NOVEL LIGHTWEIGHT, HIGH-OPACITY PAPERS MADE FROM MECHANICAL PULPS[1]

John H. Klungness[1], Aziz Ahmed[1], Said AbuBakr[1], Mike J. Lentz[2], Eric G. Horn[2], and Masood Akhtar[2]
[1]USDA Forest Service, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398
[2]BioPulping International, P.O. Box 5463, Madison, WI 53705

ABSTRACT

Compared with direct loading of calcium carbonate fillers to chemical pulps, fiber loading increases the strength of reinforcing chemical pulps. Increasing the strength of chemical pulps also permits reduced chemical pulp usage, reduced grammage, and increased ash. The objective of this study is to explore the potential of combining fiber loading with biotreatment of thermomechanical pulps (TMP) for printing papers. Handsheet evaluations of pulps produced by fiber loading are presented. The data suggest that fiber loading the chemical reinforcing portion of printing paper fiber furnishes combined with biopulped TMP pulps can allow the papermaker to reduce the expensive chemical portion of printing papers and lower grammage while maintaining bulk. In addition, the energy savings of biopulping combined with fiber loading will further reduce the cost of manufacturing printing papers.

KEYWORDS

Calcium carbonate, filler, high consistency, optical property, particle size, printing paper, stock preparation, strength property

INTRODUCTION

Mechanical pulping accounts for about 25% of the wood pulp production in the world today. This volume is expected to increase in the future, because mechanical pulping has a high yield and is used as a way to extend forest resources. Current efforts in mechanical pulping are directed towards producing lightweight papers. Typically, when grammage of printing paper is decreased, mechanical pulps are used to maintain bulk and opacity. However, the strength of the paper is usually decreased. To reduce grammage, paper optical properties and paper strength must be increased. Fiber loading is a new technology that has the potential to produce reduced grammage papers cost effectively. This study examines the potential of increasing the strength of the reinforcing chemical pulp by fiber loading to permit combinations of reduction of chemical pulp use, reduction in grammage, and increase in ash for printing papers.

Methods for incorporating fillers within pulp fibers have been the subject of extensive research (1,2,3). The initial goal of this study was to incorporate filler within the fiber to produce high strength fiber at high ash content. A later goal was to substitute low-cost calcium carbonate for high-cost fiber using fiber loading (4). Fiber loading, a two-step process (5), was developed at the USDA Forest Service, Forest Products Laboratory (FPL). In the first step, calcium hydroxide is mixed into the pulp slurry. Then, the pulp and calcium hydroxide mixture are reacted using a high consistency pressurized reactor (refiner or disk disperser) under carbon dioxide pressure to precipitate calcium carbonate. Calcium carbonate is deposited within, on the surface of, and outside the pulp fibers, and is termed fiber-loaded precipitated calcium carbonate (FLPCC) (Fig. 1). As a result of fiber loading, fiber bonding is increased as shown by increased handsheet strengths. Fiber-loaded pulps are stronger than similar direct-loaded pulps at the same precipitated calcium carbonate (PCC) levels due to three independent mechanisms: i) deposit of FLPCC within the fiber wall and lumen, (ii) gentle refining at high pH, and (iii) gentle refining of fiber at high consistency (6.7).

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

The strength improvement of chemical pulp, typically used for reinforcing mechanical pulp containing papers, resulting from fiber loading plus the cost effective production of FLPCC could be used in combination with biopulped TMP. Biopulped TMP has the typical mechanical pulp advantages of high bulk and opacity along with the unique advantage of more than 30% energy reduction in refining energy compared with conventional TMP (8

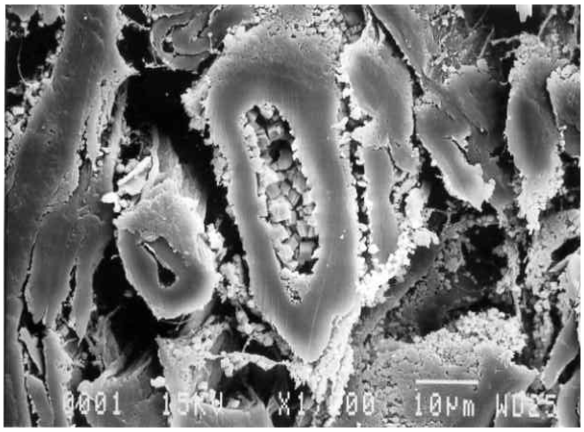

Fig. 1. Scanning electron microscope (SEM) micrograph of handsheet cross section. This micrograph shows fiber-loaded precipitated calcium carbonate (FLPCC) deposited within, on the surface of, and outside the pulp fibers.

