6
Dimensional stability

6.1 Introduction

The dimensional stability of a fabric is a measure of the extent to which it keeps its original dimensions subsequent to its manufacture. It is possible for the dimensions of a fabric to increase but any change is more likely to be a decrease or shrinkage. Shrinkage is a problem that gives rise to a large number of customer complaints. Some fabric faults such as colour loss or pilling can degrade the appearance of a garment but still leave it usable. Other faults such as poor abrasion resistance may appear late in the life of a garment and to some extent their appearance may be anticipated by judging the quality of the fabric. However, dimensional change can appear early on in the life of a garment so making a complaint more likely. A recent survey of manufacturers [1] rated shrinkage as one of the ten leading quality problems regardless of the size of the company.

Fabric shrinkage can cause problems in two main areas, either during garment manufacture or during subsequent laundering by the ultimate customer. At various stages during garment manufacture the fabric is pressed in a steam press such as a Hoffman press where it is subjected to steam for a short period while being held between the upper and lower platens of the press.

Laundering is a more vigorous process than pressing and it usually involves mechanical agitation, hot water and detergent. Tumble drying can also affect the shrinkage as the material is wet at the beginning of the drying process, the material being agitated while heated until it is dry. Dry cleaning involves appropriate solvents and agitation; the solvents are not absorbed by the fibres so they do not swell or affect the properties of the fibres. This reduces some of the problems that occur during wet cleaning processes.

There are a number of different causes of dimensional change, some of which are connected to one another. Most mechanisms only operate with fibre types that absorb moisture, but relaxation shrinkage can affect any fibre type. The following types of dimensional change are generally recognised:

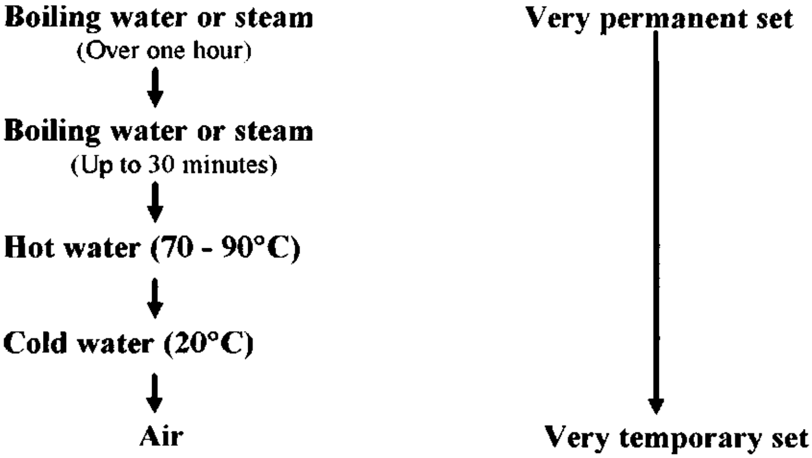
1 **Hygral expansion** is a property of fabrics made from fibres that absorb moisture, in particular fabrics made from wool. It is a reversible change in dimensions which takes place when the moisture regain of a fabric is altered.
2 **Relaxation shrinkage** is the irreversible dimensional change accompanying the release of fibre strains imparted during manufacture which have been set by the combined effects of time, finishing treatments, and physical restraints within the structure.
3 **Swelling shrinkage** results from the swelling and de-swelling of the constituent fibres of a fabric due to the absorption and desorption of water.
4 **Felting shrinkage** results primarily from the frictional properties of the component fibres which cause them to migrate within the structure. This behaviour is normally considered to be significant only for fibres having scales on their surface such as wool.

The dimensions of fabrics can become **set** while they are deformed if they are subjected to a suitable process. Fibres that absorb water can be set if they are deformed while in the wet state and then dried at those dimensions. Thermoplastic fibres can be set if they are deformed at a comparatively high temperature and then allowed to cool in the deformed state. The set may be temporary or permanent depending on the severity of the setting conditions. During relaxation shrinkage it is temporary set that is released. It is generally the case that deformation that has been set can be released by a more severe treatment than the setting treatment. Conversely if it is wished to make the dimensions of the fabric permanent it is necessary to carry out the setting at conditions that the fabric will not meet in use.

