25. Wet Finishing of Wool Fabrics

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Learning objectives

By the end of this lecture, you should be able to:

- Outline the various levels of set that can be achieved in wool fabrics.
- Describe the various machines used to scour wool fabric.
- Understand the principles of wool fabric carbonising.
- Outline the objects of crabbing.
- Describe the process of milling.
- Outline the various methods available for the shrink proofing of wool fabrics.

Describe the process of bleaching

Key terms and concepts

Setting, cohesive set, permanent set, scouring, crabbing, carbonising, milling, shrink proofing, bleaching, dyeing, hydroextraction, back-rolling, scutching.

Introduction

The objects of the wet finishing of wool fabrics are firstly to remove contaminants from the wool by scouring and, if necessary, by carbonising. The latent stresses and strains the fabrics must then be relaxed, and the fabric set, in a process known as crabbing. Special qualities can then be developed in the wool fabrics by processes known as milling, shrink proofing, bleaching and dyeing. These so called wet finishing processes are grouped together, the aim being to minimise water consumption and to dry the fabric only once.

This lecture provides details on the topics of wool setting, scouring, crabbing, carbonising, milling, shrink proofing, bleaching, hydroextraction, scutching and back-rolling. The topic of dyeing is dealt with separately in Lectures 30 and 31.

The general references for this lecture are (Rouette and Kitten, 1991), (Brady, 1997), (Levene, 1984), (Shaw and White, 1984) and (Miles, 2003).

25.1 Setting of wool

Wool is a hydrophilic fibre and, given the opportunity and time, comes to an equilibrium moisture regain as determined by the prevailing atmospheric conditions. The moisture regain of wool plays a crucial role in determining many of wool's properties, e.g. glass transition temperature, and its performance in all setting processes.
The term ***set*** is generally considered to mean the retention of fibre and fabric shape developed in a particular setting process. In the middle 1930's it was thought that two levels of set could be achieved in wool, being:

- Temporary set (a level of set not stable to steaming), and,
- Permanent set (a level of set not released by steaming).

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By the late 1940's wool setting theory had developed to the point where three levels of set were distinguished as follows:

- Cohesive set (a level of set that is achieved by deforming in water and drying),
- Temporary set (a level of set released after a short time in hot water), and,
- Permanent set (a level of set that is not released in boiling water or steam).

Brady (1997) considers that two types of set, being ***cohesive set*** and ***permanent set***, are important in practical wool finishing operations.

Cohesive set

Wool protein chains, like all polymer chains, are held together by a combination of weak and strong inter-chain forces. The weak forces include hydrogen bonds, van der Waal's forces, dipolar forces, etc and, whilst individually weak, these forces are collectively strong and hold the polymer chains together. The strong inter-chain forces are principally the covalent disulphide bonds of the amino acid cystine.

All polymers, including wool, have a property known as a glass transition temperature. The glass transition temperature is the temperature above which the thermal energy in the polymer chains (vibrational energy) is able to overcome the weak forces that prevent movement of the polymer chains. The polymer is said to transform from a glass-like state to a rubbery state.

The regain water of wool acts a plasticiser and hence the glass transition temperature of wool varies with the amount of adsorbed water. For a regain of 14-16%, the glass transition temperature of wool is about 40^{o}C, while for wool saturated with water the glass transition temperature is about 0^{o}C. When wool is above its glass transition temperature it is in a so called rubbery state and the wool can be easily deformed because the protein chains readily rearrange to reduce the induced stress. If the deformed wool fibres are maintained in the deformed state whilst the wool is taken below its glass transition temperature, then the new shape becomes cohesively set.

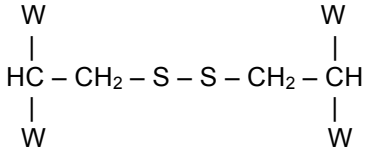
A common example is the drying of human hair whilst wrapped around hair curlers. The wet human hair, like wet wool, is "plastic" and can be easily deformed and wrapped around the curlers because the adsorbed water reduces the glass transition temperature of the hair to below the ambient temperature. Put another way, the ambient room temperature is above the glass transition temperature of the wet hair. Blow drying of the wet hair reduces the moisture regain of the hair and hence its glass transition temperature increases above the ambient temperature and the hair has become cohesively set. When the curlers are removed, the hair retains its curls until such time as the cohesive set is lost, e.g. by the addition of water.

With respect to wool finishing, wool fabrics can be relaxed by wetting and then drying without physical restraint, e.g. tensionless drying. The wetting process reduces the glass transition temperature, thereby allowing the rearrangement of the protein chains. Drying removes the excess moisture from the fabric, thereby increasing the glass transition temperature to above the ambient temperature.

Permanent set

The disulphide bonds of the amino acid cystine provide the stabilising crosslinks that hold the protein chains of the wool matrix together. Under suitable conditions, the disulphide bonds are able to rearrange by a process known as the thiolate/disulphide interchange reaction. In some texts this reaction is also referred to as the thiol/disulphide interchange reaction.

