Optimal refining conditions for development of OCC pulp properties

Ronald J. DeFoe

ABSTRACT: Pilot-plant trials were carried out to determine optimal refining conditions for pulps containing OCC (old corrugated containers). Pulps were refined at low consistency (3.5%) using coarse, medium, or fine plates and at high consistency (30%) using a fine plate. High-consistency refining consumed much more energy and produced pulps that were at best equal or slightly lower in burst and compression strength. Tear strength and porosity were higher for pulps refined at high consistency. Lower-strength furnishes were slightly more sensitive to the conditions under which low-consistency refining was carried out. With the trend toward increased recycling and consequent furnish degradation, this sensitivity is likely to become a significant factor in determining the conditions under which low-consistency refining is carried out.

KEYWORDS: Boxes, consistency, corrugated boxes, development, furnish, high consistency, low consistency, paper board containers, properties, pulp properties, pulps, recycling, refining, solid wastes, solids content, variables, waste papers.

The current interest in recycling, along with natural economic incentives, has led to an increase in the use of old corrugated containers (OCC) in linerboard grades. This, in turn, has stimulated interest in the production variables that affect the quality of OCC pulp. The upward trend in the use of recycled fiber is expected to continue, providing a powerful incentive for producers of linerboard and corrugating medium to adjust their manufacturing processes in an effort to maximize the quality of OCC pulps.

Conversion of waste OCC to a papermaking furnish involves many steps. The strength of secondary fibers is enhanced via two recycling operations—contaminant removal and fiber development.

- **Contaminant removal** is normally associated with visual appearance, but it is also an important factor in the development of pulp strength. The physical performance of the sheet is enhanced by eliminating materials that can interfere with fiber bonding (waxes and plastics) or result in stress concentrations and sheet failure (cubical contaminants). Unit operations for contaminant removal are key steps in processing secondary fiber, and machines for high-efficiency fine screening and light and heavy-weight cleaning are well developed[1].
- **Fiber development** becomes the overriding concern for enhancing physical properties after the OCC has been highly decontaminated. Process conditions in the OCC plant can affect development of fiber properties. There are also many processes that incorporate chemical modification and/or fractionation and separate refining of the pulp. This article concentrates solely on fiber development through mainstream refining of whole pulp.

A major focus of the work presented here is to settle the ongoing debate about whether low-consistency or high-consistency refining provides the greatest strength development for OCC fiber. The issue was addressed by comparing strength properties for two OCC pulps after refining at high and low consistency in a pilot plant.

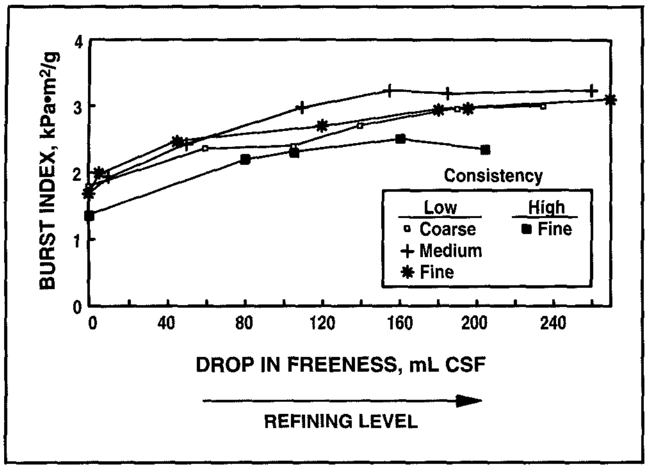
Pilot trials

Trials were carried out in a pilot plant at Beloit Corp.'s Research and Development Center in Pittsfield, MA. Ma-

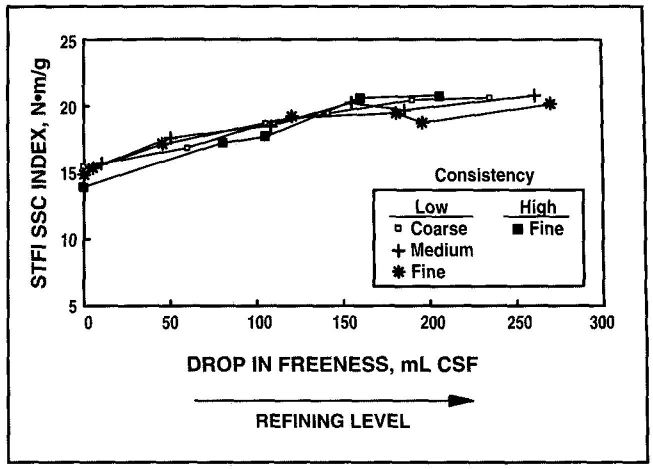
DeFoe is director of research, Beloit Corp. Research, 448 Hubbard Ave., Pittsfield, MA 01201.

