

Refining recycled fibers: advantages and disadvantages

Jorma J. Lumiainen

Correct refining after other process stages can improve the papermaking potential of recycled fibers and reduce paper manufacturing costs.

The rapidly increasing use of recycled fibers for more and more demanding paper and paperboard grades has strongly stimulated the development of secondary-fiber upgrading processes. Most of the efforts have been directed toward developing various equipment and processes which produce cleaner and cleaner fibers (1).

It is natural that a visually good-looking end product requires clean furnish. Some heavier multilayer grades set lower requirements for the cleanliness of recycled fiber than thinner one-layer grades since this furnish component cannot be hidden between outer layers of the end product.

During this development stage, very little attention, if any, was paid to the bonding ability of recycled fibers. These fibers are often used as a filler; in fact, chemical short-fiber pulp was used in this way earlier. Low bonding is typically compensated for by using chemical binders, e.g., starch, which fasten low-bonding-ability furnish components to the paper web.

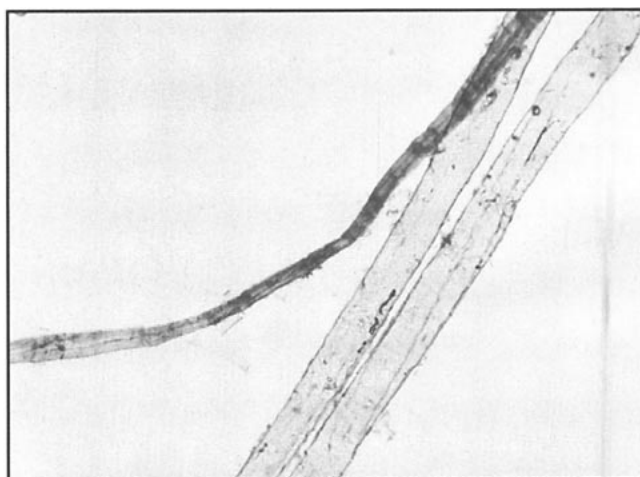
Refining is a commonly used method to increase the bonding ability of all virgin fibers, and it is normally applied also to old corrugated containers (OCC) when it is used for fluting or test liner. In so-called developing countries, many fine-paper grades also are produced from 100% recycled fiber such as computer printouts (CPO) and other high-quality, selected-best white waste grades. Refining has for a long time been common practice at these paper and board mills simply because they needed to improve the papermaking potential of recycled fibers.

The swelling and bonding ability of fibers are reduced every time they pass through the papermaking process. In papermaking, pressing and drying are much more intensive than in pulp drying. Furthermore, slushing and cleaning of already-used fibers decrease the amount of fines and fibrils needed for good fiber bonding (Fig. 1).

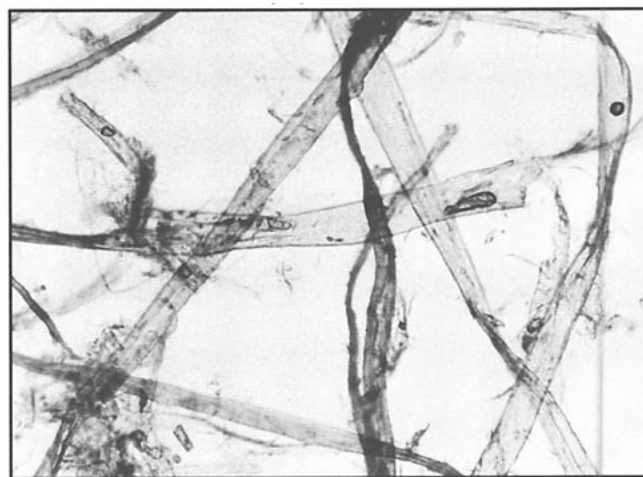
Various recycled-fiber treatment stages regenerate swelling and bonding ability to some extent, but not enough. Therefore, somewhat more intensive treatment—refining—is needed to redevelop the fibers. The effect of refining can be seen in Fig. 2. Refining has created fibrils and thus improved bonding ability.