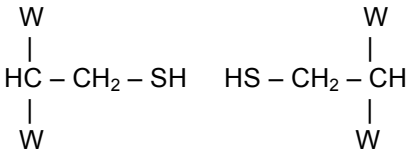
The disulphide crosslink (-S-S-) of cystine is given in Scheme 25-1 below where "W" represents the polypeptide chains of wool.



Scheme 25-1

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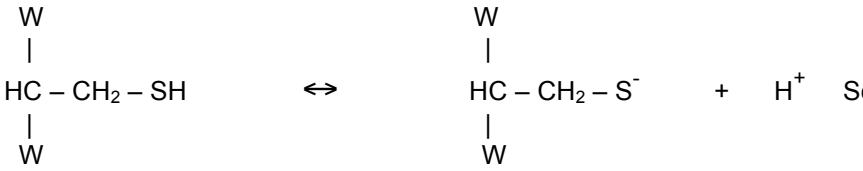
The disulphide bond can be broken by reduction to form two thiol groups, as shown in Scheme 25-2. Providing that the wool is above its glass transition temperature, the polypeptide chains can now move freely past each other, relaxing the stresses and strains, and take up the new physical shape.



Scheme 25-2

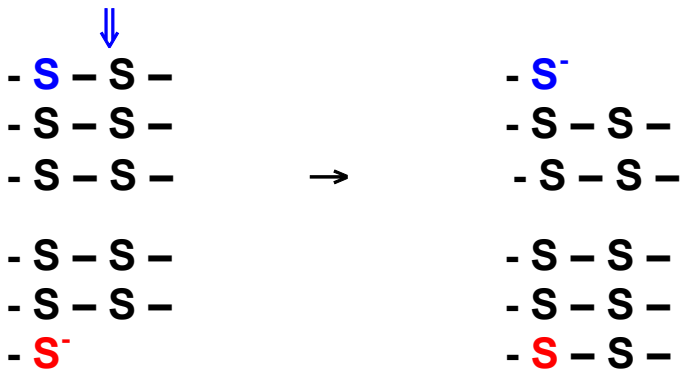
Once in the new configuration, the polypeptide chains can be locked together by the action of an oxidising agent, which reverses the above reaction, reforming the disulphide bonds. This is the basic chemistry behind the permanent setting of human hair and the chemical setting of wool fabrics.

The thiolate/disulphide exchange reaction does not require the use of reducing agents. Wool normally contains low levels of thiol groups, present as the amino acid cysteine. Thiol groups and thiolate anions are in equilibrium, as shown in Scheme 25-3, and this equilibrium is a function of pH, the higher the pH, the higher the concentration of thiolate anions.



Scheme 25-3

As shown in Scheme 25-4, on the left hand side of the equation we have a series of disulphide bonds, with a thiolate anion (shown in red) situated at the bottom left hand side. Now imagine that the structure is distorted by pushing down as depicted by the blue arrow. The disulphide bonds become stressed, and that stress is released by a progressive interchange of the thiolate anion until, as shown in Scheme 25-4, the thiolate anion resides at the top left of the model. The sulphur atom of the thiolate anion has not moved, but rather the electron has moved and finally resides on the top sulphur atom (shown in blue).

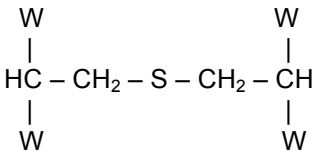


Scheme 25-4

The thiolate/disulphide exchange reaction is a function of the concentration of thiolate anions and temperature. The concentration of thiolate anions depends on the pH of the fabric and the past processing history of the wool. As discussed above, the concentration of thiolate anions can also be increased using reducing agents.

New permanent cross-links are formed in wool by the conversion of the amino acid cystine into the amino acid lanthionine. As shown in Scheme 25-5, lanthionine has a single sulphur cross-link which is stable to reduction,

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Scheme 25-5

and hence provides stable cross-links. Detailed accounts of the chemical reactions leading to the formation of lanthionine may be found in McLaren and Milligan (1981).

Scouring

Scouring is a washing process that is used to remove the various contaminants from the wool fabric, e.g. processing oils, unfixed dyestuffs (from stock, sliver, top or yarn dyeings), oil stains, adventitious dirt and soil, etc.

Subject to the dimensional stability of the fabric, the finisher will decide as to whether the fabric should be scoured first, or crabbed first. In the case of woollen fabrics, scouring is often the first processing step in the finishing routine. Worsted fabrics, however, may need to be crabbed first in order to prevent cockling and other fabric distortions.

Scouring removes contaminants from the wool fabrics using a combination of mechanical action and detergency. The controllable scouring parameters are as follows:

- Mechanical action (as set by the choice of scouring machine).
- Surfactant type.
- pH of the scouring liquor.
- Scouring temperature.
- Scouring time.

