

Improvement of linerboard properties by Condebelt drying

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ABSTRACT

The Condebelt drying process, originally developed to increase drying rates, also provides opportunities to improve sheet strength properties, thus allowing the papermaker to reduce basis weights or increase the utilization of recycled furnishes.

This paper investigates the effects of operating conditions in the Condebelt press dryer—temperature, pressure, dwell time, and inlet sheet moisture content—on sheet properties. Laboratory experiments simulating the Condebelt process were performed with a static rig, and repetitively recycled Korean OCC (old corrugated containers) was used as the principal raw material.

Condebelt drying produced significant improvements in sheet density, compression strength, tensile strength, and surface smoothness. Control of pressure and inlet dryness was critical in improving sheet properties. The discussion concludes with a brief description of industrial experience with a Condebelt drying press in a Korean mill producing corrugated board from 100% OCC.

INTRODUCTION

Linerboard and corrugating medium must meet minimum strength requirements, but this is not an easy task in countries that rely on recycled old corrugated containers (OCC) as their principal source of fiber. For instance, in Korea it is common to use more than 80% and 100% of recycled OCC to produce linerboard and corrugating medium, respectively.

Sheet strength properties can be increased using wet-end papermaking technologies, including mechanical treatment of papermaking fibers by refining and chemical treatment

with strength resins. However, these options are limited for brown paper grades produced from recycled OCC.

- Refining of recycled OCC furnishes produces a substantial amount of fines, which impedes drainage on the wire and reduces retention. Furthermore, secondary fiber fines generated during refining change to fillerlike materials after drying due to irreversible hornification, with a resultant negative impact on paper properties. The amount of fiber fines often exceeds 50% when using OCC that has been repeatedly recycled. The detrimental impact of fines can be mitigated by removing the primary fines before refining, but this approach significantly reduces yield and has a negative impact on waste treatment.
- Most of the closure work in the paper industry has occurred in brown paper grades. Closure of process water circuits increases the concentration of organic and inorganic materials, which results in deterioration of the physical properties of the produced paper while reducing the effectiveness of polymeric additives. Consequently, the opportunity for improving strength properties with chemical additives greatly diminishes for brown grades based on OCC.

Thus there is a clear need for a papermaking process that improves the strength properties of brown grades without relying on mechanical treatment of fibers or chemical treatment of papermaking stocks. If these wet-end technologies are not appropriate for increasing the strength properties of brown grades made from repetitively recycled OCC, then it is logical to look for a solution at the dry end of the papermaking process. The question is what kind of dry-end technology is most effective for improving strength and interfiber bonding. To make strong sheets, the stiff recycled fibers must be made more flexible and deformable. This requires a process that treats the wet web at high pressure and temperature, and this is possible in Condebelt drying.

In the Condebelt process, the paper web sits atop two permeable wires and is fed into an extended nip between two smooth steel belts, as seen in **Fig. 1**. While the upper steel belt is heated by high-pressure steam at temperatures of 110–160°C, the lower steel belt is cooled by circulating water at around 80°C. The top side of the web is in direct contact with the upper steel belt, while the wire side of the web contacts a fine wire with a coarse wire underneath (1). Vapor generated from the web passes through the wires and condenses on the lower steel belt. Water condensed on the surface of the lower belt or in the interstices of the wires is removed with a doctor or by applying vacuum. A web dried under such unsymmetrical conditions will show distinct two-sidedness. However, for certain grades such as linerboard and corrugating medium, two-sidedness may not be of great concern.

