Effect of Mechanical Impact Treatment on Fiber Morphology and Handsheet Properties

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Abstract

Alternative way of shaping fibers suitable for papermaking was introduced. Impact refining, which was done simply by hitting wet fibers with a metal weight vertically, was intended to keep the fibers from shortening and to cause mostly internal fibrillation. Virgin chemical pulp, its recycled one and OCC were used in the experiment. It was noticed from the experiment that impact refining on virgin chemical pulp kept the fiber length and increased bonding properties greatly. However, in the recycled fibers from the chemical pulp, fiber length and bonding properties were decreased. In OCC, which seems to contain fractions of semi-chemical pulp and mechanical pulp (GP), and which is recycled pulp from corrugated boxes, fiber length and bonding properties were decreased disastrously. We believe recycled cellulosic fibers (recycled chemical pulp and OCC in this case), which went through hornification, were less resistant to the mechanical impact than virgin chemical pulp. For virgin chemical pulp, impact refining allowed no significant fiber length shortening, high WRV, and high mechanical strength.

Key words

Mechanical treatment, Water retention value, Wet fiber flexibility, Impact refining, Internal fibrillation, External fibrillation, Fiber length, Folding endurance

Introduction

The purpose of fiber mechanical treatment with double disk refiner or conical refiner in stock preparation step is to develop fiber morphology suitable for papermaking process and to meet the end product property requirement. It has been found that fiber cutting is usually undesirable in stock preparation step because tear strength can be lowered (1,2). External fibrillation of fibers turned out to contribute less to interfiber bonding, but more to scattering coefficients (3).

The loosely attached microfibrils on the surface of fibers in external fibrillation could contribute only to slow drainage. Internal fibrillation may contribute to increasing wet fiber flexibility and interfiber bonding(4,5). Straightening fibers from their originally curved and twisted shapes is also claimed to contribute to increase paper tensile and burst strength(6,7). In short, for developing more interfiber bonding at high freeness level, fiber cutting and external fibrillation should be minimized, but internal fibrillation should be maximized.

To achieve more internal fibrillation, we used the impact refining, in which fibers were pounded by metal-headed rod in a mortar (Fig. 1). Impact refining effect will be, we think, very similar to the stamp mill (8). We took the mechanism of the impact refining after Korean traditional fiber treatment method called as Dakmuji. We kept the weight of the head, the frequency of the impact, and the pressure of the compressor attached to the impact device to be constant, but changed the duration time of treatment to cause freeness change. This kind of fiber treatment method is not available now in real paper mills, but is worthwhile to visit because it will suggest the direction of R&D for the emergence of more efficient stock preparation process. Several questions may arise. Are there any differences between virgin and recycled fibers in responding to impact refining? Are there many differences between chemical and mechanical pulps? How much impact should be applied for shaping fibers best fitted to the existing papermaking process and for satisfying end user requirement for different furnishes? We could not answer all these questions in our experiment, but tried to differentiate the virgin chemical pulp from its recycled one. OCC was also selected for comparison.

Materials and Methods

Commercial bleached chemical pulps (softwood and hard wood) in dry lap imported from north America, and OCC collected in Korea were used as fiber furnishes. In impact refining, metal-headed rod hit the fiber furnish repetitively in piston-like movement that was powered by an air compressor. The moving distance of the rod was 40 cm, and the compressor chamber pressure was maintained everytime close to 5 bars. In the mortar, wet fibers (about 20% solid content) of 30 g (O.D. weight) were contained, and the frequency of the hit was 30 times per minute (Fig. 1). The weight of the stone-headed rod was 1Kg. It took long time to the reach to the target freeness for the virgin fibers, but took relatively very short time for OCC. We expected no change of fiber length by impact refining for the virgin fibers as well as for their recycled fibers because only high compressive stress was applied to the fibers at the time of impact. Fiber length were measured by Kajaani fiber analyzer. Handsheets were made according to TAPPI standard (T205 om 81).

Results and Discussions

It was reported that conical refiner gave more internal fibrillation than double disk refiner because conical refiner allowed less mechanical intensity and more residence time for the fibers inside the refiner (9). Recycled fibers are known to give better refining results at low impact refining. When we say 'better' refining results, we mean less fiber cutting, and less fine generation that causes abrupt increase of drainage time. It is hardly imagined that there exist extensive tensile or shear stresses at the time of impact in our impact refining. It is known that fiber cutting is caused by high tensile and shear stresses formed by interaction between neighboring and adjoining bars in the disk or conical refiners (6).

