Journal of Korea TAPPI
Vol.40. No.5, 2008
Printed in Korea

Pilot Study on the Manufacture of Kraft Paper from OCC

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(Received September 10, 2008: Accepted November 21, 2008)

ABSTRACT

In order to determine the most appropriate recycling line to treat old corrugated container (OCC) to substitute unbleached kraft pulp (UKP) for the manufacture of kraft paper, three recycling lines were evaluated in pilot scale tests. The recycling line consisting of kneading, flotation, washing, dispersion and screening steps was able to produce pulp with acceptable appearance. Kneading was shown to be more efficient treatment to reduce specks than dispersion. In addition, 0.2 mm slot screen was very effective to remove specks. Severe damages on fiber morphology such as shortening of fiber and formation of fines were not observed during mechanical treatments such as kneading and dispersion. Most of strength properties of the kraft paper produced with the recycled pulp were found to be slightly increased after treated in the recycling lines.

Keywords : *recycling of OCC, pilot trial, kneading, flotation, washing*

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 appearance of kraft paper should be clean since it is used for wrapping and packaging. Hence kraft paper has been generally produced with virgin unbleached kraft pulp (UKP).

In recent years, the price of UKP has been steadily risen 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 utilizing cheaper raw materials such as old corrugated container (OCC). Usually OCC is recycled to produce the base paper of corrugated containers (i.e., liner grades) without deinking treatment. When OCC is used as a raw material to produce kraft pulp, it can cause problems. Use of recycled pulp will decrease the strength properties of the produced kraft paper. Due to the contaminants such as ink and dirt from recycled pulp, appearance of the products will be deteriorated.

Most of researches on recycling of OCC have been focused on improving the quality of testliner. Air froth flotation and enzyme treatment were applied in order to fractionate hydrophobic fine materials from Korean old corrugated container (KOCC) stock and to improve strength and drainage properties of testliner

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(1). According to Seo et al., froth flotation followed by kneading treatment can improve strength and drainage properties as well as optical cleanliness of testliner made from 100% KOCC (2). Yeo et al. improved both of strength and drainage properties by fractionating fines through froth flotation (3). The fractionated fines fraction was selectively treated with flocculants and the long fiber fraction was refined. Simpson Tacoma Kraft Company reported the reduction in the use of virgin softwood kraft pulp required in linerboard by replacing UKP with the recycled OCC (4). Increase of strength properties of OCC recycled pulp was achieved by optimizing OCC repulping system and screening system. De Ruvo et al. treated OCC with oxygen bleaching to improve the quality of pulp such as swelling ability and flexibility of fiber (5).

Jackson et al. introduced a process system that converts OCC to high quality bleached fiber as market pulp for use in printing and writing paper production (6). The system consisted of pre-treatment of OCC to remove contaminants and delignification by an alkali and oxygen treatment. Lee et al. tried to manufacture printing and writing grades from American old corrugated container (AOCC) and KOCC by soda-AQ (anthraquinone) or kraft-AQ cooking followed by elemental chlorine free (ECF) bleaching or totally chlorine free (TCF) bleaching (7). It was shown that strength of KOCC pulp was lower than AOCC pulp and that KOCC pulp was difficult to achieve ISO brightness over 85%.

Van Tran tried to partially replace virgin hardwood kraft pulp by recycled OCC (8). It was concluded that kneading treatment of recycled OCC pulp can improve the papermaking properties of the pulp except for dirt content and that the recycled OCC pulp can replace virgin hardwood kraft pulp up to ten percent. Dutt et al. tried to manufacture kraft paper from the blend of wheat straw pulp and OCC but the result was not satisfactory (9).

S paper mill producing kraft paper has two paper machine lines: line no 1 treats UKP and line 2 treats OCC. In order to reduce the costs for the purchase of UKP, S paper wants to replace a part of the UKP in the line 1 by the recycled pulp from the line 2. Current recycling system of paper machine line 2 consists of series of screens and cleaners. Since the recycling line does not involve deinking process, the appearance of the product manufactured with recycled OCC is poor compare to that manufactured with UKP. The objective of the pilot trial 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. Recycling lines including froth flotation deinking, washing, and dispersion or kneading were tested.

