Acousto-optical fiber characterization

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Other researchers have pointed out the importance of fiber length measurements in characterizing mechanical pulps (*1, 2*). The weighted average fiber length can be measured by projection, microscope, and by Bauer-McNett classifier using the TAPPI method. The Domtar researchers developed the Celleco fractionator, in which the pulp suspension under evaluation is sprayed through a nozzle against a vertical nylon screen that splits the flow into accepted and rejected fractions. The weighted average fiber length is computed from the flow and consistency of each of the two pulp streams—the feed stream and either the accepted or rejected fraction. The accuracy of the measurement depends on the measuring equipment (*3*).

The Swedish Forest Products Research Laboratory (STFI) (*4, 5*) has developed an instrument where the aligned fibers pass into a capillary tube, interrupting a light beam and generating light pulses. The duration of the pulses is proportional to the fiber length, and the intensity of the pulses is proportional to the fiber width. Three light beams of different widths illuminate the dilute pulp suspension and generate data for four fiber length fractions. The French researchers have developed the "histofiber," using mainly the same principle (*6*).

The Kajaani instrument (*7*) is also an optical measuring device. The ability of the fibers passing through a capillary tube to change the direction of the light polarization provides a signal related to the size of the fibers. This signal is used to compute a fiber length distribution. It takes a few minutes to measure 3000 fibers and assign the fibers to 24 different length classes.

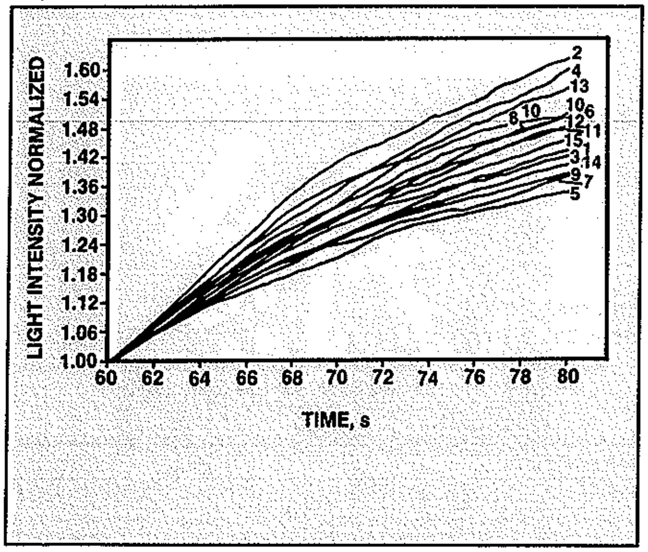
Recently, a scanning laser microscope was proposed (*8*). The light output from a laser diode is focused down to a diffraction-limited beam spot. The light beam is scanned at a constant known velocity. The light pulses scattered back from individual fibers are detected by a set of stereoscopic photodetectors. This instrument measures the width of individual fibers and classifies them into eight size fractions.

The researchers of the Université du Québec have developed a new instrument to measure fiber properties. When submitted to a stationary ultrasonic field, particles of cylindrical shape diluted in water and shorter than one fourth of the acoustic wavelength migrate to nodal planes of acoustic radiation pressure. The fibers reorient themselves parallel to these planes. The evolution of the fiber suspension is monitored with a collimated beam of light during ultrasonic excitation.

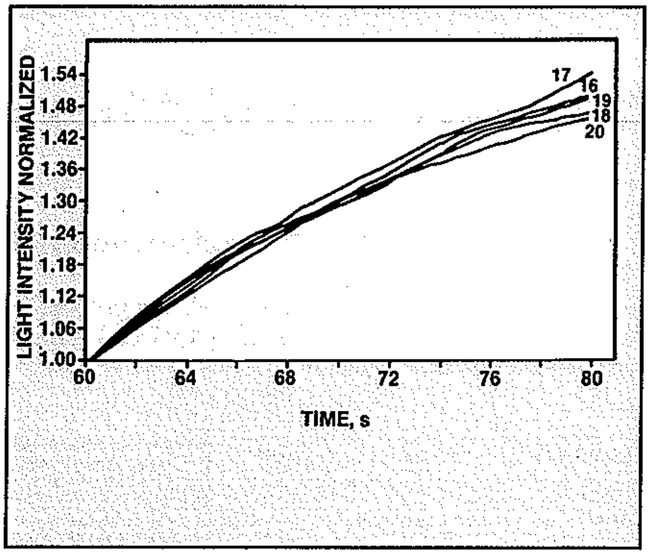
I. Characteristics of the 20 fiber mixtures

