11
Finishing

S A MYERS©THE WOOLMARK COMPANY

11.1 Finishing of woven fabrics

Finishing machinery and practices vary from one company to another, depending upon the type of fabrics being produced. Finishing starts once the fabrics have been inspected, after being received from the weaving department. The fabrics, described as 'grey' at this stage, are generally dirty and can contain lubricants and waxes from spinning and weaving. They may also be stiff and feel thin and flat.

On receiving the fabrics, the finisher has to design a finishing procedure, based around several individual operations, that will produce a finished fabric that:

- is clean from contaminants
- has a soft handle and desired aesthetics
- is the correct working width
- has the correct dimensional stability for successful garment manufacture
- has additional performance features if required, and
- is at the required cost

The finishing manager, therefore, must have an intimate working knowledge of all machinery-operating parameters and of which are most suited for a particular fabric quality. A finishing procedure can contain many steps to achieve the desired finish.

Many of the individual finishing processes are unique to wool, and finishing can contribute in a major way towards product variety in wool fabrics.

11.1.1 Fabric setting (crabbing)

Setting or crabbing is mainly applicable to worsted fabrics and is required to relax and set the strains introduced into the yarns and fabric during spinning and weaving. If some weave structures are not set in this way, they may be susceptible to the formation of distortions (e.g. 'crowsfooting') during subsequent wet finishing. The crabbing operation is carried out in the presence of heat and moisture, during which the intermolecular bonds in wool are broken and then reformed in a more relaxed configuration. Setting is arrested by shock cooling. The chemistry of setting when assisted by reducing agents is described in Section 5.12 of Chapter 5, and the physics of stress relaxation is discussed in Section 4.4.3 of Chapter 4.

Two basic types of set, cohesive and permanent, may be induced by finishing procedures, depending on the severity of operating conditions used. Many processes will incur some of both. Moisture (and fabric moisture content) is a pre-requisite of setting and the degree of setting is also dependent upon temperature and time. Fabric pH is also important, for example in pressure decatising, a higher level of set can be expected at pH values neutral to slightly alkaline than strongly acid. Cohesive set is believed to be due to rearrangement of hydrogen bonds within the wool structure and occurs when wool is distorted at temperatures above its glass transition temperature (T_g) and cooled whilst distorted. This set is largely temporary. For example, the dimensions of a fabric stretched during tenter drying are mainly held by cohesive set. Permanent setting occurs when conditions are sufficient to disturb and reform, primarily, both disulphide and hydrogen bonds. Permanent set occurs mainly in finishing operations such as crabbing and pressure decatising and is generally defined as the set remaining in a fabric which is stable to release by hot water (70 °C) – conditions that would release cohesive set.

11.1.1.1 Batch crabbing

In a traditional batch crabbing machine, the fabric is wound onto a cylinder (covered with a cotton wrapper) which is rotated, whilst half immersed in hot or boiling water, for a predetermined time. To ensure even treatment, the fabric is reversed and the treatment repeated. The fabric may then be steamed and finally passed through a tank of cold water to arrest the setting process. Batch machines allow for long treatment times and, at appropriate temperatures and pH, high levels of set can be achieved.

Despite reversing the fabric direction, traditional batch crabbing machines remain associated with uneven treatment which, for piece dye qualities, can result in end-to-end or piece-to-piece variation. Improvements on traditional machines include the use of large crabbing cylinders and bigger treatment lots, minimising variation. Absolute control of loading tensions, centring devices and anti-slipping compacting rollers, ensure uniform package build up.

11.1.1.2 Continuous crabbing

Continuous crabbing machines are now widely established in the industry and offer faster production and even fabric treatment. However, the treatment time is generally quite short and the levels of set can be lower than those attainable with batch systems. Two basic types of continuous crabbing machine are available.

Cylinder types. The fabric is initially wetted through a trough of hot water and then passed around a large, rotating, heated cylinder. The fabric is pressed at high pressure against the heated cylinder by a specially engineered impermeable belt. Special seals resist escape of steam and entry of air at the edges of the belt. Fabric operating temperatures as high as 135–140 °C are claimed and superheated steam is created *in situ*, setting the fabric. Setting is arrested by shock cooling. Chemical setting agents are sometimes added to the wetting tank to promote higher levels of set.

Superheated water machines. These differ in design from the cylinder types in having no pressure belt to maintain fabric/cylinder contact and use superheated water to facilitate setting. A possible advantage for fabric quality is that yarns are claimed to fully swell with minimal fabric compacting. The fabric enters and exits through barometric columns. Water temperatures are around 110 °C, although a series of steam battery heaters situated around the main cylinder are claimed to elevate the fabric temperature during its contact time with the cylinder, promoting fabric set.

