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MECHANISM OF FIBRE TENSTON THROUGH MICROSCOPIG INVESTIGATION

BY

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ABSTRACT

Cotton morphology and mechanism of fibre tension was assessed by making use of light microscopy. In essence, a solution was prepared consisting of Z_nCl_2 (100 g), KI(32 g), water(34 ml) and I_2(till saturation). This solution was used asa swelling agent for cotton during microscopic examination. It was found that the primary wall takes a spiral shape, a spherical shape, or combination of both whereas the secondary wall appears as beads. The shape and size of both primary and secondary wall depend upon the history of the fibre before swelling. When this fibre is subjected to the tensile load, the initial spiral is straightened upon increasing the load. Futher increase in the load causes breakage of straightend spiral (primary wall). There after the secondary wall has to stand the load alone till the latter is sufficient enough to break the secondary wall.

INTRODUCTION

Morphology of cotton fibre represents the manner in which the molecules of the fibre arrange them-selves. Hence it is to be expected that in high oriented fibres the molecules are parallel to each other along the longitudinal axis of the fibre.

In low oriented fibres, on the other hand, the molecules may be arranged at random. Consequently the fibre morphology has a significant effect on the physical properties of fibres such as strength and ductility. In order to understand the mechanism of fibre tension and to get more information about what happens when a fibre breaks, the pressnt state of knowledge concerning the fibre morphology is reported below. Figure 1, shows schematic diagram of the cotton fibre given by Summer (1), showing the majour structure feature and round shape of fibres.

It is clear that the fibre consists of cuticle, primary wall, winding layer, secondary wall and lumen. The primary wall is the outer skin of the cotton fibre. It consists of a network of cellulose microfibrils randomly interlaced and encrusted with noncellulosic materials. Chemical analysis of the primary wall

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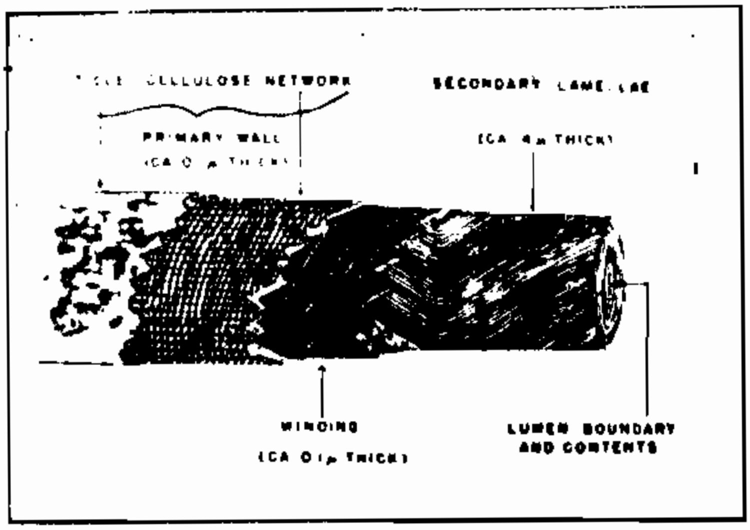

Fig.(1): Schematic diagram of the cotton fibre given by Summer, showing majour structure features and round shape of fibres before, collapse and drying.

Fig. (2): S.E.M. photograph of the cuticle.

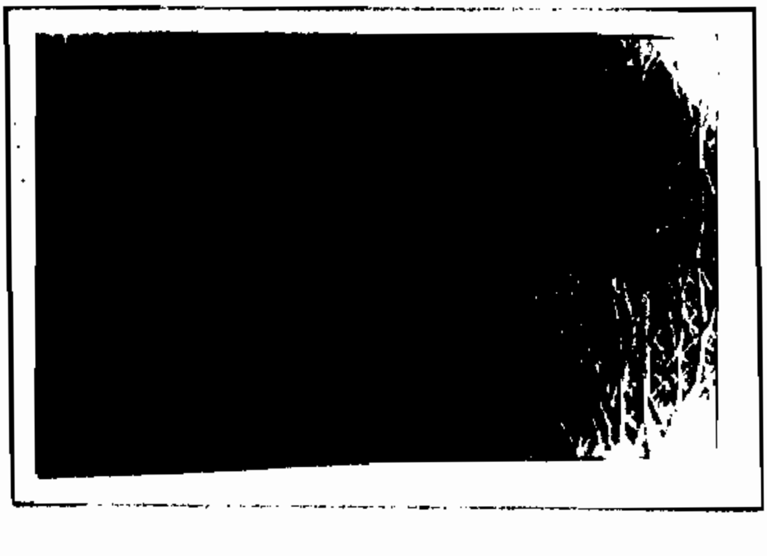

Fig. (3): S.E.M. photograph of the primary wall.