At the same time, the scouring conditions must not be so vigorous as to cause excessive felting shrinkage. Indeed, a small amount of fibre migration is desirable because fibre migration to the fabric surface leads to a softer handle. Fibre migration also leads to an increase in the cover of the scoured fabric.

Scouring recipes can be either water (aqueous) based or solvent based systems; aqueous scouring systems being far more common. The quality of the water supply is very important as dissolved salts and impurities can have a deleterious effect on scouring efficiency. Water supplied to the mill may contain suspended matter, dissolved salts, organic matter, etc. If the water quality is poor, then the water would be treated, or “softened” before use in wet finishing processes.

Detergents

The four basic types of detergents are anionic, cationic, non-ionic and amphoteric surfactants. Cationic surfactants are not used in the scouring of wool. Cationic surfactants are commonly used as fabric softeners and, because they complex with the anionic dyes employed in the dyeing of wool, can cause interference in wool dyeing. Thus only anionic and non-ionic surfactants are used in wool scouring.

Soap is the sodium, potassium or ammonium salt of a fatty acid, e.g. sodium stearate, and hence is a form of anionic surfactant. Soap is sensitive to the water hardness salts of calcium and magnesium, forming insoluble calcium and magnesium soap deposits on the wool fabric. Thus the finisher must ensure that he is using “soft” water or has added water softeners to the scour liquor. Soap has a number of useful properties as a detergent for wool scouring, including good wetting properties, high soil carrying capacity and the development of a soft handle in the wool fabric. However, on the negative side, soaps are expensive, unstable in acidic media and hard water, and may leave residues that could lead to colourfastness and odour problems.

Synthetic anionic surfactants have an affinity for wool, giving a mild softening effect on wool fabrics. They are good wetting agents and are reasonably insensitive to changes in pH. However their performance can be adversely affected by high levels of water hardness wherein the sodium cation is replaced by the calcium cation in hard water. Residues may be left on the fabric, giving a harsh fabric handle.

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Nonionic surfactants, in the main, give better scouring efficiency than anionic surfactants. They are quite cheap and are not sensitive to the calcium cations in hard water. A further advantage of non-ionic surfactants is that they are quite good at removing surface residues of dyestuffs, thereby improving the colourfastness to rubbing of the dyeings. Whilst non-ionic surfactants are very efficient at removing oils from the wool fabric, they tend to give the wool a slightly harsh handle.

Amphoteric surfactants have both an anionic and a cationic moiety in the surface-active part of the molecule. They are not commonly used in wool scouring because of their high cost.

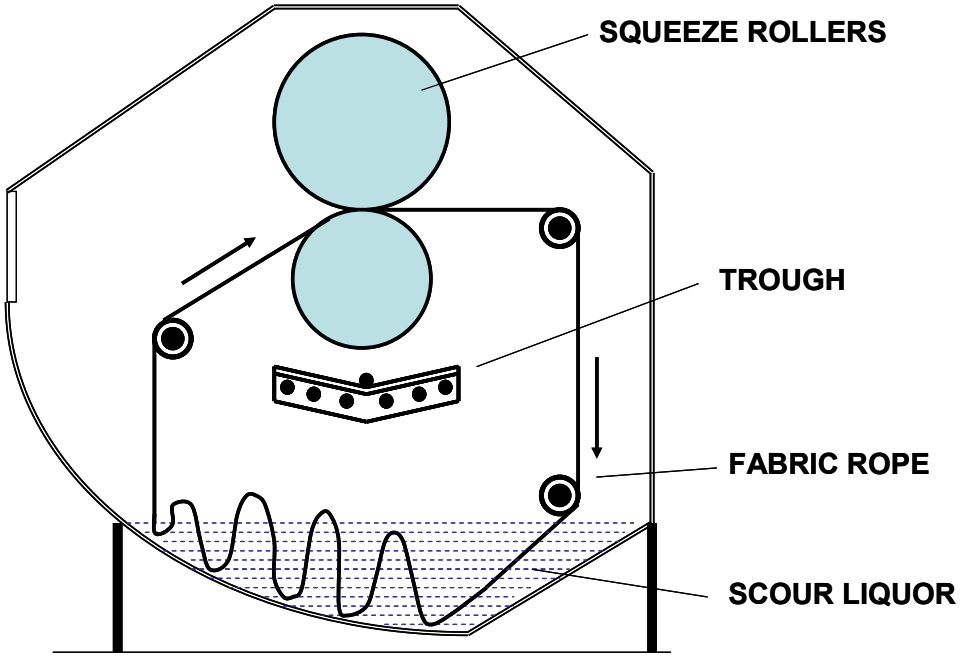
Scouring machinery

Wool fabrics may be scoured in either rope form or in open width form. The machines are designed to provide the correct degree of mechanical action to aid the scouring action. Rope scouring machines provide a better cleaning action but have the disadvantage that they can introduce permanent creases in some fabrics.