Choice of machinery depends on the level of set required, which in turn depends on the fabric type and subsequent processing. For example, a colour woven plain weave fabric for rope scouring will generally require lower levels of set than a plain weave fabric for piece dyeing.

11.1.2 Scouring

Scouring to remove spinning lubricants and soil is mainly carried out in aqueous media with the addition of a suitable detergent. If fabrics are heavily stained, for example with mineral oil, solvent scouring (or padding with solvent-based detergents and storing) prior to aque-ous scouring can be used to ensure a clean fabric, particularly for piece dye qualities. Alternatively, spot solvent guns are used for localised staining.

Concurrently with cleaning the fabric, handle and cover can also be developed during the scouring process, which influences the quality and appearance of the finished fabric.

11.1.2.1 Detergents

Anionic and non-ionic detergents are used for scouring wool and wool/blend fabrics. Synthetic detergents have largely replaced traditional soaps, mainly because they have better all-round stability to variations in water supply (particularly hard water supplies), are cheaper, easier to remove from fabrics during rinsing and are usually fluids and easier to handle.

Anionic detergents work by electrostatic repulsion. Scouring pH is important and should be pH 8.5–9.0, with the addition of ammonia or sodium carbonate to the scouring bath.

With non-ionic detergents, scouring pH is not as critical. However, alkaline scour baths are recommended as alkaline conditions aid fibre swelling, allowing release of soil, and enhance the stability of the scouring emulsion. Non-ionic detergents have a strong de-greasing effect and can give firmer handling fabrics than those scoured with anionic detergents. They are also effective for scouring-off surface dye residues and are useful for colour woven fabrics which may be prone to bleeding, since scouring may be carried out at slightly acid pH values.

With both detergent types, concentrations of 1% (owf) are normally used and the cycle may be single or double bath, depending upon the degree of soiling. Scouring conditions are typically 40–45 °C for 30–60 minutes for batch operations, depending on fabric length and processing speed, followed by thorough rinsing. Slightly higher temperatures are used for continuous scouring operations to compensate for the reduced processing times.

11.1.2.2 Batch scouring machines

During batch scouring, the fabric in rope form is sewn into an endless loop. Nip rollers facilitate fabric transport. As the fabric passes through the nip rollers, scouring liquor is interchanged, promoting scouring action and developing cover and handle. Traditional rope scouring machines ran at relatively slow speeds (80–100 m/min) with a risk of fabrics running continually in the same folds, causing processing marks and creases that could be difficult to remove in subsequent processing.

Modern rope scouring machines can scour at speeds of 200 m/min or more. At increased speeds, scouring times are reduced and fabrics are more effectively opened before the nip, reducing the tendency for processing marks. Many machines include pneumatic opening jets, to further encourage fabric opening during processing. Baffle plates or similar may be located at the back of the machine to allow for rapid scouring/semi-milling procedures. Independent channel control with automatic seam monitoring and knock off for fabrics of differing lengths ensure consistency of finish. Alternatively, different fabric qualities and weights can be processed in the same lot.

Milling is described in Section 11.1.3. Combined scour/milling machinery allows for scouring and milling in the same machine, combining two traditionally separate operations. This type of machine has facility for scouring, i.e. a scouring bowl to retain liquor, a sud box to collect expressed liquor from the nip rollers, and a milling spout or trough to facilitate milling. Increasing nip pressure enables the fabric moisture content to be lowered for milling operations.

Alternative designs for transporting the fabric, particularly for lighter weight fabrics that would be susceptible to creasing with nip transport systems, include transport between lightly-pressured conveyor aprons or 'lungs', or transport around large slatted drums. Such profiled drums are designed to provide processing without slippage. Some designs include a lightly pressurised air lung or brush, to ensure drum/fabric contact. Increased processing speeds and baffle plates allow for semi-milled finishes to be achieved.

After rope processing, fabrics are opened and plaited, a process known as 'scutching'.

11.1.2.3 Open-width scouring machines

Open-width scouring machines may be batch machines (for small lots), but are more usually continuous machines. Both are used mainly for processing lightweight fabrics in open width, where rope scouring would cause unacceptable creasing or fabric damage. Continuous scouring machines scour fabric evenly and effectively, with high productivity, and produce a clean, clear finish. Open-width machinery with slight felting action is available, for example by the use of 'V' shaped baffle plates against which the fabric is processed during scouring.

Different modes of scouring action are available. The most conventional design for wool fabrics involves tangential jets of scouring and rinsing liqours, followed by squeeze rollers or suction slots. Complete immersion systems are also available, having liquor interchanged by sucking large volumes of scouring solution through the fabric. Suction drum type designs are also available, with varying flow direction. Machines are generally modular in construction, allowing lines to be assembled, depending upon the fabric qualities processed. Driven guide rollers, relaxation zones or overfeeding onto drums ensure minimum processing tensions, important for lightweight fabrics and fabrics containing elastane filaments.

