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INSTRUMENTAL METHOD OF GRADING COSMETIC NONWOVEN SOFTNESS

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Abstract

Softness of cotton nonwoven for cosmetics is a key character to attract consumers. Evaluation of the cosmetic nonwoven softness is always subjective, that is, relying on human hand assessment. Development of an instrumental method for grading the cosmetic nonwoven softness is, therefore, helpful for both manufacturers and customers to avoid subjective bias and communicate with each other using numerical data. This work proposes an approach to characterizing cosmetic nonwoven softness using a set of mechanical properties. Four types of cosmetic cotton nonwoven were selected for study. The mechanical properties of these nonwovens in terms of extension, shear, and surface friction were measured using a QTest tensile tester equipped with specially designed attachments. Obtained mechanical data were input into a neural network model for softness grading. This neural network model was established on a training data set composed of a typical plain cotton shirting fabric with and without softening using the Downy® softener. The fabric softness with the Downy® treatment was defined as "1" and the fabric softness without the Downy® treatment was defined as "0." This neural network model graded softness of the four cosmetic cotton nonwovon samples between 0 (indicating the worst softness) and 1 (indicating the best softness).

Introduction

Softness is one of the most important properties for health and personal care nonwovens. Cotton fiber has been widely used for making these nonwoven products because of its excellent performance of being absorbent, breathable, soft, non-allergenic, and biodegradable. Cotton cosmetic pads are among those demanded cotton nonwoven products that attract consumers in the health and personal care market. Apart from fiber attributes to nonwoven softness, many new techniques, in terms of mechanical processes, fiber pretreatment, finishing, and special softening, have been applied with a purpose of enhancing nonwoven soft hand. A recent rapid development is hydroentangling (spunlacing) technology. Use of the spunlacing technique for bonding cotton nonwovens can allow production of polymer-binder-free and chemical-free cotton nonwovens with higher quality and lower cost [Watzl et al., 2001]. It is reported that nonwoven softness is also improved significantly [Gillespie, 2002].

Traditionally, evaluation of fabric softness relied for the most part on sensory adjustment by a panel, that is, on experts' hand evaluation. This subjective (non-engineering) approach now becomes very limited because of scarcity of experienced hand evaluators and intensive use of diverse man-made fibers [Hearle, 1993a,b]. Then, a question raised by nonwoven manufacturers and customers is, "Can we evaluate objectively the improvement of nonwoven softness after using the new processing technique or modified fiber materials?" This means we need to develop an instrumental method that is able to sensitively detect any incremental progress of fabric softness.

Previous research with this aim was focused primarily on issue and paper towel products. Rust et al. [1994] used a mechanical stylus scanning method to measure surface property of tissues. They proposed a frequency index obtained through the Fast Fourier Transform (FFT) to describe tactile sensitivity. Kim et al. [1994] studied the softness property of paper towels using the Kawabata KES-FB instruments. They developed a linear regression model to predict the so-called softness intensity. Both of the above research studies rely on humans' subjective input in grading the softness of tissue or paper towel products. Objective hand measurement of nonwoven fabrics was investigated in Japan [Kawabata et al., 1994]. This research applied the same technique that Professor Kawabata and his co-workers developed for evaluating hand of wool and wool-rich suiting fabrics. Artificial neural network has become a useful computing technique for solving real-life fuzzy problems because of its power in pattern recognition, particularly in learning highly nonlinear complexity. Some recent research reports in this field include on-line prediction of tissue softness with an inferential sensor operated in real time together with a distributed control system [Sarimveis and Retsina, 2001] and application of the neural network technique for predicting fabric end-use was reported also [Chen et al., 2001].

This paper presents a study on evaluation of nonwoven softness based on nonwoven mechanical properties instead of humans' hand judgment. Fabric mechanical properties deal with these basic mechanical deformations: extension, shear, bending, and compression. Fabric softness and hand are believed to be a complex behavior of these mechanical properties, plus surface friction and roughness [Hearle, 1994]. The purpose of this study is to investigate applicability of the neural network technique for solving the real-life problem of grading nonwoven softness.