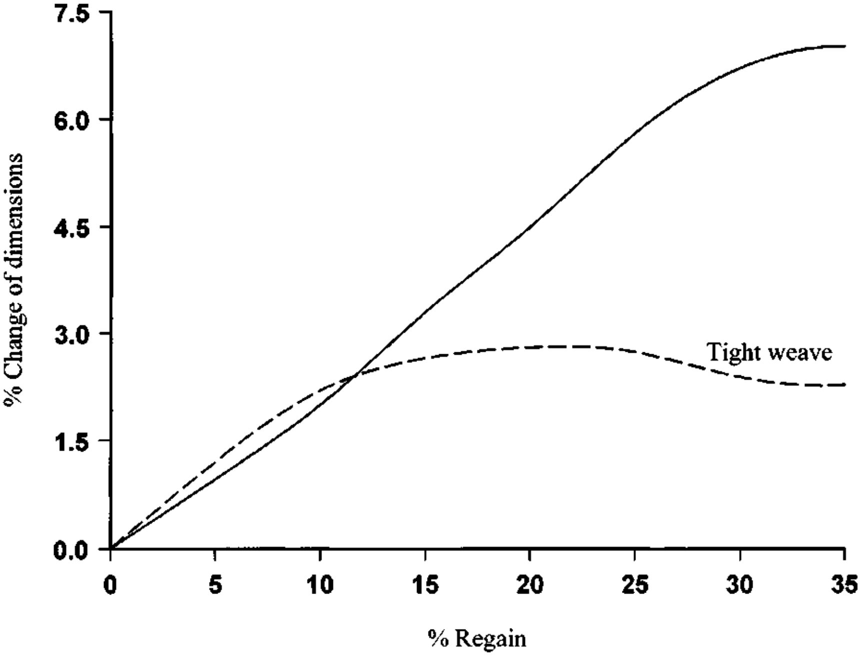
Figure 6.1 shows the relative scale of severity for treating wool. Any setting that has taken place under one of the conditions listed can be relaxed by subjecting the material to any of the conditions above it on the list.

6.1.1 Hygral expansion

Hygral expansion refers to the property of certain fabrics that absorb moisture, where the fabric expands as the moisture content increases, owing to the swelling of the constituent fibres. This is particularly a property of wool fabrics. All of the expansion is subsequently reversed when the fabric is dried to its original moisture content. The increase in dimensions takes place in both warp and weft directions and its magnitude is related to the amount of moisture in the material. Figure 6.2 shows the increase in



6.1 The setting of wool.



6.2 The hygral expansion of wool.

dimensions of two wool fabrics with increasing atmospheric moisture content; in one case the expansion increases with regain almost up to the maximum value for wool, whereas in the other fabric the expansion reaches a maximum at around 20% regain. This is considered [2, 3] to be due to the tighter weave of the second fabric which causes the widthways expansion of the warp yarn to interfere with the lengthways expansion of the weft yarn. Hygral expansion is believed to be caused [2] by the straightening of crimped yarn as it absorbs moisture. This is due to the fact that wool fibres swell to 16% in diameter and 1% in length when wet. The swelling causes fibres which have been permanently set into a curve to try to straighten out due to the imbalance of forces. When the fibres dry out they revert to their former diameter and so take up their original curvature.

The increase in dimensions due to hygral expansion can take place in the fabric at the same time as any shrinkage because of relaxation of set in stresses such as occurs when the fabric is soaked in water. The magnitude of the expansion can in fact be greater than that of the shrinkage. The dimensions of a fabric when it is first wetted out and then dried depend on its moisture content and are a combination of the increase due to hygral expansion and any decrease due to shrinkage. It is for this reason that in making shrinkage measurements, a fabric should always have the same moisture content during the final measurement as it had when the initial measurement was made.

Hygral expansion of a fabric in a finished garment can cause problems when the garment is exposed to an atmosphere of higher relative humidity than that in which it was made. The expansion can cause pucker at seams and wrinkling where it is constrained by other panels or fixed interlinings.

