

Fiber vibrations and distributions in melt blowing

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REVIOUS PAPERS (1–4) PRE-SENTED a mathematical model for melt blowing. This model predicted characteristic frequencies and amplitudes associated with the movement of fibers during melt blowing. This paper reports extensive experimental measurements of fiber frequency and amplitude.

One can observe the amplitude of vibrations qualitatively with the naked eye. Under mild conditions such as low gas velocities, the amplitude is almost imperceptible. As conditions become more severe at higher gas velocities, the vibration amplitude steadily increases. Shambaugh (5) defined three regions of melt blowing that relate to fiber breakup. The regions correspond to the severity of vibration amplitude.

EXPERIMENTAL EQUIPMENT

The polymer used in all experiments was 75 melt flow rate (MFR) Fina Dypro polypropylene with $M_w = 122,500$. The polymer was melted and pressurized with a Brabender extruder of 19.0-mm (0.75-in.) diameter and 381-mm (15-in.) length. After exiting the extruder, the polymer was fed to a modified Zenith pump that fed a single hole melt blowing die. The polymer capillary had an inside diameter of 0.407 mm and a length of 2.97 mm. The two air slots were 0.65 mm wide and 76.4 mm long. The ranges of basic operation conditions used for the experiments were the following:

- Air velocity 17.6–39.7 m/s
- Air temperature 300–340 °C
- Polymer flow rate 0.40–0.70 cm³/min
- Polymer temperature 300–350 °C.

The laser measurements were made with a one-dimensional, frequency shift, fiber optic laser Doppler velocimeter (LDV) system assembled by TSI Incorporated. The laser was a 15 mW He-Ne laser. A Bragg cell provided frequency shifting for measuring flow reversals. The measuring volume (mv) was produced by a backscatter probe at the end of a 10 m long optic cable. The probe was mounted on a Velmex 3-D traverse system that permitted x, y, and z motions in 0.01 mm increments.

RESULTS AND ANALYSIS

For the melt blowing die, **Fig. 1** shows arrangement of the two air slots parallel to the y axis. The air field is therefore not radially symmetric with respect to the z axis. The fiber amplitudes therefore might not be radially symmetric. In the Cartesian system of **Fig. 1**, the amplitude in the x direction might be different from the amplitude in the y direction.

Figure 2 is a multiple image photograph of the fiber cone during typical melt blowing conditions. For this photograph, the camera was positioned along the +y axis as shown in **Fig. 1**. The photograph therefore shows the fiber cone size in the x direction. Remember that this photograph shows 150 exposures of a single thread line.

ABSTRACT

The authors experimentally examined the process of melt blowing from the standpoint of fiber motion below the spinneret. They measured fiber amplitude with multiple image flash photography and laser Doppler velocimetry and fiber frequency with laser Doppler velocimetry. Comparison of the experimental results to predictions used a mathematical model for melt blowing.

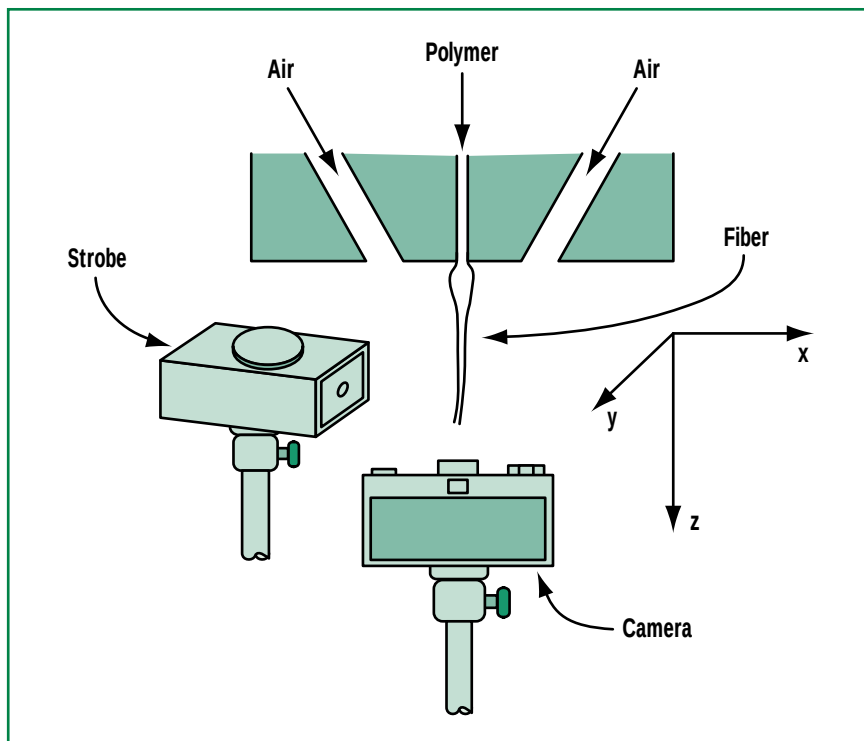
Application:

Fiber oscillation and cone size can predict fiber laydown pattern and fiber-to-fiber contact and entanglement.