On the other hand, every reuse has weakened these fibers

1. Unrefined fibers in deinked pulp



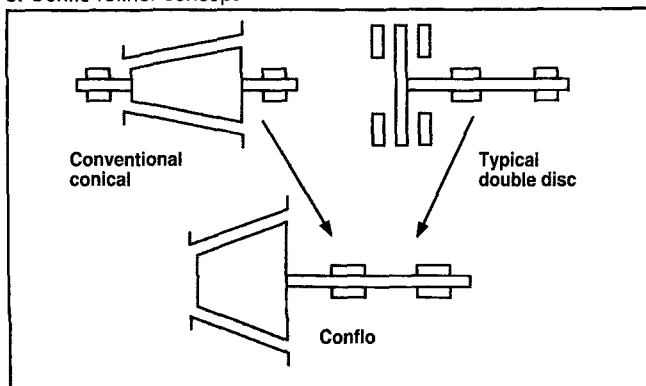
2. Refined fibers in deinked pulp



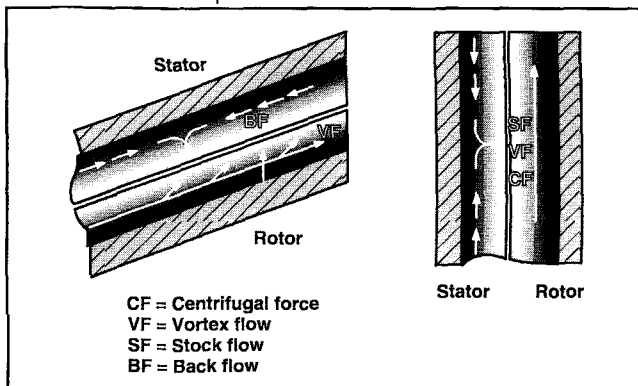
and caused irreversible changes, which make recycled fibers more sensitive to errors in refining than virgin fibers. If not refined correctly, the result can be disastrous. Negative effects such as too high an increase in the drainage resistance, heavy fiber length, and tear-strength reduction can be avoided by selecting both equipment and other refining conditions correctly (2, 3).

Lumiainen is vice president, stock preparation refining technology for Sunds Defibrator Jylhä Oy, Box 125, Valkeakoski SF 37601, Finland.

