Distortion Phenomena in Bast Fibers[1]

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The cell walls of bast fibers consist of concentric layers, which can be compared with concentric tubes that are placed or moved one into the other. The little tubes are composed of more or less spiral fibrils, which form an angle with the central fiber axis. The fibrils appear particularly prominent when they are caused to swell, and they can be separated by mechanical means (colloid mill), as previous tests have shown repeatedly. According to personal measurements on microscopical photos made with monochromatic light and 2,400 linear magnifications, the width of these fibrils or long fibers (in water) has been found to be 0.2 to 0.3μ. Its building steps are the cellulose crystallites, which are ultra-microscopically small and possess a width of 4 to 6 $\mu\mu$ and about ten times that quantity in length.

The fibrils form a firm, adhesive whole, so much so that when the bast fibers are taken from the plant and are dried, they suffer various contortions and on account of their spirality show distortions. Nothing more definite can be said about the cause of these distortions and also about the cellulose crystallites themselves.

In ramie, which was investigated especially, very strong distortions were noted in an air-dry condition, which were increased most likely by the band-like form of the fibers. Bast fibers show differences in their spiral construction, in regard to the angle of the spirals as well as the degree of twist in the corkscrew.[2]

Hemp has an angle of spirality on the outside of 3.6° to the left, inside 1° to the left. In ramie the angles are outside 12.5° to the right, inside 5° to the right. Flax shows an outside angle of 10.1° to the right and inside an angle of 5° to the left. If one calculates on a mean diameter of 30μ the resulting twists on the basis of one meter, with the assumption that the layers in regard to the cross-section are all equal, are the following for the various materials: Hemp, inside 300, outside 600; ramie, inside 2000, outside 2400; flax, inside 400, outside 2200. With hemp the twist is the least, and with ramie very strong, and as for both layers with flax the directions are opposite and inside slight as compared with the outside. Hence, the distortions must be slight with hemp, considerable with ramie, and flax much less.

If the water content is gradually withdrawn the fibers will twist in the direction of their outside spirality and at the return of the water content will untwist in the same relation. This return can also be attained by suspending the fiber freely in a uniform atmosphere and weight the same at one end, gradually increasing the same.

Experiments

For the observation of these distortions with changing humidity a very deep desiccator with annexes on each side was used, the cover of which had a wide opening. On this opening a round metal ring was puttied. A piece of metal with adjustable and sharpened suspension point acted as a cover, on which the test fiber was fastened. For the purpose of weighting, a thin glass rod was fastened at the lower end of the test sample. This glass rod carried four tiny mirrors made from small cover glass strips, which were fastened at the same height all around the glass rod. The reading of the turns was accomplished with a light pointer, which was focused on a transparent cross-section paper which surrounds the desiccator.

Wet filter paper strips or powerful drying agents (phosphor pentoxide) were used. Under these conditions all bast fibers showed torsion phenomena. With increasing dryness the fibers twisted in the direction of their twist of

[1] The experiments described in the following article were completed in 1928.

[2] Botanically with bast fibers almost always a distinction is made between inner and outer layers which in most cases show a different angle of spirals. Furthermore, a distinction is made between structures with a right and with a left turn. "Right turn" in the botanical sense is a turn in which the spiral rises from the lower right forward to the left (also contrary to the customary technical determination).

Reimers (Ang. Botanik, Vol 4, p. 70, 1922 and Mitt. Karlsruher Text. Forsch. Inst., 1922, p. 203) distinguishes three groups:
a Hemp: inside and outside turn to the left.
b Nettle: inside and outside turn to the right.
c Flax: inside to the left, outside to the right.

the outer membranes, and when the moisture was increased the twist would be opposite or untwist. These results are reversible and could be reproduced at will on the same fiber sample as often as desired.

A ramie fiber of 20 cm. length, from a damp condition to complete dryness, gave 30 full revolutions and hence had 150 twists per meter. Flax and hemp always show opposite torsion twists. If simpler or cruder procedures are used like that which A. Herzog[3] describes, the same results are not continually obtainable and one is forced to use the microscopic test method described by him.

As mentioned before, the same object can be attained by holding the atmospheric conditions constant and determine the direction of twist by gradually weighting the fiber in suspended condition and increasing the same. Regarding such experiments C. Steinbrinck[4] has reported extensively. The gradual increase of the weight was accomplished by means of a float in a reagent glass, which was attached to the lower end of the suspended fiber, and the level of the liquid gradually lowered until the desired result was obtained. A definite load corresponded to a definite amount of twist.

The above experiments led to the construction of a simple apparatus for technical purposes, primarily to distinguish hemp from flax, when only long and stretched bunches of fibers were available. The operation of the device can be gleaned from the accompanying illustrations. The fiber is weighted at first with a tiny weight in form of a small disc, to which can be added others. The resulting turns of the fiber are allowed to work themselves out. Then the disc is pressed upward a short distance by means of a spring against another stationary disc and so held firmly and stationary.