Rope scouring

The traditional rope scouring machine is known as the Dolly or Scouring Dolly.

Figure 25.1 Dolly Scour. Source: Pailthorpe, 2006.



As can be seen in Figure 25-1, the fabric rope circulates in a clockwise direction, being lifted out of the scouring liquor, over the guide roller, through the squeeze rollers, and then on back into the scour liquor. The cycle then continues as the continuous rope is circulated at speeds of up to 80-100 metres/minute. The liquor squeezed out of the fabric rope by the squeeze rollers is collected in the trough underneath the squeeze rollers. During scouring, this liquor is returned to the bottom of the machine. However, during rinsing, the squeezed out liquor is directed to the drain.

Many of the disadvantages inherent in traditional Dollys have been rectified in modern machines. For example, both the top and bottom rollers, and the guide rollers, are driven and the pressure on the top roller can be controlled by either pneumatic pistons or springs.

Rapid rope scouring machines operate with speeds up to 220 metres/minute. As the fabric rope leaves the squeeze rollers, or scouring rollers, it is picked up by a doffing roller and propelled towards the rear wall of the machine. The compression of the fabric so produced can provide substantial relaxation of the fabric.

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The Zonco FLEXIRAPID 600 high speed scouring machine shown in Figure 25-2 is used for both scouring and high speed scouring and rinsing of wool and wool blend fabrics in both rope and tubular form. The manufacturers claim that the machine achieves very short processing times, with considerable savings on water and chemicals.

Figure 25.2 The Zonco FLEXIRAPID 600 High Speed Rope Scouring Machine.
Source: Zonco website (www.zonco.it)



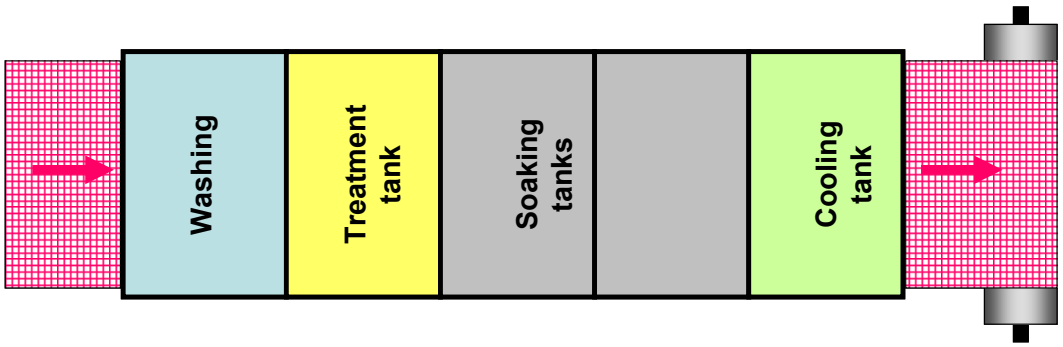
The technical specification of the FLEXIRAPID 600 may be found at:

www.zonco.it/inglese/flexir.htm

Open width scouring

Open width scouring can be carried out in either batch or continuous scouring machines.
In the batch style of machine, the fabric, in open width, is processed in a closed loop. The fabric circulates in much the same way as in the Dolly, except that it is maintained in open width.
As shown in Figure 25-3, continuous open width scouring machines combine a series of washing, soaking, rinsing and cooling tanks to achieve the required dwell time and scouring action. There are two general machine principles employed in continuous open with scouring machines being, dips, squeezes and sprays, and sprays and suction slots.

Figure 25.3 Schematic of a continuous open width scouring machine.
Source: Pailthorpe, 2006.



The CIMI Lavanova Multifix continuous open-width scouring machine is shown in Figure 25-4. CIMI claim that their machine is eco-friendly due to reduced water consumption, reduced chemical usage and reduced effluent. The technical specification of the machine may be found at:

www.cimi.it/ing/prod/lavano.html

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Figure 25.4 CIMI Lananova Multifix Open-width Scouring Machine.
Source: CIMI website (www.cimi.it).



25.2 Carbonising

Carbonising is the chemical process used to remove vegetable matter fault from wool fabrics. The vegetable fault includes all of the vegetable contaminants from the fleece, e.g. grass, seeds, burrs, etc. In the woollen system, vegetable matter is usually removed by carbonising the wool after raw wool scouring. Thus fabrics made from carbonised wools would not normally be carbonised. Fabric carbonising is used to remove small amounts of vegetable matter from worsted and woollen fabrics that have been manufactured from relatively clean wools.

Carbonising makes use of the chemical differences between wool and vegetable matter; in particular their sensitivity to acid hydrolysis. Whilst wool keratin is more resistant to acid hydrolysis than is cellulose, some damage to the wool occurs. Clearly then the object of carbonising is to use treatment conditions that effectively remove the vegetable fault whist causing minimum damage to the wool. The acids employed in wool carbonizing include sulphuric acid, hydrogen chloride gas and aluminium chloride.

