NEW INSTRUMENTAL METHOD FOR EVALUATING FABRIC SOFTNESS

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Abstract

This study dealt with a new instrumental method for grading fabric softness. A pure cotton plain weave and 35/65 cotton/polyester twill were washed with Tide® and softened with Downy®. Variations of fabric mechanical properties determined by the Downy® treatment was measured using an LSU instrument composed of a QT/5 tensile tester, a set of attachments, and test methods software. The neural network software NeuroSolutions was employed in predicting models for grading fabric softness based on the measured fabric mechanical properties. To verify the grading models, the softener Snuggle® was used as a test softener. There was no predicting error in the present study. The new method of fabric softness evaluation is suitable for practice in a dynamic industrial environment because the new instrument can be routine laboratory equipment and the neural networking models can be updated on a daily basis to include new types of fabrics and softeners.

Introduction

Traditionally, fabric softness has been assessed by a qualitative hand measurement. This sensory judgment is usually implemented by a panel. The term of fabric hand, a general expression of persons’ reaction when touching a fabric, is then used for communications among fabric manufacturers, softener producers, apparel designers, garment makers, clothing retailers, and consumers. Fabric hand is a complex interaction of the characteristics of fiber behavior, yarn behavior, and fabric behavior. These combined attributes are, so far, still difficult to characterize objectively [Hearle, 1993a]. In particular, with the increasing use of various kinds of synthetic fibers, and the scarcity of experienced fabric hand evaluators, this traditional approach is not now practical.

As today’s consumers are demanding high performance garments and soft hand, industries are zealous to develop an engineering method of quantifying fabric softness, so that they can present fabric softness numerically, transmit information of fabric softness through the Internet conveniently, and standardize fabric softness rationally. To achieve this goal, two important technical issues need to be taken into consideration. One is how to measure those physical attributes of fabric softness. The other is how to establish a physical model that can predict (or quantify, or grade) fabric softness according to the instrumentally measured attributes.

The most notable impact on this research is the Kawabata method of standardizing fabric hand [Kawabata, 1980]. In this method regression technique was used to establish relationship between fabric mechanical properties measured by the KES-FB instruments and fabric hand values subjectively graded by a Japanese expert panel. Regression equations developed were then used for calculating the "total hand value" of apparel fabrics. However, industry implementation of the Kawbata method was hindered owing to the following reasons [Lloyd and Leaf, 1990; Hearle, 1993b]. First, the KES-FB instruments are too expensive and the testing procedures are complicated and time-consuming. This has made them unaffordable for most textile companies. Second, the concept of total hand lacks mathematical foundations. This will continue challenging scientists in fundamental research.

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This paper introduces a new approach to objective evaluation of fabric softness. This approach involves two new techniques. One technique is a new instrument that can measure fabric mechanical properties like the KES-FB instruments. The Kawabata parameters can then be obtained quickly and inexpensively by using this instrument, composed of a universal tensile tester, software on testing methods, and a set of instrumental attachments developed by the author (approximately 1/5 of the KES-FB’s total price). The other technique is a neural networking computer simulation that can help develop a model for grading fabric softness based on the instrumental data from this new instrument. This approach is cost and time effective because all data manipulations are computerized, so that it is more suitable for implementation in a dynamic industrial environment and for functioning as a routine laboratory facility affordable for medium and small textile manufacturers. As a case study, the present work demonstrates a direct application of this new approach for evaluating softener quality in improving softness of cotton and cotton blended fabrics. This will benefit both fabric and fabric softener manufacturers.

Experiment

The softeners Downy® (The Procter & Gamble Company) and Snuggle® (Lever Bros. Co.) are widely used as softening agents in home and hotel laundry. To assess their effectiveness on fabric softness, a pure cotton plain weave and 35/65 cotton/polyester twill weave were selected for softening treatment using these two softeners. The pure cotton and cotton blended fabrics were washed in a Launder-Ometer with the Tide® detergent only and Tide® plus Downy®. The experiment referred to the AATCC Test Method 61-1994 [AATCC, 1995]. Snuggle® was used to treat the Tide®-washed fabrics in the same way as the Downy®. The washing and softening procedures are listed below.

