NOTE

What Is the True Spiral Angle in Cotton? Does Solvent Exchange Alter It?

In a recent communication, Moharir[1] used the data reported by Iyer et al.[2] on Hermans' orientation factor f (Ref. 3) and convolution angle (θ) on air-dried and solvent-dried cotton fibers to calculate the average crystallite orientation angle α_m using the relationship

$$f = 1 - 3/2\ \overline{\sin^2 \alpha_m}$$

The convolution angle was then subtracted from α_m such that ($\alpha_m - \theta$) could be regarded as the true spiral angle of the fibrils in cotton. On computing ($\alpha_m - \theta$) and ($\alpha'_m - \theta'$), respectively, for the air-dried and solvent-exchanged fibers, the author found that the latter is generally higher. Based on this observation, he pointed out that the convolution angle in the solvent-dried fiber could have been underestimated or that the solvent-exchange process could have altered the spiral structure. This interpretation appears to be rather simplistic. To understand why ($\alpha'_m - \theta'$) was, in general, higher than ($\alpha_m - \theta$), a closer look at the spiral structure seems to be necessary. The present communication intends to accomplish this.

The author's observation[1] that ($\alpha_m - \theta$) works out to be lower than ($\alpha'_m - \theta'$) is not a revelation following from the use of α_m in place of the 50% X-ray angle (ψ). An examination of the values in columns 3 and 6 in Table I will show that in 18 cases out of 21 ($\psi - \theta$) is found to be lower than ($\psi' - \theta'$). Thus, the anomaly in the spirality of solvent-dried and air-dried fibers was already evident from our original data. However, we did not proceed to highlight this aspect for two reasons: First, our interest was only to demonstrate that the range of the true spiral angle in different varieties is lower for the solvent-dried fibers than for the air-dried. The actual values of the spiral angle were not intended to be discussed and the range, indeed, reduced from 7.71° to 4.77° (see Table I). This is equally true for α_m and α'_m, where the range reduced from 6.69° to 2.95°. In other words, physical removal of convolutions reduces the spread in the mean orientation angle among varieties in a remarkable way. Second, it appeared inappropriate to compare the nett spiral angle in solvent-dried and air-dried cotton as air-drying would produce geometrical and structural changes in the fiber. In accordance with the constant pitch model[4] of cotton fiber, a reduction in diameter of the fiber resulting from air-drying should cause a decrease in the average spiral angle of the fibrils. On the other hand, in the solvent-dried fiber in which the structure is preserved, the fiber diameter and spiral angle should remain undiminished.

Moharir, while attempting to reinterpret our results, hasten to equate the nett spiral angle in a preserved structure (solvent-exchanged fiber) with the spiral angle in a structure that has been allowed to change on account of desiccation. ($\alpha_m - \theta$) can never be equal to ($\alpha'_m - \theta'$), as removal of moisture should be expected to reduce the measured value of α_m in two ways: One is the geometrical effect following from the lateral shrinkage of the fiber as discussed in the last paragraph. The other is the coming together or compacting of elementary fibrils and their alignment closer to the axis of the helix when the fiber is desiccated. Measurement on fibers in the never-dried state have shown that fibrillar aggregation is almost absent in turgid fibers.[5,6] Aggregation during drying could result in nett improvement in the molecular (b-axis) orientation with respect to the direction of the helix. In other words, the compacting effect produced during drying does not seem to be fully annulled by removal of convolution. Hence, orientation of crystallites in the never-dried state could be more random than in the air-dried fibers from which the effect of convolution has been removed by substracting the convolution angle from α_m. Thus, whereas solvent exchange preserves the never-dried state, the true spiral angle for the air-dried cotton could be less than that for the solvent-dried fibers.

Deduction of α_m from f was attempted by Moharir with the presumption that it would be a more rational orientation angle than ψ, from which the convolution angle could be subtracted to arrive at the true spiral angle in cotton. However, this is perhaps not quite true, as would be evident from Figure 1, in which ($\psi - \psi'$) and ($\alpha_m - \alpha'_m$) are plotted against ($\theta - \theta'$). It is seen that ($\psi - \psi'$) is much closer to the equality line than is ($\alpha_m - \alpha'_m$). In other words, ($\psi - \psi'$) would be a truer representation of changes in the convolution angle. A modal angle such as ψ would thus appear to be a better choice than the average orientation angle α_m if the true spiral angle is to be obtained by subtraction of the convolution angle.