	Fiber length, %			Freeness, mL CSF	Wet web strength, km	Tear index, mN·m²/g	Scattering coefficient, m²/kg	Bulk, cm³/g	Surface under curves
Mixture	Long	Med.	Short						
1	33.2	17.1	49.7	112	70	4.0	75.0	2.90	4.8
2	52.1	12.3	35.6	251	60	4.7	63.7	3.18	7.5
3	30.7	23.3	46.0	13.5	64	3.6	73.1	2.87	5.2
4	49.3	17.0	33.7	280	62	4.1	63.7	3.17	6.8
5	26.1	13.5	60.4	71	62	3.3	78.0	2.68	4.0
6	43.6	10.3	46.1	183	66	4.1	69.6	3.07	5.9
7	24.6	18.6	56.9	89	64	3.3	80.0	2.79	4.6
8	41.6	14.4	44.0	185	69	3.9	69.7	3.02	5.7
9	19.0	20.3	60.7	66	62	3.0	82.3	2.70	4.6
10	50.5	12.4	37.1	234	60	4.6	65.5	3.15	7.9
11	40.5	11.0	48.4	126	66	3.8	71.8	2.92	5.6
12	36.8	19.3	43.9	163	62	4.0	69.4	2.88	5.4
13	46.3	18.5	35.2	252	67	4.0	65.3	3.20	6.5
14	33.0	13.2	53.8	110	71	3.7	75.8	2.85	6.7
15	38.6	15.4	46.1	140	68	3.9	72.5	2.84	5.3
16	38.6	15.4	46.1	140	70	4.5	70.9	3.00	6.0
17	38.6	15.4	46.1	152	70	4.2	73.1	2.85	6.0
18	38.6	15.4	46.1	156	70	4.0	70.5	2.92	5.7
19	38.6	15.4	46.1	145	68	4.1	71.6	2.89	5.7
20	38.6	15.4	46.1	155	67	3.7	71.2	2.92	5.4

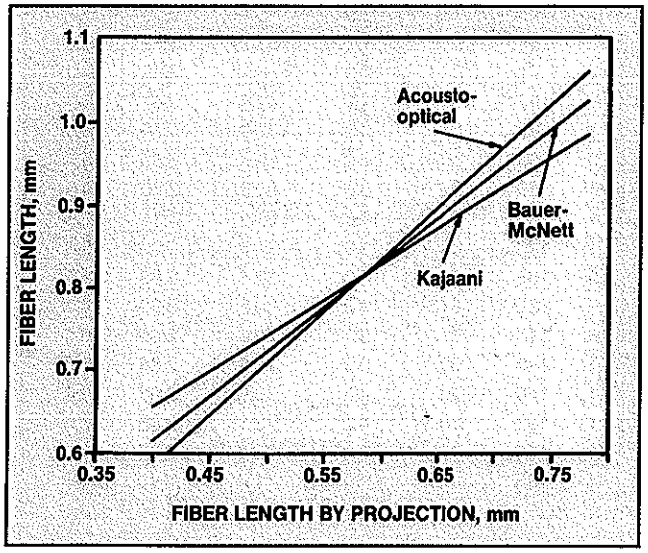
1. Scattered light intensity vs. time for 15 mixtures with different fiber lengths



