ABSTRACT

A fiber quality analyzer rapidly measures the length and shape of cellulose fibers in suspension. The unit combines 2 dimensional image analysis with a novel flow cell that does not plug or foul. The flow cell orients the pulp fibers properly to ensure the accurate measurement of length, curl, kink, and coarseness. The paper discusses principles of operation and presents application results.

Application:

A fiber quality analyzer supplies the operator with realistic information about fiber quality including fiber contour length and shape.

Automatic fiber length and shape measurement by image analysis

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PAPRICAN, THE UNIVERSITY OF British Columbia, and the author's company jointly developed a fiber quality analyzer (FQA). Another paper reports the performance and validation of the FQA prototype *(1)*.

The definition of fiber quality often uses fiber length and shape *(2–4)*. The normal description of fiber length is fiber contour length, L, or the end-to-end (projected) length, l. **Figure 1** shows a diagrammatic representation. Two common measures of fiber shape are curl and kink. Curl is the gradual and continuous curvature of a fiber and has the following definition *(2, 5)*:

$$\text{Curl Index} = (L/l) - 1 \qquad (1)$$

Kink is the abrupt change in the fiber curvature defined by Kibblewhite's Kink Index *(4)*. This index is a weighted sum of the number, N_x, of kinks within a range of "x" kink angles:

$$\text{Kink Index} = (2N_{21-45} + 3N_{46-90} + 4N_{91-180}) / L_{TOTAL} \qquad (2)$$

Fiber length and shape change during pulping and bleaching. These changes can greatly affect the quality and performance of the final product. **Figures 2 and 3** give examples.

The determination of fiber shape has traditionally involved considerable manual labor in specimen preparation and data analysis. Unfortunately, this has limited the use of such measurements in mills. Measuring fiber length and shape simultaneously can help optimize pulp quality and performance of the paper or board manufactured from it.

PRINCIPLE OF OPERATION

The image analyzer incorporates the cytometric flow cell shown in **Fig. 4** that orients the fibers for precise measurement of length and shape *(1, 6, 7)*. The flow cell design prevents fouling and plugging.

The fouling resistance enables the flow cell to characterize the fibers in mill flows containing nonbirefringent contaminants such as ink, fillers, extractives, and pitch. The large 33 mm² cross-sectional area of the flow cell virtually eliminates plugging of the cell.

Figure 5 shows the 2 dimensional imaging of the fibers as they flow through the cell. This requires very uniform illumination over the entire 100 mm² viewing area. Diffuse illumination previously described this lighting *(8)*. The illumination is in the far-red at ca. 680 nm. Matching with the imaging charge coupled device (CCD) sensor and circular polarizing filters provide maximum sensitivity. Circular polarizing filters are superior to linear polarizing filters because the former will illuminate all parts of the fiber in the imaging plane whatever the in-plane fiber orientation or shape. Figure 5 demonstrates this.

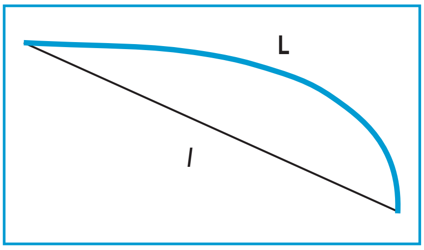
The furnish to be tested is diluted to give a fiber measurement frequency of 5–50 fibers. This corresponds to a consistency of approximately 4 mg/L.

The results are displayed, printed, and available for permanent storage. They include the following:

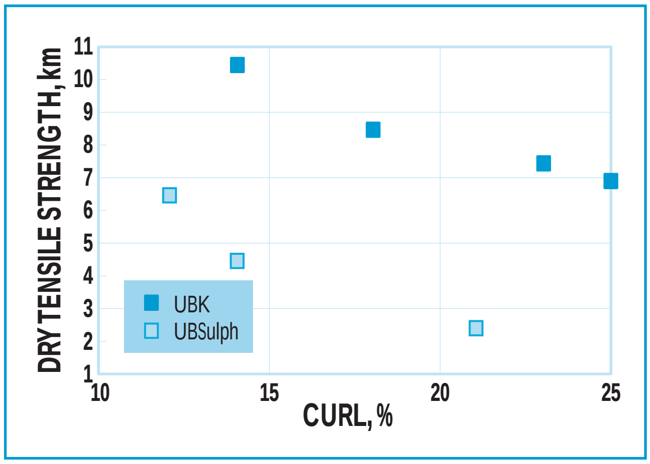
- Length distributions in mm and mean lengths (arithmetic, length, and mass weighted)
- Curl Index means and distributions
- Mean Kink Angle, Kink Index means, and distributions
- Coarseness of the entire sample
- Hardwood/softwood ratios.

