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Effect of Fines Distribution on Press Dewatering and Physical Properties of Multi-ply Sheet

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ABSTRACT

Multi-ply sheet forming has many advantages including the possibility of using wide range of materials in a given structure, lowering production cost, making higher grammage products and so on. But, incorrect structure of sheet makes flow resistance higher so that it shows poor dewatering in press section. One of major factors that affect sheet structure and dewatering property is fines content in each layer. We, therefore, examined the press dewatering of multi-ply sheet that has the different fines content in each layer and the effect of fines distribution on physical properties of sheet to find a technology for optimum utilization of raw materials. In case of two layered sheet, the sheet which was composed of layers with the different flow resistance showed higher dewatering rate than one which has the same flow resistance. And the more difference in fines content for layers existed, the more dewatering occurred. For three layered sheets, dewatering is mainly dependent on fines content of bottom layer. Strength properties were affected by dewatering degree and multi-ply sheet structure.

Keywords : *multi-ply, fines, pressing, physical properties, fractionation*

1. Introduction

To utilize OCC (Old Corrugated Container) fibers efficiently, fractionation and mechanical treatment technology were studied and adopted by many linerboard paper mills. OCC fibers were fractionated into long fiber and short fiber fractions, and long fiber fraction was treated mechanically using refiner or other equipment. According to Musselmann, selective mechanical treatment on long fiber fraction improves paper strength without deteriorating drainage (1). In case of KOCC, however, selective mechanical treatment on the fractionated stock doesn't show a remarkable improvement of strength and drainage compared with whole stock treatment (2). Fractionation, however, has been thought as a good technology for multi-ply forming.

Most of linerboards with basis weight of 125 to 350 g/m^2 are produced by multi-ply forming of 2-4 plies.

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Multi-ply sheet forming has many advantages including the possibility of using wide range of materials in a given structure, lowering production cost, making higher grammage products and so on (3). But, incorrect structure of sheet makes flow resistance higher so that it shows poor dewatering in press section. Especially, higher flow resistance in press causes air blowing and sheet crushing. Finally sheet properties are influenced. Press dewatering is affected by many variables including roll type, press load, nip length, fiber furnish, flow resistance, fines distribution, basis weight, felt property, etc (4). One of major factors that affect press dewatering and sheet structure in multi-ply forming is fines content in each layer. As recycled pulps like OCC which has much fines content were used as raw materials for linerboard, drainage became a critical issue frequently. Especially KOCC shows severe drainage problem due to repeated recycling. Because fines have a higher specific area and can fill up pores between fibers, they bring about a slower dewatering or problems related with dewatering. Their effect would be dependent on type of fines, that is, primary fines or secondary fines. Generally the specific surface area of secondary fines is four times as large as one of primary fines and more swollen (5,6). And process runnability and sheet properties are differently influenced depending on fines type (7).

To find a technology for optimum utilization of raw materials for multi-ply forming, therefore, the press dewatering of multi-ply sheet that has the different fines content in each layer and the effect of fines distribution on physical properties of sheet were examined in this study.

2. Experimental

2.1 Materials

Softwood unbleached kraft pulp (Sw-UKP) and corrugating medium made of KOCC with 100% were used for experiments.

2.2 Stock preparation

Sw-UKP was beaten using laboratory Valley beater and KOCC stock was prepared by disintegrating or beating depending on type of fines which were used for experiment. Beating time was controlled to obtain the stocks with different fines content.

2.3 Fines preparation

Fines were obtained by fractionating stock with Sweco screen equipped with 200 mesh wires. Shower water was supplied consistently during fractionation. Fines passed through 200 mesh wire were collected and concentrated by settling for 8 hrs. Consistency of concentrated fines was measured.

2.4 Handsheet making and evaluation of press dewatering

One-ply handsheets with basis weight of 100 g/m^2 were made using laboratory sheet former to evaluate dewatering characteristics of stock and establish the couching condition. To obtain wet sheet with the similar solids content after couching, sheet dryness was measured at the different couch number. Fig. 1 shows the dryness of wet sheet after couching. Based on this result, couch was carried out 5 times and then dryness of wet sheet was around 21%.