2. Experimental

2.1 Recycling lines tested

A roll of paper supplied by S 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 only with basic cleaning and screening systems and without a deinking treatment. Paper was disintegrated for 30 minutes with a pilot low consistency pulper. Repulping concentration was about 4%, pH was neutral and temperature was 40℃ After repulping, three recycling lines were tested.

2.1.1 Recycling line 1

The schematic diagram of recycling line 1 is presented in Fig. 1. After repulping, pulp slurry was transferred into a mixing chest. Then it was thickened by a vacuum filter and a screw press up to a concentration of 30%. The thickened pulp was treated with a single shaft kneader. Kneading energy was 80 kWh/T and kneading temperature was 50℃. The kneaded pulp was deflaked in order to remove agglomerates of fibers occurred during the mechanical treatment at high consistency. The pulp was then diluted to 1% with the filtrate from the thickener and

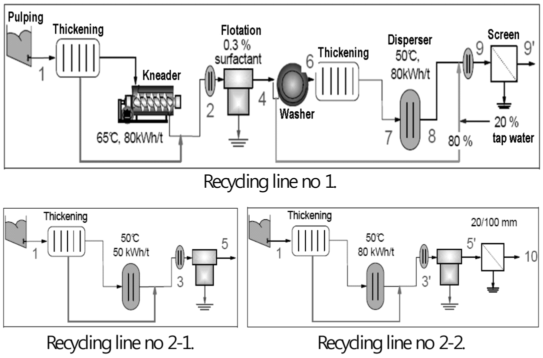

Fig. 1. Experimental schemes for three recycling lines. The numbers in the figures indicate sampling points.

froth flotation was performed to remove ink and hydrophobic contaminants from the pulp suspension. It was performed at a neutral condition. Only a surfactant (0.3% on pulp weight) was added. The accepted pulp from the flotation cell 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 80 kWh/T. To simulate a DAF (dissolved air flotation) treatment on process water, the filtrate from the washer (80%) was mixed with tap water (20%). Generally DAF treats 20 % of the total flow. The dispersed pulp (30%) was diluted to 1% with the mixed water. Deflaking treatment was then performed, followed by fine screening. Slot width of the screen was 0.2 mm and inlet consistency into the screen was 1%.

2.1.2 Recycling lines 2-1 and 2-2

Recycling line 2-1 is shown in Fig. 1. After slushing, pulp slurry was transferred into a mixing chest. The pulp slurry was thickened up to 30% and then was dispersed by a disc disperser. Dispersion energy was 50 kWh/T and temperature was 50℃. The dispersed pulp was deflaked and then froth flotation was performed at a 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 pulp weight.

Recycling line 2-2 (Fig. 1) was the same with recycling line 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 stage. Inlet concentration into the screen was 1%.

2.2 Analysis of samples

After each treatment, samples were taken and analyzed. Dewatering property of a sample 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% was 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 a sample was measured by igniting the sample in a muffle furnace at 525℃ (TAPPI standard T211). Handsheets were prepared from the samples taken and the surface of the sheets was scanned. The specks on the sheets were quantified by image analysis. Fiber characteristic such as fiber length, coarseness, kink and curl were analyzed with the fiber analyzer, MorFi, developed by CTP. In addition, 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

3.1 Yield

Distribution of solids along the process for three recycling lines tested is shown in Fig. 2. Yields of recycling lines 1, 2-1 and 2-2 were 83%, 93.5% and 88.0% respectively. Whatever the recycling line is, solids are mainly removed at froth flotation and screening stages. There would be some fibers in the rejects and that can be reused by reintroducing the

