Fiber morphology and the response of pulps to medium-consistency fluidization

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ABSTRACT: The response of pulp fibers to mechanical treatment imparted during medium-consistency fluidization has been investigated as a function of fiber morphology. Fluidization beats and induces curl and microcompression in the fibers. The pulp freeness decreases, and the sheet stretch per unit tensile strength increases as the treatment energy increases. This change is observed irrespective of fiber morphology. Thicker-walled fibers are more microcompressed by this treatment than thinner-walled fibers.

KEYWORDS: Alkaline pulps, chemical pulps, consistency, fiber structure, fluidization, hardwood pulps, kraft pulps, mechanical treatment, medium consistency, pulps, softwood pulps, solids content.

Processing pulps in the medium-consistency range (8–14%) using fluidizing technology is now common in the industry. The turbulent state created in pumping and mixing operations exposes fibers to a mechanical treatment that was shown in previous work to be different from that experienced by pulp during conventional laboratory beating in a PFI mill *(1, 2)*. While treatment in the PFI mill mainly flexed the fibers and made them more conformable, the high shear received during fluidization induced curl and microcompression in addition to beating the fiber. These differences manifest themselves as follows.

At a given freeness, the fluidized pulp had a lower sheet density than the pulp when beaten in a PFI mill. Furthermore, the tensile strength of a sheet prepared from fluidized pulp initially increased slowly with energy input, but the stretch increased considerably. In contrast, beating pulp in a PFI mill increased tensile strength rapidly, with a smaller increase in sheet stretch. The extent of the measured responses increased with the energy expended in fluidization up to treatments of 2.5 MJ/kg. In mill situations, the use of multiple process units exposes the pulp to energies on the order of 0.2 MJ/kg, and changes in pulp properties in the range of 5–10% can be expected *(1, 2)*. When the pulp is given an extreme treatment in the fluidizer, the induction of curl and microcompression can be so severe that the sheet tensile strength decreases while the stretch continues to increase. This occurred at treatment energies above 2.5 MJ/kg *(1)*.

In this report, which is a continuation of earlier work, we examine the response of different-morphology fibers to fluidization treatment.

Experimental

Four laboratory-made, never-dried, unbleached kraft pulps, one hardwood and three softwoods with different fiber coarseness, were investigated. The softwood pulps were made to approximately kappa no. 30. The kappa number of the hardwood pulp was 17. The fiber properties measured for these pulps are summarized in **Table I.**

The pulps were treated in a bench-scale laboratory fluidizer at 10% consistency. The fluidizer is a concentric-cylinder device that is used to create turbulent flow in a pulp suspension located between an inner lugged rotor and a baffled outer housing. This device has been described in detail in previous work *(3)* and was shown to simulate mill-scale equipment *(2)*.

In our tests, the gap between the rotor and stator was 50 mm. Pulps were treated at 4 x 10^6 W/m^3 for various periods to expose the fibers to energies as high as 2.5 MJ/kg. While this treatment is greater than

