FILLER PERFORMANCE

The effect of filler location on the drainage, pressing, and drying of pulp and paper

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ABSTRACT

Drying cost and energy demand can be 16% less for fiber-wall-filled papers, since these papers contain less moisture after pressing than their conventionally filled counterparts. The enhanced drainage characteristics of the fiber-wall-filled fibers are a consequence of the lower absorbency, moisture content after pressing, water retention values, and higher CSF. The location of calcium carbonate within the cell walls of never-dried fibers therefore offers potential savings in energy and costs for paper mills.

Application:

Paper containing calcium carbonate within the fibers has better drainage, pressing, and drying characteristics than paper with the filler on and between the fibers.

THE LOCATION OF INORGANIC fillers within, rather than between, wood pulp fibers is receiving attention as a means of enhancing the performance of paper and the profitability of papermaking *(1–10)*. One factor significantly affecting the efficiency and economics of papermaking is the removal of water from the fiber web, because this is an energy-intensive unit operation *(11)*. The presence of filler within the structure of individual pulp fibers obviously influences their water-holding capacity and the drainage and drying behavior of webs made therefrom. There is no information in the literature concerning the measurement of these parameters on pulp or paper containing filler inside of the fibers.

Several researchers have nevertheless studied the drainage, pressing, and drying behaviors of papers containing filler located on and between the fibers *(12–22)*. Kenaga, Moore, and Meath found that at the point of entry to the paper machine dryer section, papers filled conventionally with ground limestone had a lower moisture content than unfilled papers of equal basis weight. This indicated better drainage or pressability characteristics or both. Once actually in the dryer section, the filled papers dried at a faster rate than the corresponding papers containing no filler. In addition, the rate of drying increased with the filler content.

Gerteiser and Laufman also investigated the effect of the presence of filler on and between the fibers. They concluded that the use of rhombohedral calcium carbonate instead of platelet clay facilitated drainage in a fiber web by sealing the web to a lesser extent and leaving more capillaries open. The improved drainage allowed a reduction in the amount of suction box vacuum needed on the paper machine wire. This lowered the energy and costs associated with papermaking and permitted faster paper machine speeds.

In yet another study, Fairchild examined the effect of the morphology of precipitated calcium carbonate (PCC) on the drainage behavior of paper. He concluded that papers containing prismatic PCC had drainage characteristics superior to those of papers containing scalenohedral PCC. He also attributed the higher solids content attained after pressing to the presence of the prismatic PCC. Earlier work therefore has established the effects of conventionally added PCC on the drainage and drying of paper. There has been no comparable study of paper made from fiber-wall-filled fibers.

EXPERIMENTAL

Materials

This work used commercially produced, never-dried pulps. Weyerhaeuser Co., Tacoma, WA, supplied (a) a softwood kraft pulp made at the mill in Prince Albert, SK, Canada, from a mixture of black spruce (*Picea mariana* B. S. et P.), Jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* Mill.), and western hemlock (*Tsuga heterophylla* Sarg.) and (b) a southern softwood kraft pulp consisting of a mixture of loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* Mill.) pines. Pulps provided by Boise Cascade Corp., Portland, OR, from their mill at International Falls, MN, were (a) a softwood kraft pulp from Jack pine (*Pinus banksiana* Lamb.) and (b) a hardwood kraft pulp of aspen (*Populus tremuloides* Michx.). The calcium carbonate came from the reaction of commercial grades of sodium carbonate monohydrate (McKesson Chemical Co., San Francisco, CA) and the soluble calcium salt of either calcium nitrate:ammonium nitrate (5:1) decahydrate (Norsk Hydro A.S., Oslo, Norway) or calcium chloride (Dow Chemical Co., Midland, MI). Hercules, Inc., Wilmington, DE, supplied a cationic polyacrylamide retention aid, Reten 1232.

