Measuring Fiber Fineness by Horizontal Air-Flow
Part 2: Measuring Apparatus and Results of Measurements

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Abstract

An apparatus to measure fiber-fineness by horizontal air-flow has been devised. Several specimens were measured with this apparatus, and the results have been compared with theory.

The comparison has shown that:

1. The apparatus can measure the weight-fineness of each single fiber, irrespective of the fiber-length or the kind of raw cotton used.
2. Using the correction coefficient inherent in the apparatus brings an experimental value into good agreement with theory.
3. The experimental error is about ±0.1 on micronaire reading for fineness below 4. For fineness above 4, the error is slightly larger.

1. Introduction

Based on the theory and preliminary experiment reported on in the previous article[1], an apparatus to measure the weight-fineness of fibers has been devised. The measurement utilizes the different landing points when fibers are separated into singles and allowed to fall freely in a horizontal air-flow. Several specimens were measured with this apparatus and the results were compared with theory.

2. Measuring Apparatus

(i) General construction

The trial fineness-measuring apparatus, shown in Fig. 1, consists of three parts, A, B and C. A mass of cotton fibers is separated into single staples in opening box A, falls from guide tube B into measuring room C, and travels in horizontal air-current through the measuring room while falling freely, and lands on board 7.

(a) Opening Box

The opening box shown in Fig. 2 has three cylinders, each 30 cm in diameter and 40 cm in width, arranged 120° open as illustrated in Fig. 1. The first cylinder, I, is clothed in metallic wire used for cotton
card doffers. The second and third cylinders, II and III, are clothed in metallic wire used for cotton card cylinders. They all have the same number of points, 508/in². These cylinders are driven by belts and gears at the revolution ratio of 1 : 3 : 9.

Materials on feed plate 1 are transmitted to cylinder I by feed roller 2 which has grooves 3 mm wide, 2 mm deep and arranged 6 mm apart. The ratio of circumferential speed of feed roller 2 to that of cylinder I is 1 : 1130.

Raw cotton is then combed by cylinder I in the direction shown by the arrow and is further separated into single fibers by cylinders II and III. Thereafter each single fiber is blown off by the centrifugal force of cylinder III into guide tube B.

To prevent fibers from being thrown away, covers 4 are placed around each cylinder with the clearance shown in the figure. Mote knife 3 is fixed under plate 1 with a clearance of 0.4~0.8 mm to remove dust from raw cotton. To increase carding action, sand paper 5 is stuck on the under-cover of cylinder I, and two top-wires 6, the wire-directions of which are opposite to each other, are attached inside the top-cover of cylinder II.

The opening box can handle 100 grams of cotton fibers in about 15~20 minutes if cylinder III is rotated at 1,600 rpm. In this case, the higher the rotation of the cylinder, the better the fiber opening. In our experiment, however, the vibrations of the apparatus were large and damage to fibers increased owing to the imperfection of the apparatus, if cylinder III was rotated at over 1,600 rpm.

The air-supply aperture 11 (4 cm wide) at the exit of cylinder III supplies air to the outlet, reduces the speed of air-current produced by cylinder III and prevents eddies from forming in the guide tube.

(b) Guide Tube and Measuring Room

Each fiber separated in opening box A and carried by the air-current produced by cylinder III is guided into the guide tube and enters the measuring room. The measuring room is a rectangular box 1 m high, 50 cm wide and 4.6 m long, through which a horizontal air-current having a constant speed (average 0.3 m/sec) is blown by fan 9 placed at the end of the room. Fibers guided by the guide tube travel in this horizontal air-current while falling freely and deposit at various points on board 7, depending on the degrees of their fineness.

The Saran-net 8 at the exit of the room keeps fibers out of fan 9. Observation windows a to f are on one side of the room. Fig. 3 shows the outside view of the measuring room.

(ii) Air Velocity

Measurement by this method is influenced largely by the distribution of the air velocity. (The velocity of the air coming from the guide tube into the measuring room has no direct influence on the measurement. See Appendix.) The horizontal air-velocity should be constant in all parts and should be slow enough for all fibers to fall on the board inside the measuring room.

Therefore, the air-velocity distributions in the measuring room and the guide tube are measured with Anemomaster—with the result shown in Fig. 4. The figure shows that the maximum speed at the inlet of the guide tube, 2 m/sec, drops to 0.6 m/sec at the exit. The figures shows also that, despite the disturbance of air in the measuring room observed within
a 1-m distance from right below the exit of the guide tube, the air-velocity in the other parts is roughly constant in speed, 0.3 m/sec on an average. It seems, then, that the error due to the unevenness of air speed is relatively small except near the guide tube.

