FAST for fabric designing and finishing

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AWI

Innovative solutions for textile problems

Fabric objective measurement

This lecture seeks to develop the concept of innovation through the study of the ‘invention’, ‘exploitation’ and ‘redevelopment’ of fabric objective measurement. The development of fabric objective measurement is in many ways a case study for the analysis of innovation.

What I will try to establish in this lecture is:

- the identification of the need
- the initial steps – the first attempts at innovation
- the learning process
- modern re-evaluations – the second stages of innovation
- ‘additional’ innovations to improve and augment the initial invention.

The history of fabric objective measurement is not the history of a single innovation but of the many innovative steps that have led to the current technology. I will try to identify and analyse these innovative steps (large and small) and show how each has contributed to the next goal and the current solution.

The last stage in this lecture will be an exercise in innovation, in which you will be given the opportunity to develop an innovative solution (or solutions) for a problem.

The properties of fabrics

What is it that attracts people to particular garments? Certainly the style and cut of the garment, but also the colour and perceived quality of the fabric from which it is made. The properties of fabrics than determined its ultimate quality may be grouped in two ways:

- functional properties, which include tear strength and abrasion resistance
- aesthetic properties, which include attributes such as handle and appearance.

The functional properties of fabrics are relatively easy to measure. A large number of standard test methods to predict fabric functional performance have been established and are widely available.

Generally, the aesthetic characteristics of fabrics are measured by a mixture of subjective evaluation and objective tests. Some of the aesthetic properties of fabrics may be measured in standard tests (such as those for pilling or wrinkle recovery). Although the relationship between the performance of the fabric and the results of test procedures is much less exact in these tests than in tests for functional properties, testing for these aesthetic characteristics remains part of the quality control program in many mills.

Despite its acknowledged importance, in most sectors of the industry, 'handle' remains an inherently subjective characteristic of fabric and, as such, is affected by the whims and perceptions of the handler. It remains one of the key components of the perceived quality of fabrics and garments and, consequently, is the source of commercial dispute, claim and counterclaim. In spite of the importance of handle, there is no agreed way to measure objectively this key characteristic of fabric.

Likewise, the appearance of garments after manufacture and in wear is normally subjectively determined and, until recently, there was no agreed method for fabric makers to predict fabric behaviour in garments.

So what’s the problem?

The problem is that fabric manufacturers would like to be able to predict all aspects of fabric performance that impact upon the ultimate quality of the garment. While they can successfully predict functional performance, they need to be able to measure and predict aesthetic characteristics as well.

The problem is best illustrated by a simple example: If a manufacturer makes a high-quality fabric costing $50 per metre and during manufacture a problem is discovered, normally that problem can be fixed for an additional cost of less than five dollars per metre. If the fabric is cut and sewn into a garment of poor appearance resulting from some hidden fault within the fabric, the garment maker must bear, fully or in part, the cost of the garment. An order of high-quality fabric may be as much as 500 metres valued at $25,000. It would cost less than $2,500 to re-finish. The value of the 150 (unsaleable) suits made from this fabric could be as high as $65,000.

Once the fabric has been cut it is almost impossible to retrieve the value of the goods.

The challenge

The challenges are:

- to agree on the relevant descriptors for fabric aesthetics and their subjective evaluation
- to ascertain the appropriate mechanical properties
- to agree on the conditions under which they should be measured to establish the necessary correlations and/or descriptive algorithms between aesthetics characteristics and fabric properties.

It has taken over 80 years to reach a partial consensus

The opportunity

Notwithstanding the prior comments, objective measurement of a fabric’s aesthetic properties can result in great savings for garment makers.

It is much more likely to do so than guessing.

Historical context (pre-reading)

History of Fabric Objective Measurement (FOM)

As preparation for this section please read the attached paper by Postle et al., which describes the more detailed history of fabric objective measurement.

1930s Pierce analysed the relationship between the mechanical and physical properties of fabrics and their handle/feel – identified fabric bending, compressional and surface frictional properties. Later, drape was added.