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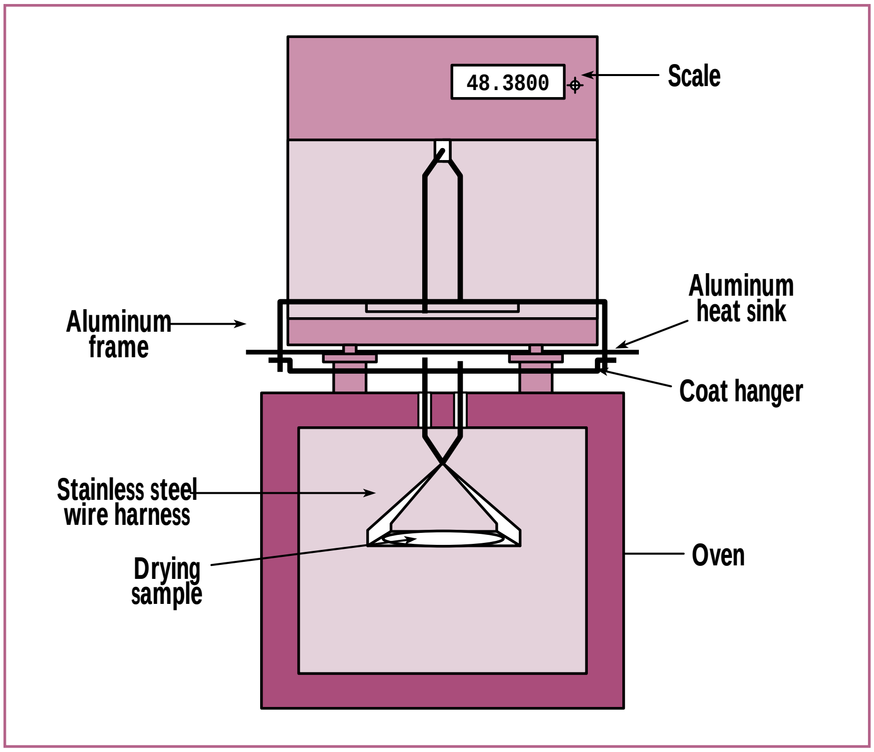


1. Diagram of apparatus to measure drying rate

Methods

The following is a representative example of the methods used to fiber-wall-fill pulp for the various experiments. A sample of never-dried pulp (10 g o.d.) was soaked at least 15 min in a sodium carbonate solution of 20–30% w/w at 40°C using a consistency of 5% w/w followed by filtration under reduced pressure. The resulting pulp was pressed between two sheets of blotting paper to a consistency of approximately 20% and then added in portions to a high-speed blender (Waring Products Div., New Hartford, CT) containing a calcium chloride solution (500 mL, 40% w/w, 100°C). After mixing for 1 min, the slurry was poured onto a 120-mesh wire screen. The collected pulp was then rinsed thoroughly with distilled water at 20°C. Additional fiber-wall-filled samples with different filler levels were prepared by the adjustment of the concentration of the sodium carbonate solution.

Control pulps and handsheets with conventional additions of filler were prepared by the mixture of never-dried pulp with calcium carbonate freshly precipitated in the high-speed blender.

The water retention value (WRV), filler level, and CSF of the filled pulps were determined according to TAPPI Test Methods UM 256, T 211 om-93, and T 227 om-94, respectively. The absorbency was measured by a fluff absorbency quality (FAQ) test from the Weyerhaeuser Co. *(23)*.

Handsheets were formed in a standard British sheet mold in accordance with TAPPI Test Method T 205 om-88. The wet handsheets were pressed at 50 psi (345 kPa) for 2 min in a standard sheet press. Each handsheet was next attached by four paper clips to a stainless steel wire harness. The harness was then connected to a steel hook hanging on the inside of an oven. The other end of the hook was linked to an analytical balance located on the outer top of the oven as **Fig. 1** shows. The sheets were subjected to two-sided drying in the oven at 110°C. The loss of weight at various time intervals was measured until the handsheets were dry.

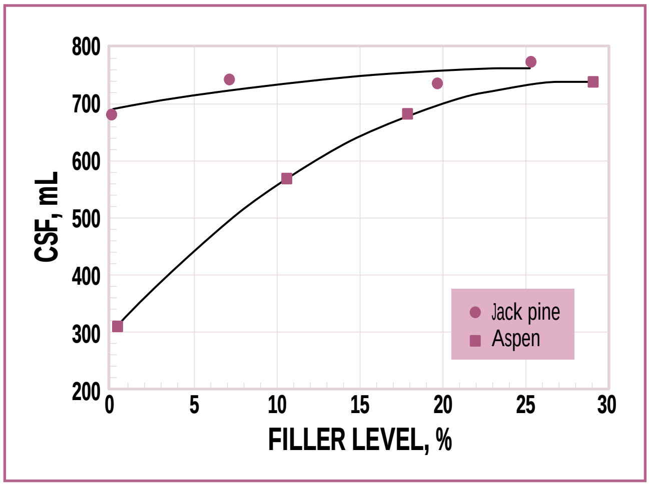
An aqueous solution of retention aid at 0.1% or 1.25 lb/ton was mixed with both the conventionally and fiber-wall-filled pulps in the drying rate and pressing experiments and in the WRV test.

