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THE KAWABATA EVALUATION SYSTEM AND ITS APPLICATIONS TO PRODUCT/PROCESS ENHANCEMENT

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Abstract

The Kawabata Evaluation System (KES) is a system of sensitive electronic equipment designed to accurately measure the low-stress mechanical and surface properties of the whole range of flexible fibrous products, namely woven fabrics, knitted fabrics, and nonwoven materials. The system consists of a bending tester, a compression tester, a surface tester, and a combined tensile-shear tester. The uniqueness of the equipment lies in the fact that the instruments permit the measurement of the complete recovery behavior of the fabrics, in addition to the deformation behavior. Also, the peak loads for different mechanical tests can be pre-selected to suit the specific use of the test results (such as softness measurement, measurement of flexibility, surface roughness, elastic recovery, the ability to withstand cyclic loading, etc.). The precision and versatility of the equipment, therefore, provide unique opportunities to produce and deliver truly "engineered" products for a range of demanding end uses. The measurements can also be used to select the most appropriate raw materials, product designs, and processing parameters for a wide a range of products and production processes.

This paper describes the specific mechanical and surface properties that can be measured using the KES equipment. It gives some examples of how the measurements were used in recent years to improve nonwoven products and production processes. It also describes the future scope and application possibilities of the equipment for the nonwovens industry.

Introduction

The group of instruments developed by Kawabata for the objective charcterization of the tactile properties of textile materials are collectively known as the Kawabata Evaluation Sytem (KES). Subjective evaluation of tactile feel involves rubbing and squeezing of fabrics between fingers and the major modes of deformation sustained by fabrics when they are rubbed between fingers are bending, shear, compression, and tensile deformations. The instruments developed by Kawabata basically characterize fabric response to low levels of bending, shear, compression and tensile forces. The shape of the force-deformation curves and certain numerical values extracted from the curves characterize the tactile response of the fabric. The following paragraphs provide a brief description of the individual Kawabata tests and the parameters evaluated from each test. More detailed description of test methods and measuring principles can be obtained by referring to the publications of Kawabata et al (1-2).

Description of Equipment and Test Procedures

Tensile Test

Stress/strain curves are generated in a manner similar to those under high stress conditions except that the peak stress values are much less, being comparable to those encountered during the actual wearing of the garment. Test specimens 20 cm wide and 5 cm long (20cm by 5cm) are stressed between two sets of clamps until a peak load of 10 kg is imposed on the 20 cm wide sample. The stress on the fabric is then gradually relieved by reversing the motion of the movable clamps (the movable clamps are allowed to go back to their original position). Figure 1 shows the tensile & shear tester and the typical force-deformation curves for the tensile and shear tests.

The parameters obtained from the tensile test are:

- **EMT% -** percentage tensile elongation which is the ratio of the actual extension to the original sample length, expressed as a percentage,
- **WT -** tensile energy or work done in tensile deformation represented by the area under the stress-strain curve (J/m^2),
- **WT'** - energy or work recovered as a result of relieving stress on the material, represented by the area under the recovery curve (J/m^2),,
- **RT% -** tensile resilience, which is the ratio of work recovered to the work done in tensile deformation, expressed as a percentage, 100(WT'/WT), and

LT - A measure that defines the extent of non-linearity of the stress/strain curve. LT values below 1.0 indicate that the stress/strain curve falls below a 45 degree straight line while LT values greater than 1.0 indicate that the stress/strain curve falls above 45-degree straight line.

Shear Test

The shear test is carried out on the same instrument used to run the tensile test (the KES Tensile and Shear tester performs both the tensile and shear tests, one at a time). As in the case of the tensile test, the fabric sample is mounted between two sets of clamps (forward and backward clamps) but the front set of clamps moves side ways to impose a shear stress on the fabric. The size of the test specimen used is again 20 cm by 5 cm. Starting from the initial position, the 20 cm wide fabric sample is first sheared 10 degrees to the right and then the horizontal shearing motion of the front clamps is reversed until they reach their original (zero shear angle position). The sample is again sheared 10 degrees to the left and then the shear motion is fully reversed as before. The shear test therefore permits the measurement of both shear modulus and shear hysteresis properties when the fabric is sheared in both directions. The physical parameters computed in the shear test are:

G - shear modulus, which is the slope of the shear curve(N/m),
2HG - hysteresis width at a shear angle of 0.5 degrees (N/m), and
2HG - hysteresis width at a shear angle of 5 degrees (N/m).