[1]LeBlanc, P. E. and McCool, M. A., "Recycling and separation technology," TAPPI 1988 Pulping Conference Proceedings, TAPPI PRESS, Atlanta, p. 661.

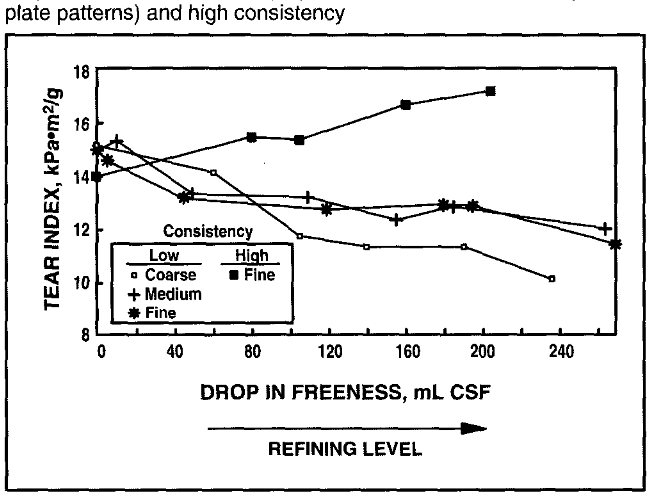
1. Burst index as a function of refining level (measured as freeness drop) for commercial OCC pulps refined at low consistency (three plate patterns) and high consistency



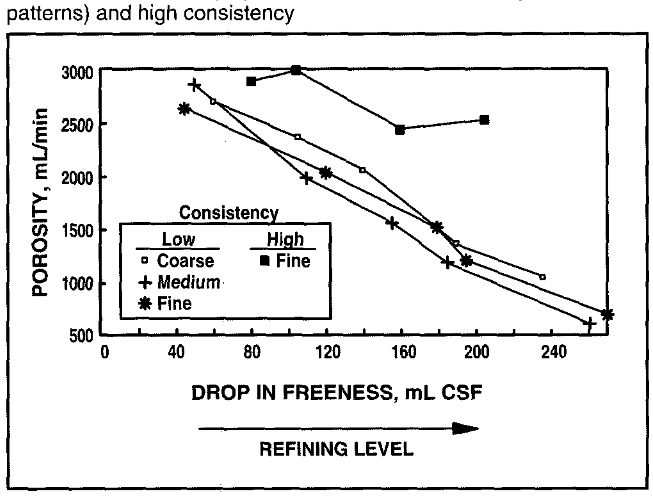
2. STFI short-span compression index as a function of refining level (measured as freeness drop) for commercial OCC pulps refined at low consistency (three plate patterns) and high consistency



3. Tear index as a function of refining level (measured as freeness drop) for commercial OCC pulps refined at low consistency (three plate patterns) and high consistency



4. Porosity as a function of refining level (measured as freeness drop) for commercial OCC pulps refined at low consistency (three plate patterns) and high consistency



terials were prepared for refining during the trials using appropriate slushing and thickening equipment installed in the pilot plant.

OCC pulps at 3.5% consistency were refined in a 20-in.-diam. double-disc low-consistency refiner. Low-consistency pulps were refined with one of three plate patterns: coarse, medium, or fine. The plates were operated at specific edge loads of 2.6, 1.8, or 1.2 W·s/m, respectively. These edge loads were selected based on a typical refiner operating at 85% of its gross motor load with each plate pattern.

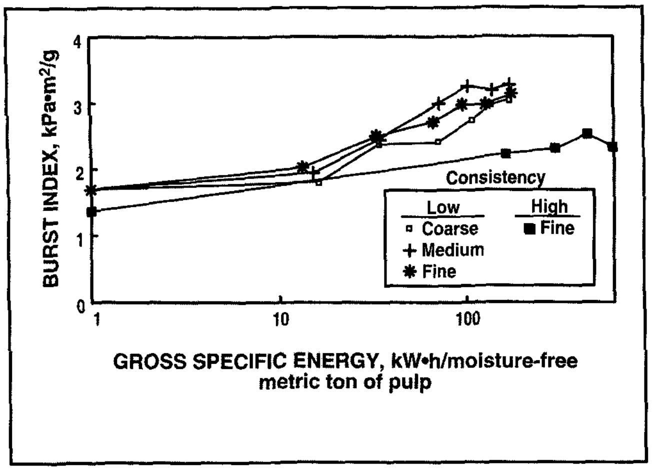
OCC pulp at 30% consistency was refined in a 12-in.-diam. single-disk high-speed refiner. A fine-barred plate pattern was chosen based on previous operating experience with OCC pulps.