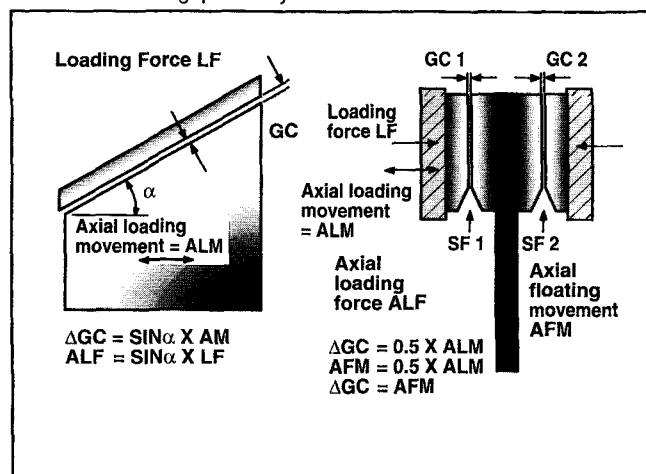
3. Conflo refiner concept



4. Conflo vs. disc flow pattern



5. Conflo vs. disc gap stability

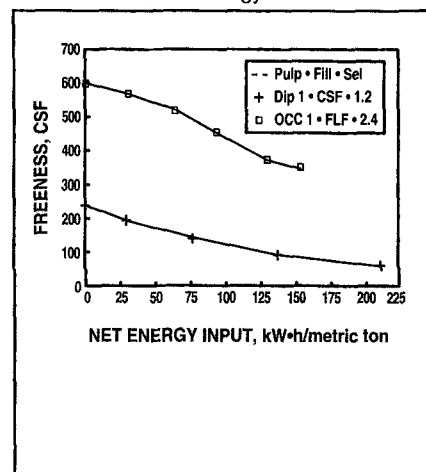


I. Refining conditions for DTP 1 and OCC 1

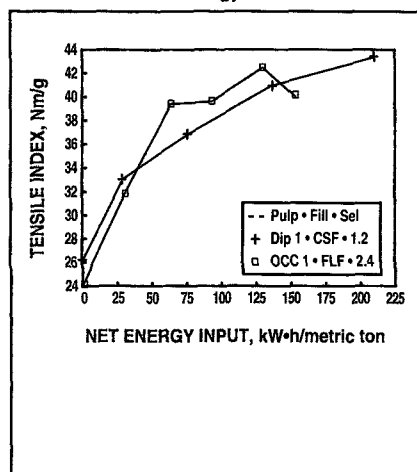
Trial no.	Pulp grade	Fillings used	Refining consist., %	Specific edge load, Ws/m	Specific surface load, Ws/m ²
1	DIP 1	CSF	4.5	1.20	392
2	OCC 1	FLF	3.9	2.40	652

CSF = Coarse short-fiber type fillings
FLF = Fine long-fiber type fillings

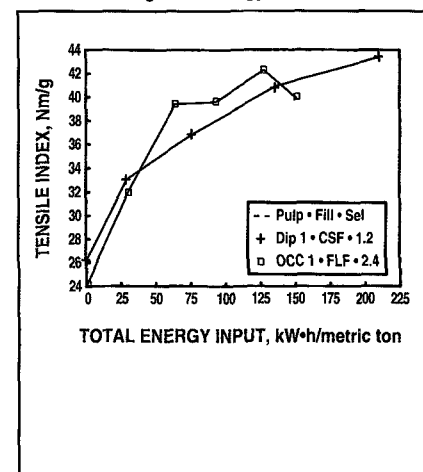
6. Freeness vs. net energy



7. Tensile vs. net energy



8. Tensile vs. gross energy



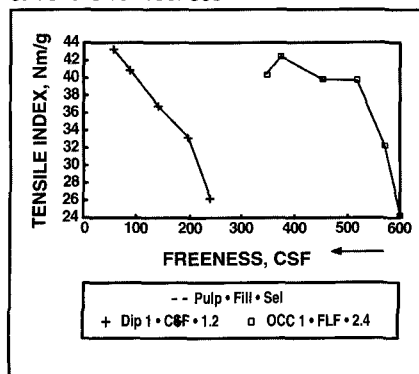
Finally, recycled fibers very often also contain shives coming from mechanical pulp components. Since these shives can be harmful, if recycled fibers are used for fine or coated paper grades, refining is needed for shives removal.

The Conflo refiner concept was developed to perform gentle and fiber-saving refining, in other words, to develop the bonding ability of fibers with a minimum increase of drainage resistance

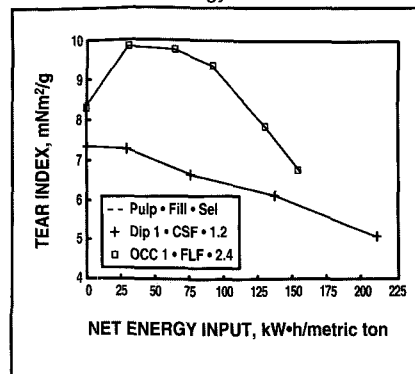
and a minimum decrease of fiber length. The other targets, such as low energy consumption and easy maintenance, are also met (Fig. 3) (4).

The advantages mentioned earlier are due to the refiner geometry, which ensures a favorable fiber flow pattern inside the refining zone (Fig. 4). This refiner concept has only one gap, which is accurately controlled and very stable (Fig. 5).

