Pilot study on the manufacture of kraft paper from old corrugated container

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1. Introduction

Kraft paper is used for grocery bags, multiwall sacks, envelopes and other packaging. The strength properties such as tensile strength, tearing strength and bursting strength are of importance. In addition, the surface of kraft paper should be clean since it is used for wrapping and packaging. Hence kraft paper is generally produced with virgin unbleached kraft pulp (UKP).

In recent years, the price of UKP has been steadily rose and hence kraft paper mills have been suffered due to the increased production costs. One of the possible solutions is to reduce the manufacturing costs by using cheaper raw materials such as old corrugated container (OCC). Usually OCC is recycled to produce the base paper of corrugated containers without deinking treatment. It can cause problems to utilize OCC as a raw material to produce kraft pulp. Use of recycled pulp will decrease the strength of the produced kraft paper. Due to the contaminants such as ink and dirt in the recycled pulp, appearance of the products will be deteriorated.

Ssangyong paper mill producing kraft paper has two paper machine lines: line no 1 treats unbleached kraft pulp; line 2 treats old corrugated container (OCC). In order to reduce the costs for the purchase of UKP, Ssangyong paper wants to replace a part of the UKP in PM 1 by the recycled pulp from the line 2. Current recycling line of PM 2 consists of series of screens and cleaners. The recycling line does not equipped with deinking equipments such as kneader and flotation cell.

The objective of this study was to determine the most appropriate recycling line to treat recycled fibers in order to obtain a finished paper with the same appearance of paper made from unbleached kraft pulp.

2. Experimental

2.1. Recycling lines tested

A roll of paper supplied by Ssangyong Paper was sent to CTP (Centre Technique du Papier) and used as a raw material for the pilot trial. The paper roll was produced from AOCC (American Old Corrugated Container) without a deinking treatment. Paper had disintegrated for 30 minutes with a pilot low consistency pulper. Pulping concentration was about 4%, pH was neutral and temperature was 40°C. After repulping, three recycling lines were tested.

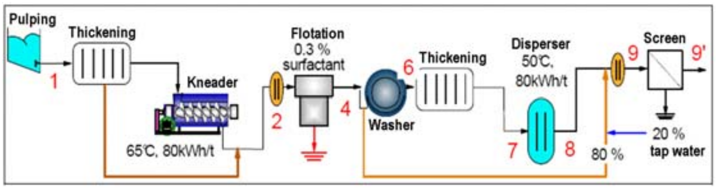
Recycling line no 1

The schematic diagram of recycling line no 1 is presented in Fig. 1. After slushing, pulp slurry was transferred into a mixing chest. Then it was thickened by a vacuum filter and a screw press to a concentration of 30%. The thickened pulp was dispersed by a single shaft kneader. Kneading energy was 80 kWh/T and kneading temperature was 50°C. The pulp was deflaked in order to remove agglomerates of fibers during the mechanical treatments at high concentration. The high concentration pulp was diluted to 1% with the filtrate from the thickener and froth flotation was performed to remove ink and hydrophobic contaminants from the pulp suspension. Flotation was performed on a neutral condition. Only a surfactant was added. The dosage of the surfactant was 0.3%. The pulp slurry was washed in order to further remove contaminants. The outlet concentration from the washer was 8%. The pulp was further thickened up to 30% and then dispersed with a disc disperser. Dispersion energy was 80kWh/T. To simulate a DAF (dissolved air flotation) treatment on process water, the dispersed pulp (30%) was diluted to 1% with a mixture of 80% untreated water from the washer and 20% of tap water (generally DAF treats 20% of the total flow). Deflaking treatment was followed by fine screening. Slot width of the screen was 0.2 mm and inlet concentration into the screen was 1%.