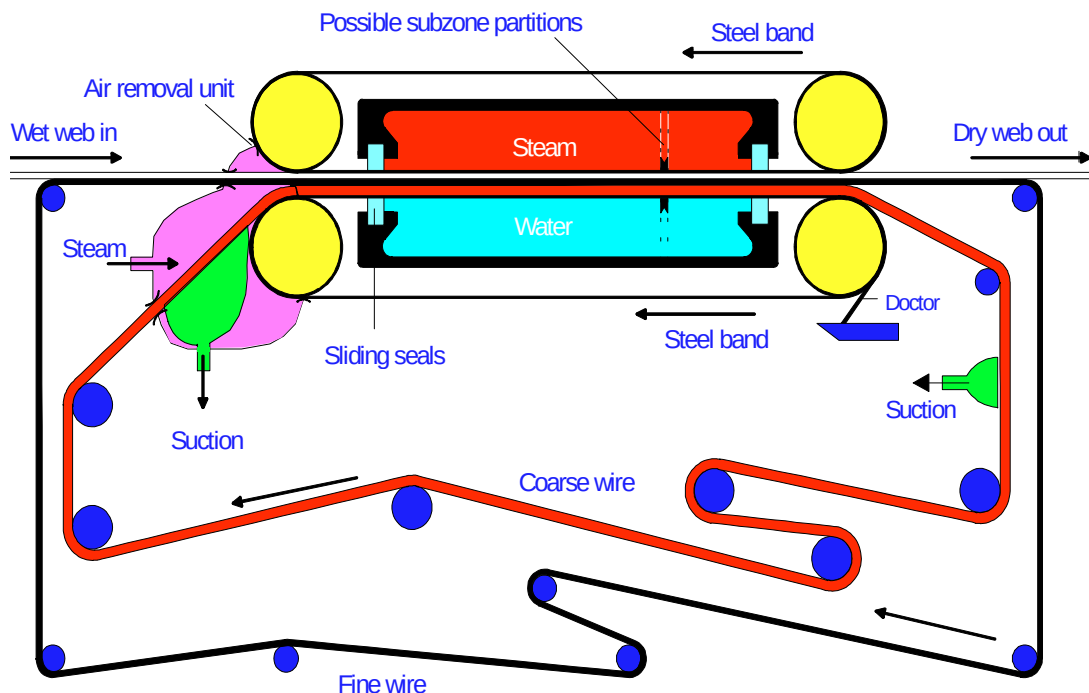


Figure 1. Condebelt drying process

The Condebelt drying process, originally designed to improve drying rates, also has a wide range of beneficial effects on sheet properties, mainly because it dries the web at elevated pressures and temperatures that are not attainable in conventional cylinder drying. The z-directional pressure and temperature plasticize lignin, cellulose, and hemicellulose, which promotes fiber flattening, web densification, and interfiber bonding (2, 3). Furthermore, the Condebelt press dries the sheet in such a fully restrained condition that it improves compressive stiffness in the cross-machine direction, which is critically important in increasing compression strength of corrugated containers (4). These opportunities of strength improvement provided by the Condebelt process are especially beneficial for mills producing linerboard and corrugating medium.

The first commercial Condebelt dryer—2.5 m wide with a machine speed of 200 m/min—was installed at Stora Enso's Pankakoski board mill in Finland in 1996. In 1998, Dong-Il Paper Mfg. in Korea installed the second commercial Condebelt dryer, which is 4.5 m wide and runs at 650 m/min.

The Condebelt process offers opportunities for reducing the basis weight while utilizing more recycled furnishes and high-yield pulps, thus reducing the cost of raw materials (5). In addition, the Condebelt process facilitates the manufacture of new products with excellent surface smoothness, humidity resistance, and printability.

Research efforts have been made to evaluate the effects of the Condebelt drying process on the properties of paper and board produced using diverse pulps and Finnish OCC (6). However, the effects of Condebelt drying on linerboard properties made from 100% recycled fibers have not been examined. The immediate objectives of this study were to investigate the effects of Condebelt operating conditions (pressure, temperature, inlet moisture content of the web, and dwell time) on the properties of linerboard made from Korean OCC.

EXPERIMENTAL

Static Condebelt dryer

A static laboratory device, illustrated in **Fig. 2**, was used to simulate the Condebelt operating conditions, including z-pressure, upper and lower platen temperatures, inlet web moisture content, and dwell time. The upper platen temperature can be increased electrically up to 200°C, and the lower platen temperature is controlled with circulating cooling water. The cooling water circulation system consisted of a storage tank and heating and cooling tanks. Temperature and pressure were controlled independently, with the temperature of the upper platen adjusted by electrical heating and the pressure adjusted hydraulically. The upper platen moves at 25 cm/s downward when closing, and the dwell time of press drying could be adjusted in increments of ± 0.1 s. The commercial machine uses coarse and fine wires made of polyphenylene sulfide (PPS) monofilament, and these same wires were used in the laboratory experiment. The fine and coarse wires had calipers of 0.88 mm and 1.9 mm, respectively.