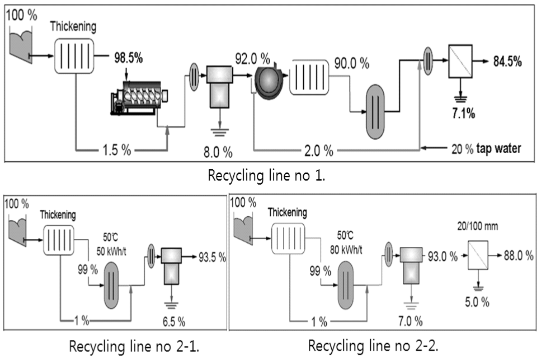

Fig. 2. Distribution of the mass of solids in three recycling lines.

flotation and screening rejects to the stock preparation line of the paper machine line 2.

3.2 Dewatering property and ash content

Fig. 3 shows the changes in concentration, ash content and drainage resistance (expressed in SR number) of the recycled pulp along the recycling line 1. Ash content of the stock along the recycling line was generally low: that in the pulper was 5.51%. In the thickening stage, relatively small amount of fillers were removed from the pulp suspension. Froth flotation removed a significant fraction of fillers and the washing stage 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 repulped stock and the final screen accept, the ash content of the stock was decreased from 5.51% to 3.76%.

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

After kneading and washing, SR 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 (10). 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

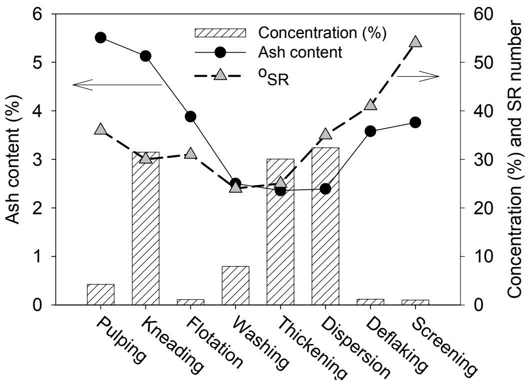

Fig. 3. Ash content and drainage resistance of the stock along the recycling line 1.

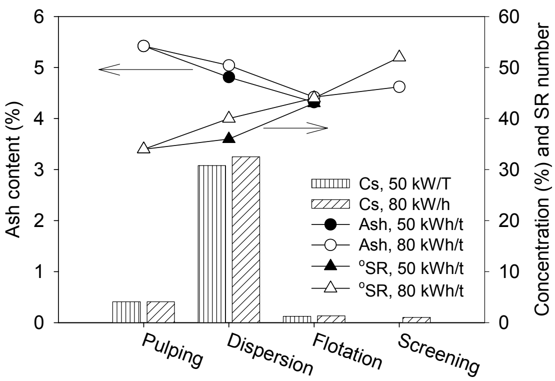

Fig. 4. Ash content and drainage resistance of the stock along the recycling lines 2-1 and 2-2.

Table 1. Fiber characteristics along the recycling line 1

	Pulping	Kneading	Flotation	Washing	Thickening	Dispersion	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

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 washer (80%) and tap water (20%) contributed to decrease drainage (increase in SR number) due to the reintroduction of the fine elements. 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 final accepted pulp. This increase in the SR value can be managed by mixing the recycled pulp with virgin UKP.

In recycling lines 2-1 and 2-2, dispersion slightly increased the SR number (Fig. 4). When higher dispersion energy (80 kWh/T) was applied, the SR number was higher. However, after flotation, the differences between low (50 kWh/T) and high (80 kWh/T) energy dispersion become 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.