The wool fabric is impregnated with a 3-6% aqueous solution of sulphuric acid, dried and then baked at 130^{o}C. During baking, the cellulosic material is hydrolysed by the sulphuric acid, forming hydrocellulose, which is brittle and can be crushed and mechanically removed from the fabric. After crushing, the residual acid is neutralised and the carbonised fabric is scoured.

The sulphuric acid solution also contains a wetting agent, usually of the non-ionic surfactant type, to ensure that an even uptake of the acid takes place by the wool. The wool fabric must be uniformly treated by the sulphuric acid otherwise uneven dye uptake will take place during subsequent piece dyeing. The sulphuric acid reacts with the functional groups of the wool protein that act as dye sites for acid dyes or nucleophilic sites for reactive dyes, leading to a dye resist effect. Clearly an uneven reaction between the sulphuric acid and wool will lead to uneven dyeings.

Sperotto Rimar has developed a solvent carbonising process in which the wool is first impregnated with perchloroethylene. Because the wool surface is hydrophobic in character, the wool is rapidly wetted by the solvent. The solvent impregnated wool is then passed through a 6% aqueous solution of sulphuric acid which, it is believed, it taken up preferentially by the vegetable matter. After impregnation with the sulphuric acid, the fabric is dried and baked at 140^{o}C in a closed

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system. Great care must be taken to prevent gas leaving the machine and entering the workplace as quite noxious gasses, e.g. phosgene, can be produced by reactions between sulphuric acid and perchloroethylene. Sperotto Rimar claims that its process provides a uniform treatment with lower acid consumption and less damage to the wool. Even so, solvent carbonising of wool fabric is not in widespread use.

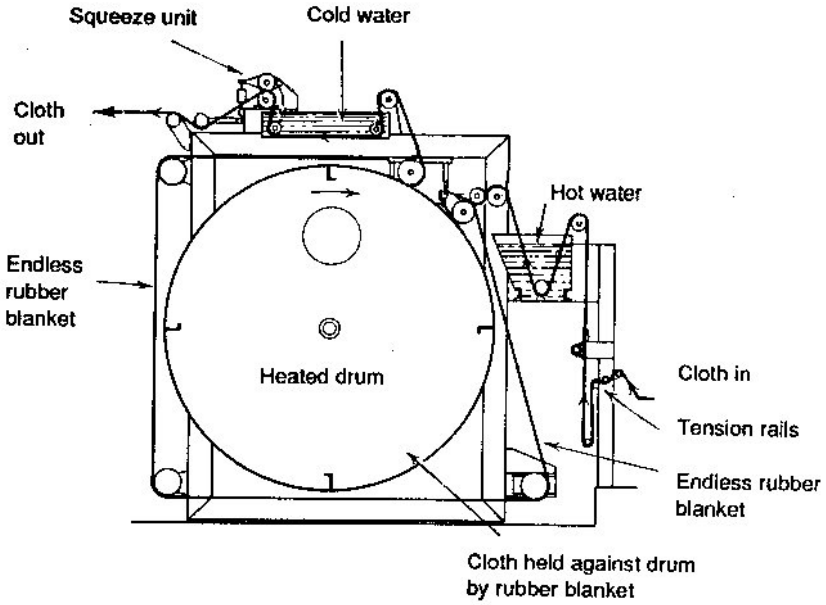
25.3 Crabbing

Crabbing relaxes tensions in woven wool fabrics, usually in worsteds. It sets the fabric length and width so that warp and weft are in correct relation to each other. By removing residual strains from woven fabric, creasing, cockling and wrinkling caused by uneven shrinkage, and other distortions are prevented in piece dyeing and in later finishing.

Plain weaves are most prone to cockling and distortion. Crabbing permanently sets the weave and is essential for some kinds of wool cloth. It is, however, a preliminary finishing process. There are various methods and machines used for crabbing.

Crabbing fabric on traditional machinery is labour intensive and slow, and care is needed to avoid problems in later piece dyeing. Modern machinery, such as the Konticrab line for the continuous processing of piece goods, has largely overcome these problems. A modern continuous crabbing machine is shown in Figure 25-5.

Figure 25.5 Konticrab continuous crabbing machine. Source: Pailthorpe, 2006.



The open-width fabric is first treated with hot water (80-100°C) or steam to relieve tension. Then the fabric is set at the correct dimensions by passing it around the heated drum whilst held by the endless rubber blanket. As the fabric rotates, it is moistened, heated, and pressed. Finally the fabric is cooled by the cold water trough while stretched out, and batched ready for the next process.

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25.4 Milling

Milling is the controlled felting of woven or knitted fabrics that contain only or mostly wool fibres. Milling, or *fulling*, compacts and consolidates woollen fabrics and makes worsteds feel slightly fuller or thicker. Surface hairiness results and the weave or knit structure is gradually obscured by milling.