2-ply sheet was made by couching two 1-ply sheets

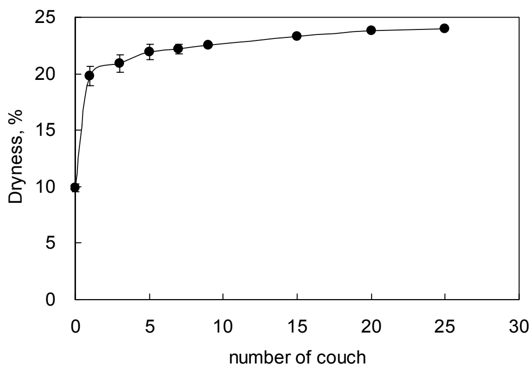

Fig. 1. Dryness of wet sheet depending couch number.

Fig. 2. Scheme of wet pressing.

with basis weight of 100 g/m^2 together. And 3-ply sheet was also made by combining three 1-ply sheets with basis weight of 50 g/m^2. Fines content of each layer stock was different. Pressing was carried out using laboratory press. To simulate unidirectional dewatering from top to bottom layer, steel plate was put on the top side of sheet and the only bottom ply was contact on press felt and blotting paper (Fig. 2). Pressing pressure and time were controlled to set the sheet dryness after pressing to 35-45%. The weight of each sheet was measured before and after pressing. Weighed wet sheet was dried by laboratory cylinder dryer. Press dewatering was evaluated from the difference of dryness or moisture ratio between before and after pressing.

2.5 Measurement of sheet properties

Physical properties and mechanical properties of multi-ply sheet were evaluated. For sheets which have different fines distribution for each layer, density, tensile strength, compressive strength and bending stiffness were measured.

3. Results and Discussion

3.1 Press dewatering of 2-ply sheet

Three Sw-UKP stocks with different freeness level were prepared and their stock properties were shown Table 1. Using three stocks, i.e., U1, U2, and U3, we made various 2-ply sheets depending on fines distribution for each layer and evaluated press dewatering. Fig. 3 represents the increase of moisture ratio by pressing for various 2-ply UKP sheets. When top ply was made of the stock which has less fines content, the increase of moisture ratio by pressing didn't show any difference depending on fines content of bottom layer. But when U3 stock that has the highest fines content was located in top ply, press dewatering was affected significantly. Press dewatering is higher when bottom layer has lower fines content. It is because those secondary fines of UKP hinder water flow to press felt.

Table 1. Sw-UKP stock properties

Notation	Fines content (%)	Freeness (mL CSF)	WRV (g/g)
U1	15	645	1.96
U2	20	410	2.16
U3	26	240	2.34

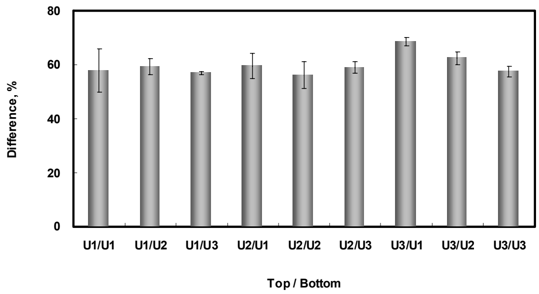

Fig. 3. Difference of moisture ratio of 2-ply UKP sheet.

Press dewatering of 2-ply KOCC sheet was evaluated using disintegrated KOCC stock that has the different fines content of 16%, 23%, and 33%, respectively. Fines in KOCC stock were considered as primary fines and ashes because beating treatment wasn't carried out. Fig. 4 shows press dewatering in a point of view of difference of moisture ratio. When both of top and bottom ply have the same fines contents, the stock (K3) with higher fines content showed rather better dewatering in press. It would be

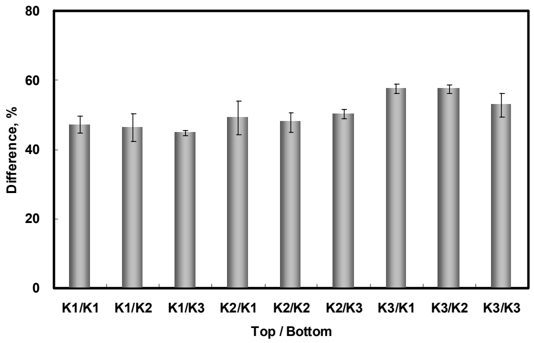

Fig. 4. Difference of moisture ratio of 2-ply KOCC sheet.