We would like to emphasize that there is no direct way of measuring the spiral angle in the turgid convolution-free state of the fiber on account of interference from wa-

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Table I 50% X-ray Angle (ψ), Convolution Angle (θ), and Mean Orientation Angle (α_m) for Air-Dried and Solvent-Dried Cotton Fibers of Different Varieties

Serial No.	Variety of Cotton	Air-Dried			Solvent-Dried		
		(α_m)	($\psi - \theta$)	($\alpha_m - \theta$)	(α'_m)	($\psi' - \theta'$)	($\alpha'_m - \theta'$)
G. barbadense							
1	Giza 7	29.78	22.35	19.13	26.57	23.47	25.24
2	ERB.4600	28.43	23.93	21.86	26.08	22.22	24.70
3	Suvin	27.04	20.27	19.41	26.08	21.77	24.45
4	IBSI.25	27.04	21.03	20.07	26.08	22.90	25.18
5	IBSI.53	25.60	16.22	17.82	24.09	20.15	22.84
G. hirsutum							
6	IAN.579	31.09	22.15	18.74	25.10	21.79	23.69
7	MCU.5	29.78	21.70	17.68	25.60	24.03	24.43
8	HH.35	30.22	20.47	19.09	26.08	23.90	24.48
9	Hybrid.4	29.33	22.82	20.65	25.60	23.47	24.27
10	Hybrid.5	27.04	23.10	20.64	25.10	21.29	23.19
11	G.Cot.11	30.66	22.92	21.08	26.57	24.75	24.62
12	G.Cot.10	27.51	20.22	20.23	26.57	21.55	23.92
13	IAN.4975	27.97	19.97	19.74	24.09	21.07	21.46
G. herbaceum							
14	Suyodhar	29.78	22.03	23.31	25.60	23.50	24.00
15	Jayadhar	29.33	21.43	22.06	25.60	22.22	24.22
16	Sujay	26.08	18.60	21.68	25.10	20.55	24.05
17	Digvijay	28.88	20.40	22.08	26.08	22.09	24.97
G. arboreum							
18	Sanjay	24.60	17.30	19.90	24.09	20.30	23.39
19	K.9	29.78	22.19	24.37	26.57	23.07	24.44
20	AKH.4	27.51	22.70	22.01	27.04	24.67	26.21
21	AK.235	28.88	21.03	22.41	27.04	24.92	25.76
Range		6.49	7.71	5.63	2.95	4.77	4.75

All angles are in degrees. θ and θ' were taken from Ref. 2.

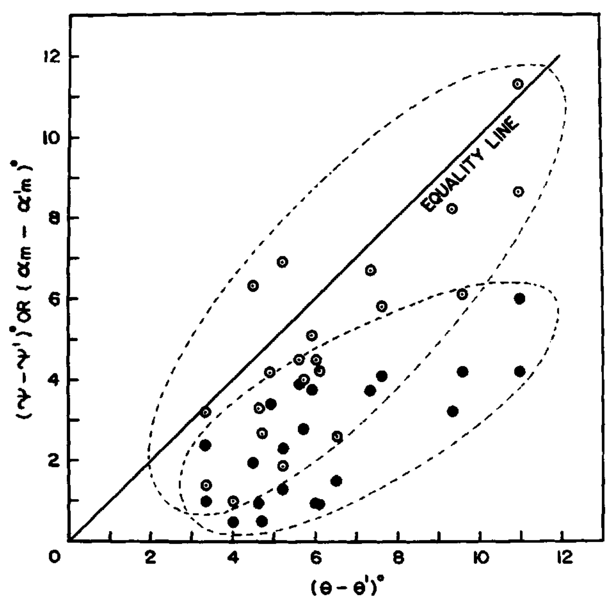

Figure 1 Difference in the 50% X-ray angle ($\psi - \psi'$) and mean orientation angle ($\alpha_m - \alpha'_m$) against difference in convolution angle ($\theta - \theta'$). ψ, α_m, and θ refer to air-dried samples, whereas ψ', α'_m, and θ' refer to solvent-exchanged samples. (⊙) $\psi - \psi'$; (●) $\alpha_m - \alpha'_m$).

ter. Solvent exchange has been suggested by many workers[7,8] as a suitable method that would preserve the original state of the fiber without affecting the accessibility and porosity[5,6] of the fibers. An alternative would be a method of measurement that would not be influenced by the presence of water in the fiber. Until such a method is evolved, the ψ values yielded by measurement on never-dried fibers, produced by solvent-exchange and corrected for convolution if any, should represent the true spiral angle of cotton. A higher value for the spiral angle for solvent-dried fibers is quite in keeping with the changes that are likely to occur during the first drying of these fibers. More precisely, solvent drying per se does not change the spiral angle in the never-dried state.

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