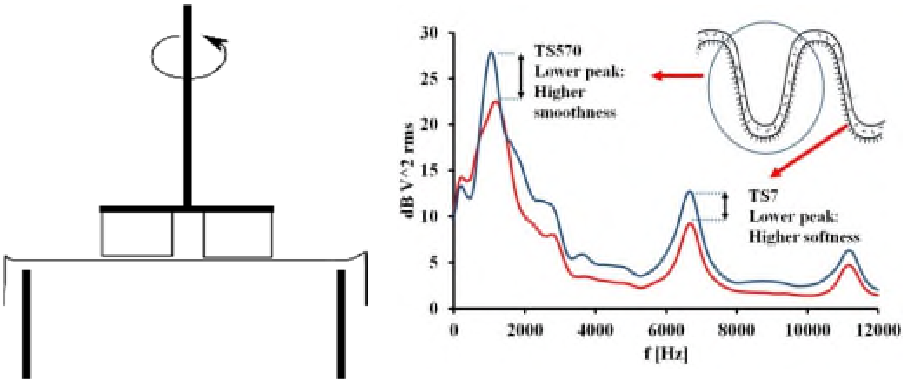

Figure 1. TSA measurement principle (left) and the resulting acoustic peaks and relation to fabric surface elements (right)

Wood-based cellulosics such as viscose (CV), modal (CMD) and lyocell (CLY) are known to offer softer fabrics than cotton (CO) and linen [6, 7]. MicroModal® (a registered trademark of Lenzing AG, hereafter abbreviated µCMD) is a fiber with a fine titer (0.9 dtex) and is well known for its soft touch [8].

The complexity of human feel and subjective judgment goes beyond mechanical fabric properties. Physical methods are hence expected to cover only a partial aspect of handfeel. Correlation between hand evaluations and a set of physical measurements can be found when the comparison is limited to well-defined fabric constructions (depending on the targeted application). In this work we focused on woven constructions, which represent a wide range of light and heavy apparel and home textile segments, comparing wood-based fibers with cotton, applying TSA in comparison to other classical methods as well to human perception.

2. Experimental

All fabrics were produced by Lenzing AG. The following methods and instruments were employed to assess the fabric hand. If nothing else mentioned, all evaluations took place on the fabric right side. The tests a-d hereafter were performed at Lenzing AG. The fabrics were conditioned at 23°C and 50% RH

a. Handle-o-meter measurements is leaned to the EDANA norm test WSP 90.3. Test principle is measuring the force required for inserting a 20x20 squared fabric into a 6.4 mm slit [9]. The fabric is measured on both sides and in both directions. The average value is given in Newton [N]. The higher the force, the stiffer the fabric.

b. Ring pull-through: Round fabric samples of 20 cm diameter, are pulled through a metal ring with diameter of 2 cm and the displacement/force diagram is measured. The value of maximal force measured (F_{max}) is related to handfeel-relevant parameters such as bending rigidity, friction and compressibility.

c. **Drape coefficient** was measured following ISO9073-9:2008. Fabric shadow was quantified by photography and black/white image analysis. Higher drape coefficient means higher bending rigidity.

d. Tissue Softness Analyzer (TSA) measurements were performed using a device supplied by Emtec. The acoustic signal peaks were given measured in dB V^2 rms. Four specimen of each fabric quality were measured.

f. Fabric Touch Tester (FTT) measurements were performed by the University of Ghent (UGent). The physical properties simultaneously measured by this device are bending, friction, roughness, compression and thermal conductivity. [10, 11] Based on these values, primary handfeel indices such as smoothness, softness are calculated as well as two global hand indices (total hand and total feel). In this study, we only consider the bending work (BW) measured by FTT and the active softness and smoothness (mean values of 10 individual measurements).

g. Hand evaluations of selected plain weave fabrics by expert human panels were performed at University College Gent (HoGent). Four fabrics attributes (softness, smoothness, flexibility and warmth) were assessed on a 1-10 scale using a questionnaire. The test is executed under standard atmospheric conditions of 21°C and 65% RH on 24 h pre-conditioned fabrics, according to AATCC5 (2011) evaluation procedure 8.1.2. The test was performed by ten assessors, 5 men and 5 female aged between 36-54, on 20x20 cm samples. Assessors' sensitivity was a selection criteria and was tested by JVP Domes method [12]. A non-expert panel of six person ranked also the fabrics according to their softness. This test was performed at Lenzing on the heavy atlas fabrics.

3. Results and discussion

3.1. Plain weave fabrics

Light-weight plain weave fabrics (table 1) made of different fiber types in 100% were prepared.

