Wool Shrinkage and its Prevention

RAMGOPAL H. MEHRA*

Introduction:

WHEN woollen goods are washed, there is a very considerable reduction in area, which is commonly termed shrinkage and indeed it may be said that the great defect of wool in popular opinion is associated with this shrinkage. The diminution of area on laundering can occur due to two types of shrinkages. Firstly, it may shrink as a result of relaxation of tensions which are developed during processing of fibre, yarn and fabric. Secondly, it may shrink as a result of the tendency of the fibre to migrate and form a dense, interlocking, matted structure. The first is known as "*relaxation shrinkage*", and the second as "*felting or milling shrinkage*". But the consumer, the ultimate purchaser of a wool fabric, will be concerned only with the total shrinkage of his garment or cloth during washing and wearing. It will not interest him very greatly to be told that shrinkage undergone by the garment or cloth is due solely to relaxation and not at all to felting and *vice versa.* Although once a garment has been washed the relaxation shrinkage is usually completed and no further shrinkage due to relaxation will take place on subsequent washing; the shrinkage due to felting will become progressively worse with repeated washing.

Causes of relaxation shrinkage:

All fibres when wetted, swell and increase in length. Some fibres increase very greatly in diameter; and quite significantly in length, and the wool fibre is typical of these. But it does not follow, however, that yarns and fabrics made from these fibres will also extend when wetted. Relaxation shrinkage can arise out of three different causes given below:

(a) Wool and all other textile fibres have a strong tendency to imbibe water when wetted, and the water thus absorbed into their interior distends their fine structure. Now the yarn may be so highly twisted that the fibres assume the form of helices which makes a considerable angle to the long axis of the yarn. In such cases one fibre may be wrapped round several others and when they are wetted there is such a great increase in the diameter of the fibres that although the length of each fibre increases slightly, this increase is not sufficient to meet the greater length required by swollen helix so that the helix as a whole contracts. Consequently, the yarn contracts or shrinks.

(b) Fabric is knitted or woven from yarn that is under tension. When such a fabric is wetted it "relaxes" i.e. the tension is lost and the fabric suffers a "Relaxation Shrinkage". It occurs not only with wool but with other fibres and is quite separate and distinct from felting shrinkage.

(c) Sometimes when a fabric is finished, the finisher is instructed to finish it to a width and/or length greater than it had in the raw state. The reason is obvious; fabric is sold by the yard not by the pound, and if it is stretched there is more fabric to sell. And so, such fabric when wetted as in the first washing, relaxes and shrinks very considerably.

Prevention of relaxation shrinkages:

Whilst normally, proper control of weaving, knitting and finishing conditions

*Research Student, Textile Chemistry Section.

will ensure that the shrinkage due to relaxation on wetting a garment or fabric is only small, devices have been suggested and practised whereby it can still further be reduced or even eliminated altogether.

The London shrinkage process is probably the best known treatment involving the use of cold water and, as originally carried out, consists in folding the cloth in layers between dampened wrappings and allowing it to stand for a certain number of days according to the amount of potential relaxation present in the material. The modern method, however, accelerates the process by impregnating the wrapper with water on a damping machine in the usual manner by rubber bowls, and then winding the wrapper, together with the wool cloth to be damped, on to a roller; the machine is then reversed and the damped cloth is packed and allowed to stand for sometime before passing on to the hanging drier. The drying operation after the London shrinkage is carried out on a hanging frame from which the cloth is suspended in loops or folds by laths or poles.

Steaming methods have been devised to expedite the relaxation shrinkage and one of the simplest of these is to blow hot steam into the fabric until it is thoroughly wet, after which it is plaited down and allowed to cool. Wool fabrics may also be steamed on cylinders, plaited down, and allowed to cool before drying on a festoon drier. The open steaming method is preferable for heavy cloths, napped goods, and pile fabrics, but the cylinder method is better for suitings, tweeds and similar cloths.

Pre-relaxation shrinkage control or compressive shrinkage methods have also been applied to wool. Wrigley, Melville, and Kellet, in B.P. 529,579 (1940), have described a process which would reduce relaxation shrinkage but not felting shrinkage. Fabric is passed between two pairs of nip rollers, the first pair going slightly faster than the second pair. The fabric shrunk a little to accommodate itself to the lower speed of the output rollers. It was necessary for the nip to cover the whole width of the fabric, which advantageously, could be damped or steamed in its passage between the two nips. As a result of this treatment, the fabric becomes heavier and denser, with a substantial increase in elasticity. Purely as a new finish, the effect is interesting and valuable. On account of the comprehensive shrinkage in the direction of the length of the fabric, the tendency to shrink in length by felting during washing is eliminated or very substantially reduced; but the process does not prevent felting and shrinkage in the weft direction.