Experimental

Although the Kawabata KES-FB instruments are a de facto standard method for measuring fabric mechanical properties in industries and academia, this instrumental system is not accessible to most manufacturers, in particular, medium and small textile companies, because of its unaffordable price and complicated measuring procedures. An approach of using a QT/5 tensile tester (MTS product) to measure fabric mechanical properties was developed in the LSU Textile Testing Laboratory [Chen, 2001]. In a previous fabric softness study, this instrument was used to test a cotton woven fabric with and without softening treatment [Chen et al., 2001]. In the present study, four types of needle-punched cotton nonwoven were selected and tested using the QT/5 tester in terms of tensile, shear, and frictional properties. The reason why only the tensile, shear, and frictional properties of the fabric were measured is that these properties were significantly influenced by softening treatment as indicated in the previous study. Table I lists sample information, and Table II gives summary of the tested data (Kawabata parameters). Most of these parameters have physical units. To normalize the data set, the following formulae were used to make those dimensional variables dimensionless (scale-invariant):

$$Dim[WT] = \frac{WT}{W \cdot T_0} \times 10^{-5}$$

$$Dim[G] = \frac{G}{0.0175W \cdot T_0} \times 10^{-5}$$

$$Dim[HG] = \frac{HG}{W \cdot T_0} \times 10^{-5}$$

The commercial software NeuroSolutions (V. 4) for PCs [NeuroDimension, 2001] was used for neural network computing. This software features MS Excel compatibility and can easily run in a PC desktop with Excel-format data input. The training data set used for the neural network computing was obtained from the previous study by testing two samples of a plain cotton shirting fabric, one with Tide® washing only and one with Tide® washing and Downy® softening. The fabric softness with the Downy® treatment was defined as "1" and the fabric softness without the Downy® treatment was defined as "0." The four cosmetic cotton nonwovon samples constituted a testing data set. Softness of each sample was graded between 0 (indicating the worst softness) and 1 (indicating the best softness). This softness grade can be defined as softness index.

The method of CANFIS networks (fuzzy logic) was selected for the data training. This method integrates fuzzy inputs with a neural network to enhance computer learning performance. With fuzzy rules (membership functions) as a preprocessor, the neural network can characterize poorly discretized inputs and establish an efficient model quickly. Figure 1 illustrates the structure of the neuro-fuzzy network.

Results and Discussion

A fuzzy logic neural network model was established by training the training data set with a minimum mean square error (MSE) 0.0023 for the training and 0.0098 for cross validation. This means that the trained model is highly accurate. Figure 2 is a learning curve for this model.

Table III lists the grading result for the 4 tested samples. According to these softness indexes, all 4 samples of the cotton nonwoven have considerably low softness grades in comparison with the Downy-softened cotton shirting fabric. Within these 4 cosmetic pads, however, Samples 1 and 2 show closer and relatively higher softness indexes and Samples 3 and 4 indicate lower softness indexes. It needs to be noticed that the present neural network model is still not ideal because the training data set was from the previous study of evaluating the softener effectiveness on a cotton shirting fabric. It is obvious that the cotton shirting woven fabric is quite different from the spunlaced cotton nonwoven in fabric structure and each fabric basic mechanical property may play a different role in a different fabric structure for influencing fabric softness. It was already observed that shear rigidity and shear hysteresis were critical for assessing softness of the cotton shirting fabric in the previous study. However, it is not the case for the cotton nonwoven of which compressive property might be more important than the shear property in determining softness. Therefore, a better way is to establish a training data set by targeting cosmetic pad products made of spunlaced cotton nonwovens. This training data set should include bending and compressive properties.

Conclusions

Four needle-punched cotton nonwovens used for cosmetic application were measured using the QT/5 tensile tester and special attachments in terms of tensile, shear, and frictional properties. These instrumental data were input into the neural network software for evaluating fabric softness. The computed result indicated that the training data set, previously established for evaluating the cotton shirting fabric, could also be used to calculate softness index for the cosmetic cotton nonwovens. The objective method for assessing needle-punched cotton nonwovens was proven practical in this study. Further research will target commercial cosmetic cotton nonwoven products and develop a substantially large training data set for establishing a new fuzzy neural network model that can be used to grade softness of new needle-punched or spunlaced cotton nonwovens.