Bending Test

The bending test involves bending a 20cm by 1cm sample to a standard curvature and then reversing the bending motion in order to study both bending and recovery behavior. The fabric sample is bent not only in the warp and filling directions, but also on the face and reverse sides. Average values of test parameters(bending rigidity and bending hysteresis)are reported for the fabric as a whole, taking into account both warp and filling direction tests and forward and backward tests. Figure 2 shows the bending tester and typical bending charts.

The parameters evaluated from the bending chart are:

B - bending rigidity (modulus), which is the slope of the bending curve that lies between the radius of curvatures 0.5 cm^{-1} and 1.5 cm^{-1} (μnm), and
2HB - hysteresis width at a bending curvature of $\pm$ 0.5 cm^{-1}(mN).

Compression Test

In the compression test (please refer to Figure 3), a standard area of the fabric (3.14 sq.cm) is subjected to a known compressive load (50 g/sq.cm)and then the load is gradually relieved. The load is applied through a movable plunger that moves up and down and compresses the fabric sample kept on a stationary platform. The following physical parameters characterize the compression and recovery behavior of the fabric:

TO - fabric thickness (mm) at a very low compressive load (0.5 g/sq.cm),
TM - fabric thickness (mm) at the maximum compressive load (50.0 g/sq.cm),
WC - work done in compression, represented by the area under the compression curve(J/m^2),
WC' - work recovered as a result of relieving the load imposed on the fabric, represented by the area under the recovery curve (J/m^2),
RC% - compressive resilience, which is the ratio of work recovered to work done, expressed as a percentage, 100(WC'/WC)
LC - linearity of the compression curve, which will have values similar to that of LT, and
EMC% - compressibility, which is the ratio of measured reduction in thickness to the original fabric thickness, expressed as a percentage, 100(TO–TM)/TO.

Surface Test

The surface tester (Figure 4) uses two different electronic sensors that record the geometric roughness of the fabric surface and the coefficient of surface friction, respectively, as the fabric moves forward and backward underneath the two sensors. Both sensors directly contact the fabric surface at two different places and the contact pressure is standard for all measurements. The fabric also carries a preset tension on it as it moves underneath the sensors. Roughness and friction coefficients are computed for a three-centimeter length of fabric; the computation includes both forward and backward movements in both the warp and filling directions. In addition to an overall roughness index and coefficient of friction values, separate traces that show variations across a three-centimeter length of the fabric are also obtained. The parameters obtained from the surface test are listed below:

MIU - coefficient of surface friction as measured over three-cm length of fabric,
MMD - mean deviation of coefficient of friction, and
SMD - index of surface roughness (mean deviation of surf ace peaks representing thick and thin places, μm).

Shear Fatigue Test
Specimens measuring 20cm by 5 cm are mounted between the clamps of the shear fatigue tester under a pretension of 50 g/cm (or 1000g for 20 cm width) and sheared repeatedly to eight degrees on either side of the fabric. The shearing can be repeated for any desired nimber of cycles and the creep elongation (elongation occuring with time under a constant pretension load) measured at every 500 shear cycles. The elongation measured at zero cycles is the elongation corresponding to the pretension load alone, which is measured immediately after the load is applied on the fabric, but before shearing has commenced. Dynamic creep is computed as the ratio of the elongation obtained under dynamic conditions (under shearing conditions) to that obtained under the pre-tension load alone.

The amount of pre-tension applied has a significant effect on the creep elongation and the dynamic creep. When comparing different fabrics with different degrees of stretchability, it is necessary to choose the pre-tension that is applicable for the most extensible fabric and use the same tension for the other fabrics as well.