Virgin chemical pulp

The assumption of no significant fiber shortening in impact refining seemed to be valid as shown in Fig. 2, where the fiber length for virgin chemical pulp was not changed significantly in the impact refining when its freeness was lowered down to 300 CSF. The freeness changes, therefore, could be explained only by internal fibrillation. If internal fibrillation was the major mechanism of lowering freeness for the virgin chemical pulp, we can expect high wet fiber flexibility and high interfiber bonding. In Fig. 3, we can see that impact refining increased water retention values (WRV) for both softwood and hardwood even though mean fiber lengthes of the pulps were much greater (Figs. 2). Density differences between two different refining method were compared in Fig. 4. Higher density may means more bonding for the papers of equal basis weight and of the same fiber source. Impact refining allowed higher densities for the softwood and the hardwood as shown in the figure. The breaking lengthes, folding endurances, and Scott internal bonds of the softwood and the hardwood were all increased for the fibers treated with impact refining method (Figs. 5-7). Specially, the increased of folding endurance were remarkable for both hardwood and softwood as shown in Fig. 6. In summary, impact refining of virgin chemical pulp, when compared to valley beating, did not shorten fiber length, and increased internal fibrillation greatly. The difference of fiber morphology by different refining methods caused the large differences in breaking length, folds, and internal bond.

Recycled chemical pulp

In the second experiment, virgin bleached chemical pulps were refined by valley beater to the target freenesses (300, 400, and 500 CSF) to make control samples. Parts of the handsheets from the virgin fiber furnish of 500 CSF were recycled for further treatment. The recycled fibers were refined by PFI mill and impact refining to the target freenesses. Fig. 8 showed the fiber length changes of virgin and recycled fibers. Surprisingly, the impact refining gave no significant improvement of fiber length in recycled fibers (Compare Fig. 8 to Fig. 2). We tried one more set of experiment, and got the same results. Water retention values of impact refining were not higher, but lower (in softwood case) than those of the furnish refined by PFI mill (Fig. 9). Density of paper usually represents degree of fiber bonding and paper strength properties. In Fig. 10, the densities of PFI mill refined furnish were equivalent to or higher than those of the furnish prepared by impact refining. In tensile index and double folds in Figs. 11 and 12, respectively, we observed virgin fibers gave the highest strength and impact refining the lowest. In internal bond, at low level of refining, virgin chemical pulp gave the highest, but at high level of refining, the difference became unpredictable (Fig. 13).

From the results we obtained in the above experiment, we found that the impact refining was no longer a special refining method of fiber length protection for recycled fibers. Lower impact on the recycled fibers may protect fiber length better, but it should take much longer refining time than ours.

OCC (Old corrugated container)

Impact refining gave significant fiber length shortening and loss in strength properties. In Fig. 14, valley beater beating to 200 CSF gave longer fiber length than impact refining to 300 CSF. Breaking length, burst strength , and tear index of impact refining furnish were also lower than those of the valley beater furnish at the same freeness (Fig. 15). Normally, OCC in Korea contains mostly recycled unbleached chemical pulp and fractions of semi-chemical pulp, and ground wood pulp. Mechanical pulp is not flexible as chemical pulp and is apt to be broken into pieces by high degree of impact.

The sensitivity of fibers to physical impact could be an important factor to apply the impact refining concept. The intensity and duration of the impact should be carefully selected to make the best use of the all the potentials the fibrous materials we have.

Conclusions

We found a few interesting facts in the impact refining. Impact refining, if it can be accomplished in real paper mill, can be an excellent refining method to keep fiber length and to develop paper strength greatly from virgin chemical pulp. For the recycled chemical pulp (hornified fiber by drying or aging), the impact refining gave undesirable effect such as extensive fiber shortening and low paper strength. The OCC from Korea, which may contain mechanical pulp as well as recycled unbleached KP, was extremely sensitive to the impact refining and gave extensive fiber shortening. From these results, we may suggest that for the recycled fiber refining, low impact refining be more desirable. For the virgin chemical pulp, any kind of impact refining will give longer fiber length, and higher mechanical strength properties.