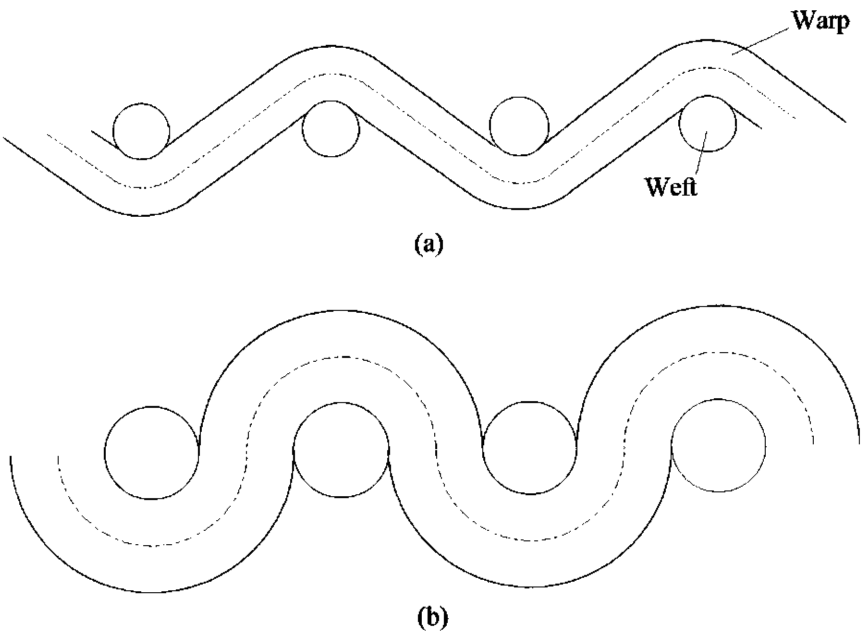
6.1.2 Relaxation shrinkage

When yarns are woven into fabrics they are subjected to considerable tensions, particularly in the warp direction. In subsequent finishing processes such as tentering or calendering this stretch may be increased and temporarily set in the fabric. The fabric is then in a state of dimensional instability. Subsequently when the fabric is thoroughly wetted it tends to revert to its more stable dimensions which results in the contraction of the yarns. This effect is usually greater in the warp direction than in the weft direction.

Relaxation shrinkage in wool fabrics is caused by stretching the wet fabric beyond its relaxed dimensions during drying. A proportion of the excess dimensions is retained when the dry fabric is freed of constraint. The fabric will, however, revert to its original dimensions when soaked in water. This effect is related to the hygral expansion value of a fabric [3] in that a fabric with a high value of hygral expansion will increase its dimensions more when it is wetted out so that it subsequently needs to contract to a greater extent when it is dried. Merely holding such a fabric at its wet dimensions will thus give rise to a fabric that is liable to relaxation shrinkage.

6.1.3 Swelling shrinkage

This type of shrinkage results from the widthways swelling and contraction of the individual fibres which accompanies their uptake and loss of water. For instance viscose fibres increase in length by about 5% and in diameter by 30–40% when wet [4]. Because of the fibre swelling, the yarns made from them increase in diameter which means that, for instance, a warp thread has to take a longer path around the swollen weft threads. This is shown diagrammatically in Fig. 6.3 where the swelling of the yarns from the dry state (a) to the wet state (b) causes an increase in the length of the path the yarn must take if the fibre centres remain the same. In a fabric the warp yarn must either increase in length or the weft threads must move closer together. In order for the warp yarn to increase in length, tension needs to be applied to the fabric to stretch it. In the absence of any tension, which is usually the case during washing, the weft threads will therefore move closer together. Although the fibre dimensions will revert to their original values on drying, the forces available for returning the fabric to its original dimensions are not as powerful as the swelling forces so that the process tends to be one way. The overall effect of the swelling mechanism on a fabric's dimensions is dependent on the tightness of the weave [4]. This mechanism is the one that is active when viscose and cotton fabrics shrink.



6.3 The effect of swelling of yarns.

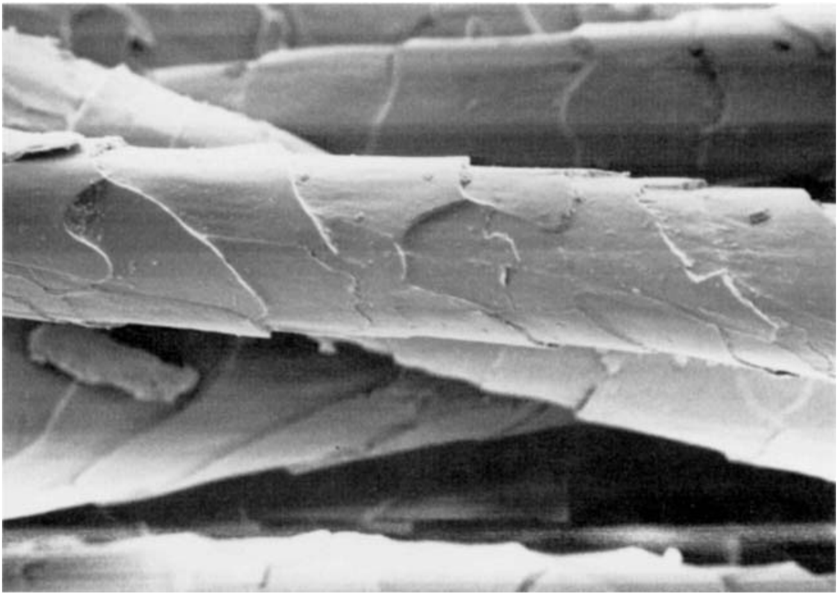
Processes have been developed to pre-shrink cotton material in finishing to reduce the amount of shrinkage in consumer goods.