Felting shrinkage and its causes:

The other type of shrinkage, which has been referred to earlier, is felting shrinkage or milling shrinkage. Actually, this type of shrinkage is more important and will be considered in greater detail. Felting shrinkage arises due to the inherent property of wool and other hair fibres which is termed as "Felting". By felting we mean that property of ordinary wool which causes the individual fibres to close upon each other during washing or similar treatment in aqueous liquors in which wool material is repeatedly squeezed or rubbed, so that the material becomes denser and more compact, and undergoes an irreversible decrease in area. Feltability is a highly valued property that is peculiar to wool and hair fibres; many wollen clothes are deliberately felted by the milling process. Nevertheless, there are multitudes of purposes to which wool is put for, in which felting and shrinking tendencies are neither required nor desired, where they become a source of considerable inconvenience, discomfort and loss.

The "Felting" of wool has been explained from time to time in terms of various theories and explanations. It appears to have been suggested by Youatt that the actual fibre shortens and telescopes itself under the influence of moisture. Ditzel, however, milled some wool fibres, and noticed that if the wool fibre is rubbed between finger and thumb in the direction of its length, then it travels in the direction of its root; this is because all the scales project towards the top of the fibre and oppose motion in that direction. The fundamental cause of felting was discovered by Monge in 1790, who found that during felting the wool hairs always migrate in the direction of their root ends. He attributed this tendency to their imbricated surface. Shorter has drawn attention to the fact that the wool fabric is a collection of "self-tightening mechanisms", for, each fibre in the cloth will have places of tight and loose entanglement. Hence, fibre travel will diminish the distance between the entanglements by drawing them together if the scales are properly orientated. If it should happen that the scale structure is not directed so as to draw the entanglements together, then they should be moved apart and extend the fabric. However, the lack of rigidity prevents this, so the fibre loops and so forms further entanglements with other fibres as felting proceeds, and it contracts or shrinks as a result. Scholfield suggested that change in porosity is the primary factor in cloth felting. Justin Mueller considers that the epithelial scales play no part in felting, nor does the crimp of the wool. He assumes that each fibre is covered by a layer of protein substance which he terms protogel, and that this substance becomes gelatinous during the felting process, causing the fibres to adhere together and so become matted. It cannot be said that this view has found many supporters. These and many other theories of felting are recorded in literature.

Whatever theory is held about the cause of wool felting, it is now generally accepted that peculiar unidirectional roughness of the epithelial scales, which cover each wool fibre, plays an important part. And if we examine the surface a wool fibre, we find that it consists of overlapping scales such that when fibre is rubbed from tip-to-root, it is about twice as rough as when rubbed from the root towards tip. And this has been termed "Directional Frictional Effect" or "D.F.E.". There is now considerable evidence to show that ease, with which wool materials felt and shrink in washing is approximately proportional to the "D.F.E.". In some cases it has been shown that a satisfactory process for making wool non-felting leaves the fibre rougher than before the treatment. But there is an important change that the difference between the roughness in the two directions has been reduced. Any treatment which can change a wool so as to make it more equally rough or smooth in the root-to-tip and tip-to-root directions is likely to reduce the felting power. Other factor which causes felting is agitation. Nothing contributes so much to felting as agitating and working the wool. The last factor which is responsible for felting is the presence of moisture. The dry fibres will not felt at all.

Recently, Speakman has shown that felting is due to the breakdown of disulphide bonds in wool. He has also shown that any process which leads to the breakdown of disulphide bonds in wool results in non-shrinkage of wool, although the scale structure has not changed much.

Prevention of felting or milling shrinkage:

The only way to prevent felting or milling shrinkage is to reduce or take away the inherent felting properties of wool. In recent years, very intensive research has been given to this problem, although somewhat crude methods have been known for over fifty years for making wool non-felting and thus unshrinkable. The objection to these early methods is that they also impoverish the wool. Therefore, it is apparent that the problem to be faced in the chemical treatment of wool is to alter the surface frictional properties of the fibre, without at the same time impairing the other desirable properties such as strength, elasticity, hand, etc.

The shrinkage prevention and shrinkage control processes that have been used commercially fall into four main classes :

1. Various oxidation and chlorination processes.
2. Enzymatic processes.
3. Solvent processes.
4. Resin processes.

1. *Various oxidation processes:*

There are a number of oxidation processes available, possibly we should consider only those that have been used on large production lots. Most of these processes involve the use of chlorine and are referred to as " chlorination " processes. A recent survey of literature indicates that about sixty processes have been described for the production of shrink-resistant wool and of these about half involve the use of chlorine. Such a large number of chlorination processes suggests that wool can be treated under a great variety of conditions.