The following table lists the standard instrument settings and stress levels used in compression, tensile, shear, bending and cyclic shearing tests. These settings, of course are not applicable for materials that are either weak or are highly extensible. For such materials, high sensitivity settings are more appropriate than the standard settings.

Applications of KES in the Nonwovens Industry

The high sensitivity and high level of accuracy associated with KES equipment make the system an ideal tool in the hands of the process engineer. Virtually all aspects of product design and product engineering, including raw material selection, web formation, web consolidation and finishing can benefit from the data generated through the Kawbata Evaluation system. While helping to engineer products that provide consistently optimal performance properties, the data can eliminate wastage in the assembly processes through the optimization of individual process steps and the input materials.Some specific examples of the applictaions of the measured KES data are listed below:

Optimization of raw materials
Optimization of web forming, consolidation, and finishing processes
Development of structure-property realationships
Quantitative evaluation of primary tactile sensations such as softness, stiffness, smoothness, etc.
Evaluation of the effects of heat setting treatments
Development of end products with specifically engineered and precisely controlled performance properties
Refinishing of fabrics to meet certain specific property requiremnts of end products
Understanding the influence of dozens of process parameters on specific performance properties
Prediction of useful life and durability
Selection of appropriate binders and other finishing agents.

References

Kawabata, S., Postle, R., and Niwa, M., Eds. May 1982. Proceedings of the Japan-Australia Joint Symposium on “Objective Specification of Fabric Quality, Mechanical Properties and Performance.” Textile Machinery Society of Japan, Osaka, Japan.

Kawabta, S., Ed. 1980. Standardization and Analysis of Hand Evaluation. Textile Machinery Society of Japan, Osaka, Japan.

Table A. Standard KES Instrument Settings for Fabric Testing.

Compression

Rate of compression: 0. 02 mm/sec
Maximum compressive force: 50.0 g/sq.cm
Area compressed: 2.0 cm. diameter circle

Bending

Rate of bending: 0.5 cm-1/sec
Maximum curvature: ±2.5cm-1
Specimen size (LxW): 20cm x 1cm.

Shear

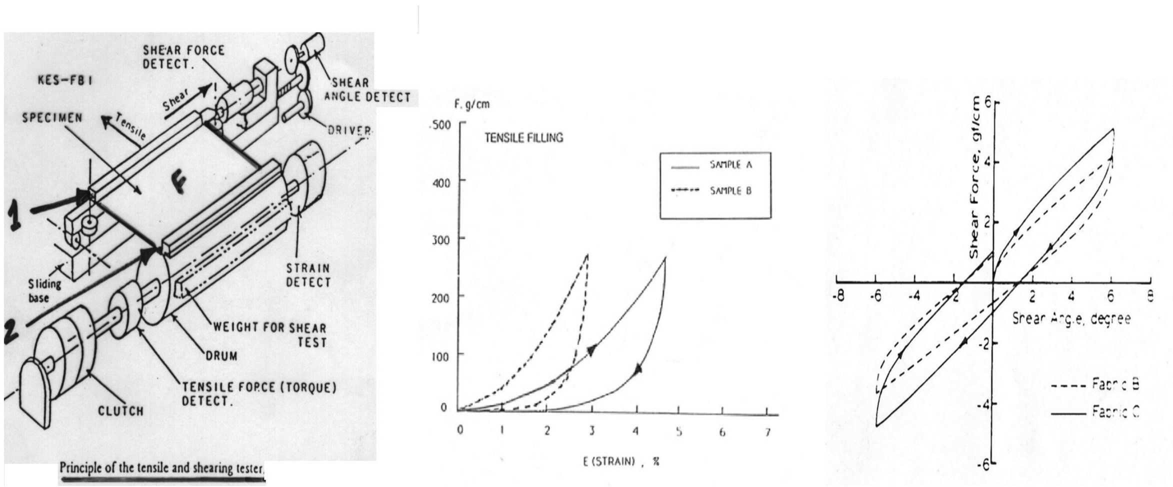
Rate of shearing: 0.417 mm/sec
Max. shear angle: ±8 degrees
Pre-tension: 10 gf/cm
Specimen size (W*L): 20cm x 5cm