Two OCC pulps were studied. One was produced in a commercial recycling system at a southern U.S. mill manufacturing linerboard and corrugating medium. The pulp, consisting of 100% OCC and no virgin fiber, was thickened to about 30% consistency with a screw press and shipped in containers to the pilot plant for the refining studies. Upon reslurrying, this pulp had a freeness of approximately 600 mL CSF.

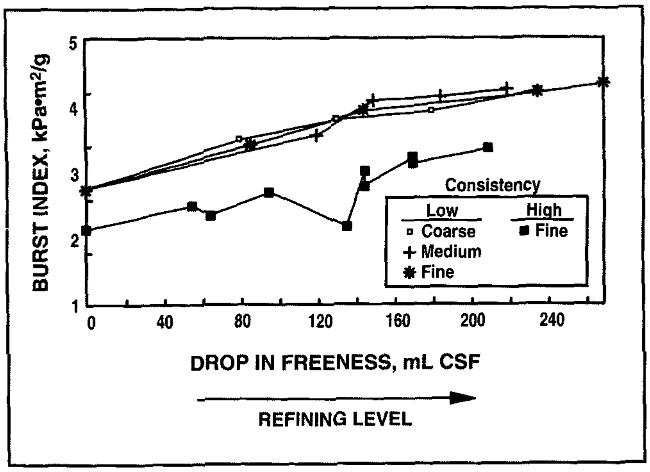
A second series of trials was conducted using an "artificial" OCC furnish prepared in the pilot plant from rolls of linerboard and corrugating medium obtained from the same mill. Both liner and medium were manufactured from approximately 30% OCC and 70% virgin pulp. Rolls of liner and medium were reslushed in a carefully measured 70/30 liner/medium ratio. This pulp was then effectively considered as 100% OCC taken from the reel of the paper machine. The freeness of this blend was approximately 550 mL CSF.

The artificial pilot OCC pulp was produced in an effort to obtain a large amount of uniform and readily avail-

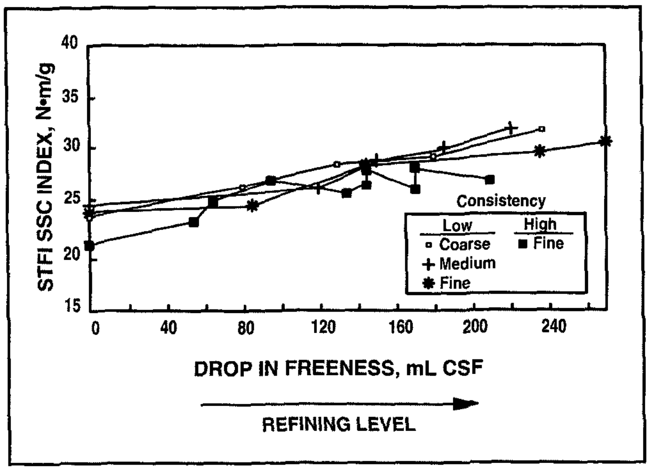
5. Burst index as a function of energy consumption during refining of commercial OCC pulps at low consistency (three plate patterns) and high consistency



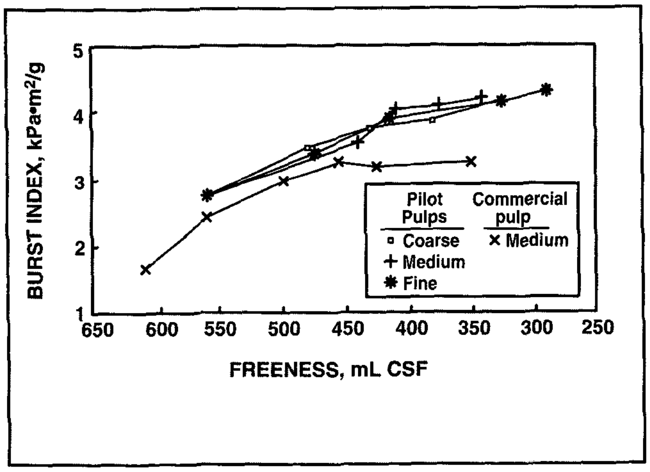
6. Burst index as a function of refining level (measured as freeness drop) for pilot OCC pulps refined at low consistency (three plate patterns) and high consistency