6.1.4 Felting shrinkage

Felting shrinkage is a mechanism of shrinkage that is confined to wool fabrics and it is a direct consequence of the presence of scales on the wool surface as shown in Fig. 6.4. Deliberate use of this effect is made in milling to increase the density of structures. Felting is related to the directional frictional effect (DFE) which is found in wool fibres. The coefficient of friction of wool fibres is greater when the movement of the fibre in relation to another surface is in the direction of the tip than when it is in the direction of the root. This effect can be measured directly. Shrinkage is caused by the combined effects of DFE and fibre movement promoted by the elasticity of wool. The behaviour is promoted if the fibres are in warm alkaline or acid liquor.

When alternating compression and relaxation are applied to the wet material, the compression force packs the fibres more tightly together but on relaxation of the force the DFE prevents many of the fibres from reverting to their original positions.

Wool can be made shrink resistant by treatment to reduce the effect of the scales on friction. Chlorine treatments tend to remove the scales;



6.4 The scales on a wool fibre ×1300.

however, too drastic a treatment can reduce the strength of the fibres. Resin treatments are used to mask the scales. The most successful treatments use a combination of the two approaches.

6.1.5 Weft knitted wool fabrics

Knitted fabrics are similar to woven fabrics in that they are subject to relaxation shrinkage and also to felting shrinkage if they are made of wool. However, it has been found difficult experimentally to determine when a fabric has reached a totally relaxed state in which it is in a stable state with the minimum energy. This is because the stable state of a knitted fabric is controlled by the interplay of forces required to shape the interlocking loops of yarn, whereas the stable state of a woven fabric is controlled by the balance of forces required to crimp the yarns. The resistance provided by inter-yarn friction prevents the yarn taking up its lowest energy state and the magnitude of the restoring forces in a knitted fabric is not great enough to overcome this.

Because of this difficulty a number of relaxed states have been suggested [5]:

1 **Dry relaxed state**. This is the condition the fabric reaches after a sufficient period of time subsequent to being removed from the knitting machine.
2 **Wet relaxed state**. This is achieved by a static soak in water and flat drying.
3 **Finished relaxed state**, also known as the consolidated state. This is achieved by soaking in water with agitation, agitation in steam or a static soak at higher temperatures (>90 °C) and drying flat.
4 **Fully relaxed state**. This is achieved by a water soak at 40 °C for 24 h followed by hydro-extraction and tumble drying for 1 h at 70 °C.

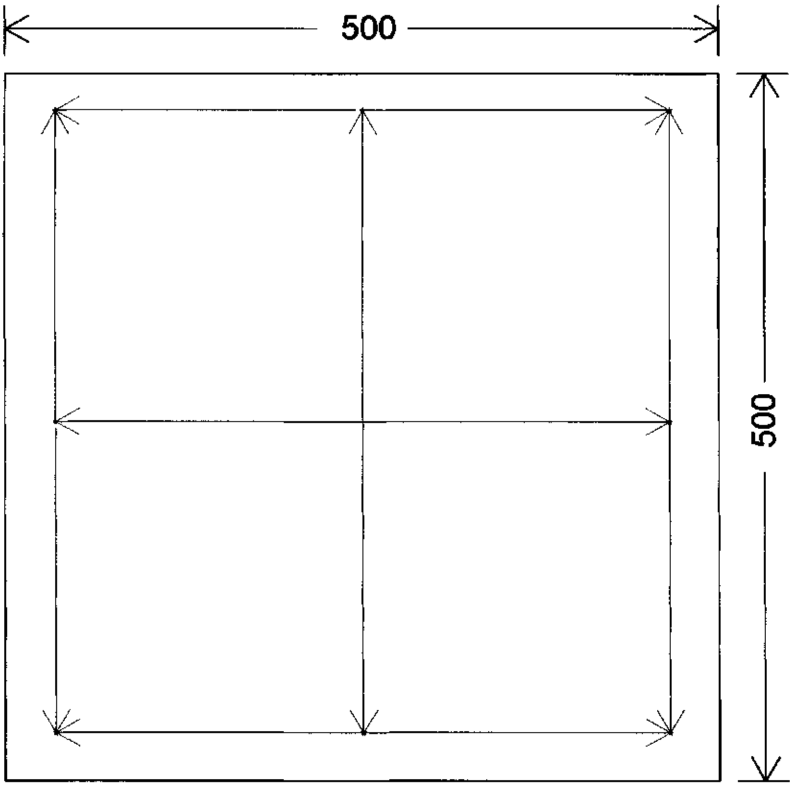
The most appropriate treatment will depend on the conditions that the material encounters during finishing.