Sample Size:	4’8 inch for tensile and friction test; $5^{5/8}$H$5^{5/8}$ inch for shear test.
Washing:	preheating for 20 minutes at 40°C, Tide load (detergent/water ratio) 0.89g/L; washing for 26 minutes at 40°C, fabric load (fabric/water ratio) 30.26 g/L; hand squeezing.
Softening:	after the above washing, preheating for 20 minutes at 40°C, softener loads: 0 g/L (for Tide®-washing only) and 2.10 g/L (for Downy®-softening); washing for 26 minutes at 40°C with the same fabric load as above; rinsing 10 minutes.

After washing and softening, the fabric samples were placed in a testing laboratory for temperature/humidity adjustment for 24 hours, and then tested using a QT/5 tensile tester (Figure 1) with the instrumental attachments. Fabric tensile property, shear property, and surface friction were measured, because they were most respondent to the softening treatment [Chen et al., 2000].

The tested instrumental data of the two fabrics washed with Tide® and softened with Downy® were input first using the NeuroSolutions Version 3 [NeuroDimension, Inc., 1998] software for analysis. Two neural networking models, with respect to the pure cotton and cotton blended fabrics, were established to grade the softness of the Tide-washed fabric as "0" and the Downy®-softened fabric as "1." The instrumental data of the Snuggle®-treated fabrics were tapped into the computer for evaluation by the developed models. Each of these fabrics was assigned a numerical value between "0" and "1," a softness grade with reference to the Downy®-treated fabrics.

Results and Discussion

Fabric Mechanical Properties

The effectiveness of softeners on fabric softness is reflected by how many changes in fabric mechanical properties take place. Obtaining this information becomes the first important step in fabric objective evaluation. Using the LSU instrument system, most important fabric mechanical properties before and after the softening treatment were determined (Table 1). Figures 2 to 4 present the stress-strain or load-displacement curves of the softened pure cotton fabric. These properties include tensile linearity (LT), tensile energy (WT), tensile resilience (RT), shear rigidity (G), shear hysteresis (2HG and 2HG5), surface frictional coefficient (MIU), and mean deviation of the frictional coefficient (MMD).

Overall, after softening treatment, fabric tensile parameters LT and RT increase mildly and shear rigidity and hysteresis decrease significantly. The softener also tends to reduce fabric surface friction. It can be observed that different fabric may respond to the softening treatment differently due to different fiber contents and fabric structure. The pure cotton fabric is more sensitive to the Downy® Softener.

Neural Network Modeling

In this study, Downy® was assigned as a reference softener. The instrumental data of the pure cotton and cotton/polyester fabrics with and without Downy® were imported to a PC to form a training data set. The NeuroSolution software run a learning procedure using this training data set and a selected neural networking method. This software provided 9 neural networking methods. In this case, the method of multilayer perceptron (MLP) was selected because of its powerful features of nonlinear processing elements and full interconnections between each pair of layers. Figure 5 illustrates the structure of MLP. Figure 6 is a learning curve produced in this neural network modeling. A quick drop to zero means high accuracy for evaluating fabric softness.

Predicting Model Validation

To verify the accuracy of the neural networking model in predicting fabric softness modified by any new softener, Snuggle® was used as a test softener. Three fabric specimens treated with Snuggle® were input into the pure cotton model and cotton/polyester model for evaluation respectively. Output values (Table 2) indicate that they are close to the maximum softness grade "1," (Downy® treatment). Therefore, the Snuggle® is ranked with the same softening quality as Downy®. In industrial applications, a tolerance of softness grade needs to be identified, so that manufacturers or customers can determine if the quality of a new softener is acceptable or refusal.

Summary

Variations of fabric mechanical properties correspond to softening treatment by different softeners. Objective evaluation of fabric softness can be carried out, first by instrumentally measuring these variations, and then by grading the fabric softness using the computing technique of neural networks. In the present work, a cotton plain weave and a 35/65 cotton/polyester twill were used as test fabrics. Downy® and Snuggle® were selected as reference and test softeners individually. The LSU instrument (including a QT/5 tensile tester, a set of attachments, and test methods software) was employed to test the important fabric properties of extension, shear, and friction. Two neural-networking models were established in the NeuroSolutions software for grading fabric softness (numerical between 0 to 1) with different softener treatments. These models are useful for evaluating other new softeners or determining optimal softener loading, as they are dynamically updated and become more robust.