RESULTS

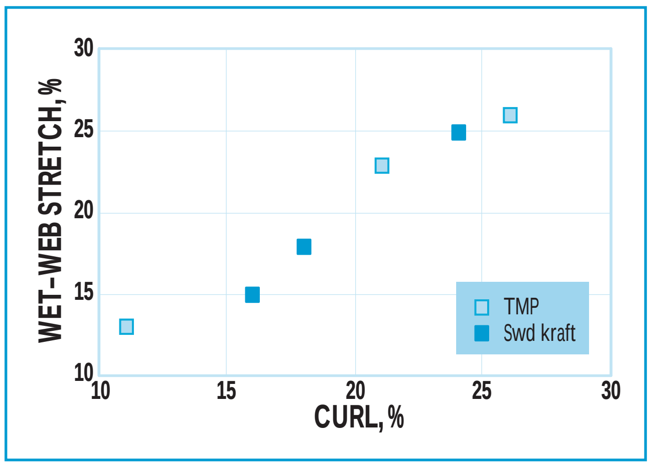
A spruce chemithermomechanical pulp (CTMP) was fractionated in a Bauer-McNett *(9)* device. The fractions were then tested on the analyzer with cytometric flow cell giving the results shown in **Fig. 6**. The R14 fractions were run twice and yielded arithmetic mean lengths of 2.87 mm and 2.82 mm. The pixel resolution of the image analyzer is 36 µm, and the difference between repeat runs are not statistically significant. In general, the R14 fractions had curl indices that were nearly double the whole pulp. The fractions of R28 and above had curl indices very close to the whole pulp.



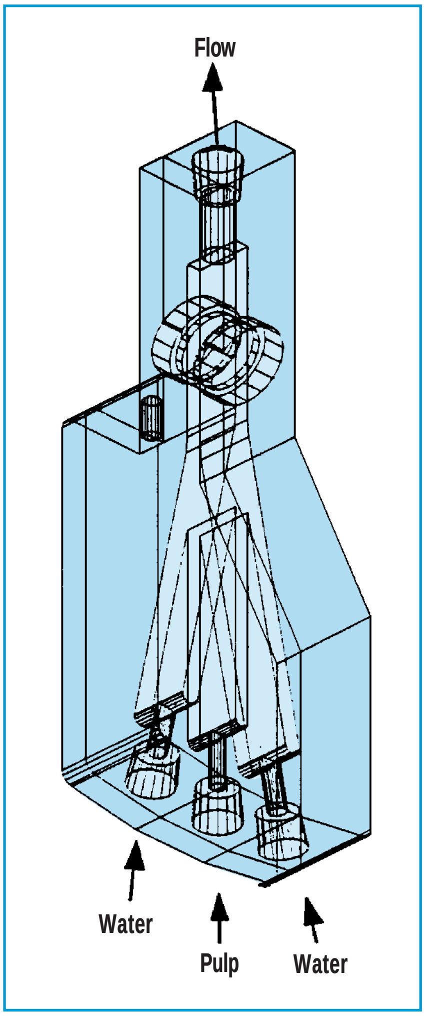
1. A diagrammatic representation of a curled fiber with 2 definitions of length



2. Relationship between curl and dry tensile strength



3. Relationship between curl and wet web stretch



4. Cytometric flow cell

A fully bleached softwood kraft (FBK) furnish was fractionated on the Bauer-McNett device. The fractions from R14 to R100 were run on the FQA and Kajanni FS200. **Figure 7** is a plot of the arithmetic mean lengths. The linear correlation between the FS200 and the FQA was $r^2 = 0.95$ for the arithmetic mean lengths. An $r^2 = 0.99$ was obtained with the length weighted mean lengths. This agrees with published results *(1)*. Note that the FQA measures the fiber contour length, but the FS200 measures the projected length. With the cytometric flow cell's higher tolerance to fiber "orientation" and the ability to pass very curly or coarse fibers, this explains why the mean lengths reported by the FQA with cytometric flow cell are sometimes different.

CONCLUSION

The image analyzer with cytometric flow cell measures the fiber contour length and shape. These factors supply the operator with more realistic information about fiber quality. Using this information can achieve the desired fiber quality required for a particular application and determine the source of fiber damage.