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Table 1. Spunlaced Cotton Nonwoven Samples.

Sample #	Fiber Content	Weight (g/m^2)	Thickness (mm)
1	50% bleached comber Noil 50% bleached raw cotton	238.9	5.332
2	40% bleached comber Noil 40%bleached raw cotton 20% Tencel	258.0	5.700
3	37.5% bleached comber Noil 37.5% bleached raw cotton 25% biocomponent fiber	103.5	3.521
4	32.5% bleached comber Noil 32.5% bleached raw cotton 35% Tencel	95.8	3.723

Table 2. Sample Mechanical Properties.

Property	Parameter	Sample # 1	2	3	4
Tensile	LT	1.000	1.080	1.030	0.910
	WT ($g{\cdot}cm/cm^2$)	1.520	0.980	8.930	3.060
	RT (%)	22.10	21.75	10.00	15.14
	EMT (%)	6.08	3.57	34.58	13.35
Shear	G (g/cm·degree)	1.70	2.62	0.30	0.52
	2HG (g/cm)	6.40	11.78	1.42	2.92
	2HG5 (g/cm)	8.82	16.08	1.80	3.71
Friction	MIU	0.954	1.046	0.878	0.839
	MMD	0.0612	0.0683	0.0835	0.0769

Table 3. Softness Grades by Neural Fuzzy Model.

Sample ID	Tide-washed	3	4	1	2	Downy-treated
Softness Index	0	0.395	0.449	0.550	0.551	1

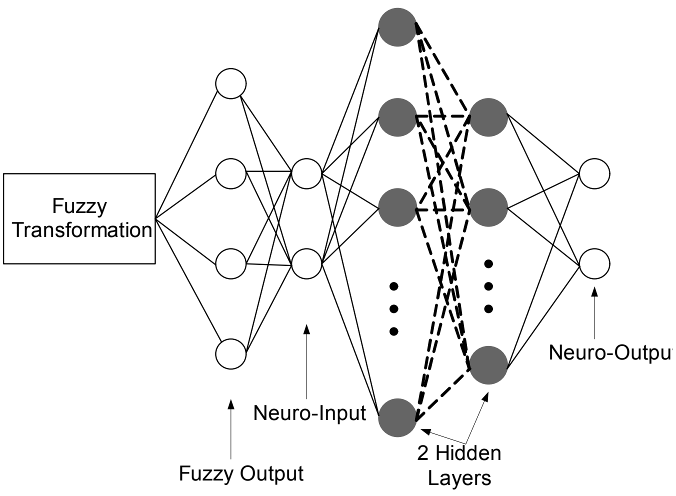

Figure 1. Neuro-Fuzzy Structure.

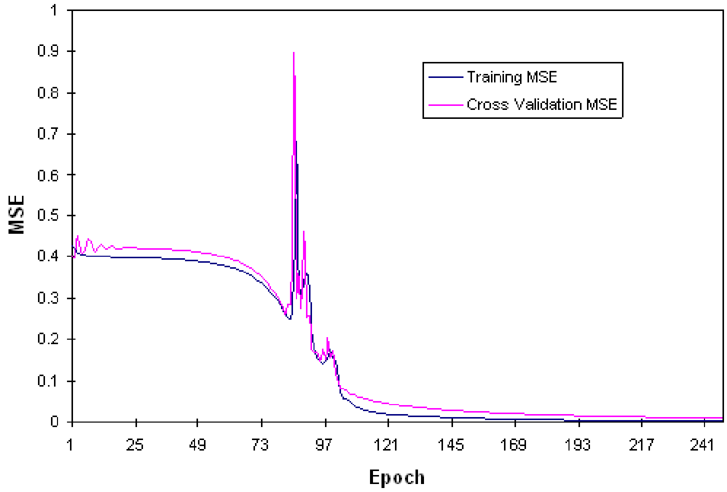

Figure 2. Neural Network Learning Curve.