6.2 Methods of measuring dimensional stability

6.2.1 Marking out samples

The general procedures for preparing and marking out of samples is laid down in the British Standard [6]. Many dimensional stability tests follow very similar lines differentiated only by the treatment given to the fabric, so that these procedures may be followed if no specific test method exists.

For critical work the recommended sample size is 500 mm × 500 mm and for routine work a minimum sample size of 300 mm × 300 mm is consid-

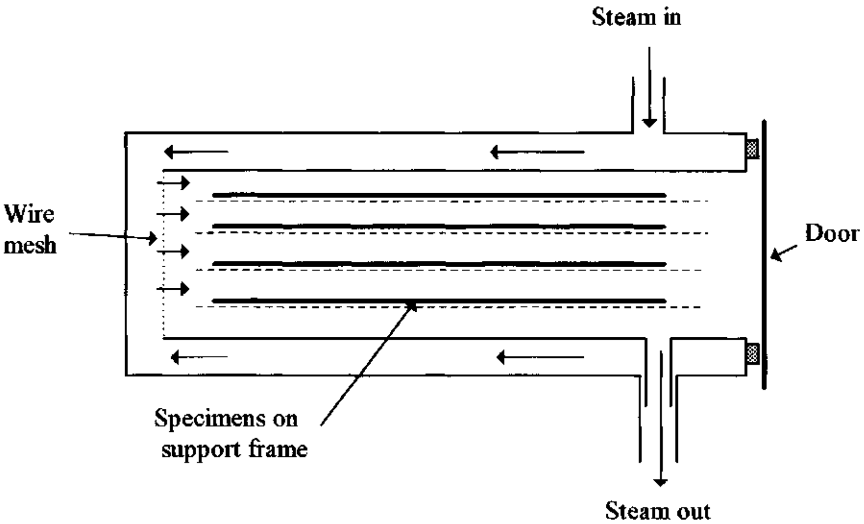


6.5 Marking out of a sample for measuring dimensional stability.

ered sufficient. The samples are marked with three sets of marks in each direction, a minimum of 350 mm apart and at least 50 mm from all edges as shown in Fig. 6.5. In the case of the smaller sample the marks are made 250 mm apart and at a distance of 25 mm from the edge. For critical work it is recommended that the samples are preconditioned at a temperature not greater than 50 °C with a relative humidity of between 10% and 25%. All samples are then conditioned in the standard atmosphere. After measurement the samples are subjected to the required treatment and the procedure for conditioning and measuring repeated to obtain the final dimensions.

6.2.2 WIRA steaming cylinder

The WIRA steaming cylinder [7] is designed to assess the shrinkage that takes place in a commercial garment press as steam pressing is part of the normal garment making up process. The shrinkage that takes place when a



6.6 The WIRA steaming cylinder.

fabric is exposed to steam is classified as relaxation shrinkage not felting or consolidation shrinkage.

In the test the fabric is kept in an unconstrained state and subjected to dry saturated steam at atmospheric pressure. These conditions are slightly different from those that occur in a steam press where the fabric is trapped between the upper and lower platens while it is subjected to steam.

Four warp and four weft samples are tested, each measuring 300 mm × 50 mm. They are first preconditioned and then conditioned for 24 h in the standard testing atmosphere in order that the samples always approach condition from the dry side. Markers (threads, staples, ink dots) are then put on the fabric so as to give two marks 250 mm apart on each sample.

The four specimens are then placed on the wire support frame of the apparatus shown in Fig. 6.6 and steam is allowed to flow through the cylinder for at least one minute to warm it thoroughly. The frame is then inserted into the cylinder keeping the steam valve open and the following cycle carried out:

- Steam for 30 s
- Remove for 30 s

This cycle is performed three times in total with no additional intervals.