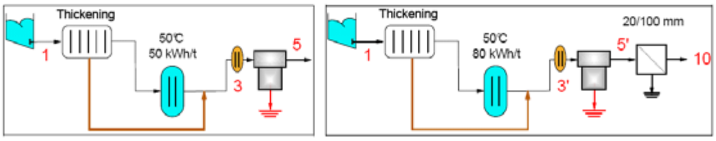
Recycling line no 2-1 and 2-2

Recycling line no 2-1 is shown in Fig. 1. After slushing, pulp slurry was transferred into a mixing chest. The pulp slurry was thickened to 30% and then was dispersed by a disc disperser. Dispersion energy was 50 kWh/T and temperature was 50°C. The dispersed pulp was deflaked and then a froth flotation was performed at neutral condition after diluting to 1% using the filtrate from the thickening process. Only a surfactant was added and the amount of the surfactant added was 0.3% based on weight.

Recycling line no 2-2 (Fig. 1) was the same with recycling line no 2-1 except that dispersion energy was increased from 50 to 80 kWh/T. In addition, the fine screen with the slot width of 0.2 mm was added after the froth flotation. Inlet concentration into the screen was 1%.



Recycling line no 1.



Recycling line no 2-1.

Recycling line no 2-2.

Fig. 1. Experimental schemes for three recycling lines. The numbers in the figures indicate sampling points.

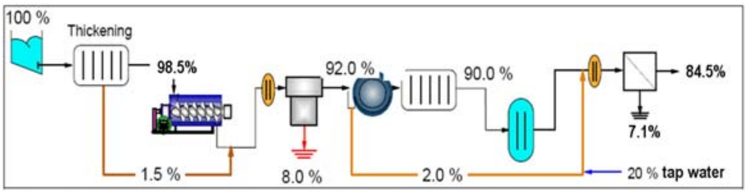
2.2. Analysis of samples

After each treatment, samples were taken and analyzed. Dewatering property of pulp was measured according to Schopper-Riegler (SR) testing method (ISO 5267-1). In SR testing, 1 L of pulp suspension with a concentration of 0.2% filtered through the wire screen of the SR tester. High SR number means that the drainage resistance of the stock is high. Ash content of samples was measured by igniting the samples in a muffle furnace at 525°C (Tappi standard T211). Hand sheets were prepared using the samples taken and the surface of the sheets was scanned. Quantification of specks on the sheets was performed by image analysis. Fiber characteristic such as fiber length, coarseness, kink and curl were analyzed with the fiber analyzer, MorFi, developed by CTP. Inaddition, the following strength properties were measured: breaking length (ISO 1924), burst index (ISO 2758), Tear index (ISO 1974) and zero-span tensile strength (Tappi T494).

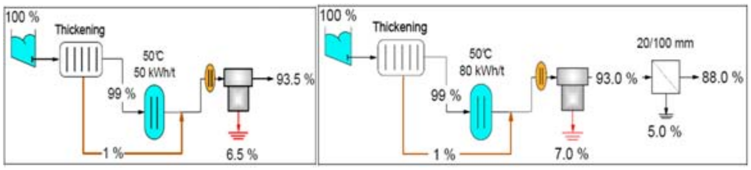
3. Results and discussion

Yield

Distribution of solids along the process for three recycling lines tested is shown in Fig. 2. Yields of recycling line no 1, 2-1 and 2-2 were 83%, 93.5% and 88.0% respectively. Whatever the recycling lines, solids are lost at the froth floatation and the screening step. There would be some fibers in the losses and that can be reused with a reintroduction of the flotation and screening rejects to the recycling line of the PM2.



Recycling line no 1.



Recycling line no 2-1.

Recycling line no 2-2.

Fig. 2. Distribution of mass in three recycling lines.

Dewatering property and ash content

Changes in concentration, ash content and drainage resistance (expressed in SR number) of the recycled pulp along the steps in recycling line 1 is shown in Fig. 3. Ash content of the stock along the recycling line was generally low: that in the pulper was 5.51%. With the thickening step, relatively small amount of fillers were removed from the pulp suspension. The flotation step removed a significant fraction of the fillers and the washing step was particularly efficient to remove a large part of the residual fillers. With the reintroduction of the process water (the mixture of the filtrate from the washer (80%) and tap water (20%)) after the dispersion stage, the ash content was increased again from 2.36% to 3.8%. Comparing the pulping stage and the final screen, ash content of the stock was decreased from 5.51% to 3.76%.