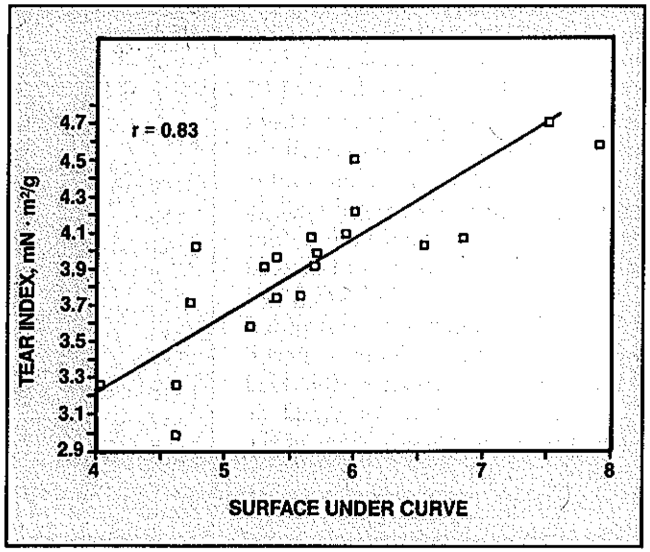
2. Scattered light intensity vs. time for 5 mixtures with the same fiber fractions



3. Weighted average fiber length computed from three instruments vs. that calculated from projection measurements



4. Tear index vs. the surface under the curves of scattered light intensity with time, for the 20 mixtures



Unlike the previously reported experimental setup (*9–11*), the probing light is now restricted to the expected fiber layer positions only. This arrangement provides a direct relationship between fiber concentration and scattered light during layer formation. Hence, scattered light signals collected near the axis in the plane perpendicular to the layers are shown to increase in a simple manner as a function of time.

Here, we present some new results, obtained with this acousto-optical instrument. We also present some relationships between the signals from this instrument and some pulp properties.

Experimental procedures

An industrial stone groundwood pulp was classified in a Bauer-McNett apparatus. Twenty mixtures of long (L_{14} + L_{28} + L_{48}), medium (L_{100}), and short (L_{200} + P_{200}) fibers were prepared according to a mathematical design. The fines (P_{200}) were collected by centrifuging. The 20 mixtures were analyzed for their main characteristics (**Table I**) using the TAPPI methods for fiber classification (T232 cm-82), freeness (T227 om-85), tear index, bulk, and scattering coefficient on handsheets (T220 om-83). Wet web strength was performed according to Seth *et al.* (*12*).

Plots of the scattered light intensity vs. time during the excitation period for the 20 mixtures are shown in **Figs. 1 and 2**, respectively, for the 15 mixtures with different fiber lengths and the 5 identical mixtures. The 60-s initial time coincides with the end of the 60-s period in which the fiber suspension turbulence slows down. Curves are normalized to identical initial levels at $t = 60$ s. Therefore, they are relative to each other. Various parameters were computed from these curves, but we found that the most reliable parameter was the surface under each curve during the time interval of 60–80 s.

The fiber lengths for the 20 mixtures were computed successively, using the projection, Bauer-McNett, Kajaani FS-100, and the new acousto-optical methods. For the latter, the surface areas under each curve of Figs. 1 and 2 were taken as a relative measure of weighted average fiber length. The fiber length obtained by projection was taken as a reference, and the weighted average fiber lengths obtained from the three other methods were plotted against them. This graph is shown in **Fig. 3**. The three methods indicate the same values for the fibers of medium length. The acousto-optical method gives lower length for short fibers and higher length for long fibers as compared to measurements made with the Bauer-McNett and Kajaani instruments.

The surfaces under each curve of Figs. 1 and 2 were also plotted against the usual pulp properties. A correlation coefficient superior to 0.8 was noted for the relationships with weighted average fiber length (as calculated from a Bauer-McNett classification and Kajaani), bulk, tear index, freeness, and light scattering coefficient. The relationship with tear index is shown in **Fig. 4**.

Conclusions

The results have confirmed previous theoretical models. This new acousto-optical instrument has excellent potential for fast characterization of the pulp properties. The design includes no capillary tubes and no classified pulp, as pit stone groundwood can be used directly. Research has to be continued (a) to improve reproducibility by using larger pulp samples and (b) to adapt this instrument on-line.□

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