shows about 50% cellulose and contains about 10% pectic material, 10% fatty material, and 15% proteinaceous material (2). The cuticle is believed to be a continuous sheet of waxy material covering the whole fibre as can be seenfrom Fig. 2. The cuticle and the primary wall are usually indistinguishable in microscopical observations. Fibrils on the outer face of the speciman appear to lie more or less parallel to the fibre axis whereas those at the lower level lie at various angles to the fihre axis. It has been suggested that the arrangment parallel to the axis is the result of tension developed during the longitudinal growth of the fibre as shown in Fig. 3. Upon swelling in chemical reagents, individual microfibrils increase in diameter and shorten (cf. Figs. 4, 5 and 6). It is obvious from these photographs that the net effect of this phenomenon is shrinkage of the primary wall sleeve into a constricting casing around the fibre.

The first layer of the secondary wall deposited inside the netlike primary wall of the cotton fibre referred to as the S-1 layer or "winding layer" of the fibre wall.
It's structure is that of a wide system of bands or tapes lying at a wide angle to the axis of the fibre (cf. Fig. 7). The alignment of this fibrillar system is 45-70° to the fibre axis and the interlacing between the fibrils produced an open "leno weave" pattern.

The main body of the cotton fibre consists of cellulose microfibrils arranged in more or less parallel array pictured in Fig. 8. Current concepts of cellulese structure indicated that microfibrils such as those pictured here aggregates of finer cellulose threads, "elementary" fibrils, those cross-sectional measurements are about 35°A. The elementary fibril is considered to be brittle, needlelike crystal on the face of which regions of elight disorder have cellulose chains availble for reaction.

Interpretation of fibre breakage in dry and wet states has been given by a number of investigators (3-7) According to these investigators, breakage usually occurs adjacent to a reversal zone (3). On initial application of load, deconvolution takes place, and as strain increases there is tendency for the helical arrangment of fibrils to straighten out parallel to the fibre axis, possibly by frequent reversals of spiral direction in the fibre structure.

One or more cracks develop along the spiral angle, propagate, and result in fracture. The details of fracture mechanism are depicted in the model shown in Fig. 9, in which a smooth crack develops at (X) near the interface of zones A and C and runs parallel to the spiral angle through zones B, A and C to (y), again at the inter facs of A and C, and tear occurs irregularly from (y) to (x). In the completely dry state crack propagation occurs less readily, and the crack is more nearly perpendicular to ths fibre axis in the completely wet state fibrils movs and reduce the spiral angle and cause a longer break with fibrils almost parallel to the fibre axis (8).

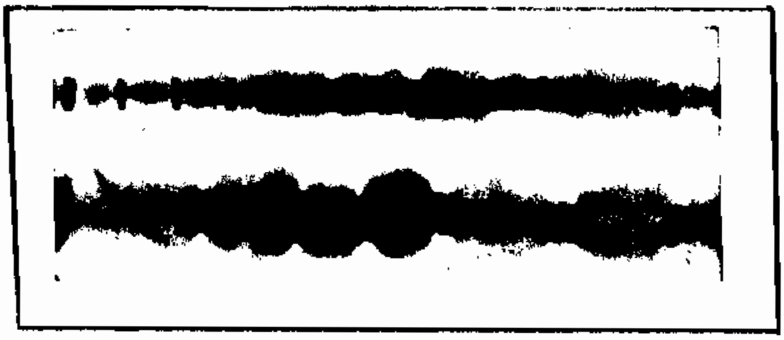

Fig.(4): Longitudinal view of swellen fibre, (spherical swelling).