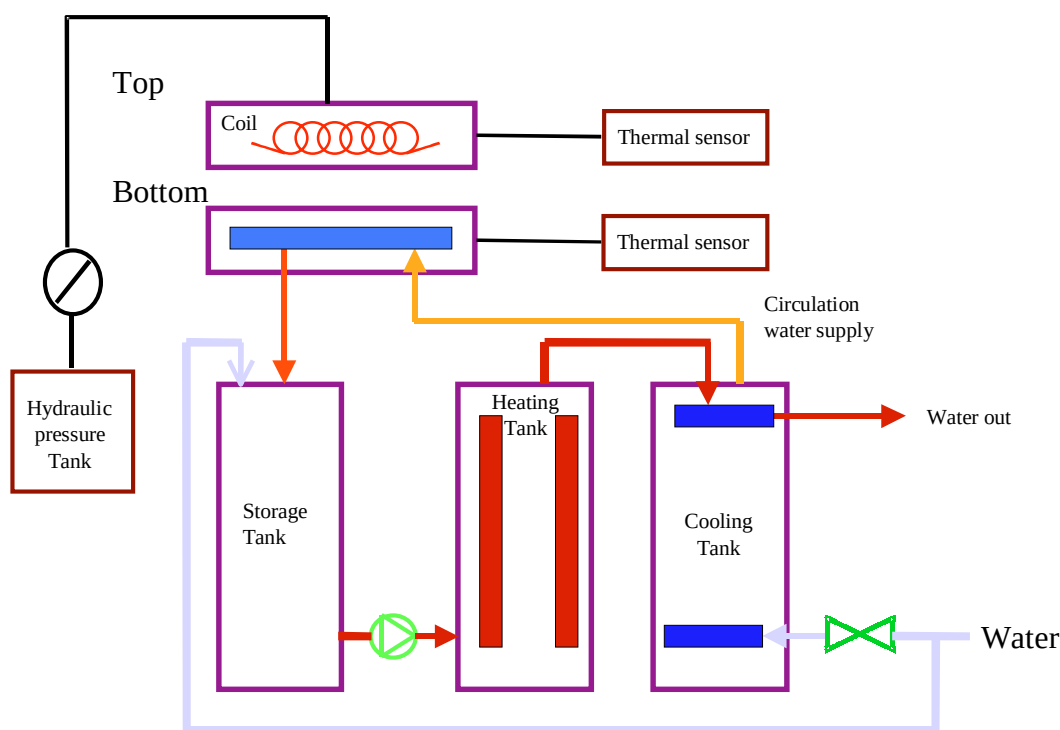


Figure 2. Static Condebelt apparatus used in laboratory experiments

MATERIALS AND METHODS

Linerboard made from Korean OCC (KOCC), American OCC (AOCC), softwood unbleached kraft pulp (UKP), and hardwood bleached kraft pulp (BKP) were used as furnishes. All furnishes were disintegrated and beaten in a laboratory Valley beater. Handsheets with basis weights of 150 g/m² were made in a laboratory sheet mold with tap water and then pressed to 40% or 50% dryness. Handsheets with 60% dryness were prepared by drying the pressed sheets in a laboratory cylinder dryer.

Handsheets with a known moisture content were placed atop the two wires, and this stack was then placed on the bottom platen of the static rig and press dried. Outlet dryness was determined by weighing the dried sheet. Handsheets with an outlet dryness lower than 95% were dried to 95% on a laboratory drum dryer. Physical and strength properties of dried handsheets were measured according to TAPPI test methods.

RESULTS AND DISCUSSION

Effect of z-directional pressure

As shown in **Fig. 3**, the density of press-dried sheets in the laboratory Condebelt device was higher than that of the cylinder-dried control sheets. Sheet density, which depends strongly on the z-directional pressure as well as pulp type and freeness, increased rather steeply at a low z-directional pressure range. The density increase was quite dramatic for OCC, indicating that the plasticization effect brought on by the high temperature and pressure is substantially greater for stiff recycled fibers than for kraft pulps.

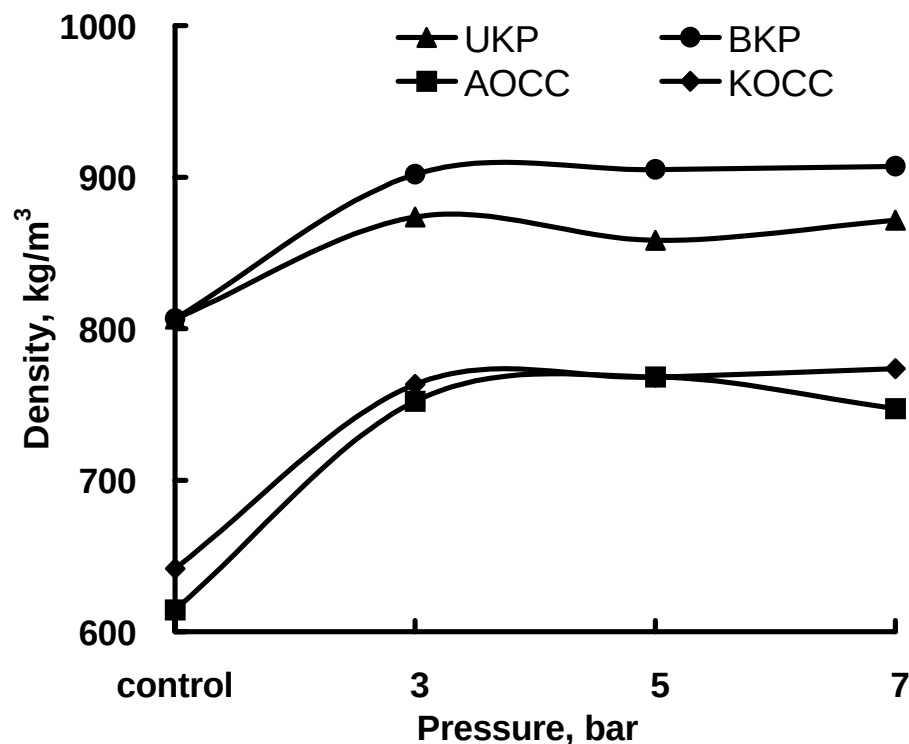


Figure 3. Effect of *z-directional* pressure on sheet density (inlet dryness, 50%; top platen temperature, 160°C)

Improvement in sheet density is highly associated with an increase of interfiber bonding and strength properties. Tensile indices for the sheets made from OCC and kraft pulps are illustrated as a function of sheet density in **Fig. 4**. The improvement of tensile indices for UKP was greater than would be expected from Fig. 3. This suggests that the beneficial effect of restraint drying conditions on tensile strength is prominent in the case of unbleached kraft pulp.