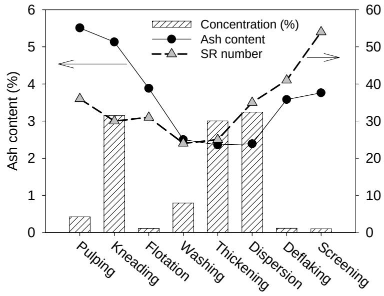


Fig. 3. Ash content and drainage resistance of the pulp along the steps in recycling line no 1.

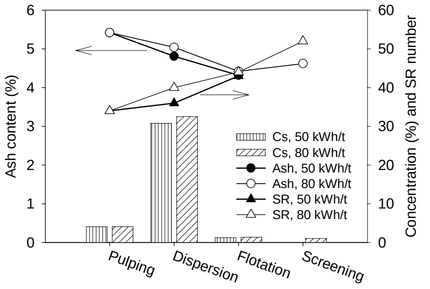


Fig. 4. Ash content and drainage resistance of the pulp along the steps in recycling line no 2-1 and 2-2.

In recycling lines 2-1 and 2-2, ash content was slightly decreased at the thickening step and at the flotation step (Fig. 4). The screening step of the recycling line 2-2 did not affect the ash content. Dispersion energy did not show a significant effect on filler removal from pulp suspension at the flotation stage. For both 50 kWh/T and 80 kWh/T, the ash content in the recycled pulp was decreased about 1% from the pulping stage to the outlet of the flotation step.

After kneading and washing stages, SR (Schopper-Riegler) number decreased, which means that dewatering property of the recycled pulp was improved (Fig. 3). This is due to the removal of fine elements which was removed from the pulp suspension with the filtrate at the thickening and washing stages. Fines can block the passage for water to pass through fiber network (wet web) and hence cause poor drainage. Also treatment in high concentration causes fiber to deform, increasing the amount of curled or kinked fiber. The curled or kinked fibers provide spaces for water to escape through the forming web, improving drainage. The dispersion performed at a high energy level (80 kWh/T) can induce formation of fines (Table 1) and probably fibrillation onto fibers which caused higher drainage resistance and hence higher SR number. Dilution of the thickened pulp with the mixture of the filtrate from the thickener (80%) and tap water (20%) contributed to decrease drainage (increase in SR number) due to the reintroduction of the fine elements present in water. Then the final screening step increased SR number due to the removal of long fibers. As a result, the SR value of the recycling line 1 increased about 20 points from the initial chest to the accepted pulp. This increase in the SR value can be managed easily by mixing the recycled pulp with virgin UKP.

Table 1. Fiber characteristics along the recycling line 1

	Pulping	Kneading	Flotation	Washing	Thickening	Dispersing	Deflaking	Screening
Length weighted average fiber length (mm)	1.23	1.08	1.11	1.14	1.13	1.17	1.16	1.14
Fiber width (µm)	25.4	24.6	24.8	25	25	24.7	25	24.7
Fiber coarseness (mg/m)	0.179	0.201	0.194	0.170	0.114	0.192	0.171	0.169
Fines content (% area)	14.9	17.5	16.3	11.5	8.7	12.8	12.8	14.4
Average kink number (%)	1.17	1.52	1.46	1.48	1.48	1.48	1.32	1.26
Kinked fibers (%)	23.3	45.6	44.3	45.5	43.7	44.6	36.9	32.5
Average curl (%)	7.2	12.0	11.6	11.8	11.7	11.5	9.1	8.4
Flexibility index	9.59	17.66	16.98	17.48	17.70	16.64	12.98	12.27
Ratio of broken ends (%)	29.0	29.8	29.3	29.1	28.8	28.0	30.0	29.4

In recycling lines 2-1 and 2-2, dispersing stage slightly increased the SR number (Fig. 4). When higher dispersion energy (80 kWh/T) was applied, the SR number was higher. However the differences between low (50 kWh/T) and high (80 kWh/T) energy dispersion for the SR number were minimal. After flotation, SR number was increased due to the reintroduction of the filtrate from the thickener which contains lots of fine elements. In the screen stage, lots of long fibers were removed and consequently the increase in the SR number became significant.