We examined the effect of fiber loading the chemical pulp portion of a typical lightweight coating base stock pulp furnish. We compared this to the effect of direct loading at the same filler level with commercial precipitated and ground calcium carbonates. We did these experiments to prepare for subsequent experiments. The subsequent experiments will quantify the savings possible from i) reducing chemical pulp, ii) reducing grammage, iii) increasing ash level, and iv) reducing the level of TMP refining energy.

EXPERIMENTAL

Materials

Fully bleached eucalyptus and northern pine kraft commercial pulps were used for this study. Commercial calcium carbonate fillers were obtained from suppliers and examined for both particle size and shape.

For the commercial calcium carbonates, particle size analysis was conducted with a Horiba (Irvine, CA) LA–910 laser light-scattering particle size analyzer. Scanning electron photomicrographs were obtained for the fiber-loaded calcium carbonate. The two polymer retention aids used were cationic (polyacrylamide, BMB 2410) and anionic (colloidal silica, BMA–780) materials obtained from Eka Chemicals, Inc. (Marietta, GA). Mississippi Codex (Alton, IL) hydrated lime (mean particle diameter ~2.9 μm) industrial-grade calcium hydroxide was used for the fiber loading process.

Equipment

Low-consistency refining was performed with a 305-mm atmospheric double-disk Sprout Waldron (Springfield, OH) refiner. Fiber loading was accomplished in a 305-mm-diameter pressurized disk refiner manufactured by Sprout Bauer (Springfield. OH) using Pattern D 2B505 refiner plates.

Methods

Both the eucalyptus and pine kraft pulps were refined at a low (–3%) consistency level to about 350 mL Canadian Standard Freeness (CSF). After the pulp was dewatered. it was shredded in a laboratory shredder. For fiber loading, 500 g (ovendry basis) pulp was used for each batch. A slurry of calcium hydroxide and water was prepared and added to the pulp in a Hobart-style dough mixer. The consistency of the pulp was adjusted to 21%. After the pulp slurry was mixed for about 30 min, it was placed in a polyethylene bag and sealed for later use in the fiber loading process.

For fiber loading, the refiner plate gap was adjusted to 0.7 mm. Pulp and calcium hydroxide were removed from the sealed bag and placed in the refiner holding tank. The holding tank was then pressurized with carbon dioxide to 207 kPa. The pulp was held in the holding tank for about 3 min before being screw-conveyed to the refiner zone and passed through to the pressurized receiver tank. About 68 MJ/metric ton of energy were used, The refining and holding time of the pulp in the receiver tank was 12 min. The total time for fiber loading was 15 min.

For handsheet preparation, the consistency of the fiber-loaded pulp was measured and diluted with the needed water in a doler tank. The concentration of fiber-loaded pulp or the pulp being evaluated was adjusted to result in a 1.5-g (75-g/m^2) handsheet from 790-mL slurry. This grammage was selected because it is commonly used for copy paper. A 790-mL dole of slurry was taken from the doler tank, and the cationic polymer (polyacrylamide) was added, followed by the anionic (colloidal silica) polymer. The dosage of the retention aids was adjusted to give final ash content of 25% (±1%) as calcium carbonate. The mixture was then placed in a handsheet former and mixed for uniformity before being drained and formed into handsheets. For direct loading, the refined pulp was added to the doler tank as described for fiber loading, and the calcium carbonate being evaluated was added as needed. The remainder of the direct-loaded handsheet preparation, including the addition of retention aids, was identical to that for the fiber-loaded handsheets.

The following test methods were used for handsheet testing: tensile index, Tappi T494; tensile energy absorption (TEA), Tappi T494; tear index, Tappi T414; diffuse brightness, diffuse opacity of paper, Tappi T519; and diffuse scattering coefficient, Tappi 519.

RESULTS AND DISCUSSION

Tensile index values are given in Fig. 2. Fiber loading of handsheets of both eucalyptus and pine kraft pulps resulted in greater tensile index values compared with that of handsheets from direct-loaded pulps. This is an indication of stronger fiber-to-fiber bonding, most likely due to less interference to interfiber bonding from filler deposited within the fibers. The tensile index values for fiber-loaded pulp were about 10% to 40% higher than those of direct-loaded pulp depending on which type of pulp or filler was compared. No trend in the data for direct loading or for pulp type was noted.