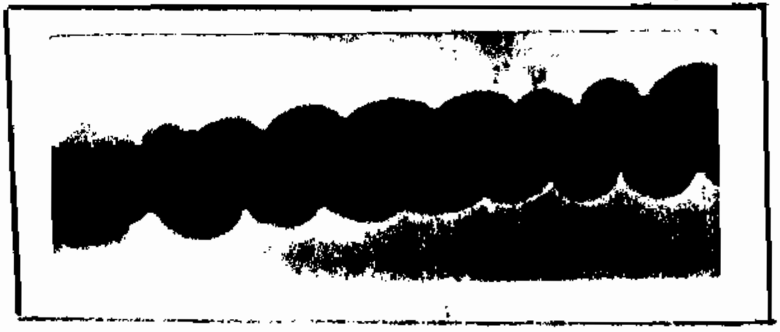

Fig.(5): Longitudinal view of spiral swelling.

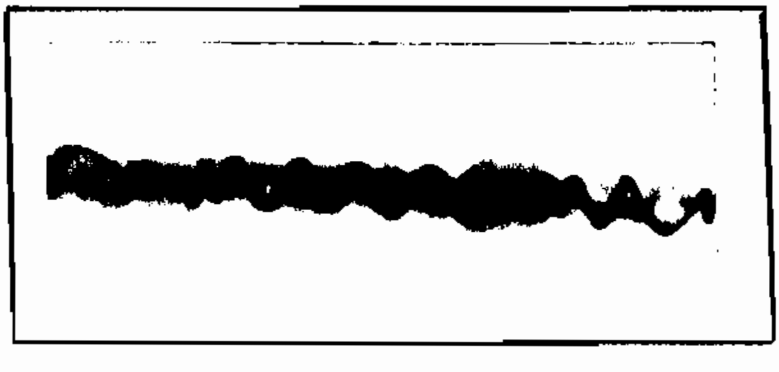

Fig.(6): Longitudinal view of swellen fibre, (combined swelling).

Fig.(7): S.E.M. photograph of the winding layer.

Fig.(8): S.E.M. photograph of the secondary wall.

The primary objective of the present work is to elucidate the mechanism of fibre tension while the fibres are in a swollen state. For this reason cotton fibres were subjected to loads sufficient to break them. After being subjected to such loads, fibres were treated with a swelling agent.

A New Approach For The Mechanism Of Tension

Previous reports (9) have shown that treating a cotton fibre with a swelling agent consisting of Z_nCl_2(100 g), KI (32 g)water (34 ml) and I_2 (till saturation) followed by examination of the swollen fibre by a light microscope produce a particular picture. In the latter the primary wall takes a spiral shape, spherical shape, or combination of both whereas the secondary wall appears as beads. The shape and size of both primary and secondary wall depend upon the history of fibre before swelling.

Figure 10 illustrates a schematic diagram takes a spiral shape. When this fibre is subjected to the tensile load, the inital spiral is straightened upon increasing the load. Further increase in the load would cause breakage of the straightend spiral (primary wall). There-after the secondary wall has to stand the load alone till the latter is sufficient enough to break the secondary wall.

Figures 11 - 13 show longitudinal view of swollen cotton fibres subjected to tension. As can be seen the primary wall was straightened in certain parts of the fibre. This represents the initial stage of the fibre breakage. Fibre breakaga can also be seen where the primary and secondary walls are broken. This validates the mechanism postulated above.

An intresting feature in Figure 14 is the appearance of a cotton fibre that has not been affected by the load. This is seen in the extreme right corner of the figure. In this fibre it is obvious that the primary wall takes a normal spiral shape while the secondary appears as beads. Bearing this feature in mind, it may probably be correct to say that microscopical examination of abundle of cotton fibres after swelling would give useful information about the uniformity of fibre length and their contribution in the tensile strength. That is, the longitudinal view of a fibre in a bundle of fibres that has been subjected to load will differ from that of unimpaired fibre.