The wet chlorination with hypochlorite is carried out usually in the presence of an acid. Briefly, when wool is steeped for about 30 minutes in an acidified solution of hypochlorite, it loses its power of felting or milling. Chlorination takes place so quickly that it is difficult to obtain a uniform effect ; two alternative methods have been devised to obviate this defect. In the first, the fabric is run on a winch machine and the chlorine liquor is added at intervals. In the second, a large volume of liquor is prepared and the fabric is immersed in this and agitated rapidly. It is usual to employ 2% to 5% of active chlorine calculated on the weight of wool. At the end of the process, the goods are washed with water, and then treated with a dilute solution of sodium bisulphite to destroy any residual chlorine, followed by a final rinsing process. The antichloring treatment with sodium sulphite or bisulphite solution can improve the non-felting effect beyond that produced by chlorination.

The essential weakness of this and many other wet chlorination processes, arises from the speed with which chlorine reacts with wool in the presence of an acid. Chlorination is accompanied by some damage to the wool, so that in commercial practice, it is customary to carry out the action only to the stage where the wool has lost most of its tendency to felt, without being unduly impoverished. Generally, if the treatment is taken to that point where zero shrinkage is attained, then the wool is definitely damaged in subsequent washing treatments. The wool becomes yellow, and possesses a harsh feel in the dry state and sometime there is a loss of elasticity. Over-chlorination does not only lead to a loss in weight of the material, but it is possible to exceed the limit of zero shrinkage, where the wool does not shrink, but actually extends in area on washing. Thus, it is highly desirable that the unshrinkable treatment, such as aqueous chlorination, should proceed slowly enough to enable a uniform treatment to be obtained. Therefore most of the latter processes of chlorination are aimed at a more stringent control of the treatment, and it is in this respect, the method in which they achieve control, that most of the new chlorination processes differ. Some of the techniques to achieve control are—by pH adjustment, dilution, slow addition of hypochlorite solutions, use of other weak organic acids and so on.

In "Negafel" process, control is achieved by ensuring slow chlorination. The use is made of formic acid, instead of the usual sulphuric acid for acidifying the sodium hypochlorite solutions. In this process, the wool material is treated with a solution of sodium hypochlorite to which suitable amount of formic acid has been added. The process is generally carried out between 5°C and 10°C, and the total amount of available chlorine varies according to the type of wool. The treated wool maintains its weight and has good wearing properties, being practically free from chemical damage and possessing good colour. The "Hypak" process is based on the addition of certain organic compounds to the hypochlorite liquors. These organic compounds are intended to absorb the chlorine which is liberated on acidification, and then slowly deliver it to the wool, so that the aggressive action of the chlorine is decreased. Other methods for slowing down the absorption of active chlorine include the use of substances such as para-toluene sulpho-dichloramide (also known as PERAKTIVIN and DICHLORAMINE T), para-toluene sulphomonochloramide (known as AKTIVIN), and also chloramines have been recommended. Another line of approach to the problem has brought out the chlorination treatment in non-aqueous solvents. The use of chlorine in an inert solvent has been suggested by E. R. Trotman. Another patent describes the treatment of wool with organic hypochlorites of which tertiary butyl hypochlorite and tertiary amyl hypochlroite are preferred.

Very good control has been achieved by the use of gaseous chlorine also. Dry chlorination was discovered in the laboratories of the Wool Industries Research Association (W.I.R.A.) at Toridon. By this process, wool materials first conditioned so as to have a moisture regain of about 8 per cent, are placed within a closed chamber or autoclave which is then evacuated of all its air content. Then controlled amount of chlorine gas is admitted, which reacts with the wool for about half to one hour at room temperature. Residual chlorine is then pushed out by pumping in dry air and the chlorinated wool goods are then taken out and washed free from chlorine. This process may be assisted by using sodium bisulphite as an antichlor. If the conditions have been correctly controlled then the wool materials are left nearly non-felting and unshrinkable, yet without suffering any appreciable damage.

One of the most important advances in the production of non-felting and unshrinkable wool has been outlined by A. J. Hall. The process has been protected by a series of patents under the name of "DRI-SOL" process. It consists in immersing air dry wool goods for one hour at room temperature in a 2% solution of sulphuryl chloride in white spirit. The residual liquor is then hydro-extracted and wool quickly washed free from residual white spirit and sulphuryl chloride. At first, it was believed that this process was based on the hydrolysis of sulphuryl chloride by the moisture present in the wool, so that the nascent sulphuric acid and hydrochloric acid were produced, and that these acids parchmentised the scale edges or otherwise reduced their roughness, but recent resarch has indicated that sulphuryl chloride acts by chlorinating the wool.

