Effects of Stock Characteristics on Paper Bulk

Jin-Ho Lee*, Jong-Moon Park†

*Doctoral candidate, †Professor
School of Forest Resources, Chungbuk National University, Cheongju 361-763, Korea
jmpark@cbu.ac.kr

ABSTRACT

Paper has fibers and fines network structure and it is strongly affected by interface bonding between fibers. Depending on the inter-fiber bonding, paper bulk is determined. Fines play an important roll in Campbell and consolidation effect through wet pressing and drying operations. Refined Sw-BKP, Hw-BKP and BCTMP fines were used to investigate the fines effect. Wet-web strength, breaking length, scattering coefficient, and hydrodynamic specific volume were measured.

According to the result of experiments, chemical and morphological compositions of fines do not strongly affect to wet-web forming, but strongly affect to drying operations which form hydrogen bonding among fiber-fines-fiber matrixes. Paper bulk should be controlled by the extent of hydrogen bonding between fibers during drying operations.

INTRODUCTION

The most popular definition of fines is that a portion of the cellulosic materials that passes through a 200-mesh sieve in a Bauer-McNett classifier. As Kaat[1] pointed out, a universally accepted method of defining and characterizing the fines fraction does not exist at present.

The fines are essential for the formation of bonds between fibers and for the improvement of strength properties of papers.

Since the fines are components of the pulp, there are always two factors to be considered: the quality and quantity of the fines. Although the amount of fines is an important variable in controlling pulp and paper properties, the quality of fines has also attracted considerable attention. In fact, the quality of fines might be a potential variable to give a more accurate picture of the papermaking potential of the pulp.

The object of this study is to investigate the effect of different types of pulp fines on the properties of paper and to access the potential of fines for controlling the bulk of paper.

Material and method

Fines samples

Fines were collected with a laboratory classifier using a 200 mesh screen from Sw-BKP, Hw-BKP and BCTMP pulps refined 350 ml CSF.

Methods

Strength of wet-webs

Handsheets having 60 g/m^2 were prepared by mixing 85% of Sw-BKP long fibers and 15% of Sw-BKP, Hw-BKP or BCTMP pulp fines. Ten strips, 14 cm x 2.5 cm each, wet-webs were obtained from each sheet by placing a template on the wire before forming the sheet[2]. Wet-web solid concentrations were varied from 18 to 50% by the laboratory roll-press. Tensile tests were performed using Haunsfield tensile test machine with 5 cm / min elongation rate.

Dry strength of handsheets

60 g/m^2 handsheets were prepared by mixing Sw-BKP long fibers and 5, 10, 15 % of Sw-BKP, Hw-BKP and BCTMP pulp fines. Tensile test were performed by using L&W tensile tester. Scattering coefficient and bonding strength were also measured.

SEM image

Sw-BKP, Hw-BKP and BCTMP pulp fines were freeze-dried and SEM images were obtained.

Hydrodynamic specific volume and settling rate

Hydrodynamic specific volume and settling rate of the fines were measured by using a modified method described by Marton et al[3] and Luukko[4]. Fines (1.0g/l) were settled in a 0.5 mg/l $MgSO_4$ aqueous solution for 24, 72, 96, 216 hours in a meter glass at constant conditions at 20℃. Settling rate is the initial slope of settled distance and time curve.

Results and discussion

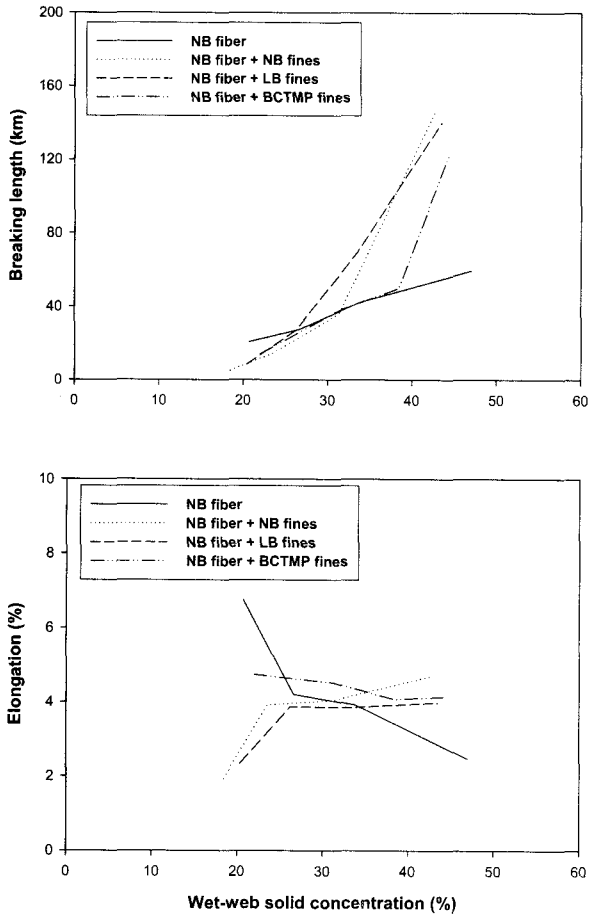

Fig. 1. Effect of fines on wet web strength of handsheets.