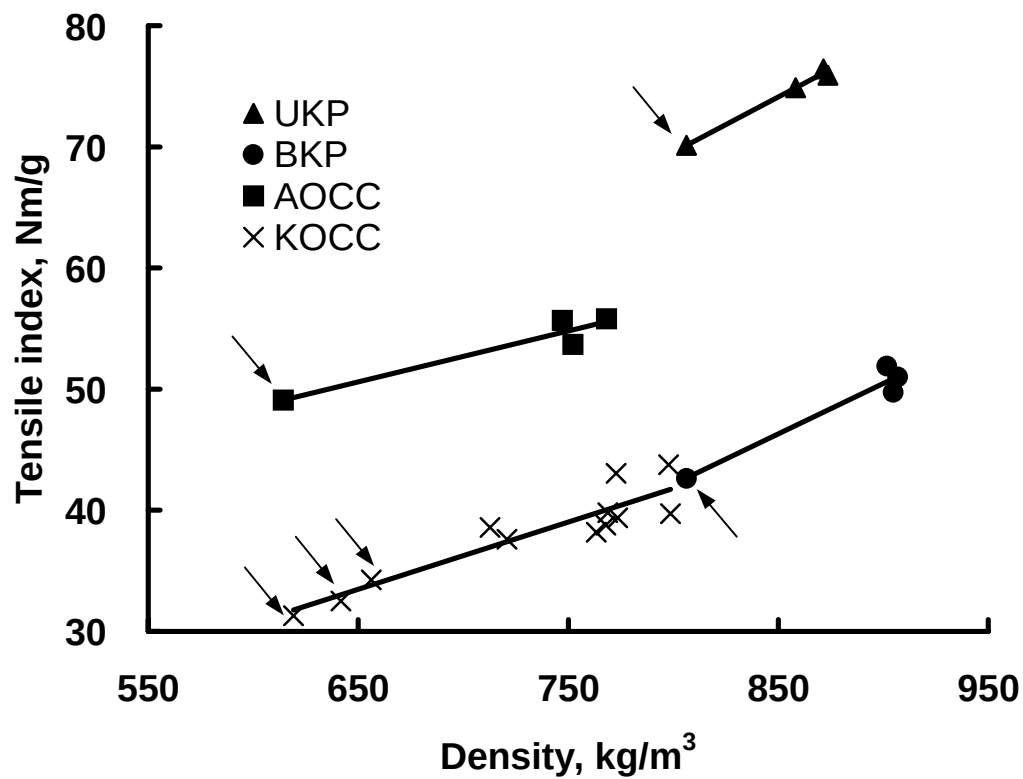


Figure 4. Effect of furnish types on tensile strength of Condebelt and conventionally dried sheets (arrows indicate results for sheets dried on conventional cylinder; KOCC was refined to three different freeness levels)

Figures 5 and 6 show the compression strengths of Condebelt and cylinder-dried sheets as measured by ring crush test (RCT) and short-span compression test (SCT), respectively. The results in Fig. 5 show that compressive strength increased sharply with the initial application of z-directional pressure and reached a plateau thereafter.

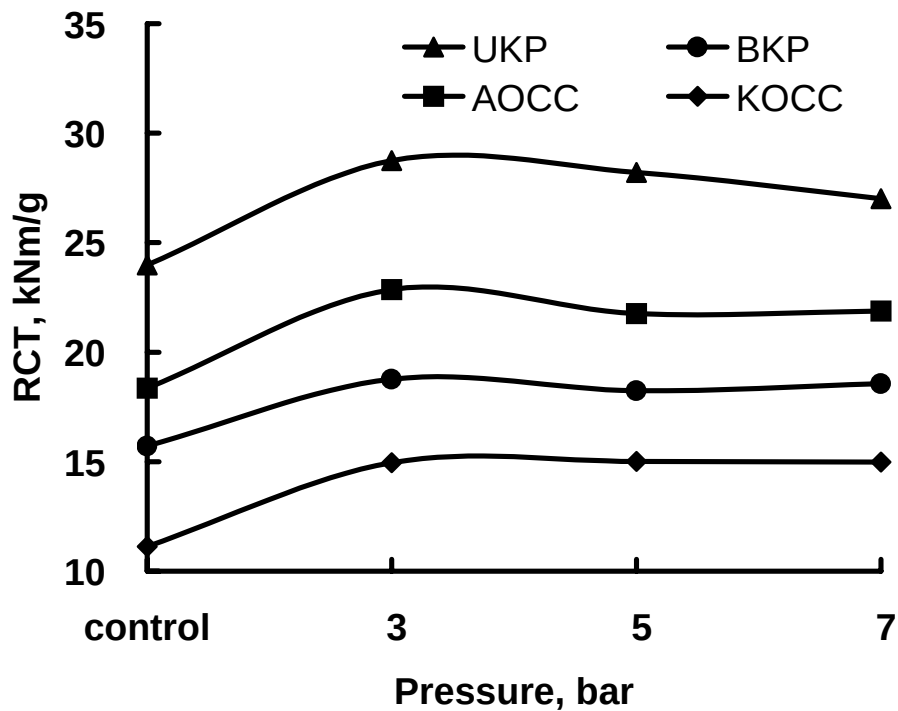


Figure 5. Effect of pressure on compressive strength (RCT) (inlet dryness, 50%; top platen temperature, 160°C)