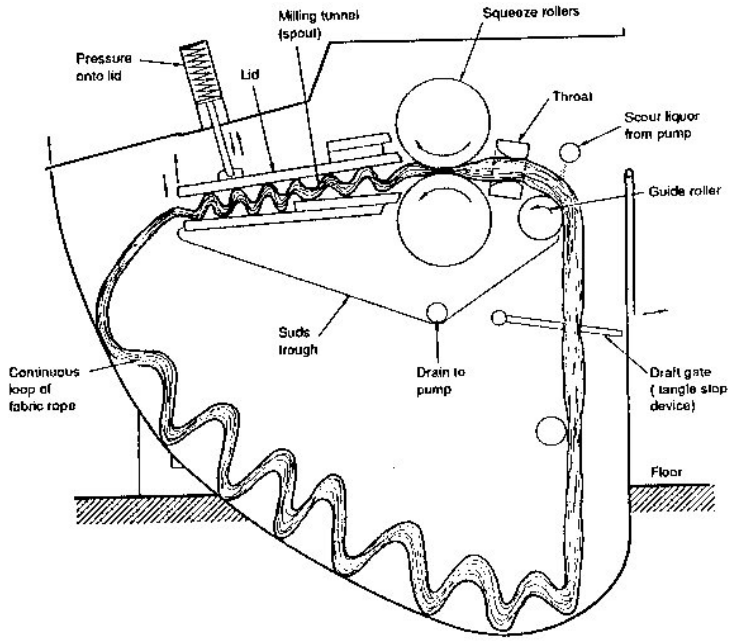
There are essentially three types of machines used for the milling of wool fabrics, being:

- Rotary milling machines,
- Combined scouring/milling machines, and,
- Stocks.

Rotary milling machines

In piece milling the fabric is sewn into a tube, called bagging, with the fabric face protected inside the tube. Bagging allows the fabric rope to balloon, which prevents wrinkles and creases from being milled in. As shown in Figure 25-6, the fabric rope is moving in an anticlockwise direction, being lifted out of the milling liquor, through the draft gate, over the guide roller and into the throat piece.

Figure 25.6 Rotary milling machine. Source: Pailthorpe, 2006.



Just before entering the throat, the fabric rope is sprayed with liquor. The fabric rope then enters the squeeze rollers and milling tunnel. The squeeze rollers and the milling tunnel, which is like a stuffer box, act mechanically on the wet cloth. The draft gate pulls lengthwise to reduce the cloth width and stops the squeeze rollers if a tangle occurs.

Three main milling systems are used in the rotary milling machine.

1. Grease milling. When soap-making yarn oils are used, alkali is added to the milling bath to saponify the oils. After milling, the fabric is scoured.
2. Soap milling. After scouring, the fabric is milled in dissolved soap noodles or synthetic detergent.
3. Acid milling. After scouring, the cloth is rinsed free of soap or detergent. The cloth is milled in a dilute solution of sulphuric acid. This method suits fabric dyed with dyes not fast to alkali.

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Different substrates give varying results.

1. The higher the percentage of wool, and of fine wools in the blend, the faster the milling. Short wools mill more quickly than long wools.
2. Fabrics made from open-structured woollen yarns mill faster than those made from worsted yarn.
3. Low-twist yarns mill faster than high-twist yarns.
4. Tight fabric structures are slow to mill.

Process variables affect the milling.

1. The number of passes the fabric makes through the squeeze rollers, which can be set on modern machines.
2. The mechanical action of both the squeeze rollers, and the milling tunnel, which are machine controlled.
3. The milling bath temperature. Increasing the temperature makes fibres more mobile and so the milling rate increases. However, dye-bleeding is more likely at higher temperatures.
4. Liquor ratio. As the liquor ratio is reduced, the milling rate increases. Above a liquor ratio of 12:1, milling is slow. The draft gate and squeeze rollers control the amount of water in the cloth during mechanical action.
5. Concentration of the milling bath. Too much soap or detergent makes rinsing difficult, so just enough is used to make the cloth slippery.

Chemical processes, including dyeing, make wool fibres a little harder to mill.

Milling is progressive and must be stopped when the desired effect is reached. Milling ranges from a slight change in handle that makes fabric warmer and softer to the touch, to densely matted fabric. Prolonged milling makes the fabric shrink greatly, thicken, and become firmer and stronger. The yarn and fabric structure is almost completely obscured after prolonged milling.

The machine shown in Figure 25-5 can be used for scouring as well as milling. Scouring needs more water than milling. It can also be used for the dry milling of carbonised fabrics to crush charred vegetable matter.

Machine design and milling has changed little over the past 50 years. However, recent developments allow more process control. For example, the machine can be pre-set to stop when a particular length shrinkage is reached.

When solvent milling, some water must be emulsified in the solvent by using a charge of soap or detergent. Water is the essential ingredient of milling.

Stocks

Milling stocks are wooden hammers that beat the wet fabric whilst it resides in a specially designed trough. Milling stocks are rarely used these days, but were commonly used to hide running marks and other faults in woollen fabrics.