RESULTS AND DISCUSSION

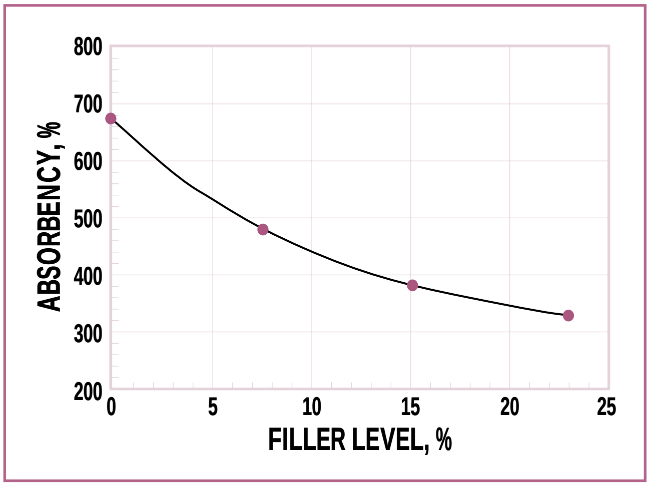
Indicators of the drainage behavior of pulps include both the CSF and the water absorbency. **Figure 2** compares the CSF values for a variety of fiber-wall-filled pulps. It is apparent that the fiber-wall-filled softwood pulps had higher CSF values than their hardwood (aspen) counterparts. The CSF values of both pulps also increased with the filler level. This increase therefore indicates enhanced drainage.

Water absorbency measurements made on the fiber-wall-filled Southern pine pulps supported this conclusion. The data in **Fig. 3** show that pulps with higher filler contents have lower water absorbencies. Although it is not a direct measure of the drainage, the water absorbency test shows that with a lower amount of water held within the fibers there is less water to drain from the fiber web. The lower water absorbency of the fiber-wall-filled pulps compared to the unfilled pulp presages better drainage of the fiber web.

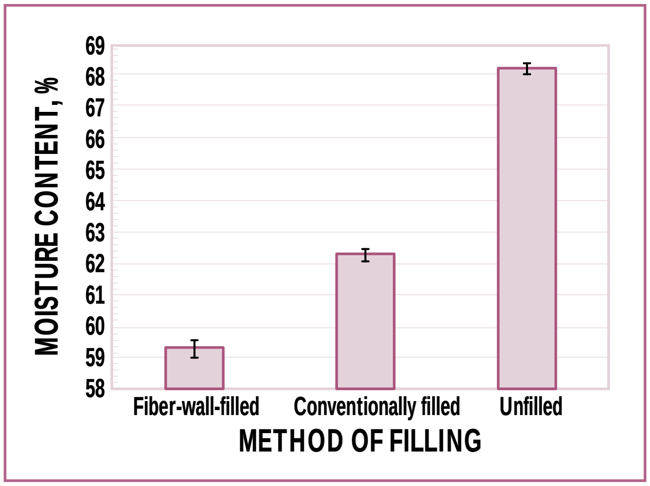
Both the CSF values and the water absorbency measurements can provide a general profile of the drainage characteristics of a fiber web on the wire of a paper machine. Neither test measures the amount of water held within individual fibers nor applies a force to the fiber web. During the papermaking process, the fiber suspension undergoes dewatering with the help of vacuum boxes and roll presses. The forces generated by this equipment primarily remove water from between the fibers and from within the fiber lumens *(24–26)*. The residual water that remains in the sheet after it leaves the press section is mainly



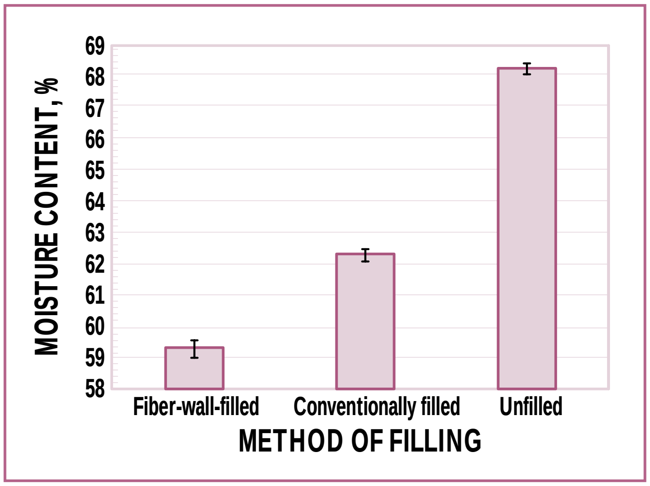
2. CSF variation with filler level for never-dried pulps fiber-wall-filled with calcium carbonate