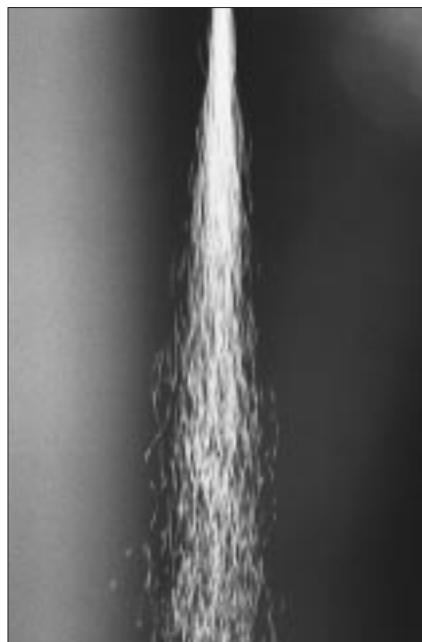
Figure 3 is a multiple image photograph taken with the camera located along the +x axis. The position is oriented 90 degrees to the arrangement of **Fig. 1**. **Fig. 3** therefore shows fiber cone size in the y-direction. As observed qualitatively, the cone sizes in both directions are of similar magnitude. This implies that the cone cross-section—in a plane of constant z—is approximately circular. The nonradial symmetry of the air slots therefore does not cause a large nonradial symmetry in the cone amplitude.

Figure 4 shows measurements of x-axis cone diameter via LDV. For comparison, results from photography are also given. The two techniques give similar results. The slopes of the data are nearly the same, and the magnitudes are close. **Figure 5** compares y-axis cone diameters determined via the two techniques. The two techniques again give very similar results.

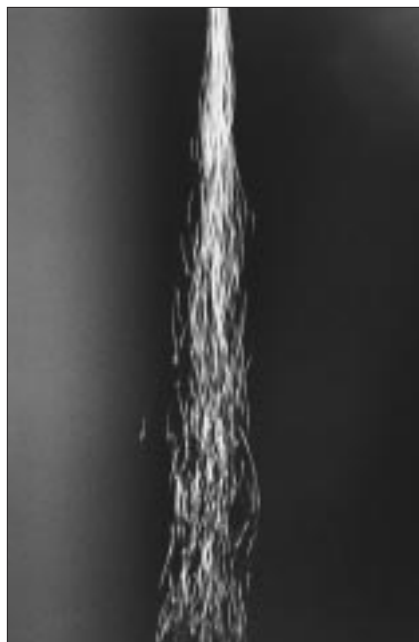
Figure 5 shows the corrected crossover frequency determined by LDV. Corrected frequencies are given at $z=10$ cm for crossover of the y axis and crossover of the x axis. Note that the frequency per mv length



1. Photographic apparatus used to measure fiber cone diameter in the x direction



2. A typical multiple image photograph of the x axis fiber cone from $z = 1$ to $z = 8$ cm



3. A typical multiple image photograph of the y axis fiber cone from $z = 1$ to $z = 8$ cm

KEYWORDS

Fibers, frequencies, graphic arts, lasers, mathematical models, measurement, melt blowing, models, motion, photography, vibration.

was larger across the y axis than across the x axis. Since the mv length is less than the cone width, the ordinate value can also be interpreted as the local frequency per length.

For crossovers of the x axis, **Fig. 6** shows the corrected crossover frequency at different z levels. As z increases, the center or maximum value decreases, but crossovers occur at larger values of absolute x. **Figure 7** shows similar results for crossovers of the y axis. A comparison of Fig. 7 with Fig. 6 shows that the frequency per length levels are higher for crossings of the y axis as Fig. 6 suggested.

CONCLUSIONS

High speed photography or laser Doppler velocimetry can measure fiber cone dimensions with comparable results. The fiber cone cross-section is elliptical. The x axis is the major axis. The cone cross-section becomes circular at large distances from the die.