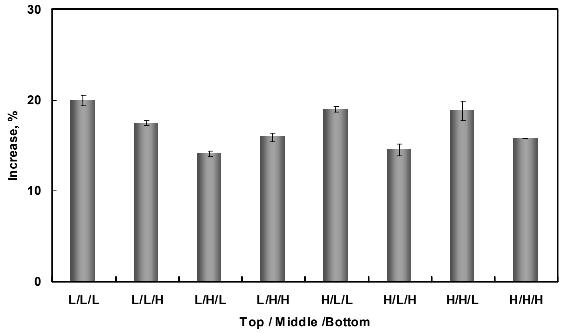

Fig. 5. Increase of moisture ratio of 3-ply UKP sheet.

caused by the low dryness after couching and property of primary fines. As fines content of bottom ply was relatively lower than one of top ply, better dewatering was shown. As like the results of 2-ply UKP sheet, press dewatering of KOCC sheet is affected by fines distribution of each ply, but it is less remarkable than in UKP because that most of fines were derived from primary fines.

3.2 Press dewatering of 3-ply sheet

Using stocks which have higher fines content (H) and lower fines content (L), 3-ply UKP sheets were made. Freeness of UL stock was 480 mL CSF and one of UH was 270 mL CSF. 'LLL' sheet means that all of three plies are made of stock with lower fins content. Increase of moisture ratio by pressing was shown in Fig. 5. 'LLL' multi-ply sheet showed the highest increase of dryness because of low overall fines content and small flow resistance from top to bottom side in pressing. Generally, when 'H' stock was located in bottom ply, the increase of moisture ratio decreased. To produce multi-ply sheet at a faster machine speed, therefore, the arrangement of stock or raw materials for each layer should be considered prudently and it would be recommended that stock with low flow resistance be utilized in bottom layer. In Fig. 5, it is interesting that symmetrical structure of three ply sheets, i.e., 'LHL' and 'HLH' showed poor press dewatering.

To prepare the stock with different fines content disintegrated KOCC pulp slurry was fractionated firstly with 200-mesh wire. Collected fines were mixed into long fiber fraction to make stock with fines content of 20, 30, and 40%, respectively. Each ply was arranged into top, middle, and bottom ply but total fines content was adjusted to 60% (Fig. 6).

Actual fines content and ashes content in a sheet were shown in Fig. 7. Even sheet with fines content of 0% contained about 7% of fines and 2.5% of ashes in

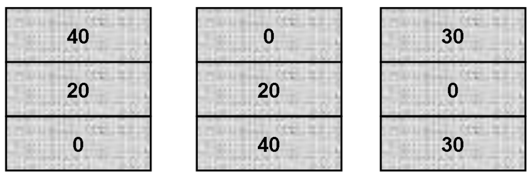

Fig. 6. Ply arrangement of 3-ply KOCC sheet.

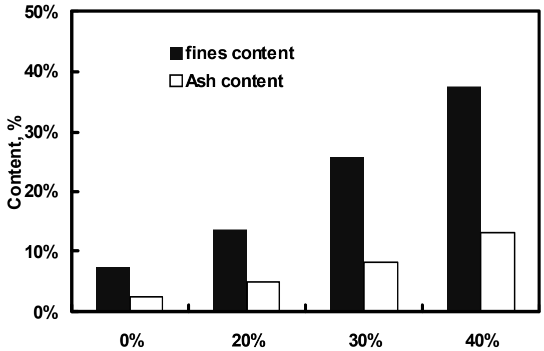

Fig. 7. Fines and ashes content in paper sheet.

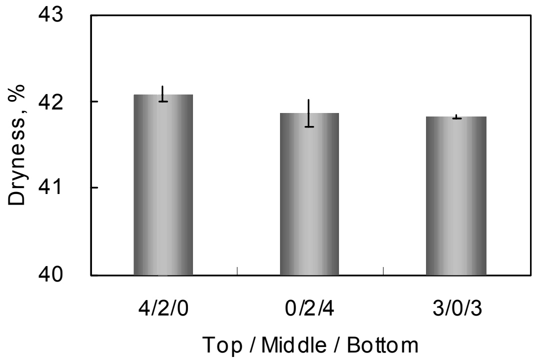

Fig. 8. Dryness of 3-ply KOCC sheet after pressing.