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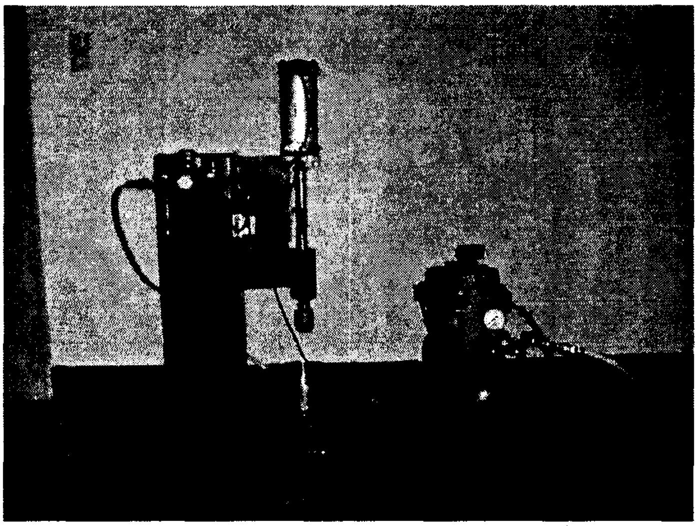
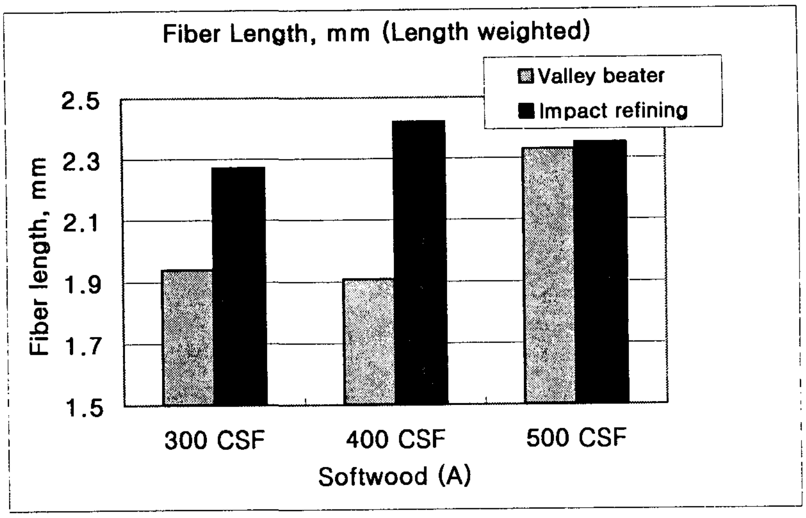


Figure 1. The impact refining device and a compressor



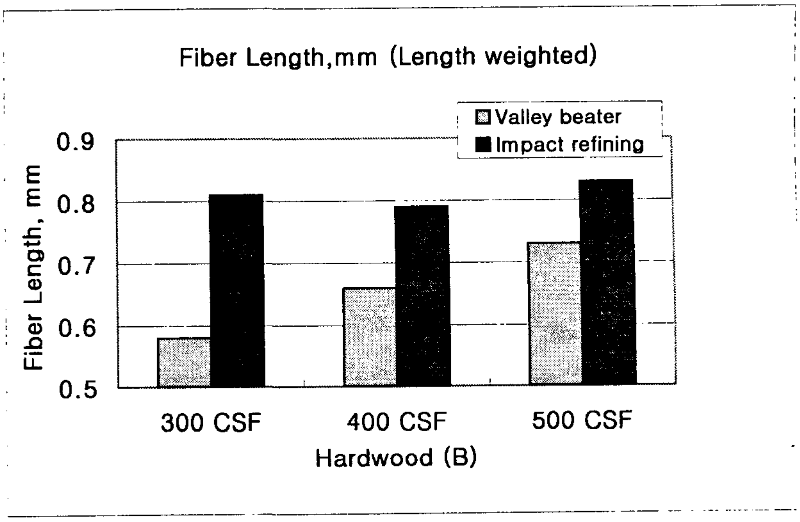
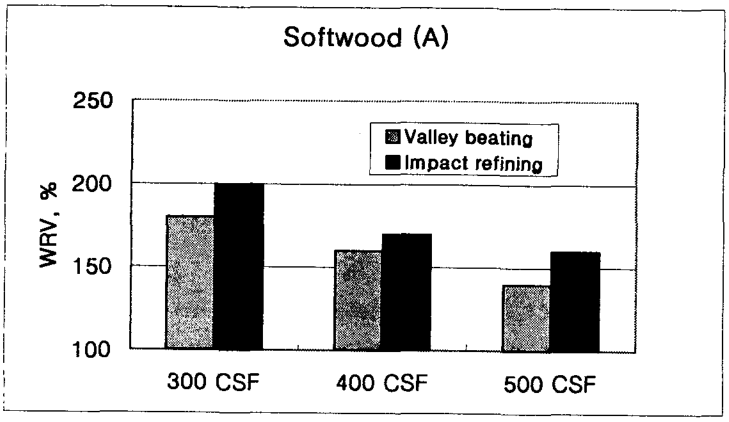