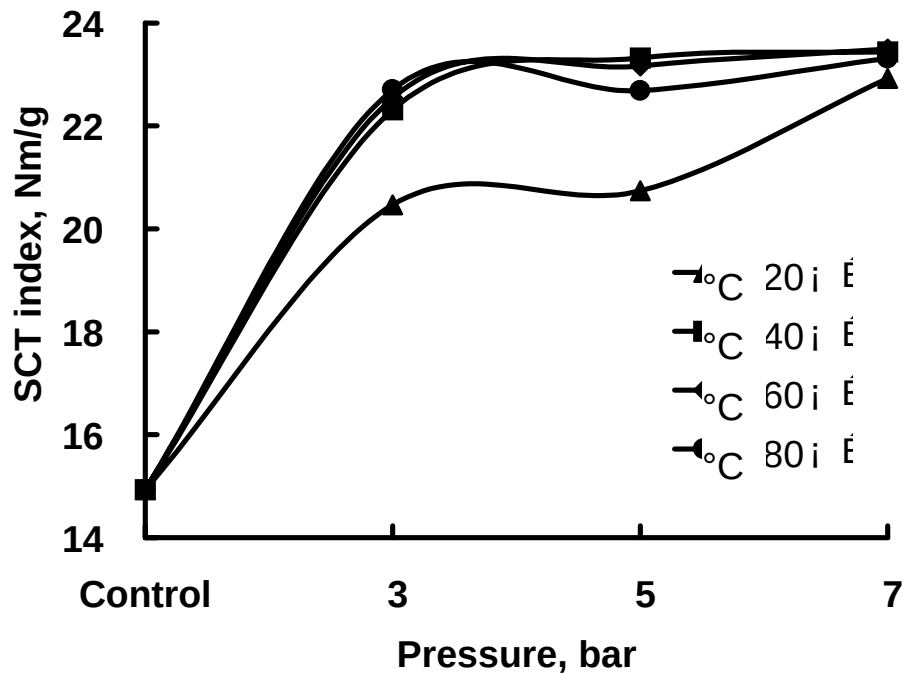


Figure 6. Effect of top platen temperature on compressive strength (SCT) (inlet dryness, 50%)

Effect of temperature

When the pressure was kept constant, the temperature of the upper platen had a negligible effect on SCT compression strength, as seen in Fig. 6. However, when the temperature decreased to 120°C, the effect of Condebelt drying diminished (7).

Increasing the top platen temperature decreased the gloss of Condebelt dried sheets because the fibers tended to stick to the high-temperature platen. The pressure, however, had an opposite effect, i.e., airflow resistance and gloss increased significantly as z-directional pressure increased.

Effect of dwell time and inlet dryness

The dwell time showed a minor effect on sheet properties if the dryness of the web at the exit of the Condebelt dryer was higher than 82%, indicating that minimal improvement occurs at higher sheet dryness. The inlet dryness, however, was found to have a great effect on sheet properties. As shown in **Fig. 7**, the tensile strength decreased as the inlet dryness increased, indicating that the effect of Condebelt drying was greater when the web contained more moisture (8).

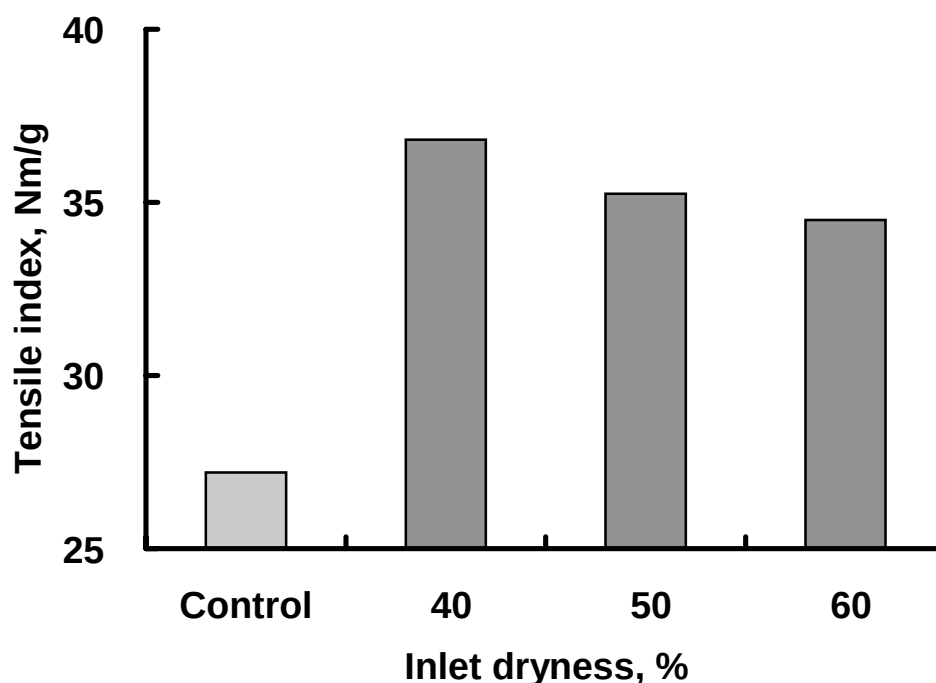


Figure 7. Effect of inlet dryness on the tensile index (top platen temperature, 180°C; pressure, 5 bar).

Inlet dryness and temperature affect not only sheet properties but also runnability. Deposition of stickies on the wire increased in both the static rig and the commercial machine as inlet dryness decreased, which impaired runnability.

Pulp substitution and basis weight reduction

Figures 4 and 5 clearly show that Condebelt drying improves tensile and compressive strength. However, these figures also show that Condebelt-dried KOCC sheets could not achieve the same strength levels as cylinder-dried AOCC sheets. To examine how much KOCC can be substituted for AOCC when Condebelt drying is employed, the strength properties of handsheets formed from a mixed furnish of KOCC and AOCC were evaluated. **Figures 8 and 9** show that the compressive and tensile strengths achieved with cylinder-dried sheets of 100% AOCC could be matched by Condebelt drying mixed-furnish sheets containing 60% and 50% of KOCC, respectively. These figures also show that one-ply sheets gave better strength properties than two-ply sheets. The difference in strength properties

between one-ply and two-ply sheets decreased in Condebelt drying, presumably because of improved plybonding.