Fig. 1. shows the effect of fines on wet web strength of handsheets. Three kinds of fines shows similar increasing trend of strength as the wet web solid concentration increased. Several investigators have proposed that the key role of fines is one of the factors contributing to the Campbell or consolidation effect as the web proceeds through the wet pressing and drying operations. In this operation, the network strength is enhanced through surface tension force by the cooperative effect of fines fraction with its high specific surface area.

Although chemical pulp and mechanical pulp have different chemical compositions, generated fines have similar effect during network forming.

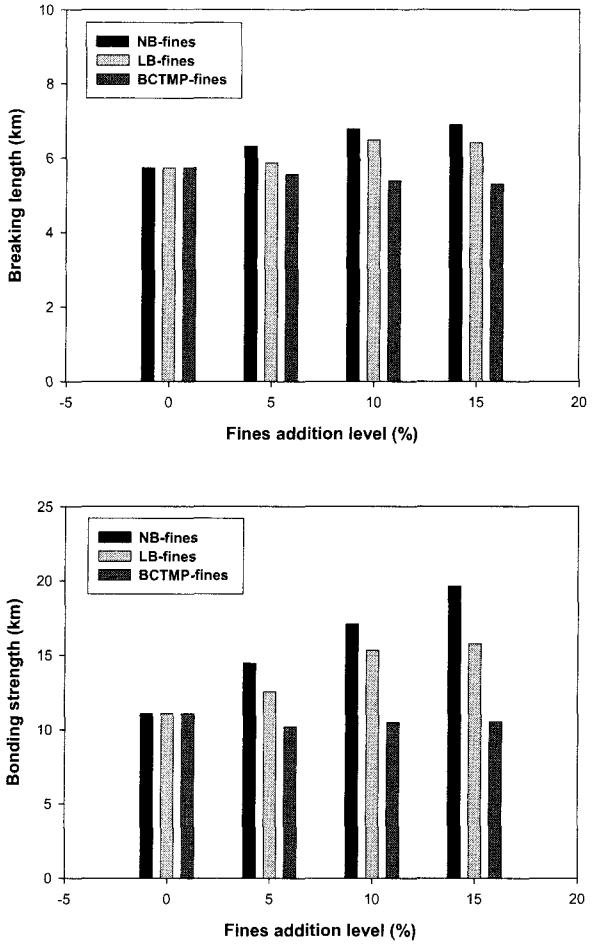

Fig. 2. Effect of fines on dry strength of handsheets

Fig. 2. shows different effect of fines on dry strength of handsheets. Sw-BKP and Hw-BKP fines increased but BCTMP fines decreased the breaking length of handsheets. Because chemical and mechanical pulps have different chemical compositions, chemical pulps have poor lignin contents but mechanical pulps have rich lignin contents. Sw-BKP and Hw-BKP fines are composed of lignin poor fibrils, on the contrary, BCTMP fines are composed of lignin rich fibrils. Lignin is hydrophobic materials which prevent formation of hydrogen bonding between fibers. Though BCTMP fines have higher surface tension force, BCTMP fines do not promote hydrogen bonding between fibers.

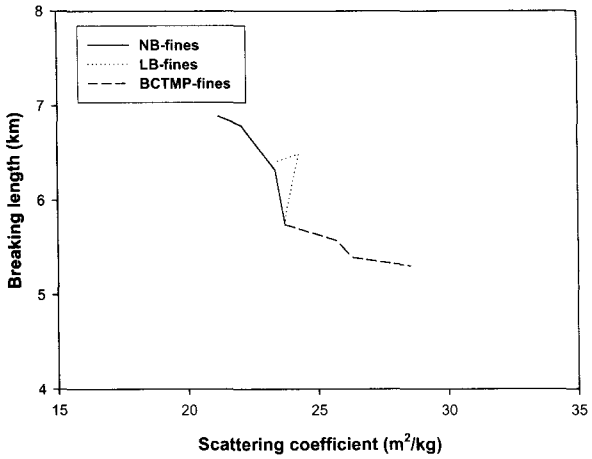

Fig. 3. Effect of fines on breaking length and light scattering coefficient of a fiber/fines mixed handsheets.