The large cross section area of the cytometric flow cell permits the passage of shives and very curly fibers without plugging. The analysis of shives is therefore possible. TJ

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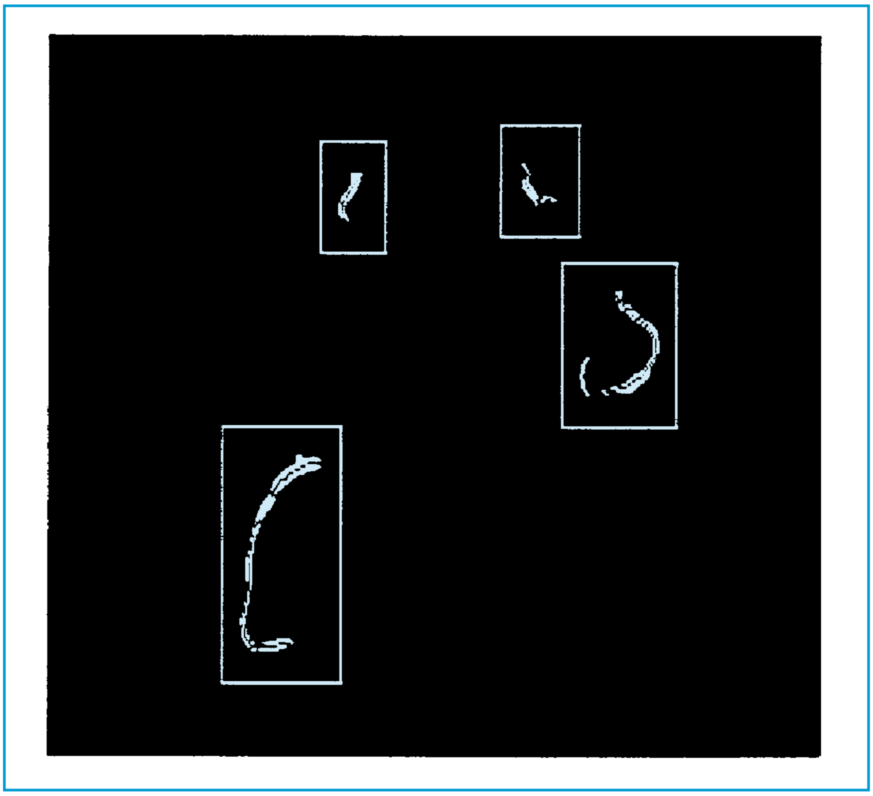

5. View of fiber images using circular polarized light oriented by the flow cell described in Fig. 4

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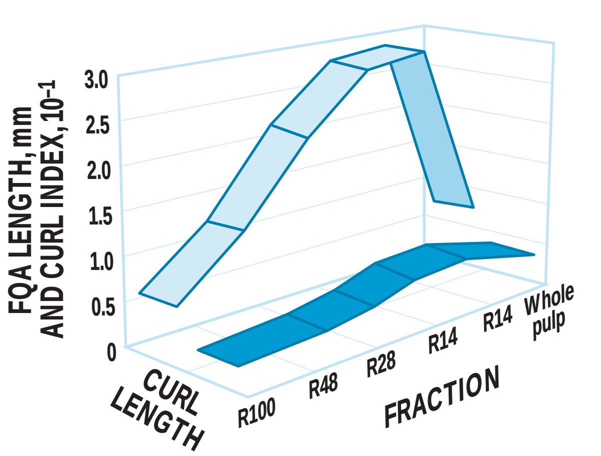
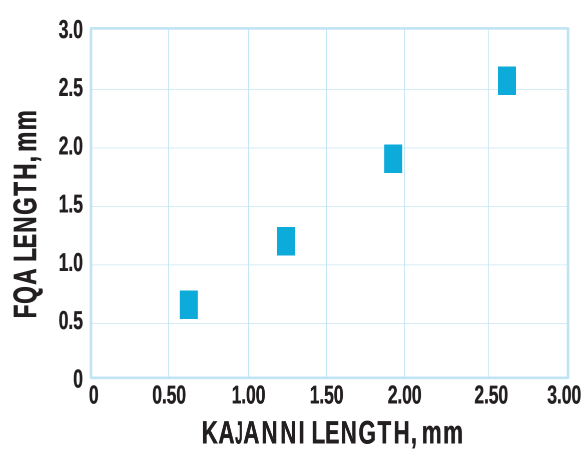


6. The FQA length and curl results for Bauer-McNett fractions of spruce CTMP



7. Comparison of the FS200 and the FQA arithmetic mean length of a softwood FBK pulp fractionated on a Bauer-McNett unit

KEYWORDS

Automatic control, cellulose fibers, curl, electric analyzers, fiber dimensions, fiber kinking, image analysis, picea, quality.