25.5 Shrinkproofing

Because of wool's natural propensity to shrink via felting, wool fabrics must be shrinkproofed if they are to meet machine-washable standards.

For various technical and economic reasons wool products are shrinkproofed at either:

- The combed top stage,
- The knitted or woven fabric stage, or,
- The knitted garment stage.

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The most widely used process for the treatment of combed tops is the so called Chlorine-Hercosett process. The treatment process involves six steps, as follows:

- Chlorination pre-treatment.
- Antichlor and neutralisation.
- Rinse
- Hercosett polymer application.
- Softener application.
- Drying and curing of the polymer.

The chlorination pre-treatment is required to modify the exocuticle of the wool fibres so that the Hercosett polymer solution will spread evenly over the fibre surface. The pre-chlorination treatment is a cold acid chlorination process employing sodium hypochlorite at pH 1.3-1.7. After chlorination the wool is neutralised with sodium carbonate solution and any residual chlorine is destroyed with sodium sulphite, followed by rinsing.

The wool tops are then treated with the Hercosett polymer, which is a polyamide epichlorohydrin based reactive polymer. The reactive polymer self-cross links during curing and hence is fixed to the fibre surface. The polymer coating effectively masks the scales of the wool and reduces the directional frictional effect. During washing the polymer swells, further reducing the fibre movement caused by the mechanical action of washing.

The softener application is necessary to prevent the polymer from sticking the wool fibres together, thereby improving processing performance. The softener also improves the handle of the Hercosett treated wool.

Shrink resist treatments for wool fabrics involve the application of aqueous solutions or emulsions of reactive prepolymers by padding, drying and curing. For example, the Sirolan BAP process is applied to wool fabrics after wet finishing and drying. A typical recipe would be:

10-30 g/l Synthappret BAP
10-30 g/l Impranil DLH
3-5 g/l sodium bicarbonate.

The Sirolan BAP process works by both coating the wool fibres and by spot welding the wool fibres together, preventing fibre migration.

25.6 Bleaching

Whilst the brilliant bleached whites commonly achieved on cotton and synthetic fibres cannot be achieved on wool, wool can be bleached to an acceptable level of whiteness. Bleached wool is favoured in many applications including baby's knitwear and as a substrate for dyeing bright and pastel shades.

The object of bleaching is to destroy the natural cream and yellow pigments in wool using either oxidative or reductive chemical processes. Since wool itself can suffer damage by the action of oxidising and reducing agents, great care must be taken in formulating the bleaching recipes.

The ancient Romans were the first to bleach wool using sulphur dioxide gas. The process was known as stoving wherein the wet wool was hung in a closed chamber and exposed to sulphur dioxide gas, produced by burning sulphur. Stoving was continued well into the 20th Century, but soon lost popularity after the development of stabilised hydrogen peroxide in the late 1920's.

Hydrogen peroxide is a very powerful oxidising agent, with its oxidising power increasing with increasing pH. Of course, wool is sensitive to hydrolytic damage at high pH, so the pH of the bleaching bath must be controlled to a maximum of about pH 9.0-9.5. A typical hydrogen peroxide bleaching recipe would include hydrogen peroxide (1-4 volume), a wetting agent, a pH buffering agent and a stabiliser. The stabiliser is necessary because various heavy metal cations, e.g.

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copper, iron and manganese, can catalytically decompose hydrogen peroxide. The wool fabric is normally entered into the cold bleaching bath, the temperature is then raised to 40-50^{o}C, and held for the required bleaching time (2-6 hours). Hydrogen peroxide bleaching may be carried out in rope form or open with form; and can even be combined with scouring.

Wool may also be bleached using reductive chemicals, e.g. sodium dithionate (also known as sodium hydrosulphite or "hydros"). The wool is treated in stabilised aqueous hydrosulphite (2-5 g/l) at 45-65^{o}C for 1-2 hours in a sealed vessel. Whilst hydrosulphite bleaching is cheaper than bleaching with hydrogen peroxide, there is the problem of a residual smell. The residual smell can be eliminated by using hydrogen peroxide in the rinse bath.

The bleaching of wool does cause some damage to the wool, e.g. hydrogen peroxide bleaching at 50^{o}C for 4 hours increases the alkali solubility from 14% to 24%. Clearly, then, the benefit of increased whiteness must offset the wool damage.

25.7 Dyeing

The dyeing of wool fabrics is a large topic and is dealt with in Topic 27.

25.8 Hydroextraction

Wet wool fabrics can hold substantial amounts of water in the pores and spaces between the individual fibres and yarns. This water is held by a combination of surface tension forces and capillary action; and hence can be removed by mechanical force. From an energy savings point of view, hydroextraction is a much cheaper way of removing water than drying. For example, in relative terms, hydroextraction using a pad mangle is 25 times less expensive than removing the same amount of water by drying using heat energy.