The new approach to objective evaluation of fabric softness is actually a procedure of computer-aided analysis based on artificial intelligence software. This may help promote research advances in this field and encourage direct industrial application. In particular, the newly-developed LSU instrument is proven to be inexpensive to obtain, easy to use, and quick to output. Even small textile manufacturers can afford it as a routine quality control tool.

Acknowledgements

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Table 1a. Fabric Mechanical Properties from the LSU Measuring Instrument.

Kawabata Parameter*	N	Pure Cotton: Tide® Mean	Pure Cotton: Tide® S. D.	Pure Cotton: Tide® + Downy® Mean	Pure Cotton: Tide® + Downy® S. D.
LT1	30	0.65	0.05	0.69	0.03
WT1 (gf·cm/cm^2)	30	5.44	0.40	5.07	0.14
RT1 (%)	30	46.70	2.37	47.08	1.11
LT2	30	0.65	0.01	0.66	0.02
WT2 (gf·cm/cm^2)	30	15.94	0.46	16.58	0.50
RT2 (%)	30	43.74	0.66	44.92	0.63
G1 (gf/cm·degree)	30	3.43	0.19	2.46	0.14
2HG-1 (gf/cm)	30	13.14	1.27	8.01	0.76
2HG5-1 (gf/cm)	30	37.30	2.18	22.93	1.36
G2 (gf/cm·degree)	30	3.23	0.19	2.25	0.17
2HG-2 (gf/cm)	30	10.87	0.95	6.79	1.14
2HG5-2 (gf/cm)	30	34.01	2.04	21.11	1.89
MIU1	30	0.583	0.032	0.509	0.036
MMD1	30	0.040	0.006	0.034	0.004
MIU2	30	0.508	0.021	0.476	0.014
MMD2	30	0.037	0.004	0.034	0.004

* 1 = fabric warp direction; 2 = fabric filling direction.

Table 1b. Fabric Mechanical Properties from the LSU Measuring Instrument.

Kawabata Parameter*	**N**	**35/65 Cotton/Polyester**			
		Tide®		**Tide® + Downy®**	
		Mean	**S. D.**	**Mean**	**S. D.**
LT1	30	0.75	0.04	0.80	0.02
WT1 (gf·cm/cm^2)	30	4.37	0.62	4.74	0.23
RT1 (%)	30	43.52	2.95	40.37	1.61
LT2	30	0.68	0.04	0.73	0.01
WT2 (gf·cm/cm^2)	30	16.67	0.73	17.12	0.50
RT2 (%)	30	52.80	1.23	52.90	1.01
G1 (gf/cm·degree)	30	2.09	0.17	1.97	0.13
2HG-1 (gf/cm)	30	7.65	1.24	6.27	0.75
2HG5-1 (gf/cm)	30	19.27	1.74	16.69	1.08
G2 (gf/cm·degree)	30	2.28	0.25	1.83	0.19
2HG-2 (gf/cm)	30	7.95	1.64	5.84	0.89
2HG5-2 (gf/cm)	30	21.27	2.68	15.91	1.73
MIU1	30	0.477	0.014	0.450	0.006
MMD1	30	0.035	0.004	0.034	0.003
MIU2	30	0.545	0.016	0.494	0.010
MMD2	30	0.038	0.006	0.034	0.004

Table 2. Model Validation Using Downy® –Treated Speicmens.

Exemplar	**Type**	**Tide® only (0) Desired**	**Downy® (1) Desired**	**Tide® only (0) Output**	**Downy® (1) Output**
1	Cotton	0	**1**	0.00	**1.00**
2	Cotton	0	**1**	0.00	**1.00**
3	Cotton	**1**	0	**1.00**	0.00
4	Cotton	**1**	0	**1.00**	0.00
5	Cotton	**1**	0	**1.00**	0.01
1	C/P	0	**1**	0.00	**1.00**
2	C/P	0	**1**	0.00	**1.00**
3	C/P	0	**1**	0.00	**1.00**
4	C/P	**1**	0	**1.00**	0.00
5	C/P	**1**	0	**1.00**	0.00

Table 3. Model Validation Using Snuggle® -Treated Specimens.