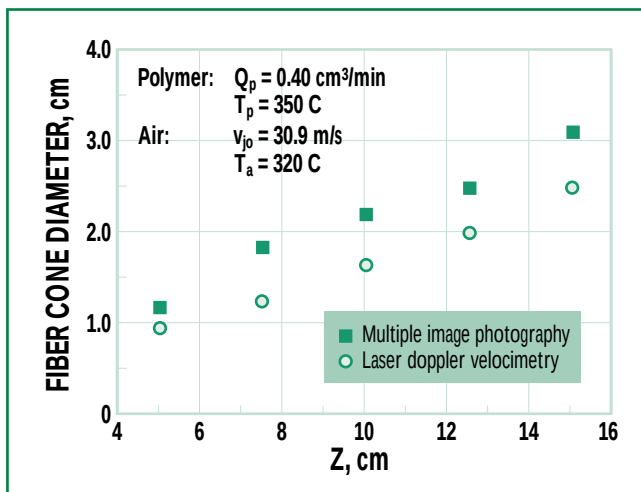
Laser Doppler velocimetry can measure the fiber oscillation frequency. The oscillation frequency across the y axis is higher than the frequency across the x axis. For a given set of operating conditions, the frequency is constant along the thread line.

The measured frequency range matches the frequency range predicted by the model of Rao and Shambaugh (4). Knowledge of fiber oscillation and cone size can predict items such as fiber lay down pattern and fiber-to-fiber contact and entanglement. TJ

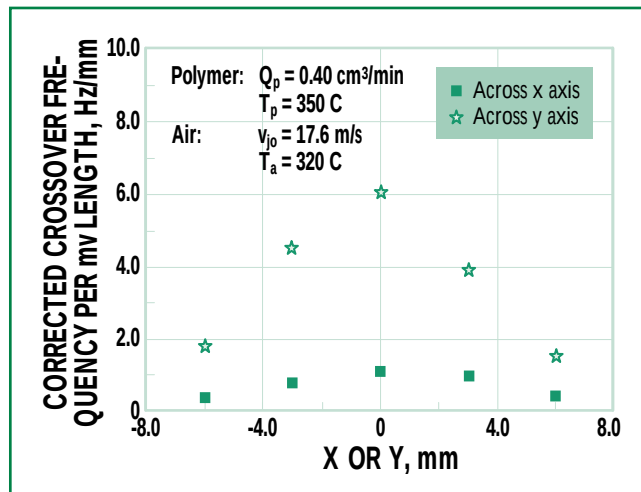
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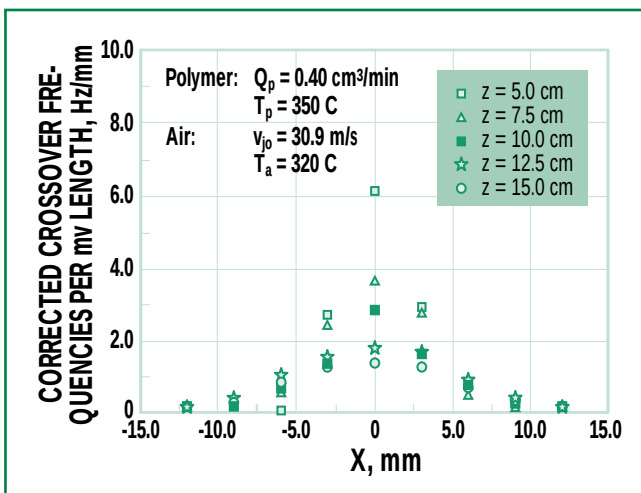
Presented at the 197 TAPPI Nonwovens Conference.



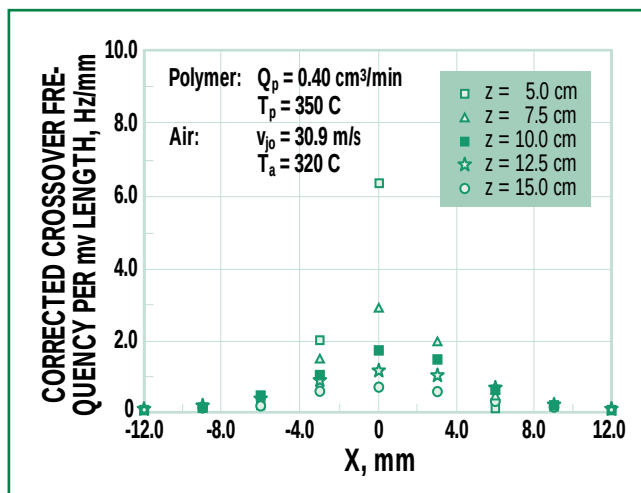
4. The x axis cone diameters measured via LDV and multiple image photography



5. A comparison of corrected crossover frequencies per unit length across x and y axis at z = 10 cm



6. The fiber crossover frequency per unit length across the x axis



7. The fiber crossover frequency per unit length across the y axis

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