Continuous open width scouring machines are often used in-line with crabbing tanks to effect cleaning and setting of fabrics.

11.1.3 Milling

The purpose of milling is to provide:

- interfibre felting and fabric consolidation, e.g. as preparation for raising
- increased fibre cover and an increase in fabric strength, particularly with woollen fabrics
- subduing or totally obscuring of the weave structure
- increase in fabric weight and density, and
- improved handle (providing milling levels are not too high)

During milling, much lower levels of liquor are used than for scouring; detergent levels are generally higher, typically 5–6% on the weight of fibre (owf); and greater mechanical action is applied. The differential friction effect derived from the surface scale structure of wool, as described in Sections 4.4.5 and 7.5.3, is the primary reason why wool fabrics consolidate and ultimately become felted by a ratchet mechanism. Traditional milling machines are equipped with nip rollers to transport the fabric into a tapering milling box (spout) having a weighted lid. In the milling box (with the milling lid lowered) the passage of the fabric is restricted, encouraging fabric shrinkage in the length direction. To aid milling, fabrics are milled at low liquor content (typically 100–120% owf) as excess liquor can reduce mechanical action and also cause slippage. Heat promotes milling (felting) and temperatures of 40–45 °C are normally used. pH is also important as wool mills (felts) least in neutral to slightly acid conditions (near its isoelecric point) so that milling is generally carried out with alkali to pH 9.5–10. Acid milling at pH 2–3 for very dense felts is also carried out. To control fabric dimensions during milling, nip roller and milling box pressures are adjusted. For example, if greater width shrinkage is required, the milling lid is lifted and the mouthpiece narrowed so that pressure is applied only by the nip rollers. Fabrics are regularly opened out or may be bagged (sewn selvedge-to-selvedge) to reduce milling lines or rigs. When milling is complete, fabrics require thorough rinsing. New developments in milling machinery include the use of pneumatic fabric transport (jet type), eliminating the need for nip rollers. The fabric is transported to a traditional style milling box with milling speeds up to 200 m/min. Elimination of nip rollers removes the problems of processing marks.

11.1.4 Carbonising

Carbonising is mainly applicable to woollen fabrics that are contaminated with vegetable matter. Its purpose is to break down (hydrolyse) cellulosic impurities to brittle residues that can be removed mechanically, while retaining the properties of the wool as far as possible. Carbonising is carried out by treating the fabric with acid (usually sulphuric acid) followed by drying, baking, beating (dry milling), and neutralising. Fabrics for carbonising are usually scoured but carbonising may be carried out on loom-state or dyed fabrics.

Typically, fabric is impregnated with sulphuric acid containing an acid-resistant wetting agent. Drying is carried out quickly, and baking follows at 130–140 °C. 'Dry milling' consists in crushing and beating the fabric to remove vegetable residues.

Solvent carbonising procedures are available, where the fabric is initially solvent scoured in open width, prior to entering the carbonising bath. Advantages claimed are prevention of contamination of the acid bath by oils etc., low absorption and reduced usage of acid, and less fibre damage due to the 'protective' action of the solvent. By increasing solvent scour temperatures and duration times, removal of polypropylene contaminants is also claimed.

11.1.5 Drying

Prior to tenter (stenter) drying, excess water is removed using hydroextractors, mangle or vacuum type systems. Tenters work by hot air convection currents blowing through and/or across the fabric, whilst it is held at the edges by pins or clips. The process is continuous, with width settings and overfeed adjustments made to control fabric dimensions. Two basic types of tenter frames are available, single-layer and multi-layer.

Single-layer tenters are common in the worsted industry whereas multi-layer tenters are more common for woollen or heavier fabrics. Multi-layer tenters allow longer drying duration and also gentler air circulation, preferred for pile and raised surfaces.

Drying temperatures depend upon processing speed but generally 120–140 °C is used for wool fabrics: 140 °C should be regarded as the uppermost limit. It is important that wool fabrics are not overdried because this affects fabric quality. Residual moisture contents of 7–8% after drying should be attainable. Wool fabrics should always be dried close to relaxed dimensions as excessive stretching can affect finish quality and cause problems of relaxation shrinkage if the stretched dimensions are not stabilised in decatise finishing.

Modern single-layer tenters are equipped with video display of operating parameters such as width settings, overfeed, temperature and speed. Further developments include optimised airflow systems to ensure energy-efficient and uniform drying, guide plates to direct heat away from fabrics if the machine is stopped, and valves to divert airflow to upper or lower fabric surfaces as required. Monitoring of residual fabric moisture content allows control of drying parameters. Other developments include automatic or minimum maintenance chains, ease of removal and cleaning (or self-cleaning) of lint screens, and pyrometers to control heat setting operations. Modern tenters are environmentally-friendly, with heat-recovery units and systems to purify exhaust air gases.