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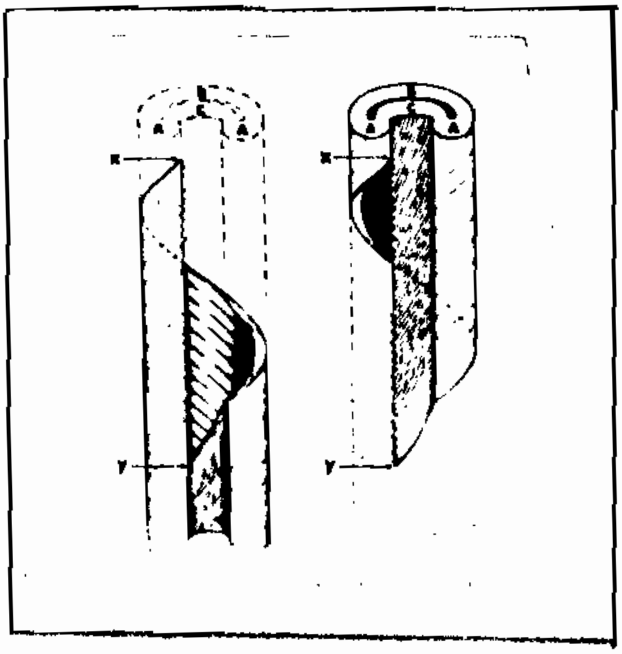

Fig.(9): Model of feature mechanism for the cotton fibre at ambient moisture content.

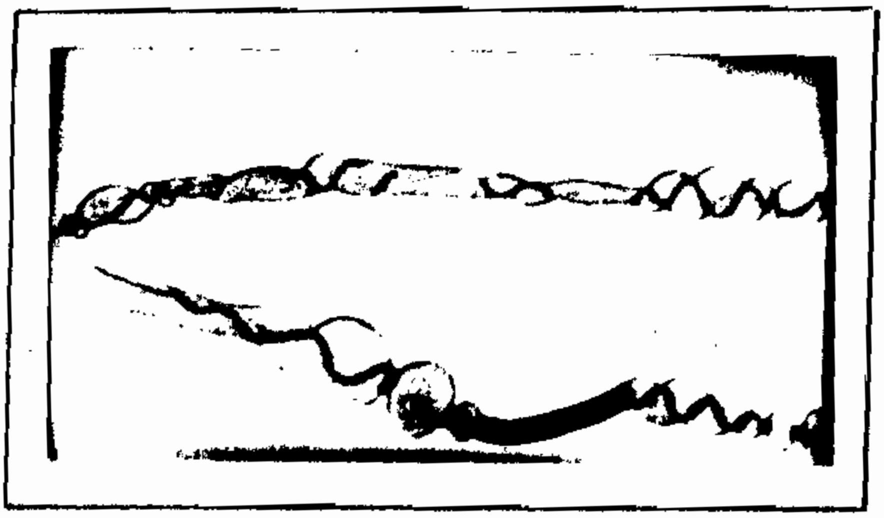

Fig.(10): Schematic diagram showing the various stages for fibre breakage, based on fibre swelling.

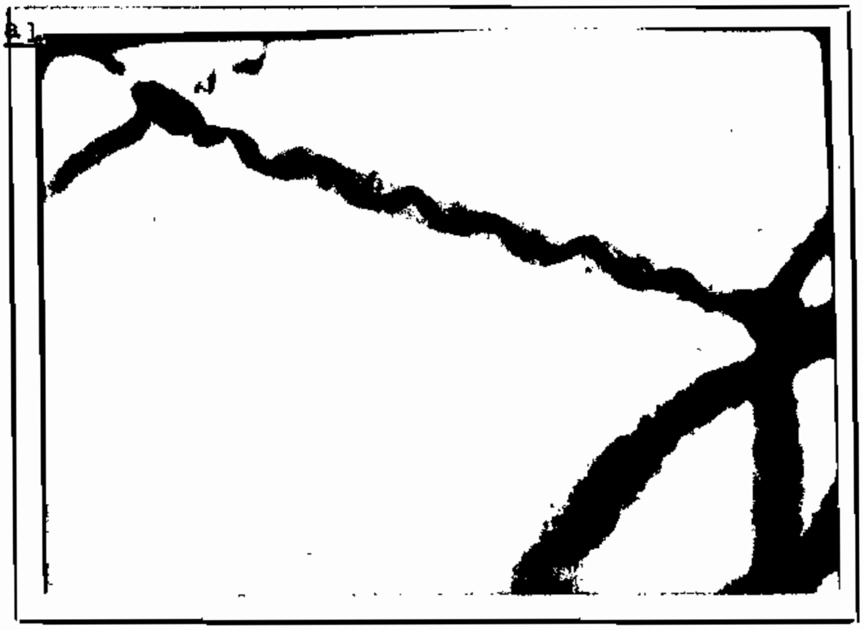

Fig.(11): Longitudinal view of swellen fibres subjected to tension.