Table 1. Fiber contents and physical properties of the selected plain weave samples

Fabric	CO	CO/CMD	CMD	µCMD	CLY	CV
Mass / unit area [g/m²]	131	142	141	130	131	143
Thickness [µm]	500	510	370	400	410	400

The fabrics were tested using the TSA, Handle-o-meter and ring-pull-through method. Rankings achieved by these methods were compared with the expert and non-expert panel evaluations. The results of the TSA test (figure 2) show that man-made cellulosics exhibit lower TS750 peaks than cotton, meaning smoother surface, with µCMD fabric being the smoothest. TS7 peaks as shown in figure 2 indicate µCMD and CO/CMD as the softest fabrics and cotton as the roughest. The CLY, CMD and CV fabrics gave similar results for softness.

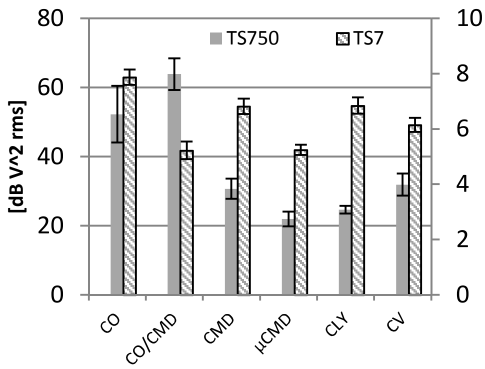

Figure 2.TSA measurement on plain weave fabrics

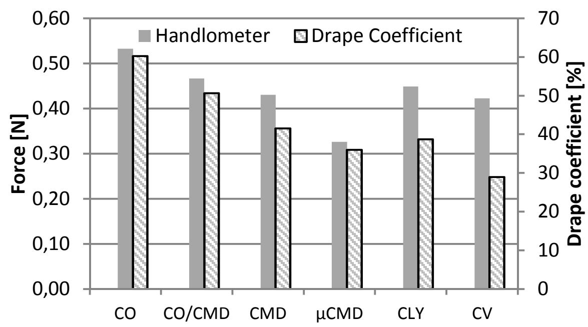

Figure 3. Drape coefficient [%] and handle-o-meter results of bending force of plain weave fabrics

TSA results were compared with Handle-o-meter, drape test and the ring-method measurements. All three methods are based on the bending of the fabric and we expect consequently a similar outcome. In the Handle-o-meter measurement (figure 3) µCMD exhibited the lowest bending force, followed by the other wood-based cellulosics. Cotton showed the highest bending rigidity which can be reduced by adding wood-based cellulosic. The same trend was measured by the drape test, as shown in the same figure 3. In figure 4 the results of the ring pull-through method are shown which indicate that MicroModal® (µCMD) and viscose (CV) fabrics exhibited lowest F_{max}, followed by CMD and CLY.

Human evaluations were provided by the expert panel that assessed the softness, smoothness and flexibility on a scale from 1 (worst) to 10 (best). The mean values of the scores given by the 10 assessors are shown in figure 5. The results of the expert panels show that all wood-based cellulosics are perceived as softer, smoother and more flexible than cotton. Among the wood-based cellulosics, CMD and µCMD were evaluated by the expert panels as the smoothness. They were also the softest, closely followed by CLY and CO/CMD. The TSA results for CO/CMD contradict with other methods, showing less smoothness than 100% cotton. This could be explained by the usually applied higher yarn twist in CMD/CO blends.

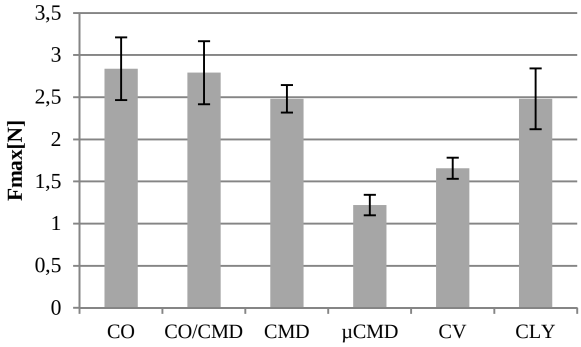

Figure 4. Ring pull-through force (F_{max}) of plain weave

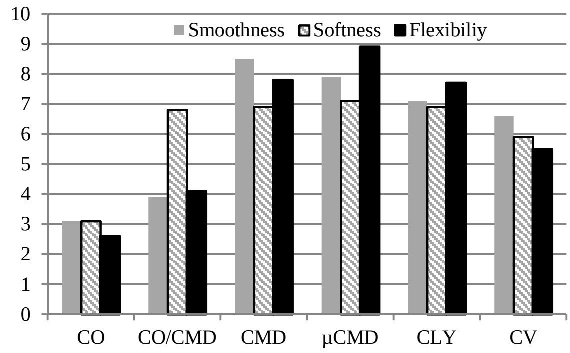

Figure5. Expert panel handfeel evaluation (scale 1-10) of light woven fabrics

FTT results for softness and smoothness are shown in figure 6. An Anova analysis (alfa=0.05) was performed to identify significant differences between the fabrics. A post-hoc Tukey test showed a significant difference ($p<0.05$) between the smoothness of the µCMD fabrics and two cotton fabrics, with µCMD and CMD being the smoothest, as shown by the non-overlapping bars of the chart left. Similarly, the figure right indicates the CMD as the softest, followed by µCMD. All wood-based cellulosic fabrics were found to be significantly softer and smoother than CO. The µCMD and CMD fabrics showed by best hand among the wood-based cellulosics