7. STFI short-span compression index as a function of refining level (measured as freeness drop) for pilot OCC pulps refined at low consistency (three plate patterns) and high consistency



8. Burst index as a function of freeness for pilot and commercial OCC pulps refined at low consistency. (Pilot pulps refined using one of three plate patterns.)



able furnish for the pilot-plant trials without incurring the expense (and the problems) of shipping large amounts of commercially produced pulp. Trials with the artificial pilot OCC pulp were performed largely to confirm the results obtained during the trials with commercial pulp. Comparison of data from both trials revealed some interesting differences between the commercial and pilot OCC pulps.

The range of specific energy over which the furnishes were refined was appropriate for production of pulps with properties suitable for use in linerboard manufacture. All reported properties are based on testing of handsheets formed from the refined pulps.

Trial results

Results from the trials were analyzed using typical criteria for measuring the success of a refining operation, namely that the desired strength property be achieved with minimal loss in freeness and with the minimum expenditure of refining energy. Results for the commercially produced OCC pulp and the pilot OCC pulp are discussed separately.

Commercial OCC pulp

Figure 1 shows that the medium plate provided slightly greater burst strength than the coarse or fine plates for the commercial pulp refined at low consistency. The results for short-span compression (SSC) strength in **Fig. 2** show that SSC index was insensitive to the type of plate used during low-consistency refining. Compression strength is affected by many factors, including fiber–fiber bonding, fiber length, and fiber stiffness. The degree of fiber–fiber bonding was enhanced by the medium plate operating at an edge load of 1.8 W·s/m, as evidenced by the burst response in Fig. 1. Apparently, the coarse and fine plates produced competing effects, such as fiber shortening and increased fiber flexibility, resulting in equal compression strengths for the three pulps refined at low consistency, regardless of plate type. The superior burst strength provided by the medium-style plate can be attributed to sufficiently low refining intensity coupled with good flow characteristics.

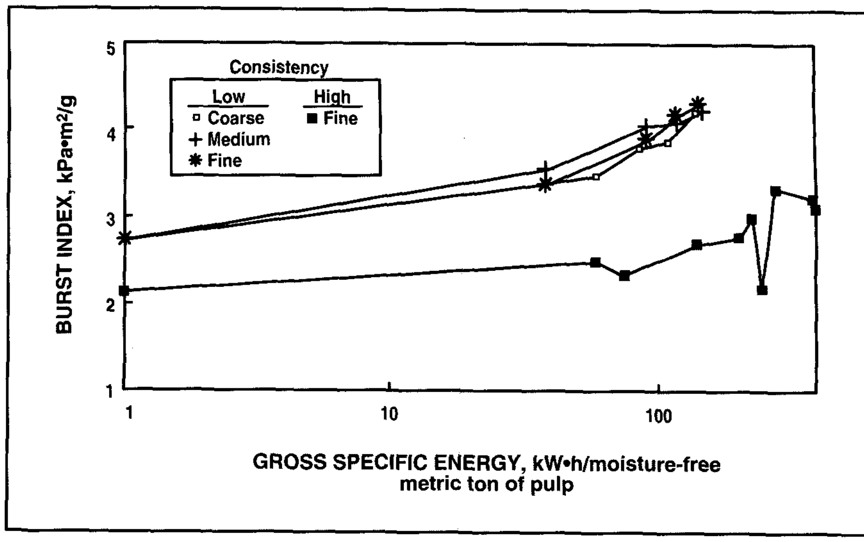
Figures 1 and 2 also show that development of burst and compression strength for the pulp refined at high consistency was at best comparable with that of the pulps refined at low consistency. It is difficult to compare results for the two refining consistencies because of the inherent changes that occur when pulp is thickened to high consistency. (As the pulp is thickened, the fibers are curled and compressed. This is what is responsible for the shift in burst index of the initial pulps in Fig. 1.) However, the similarity in slopes of the burst–freeness curves indicates comparable development from the two processes.

Figure 3 clearly shows that high-consistency refining produced a pulp of higher tear strength at a given freeness drop. High-consistency refining also provided a pulp of greater porosity, as seen in **Fig. 4**. While dispersion of contaminants is beyond the scope of this paper, it should be noted that high-consistency refining has an additional benefit in that it is an effective dispersion process[2].