3. Variation of absorbency with filler level for Southern pine mixed softwood pulp fiber-wall-filled with calcium carbonate



4. WRV variation with the filler level for Prince Albert never-dried, mixed, softwood pulps containing calcium carbonate with WRV of unfilled fibers of 1.80 g/g



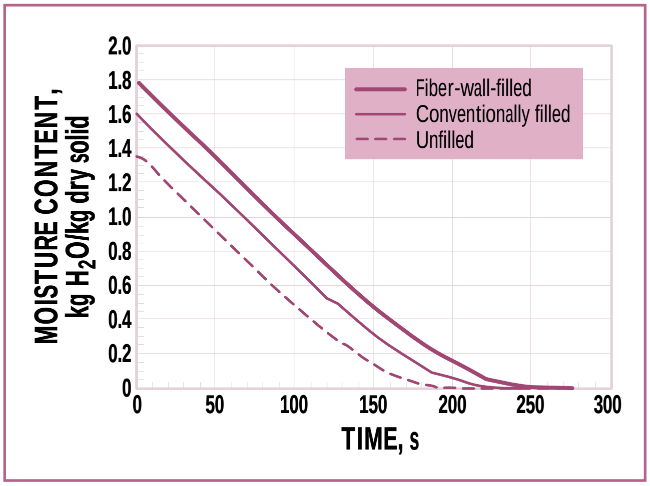
5. Moisture content comparison of handsheets pressed at 50 psi (345 kPa) for 2 min

within the fiber cell walls. It is this water rather than the water between the fibers that limits the extent of dewatering achieved on the paper machine wire *(24)*. The WRV can measure the amount of this water. This measurement can also predict the dewatering performance of a furnish on the paper machine wire and its runnability *(24, 27–30)*. A low WRV therefore should represent good dewatering behavior. This leads to wet webs of higher solids content and greater strength properties.

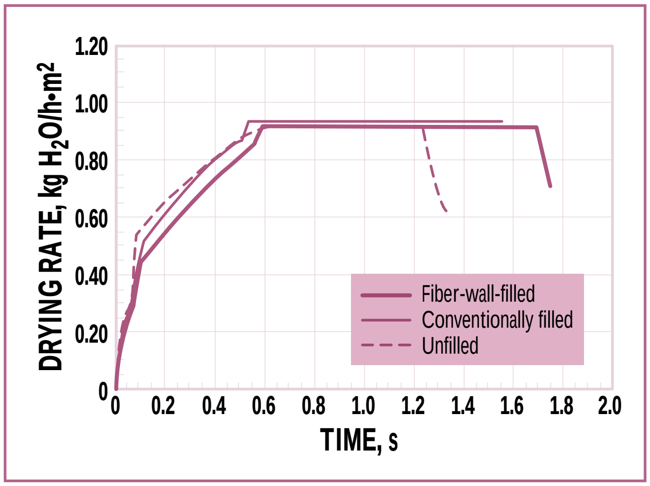
To validate this postulate, **Fig. 4** compares the WRV of never-dried, fiber-wall-filled pulps and pulps having calcium carbonate on and between the fibers. The fiber-wall-filled pulps clearly have a lower WRV than the pulps having calcium carbonate on and between the fibers. In the fiber-wall-filled pulps, the calcium carbonate precipitated therein replaces the water that normally occupies the fiber micropores. The lower WRV numbers are a consequence of this displacement of water.

Besides the drainage, **Figs. 5–7** compare the pressing behavior and drying rates of the conventionally and fiber-wall-filled sheets at the 20% filler level to those of the unfilled sheet. All sheets were pressed at 50 psi (345 kPa) for 2 min before determining their solids contents and drying rates. The data in Fig. 5 show that the fiber-wall-filled sheet has the highest solids content (lowest moisture content) after pressing compared to the conventionally filled and unfilled sheets. A sheet having a greater pressed solids content will take less time to dry in the dryer section. Since it is more economical to remove water by pressing than by evaporation, a saving in drying energy and cost will result from eliminating more water in the press section.