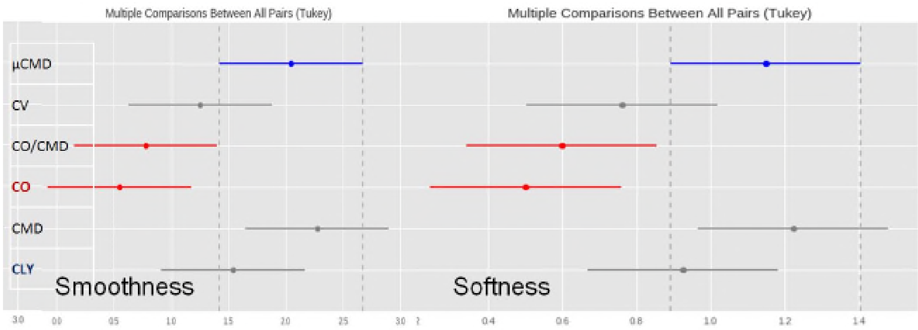

Figure 6. Active smoothness and softness Calculated by FTT system

3.2. Heavy atlas fabrics

Heavy atlas 4/1 fabrics of identical construction parameters and different fiber contents in warp and weft were woven as shown in table 2 and the effect of minority CLY (25% or 50%) on handfeel of cotton and polyester blended fabrics was investigated by TSA, drape coefficient, Handle-o-meter and FTT. The last two instruments measured the fabrics in warp and weft direction.

Table 2. Yarn blends and physical properties of atlas 4/1 fabrics with 50% CLY (2954, 2958) or 25% CLY, M is Mass per unit area, and T the thickness.

Fabric code	**Warp** Nm 50/2	**Weft** Nm 20/1	**M [g/m²]**	**T [µm]**	**Fabric code**	**Warp** Nm 50/2	**Weft** Nm 20/1	**M [g/m²]**	**T [µm]**
2953	CLY/PES	PES	280	570	2957	CLY/CO	CO	277	690
2954	CLY/PES	CLY/PES	277	550	2958	CLY/CO	CLY/CO	291	660
2955	PES	CLY/PES	290	560	2959	CO	CO	277	710
2956	PES	PES	290	570	2960	CO	CLY/CO	280	670
					2961	CO	PES	289	630

The TSA results are summarized in figure 7. Adding CLY seems to reduce TS750 and TS7 peaks, whereas the effect differs between warp and weft direction. The fabric bending rigidity was measured in both directions by handle-o-meter as shown in figure 8. CLY fiber seems to reduce the bending rigidity in weft direction. This effect is slight in CO blends (2957, 2958, 2960) and very pronounced in PES blends (2955, 2953, 2954). In PES blends, CLY in the weft direction led additionally to a dramatic decrease of bending rigidity in warp direction. In CO blends, additional CLY in the warp made no significant change.

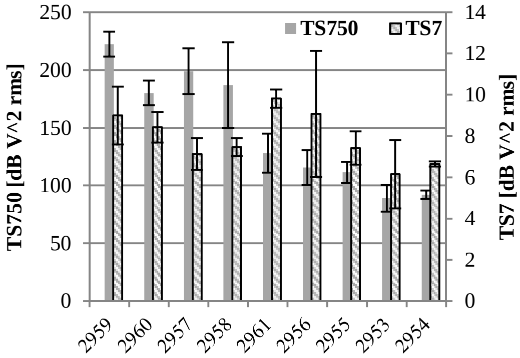

Figure 7. Smoothness (TS750) and softness (TS7) of the atlas fabrics assessed by TSA

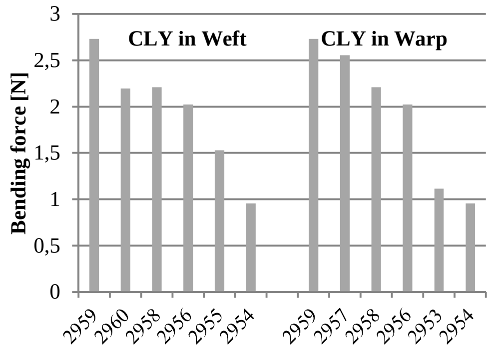

Figure 8. Effect of CLY in warp and in weft on bending rigidity of woven fabrics

Similar trends were observed in the drape coefficient as show in figure 9. In all comparisons, the fabric with PES/CLY in warp and weft gave the softest results. Human softness evaluation was provided by a non-expert panel of six assessors ranking the fabrics on a scale of 1 (worst) and 9 (best), as shown in figure 10. Humans seem to agree in the softer range. On the harder side the variance is high. It is to be remembered that these fabrics are similar and contain only 25% CLY, except for fabrics 2954 (PES/CLY) and 2958 (CO/CLY) with 50% CLY.