Fines content increases from 0% to 15%. In order to exam the effect of fines quality and quantity on the fiber network, fiber/fines mixed sheets with an increasing amount of fines (0→15%) were prepared. Functional difference among fines in the fiber network was observed. Generally, the scattering coefficient decreased as the inter-fiber bonding increased.

Sw-BKP fines increased breaking length with decreased scattering coefficient, Hw-BKP fines also increased breaking length with no change of scattering coefficient as the fines contents increased. BCTMP fines decreased breaking length with increasing scattering coefficient as the fines contents increased.

Through the relationship between breaking length and scattering coefficient of BCTMP fines, we can verify that BCTMP fines do not enhance inter-fiber bonding. Although Sw-BKP and Hw-BKP fines were generated from chemical pulps, their morphological compositions were different. Because hardwood has more vessel and ray cells than softwood, Hw-BKP fines contained fibrillar and non-fibrillar fines that caused variation of scattering coefficient in Hw-BKP fines mixed sheet.

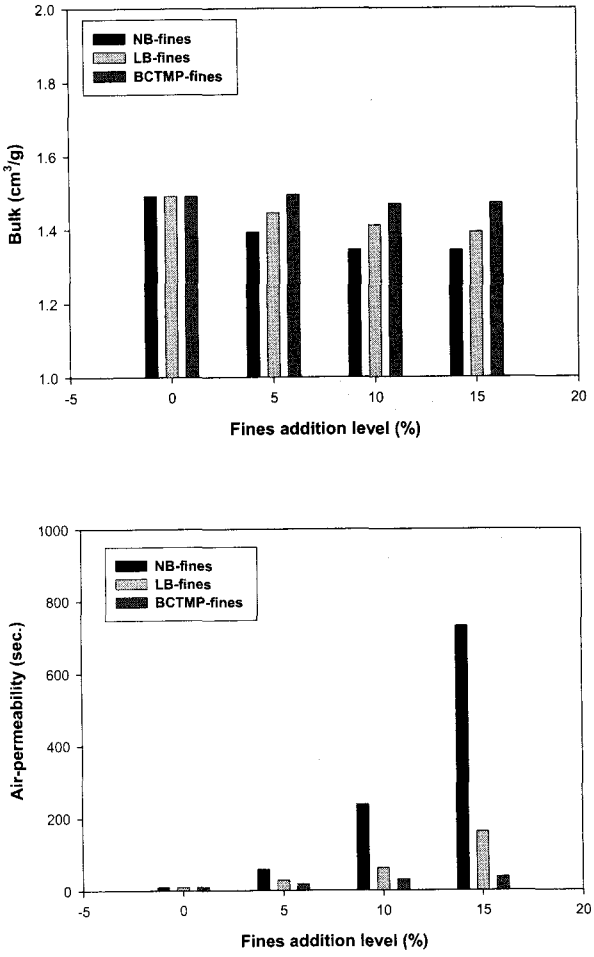

Fig. 4. Effect of fines on structural properties of fiber/ fines mixed handsheets.

Density and thickness are basic macroscopic characteristics of paper structure. Bulk is an inverse value of density, but there is no qualitative difference between the two. Bulk is one of the most important characteristics related to absorption and optical properties in printing paper grade. Fig. 4 showed the effect of fines on the bulk of fiber/fines mixed sheets. In general, paper bulk decreases as fines contents increase. Sw-BKP and Hw-BKP fines decreased bulk and BCTMP fines did not affect bulk as fines contents increased. Because chemical pulp fines are mostly composed of lignin-free fibrillar structure that enhance inter-fiber bonding, paper bulk was decreased as an increase of chemical pulp fines. On the other hand, mechanical pulp fines are also composed of fibrillar structure, but those fines contain high level of lignin that prevent inter-fiber bonding, paper bulk did not change as an increase of chemical pulp fines.

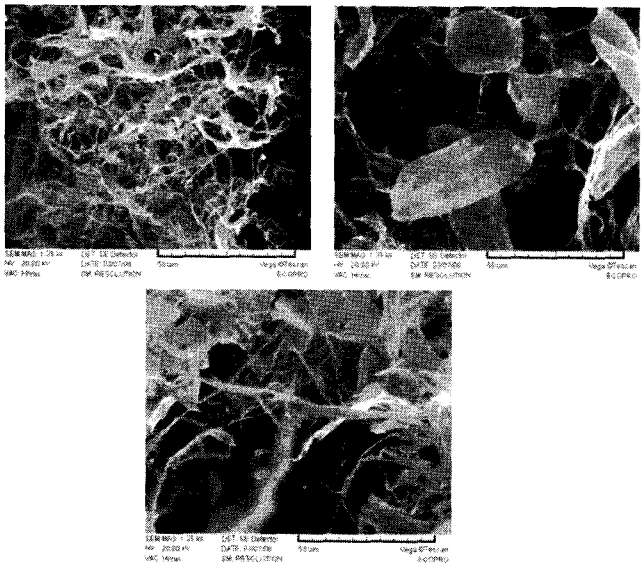

Fig. 5. SEM images of three different fines.
(Top left: Sw-BKP fines, top right : Hw- BKP fines and bottom: BCTMP fines)