Figure 2. Fiber length changes by two different refining methods
(A) Softwood, (B) Hardwood



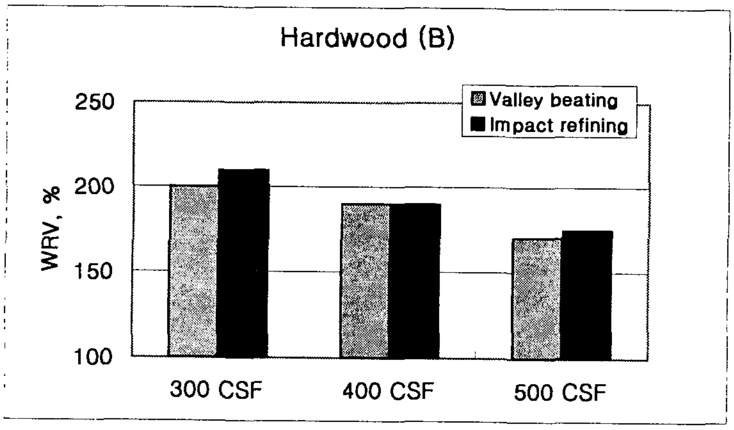


Figure 3. Water retention value changes by different refining methods
(A) Softwood, (B) Hardwood

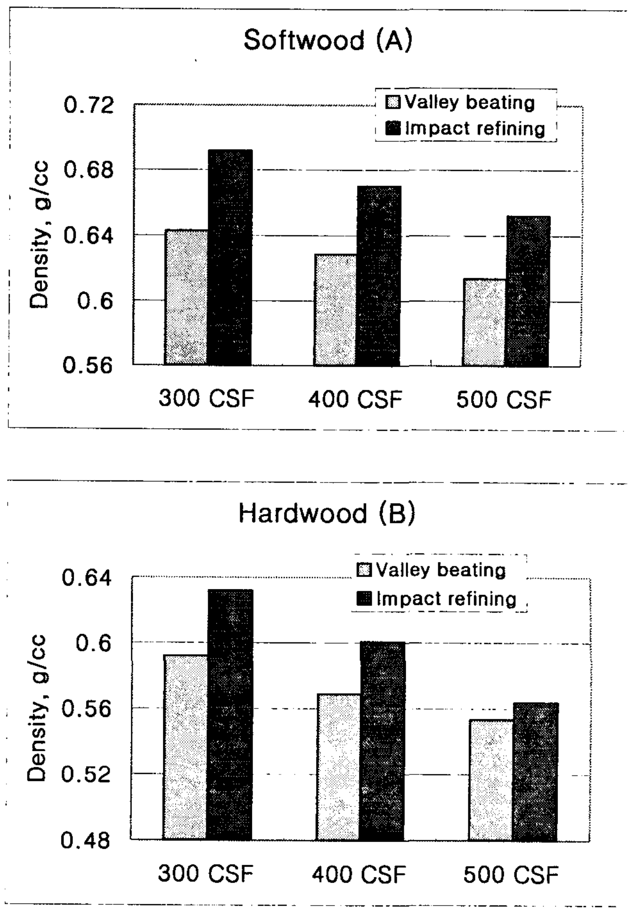


Figure 4. Density changes after applying different refining methods
(A) Softwood, (B) Hardwood

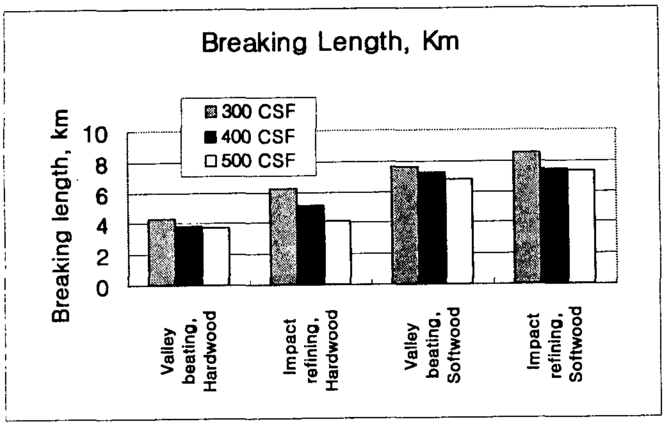
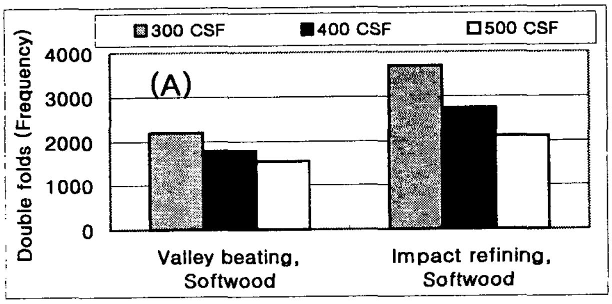