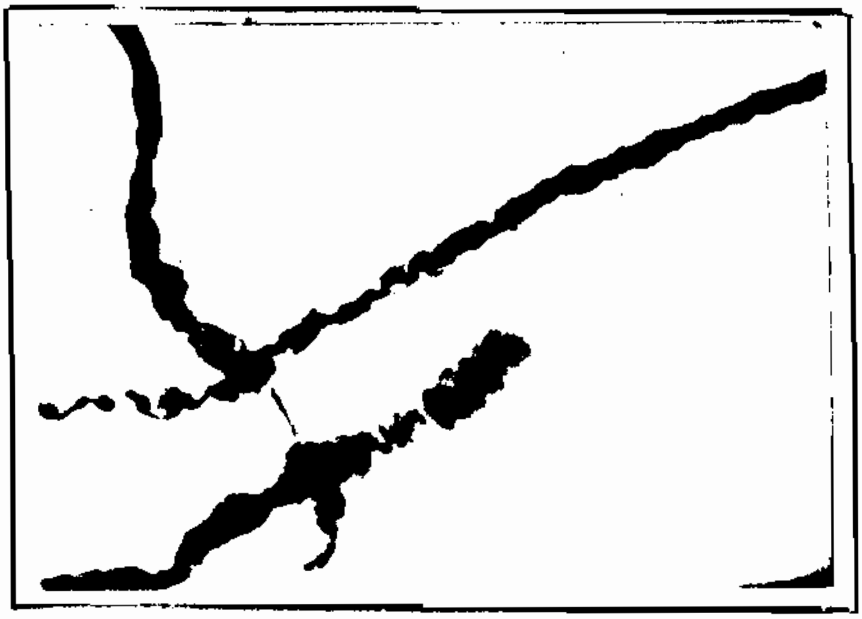

Fig.(12): Longitudinal view of swellen fibres subjected to tension.

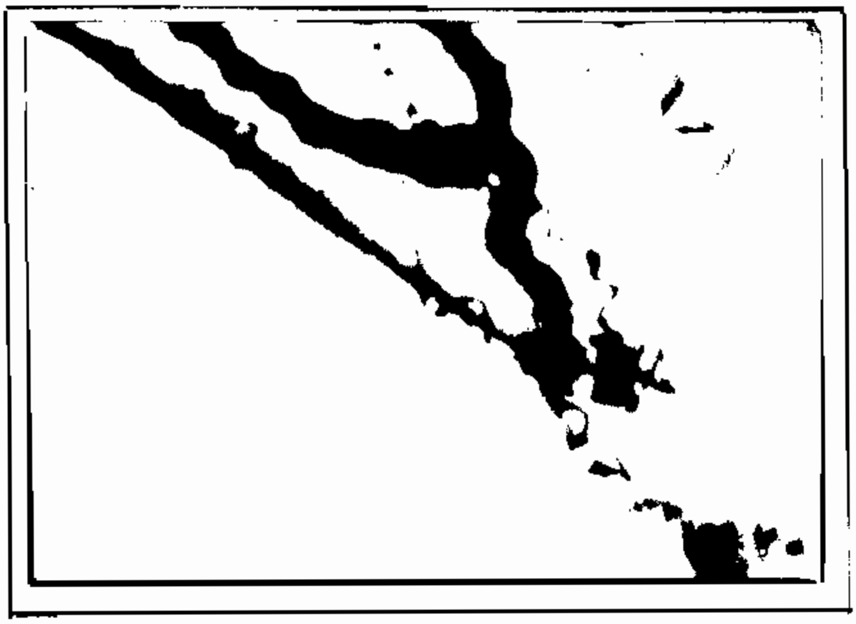

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Fig.(14): Longitudinal view of swellen fibres subjected to tension.

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