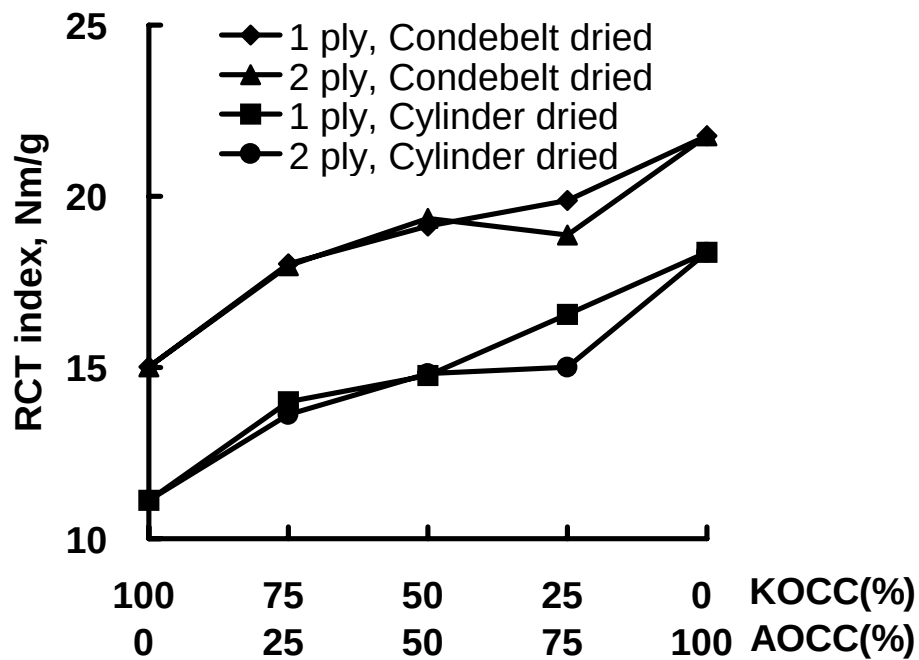


Figure 8. Effect of KOCC content on compressive strength (RCT)

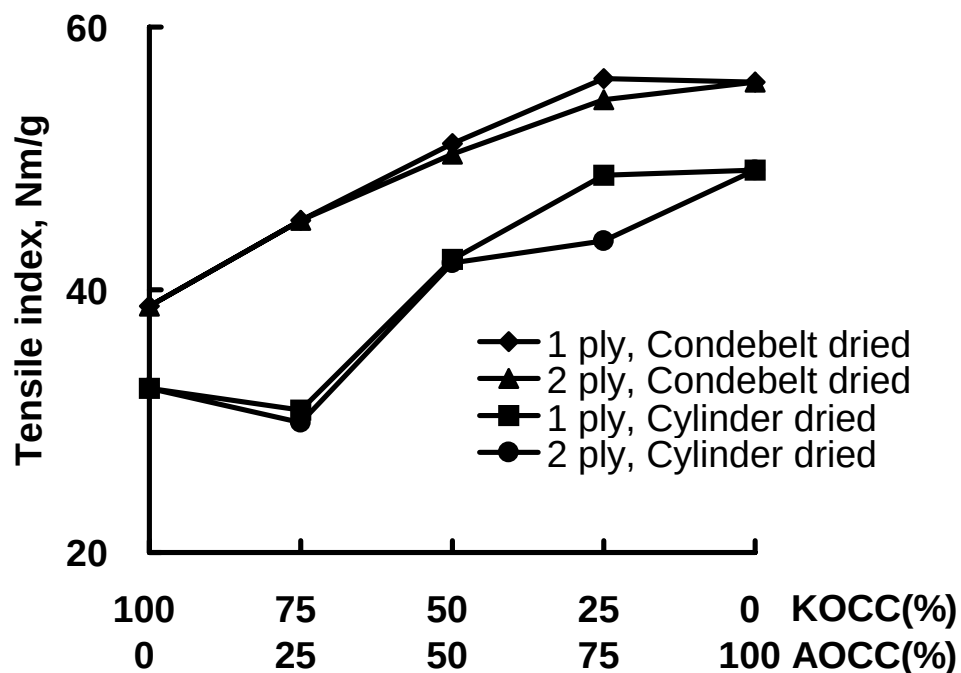


Figure 9. Effect of KOCC content on tensile strength

The improvement in strength properties obtained with Condebelt drying gives the papermaker the option of reducing the sheet's basis weight, which is beneficial not only for

cost saving of raw materials but also for reducing the costs associated with drying, sheet handling/transportation, and waste treatment (9).

Figures 10 and 11 show the tensile and compressive strength properties of linerboards as a function of the basis weight produced by Condebelt drying and conventional cylinder drying. From these figures, it is evident that basis weight reductions of 20–30% are possible with Condebelt drying.