3. Experiment on Fiber-Fineness Classification

Two specimens, each consisting of about 50 grams of fibers, one 4.4 in average fineness on micronaire reading and the other 3.45, were blown off separately with this apparatus and their weight distribution curves, after their landing on the board, were measured at intervals of 20 cm on the board along the direction in which the specimens had been blown off. The weight distribution curves measured are shown in Fig. 5.

The shaded areas show accumulation of nephs and trash. Line SS' indicates the position of the Saran-net. The dotted lines on the right-hand side of line SS' show the fiber-mass adhering to the net.

The black and white dots in Fig. 6 show the micronaire reading of each block mentioned above, the line being a modified theoretical curve, which will be dealt with later. It is interesting to note that, although a material (specimen) of one micronaire reading was fed to this measuring apparatus at a time, different degrees of fiber-fineness show up in the figure.

4. Modifying of Theoretical Formula

The horizontal displacement of fibers obtained in
the previous article applies to a case where each single fiber falls freely through a perfect, orderly horizontal air-current with the fiber axis kept horizontal. In practice, however, the air-current in the apparatus is not completely uniform and fibers are not perfectly separated into singles. Therefore, the theoretical formula, to be applied practically, needs the following modification:

The theoretical horizontal distance attained by a fiber is:

\[ L_1, \text{cm} = 0.463VHF^{0.656} \]  \hspace{1cm} (1)

Corrected horizontal distance is:

\[ L, \text{cm} = 0.463VHF^{0.656} - b/a \]  \hspace{1cm} (2)

where:
- \( V \): velocity of horizontal air-current, cm/sec
- \( H \): height of descent, cm
- \( F \): fiber fineness, \( \mu g/in \)
- \( a \): correction coefficient due mainly to degree of opening
- \( b \): correction coefficient due mainly to disturbance of horizontal air-current

The line in Fig. 6, calculated by using \( a=0.83 \), \( b=473 \text{ cm} \) in formula (2), agrees well with experimental values. The line in Fig. 7 is obtained by using \( a=0.27 \), \( b=1690 \text{ cm} \). These lines indicate that, the better the opening, the better the separability into single fibers and the smaller \( a \). The disturbance of the air-current in Fig. 7 is reduced, so that fibers land swiftly and quietly on the board and \( b \) tends to become large.

Here two values have been mentioned, \( a \) and \( b \). They need not be varied, however, and only constant values may be used if the dimensions of the apparatus is decided and if the choice of the material—raw cotton or slivers—is previously fixed. In this case the error of measurement is

\[ \delta L/L = \delta V/V + \delta H/H - 0.656\delta F/F \]  \hspace{1cm} (3)

The third term of the right-hand side need not be considered if only a single fiber is measured. Therefore, if the degree of air-disturbance is the same, it is advisable to speed up the air-velocity \( V \) and increase the height \( H \). This means an extension of the length of the measuring room, as is indicated in the theoretical formula. However, since \( L \) must, in practice, be less than a certain size, the horizontal air-flow having the least possible disturbance is required.

5. Discussion

(i) Precision of Measurement

When measured with the apparatus, fibers varying in fineness mix on the board and even fibers of the same fineness can land over a range of distribution, instead of on one and the same point. The reasons:
- (a) Fibers fall with different postures; and (b) fibers fall from different starting points because of the size of the guide tube outlet.

As shown in Fig. 6, however, two measurements of fineness distribution taken about 2 meters from the position immediately below the guide tube almost agree with each other, the error being about 0.1 on maicronaire reading. Accordingly, the fineness of cotton fibers can be measured with a slight error at such a position. The precision of measurement can be improved by reducing the width of the exit of the opening box and the disturbance of air-flow in the measuring room.

(ii) Form of Fineness-Distribution

In Fig. 6, measurement becomes inaccurate near the position right below the guide tube, because the divergence of two fineness-distributions is large and both become flat and deviate notably from the theoretical value. This is presumably because:
- (c) Theoretically, the effect of fineness upon distance decreases near the position right below the guide tube. At this place, even reason (a) has large influence, and the difference in fineness due to the difference of landing points of fibers hardly shows up.
- (d) Some fibers cannot fall freely because of the disturbance of air caused by spouting from the guide tube, and fall faster.
- (e) Neps and trash cannot be eliminated completely from the opening box but fall near the position right below the guide tube.

Cause (c) cannot be removed perfectly with this apparatus, but the influence of (d) and (e) can be reduced by improving the guide tube and the opening box.