11.1.6 Raising

Raising is mainly used for woollen fabrics, the aim being to produce a 'pile' surface, enabling a wide range of fabric styles to be produced. Depending upon the raising parameters used, the pile can be upright or laid, markedly changing the surface of the fabric. The general procedure is to subject the fabric, which may be dry or wet, to the action of raising wire, although traditional teasel (or metallic teasel) raising is still used for specialised fabrics. Raising is often carried out on fabrics that have been prepared by milling.

Emphasis has been placed by manufacturers on optimising the main factors affecting raising, e.g. drum rotation speeds, speeds of pile and counterpile rollers, fabric speed and most importantly, absolute control of tension along and across the fabric at input, exit and throughout the raising operation. Synchronisation of all these parameters produces uniform and controlled raising, minimising fabric extension and strength loss. All parameters are stored on computer. Automatic systems advise lubrication and maintenance requirements. Raising machines are often double drum, with one drum situated above the other. This provides high productivity with minimum floor space usage. Shearing machines are often incorporated into raising lines for intermediate shearing to ensure an even pile, or for final shearing.

Machinery designs are available to offer increased flexibility in the raising operation. Using a three 1-star arrangement of raising rollers around the raising drum, 24 out of 36 rollers can be brought into working position. By changing roller configuration, different raising effects can be produced.

11.1.7 Shearing (and singeing)

After wet finishing and drying, surface fibre is present on wool fabrics. Whilst some surface is beneficial for the handle, excessive fibre left on the finished fabric can rub up in wear, causing the formation of pills. Excess surface fibre is normally removed by shearing (cropping).

During shearing the fabric is initially brushed (or steam brushed) to raise loose surface fibre before passing to the shearing cylinder. The shearing cylinder is wound with helical blades and rotates at high speed. Prior to reaching the shearing cylinder, the fabric passes over an angled bed, where fibres are made to stand erect. These are caught by the rapidly rotating blades and cut against a stationery (ledger) blade. The machine operates with strong suction to remove cut fibres (and cool the shearing elements), and is equipped with metal detectors and anti-stat bars.

Modern shearing machines are normally 3-head, allowing one cut on the back initially and two on the face in a single passage. Computer control and video display allows for data storage and exact repeat of operating parameters for different lots. Piano beds (for bulky selvedges) with edge detectors and guiders and automatic seam detectors are normally standard. Careful control of tension during processing is paramount for even shearing.

Parameters in shearing include cylinder speed (typically 1000 rpm), number of helical blades, fabric speed, etc. Normally around 40–45 cuts per cm is the maximum requirement, e.g. for warp-faced worsted structures.

In some areas of the industry, singeing is also used to remove surface fibre and reduce the propensity for pilling. During singeing, protruding fibres are removed by an intensive flame. Alternative designs use reflected or radiated heat. Singeing parameters require very careful control to minimise possible damage and faults, e.g. singeing bar marks. After singeing, fabrics are rapid cooled. They require post-scouring to remove singeing residues and smell.

11.1.8 Relaxation and pressing

Prior to pressing, woven fabrics are usually passed over a steam table to relax processing tensions such as length tensions from shearing. The fabric is overfed onto a vibrating belt and passed through steaming zones. Developments in this area include the use of hoods to enclose the steaming zones. Heated elements prevent condensation. The hoods provide more intensive, controlled and uniform steaming (little dilution with air), maximising steam usage and reducing energy costs.

An alternative machinery design is based on the traditional *London Shrinkage* process. The fabrics pass in a festooned manner through steaming chambers. The manufacturers of such equipment claim relaxation free from any restraint. Festoon folds increase dwell times, to achieve maximum shrinkage.

Pressing operations are carried out to modify handle and as preparation for pressure decatising. Rotary presses were widely used, but these machines can stretch lightweight fabrics by 5–6%. Other traditional systems include paper pressing (batchwise pressing against firm, lustrous papers), which is still used due to the superior handle and improved stability of effect when compared to continuous systems, but is slow.

Modern continuous pressing machines pass the fabric around a small diameter heated cylinder, applying high pressure by an impermeable belt. The belt is driven and cylinder and guide roller speeds are synchronised to permit pressing under minimum tension. Fabric may be conditioned, e.g. by spray systems, prior to pressing.

11.1.9 Decatising

Decatising is a term applied to a family of fabric setting processes that can provide a range of levels of set and modifications to handle and finish. Decatising is a key tool in the development of the final finish of worsted fabrics in particular. Machinery, process conditions and combinations of different setting, pressing and relaxation processes are selected to give the result that is appropriate to a particular fabric.