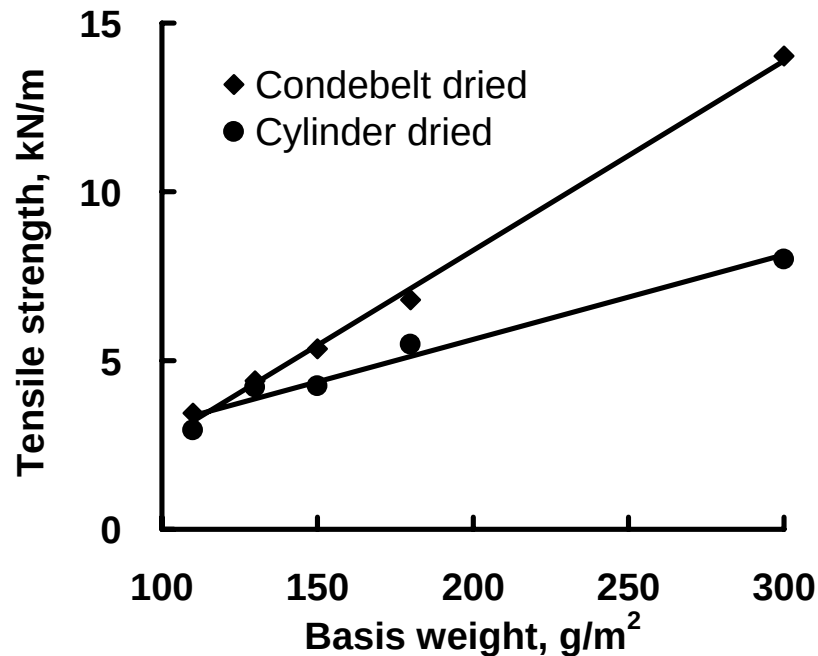


Figure 10. Effect of drying method on tensile strength

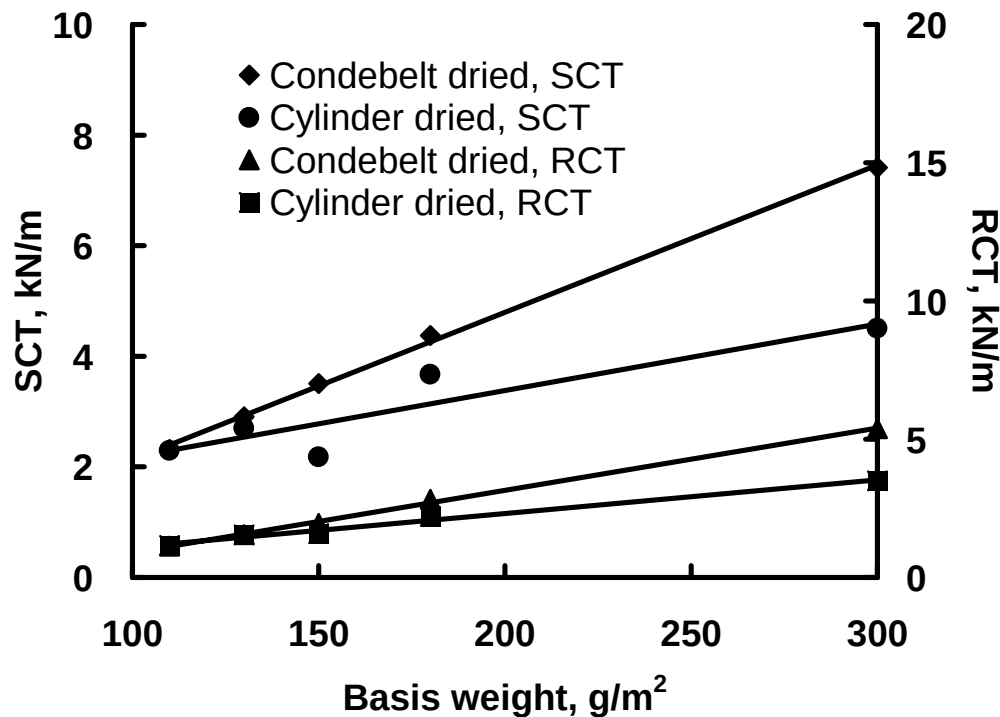


Figure 11. Effect of drying method on compressive strength (SCT and RCT)

MILL EXPERIENCE

Dong Il Paper Mfg. Co., Ltd., completed the lengthy project of installing the Condebelt drying process at its Ansan mill at the end of 1998. This drying unit was the second commercial Condebelt installation. However, in terms of the machine width (4.5 m) and speed (650 m/min), it can be regarded as the first large-scale commercial unit. The Condebelt dryer was installed on the upper deck above the cylinder dryer. The pressed web is predried with 16 cylinder dryers prior to entering the Condebelt dryer operating at a steam pressure of 4–5 bar. By controlling the steam pressure in the predrying cylinder dryers, the web dryness is adjusted to 60–63%. After passing through the Condebelt dryer, the web at a dryness of 82–85% is transferred to the cylinder dryer and dried again. These after dryers are used to control curl. The mill believes that the Condebelt process is the most suitable technology to overcome the quality deterioration of linerboard caused by repeated recycling of KOCC.