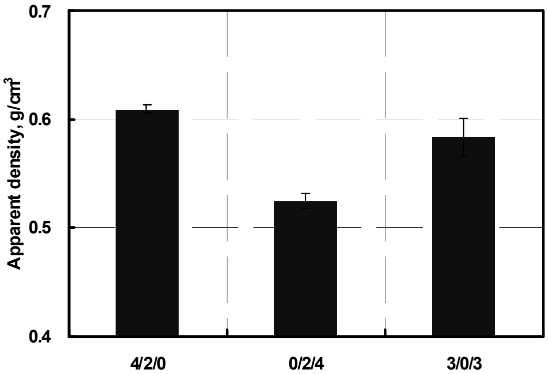

Fig. 9. Apparent density of 3-ply KOCC sheet.

practice because of limit of fractionation.

Effect of fines distribution on press dewatering was evaluated and final dryness of sheet after pressing was shown in Fig. 8. As the fines content in a multi-ply sheet decreased in the direction of water flow, that is, to the bottom side, more dewatering occurred during pressing and then the final dryness was higher. Sheets with more fines content in bottom ply or symmetrical structure showed low dryness after pressing. But its effect on final dryness is not obvious due to fines property. As KOCC fines were obtained by disintegration and fractionation, most of fines must be primary fines and ash component consisted of about 35% among them. Primary fines and ashes showed lower flow resistance than secondary fines do.

For improving press dewatering of multi-ply sheet based on these results, it is proposed that short fiber fraction be used as a stock for top ply.

3.3 Sheet properties

To evaluate effect of fines distribution on sheet properties, various mechanical properties were measured on 3-ply KOCC sheet. Fig. 9 shows apparent density of 3-ply KOCC sheet. '4/2/0' sheet that had the highest final dryness after pressing showed the highest sheet density, and sheet with more fines content in bottom ply had the lowest density. Because rewetting was not considered in this study, final dryness of sheet at the press was determined by total sheet volume reduction produced by pressing (8). Therefore, high final dryness means the occurrence of more volume reduction and then increase of sheet density. Although the difference in final dryness was small, sheet densification was influenced significantly by the final dryness and fines distribution. Fig. 10 represents tensile index and strain of multi-ply sheet. Tensile index of sheet has the same trend as the density. That is, denser sheet shows higher tensile index. But strain is negatively affected by dryness and density. As linerboard is converted to box as a form of corrugated container, strain as well as strength like tensile index is important property in converting. Also bending stiffness is one of critical properties for box material. Higher bending stiffness was obtained in the sheet that has low final dryness and higher flow resistance in

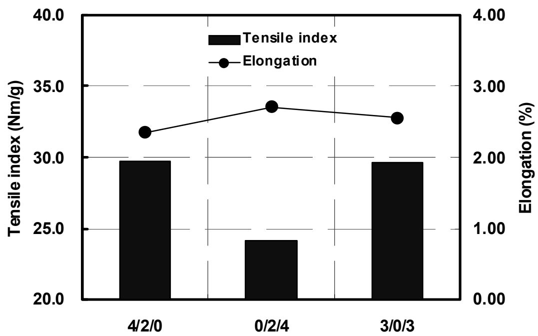

Fig. 10. Tensile index and elongation of 3-ply KOCC sheet.

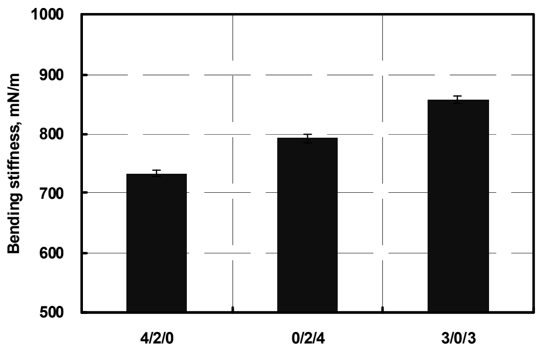

Fig. 11. Bending stiffness of 3-ply KOCC sheet.

bottom ply. Especially, symmetrical structure make sheet more resistant to bending. It seems due to I-beam effect in spite of relatively low thickness of sheet.

4. Conclusions

We examined the press dewatering of multi-ply sheet that has the different fines content in each layer and the effect of fines distribution on physical properties of sheet to find a technology for optimum utilization of raw materials. In case of two layered sheet, the sheet which was composed of layers with the different flow resistance showed higher dewatering rate than one which has the same flow resistance. And the more difference in fines content for layers existed, the more dewatering occurred. For three layered sheets, dewatering is dependent on fines content of bottom layer. Strength properties were affected by dewatering degree and multi-ply sheet structure. Density and tensile index is better as the final sheet dryness is higher, but strain and bending stiffness is negatively influenced by the final dryness.

Acknowledgement

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