Tensile

Rate of extension: 0. 1 mm/sec
Maximum tensile force: 500 gf/cm
Specimen size (W*L):20cm x 5cm

Cyclic Shearing

Cycles/min: 120
Specimen size(W*L): 20cm x 5cm



Tensile Chart

Shear Chart

Figure 1. Tensile tester with typical tensile and shear charts for two different fabrics.

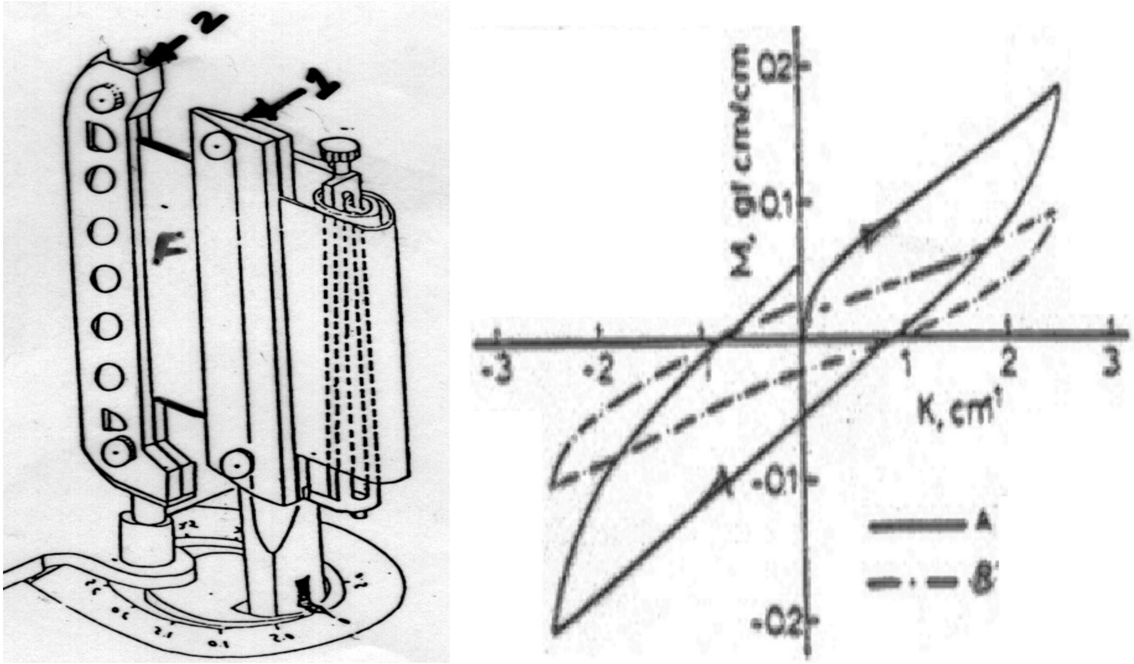


Figure 2. Bending tester and typical bending charts for fabrics A and B.