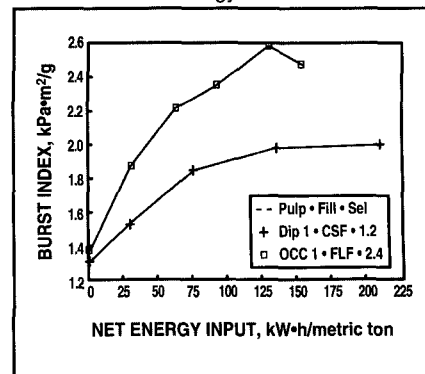
9. Tensile vs. freeness



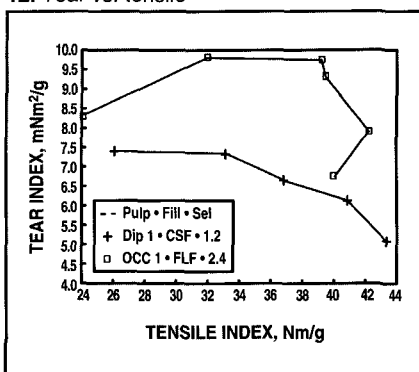
10. Tear vs. net energy



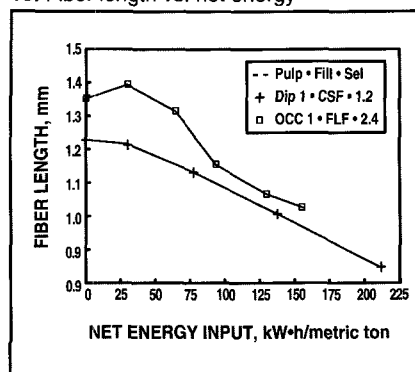
11. Burst vs. net energy



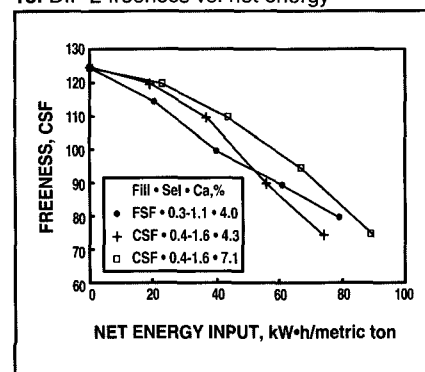
12. Tear vs. tensile



13. Fiber length vs. net energy



15. DIP 2 freeness vs. net energy



Since 1983, when the Conflo concept was introduced, almost 500 units have been delivered for various fibers and paper grades. Increasingly, the deliveries are directed toward recycled fibers.

Experimental work at the research plant

Research plant trial equipment

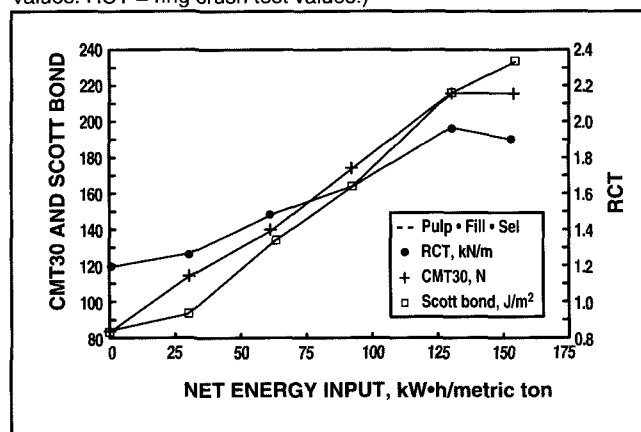
At our research plant, we used mill-scale equipment to study the refining behavior of most commonly used papermaking fibers. Slushing and refining can be performed at various consistencies from low to medium—up to 12%.

Effect of refining on fiber properties

The first trials with recycled fibers were performed with deinked household waste (DIP) and OCC at a consistency typical of low-consistency refining. Refining conditions for these trials were selected based on earlier mill experiences. Refining of recycled fiber has been normal practice at mills producing 100% recycled fiber such as OCC, CPO, and other waste grades. The most important trial variables are shown in Table I. This table also shows our new specific surface load value. The values show that finer fillings and lower refining intensity have been applied for DIP than for OCC waste pulp (4).