Fig. 5 shows three different fines at same magnification. Morphologically, Sw-BKP and BCMP fines showed similar fibrillar appearance, but BCTMP fines was observed flake like fibrils. Hw-BKP fines show the different appearance by the fragments of ray and vessel. The fragments of ray and vessel cause the increase of scattering coefficient and they reduce the positive strength effect of chemical fines.

Settling method was adapted to identity the fines characteristics. Settling phenomena are strongly influenced by the flexibility of the particles since flexibility is determined by the ratio of their three dimensions. Thin and flexible particles resist settling more efficiently than thick and stiff particles. Lignin-free fibrillar Sw-BKP fines showed highest hydrodynamic specific volume(HSV) and lowest settling rate. Lignin-rich fibril and flake like BCMTP fines shows the lowest hydrodynamic specific volume and highest settling rate. Lignin-free fibril and flake like Hw-BKP fines show similar trend as BCTMP fines. The comparisons between bonding strength and HSV are considered, high HSV value fines has a higher bonding potential, but low HSV value fines has a lower bonding potential.

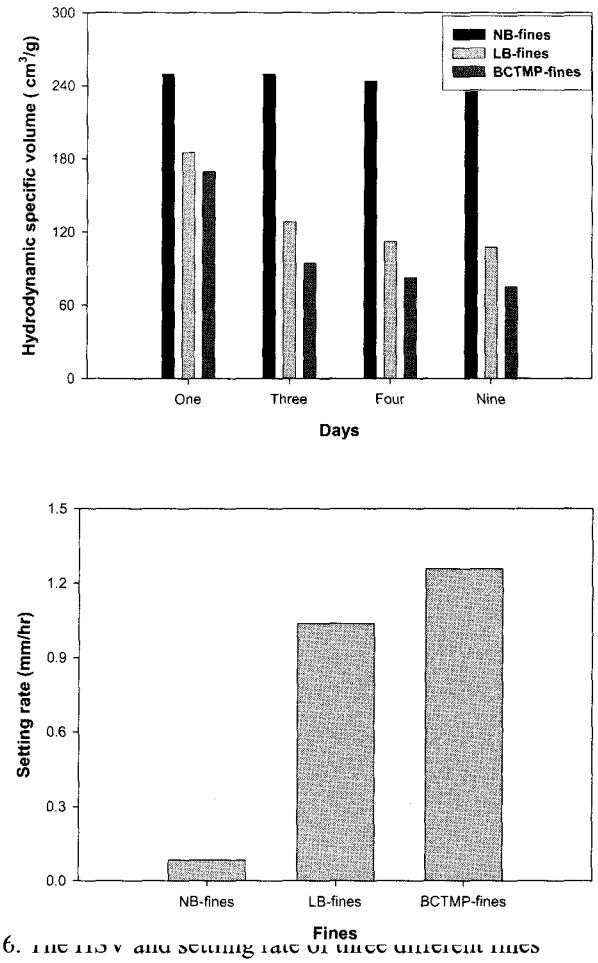

Fig. 6. The HSV and setting rate of three different fines

Conclusions

Paper has the fibers and fines network matrix structure and that was strongly affected by interface bonding between fibers. Paper structure is determined by the extent of inter-fiber bonding. Fines play an important roll in Campbell and consolidation effect through wet pressing and drying operations by their small dimensions. Chemical and morphological compositions of fines do not strongly affect to wet-web forming but strongly affect to drying operations which form hydrogen bonding among fiber-fines-fiber matrixes. Paper bulk should be controlled by the extent of hydrogen bonding between fibers during drying operations.

REFERENCE

1) Kaat, M., A-200 Problem, The Institute of Paper Chemistry (1984).
2) Seth, R. S., Barbe, M. C., Willams, J. C. R. and Page, D. H., The strength of wet-webs : A new Approach, TAPPI 65(3): 135-138(1982).
3) Marton, R. and Robie, J. D., Characterization of mechanical Pulps by a setting technique, TAPPI 52(12): 2400-2406(1969).
4) Luuko, K., Fines quantity and quality in controlling pulp and paper quality, 1999 International Mechanical Pulping Conference, 67-75 (1999).