3.3 Specks

Cumulated area of specks in the handsheets made of the recycled pulp sampled in the recycling line 1 is shown in Fig. 5. Kneading performed at high energy level (80 kWh/T) was very efficient to fragment

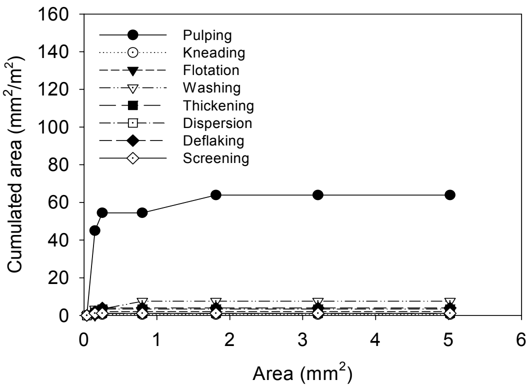

Fig. 5. Cumulated areas of specks along the recycling line 1.

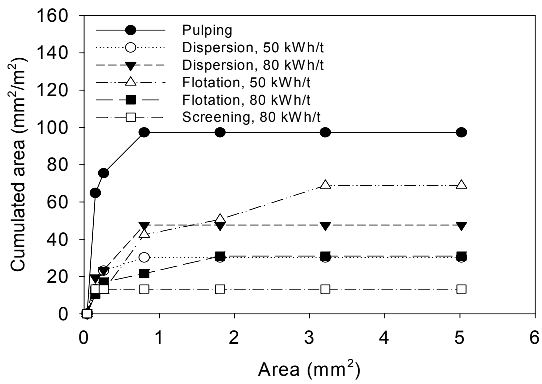

Fig. 6. Cumulated areas of specks along the recycling lines 2-1 and 2-2.

specks and to reduce the cumulated area of specks. The rest of the recycling line contributed to remove the residual specks. After the last screening stage, the final pulp was acceptably 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.

Dispersion 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 speck area along the recycling lines 2-1 and 2-2 (Fig. 6). Screening 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.

3.4 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 kneading, large changes occurred onto fibers for their visual aspect: curling and kinking (Table 1). When pulp is mechanically treated at a 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 (11). Deflaking and screening allowed restoring the fiber curl and kink (Tables 1). In recycling lines 2-1 and 2-2, same trends were observed: values of kink and curl were increased after dispersion and then decreased to the original value after deflaking and screening (Table 2). The changes in kink and curl after dispersion were less than that of stock after kneading. This is due to the fact that dispersion is performed at a very short residence time (contrary to kneading) and hence fibers were not submitted to frictions but impacts.

3.5 Mechanical properties

Fig. 7 shows the changes in breaking length and burst index along the recycling line 1. Breaking length and burst index generally showed the same tendency. Both strengths were decreased by kneading due to the curling of fibers. Thickening and dispersion restored these properties by refining effect (even limited). Screening had no effect on both properties. After treated in recycling line 1, breaking length was slightly decreased from 3566 m to 3482 m. In addition, a slight increase in 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

Table 2. Fiber characteristics along the recycling lines 2-1 and 2.2

	Pulping	Dispersion 50 kWh/t	Dispersion 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

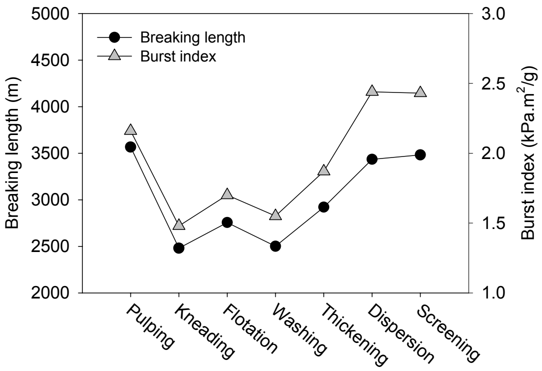

Fig. 7. Breaking length and burst index along the recycling line 1.

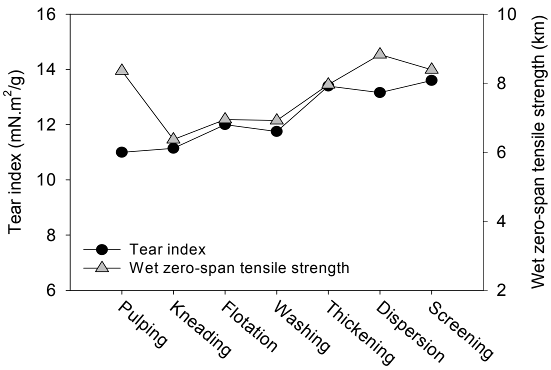

Fig. 8. Tear index and wet zero-span tensile strength along the recycling line 1.

could be inferior to those of UKP. An additional refining step implemented after the screening stage could help to develop these properties.