There are essentially three hydroextraction methods in common use, being:

- Mangling,
- Centrifuges, and,
- Suction slot.

Mangling

In mangling, the wool fabric is passed through a set of horizontally opposed pad mangle bowls. The hydrostatic pressure created at the nip between the two bowls squeezes the liquid water out of the fabric. For fabrics processed in rope form it is common to mangle twice, firstly in rope form and secondly in open width. Mangling first in rope form is performed to remove as much water as possible before opening to full width on the scutcher.

Since high pressures are applied to the ends of the bowls, some distortion of the bowls can take place, leading to an even pressure across the width of the nip. Thus specially constructed bowls, using anti-deflection rollers, are used for hydroextraction.

Centrifuges

Industrial scale centrifuges are used to hydroextract fabrics in rope form. It is important to feed the fabric rope into the centrifuge basket, or cage, to achieve a balanced load. Even so, the machines must be installed on solid foundations and be fitted with robust suspensions. Centrifuges can run at speeds of up to 1,500 revolutions per minute and generate substantial g-forces. G-forces of the order of 800-1600 are achieved in modern centrifuges.

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Suction slot

For hydroextraction via suction slot, a high powered vacuum pump draws air through the fabric via a narrow slot that runs across the full with of the fabric. Suction slot hydroextraction is used on delicate fabrics that may be damaged by mangling or centrifuging.

Suction slot hydroextraction is not particularly effective on wool fabrics, probably because of their low air permeability. In addition, suction slot extraction has the highest energy costs of all three methods, and so it is rarely used in the hydroextraction of wool fabrics.

Hydroextraction summary

The relative performances of hydroextraction by pad mangle, centrifuge and suction slot are summarised in Table 25-1.

Table 25.1 Hydroextraction Performance Estimates. Source: Pailthorpe, 2006.

Hydroextraction Method	Relative Energy Cost	Water Retention (%)
Pad Mangle	1.0	~ 60
Centrifuge	1.7	~ 40
Suction Slot	3.0	~ 80

It can be readily seen from the estimates provided in Table 25-1 that centrifugation provides the best hydroextraction result for wool; even though the energy cost is about twice that of mangling. Suction slot technology gives the worst result both in terms of energy cost and water retention.

25.9 Scutching

Scutching is the process employed in the textile industry to convert fabric from rope form to open-width form. The twist in the fabric rope is detected electronically and the electronic signal is used to control an untwisting device which removes the twist from the rope. The now untwisted fabric rope then passes through opening rollers and guides to restore the fabric to the open-width form. The fabric may then be rolled up on beams or folded (cuttled) onto a mill trolley.

25.10 Back-rolling

When wool fabrics are scoured and dyed in rope form there is always the possibility of introducing creases or running marks in the fabric. Back-rolling, which is essentially crabbing (see above), is used to remove such running marks.

Readings

The following readings are available on CD

1. Le, C., Ly, N., Phillips, D. and De Boos, A., Characterising the stability of the surface finish on wool fabrics, CSIRO, Textile and Fibre Science, Geelong, Victoria.
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3. Hauser, P., 2003. Preparation, ITMA 2003. Journal of Textile and Apparel, Technology and Management, vol 3, issue 3, pp1-10. Autumn, 2003. Available on the web and retrieved 20th August, 2006 from http://www.tx.ncsu.edu/jtatm.click on "View Articles".

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The wet finishing of wool fabrics groups together all of the aqueous based processes so that, in principle, the fabric needs to be dried only once. The objects of wet finishing are to remove the contaminants from the wool fabrics, and to relax any latent stresses and strains in the fabrics. Certain fabrics may need to be shrinkproofed to achieve machine washability.
Wet finishing processes include scouring, crabbing, carbonising, milling, shrinkproofing, bleaching and dyeing. The finished wet fabric is then scutched, hydroextracted and dried.

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Glossary of terms

Back-rolling	The removal of creases and running marks from rope dyed fabrics.
Bleaching	The application of selected chemicals to increase the whiteness of wool fabrics.
Burling	The removal of imperfections.
Carbonising	The removal of vegetable matter from the wool fabric.
Crabbing	A pre-setting process used to impart the required amount of flat set in wool fabrics.
Fulling	An alternative term for milling.
Hydroextraction	The application of mechanical force, or centrifugal force, or suction, to remove liquid water from fabrics.
Mending	The insertion of yarn into a woven fabric where the warp or weft is missing and also the correction of other faults by means of needlework.
Milling	The application of mechanical action to cause the required amount of fibre migration in wool fabrics.
Perching	An inspection process used to identify faults in the finished fabric.
Saponification	The reaction between fats and oils with KOH or NaOH to produce soap.
Scouring	The removal of contaminants from the fabric by a washing process.
Scutching	A process used to convert fabric in rope form to fabric in open width.
Shrinkproofing	The application of chemical and/or polymer treatments to wool fabrics to prevent felting shrinkage.

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