The shortening of the clamped distance takes off any tension, without changing the turns or twists of the fiber (Fig. 1). The suspension arrangement can be rotated in a vertical plane (Figs. 2 and 3). By some revolution the upper part can be turned until it locks on the bottom. The upper part has a stationary plate which carries a fiber clamp. The latter consists of a considerably heavier weight and is allowed to glide along an angle in the low position. In this way the fiber is tensioned again and considerably more than before. By an adjustment screw at the foot of the apparatus the fiber strand can be brought into a vertical position and the freely suspended torsion body forces the strand to turn. The clamping distance can be changed by moving the adjustable clamps. With this apparatus the same results can be duplicated any number of times.

By means of the desiccator method it has been tried to obtain the "torsion factor." In place of the simple unweighted glass rod, a similar rod with a torsion body was utilized and the inertia overcome by a body, the specific gravity of which was known. The torsion rod had the shape of a horizontal aluminum rod. The swings were created by two parallel condensator plates inside the desiccator, between which the little rod could swing. By passing charges into the condensator plates with AC current (220 volt), the rod would rotate and turning of fiber would be encouraged or started. After that the plates would be grounded.

For dry ramie the torsion factor was

$$\Phi = 0.8 \times 10^{10} \text{ Dyn/cm}^2$$

In the calculation the band-like character of the ramie fiber was taken into consideration. Since the turning of a fiber in a very dry state might cause difficulty, the torsion factors of rayon filaments were investigated both dry and wet. For this purpose a double-walled pipette was introduced into the desiccator, which surrounded the fiber strand completely. The inner diameter of the pipe was only 6 mm. The jacket of the pipe was filled with oil which could be heated electrically or cold solutions were introduced. The torsion factor of normal viscose gave the following values:

wet room temp.	$\Phi = 0.06 \times 10^{10}$ Dyn/cm²	or F[5] = 6
dry + 110° C	$\Phi = 0.70 \times 10^{10}$ Dyn/cm²	or F = 70
dry room temp.	$\Phi = 1.2 \times 10^{10}$ Dyn/cm²	or F = 122
dry — 65°	$\Phi = 1.7 \times 10^{10}$ Dyn/cm²	or F = 1730
dry — 185°	$\Phi = 6.0 \times 10^{10}$ Dyn/cm²	or F = 6060

[3] Die Untersuchung der Flachs und Hanffaser, Berlin, 1926.
[4] Naturw. 15, 978 (1927).

[5] F in Kg/mm².

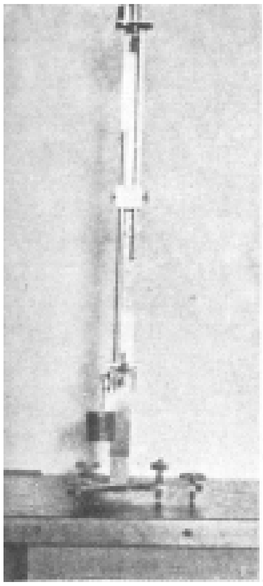

Figure 1

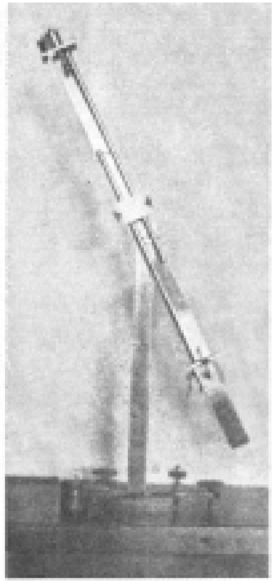

Figure 2

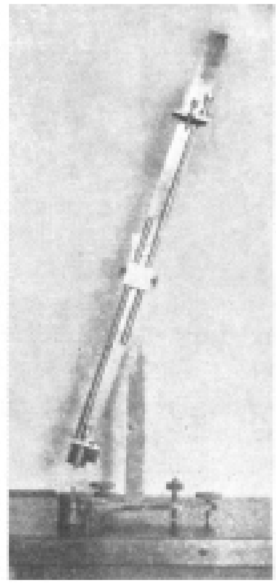

Figure 3

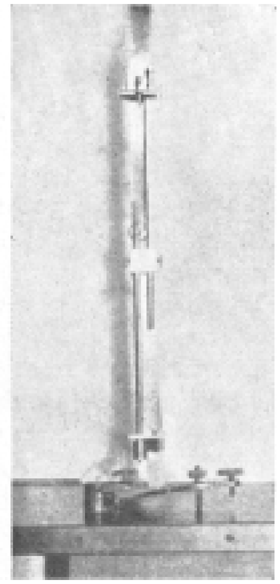

Figure 4

In numerical value the torsion factors of ramie and rayon in dry state at room temperature are identical, except for slight differences.

In every case the torsion factor at room temperature and at normal moisture conditions is very small. Only at the temperature of liquid air does it reach the value of platinum. This finding indicates some relations to the elasticity factor. This value is also very small at room temperature and at normal humidity conditions.