Specks

Cumulated area of specks in the handsheets made of the recycled pulp sampled in the recycling line 1 is shown in Fig. 5. The kneading step performed at high energy level (80 kWh/T) was very efficient to fragment specks. The reduction in cumulated area of specks was significant after kneading. The rest of the recycling line contributed to remove the residual specks. After the last screening stage, the final pulp was clean. Only some small residual specks were present but with the size small enough to be hardly detectable: 1.09 mm^2/m^2 in the area range of 0.04 - 0.15 mm^2 and 0 in the rest of the area range. Dispersing was less effective in reducing specks than kneading (compare Figs. 5 and 6).

Some specks were remained after dispersion and flotation even though there was large decrease in the area of specks along the recycling line 2-1 and 2-2 (Fig. 6). The screening step was efficient to remove specks. Only small residual specks were present after screening: 13.2 mm^2/m^2 in the area range of 0.04 - 0.15 mm^2 and 0 in the rest of the area range.

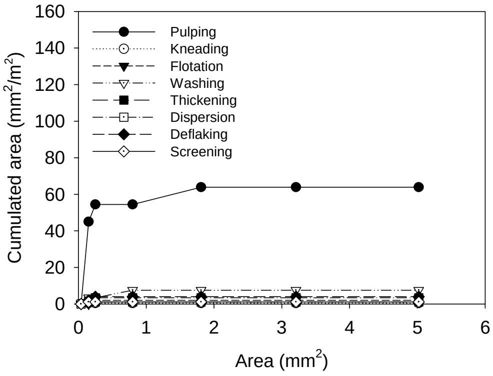


Fig. 5. Cumulated areas of specks along the recycling line no 1.

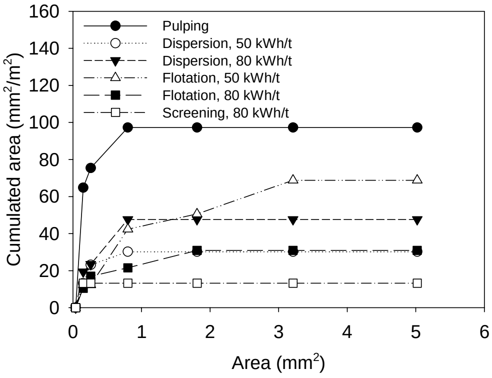
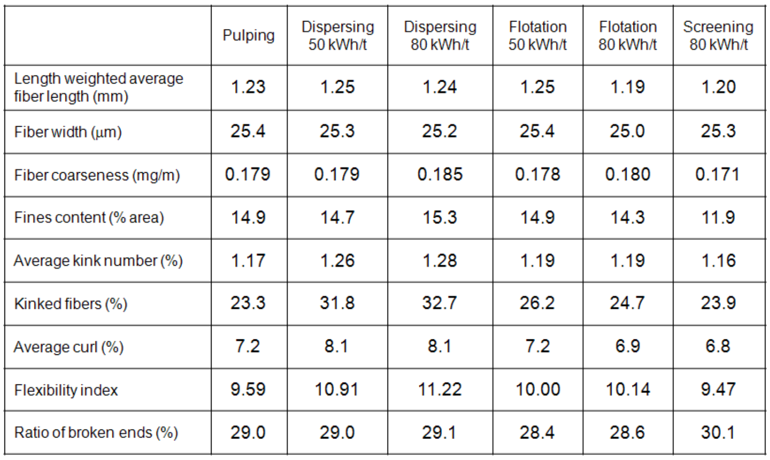


Fig. 6. Cumulated areas of specks along the recycling line 2-1 and 2-2.