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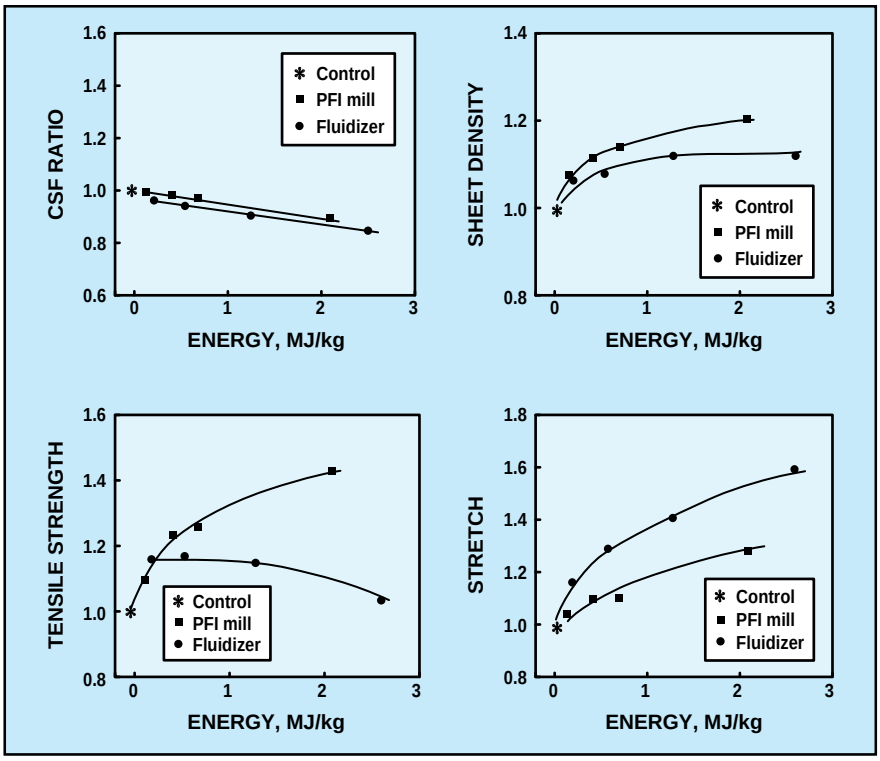
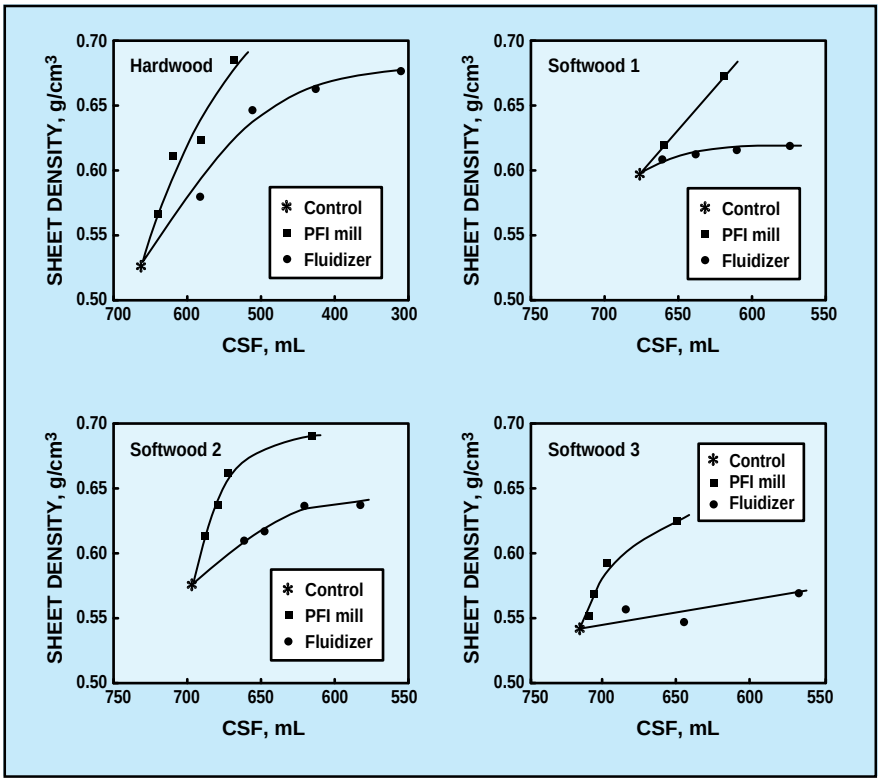
1. Pulp and sheet properties (given as ratios) as a function of treatment energy for Softwood 2



2. Sheet density as a function of pulp freeness



that encountered in normal mill operations, it was done to accentuate the effects of the treatment. The properties of the treated pulps were compared with those of the original pulps beaten to different levels in a PFI mill at 10% consistency. Here, the most severe treatment was 3000 revolutions. Standard procedures of the Technical Section, CPPA, were followed for handling pulps, in specimen preparation, and for measuring pulp and handsheet properties.

Results and discussion

Figure 1 illustrates the response of a softwood pulp (Softwood 2, Ponderosa pine rich) to treatment in the fluidizer and PFI mill as a function of energy. The results have been normalized by dividing them by the properties of untreated pulp. The PFI mill revolutions have been converted to energy using a factor of 0.7 J per gram pulp per revolution *(4)*.