The trial results indicate the general refining behavior of these fibers. Figure 6 shows the reduction in freeness, and, due to a different starting level and fiber composition, these

14. Stiffness and bond vs. energy (CMT 30 = Concordia medium test values. RCT = ring crush test values.)

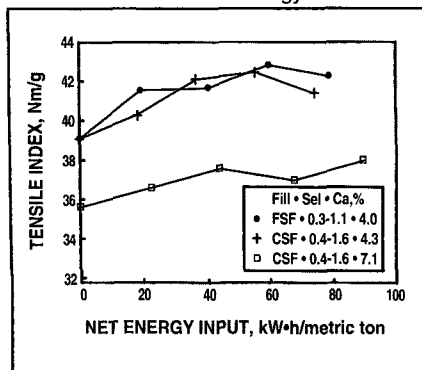


curves also have a different form. OCC behaves as slightly refined pulp; DIP performs as more heavily refined pulp.

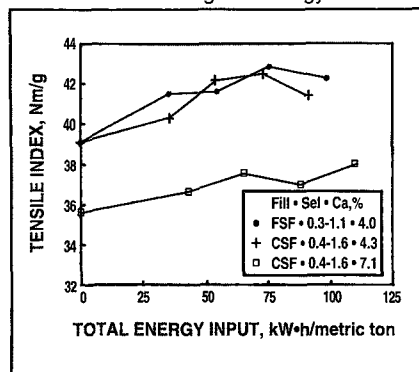
Bonding ability is quite well indicated by evaluating the tensile strength, which is clearly increased for both pulps (Figs. 7 and 8). The gross energy input is about 30% higher than the net energy input because of the no-load or idling power. In the case of OCC, tensile development seems to level or even decline just as it would when refining mechanical pulps. However, considerably favorable development indicates fairly high kraft content.