11.1.9.1 Batchwise pressure decatising

Pressure decatising is a setting process that provides conditions for achieving high levels of set. The principal objectives are:

- to stabilise lustre
- to set the finished aesthetics of the fabric
- to stabilize dimensional stability

The process involves winding the fabric with controlled tension onto a perforated beam (previously covered with a wrapper) interleaved with a decatising wrapper. When the batch is complete, it is loaded into a steaming chamber, sealed and steamed under pressure. Typical conditions for wool fabrics are 0.8–1.0 bar (120–125 °C) for 2 minutes, followed by cooling to arrest the setting process. High levels of permanent set can be imparted, producing a 'permanent' finish. This is important for stability of finish (to steaming during making up), for control of fabric dimensional properties, and for handle and lustre.

It is important that wool fabrics are at the correct pH and moisture content prior to all pressing and decatising procedures, particularly pressure decatising. Fabric pH is ideally around pH 6: more strongly acid reduces set, and more strongly alkaline may cause yellowing. Moisture content for all-wool fabrics is ideally 12–15%, since low moisture levels can result in low levels of set.

Modern pressure decatising machines offer a variety of steam cycles and choice of steam directions (in to out, out to in) to produce variations in handle, lustre and finish. Computers are used to store and retrieve data, including fault monitoring. Various wrapper types are available, e.g. satin (firm) for worsted fabrics, molleton (soft) for bulkier woollen fabrics or more matt finishes.

Large diameter decatising cylinders (with tubes to reduce air volume) reduce the problem of end marking, allow more rapid steam penetration of the package and permit more even treatment. Absolute control of fabric and processing wrapper tensions and axial movement during winding ensures even package build-up, to minimise problems of wrapper collapse, moiré and problems with bulky selvedges. Minimum tension loading and tension control at stops is particularly important for lightweight and elastane-containing fabrics. Other developments include input steam regulating valves to control small fluctuations in steam supply, and anti-condense cradle designs.

Modern machines have three stations: one batch loading, one cooling/unloading and one steaming. Production rates up to 1500–2000 m/hour are claimed.

Pressure decatising is often the final process of a finishing procedure. However, for fabrics requiring further handle or finish modification or to ensure even processing, a continuous post-decatising operation is often used. For elastane-containing fabrics it is often necessary to finally steam relax and re-dress on a continuous decatising machine, to ensure full relaxation.

11.1.9.2 Continuous decatising

Most modern decatising machines offer continuous processing. They generally provide lower levels of set than batchwise pressure decatising. Three basic types of machine are available:

Pressing/decatising machines. Fabrics are passed around a large heated cylinder and are pressed against it by an impermeable belt. Fabrics are pre-wetted, normally using spray-type systems. The larger cylinder design gives longer treatment periods than the pressing machines described in Section 11.1.8. By controlling operating parameters such as moisture content, speed, and pressures, handle and lustre variations can be achieved on finished fabrics. Alternatively, the machines are used as preparation for pressure decatising. Specially designed machines allow for additional ‘wet’ setting after pressure decatising, for improved tailorability.

Continuous steam setting. This machinery is similar in design to that previously described, but rather than pre-wetting the fabric to create steam *in situ*, the fabric is continuously steamed as it passes around the cylinder. This type of machinery is claimed to be suitable for fabric preparation for pressure decatising or afterwards, for handle variation (by varying steam pressures and wrapper tensions) and consistency of finish.

Continuous pressurised machines. Machines are available to continuously decatise fabric, using saturated steam under pressure. The decatising cylinder is covered with a permeable blanket. The fabric passes around the cylinder and is sandwiched by a continuous permeable belt. Fabric transport is at minimum tension. Steaming conditions are variable, with decatising up to 3 bar steam pressure (up to 135 °C) claimed. Effective seals at input and output prevent steam loss and entry of air. High levels of set and uniform treatment are claimed.

11.1.9.3 Batchwise decatising at atmospheric pressure

Batch machines for decatising at atmospheric pressure remain available in the industry. The fabric is rolled in a wrapper fabric onto a perforated drum and steam is passed through, in to out or out to in. Air is suctioned through the roll to cool it before doffing the fabric.

Developments in this area include the use of 'improved' chemical setting products. After impregnation, the fabric is interleaved with a special wrapper and wound onto the perforated cylinder, followed by steaming and cooling. Enhanced setting compared to non-chemical batch decatising is claimed.

11.1.10 Conditioning

It is important for wool and wool blend fabrics to be correctly conditioned. Mention has already been made of the need to avoid over-drying fabrics on the tenter. Over-dry fabrics recover moisture slowly, particularly in hot countries. Generally, 12–15% moisture regain (residual moisture on dry wool) is the basic requirement for an all-wool fabric, prior to operations such as pressing and decatising.