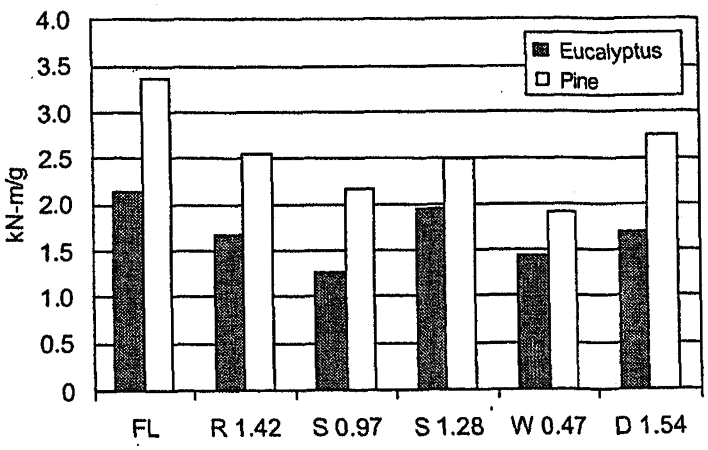

Fig. 2. Tensile index values for handsheets from bleached eucalyptus and pine kraft pulps with 25% calcium carbonate fillers: fiber loaded, rhombohedral (1.42 µm diam.), scalenohedral (0.97 and 1.28 µm), and wet ground (0.47 µm) and dry ground (1.54 µm).

The ability of paper to absorb energy (toughness) is indicated by TEA. The TEA values we obtained are given in Fig. 3. The TEA of handsheets from fiber-loaded pulps was 15% to nearly 70% greater than that of handsheets with direct-loaded fillers. indicating a greater toughness and durability for paper products made from fiber-loaded pulps.

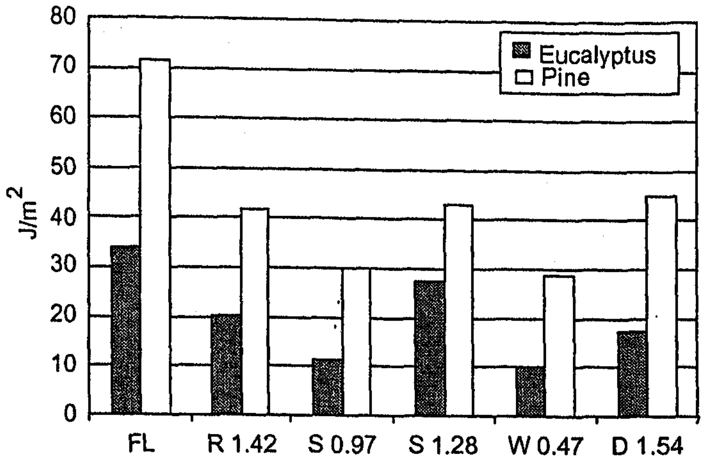

Fig. 3. Total energy absorption (TEA) values for handsheets from bleached eucalyptus and pine kraft pulps with 25% calcium carbonate fillers: fiber loaded, rhombohedral (1.42 µm diam.), scalenohedral (0.97 and 1.28 µm), and wet ground (0.47 µm) and dry ground (1.54 µm).

Fiber loading resulted in somewhat higher tear index values for handsheets made from both eucalyptus and pine kraft pulps (Fig. 4). Differences between fiber loading and direct loading were small. Tear index depends to a great extent on the fiber length of the pulps. Because the addition of filler does not change fiber length. no great differences were noted between the types of pulp loading.

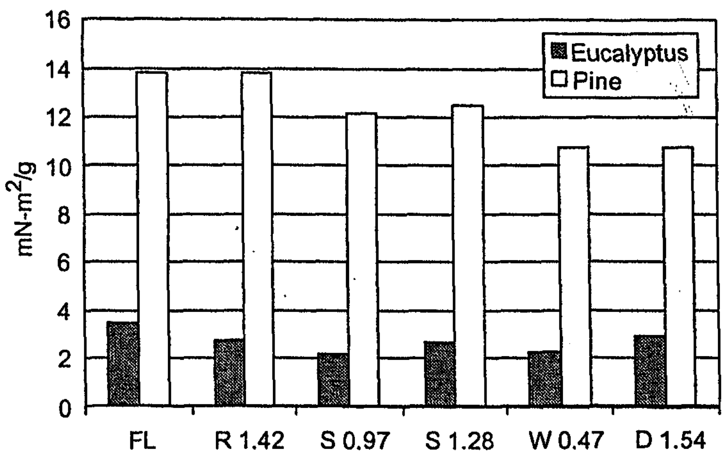

Fig. 4. Tear index values, for handsheets from bleached eucalyptus and pine kraft pulps with 25% calcium carbonate fillers: fiber loaded, rhonibohedral (1.42 µm diam.), scalenohedral (0.97 and 1.28 µm), and wet ground (0.47 µm) and dry ground (1.54 µm).