1960s Swedish workers explored the relationship between the mechanical and physical properties of fabrics and the appearance of structured and

	unstructured garments from which they are made and introduced the concept of formability, which is related to seam pucker.
1960s	The Hand Evaluation and Standardisation Committee (HESC) in Japan started its work to agree on concepts to be used in description of handle.
1970s	The Kawabata Evaluation System for Fabrics (KES-F) was released.
1980s	Application of KES-F and development of SiroFAST (Fabric Assurance by Simple Testing)
1990s	Release of SiroFAST and augmentation of SiroFAST with PressTest.
1960s–2000	Development of a range of new and alternative instruments.

Where is the innovation?

Four forms of innovation are identified:

- deciding how best to measure aesthetic properties such as handle
- deciding on the key characteristics or properties of fabrics that must be measured and relating them to the required fabric characteristics
- developing instruments designed to measure those properties
- improving instrument design to minimise testing time and increase accuracy.

HESC and KES-F instrumentation, Japan 1960–70s

Two types of innovation can be identified in the work of the HESC on the development of the KES-F instrumentation. This initiative was part of a larger program in Japan to develop an objective measurement technique for handle/quality for commercial use in fabric trading. The approach adopted was deceptively simple and consistent with early attempts to describe handle in terms of its component parts. By observing a number of experts in their subjective assessment of handle, the committee was able to develop concepts called *primary handle values,* which measured a specific component of the handle and which could be used to determine an overall handle.

The second form of innovation was developing instruments to measure the appropriate mechanical and physical properties of the fabric under the correct conditions. The instrumentation measured the bending, tensile, shear, compression and frictional properties of the fabric. These properties were correlated with subjective evaluations to determine equations to predict the primary handle values. These primary handle values were in turn used to measure the *total handle value*.

The system was adopted fully or in part in Japan by number of fabric and garment makers. The ability of the system to predict the performance of fabric in garment manufacture was the key to its success and, in spite of their relatively high cost, well over 100 instruments were sold world wide. Although the system consisted of four instruments, the shear tensile tester and bending meter were the most widely sold, being the most relevant to the garment making process.

Innovations in KESF-2B bending meter

Two forms of innovation are demonstrated in the KES-F2 bending tester (shown on the slide above) and the KES-F4 friction tester (next slide).

In KES-F2 bending meter, an innovative solution was found to the problem of moving a clamp holding one end of the sample of fabric in a way that the fabric was bent without imposing tensile or other strains. This ensured that the fabric remained in pure bending so that the relevant bending parameters (bending rigidity, coercive couple) could be derived.

The solution was found without excessive mechanical complexity in the instrument.

Innovations in KESF-4B friction meter

A major issue for all measurements of fabric friction is the nature of the substance against which the friction is measured. To predict handle one would ideally like to measure friction against the human finger.

In the case of the KES-F4 friction meter, a metal fingerprint designed from piano wire was used. The force required to drag this finger over the fabric is measured and analysed to determine the frictional characteristics of the fabric. The gauge on the wire was chosen so that it simulated the spacing of the grooves of the fingerprint. The metal fingerprint is shown in the attached slide.

An alternative 'finger' developed by Ramkumar (Texas Tech) is another solution to the problem of measuring frictional effects in fabric. Previous researchers have also use plastic sleds dragged over the surface of the fabric using a special attachment on an Instron tensile test machine to simulate the frictional action. These plastic sleds were also covered with fabric to simulate fabric-to-fabric friction, which can be an issue when fabrics are stacked for cutting.

Evolution of the KES-F system

The KES-F system was not static and was modified as the manufacturers responded to perceived problems and suggestions of sources of improvement.

Initial system (1970s)

Four instruments, manual loading and all with different-sized samples made sample preparation slow. Analogue output of data required manual calculation of properties.

System –B (1980s)

Four instruments, manual loading, all using a 200 x 200 mm samples, made sample preparation much quicker, augmented by computer analysis of instrument outputs and calculation of the fabric properties.

System –AUTO (1990s)

Automated loading, testing of the samples and computer analysis of outputs.

Australia 1980s: AWTOMEC

In the 1980s, the Australian Wool Textile Objective Measurement Evaluation Committee (AWTOMEC) was set up to evaluate the use of KES-F and other fabric objective measurement technologies and analyse the potential for their use by the Australian fabric and garment manufacturing industries. It identified many of the complexities and difficulties of the KES-F system and its industrial use. These complexities were associated with the use of the instruments and the interpretation of some of the results rather than a major issue with the properties measured or the conditions of measurement. This committee introduced new measurements – derived from the same instruments (*residual curvature and residual shear*) and, importantly, agreed that information on fabric aesthetics would be determined using the individual fabric properties rather than calculated by regression analysis.