2. *Enzyme Processes:*

Biochemical methods are capable of producing non-felting wool by utilising proteolytic enzymes. Papain and Tripsin are the two enzymes which have been used commercially. Papain, the dried juice of the papaya-tree, is employed with an addition of a small proportion of sodium bisulphite, since this substance assists the reaction. By operating the reaction at around 70°C, wool goods can be made completely unshrinkable. An interesting additional effect of the treatment is the bleaching produced at the same time as unshrinkability results and although the process is still used to some extent in England, it has not been used to any extent in U.S.A., since the loss in weight of the wool substance in comparison with the degree of shrinkage control accomplished is excessive.

3. *Solvent Processes:*

The Alcoholic—Alkali process, developed in the research laboratory of Freney and Lipson, involves the treatment of wool with alkali under such conditions that only surface structure of the wool fibre is attacked and altered to eliminate felting. In the atcual process, caustic potash is dissolved in water and diluted with methylated spirit containing glycerine, the object of which is to avoid dark reddish-brown coloration which appears in its absence. The wool material is run through this liquor, so that the immersion of the wool in the liquor is only for 75 seconds. After this, the wool is squeezed and passed into a second bath containing sulphuric acid and methylated spirit, and after which the material is passed through a third bath containing continuously flowing fresh water. The degree of control obtained is good in this but unless the procedure is carefully controlled, it tends to damage the wool and impart a harsh handle. However, the biggest objection from the mill viewpoint to this method is the use of solvents and unless an expensive solvent recovery system is installed, the cost of the treatment is much too great for commercial use. Hence, this process will be more suited to finer goods on account of, the mild nature of the treatment and reduces the possibility of interference with the quality of wool.

4. *Resin Processes:*

These processes originated with a view that the simple coating of a wool fibre with sufficient resin or ether film-forming substances so as to cover up the protruding scale edges, will make the wool less liable to felt and shrink. One type involves the use of thermo-plastic rubber-like compounds which require no cure and which are applied on a padder in the form of aqueous dispersions. Control is excellent but they have found limited use because of the objectionable hand produced, and of the ageing properties of resins. Then the attention was turned towards the thermo-setting resins, and several types of resin treatments are in current use to make wool non-felting. Urea-formaldehyde resin was employed, but it was found unsuitable, for it produced a harsh feel. Melamine-formaldehyde was an improvement over this. But now LANASET process is introduced in which resins formed from melamine methylol methyl ethers could be very effective. In this process wool fabric is impregnated with a solution of methyl melamine methylol ether and is then dried and baked at around 150°C for 3 to 5 minutes so as to insolubilise and stabilise the melamine methylol methyl ether resin. If the application of the resin is not controlled, it produces a harsh feel. Controlled treatment reduces felting and gives good results which will withstand repeated laundering.

Recently, in B.P. 727,660, British Industrial Plastics, Ltd. claim a number of advantages for a wool antifelt process of the type employing amino-plastic resins. The process is characterised by the introduction into the woollen material of an amino-plastic resin from a hot acidic aqueous solution of the resin—forming components at 80°C until wool has taken up and fixed the desired amount of the resin. Excess liquor is removed by hydro-extraction or mangling and is dried without washing. After drying, the final heat treatment may be given.

In conclusion, it may be said that the wool which has been processed to make it shrink-resistant will stand a good deal of knocking about before it felts, but it should be remembered that the best of shrink-resistant wools still have some potential shrinkage in them. So care should be exercised to give them no more agitation than is necessary.

BIBLIOGRAPHY :

1. Alexander, P. and Hudson, R. F., "Wool : its Chemistry and Physics", Chapman and Hall, London, 1954.
2. Hall, A. J., "A Handbook of Textile Finishing", The National Trade Press Ltd., London, 1952.
3. Moncrieff, R. W., "Wool Shrinkage and its Prevention", The National Trade Press Ltd., London, 1953.
4. Marsh, J. T., "An Introduction to Textile Finishing", Chapman and Hall Ltd., London, 1948.
5. Matthews, "Textile Fibres", Sixth Edition, Chapman and Hall Ltd., London, 1954.
6. Trotman, S. R. and Trotman, E. R. "The Bleaching, Dyeing and Chemical Technology of Textile Fibres", second edition, Charles, Griffin and Co. Ltd., London, 1946.

REFERENCES :

1. Anon., **The Dyer**, 1955, **114**, 767.
2. Frishman, D. and Harris Milton, **Amer.Dyestuff Rep.**, 1954, **43**, 174.
3. Murphy, F. A., **ibid.**, 1954, **43**, 469.
4. Stanfield, Jubilee issue of **J.S.D.C.**, 1934, 166.
5. Warner, J. F., **Amer.Dyestuff Rep.**, 1954, **43**, 726.