Prolonged refining of deinked pulp improves tensile

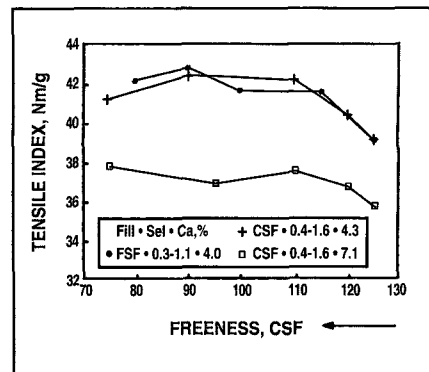
16. DIP 2 tensile vs. net energy



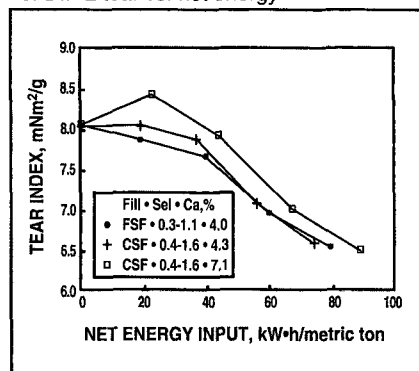
17. DIP 2 tensile vs. gross energy



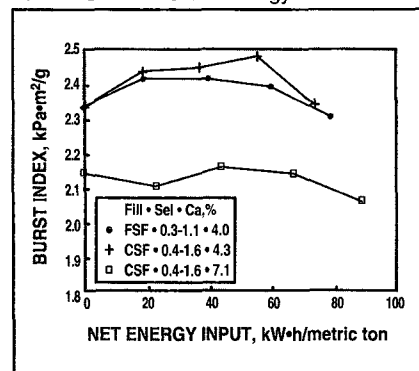
18. DIP 2 tensile vs. freeness



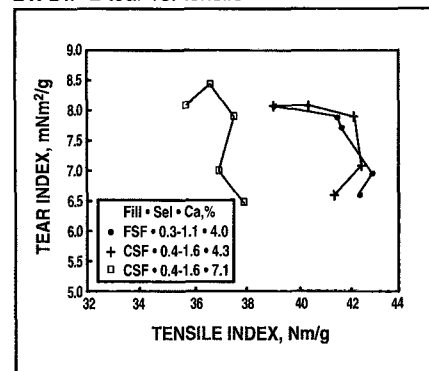
19. DIP 2 tear vs. net energy



20. DIP 2 burst vs. net energy



21. DIP 2 tear vs. tensile



II. Refining conditions for DIP 2

Trial no.	Fillings used	Refining consist., %	Specific edge load, Ws/m	Specific surface load, Ws/m²
1	FSF	4.0	0.27–1.09	135–530
2	CSF	4.3	0.42–1.62	135–530
3	CSF	7.1	0.42–1.62	135–530

DIP 2 = 75% newsprint + 25% magazine waste
 FSF = Fine short-fiber type fillings
 CSF = Coarse short-fiber type fillings

strength, which indicates a high chemical pulp content in this pulp. Tensile strength development also is reflected by the freeness in Fig. 9, which indicates the penalty in drainage decrease to be paid for strength. Tear strength of OCC is improved at the beginning, as it is when refining dried chemical or mechanical pulps. Tear strength of DIP is maintained at the beginning but then reduced in both cases (Fig. 10).

Burst also can be improved by refining, as indicated in Fig. 11. Prolonged refining indicates the limitations as seen earlier in the case of tensile.

Quite often papermakers evaluate the papermaking poten-

tial of pulp by using the tear–tensile combination as an indicator. This is revealed in Fig. 12, which shows that the papermaking potential is increased by refining.

Fiber length is naturally decreased by refining but not heavily in the beginning (Fig. 13).

Finally, the effect of refining on some typical properties important in board making are shown in Fig. 14.

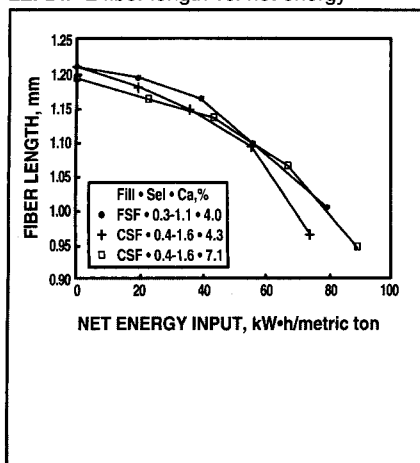
To obtain more information about the refining of recycled deinked pulp, the following trial series was performed at our plant. In this trial, both the fillings and the refining consistency were used as main variables (Table II). Before refining, pulp was effectively disintegrated so no flakes were visually seen.

The refining energy was increased by increasing the refiner load (increased load means increased intensity). Therefore, the change in freeness is slow at the beginning (Fig. 15). On its behalf, an increased consistency means slower refining if measured as freeness.

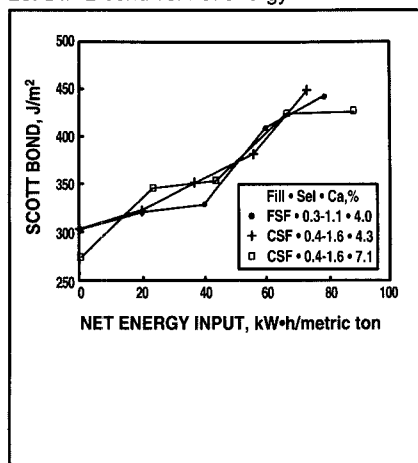
The main interest of papermakers is to develop the bonding ability of fibers, not only freeness, because freeness does not necessarily tell the strength of fibers (Fig. 16). The tensile strength development is given as a function of the net energy input. The initial strength level is higher at a lower consistency, which also gives better tensile development than higher consistency. The difference between two fillings is negligible.