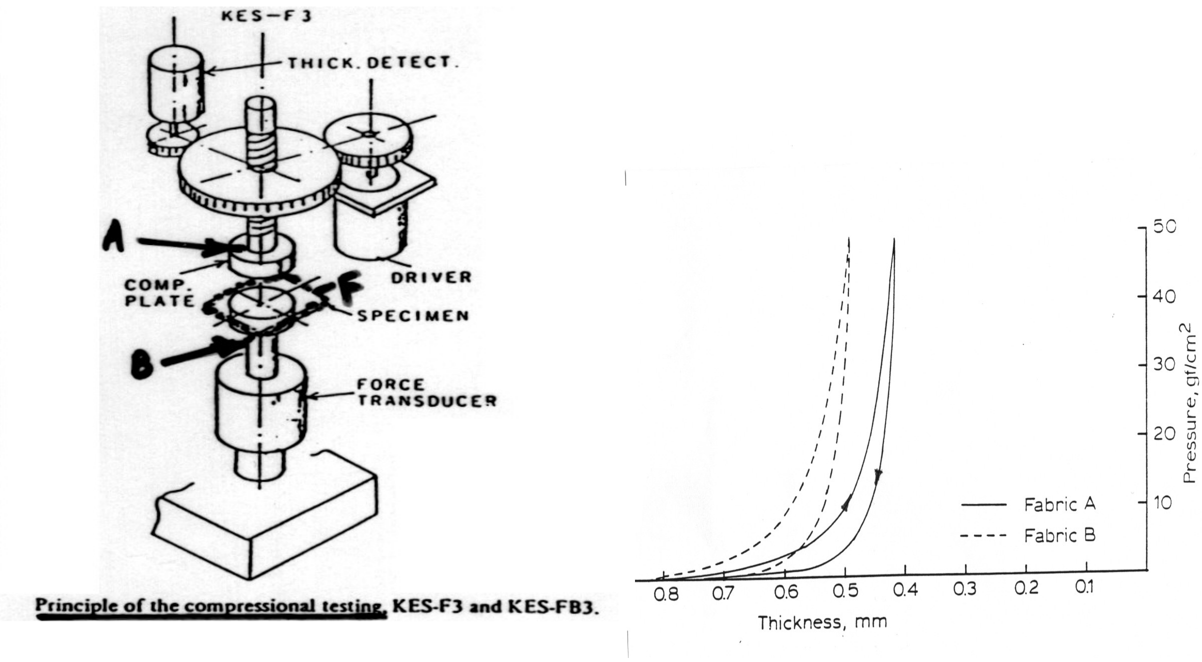


Figure 3. Compression tester and typical compression charts for two different fabrics.

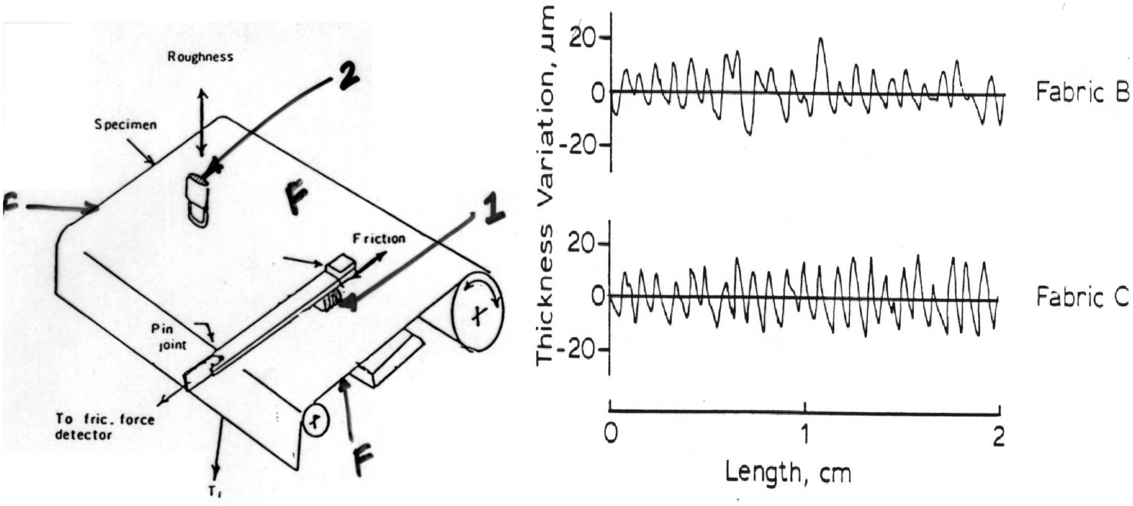


Figure 4. Friction (1) and Roughness (2) probes of the surface tester and typical roughness traces of two different fabrics.