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. Wet zero-span tensile strength was expressed in terms of breaking length. It was decreased after kneading and recovered after thickening and dispersion. 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. According to Mohlin et al., fiber deformation such as kink, twist and angular fold decreases wet zero-span tensile strength (12). The decrease in tearing strength after kneading was due to the deformation (curling and kinking) of fibers. Fortunately, the deformed fibre structure was recovered with the rest of the recycling line. With dispersion, fibers were submitted to mechanical treatment which removes the curling effect.

Fig. 9 shows the changes in breaking length and burst index along the recycling lines 2-1 and 2-2. Dispersion contributed to develop breaking length and burst strength. The higher the energy level applied in dispersion, the higher the breaking length and the bursting index. This is due to the refining effect

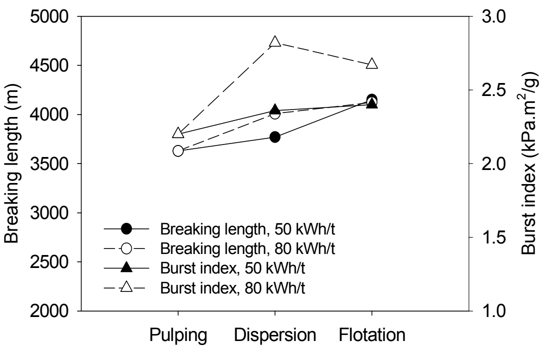

Fig. 9. Breaking length and burst index along the recycling lines 2-1 and 2-2.

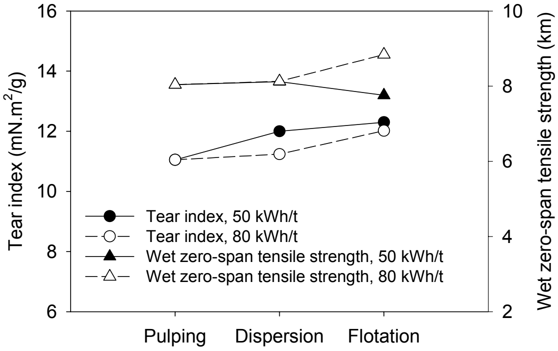

Fig. 10. Tear index and wet zero-span tensile strength along the recycling lines 2-1 and 2-2.

occurred during dispersion. Flotation applied after dispersion increased breaking length due to the removal of fillers (hydrophobic elements). Notable changes were not observed in burst index. At the dispersion 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. Tearing strength was slightly increased with dispersion (Fig. 10). The higher the energy level applied during dispersion, the lower the tear index. Flotation contributed to increase 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. Whatever the energy level, dispersion has no influence on the wet zero-span tensile strength. On the other hand, the flotation step seems to have a different effect, depending on the previous dispersion energy. 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 1 consisting of kneading, flotation, washing, dispersion and screening stages allows to produce pulp with acceptable appearance (i.e., specks) while the recycling line 2 (whatever the energy level applied at the dispersion 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 dispersion. In addition, 0.2 mm slot screen was very effective to remove specks. In all three recycling lines, severe damages on fiber morphology such as cutting of fiber and formation of fines were not occurred. After treated in the recycling lines, strength properties of the paper produced with the recycled pulp were slightly increased. However, strength properties 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.

Acknowledgements

This study was supported by the cleaner production technology development projects of Korean Ministry of Knowledge Economy. The authors wish to thank Mr. J.–H. Park and SSangyong Paper Co., LTD. for their valuable discussions and for supplying rolls of paper for the pilot trial.

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