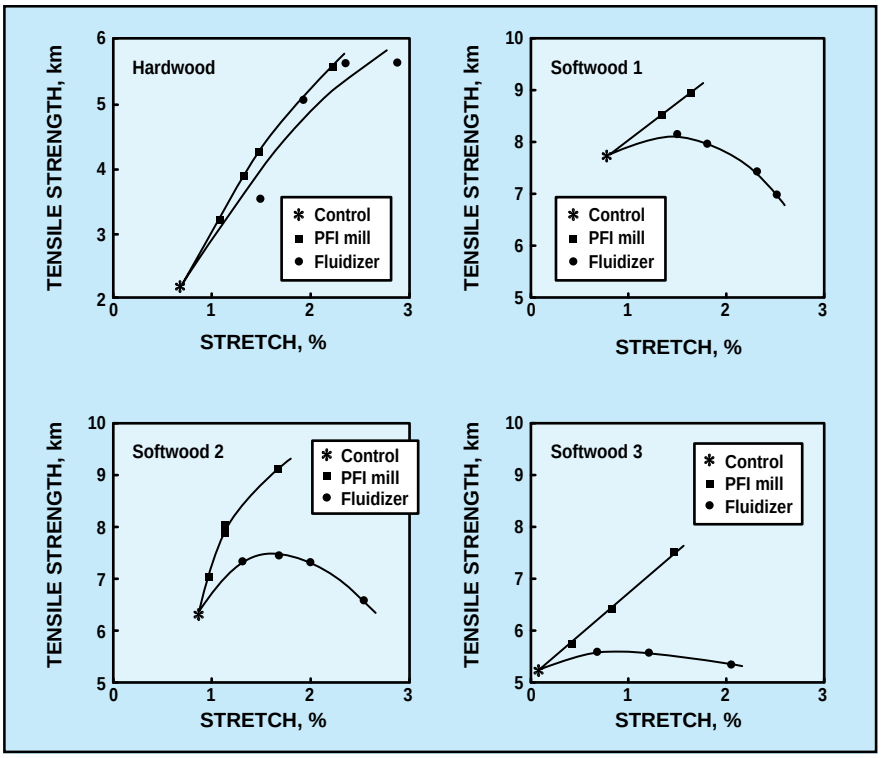
The decrease in freeness with energy was similar for pulp treated in the fluidizer and in the PFI mill. However, PFI mill beating gave sheets of higher density, and the two treatments produced different responses in tensile strength and stretch development. Whereas the PFI mill beating increased tensile strength steadily with increased energy, fluidization first increased and then decreased the tensile strength. Both treatments increased stretch with energy, but the increase produced by fluidization was greater than that produced by the PFI mill. The individual pulps responded differently to both fluidizer and PFI mill treatments, but no trend in response could be detected as a function of fiber coarseness.

In **Fig. 2,** the sheet density is plotted as a function of pulp freeness for the four pulps following treatments in the fluidizer and in the PFI mill. All pulps showed the anticipated pattern, i.e., the sheet density increased with increased mechanical treatment, which decreased pulp freeness. The sheet density at a given freeness was higher for the pulp beaten in the PFI mill. No trend with fiber morphology was apparent.

Figure 3 shows plots of the tensile strength vs. stretch. While the hardwood pulp did not show a marked difference between the two treatments, the softwood pulps showed a common pattern: at a given sheet stretch, the tensile strength of the fluidized pulp was lower than that of the PFI mill-beaten pulp. Furthermore, the tensile strength of the fluidized softwood pulp first increased with treatment, peaked, and then declined, while the stretch continued to increase. This is due to the increased induction of curl and microcompression in the fibers during fluidization in addition to the beating effect *(1, 2)*. While the increased induction of microcompres-sion increases sheet stretch, increased curl causes the stress to be unevenly distributed in the sheet, resulting in premature failure of the sheet under tensile loading. In such a situation, the stretch potential of the fibers may not be fully realized. In these cases, sheet stretch divided by tensile strength provides a useful index of increased mechanical treatment *(2)*. This increase in stretch per unit tensile strength can be used to quantify the sensitivity of pulp to fluidization at high treatment energies. The higher the index, the greater the sensitivity.

For softwood pulps, the incremental change in the ratio of stretch to tensile strength increased with energy and increasing fiber coarseness. It was lowest for the hardwood pulp. The indices [Δ(stretch/tensile strength)/Δenergy] for the four pulps of this investigation were 0.07, 0.09, 0.10, and 0.15 %/km/(MJ/kg) for the hardwood and Softwoods 1, 2, and 3, respectively. Since coarser fibers generally have thicker walls *(5)*, it is possible that these fibers were more prone to microcompression during fluidization. This conclusion was supported by microscopical examination of the treated fibers. Pulps with coarser fibers, after fluidization treatment, had more severe microcompressed regions.

3. Tensile strength as a function of sheet stretch at break



I. Fiber properties of pulps tested*

Pulp	*Length-weighted fiber length, mm*	*Fiber coarseness, µg/m*
Hardwood: Aspen	0.86	158
Softwood 1: Western red cedar rich	3.14	155
Softwood 2: Ponderosa pine rich	2.69	175
Softwood 3: Douglas fir rich	2.67	186

*Fiber properties were measured with a Kajaani FS-100 analyzer.

Conclusions

The energy imparted during medium-consistency fluidization beats and induces curl and microcompression in the fibers. Fluidization affects fiber properties in a similar manner irrespective of fiber morphology. However, the thicker-walled fibers seemed likely to be more microcompressed by this treatment. TJ

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