Since papermakers are interested in the total energy consumption, tensile also is shown as a function of the total energy consumption in Fig. 17. Improved tensile naturally means decreased freeness, and here again the effect of consis-

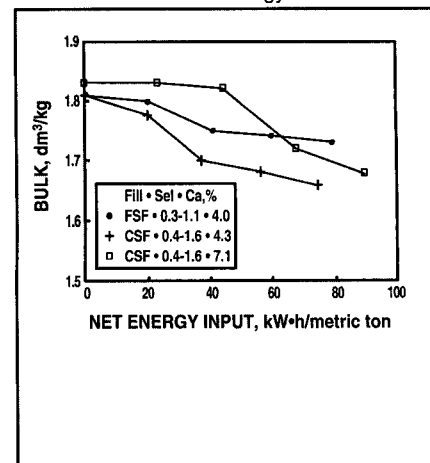
22. DIP 2 fiber length vs. net energy



23. DIP 2 bond vs. net energy



24. DIP 2 bulk vs. net energy



tency is seen (Fig. 18). Tear strength is maintained at the beginning, but reduced with prolonged refining (Fig. 19).

Refining improves burst at the beginning, but burst strength declines if the pulp is refined too much (Fig. 20). Coarser fillings at a low consistency give the best burst development.

The tear-tensile combination curves show a typical development for mechanical pulps, which is natural in this case since the furnish is made up mostly of mechanical fibers (Fig. 21).

Fiber length is maintained at the beginning, but then reduced (Fig. 22). Surprisingly, coarser fillings are somewhat more fiber-shortening than finer fillings. Reasons for this can be seen later when we evaluate the shives removal efficiency.

Refining also improves internal bonding of the pulp, which is evaluated by measuring Scott bond (Fig. 23). Development is very similar in all cases.

Bulk is reduced by refining, more when using coarser fillings at a lower consistency than with finer fillings or at a higher consistency (Fig. 24).

Sometimes shives must be refined off, and the effect of the refining is seen in Fig. 25. Increased consistency clearly decreases the shives removal efficiency of the refining, as do the finer fillings. Coarser fillings give the best shives reduction and this, in my opinion, explains the heavier fiber shortening with coarser fillings than with finer fillings when both have the same specific surface load.

Summary of research plant trials

Refining of recycled fibers improves the bonding ability of all fibers, and recycled fibers basically behave the same as corresponding virgin fibers. Earlier refining and stresses in the papermaking process have weakened these fibers, caused irreversible changes in the fiber structure, and reduced their swelling ability. Because of this, refining must be performed carefully, taking the refining characteristics of fibers into account. Recycled fibers can easily be over-refined so that strength properties after reaching the maximum start to decline.

Increased refining consistency is believed to be necessary for recycled fiber, but these results clearly indicate that favor-

able fiber development takes place at a typical low consistency. It seems like refining at an increased consistency does not really develop bonding ability very effectively because mechanical attrition forces are not strong enough. This phenomenon is very similar to the refining of sack kraft pulp, where a low-consistency refining stage is needed after the high-consistency refining for fiber strength development.

Mill installations

Approximately 10% of delivered Conflo refiners are used to refine various recycled fibers. Typical mill installations comprise one-stage refining, but in some cases there are two refiners in series, allowing more intensive fiber development than is possible in one pass. Net energy input varies from 20 kW·h/metric ton to 50 kW·h/metric ton but can be higher when refining strong kraft waste.