Figure 5. Differences of breaking lengths caused by different refining methods



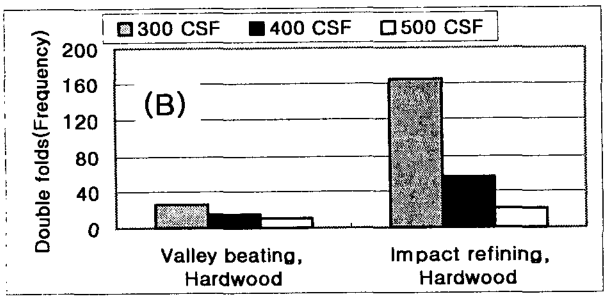


Figure 6. Differences in folding endurance caused by different refining methods
A) Softwood B) Hardwood

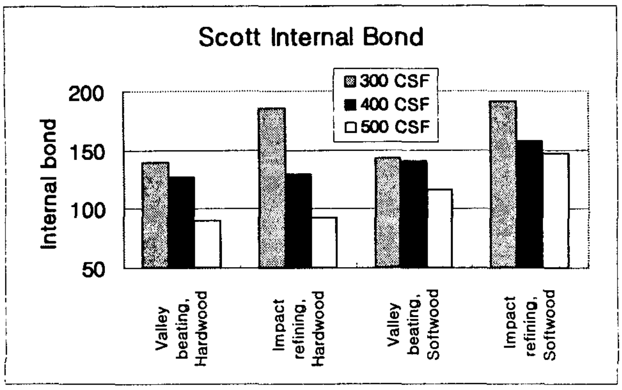


Figure 7. Differences in Scott internal bond caused by different refining methods

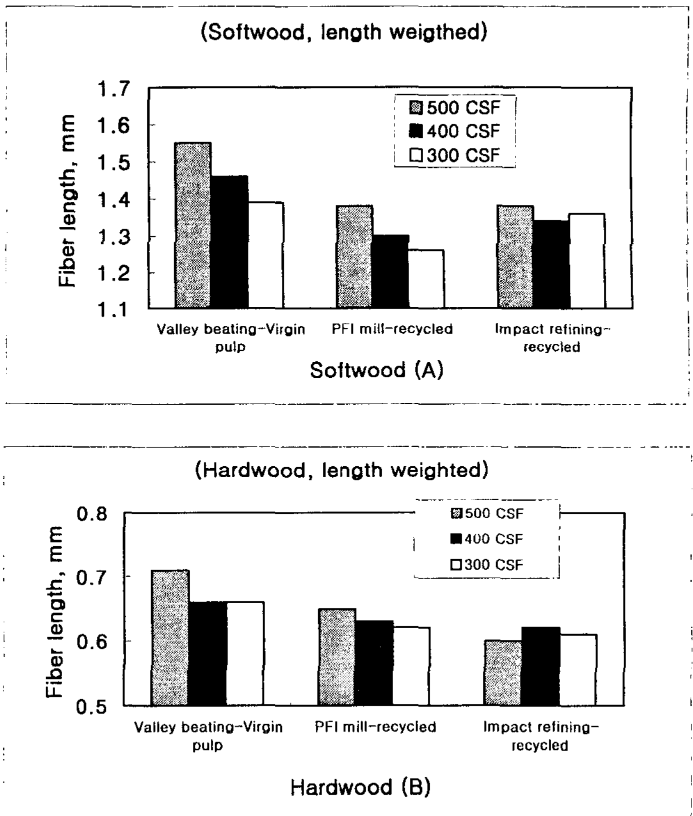
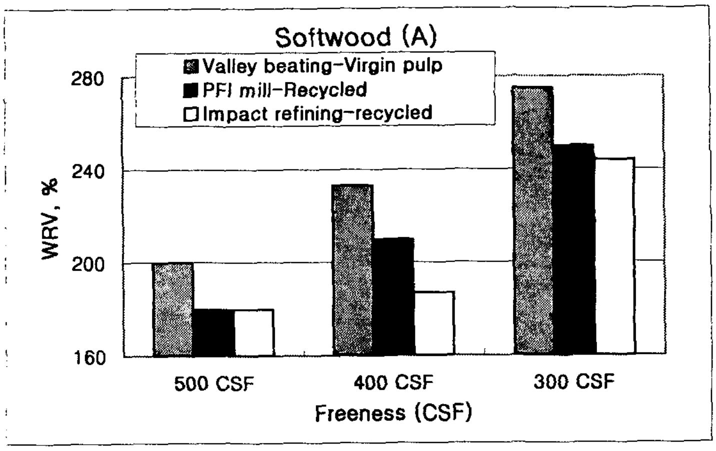