Fiber analysis

For fiber length, width and coarseness, there were no significant changes along the recycling lines 1, 2-1 and 2-2 which proved that fibers, even submitted to severe mechanical treatments, were not damaged during recycling (Tables 1 and 2). This was confirmed by the unchanged ratios of broken fiber ends for three recycling lines. After the kneading step, large changes occurred onto fibers for their visual aspect: curling, kinking and flexibility (Table 1). When pulp is mechanically treated at high concentration, frictions occur between fibers with high temperature and fibers became curled and kinked. This can be detrimental to mechanical properties of paper. The curly fibers tend to decrease tensile strength and tensile stiffness. The deflaking and screening steps allowed restoring the fiber curling, kinking and flexibility (Tables 1). In recycling lines 2-1 and 2-2, same trends were observed: values of kink, curl and flexibility were increased after dispersing and then decreased to the original value after deflaking and screening (Table 2). Deflaking stage was added before flotation. The changes in kink, curl and flexibility after dispersing was less than that after kneading. This is due to the fact that dispersing is performed at very short residence time (contrary to kneading) and hence fibers were not submitted to frictions but impacts.

Table 2. Fiber characteristics along the recycling line 1



	Pulping	Dispersing 50 kWh/t	Dispersing 80 kWh/t	Flotation 50 kWh/t	Flotation 80 kWh/t	Screening 80 kWh/t
Length weighted average fiber length (mm)	1.23	1.25	1.24	1.25	1.19	1.20
Fiber width (μm)	25.4	25.3	25.2	25.4	25.0	25.3
Fiber coarseness (mg/m)	0.179	0.179	0.185	0.178	0.180	0.171
Fines content (% area)	14.9	14.7	15.3	14.9	14.3	11.9
Average kink number (%)	1.17	1.26	1.28	1.19	1.19	1.16
Kinked fibers (%)	23.3	31.8	32.7	26.2	24.7	23.9
Average curl (%)	7.2	8.1	8.1	7.2	6.9	6.8
Flexibility index	9.59	10.91	11.22	10.00	10.14	9.47
Ratio of broken ends (%)	29.0	29.0	29.1	28.4	28.6	30.1

Mechanical properties

Fig. 7 shows the changes in breaking length and burst index along the recycling lines 1. Breaking length and burst index generally showed the same tendency. Both strengths were decreased by kneading due to curling of fibers (Fig. 7). The thickening and dispersing step restored these properties by refining effect (even limited). The screening step had no effect. Comparing breaking length after pulping and final screening, it was slightly decreased from 3566 m to 3482 m. In addition, a slight increase in the burst index was observed from the pulping chest (2.16 kPa.m^2/g) to the final pulp (2.43 kPa.m^2/g). Breaking length and burst index of the recycled pulp could be inferior to those of UKP (unbleached Kraft pulp). An additional refining step implemented after the screening stage could help to develop these properties.

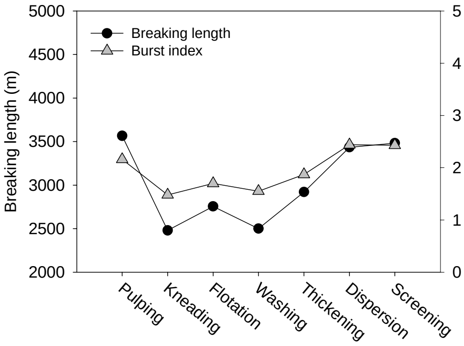


Fig. 7. Breaking length and burst index along the recycling line 1.

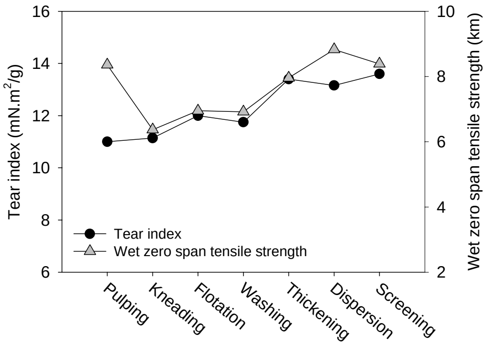


Fig. 8. Tear index and wet zero span tensile strength along the recycling line 1.