Handsheet brightness as measured by diffuse brightness is shown in Fig. 5. Handsheets made from fiber-loaded eucalyptus and pine kraft pulps were slightly less bright than those made from direct-loaded pulps. This was apparently due to the alkalinity of the calcium hydroxide used for fiber loading. Interestingly. the difference in handsheet brightness was slightly less for eucalyptus pulp than it was for pine kraft pulp. This may be an indication of less residual lignin in the eucalyptus pulp. A potential method for increasing brightness, if needed. is to add a small amount of hydrogen peroxide to the fiber loading reactor (9).

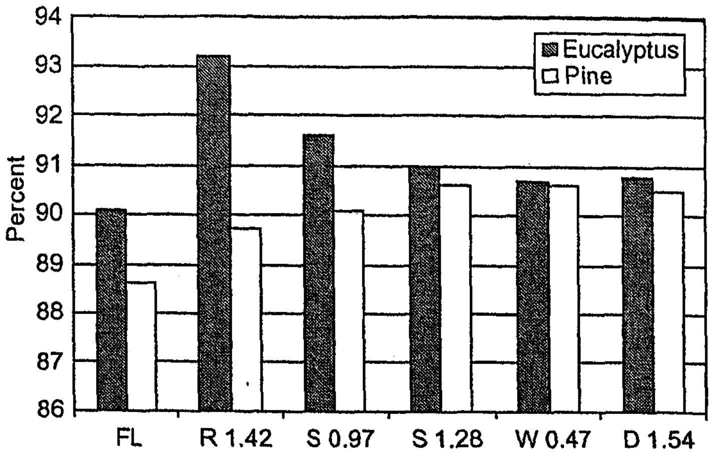

Fig. 5. Diffuse brightness values for handsheets from bleached eucalyptus and pine kraft pulps with 25% calcium carbonate fillers: fiber loaded, rhombohedral (1.42 µm diam.), scalendhedral (0.97 and 1.28 µm), and wet ground (0.47µm) and dry ground (1.54µm).

Opacity values are given in Fig. 6, and scattering coefficient values are shown in Fig. 7. For both properties, values for fiber-loaded handsheets were in the middle range of all values measured, for both eucalyptus and pine kraft pulps. Because of the strength advantage of fiber-loaded pulps, increased levels of filler can be used to offset any loss in opacity or scattering coefficient. The increased strength due to fiber loading could be used in paper manufacturing for reducing grammage, increasing filler content, or both.

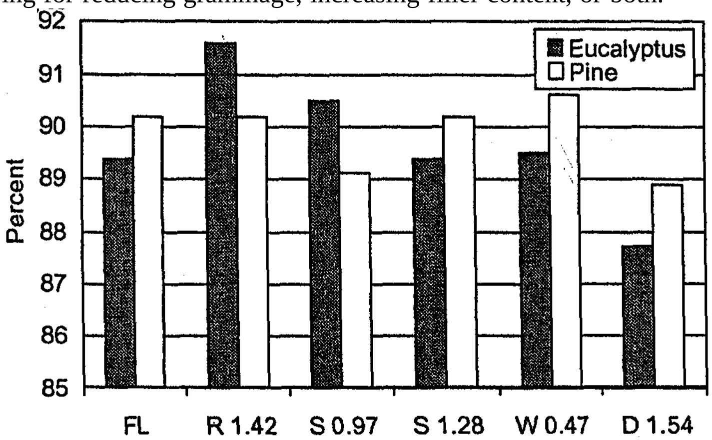

Fig. 6. Diffuse opacity for handsheets from bleached eucalyptus and pine kraft pulps with 25% calcium carbonate fillers: fiber loaded, rhontbohedral (1.42 µm diam.), scalenohedral (0.97 and 1.28 µm), and wet ground (0.47µm) and dry ground (1.54µm).