The specimens are then allowed to cool, preconditioned and then conditioned for another 24 h to bring them into the same state they were in when they were marked. They are then remeasured on a flat smooth surface and the percentage dimensional change calculated. The mean dimensional change and direction is reported:

$$\text{Shrinkage} = \frac{(\text{original measurement} - \text{final measurement})}{\text{original measurement}} \times 100\%$$

6.2.3 Relaxation shrinkage

The international standard for measuring relaxation shrinkage is the determination of dimensional changes of fabric induced by cold water immersion [8]. In the test the strains in the fabric are released by soaking the fabric without agitation in water that contains a wetting out agent. The specimen is conditioned, measured, soaked in water, dried, reconditioned and measured again.

One specimen of dimensions 500 mm × 500 mm is tested. Three pairs of reference points are made in each direction on the fabric a distance of 350 mm apart and placed not nearer than 35 mm to the edge as shown in Fig. 6.5. When knitted fabrics are to be tested they are folded to give a double thickness with the free edges sewn together.

Before the test the sample is conditioned in the standard atmosphere for 24 h and then laid on a smooth glass surface and covered with another piece of glass to hold it flat while it is measured. It is then soaked flat in a shallow dish for 2 h in water at 15–20 °C containing 0.5 g/l of an efficient wetting agent. It is removed and blotted dry with paper towels without unnecessary handling and allowed to dry flat at 20 °C on a smooth flat surface. It is then conditioned until equilibrium is reached and remeasured as described above.

The mean percentage change in each direction is calculated:

$$\text{Relaxation shrinkage} = \frac{\begin{pmatrix}\text{original measurement} - \\ \text{final measurement}\end{pmatrix}}{\text{original measurement}} \times 100\%$$

6.2.4 Washable wool

When testing washable wool products for shrinkage it is usual to carry out tests that separate any felting shrinkage from relaxation shrinkage. It is important that the contribution of each type of shrinkage to the overall shrinkage is determined because both the cause and remedy for each type are quite different.

Relaxation and consolidation shrinkage

The US Standard [9] is for knitted fabrics containing at least 50% wool and which are designed to be shrink resistant. Three sets of marks are made in each direction each pair 10 in (254 mm) apart and each mark is situated at least 1 in (25 mm) from all edges.

The relaxation shrinkage is first determined by soaking the sample for 4 h at 38 °C, hydroextracting it, drying it flat at 60 °C, conditioning it and then measuring it.

The consolidation shrinkage is determined after relaxation shrinkage by agitating the sample in the Cubex apparatus for 5 min. The sample is placed in the cubex apparatus with 25 l of buffer solution at pH 7 containing 0.5% non-ionic detergent. The total load in the machine is 1 kg which is made up of the specimens plus makeweights, and the temperature of the solution is set to 40 °C. The sample is mechanically agitated for 5 min. It is then removed, rinsed three times and hydro-extracted followed by drying flat at 60 °C. Finally it is conditioned and remeasured.

The consolidation shrinkage value is calculated from the difference between the total shrinkage and the relaxation shrinkage.

IWS method

In this test method the relaxation shrinkage is determined from a wet treatment with mild agitation (standard 7A programme [10]). The felting shrinkage is determined subsequently on the same sample using a more severe agitation (standard 5A programme [10]) possibly using a number of repeat cycles.

Yarn and combed sliver can be tested by making them into a single jersey fabric.

Marking out

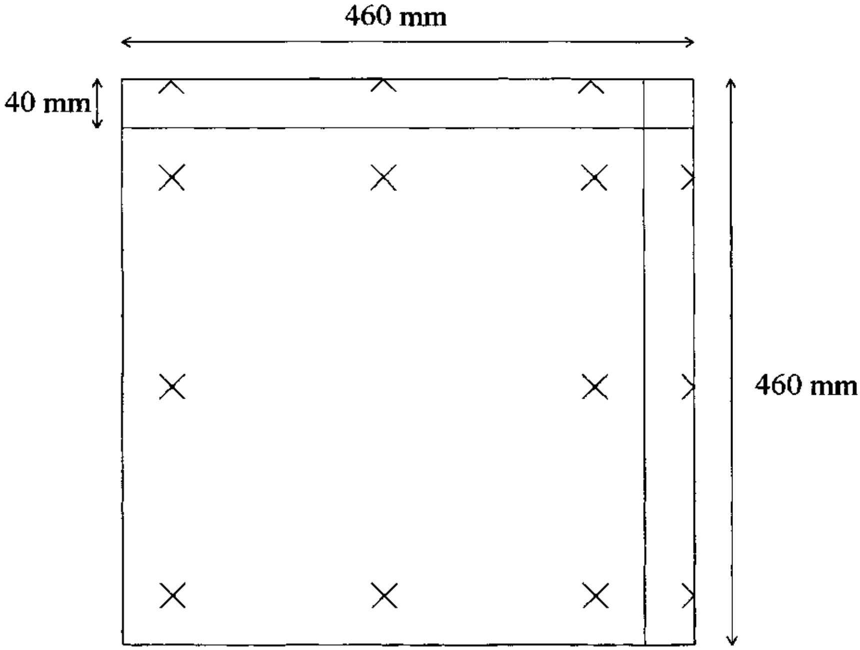
Knitted samples of size 300 mm × 400 mm are tested double with the free edges sewn together. The marks are placed not less than 25 mm from the edge.