Figure 5 shows that a substantial energy penalty can be associated with the high-consistency refining process for this fiber. The large amount of fiber–fiber action that is characteristic of high-consistency refining is inefficient at developing bonding with the large amount of chemical pulp in OCC. However, this same action also produces a high degree of fiber curl and compression, resulting in superior tear strength, and minimizes production of fines, resultin™g in higher porosity. These properties may be of interest for specific paper grades.

[2]Rangamannar, G. and Silveri, L., Tappi J. 73(7): 188(1990).

9. Burst index as a function of energy consumption during refining of pilot OCC pulps at low consistency (three plate patterns) and high consistency



Pilot OCC pulp

Figure 6 shows the burst-strength results for pilot OCC pulps refined at low and high consistency. The plate patterns used in low-consistency refining had no discernible effect on burst strength, in contrast to the results for the commercial pulp. The results for short-span compression (SSC) strength showed the same trends that were observed for the commercial pulp, as seen in **Fig. 7**. Once again, SSC index was insensitive to the type of plate used during low-consistency refining.

The difference in burst response was investigated by comparing the results for the pilot OCC pulps with the best results for the commercial pulp. As seen in **Fig. 8**, there were significant differences in the properties of the pilot and commercial pulps. The commercial pulp was higher in freeness and lower in burst strength.

There are several possible explanations for this. One suspicion is that the thickening operation during pulp collection at the mill resulted in fines loss, leading to the high freeness and low strength. However, if this was the sole cause, it is likely that refining the commercial pulp would enable it to attain or surpass the pilot OCC's burst strength at equal freeness levels. Figure 8 clearly shows that this did not occur. Another possibility worth considering is that there was an influx of material that degraded the furnish. Despite the mill's tight control of the waste furnish supply, the presence of contaminants such as waxes is unavoidable, and these materials reduce bonding. It is also possible that there is a certain amount of lower grade (i.e., foreign) OCC and non-OCC material in the feed to the mill's recycling system. Finally, there may have been some nondetected upset condition in the mill's process at the time of the pulp collection. It is likely that the differences in the properties of the pilot and commercial OCC pulps are a combination of all these factors, with each contributing to a varying degree.

Whatever the result of the lower strength, it is not intended to indicate that this sample is indicative of all mill OCC pulps, or even typical for this particular mill. The important point is that it can generally be expected that a weaker furnish will be more sensitive to low-consistency refining conditions. Since the integrity of the fiber and/or the fiber bonding is reduced, the furnish becomes more responsive, both positively and negatively, to the forces and resulting fiber modifications imparted by the refining process. This is why, in this case, the mill-produced pulp is more responsive to changes in refiner-plate design than the higher-quality pilot OCC. This relationship between pulp quality and refining response will become more important as recycling increases and OCC quality decreases.

The high-consistency results for the pilot pulp, also shown in Figs. 6 and 7, indicate (as with the commercial pulp) no burst and compression strength advantages for high-consistency refining. As with the commercial OCC, there is some shift in raw pulp strength because of the fiber curling and compression associated with the thickening process, which in this case was believed to have been complicated by chemical contamination during the thickening and redilution process. Slopes of the burst and compression strength curves are again similar, however, indicating comparable results from the two processes.

Figure 9 shows energy consumption during refining for the pilot pulps. The results confirm those obtained with the commercial pulps, namely that high-consistency refining consumes more energy than low-consistency refining.

Conclusion

When low-consistency refining was compared with high-consistency refining for OCC furnishes, the low-consistency process produced equal or superior burst and short-span compression strength at equal freeness levels. The low-consistency process also consumed less specific energy. Tear strength and porosity were enhanced by high-consistency refining, which may provide an incentive for using high-consistency refining in production of specialty grades where these properties are important. Interest in effective contaminant dispersion also may warrant the use of high-consistency refining.

It was also found that an OCC furnish of lower initial strength was slightly more sensitive to low-consistency refining conditions than a furnish of higher initial strength. In the future, as increased recycling begins to have a significant impact on U.S. OCC quality, the furnish is likely to become more sensitive to refining conditions. It is also possible that the characteristics of future OCC may change sufficiently to alter some of the conclusions of this work, such as the optimal low-consistency plate pattern and the relationship between high-and low-consistency refining.

The author wishes to thank J. Porter of the Beloit Rockton Research Center and C. Demler and B. Crossley of the Beloit Pittsfield Research Center for their many hours of labor generating the data presented in this paper.

Received for review June 10, 1992.

Accepted Sept. 23, 1992.

Presented at the TAPPI 1991 Pulping Conference.