Various types of conditioning machines are available. Steam shrinkage machinery (as discussed in Section 11.1.8) provides the possibility of shock cooling, usually after steaming (but sometimes before) to provide a dewing effect. Spray systems are widely established, usually located in bars prior to pressing or decatising operations.

New developments in conditioning machinery include passing fabric through a mist of micro droplets of moisture. A spinning brush in contact with a rotating cylinder partially immersed in water creates the droplets. A heating battery causes partial evaporation, aiding moisture penetration into the fabric. Another system passes the fabric around a large diameter drum in a saturated atmosphere, using airflow through the fabric to distribute the moisture. With this type of machine, deeper penetration conditioning is claimed. Both of these systems offer controlled conditioning to required regain levels.

Radio frequency (RF) drying systems are also finding application. RF drying at temperatures of 40–60 °C is claimed to control moisture evenly across and throughout the fabric.

11.1.11 Summary of machine developments

Many improvements in machinery designs have been highlighted in this section on the finishing of woven fabrics.

Improved reliability of processing has been an important target. All modern textile finishing equipment has a high degree of automation and microprocessor control of operating parameters. This is important to help reduce operator error, for data storage and for reproducibility of fabric finish, batch-to-batch.

Versatility of equipment is important for wool, due to the short-run nature of the business and the variety of wool fabrics produced. Batch processing operations are important in this respect; batch scouring/milling and pressure decatising in particular allow a wide variety of finishes to be produced.

Environmental and cost/energy savings are also important considerations. Open-width scouring machines are designed to use minimum water and chemicals and to reduce effluent. Rinsing liquors are often recycled. Heat-recovery units are normally fitted to tenters as standard, diverting recovered heat to operations such as scouring. Scrubbing or alternative systems are available to reduce emissions.

Attention has been drawn to progress in minimising processing tensions, beneficial for lightweight fabrics and elastane-containing fabrics.

Machinery is often modular in construction, allowing companies to build lines as appropriate, a typical example being open-width scouring lines. Individual processes are often linked, e.g. open-width scouring and crabbing; raising and shearing; steam relaxation and decatising; streamlining finishing procedures.

The variety of finishing machines available is such that they cannot be adequately illustrated in this short review. Illustrations of many machines are, however, available in Reference 1.

11.1.12 Machine-washable woven fabrics

Wool products shrink on washing due to the presence of overlapping scales on the fibre surface (see Sections 4.4.5 and 7.5.3). When subjected to mechanical action, scales on adjacent fibres that are opposed, create a ratchet action and cause the fibres to move. This phenomenon, known as felting, continues until the fibre assembly is completely entangled.

The chemistry of shrinkproofing processes is given in detail in Section 7.5. Many developments have been aimed at producing machine-washable wool products, and attention has largely been focused on wool knitwear. The main process that has been used is the *chlorine/Hercosett* process that is applied to wool tops.

Chlorine/Hercosett-treated yarns can also be used in the manufacture of woven products. A further additive may sometimes be required to improve the washed appearance and ease of ironing. However, many manufacturers prefer treatments that can be applied entirely during fabric finishing. Economic considerations often favour this route: for example, it is not necessary to hold stocks of the more expensive treated yarns as well as standard untreated versions, and a fabric can be treated in response to an order for a machine-washable quality.

The most common treatment is the application of a bisulphite adduct of a polyurethane resin to the fabric in open width, using a pad mangle. The fabric is then dried at a sufficiently high temperature to cure the resin. The anti-felt mechanism in this case is different to that for the knitwear route in that the resin forms points of adhesion ('spot welds') between the fibres and yarns, inhibiting relative movement during washing. When using this system, a slight excess of resin over that required to achieve shrink resistance is usually applied to ensure complete effectiveness and to develop a firm handle. The handle can be further modified by wet processing.

Other processes that have been developed include one based on pretreatment with permonosulphuric acid followed by application of an alternative resin. This gives a softer handling fabric that is preferred for certain products.

Whilst the above techniques are capable of meeting the requirement for machine washability, other easy care aspects may have to be considered, notably the requirement for minimum ironing and, in the case of trousers, a permanent crease.

It is possible to impart a permanent crease by application of a chemical reducing agent to the pleat line and pressing the garment. However, alternative resin-based treatments are becoming more common for imparting both minimum iron and crease-retention properties.

Based on such developments, pure wool products such as easy-care skirts, trousers, jackets and even suits are becoming available in the marketplace.