Woven samples of size 500 mm × 500 mm have two of their edges sewn over after ironing as shown in Fig. 6.7 in order to test edge felting. Marks are made on the folded edge as well as in flat area of the sample. Shrinkproof treated fabrics are particularly vulnerable at folded over edges because of the more severe mechanical action in this region.

When testing socks three separate measurements should be made.

Measurement

Before measurement the samples are dried at a temperature not greater than 60 °C and then conditioned in the standard atmosphere for not less than 4 h.



6.7 Marking out a woven sample for washable wool shrinkage test.

The measurements made are:

Original measurement	OM
After relaxation	RM
After felting	FM

Relaxation of the sample is accomplished by subjecting it to one cycle of the 7A programme in the Wascator washing machine (see below). The load is made up to a total of 1 kg with makeweights. The detergent concentration used is 0.3 g/l of the standard detergent SM49 and the washing is carried out at a temperature of 40 °C.

Felting of the sample is accomplished by washing it a number of times using the 5A programme in the Wascator, the actual number of washes depending on the product involved. The load, detergent and temperature used are the same as above.

Calculations

$$\text{Relaxation shrinkage} = \frac{(\text{OM} - \text{RM})}{\text{OM}} \times 100\%$$

$$\text{Felting shrinkage} = \frac{(\text{RM} - \text{FM})}{\text{RM}} \times 100\%$$

Cuff edge felting is unacceptable when the difference between the shrinkage of the fold and the flat area exceeds 1%.

Cubex

This test [11] is designed to measure the dimensional changes of wool-containing knitted fabrics during washing. It measures both relaxation and felting shrinkage as in the above test. Instead of a washing machine the test uses a cube-shaped drum of capacity 50l which is suspended by opposite corners. The drum revolves at 60 revolutions per minute and the action is reversed every 5 min. The cube is filled through a small door in one face and there is no built-in heating mechanism. The knitted specimens are folded to give a double thickness 300 mm × 400 mm and the free edges are sewn together.

The test is carried out in two steps: first the relaxation shrinkage is measured and secondly any felting shrinkage is measured. The sample is first conditioned and measured flat. It is then placed in the cubex apparatus with 25l of buffer solution at pH 7 containing 0.05% wetting agent. The load is 1 kg made up of specimens plus makeweights and the temperature of the solution is 40 °C. The sample is first given a static soak of 15 min which is followed by mechanical agitation for 5 min. It is then removed, rinsed three times and hydro-extracted followed by being dried flat at a temperature not above 55 °C. Finally it is conditioned and then remeasured.

In order to determine the felting shrinkage the same conditions are used but the agitation is continued for either 30 or 60 min depending on the severity of treatment required. The sample is dried, conditioned and remeasured as before.

The relaxation shrinkage, felting shrinkage and total shrinkage are calculated as in the previous test.

6.2.5 Washing programmes

Most tests for dimensional change due to washing use the procedures given in BS 4923 or ISO 6330 [10]. These standards give in detail the washing procedures for programmable washing machines. The reason that these details need to be specified is that a number of factors affect the intensity of the mechanical action of a rotary drum washing machine [12] such as the peripheral speed of the rotating drum, the height of the liquor in the drum, the liquor to goods ratio and the number and form of the lifters, in particular the height of them. Therefore a standard washing machine has to be used because the amount of agitation during washing has a bearing on the amount of shrinkage produced, particularly with wool. However, the programmes used in the machine are intended to be similar to the programmes found in domestic washing machines. The temperature and severity of the washing cycle used are also related to any care label that may be fixed to a garment made from the fabric being tested. In essence a fabric has to be able to undergo any laundering treatment recommended on the label without suffering from excessive dimensional change.