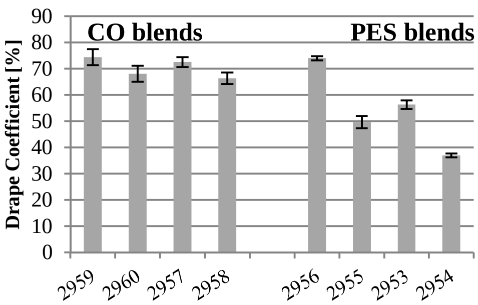

Figure 9. Effect of blending CLY on the drape of woven fabrics

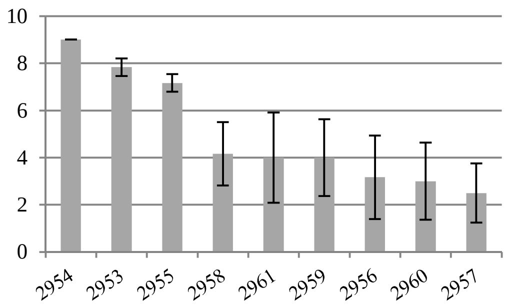

Figure 10. Overall handfeel of atlas fabrics assessed by non-expert panels

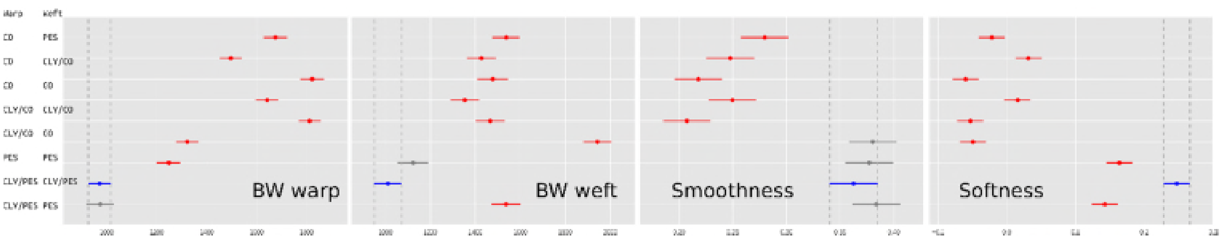

Figure 11. FTT bending work (BW) in warp and weft (left), smoothness and softness values (right)

Figure 11 (left), shows the FTT measurement of fabric bending work. It shows that CLY/PES blends have significantly less bending work than cotton and CO/CLY blends. Blending CLY to the warp or to the weft improves the fabric bending in the respective direction. This is more significant in the polyester blends and in the weft direction. Figure 11 (right) shows FTT primary hand values, where fabric 2954 (CLY/PES blend in warp and weft) is taken as reference.

It can be concluded, that all methods show similar trends in determining the softer and smoother fabrics and agree on the effect of adding CLY, which appears to have less effect if added to the warp. Adding CLY to the weft shows a small effect in the cotton fabrics. The effect of adding CLY to PES is dramatic, especially in the weft.

4. Conclusion

The handfeel advantage of wood-based cellulosics could be assessed on light and heavy woven fabrics both by objective test methods and subjective methods (panels). Especially the MicroModaL® and modal fabrics showed excellent handfeel values. TSA technology based on acoustic signals can principally offer a handfeel assessment that matches human hand evaluations of the tested construction groups so far it can be matched by a physical measurement. A wide agreement in the extreme ranges of fabric handfeel was observed. In the middle range, divergences among methods and among hand assessors were observed due to the similarity fabrics. To solidify this result, further works applying the TSA method on a wider range of textile constructions and surface treatment are to follow and to provide the basis for the optimization of the hand feel (HF) calculation system. Comparison measurements by other methods and referring to a reliable human panel are mandatory for this assessment. It should also be remembered that human handfeel perception is a sophisticated phenomenon where physical forces play only a partial role. The inclusion of the thermal aspect (warm/cool feeling) is also of high importance and could not be covered by this study due to the lack of reliable technology

Acknowledgments

The authors would like to acknowledge VLAIO and AIF for financial support of ERANET-CORNET research project Touché (2015-2016), conducted by UGent, HoGent and Hohenstein Institute (HIT)

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