Other solutions

KES-F (and the SiroFAST system described next) were and are not the only solution to the measurement of the properties of fabric. Other simpler and less expensive instruments can be used to measure the same fabric physical and mechanical properties. While this has always been an option for users of fabric objective measurement, the key to successful use of this technology lies not in the measurement but in the interpretation of the measurement made. The value of the existing multi-instrument systems lies in the appropriate application of the extensive published background information as well as that contained within the manuals of the systems. Access to information on the interpretation of data in the use of that information for improving quality will remain the main driver for the uptake of the KES-F and SiroFAST systems.

In addition to systems that measure specific fabric mechanical and physical properties, there are also systems that measure handle in a more direct way. These techniques include the instruments described on this slide. This instrumentation takes a more holistic view of handle, and derives a single number that gives a quantitative assessment of overall handle.

The development of SiroFAST

At the same time as the AWTOMEC committee were simplifying the use of KES-F, the SiroFAST system for fabric objective measurement was developed in the 1980s in Australia by CSIRO to overcome the identified problems that arose during the industrial exploitation of the KES-F system. In practice, certainly outside Japan, the KES-F system was found to be too complex and expensive for use in a mill environment – at least in all but the bigger and more sophisticated mills. The SiroFAST system was designed to be affordable for mills and simple to use and to provide robust measurements of fabric properties.

An important feature of the SiroFAST system is that it was developed to measure those properties of fabric important in the manufacture of garments rather than to measure the handle of fabrics is in a manner analogous to the approach developed in Japan. Nevertheless, by the measurement of the same properties under similar conditions, SiroFAST gave similar information on the aesthetic characteristics of fabric which impinged on the overall quality.

SiroFAST was designed to meet similar goals to KES-F at a more affordable price.

Innovations in SiroFAST-1 thickness meter

SiroFAST-1 introduced two innovations.

Most thickness meters prior to the development of SiroFAST-1 were based on the movement of a plate which was brought into contact with the surface of the fabric. The movement of the rod to which this plate was attached was measured using an electrical device called an LVDT, through which the rod passed. By using a proximity meter to detect the position of a metal cup before and after the fabric was interposed between the cup and detector, a simpler measurement could be made without moving parts in the detector.

A second innovation introduced with this measurement was the concept of ‘surface thickness’. This new term is a measure of the compressibility of the fabric, which is an important measure of one aspect of fabric handle. The surface thickness is defined as the change in thickness in the fabric between the two applied loads, 0.195 kPa and 9.807 kPa.

Later measurements using this instrument were also introduced to assess the pressing of the fabric during finishing and the stability of the flat press imparted.

Innovations in SiroFAST-2 bending meter

SiroFAST-2 used an old concept of cantilever bending (which dates back to Pierce in 1930) to measure the bending rigidity of the fabric. The instrument measures bending length and from this calculates bending rigidity.

Bending rigidity – weight per unit area * (bending length)^3 * Constant.

Although the concepts were old, the mechanisms used in the instrument were innovative.

- The movement of the fabric as it was pushed over the 'edge' to form a cantilever was measured mechanically, rather than using a ruler on the side of the earlier instrument (shown).
- The point at which the fabric crossed the plane of bending was measured using a photocell rather than by eye using mirrors. The measurement by eye was difficult and tiring for the operator.

Innovations in SiroFAST-3 extensibility meter

The innovation in SiroFAST-3 lies in the simplicity of the use of a balanced beam to load the fabric and the use of a proximity meter to measure deformation

Innovations in SiroFAST-4 dimensional stability test

There were two innovative aspects to FAST-4.

The first innovation in SiroFAST-4 lay in the use of only measurements of the dimensions of the bone-dry and wet fabric to determine dimensional stability rather than the traditional use of the conditioned dimensions. As it requires hours for a fabric to condition in a standard atmosphere, the use of only the dimensions of the wet or dry fabric results in a considerable time saving in conduct of the test.

$$\text{Relaxation shrinkage} = \frac{\text{Initial(dry)} - \text{Final(dry)}}{\text{Initial(dry)}} \times 100\%$$

The second innovation was the use of a digitising tablet to mark the measurement points and calculate the changes in dimensions and ultimately the dimensional stability of the fabric.