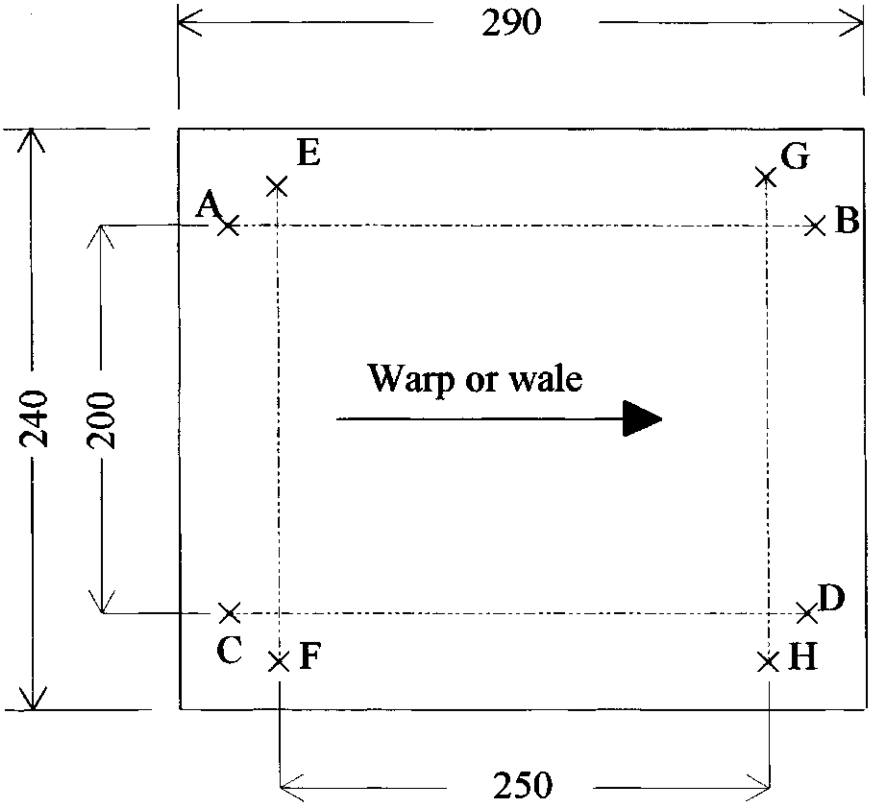
The standards specify the level of agitation during heating, washing and rinsing, the washing temperature, the liquor level during washing and rinsing, the washing time, whether there is a cool down after washing and the number of rinses and spin time. There are two sets of programmes in the standard, one for front loading machines designated type A and one for top loading agitator machines designated type B. Therefore a type 5A wash specifies a number 5 wash (40 °C, normal agitation) for a front loading machine. The use of a standard detergent without additives is also specified. The Wascator is an industrial washing machine which is commonly used for these tests and it can be programmed for all the main functions such as temperature, liquor level during washing and rinsing, washing time, time and number of rinses as required by the standard.

6.2.6 Dimensional stability to dry cleaning

The British Standard method [13] requires the use of a commercial dry cleaning machine. In the test the sample is prepared and marked out according to BS 4931 [6]. The total load used is 50 kg for each cubic metre of the machine cage made up of specimen plus makeweights. The solvent to be used is tetrachloroethylene containing 1 g/l of surfactant in a water emulsion, 6.5 litres of solvent being used for each kilogram of load. The machine is run for 15 min at 30 °C, the sample is rinsed in solvent and then dried by tumbling in warm air. The sample is then given an appropriate finishing treatment, which in most cases will be steam pressing, and it is then reconditioned and measured again.

6.2.7 Dimensional stability to dry heat

This test is intended to predict the behaviour of fabrics when heated in a hot press such as those used in various garment manufacturing processes including fusing and transfer printing. The ISO method [14] recommends that the samples are preconditioned at a low relative humidity before conditioning in the standard atmosphere. The samples are then marked out as shown in Fig. 6.8 and the dimensions AB, CD, EF and GH determined. They are then placed in a press heated to 150 °C under a pressure of 0.3 kPa for 20 s. The samples are conditioned and measured again so that the dimensional change in each direction can be calculated.



6.8 Marking out a sample for dimensional stability to dry heat.

General reading

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