Tear index was constantly developed along the recycling line 1 (Fig. 8). This means that fibers were not damaged during recycling and fibrillation was developed onto fiber surface. Wet zero-span tensile strength showed similar trends with breaking length and burst index. It was decreased after kneading and recovered after thickening and dispersing. Zero-span tensile strength was originally developed to measure fiber strength. Hence, there shall not be any changes in zero-span tensile strength since fiber strength was not varied during recycling as shown in tear index. However, fiber bonding contributes to zero-span tensile strength to a certain extend. The decrease in tearing strength after kneading was due to the deformation (curling and kinking) of fibers occurred during kneading. Fortunately, with the rest of the recycling line, a latency effect occurred which allowed to restore the fibre structure. With the dispersing step, fibers were submitted to mechanical treatment which removes the curling effect and contribute to develop this property.

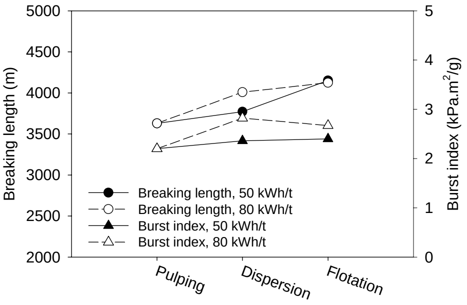


Fig. 9. Breaking length and burst index along the recycling lines 2-1 and 2-2.

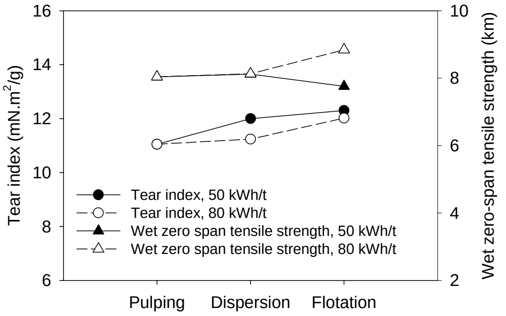


Fig. 10. Tear index and wet zero span tensile strength along the recycling lines 2-1 and 2-2.

Fig. 9 shows changes in breaking length and burst index along the recycling lines 2-1 and 2-2. Dispersing contributed to develop breaking length and burst strength. The higher the energy level applied in the dispersing step, the higher the breaking length and bursting index. This is due to the refining effect occurring during dispersing. Flotation applied after the dispersing stage increased breaking length due to the removal of fillers (hydrophobic elements). Notable changes were not observed in burst index. At the dispersing energy level of 50 kWh/T, burst index was slightly increased after flotation, while it was slightly decreased at the energy level of 80 kWh/T. Tear strength was slightly increased with dispersing (Fig. 10). The higher the energy level applied during the dispersing step, the lower the tear index. Flotation contributed to increase the tear index due to the removal of fillers. Fig. 10 also shows the changes in wet zero span tensile strength along the recycling lines 2-1 and 2-2. Wet zero span tensile strength was expressed in terms of breaking length. The dispersing step, whatever the energy level, has no influence on the wet zero span tensile strength. On the other hand, the flotation step, depending on the previous dispersing step, seems to have a different effect. At 50 kWh/T, the zero span tensile strength was slightly decreased after flotation while it was slightly increased at 80 kWh/T.

4. Conclusions

The recycling line no 1 consisting of kneading, flotation, washing and screening stages allows to produce pulp with acceptable appearance (i.e., specks) while the recycling line no 2 (whatever the energy level applied at the dispersing step) was insufficient to reach the acceptable level for the visual aspect. Kneading was more efficient treatment to reduce specks of the OCC containing stock than dispersing. In addition, 0.2 mm screen was very effective to remove specks. In all three recycling lines, severe damages on fiber morphology such as cutting of fiber and fines formation were not occurred along the recycling lines from the pulping chest to the final accepted pulp. Comparing the pulp repulped and the final accepted pulp, strength properties were slightly increased. However, breaking length and burst index of the recycled pulp could be inferior to those of the UKP. An additional refining step implemented after the screening step could help to develop these properties.

Acknowledgement

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