(iii) Posture of Falling Fiber

The assumption that all fibers fall with their fiber axes horizontal was checked by taking photographs of fibers flying in the measuring room through four windows (a, c, d and h in Fig. 1). An example of them is shown in Fig. 9. Fibers at position (a), are influenced by the intense wind spouted from the guide tube and face all directions. Presumably, however, the further from the guide tube, i.e., the smaller the influence of the air-flow blown from the guide tube, the larger the number of horizontal fibers in order of (c), (d) and (h). Since a cotton fiber is not straight, not all parts of a fiber can fly horizontally. Conversely, this means that not all parts of a fiber fly vertically. Therefore, although a vertical fiber may be somewhat smaller in air-drag
than a fiber having a horizontal posture, the variance of the coefficients may conceivably be small.

(iv) Fiber Length

As is clear from both theory and the preliminary experiment, the fiber length should have no bearing on measurement.

To check this point were measured by the sorter method the staple diagrams of fibers depositing at points on the board which were 1m and 2.5m distant from right under the guide tube and sticking to the Saran-net. The results are shown in Fig. 10.

They show that the mean length is 21.4mm at 1m and 21.0mm at 2.5m. Hardly any difference is noticed in fiber length even though landing points differ. A small quantity of fibers (about 3%) sticking to the Saran-net is considerably shorter. It may be not because their staple length is shorter but because they are so-called flies having lesser fineness and a shorter staple length that they have fled over such a distance.

over a long distance.

These assumptions are based on, among others, the fact that (i) the quantity of fibers on the Saran-net was almost constant even when the measuring room was increased in length; and (ii) that the flies are extremely low in fineness degree.

Fibers on the Saran-net have to be removed frequently lest the velocity of horizontal air-flow decrease.

(v) Degree of Opening

The cleaning action of this apparatus is not perfect. Its opening action is good if raw material contains little foreign matter. If when raw material contains much foreign matter, it is blown out of the guide tube, caught by other fibers, mingles with them and makes the opened condition worse.

Even if the opening box is improved to the extent that foreign matter is completely removed from raw material and its opened condition at the exit of the guide tube is perfect, the opened fibers immediately get entangled and fall together in small fiber masses if they touch one another during their flight in the guide tube or the measuring room.

This drawback imposes a limit on the feeding speed, and makes it impossible to reduce the length of time for processing raw cotton to below a certain value.

6. Summing up

(i) An apparatus has been devised to measure the weight-fineness of fibers by utilizing the different landing points of fibers separated into singles and allowed to fall freely in a horizontal air-flow.

(ii) The apparatus can measure the weight-fineness of each single fiber, irrespective of the fiber-length or the kind of raw cotton used.

(iii) Using the correction coefficient inherent in the apparatus brings an experimental value into good agreement with theory.
(iv) The experimental error is about ± 0.1 on micronaire reading for fineness below 4. For fineness above 4, the error is slightly larger.

(v) The apparatus still leaves room for improvement of the opening box. Besides, it has defects, such as the need for a long measuring room and an opening box placed high up. These defects, are hoped to be eliminated in the not distant future.

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Reference


Appendix

A few words about the horizontal distance attained by a fiber when air is blowing vertically through the upper part of the measuring room together with fibers at high speed which cannot be ignored.

Assume that there is an air velocity $v$ at height $H$ above plate XX and vertical to plate XX, as shown in Fig. 11, and that two-dimensional potential flow is applicable to this case. Then, the velocity at any optional point $(x, y)$ is expressed as

$$
\dot{x} = ax \\
\dot{y} = -ay
$$

This at height $H$ is given by

$$
\dot{y} = -v \\
\text{Therefore, constant "}a\text{" is fixed by}
$$

$$
a = v/H
$$

With the constant velocity of horizontal air-flow, $V$ and the terminal falling velocity $\dot{y}_m$, of fibers, added to this as in our experiment, then

$$
\dot{x} = \frac{v}{H}x + V \\
\dot{y} = -\frac{v}{H}y - \dot{y}_m
$$

Therefore, time $T$ needed for a fiber to fall from height $H$ is given, from eq. (ii), as

$$
T = \int dt = \int_0^H \frac{-dy}{\frac{v}{H}y + \dot{y}_m}
$$

$$
\therefore T = \frac{H}{v} \log \frac{v + \dot{y}_m}{\dot{y}_m} \quad \text{--------- (iii)}
$$

Similarly, horizontal distance $L$ attained by a fiber during this time is given, from eq. (i), as

$$
T = \int_0^L \frac{dx}{\frac{v}{H}x + V} = \frac{H}{v} \log \frac{v}{H} \frac{L + V}{V} \quad \text{--------- (iv)}
$$

Putting eq. (iii) equal to eq. (iv), we have

$$L = HV/\dot{y}_m
$$

This equation is the same in content as eq. (1) in this article. Therefore, if the vertical flow blown from the guide tube does not disturb the horizontal air-current, the velocity of the vertical flow itself has no direct influence on the horizontal distance attained by the fiber.