Italy 1990s, the augmentation of SiroFAST

During the 1990s, it was recognised that although SiroFAST predicted many problems that occurred during the manufacture of garments, it did not predict the blowing of seams in garments that had been improperly steam pressed, nor did it predict the blowing of seams in fabrics that were difficult to steam press.

Steam pressing is used at many stages in the construction of garments such as suits, jackets and trousers. It is used to mould fabric into three-dimensional shapes, flatten seams, introduce crisp sharp edges on lapels, remove wrinkles formed in sewing and to form sharp creases and legs. None of these required features of high-quality garments will be optimised if fabric is difficult to press.

Although it is possible to refinish a fabric to improve dimensional stability, it is impossible to correct a fabric with poor pressing performance once it has been cut ready for garment sewing.

Obviously, a test that will ensure the fabric has good pressing performance is a great value to the garment maker and their supplier.

This innovation is an interesting example of the power of feedback from users (in this case the Italian garment making industry) for modifications and improvement. In this instance, the user:

- identified the problem
- suggested the direction of the solution.

CSIRO developed the appropriate technology to standardise the conditions for pressing the fabric and measuring the effect and provided the background information to support the innovation.

Innovations in SiroFAST PressTest

PressTest determines the ease with which fabric can be pressed to form a good crease, flat seam or sharp pleat. It does this by measuring the angle adopted by a 180-degree fold that is pressed under standardised conditions and allowed to relax.

The innovative process behind PressTest lay in:

- recognition of the problem
- development of the standardised method for pressing fabric
- development of an instrument for measuring the effect achieved
- development of the background information required to correct the problem in fabrics before they were cut and sewn.

The adoption of PressTest improved the predictive power of the SiroFAST system and is now an integral part of the system.

Fifteen-minute challenge

All instruments need calibration. The standards for length (metre), weight (kilogram) and time (second) are all held by national agencies.

To ensure confidence in an instrument, a manufacturer should provide some form of calibration procedure so that the instrument can be checked at reasonable intervals.

Calibration of FAST-1 and FAST-3 is part of the regular maintenance procedures.

- FAST-1 is calibrated using a glass slide of known thickness and adjustments are made using adjustment points for zero and the slide thickness.
- FAST-3 is calibrated using a metal bar with calibration holes at precise intervals. Again, there are adjustment points for zero and the interval.

You have seen how SiroFAST-2 works, but how do you calibrate it to ensure the measurements are correct:

- that the angle of the light beam has been correctly set in manufacturing?

- that the measurement wheel is giving the correct measurement of the movement of the platen?

Students will be asked to develop, in teams, a solution. You might give it some pre-thought.

Adoption of fabric objective measurement (FOM)

Some of the observations from this lecture:

- The uptake of objective measurement systems (for example, KES-F and SiroFAST) for prediction of fabric properties and performance have had classic periods of rapid uptake followed by saturation.
- The use of simple instruments to improve prediction was relatively small.
  Why? Fabrics were relatively heavy and easy to make up, and production methods were slower, allowing more time to identify and correct mistakes.
- The introduction of the KES-F system resulted in strong uptake, especially in Japan. Why? Japan had the greatest need for prediction in a technically strong, high value industry.
- The introduction of SiroFAST considerably broadened the use of the technology. Why? Simpler, more affordable.
- The drive by China to develop high quality products for Western markets may result in a further surge in adoption. Why? Export industry for sophisticated markets (Europe, US).

Summary

The current status of fabric objective measurement for the prediction of evaluation of the aesthetic properties of fabrics is the result of nearly 80 years of innovation, development and re-development. Only in the last 15 years have these innovations been used widely in commercial enterprises. The development has shown many forms of innovation, from a solution of complex issues to the simple improvements in machine design, and everything in between.

Innovation can be a slow process:

- it is a result of iteration between problem recognition and solution development
- it is modified and slowed by movement in the ultimate goals
- it is modified and slowed by the need for simplicity
- it is speeded and facilitated by the recognition of financial gain.