11.1.13 Examples of basic finishing procedures

Product variety in woollen and worsted fabrics may be enhanced greatly by combining finishing processes in different sequences as well as by changing the parameters of the individual processes. The possible variations are enormous: a few examples of processing routines follow:

i) All wool worsted, plain weave, colour woven, clear finish:
(Crab) – open width scour – (crab) – dewater – (scutch) – dry – shear – relax/press – pressure decatise

ii) All wool worsted, 2/2 twill, colour woven flannel:
Crab – rope scour – mill – rescour – (crab) – dewater – scutch – dry – shear – relax/press – pressure decatise – continuous decatise

iii) Blend of 55% polyester (low pill)/45% wool, colour woven:
(Crab) – open width scour – (crab) – dry – heat set (170 °C, 30 sec.) – rope scour/soften – dewater – scutch – dry – shear – relax/press – pressure decatise – continuous decatise.

iv) Melton, stock dyed woollen spun:
Mill in grease – scour – carbonise in open width, 5° Beaumé sulphuric acid – dry and bake – dry mill – neutralise and rinse – tenter – shear – press/relax – pressure decatise – finish relax.

v) Velour, woollen spun piece dyed:
Mill in grease – scour – dye – (dry) – carbonise in open width, 5° Beaumé sulphuric acid – dry and bake – dry mill – neutralise and rinse – raise wet on double-action machine – tenter – shear – raise dry on teasel machine – shear – relax – decatise finish.

11.2 Finishing of knitted fabrics

Many colour knitted fabrics simply require steam-relaxation as a final finishing process, followed by decatising if a further press finish is required. However, wet finishing is used to ensure full relaxation and where improved handle and cleanliness are required.

11.2.1 Wet finishing

Wet processing procedures normally involve processing the tubular fabric in rope form in a winch, rope scour or softflow/overflow dyeing machine. Knitted structures can easily stretch and distort during wet finishing and it is important to minimise wet processing tensions, for example, by avoiding long lifts and drag. Relaxation zones with the fabric plaited allow for recovery of extension. If fabrics are stretched excessively and then set, e.g. by dyeing, it may be difficult to rectify dimensions.

Fabrics that are prone to distortion or cockling during wet finishing may require crabbing or an initial anti-cockle treatment. This involves treating the fabric in hot or boiling water, depending whether colour knitted or ecru for piece dyeing. For example, colour knitted fabrics are treated for 5–6 minutes at 70–80 °C; ecru fabrics 5–6 minutes at the boil. Reductive anti-cockle setting procedures are also used if a high level of setting is required.

To prevent creasing it is important that fabrics are slowly cooled after the setting process.

Winch scouring is traditionally used for a clear finish. Softflow/overflow machines that are suitable for dyeing wool fabrics are also used for scouring knitted fabrics because of the gentle action and low tensions applied. For more development of bulk and finish, rope scouring is used. Nip pressure should be just sufficient to grip the fabric and avoid slippage, and low enough not to crease or damage the fabric. Rubber rollers are often used to provide adequate grip and control at low pressures. Scouring is carried out at 40–45 °C for 30–45 minutes, using 1% (owf) synthetic detergent (and pH 8.5–9.0, depending on colour fastness), followed by rinsing for a similar period, gradually cooling to cold to avoid creasing. To protect the surface, it is good practice to process the fabric face in.

After wet processing, excess moisture can be removed by hydroextractor if the fabric is not susceptible to creasing, or by mangle. After extraction, the fabric is plaited and straightened in tubular form, with the slitting mark aligned in the middle. A slitting machine then slits and plaits the fabric for drying in open width. Machines that will automatically untwist, dewater and plait with minimal tension are available.

11.2.2 Drying

Slit fabric is usually dried on a tenter frame. Wool fabrics should be dried as near to relaxed dimensions as possible, as excessive stretching may lead to problems of relaxation shrinkage. It is important that tenters have effective overfeed, to facilitate removal of any length processing tensions applied during wet finishing. It may be necessary to extend width dimensions to allow for adequate overfeed. Extending the width by up to 10% is acceptable, providing some form of post relaxation process is available to remove excess width. Tenters designed specifically for knitted fabrics often have supporting beds and may incorporate clips or tapes to hold the fabric on the pins. Scroll rollers are necessary to open curling edges.

Drying machines for tubular knits include continuous drying types, where the fabric (after dewatering and plaiting) is overfed onto a moving brattice. The fabric is lightly held by a top brattice that is adjustable in height, and is dried and relaxed by a flow of hot air. Some such machines also handle slit fabrics in open width.

11.2.3 Relaxation shrinkage

To remove any relaxation shrinkage remaining after drying, a steam relaxation table is most effective. The fabric is overfed onto a moving belt and steamed at minimum tension. Vibration promotes relaxation, and some machines incorporate ironing zones to impart a press finish.

In the absence of this type of equipment, relaxation shrinkage can be reduced at the tenter by using a steam box at the tenter entry, or by repeated wetting and drying with overfeed. Rewetting fabrics on a pad mangle with minimum length tension and storing for a short while to allow relaxation is sometimes practised prior to tenter drying. Storage times should be minimal to avoid creasing.

