Response of Cotton Fibres to Anticrease Chemical Finish—
A Varietal Study by X-Ray Diffraction Method*

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A technique based on the principles of X-ray diffraction has been developed for assessing the response of cotton fibres to easy-care finish. The method is useful for varietal screening of cotton fibres. Out of 26 cotton samples tested by this method, the tensile strength of three samples (B-1007, SB-289 and SB-1085-6E) was found to increase as a result of treatment with an anticrease finishing chemical.

Whenever cotton fabrics have been treated with formaldehyde or any other crease-proofing chemical, loss in tensile strength has been observed.† Until recently, chemical technology had been tackling this problem by producing improved anticrease chemicals, but it is now clear that further progress in this direction is likely to be limited. Thus, it is felt that the problem of improving the tensile strength of easy-care fibres may be better taken up by the breeders. In this approach, the breeder has to screen the existing cotton varieties in order to breed new varieties, which, while possessing high strengths, may be better suited to withstand anticrease finish with less reduction in strength. As yet no detailed study of the varietal response of cotton fibres to chemical finishing, with special reference to the loss of strength on treatment, has been carried out by the X-ray diffraction technique, which is a potential tool for fibre structure investigation. We considered it worthwhile to take up a varietal study of cotton fibres with reference to the loss of strength due to anticrease finishing treatments by the X-ray diffraction method. In the present study, the crystallite orientation in fibres as measured by the 40% X-ray angle was taken as an index to study the effect of formaldehyde treatment on the fibres.

Materials and Methods

For the present study, 26 cotton samples were taken; of these, eight were hybrids and the rest were pure varieties (Table 1). All the samples were tested for tensile strength using the Pressley strength tester. The samples were then treated identically with formaldehyde at 60% resin pickup to impart anticrease finish, by the pad-dry-cure process*. They were tested in the Pressley tester for tensile strength. All the untreated samples and ten of the resin-treated samples, selected from different strength groups, were chosen for X-ray diffraction analysis. X-ray diffraction patterns of parallel fibre bundles were taken using X-rays produced by Philips X-ray generator PW 1010 operating at 30 kV and 20 mA, and a Philips universal flat plate camera at a distance of 4 cm from the fibre sample. An exposure time of 30 min was found to be suitable for intensity measurements. Azimuthal intensity scans of the 002 reflection of the fibre patterns were made using an integrating microdensitometer type GN2 (Barr & Stroud, London) equipped with a rotating stage.

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From the normalized relative intensity curves, the angle corresponding to 40% of the maximum intensity was determined as a measure of the crystallite orientation within the fibre.

Results and Discussion

The 40% angles of the cotton samples, before and after resin treatment, are presented in Table 1. It is seen that out of the 26 cotton samples treated with formaldehyde, the Pressley strengths of 23 decreased substantially on treatment. Three samples (B-1007, SB-289 and SB-1085-6E), however, showed increase in strength on resin treatment. The 40% X-ray angles of these three samples were found to have decreased after formaldehyde treatment, whereas in the case of the seven other treated samples subjected to X-ray analysis, the 40% X-ray angles were found to have increased (Table 1). This confirms the results of the mechanical tests.

As per Bueche’s molecular model explaining the effect of crosslinking due to resin treatment on the tensile strength of polymers, crosslinking in native cotton fibres is believed to have imparted the maximum increase in strength possible, so that any further addition of crosslinks is postulated to always lower the strength. The results of our study, wherein three out of 26 cotton samples have shown increase in strength on formaldehyde treatment, indicate that this may not be the case always and that cotton may be produced below the maximum crosslinked state, which may be either due to the genetic factors or due to environmental interactions or due to both acting simultaneously. This indicates that a thorough screening of cotton samples may be beneficial in discovering fibres better suited to withstand anticrease treatments.

To explain the change in crystallite orientation with resin treatment, the following molecular model of the cotton fibre is proposed. During formaldehyde treatment, crosslinking occurs and covalent bonds are formed, some of them replacing the weaker inter- and intra-crystallite hydrogen bonds, as per the generally accepted crosslinking theories. Also, the amorphous regions in between the crystallites are crosslinked, causing these 'hinges' to be immobilized. This causes the crystallites to be reoriented, bringing about a change in the orientation angle as measured by the 40% X-ray angle.

At this point, it is natural to ask why in certain cases the angle decreased on resin treatment, whereas in other cases it increased. Since the mechanism of this process is not readily found in the existing literature, we have tried to explain this mechanism tentatively as follows. Whenever the crystallites within a fibre are larger in size (higher DP) than the average, there is much less space for the crystallites to be accommodated laterally within a growth layer of the secondary wall of the fibre than when the crystallites are smaller. Thus, when covalent bonds are formed due to formaldehyde treatment, though the reorientation should, in general, be random, in the case of larger crystallites, the possibility of alignment towards the fibre axis is greater, since there is no room in the layer for more crystallites to be oriented at a greater angle to the axis. The situation is analogous to a number of long rods in a tube. When the rods are shaken thoroughly, the longer rods will tend to align along the tube length more easily, as they cannot be accommodated transversely. But in the case of rods shorter than the diameter of the tube, the shaking will result in higher random arrangements. Thus, when the crystallite size is small, crosslinking causes random reorientation owing to the greater degree of mobility of the smaller crystallites.

Our results fit in well with the model proposed by Krassig and Kitchen, wherein the relation

Tensile strength \( \propto \) (degree of polymerization \( \times \) degree of crystallinity \( \times \) degree of orientation)

has been derived and verified experimentally. The cases where the orientation angle increased on resin treatment correspond to losses in tensile strength, and the cases where the angle decreased correspond to increase in tensile strength on treatment. Since the degree of polymerization remains unaltered by the formaldehyde treatment and the degree of crystallinity changes a little, the tensile strength becomes directly proportional to the degree of orientation.

Thus, since it is found that the 40% angle of cotton fibres changes with formaldehyde treatment corresponding to a change in tensile strength, the X-ray diffraction method may be employed to supplement the existing methods of strength testing to screen cotton varieties to find out the ones which can withstand anticrease treatment with minimum losses in strength.

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