Figure 8. Fiber length changes after applying different refining methods



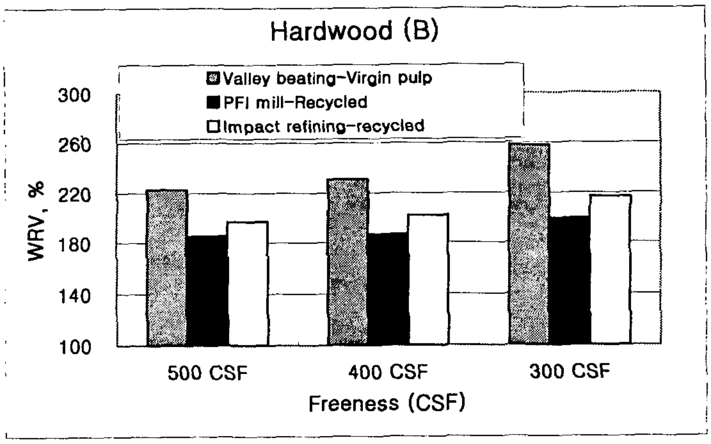


Figure 9. Water retention values after different refining treatments (A) Softwood, (B) Hardwood

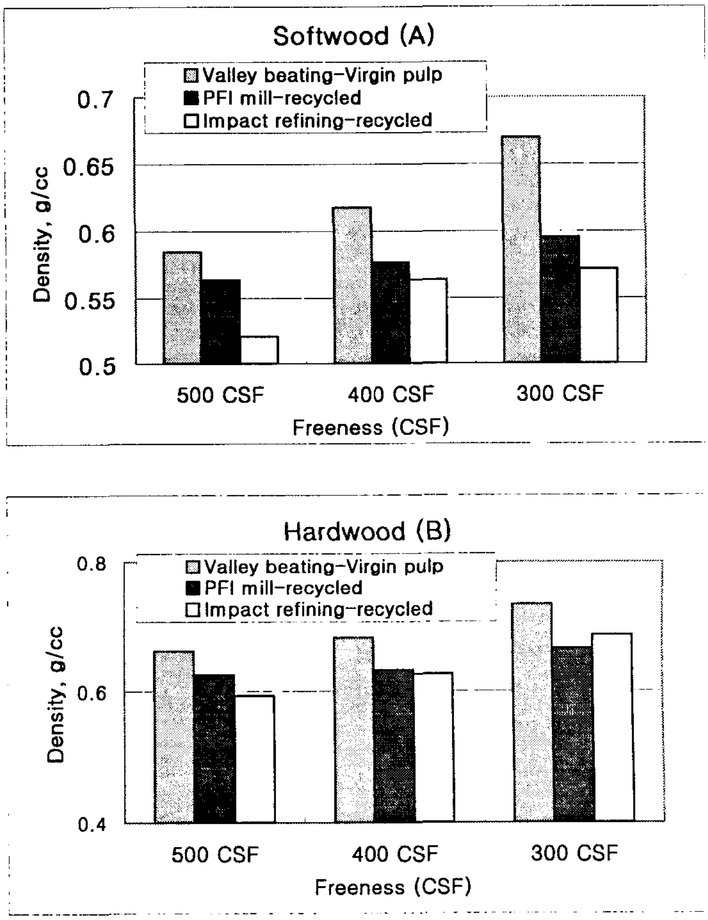


Figure 10. Density changes after different refining treatments