Exemplar	**Type**	**Tide® only (0) Desired**	**Snuggle® (1) Desired**	**Tide® only (0) Output**	**Snuggle® (1) Output**
1	Cotton	0	**1**	0.00	**1.00**
2	Cotton	0	**1**	0.00	**1.00**
3	Cotton	0	**1**	0.00	**0.99**
1	C/P	0	**1**	0.00	**1.00**
2	C/P	0	**1**	0.00	**1.00**
3	C/P	0	**1**	0.00	**1.00**

Figure 1. QT/5 Desktop Tensile Tester.

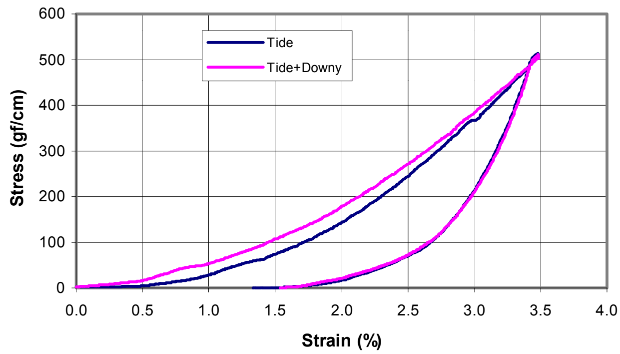

Figure 2. Tensile Curve of Pure Cotton Fabric.

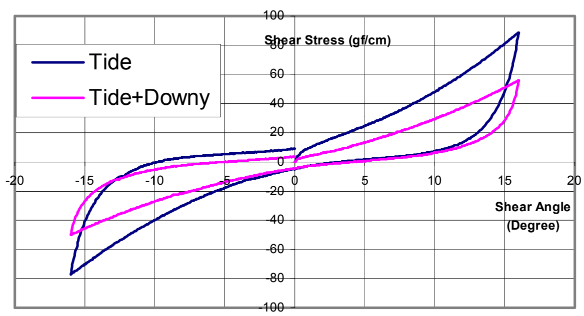

Figure 3. Shear Curve of Pure Cotton Fabric.

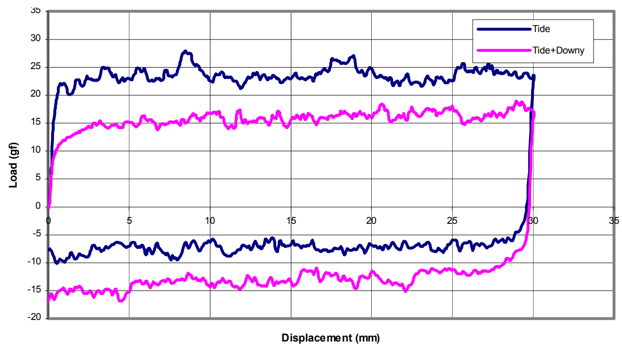

Figure 4. Surface Friction Curve of Pure Cotton Fabric.

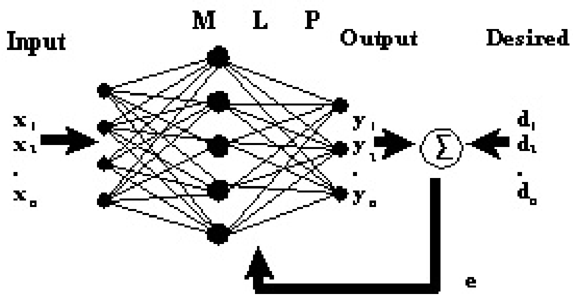

Figure 5. MLP Structure

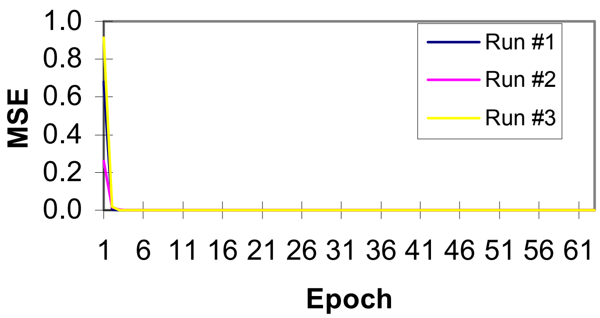

Figure 6. Training Curves for 3 Runs