11.2.4 Final finish

Fabrics requiring a further pressed effect are normally decatised, using either batch or continuous machinery. It is important to ensure minimum processing tensions.

11.2.5 Summary for knitted fabrics

The key to successful finishing of knitted fabrics is to minimise operating tensions, particularly during wet finishing. Careful handling between operations is also important. Relaxation shrinkage can then be minimised during final finishing.

11.3 Finishing of knitwear

Pure wool knitwear may be made from worsted-spun or woollen-spun yarns. The two basic types are generally associated with different finishing procedures.

11.3.1 Worsted spun knitwear

Worsted-spun articles generally require a smooth, clear finish with good stitch clarity and definition. When fabrics are knitted from dry spun yarns or yarns with low oil content, it is usually sufficient to simply steam-relax the garments (usually on frames). Steaming releases yarn or knitting tensions and reduces the potential for relaxation shrinkage. However, if further relaxation is required or if the knitwear requires scouring, wet finishing is used.

Wet finishing should be carried out as gently as possible to maintain a clear finish. To minimise facing up, the knitwear is usually turned inside out. The goods are processed partly made up, e.g. as body and sleeve, with no neck trims. Trims are finished in mesh bags.

During wet finishing, worsted-spun knitwear can exhibit cockling, due to release of localised tensions causing distortion of the knitted loop. Cockling can also be a problem along the interface between the top of the welt and the body of the knitwear panel. To overcome this problem, anti-cockling procedures are used. Several procedures are available, depending upon the severity of the problem and whether the knitwear is ecru or knitted from dyed yarns. Basically, the knitwear is treated by immersing in hot or boiling water for a predetermined time. Reducing agents are often added to improve setting.

After anti-cockle treatment, the fabric may be scoured. For both the anti-cockle treatment and scour procedures, machinery with gentle action should be used, e.g. side paddle type having a gentle paddle action. Scouring is carried out at 40 °C, using 1% on the weight of wool (oww) synthetic detergent followed by rinsing.

In some countries, garment dyeing is practised. After scouring, the garment is chlorinated to prevent it felting or shrinking during the dyeing cycle. After dyeing, a softener may be applied, or a resin plus softener to produce a machine-washable product.

Light hydroextraction is followed by intermittent tumble/rest drying at 70–80 °C. Procedures are selected to minimise creasing and to retain a clear surface finish. Steam pressing completes the finishing procedure.

11.3.2 Woollen-spun knitwear

Woollen-spun knitwear, when delivered to the finishing department, can contain high levels of spinning lubricant (as much as 8–9%), has a harsh handle and a generally 'flat' appearance. Scouring removes oil and dirt. Milling is applied to soften and bulk the hand, provide some consolidation of the structure and subdue the stitch structure of the knitwear.

To achieve such finishes, rotary washing drums are generally used. Scouring normally uses an intermittent cycle of wash/rest to allow sufficient scouring time for oil removal, without excessive development of milled finish at this stage. Processing conditions are 40 °C with 3–4% (oww) synthetic detergent, preferably at pH 8.5–9.0, depending on colour fastness. Several baths may be required, depending on the level of oil present. After scouring, the knitwear is thoroughly rinsed. Milling follows, using similar detergent concentrations but with continuous cycling of the machine for the time required to give the desired finish, followed by rinsing. Softeners may be added to the final rinse. Alternatively, special detergent/softening preparations are available for scouring and milling. The finished knitwear is hydroextracted and tumble dried, followed by steam press finishing.

Modern drum machines have compartment drums, incorporate hydroextraction and have automatic and programmable control of finishing cycles. Tilting mechanisms allow for easy unloading.

11.3.3 Easy-care knitwear

Wool can be treated to give machine-wash performance, either at the fibre stage (prior to spinning and knitting) or during wet finishing of the garment. The basic principle is similar in both cases in that an oxidising agent, typically chlorine, is applied which modifies the fibre scales and which imparts a degree of shrink resistance in its own right. A resin is subsequently applied which covers the scales, thereby producing machine-washable wool. Of the various processes, the largest production is by the *chlorine/Hercosett* process, which is applied at the fibre stage to worsted tops, and also to loose wool, for woollen spun garments.

Total Easy Care knitwear has been introduced to the market. This is both machine washable and dryable by tumbling. Such performance is achieved by selection of the physical parameters of the yarn and the knitted structure, coupled with careful attention to the chemical treatment conditions and wet finishing conditions that ensure full garment relaxation.

Reference

1 Rouette H-K and Kittan G, *Wool Fabric Finishing*, Ilkley, UK, Wool Development International, 1991.