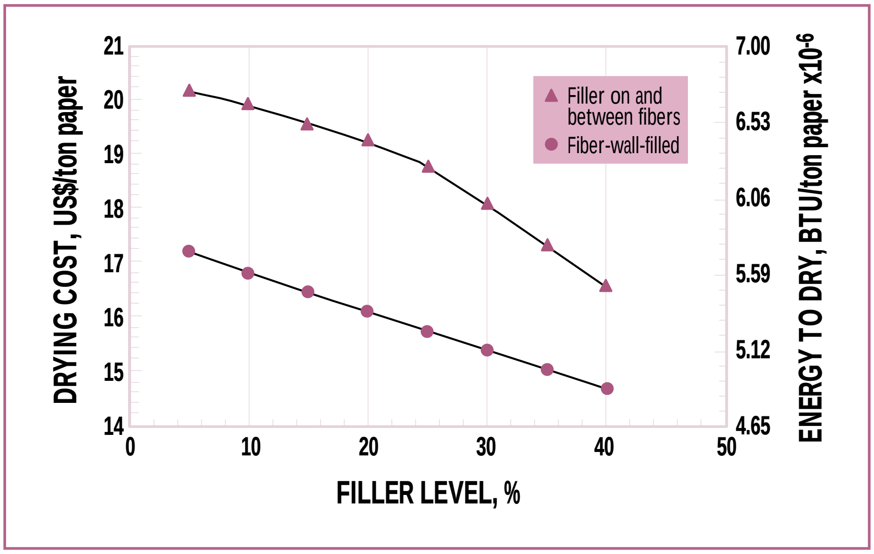
Figures 6 and 7 describe the drying rates of the different types of papers—conventionally filled, unfilled, and



6. Moisture content variation with time for Jack pine handsheets containing calcium carbonate



7. Drying rate variation with moisture content for Jack pine papers containing calcium carbonate



8. Drying cost and energy requirement variations with filler level for Prince Albert pulps

fiber-wall-filled. The data in Fig. 6 shows how the moisture contents of all three sheets vary as a function of time. Although the drying rates of all three sheets are the same according to Fig. 7, the fiber-wall-filled sheet with less initial moisture dries in less time compared to the conventionally filled and unfilled sheets (Fig. 6). Doubling the weight of the sheets did not change the drying rate. This reduction in water content for the fiber-wall-filled sheet is advantageous in minimizing the costs and energy associated with the drying process and potentially increasing the production rate on a dryer-limited paper machine.

KEYWORDS

Absorptivity, ash, bibliographies, calcium carbonate, Canadian standard freeness, cell walls, drainage, drying, fibers, fillers, hardwood pulps, paper, porosity, precipitation, pressing, softwood pulps, solids content, water removal, water retention.

ECONOMICS

The energy cost of drying unfilled paper is currently approximately US$ 21/ton. This is equivalent to approximately 7 million Btu of energy or approximately 1.21 barrels of fuel oil *(31)*. For a 1000 tons/day paper mill operating 365 days, the drying of unfilled paper costs approximately US$ 7.7 million with an energy demand of approximately 2.56 trillion Btu or approximately 440,517 barrels of crude oil. When adding PCC conventionally to paper, the energy and costs associated with the drying step decrease significantly. The location of the filler with respect to the fibers further affects these reductions. To exemplify this effect, **Fig. 8** compares the drying costs and energy requirements of conventionally and fiber-wall-filled papers based on the WRV findings (Fig. 4). The production of fiber-wall-filled paper clearly requires less energy and money than the manufacture of conventionally filled paper at all filler levels.

For a 1000 tons/day paper mill operating continuously for 365 days, the fiber-wall-filling of paper at a 20% filler level can save an estimated US$ 1.1 million or approximately 383 billion Btu. Assuming that the paper mill relies totally on fuel oil for its energy needs, the paper mill could reduce its oil consumption by approximately 66,078 barrels/year by switching to fiber-wall-filled paper. The internal loading of paper with calcium carbonate lowers the drying costs and energy by approximately 16.4% over the conventional filling of paper at the same filler level.

CONCLUSIONS

From these results, it is evident that fiber-wall-filled pulps contain significantly less water in their cell walls than unfilled pulps or pulps having calcium carbonate on and between the fibers. The energy required for the mechanical and thermal removal of water from paper therefore is lower. The energy savings and enhanced paper machine speeds from the increased drainage and drying rates of fiber-wall-filled pulps can substantially decrease the costs of papermaking. **TJ**

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A grant from the National Research Initiative Competitive Grants Program of the United States Department of Agriculture/Cooperative State Research Service during the period 1992–95 and by the Dept. of Chemical Engineering (B. A. Finlayson, chairman) provided the financial support for this work. Some paper testing was conducted at the laboratories of the Boise Cascade Corp., Vancouver, WA, and at those of the Weyerhaeuser Co., Federal Way, WA, through the courtesies of S. Tay and R. Jewell, respectively.

Received for review Oct. 10, 1996.

Accepted Jan. 18, 1997.

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Note: The previous paper in this series, "Paper for the 21st Century," appeared in Paper Age *111(1): 10(1995) and 111(3): 6(1995).*