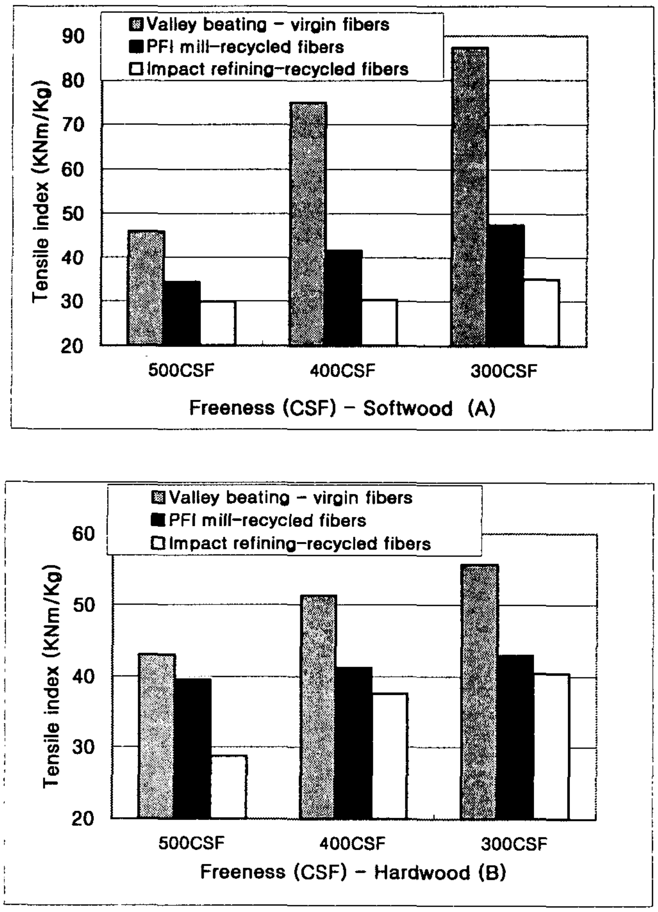
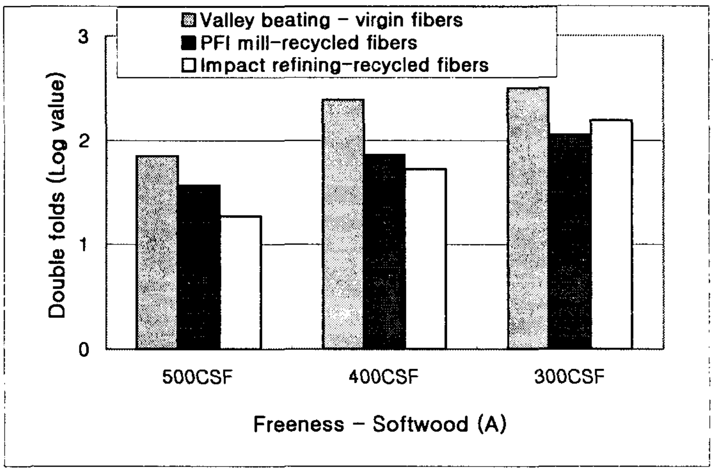


Figure 11. Tensile indexes after different refining treatments
A) Softwood B) Hardwood



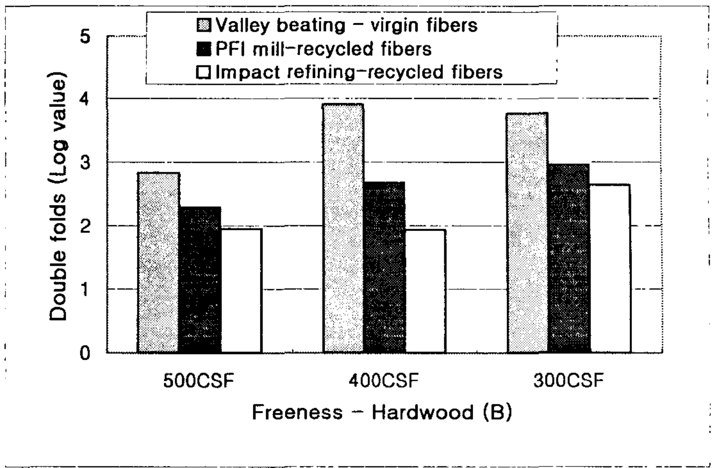


Figure 12. Folding endurances after different refining treatment
A) Softwood B) Hardwood