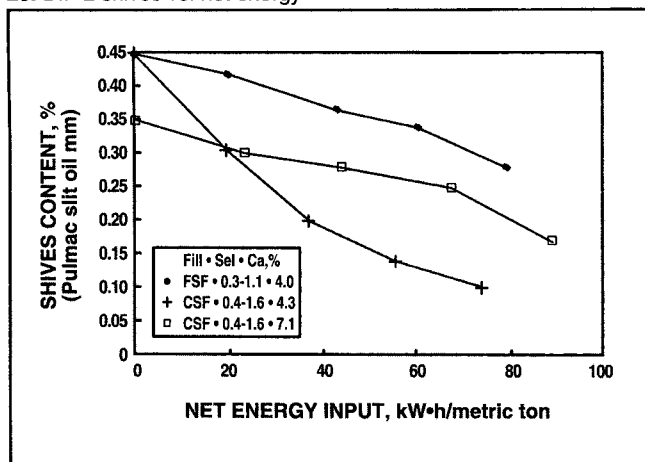
Different mills have different recycled fiber treatment systems. They evaluate different properties, and the papermaking potential of any pulp greatly depends on its origin and earlier history. However, the following mill results with the Conflo JC-01 might be of interest since they indicate the advantages obtained by applying refining after other process stages.

In this case, pulp properties of white kraft waste before refining were typically:

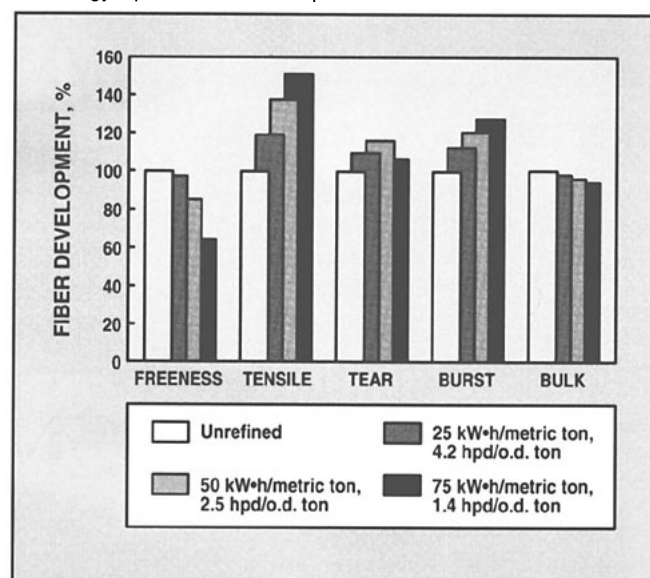
- Freeness: 440 mL (29° SR)
- Tensile index: 25 Nm/g (2550 m)
- Tear index: 10 mNm²/g
- Burst index: 2.2 kPa·m²/g
- Bulk: 1.8 dm³/kg.

Development of these fiber properties is summarized in Fig. 26. The results indicate that approximately 50 kW·h/metric ton net refining energy input yields the highest tear strength and an almost 40% increase in tensile strength without reducing freeness or bulk too much.

25. DIP 2 shives vs. net energy



26. Energy input vs. fiber development



Conclusion

We came to the following conclusions as a result of our work:

- Moderate low-consistency refining can be used to complete secondary fiber treatment.
- Total energy consumption in low-consistency refining of recycled fibers with Conflo refiners is typically between 30 kW·h/metric ton and 60 kW·h/metric ton. In some cases, when refining strong kraft waste, it can exceed 100 kW·h/metric ton.
- As in the refining of virgin fibers, the refining conditions for recycled fibers also must be selected correctly to avoid over-refining and other problems.
- Refining improves the natural bonding ability of recycled fibers, which reduces the need for chemical bonding agents.
- Improved bonding ability allows papermakers to use increasing amounts of recycled fibers in the furnish. □

Literature cited

1. Raitio, L., Paper and Timber 73: 10(1991).
2. Levlin, J-E., On the beating of recycled pulps, EuCePa Conference, Bratislava, 1976.
3. Guest, D. A., Current and Future Technologies of Refining Conference, Proceedings, Pira Intl., U.K., 1991.
4. Lumiainen, J. J., Current and Future Technologies of Refining Conference, Proceedings, Pira Intl., U.K., 1991.

Received for review Jan. 15, 1992.

Accepted March 13, 1992.

Presented at the TAPPI 1992 Papermakers Conference.

Keywords: Finland, performance evaluation, process variables, reclaimed fibers, recycling, refiners.