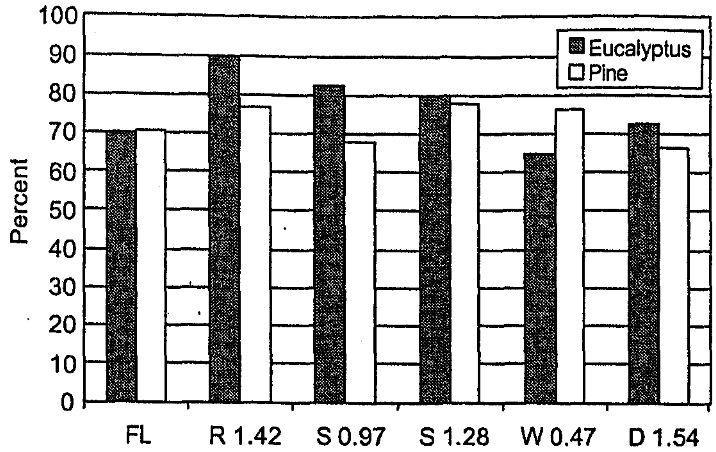

Fig. 7. Diffuse scattering coefficient for handsheets from bleached eucalyptus and pine kraft pulps with 25% calcium carbonate fillers: fiber loaded, rhombohedral (1.42 µm diam.), scalenohedral (0.97 and 1.28 µm), and wet ground (0.47 µm) and dry ground (1.54 µm).

CONCLUSIONS

Handsheets made from fiber-loaded pulps are stronger than handsheets from similar direct-loaded pulps at the same calcium carbonate levels. This is the result of the carbonate within the fiber wall and lumen and the low energy input refining of the pulp at high pH and consistency. Brightness values were slightly lower or the same for handsheets made from fiber-loaded pulps compared with those from direct-loaded pulps. Opacity and scattering coefficients were slightly lower for fiber-loaded handsheets, but increasing the filler level in the fiber-loaded pulps can easily offset this. By enhancing fiber bonding, fiber loading could be a means for producing lightweight, high-opacity paper, especially when combined with mechanical pulp such as biopulped TMP. The strength improvement of chemical reinforcing pulp combined with cost effective production of FLPCC could be used in combination with biopulped TMP. Biopulped TMP has the typical mechanical pulp advantages of high bulk and opacity along with the unique advantage of more than 30% energy reduction in refining energy compared with conventional TMP.

REFERENCES

1. Green H.V., Fox T.J., Scallan A.M.: Lumen-loaded pulp. Pulp and Paper Canada 83(1982):7, T203.

2. Scallan A.M., Middleton S.R.: The preparation of lumen-loaded pulp. In: Papermaking Raw Materials, Vol. 2, Mechanical Engineering Publications, London, 1985, 613–630.

3. Allen G.G., Ritzenthaler P.: The microporosity of pulp. Tappi J. 75(1992):3, 239.

4. Klungness J.H., Caulfield D.F.. Sachs I., Tan F., Sykes M.S., Shilts R.A.: Fiber loading: a progress report. In: 1994 Tappi Recycling Symposium Proceedings, May 15–18, Boston, MA. TAPPI Press, Atlanta, GA, 1994, 283–290.

5. Klungness J., Caulfield D., Sachs I., Sykes M., Tan F.. Shilts R.: Method for Fiber Loading a Chemical Compound, U.S. Pat. 5,223,090 (1997) RE 35,460.

6. Klungness J.H., Pianta F., Stroika M.L., Sykes M.S., Tan F., AbuBakr S.M.: Lightweight, high-opacity paper: process costs and energy use reduction. In: Proceedings of 1998 AIChE Symposium Series, Oct. 25–29, Montreal, Canada. 1998.

7. Sykes M.S., Klungness J.H., Tan F.. AbuBakr S.M.: Value added mechanical pulps for lightweight, high-opacity paper. In: 1998 Tappi Pulping Conference Proceedings. Oct. 25–29, Montreal, Canada. TAPPI Press, Atlanta, GA, 1998, 539–544.

8. Akhtar M., Swaney R.E., Horn E.G., Myers G.C., Ascott G.M., Lentz M.J., Sykes M.S.: Biomechanical pulping: a mill-scale evaluation. In: 1999 International Mechanical Pulping Conference Proceedings, May 24-26, Houston, TX. TAPPI Press, Atlanta, GA, 1999, 1–10,

9. Klungness J.H., Sykes M., Tan F., AbuBakr S., Eisenwasser J.: Effect of fiber loading on paper properties. In: 1995 Tappi Papermakers Conference Proceedings, April 23–26,Chicago, IL. TAPPI Press, Atlanta, GA, 1995,533–538.

Problem 2 **Develop technologies for conversion of wood to paper and paperboard with less effects on the environment.**

FY2001 Research Attainments

Publications
Research Unit

Klungness, John H.; Ahmed, Aziz; AbuBakr, Said; Lentz, Mike J.; Hom, Eric G.; Akhtar, Masood. 2001. Novel lightweight, high-opacity papers made from mechanlcal pulps. In: Proceedings of the 2001 international mechanical pulping conference; 2001 June 04-08: Helsinki, Finland. Espoo, Finland: Oy Keskuslaboratorio-Centrallaboratorium AB: 95-101.