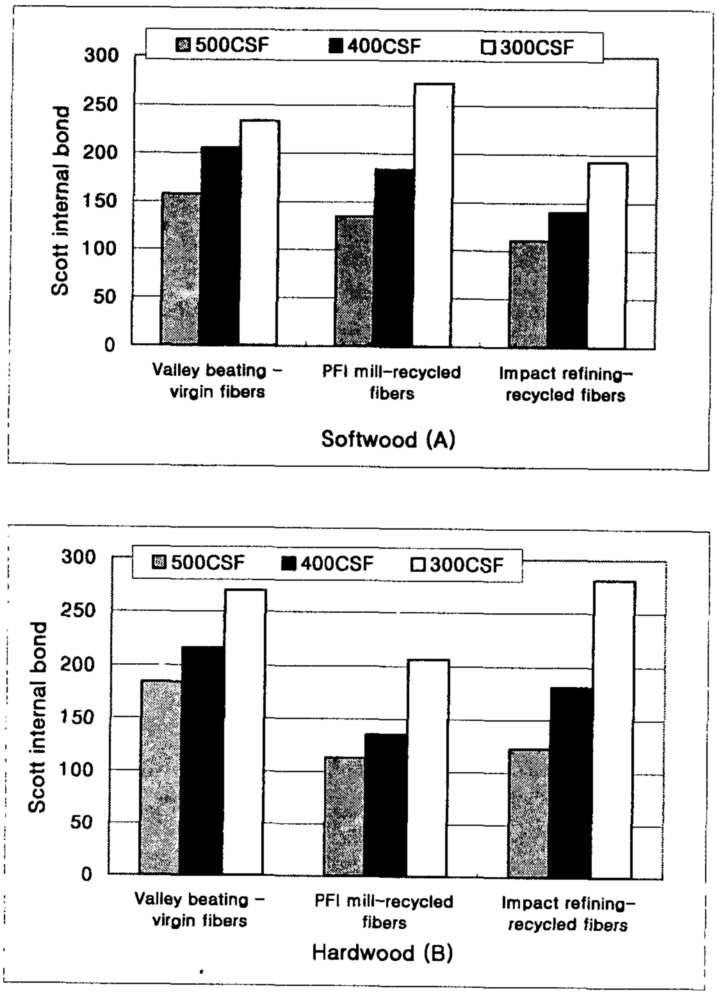


Figure 13. Scott Internal bonds after different refining treatments
A) Softwood B) Hardwood

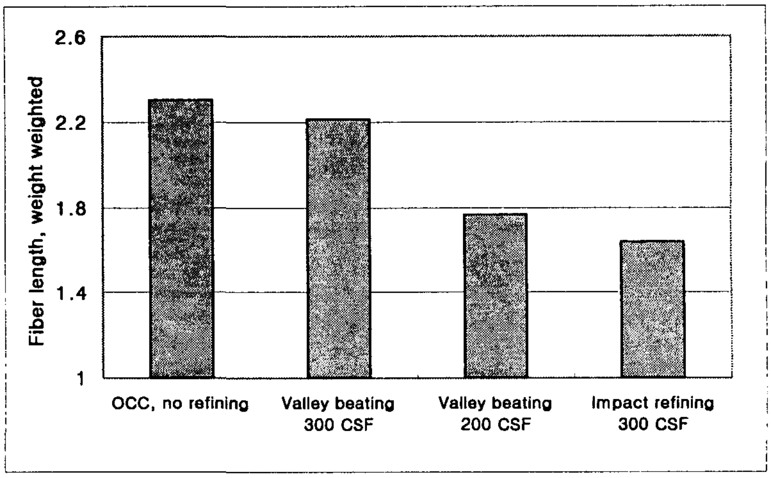


Figure 14. Fiber length changes by different refining methods

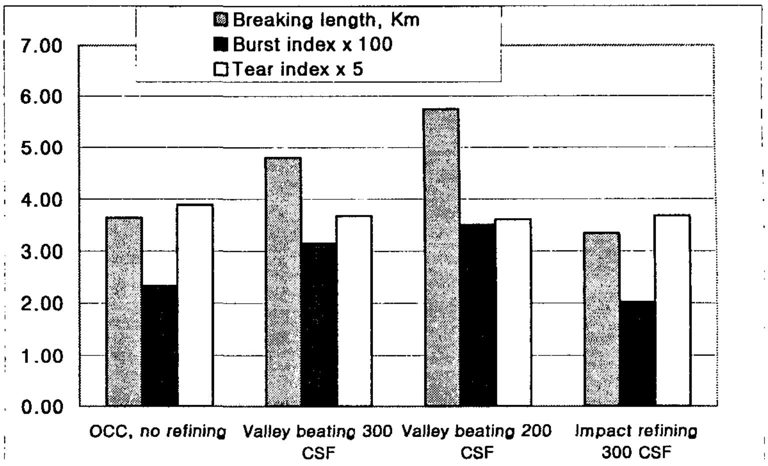


Figure 15. Comparison of physical properties