The Condebelt process has improved sheet strength properties, including tensile and compression strength, by more than 25%. To evaluate the performance of Condebelt-dried sheets in improving the compression strength of container boxes, two types of double-wall corrugated boxes were made. One type of box was made with conventional cylinder-dried corrugating mediums and linerboard, each with basis weights of 200 g/m². The other type of box was made with Condebelt dried corrugating mediums and linerboard, each with basis weights of 180 g/m². Both types of boxes used identical cylinder-dried outer liners with basis weights of 175 g/m². **Table I** shows results for both box types. The compression strength of the box made with cylinder-dried linerboard was 520 kg_f, while the strength of the box made with Condebelt dried linerboard was 720 kg_f. In this case, therefore, the box compression strength increased by 200 kg_f even though the total basis weight of the Condebelt dried corrugating mediums and inner linerboard was lighter by 60 g/m². This result shows that the improvement in compression strength is far greater for the corrugated box than it is for corrugated medium or linerboard individually.

Table I. Box compression strength test

Composition	Box size, mm	Flute profile		Box compression strength, kg _f
		outer	inner	
L/Cyl/Cyl/Cyl/L	528 × 525 × 285	B	A	520
L/Con/Con/Con/L	528 × 525 × 285	B	A	720

L: cylinder-dried linerboard, 175 g/m²

Cyl: cylinder dried, 200 g/m²

Con: Condebelt dried, 180 g/m²

The abrasion resistance of printed images was evaluated by testing images printed on Condebelt dried and cylinder-dried linerboards. Printing was carried out on the same flexo printing and die-cutting machine. **Figure 12** shows that abrasion resistance of the printed image was substantially greater for the Condebelt dried linerboard.

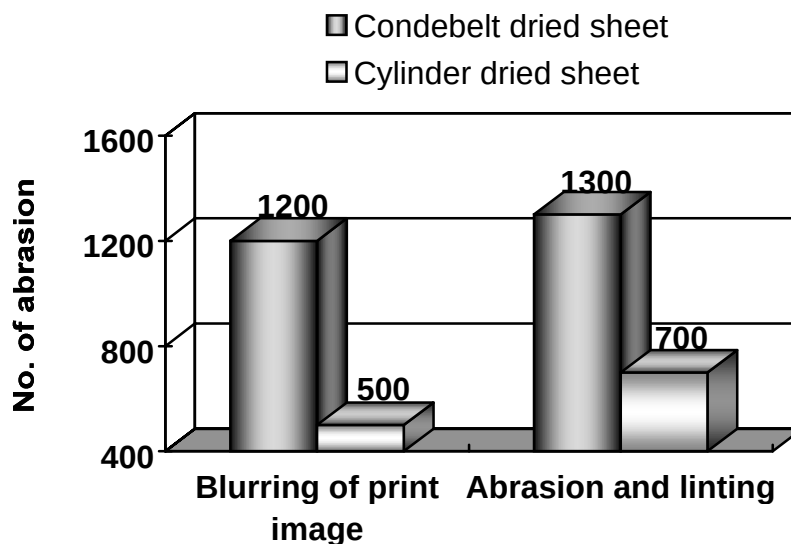


Figure 12. Abrasion resistance of printed images

The mill experienced initial problems of fine-wire contamination and sticking of the dried web onto the upper steel belt at the exit of the Condebelt dryer. However, wire contamination was reduced by using a coagulant in the stock preparation area and by spraying a cationic polymer onto the wires. The web-sticking problem was eliminated by increasing the web dryness at the exit of the Condebelt dryer above 86%.

CONCLUSIONS

Sheets dried in a Condebelt dryer had greater tensile and compressive strength than cylinder-dried sheets. Inlet dryness and z-pressure were the two most important drying variables influencing linerboard properties made from Korean OCC, which contains a high percentage of fibers that have been recycled repeatedly.

The improved sheet properties obtained with Condebelt drying gives papermakers the option of reducing basis weight or increasing the usage of highly recycled fibers such as Korean OCC. It has been found that reduction of basis weight of 25% or substitution of 50% American OCC with Korean OCC would be possible with Condebelt drying.

The benefits of Condebelt drying in sheet strength improvement were demonstrated in the laboratory experiment and in the mill production line of Dong Il Paper Mfg. Co., Ltd. Contamination of the fine wires and sticking of the dried web onto the upper steel belt were resolved by exercising proper cautions in stock preparation and drying processes.

LITERATURE CITED

1. Lehtinen, J., *Paperi Puu* 70(4): 310(1988).
2. Horn, R. A., *Tappi* 62(7): 77(1979).
3. Byrd, V. L., *Tappi* 62(7): 81(1979).
4. Kunnas, L., Lehtinen, J., Paulapuro, H., and Kiviranta, A., *Tappi J.* 76(4): 95(1993).

5. Retulainen, E., *Second Ecopapertech Conference Proceedings*, Finnish Pulp and Paper Research Institute, Espoo, 1998, p. 315.
6. Unkila, K., Lehtinen, J., and Juntunen, T., “An assessment of the quality aspects of Condebelt dried board and paper,” in *Proceedings of the Helsinki Symposium on Alternate Methods of Pulp and Paper Drying*, Finnish Paper Engineers Association, Finnish Pulp and Paper Research Institute, and Pira International, 1991.
7. Retulainen, E., Merisalo, N., Lehtinen, J., and Paulapuro, H., *Pulp Paper Canada* 99(1): T20(1998).
8. Htun, M., in *Paper Structure and Properties* (J. A. Bristow and P. Kolseth, Eds.), Marcel Dekker, New York, 1989, pp. 311–326.
9. Lehtinen, J., *Paper Technology* 36(10): 67(1995).

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