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Examination of Separate and Mixed Refining Methods on Softwood and Hardwood Pulps for Linerboard Production

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ABTRACT

The research focused on the study of process modification of chemical pulp refining for a mixed treatment and separate methods for softwood and hardwood pulps in the production of linerboard. The study had the objectives to examine the effect of treatments on pulp quality, to find out the optimum levels of pulp development and to examine their refining efficiency. This study was carried out using a laboratory Valley beater and the pulp materials were obtained from linerboard manufacturers. The results showed that the separate and mixed refining methods produced different qualities of the final blended pulp. In separate refining, the softwood pulp needed to be refined to a freeness of 500 mL and the hardwood pulp was required to be refined to a freeness of 320 mL, to obtain a superior strength of laboratory sheets. The wrong treatment of softwood and hardwood pulps produced severe degradation of the sheet quality. The treatment efficiency using the laboratory device was not clearly differentiated between the methods. The results from the study could be applied to industrial refining as criteria to control the refining levels of pulp materials in separate refining, while the energy efficiency could be further studied using a pilot refiner.

Keywords: softwood pulp, hardwood pulp, mixed refining, separate refining, linerboard

INTRODUCTION

Refining in paper and paperboard manufacture typically refers to the mechanical treatment of wet pulp including hardwood and a softwood pulp within a low consistency range of about 3-5%. The refining changes the internal and the external structures of the fiber cell walls to a desired level and by so doing improves the quality of the final products. Basically, the pulp refining process could be performed using either mixed refining or using a separate process for hardwood and softwood pulps (Campo *et al*., 1999; Lumianen, 2000). The mixed refining refers to the process where the pulp materials are mixed in the slushing process and refined to the desired quality. Separate refining involves the pulps being separately refined to their required quality and subsequently blended to required proportions and a drainability level (Lumianen, 1996).

Industrially, there has been no clear information on the advantages of the mixed and separate refining processes because the refined pulp quality and the energy use are dependent on the pulp materials, the mixing pulp ratio, refiner types and plate designs, and the refining conditions (Kibblewhite, 1994; Demler *et al.*, 2012; Nugroho, 2012; Chauhan *et al.*, 2013). It has been reported that the mixed and separate refining methods could obtain a reduction of energy consumption

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at a certain pulp quality (Baker, 2001; Hou *et al.*, 2011). Pulp materials have very different morphologies and require refining in different directions, and have been proposed to be refined using separate methods to obtain homogenous development (Lumiainen, 1996; Baker 2001). In some cases, mixed refining was found to likely impart more energy into the softwood pulp than the hardwood pulp, which maintains fiber length and obtains a high tensile strength (Lumianen, 1996). However, in the current study, the mixed refining method of the linerboard manufacturer involved fluctuations in the incoming pulp quality. This affected refining control, the refined pulp quality, the operation of the paper machine and the final linerboard products. In order to obtain stable refining and to maintain the desired pulp quality, the manufacturer needed to rebuild the refining line from a mixed process into the separate method.

Therefore, this research set up laboratory refining using the separate method with softwood and hardwood pulps for the production of linerboard, with the objectives to examine the effect of treatments on pulp quality, to find out the optimum levels of pulp development used to produce the linerboard and to examine the refining efficiency between the separate and mixed methods using a laboratory device. The results could be applied for industrial use as criteria for refining control.

MATERIALS AND METHODS

Raw materials

Unbleached softwood kraft pulp with a freeness of 740 mL and bleached kraft hardwood pulp with a freeness of 500 mL were obtained from Thaicane Paper Company Limited, Thailand and used in this experiment.

Pulp treatments

The pulp refining was carried out using a Valley beater performed under a pulp consistency of 1.57% and a beating time of 10 to 90 min according to the ISO 5264-1 standard method (International Organization for Standardization, 2011) as shown in Figure 1. In the separate refining, the softwood and hardwood pulps were separately treated to target freeness levels of 500, 450, 350 and 300 mL. The treated softwood and hardwood pulps were blended together with the weight ratio being 45:55, on which the mixing of various levels of pulp drainability were based using a factorial design with a single replication

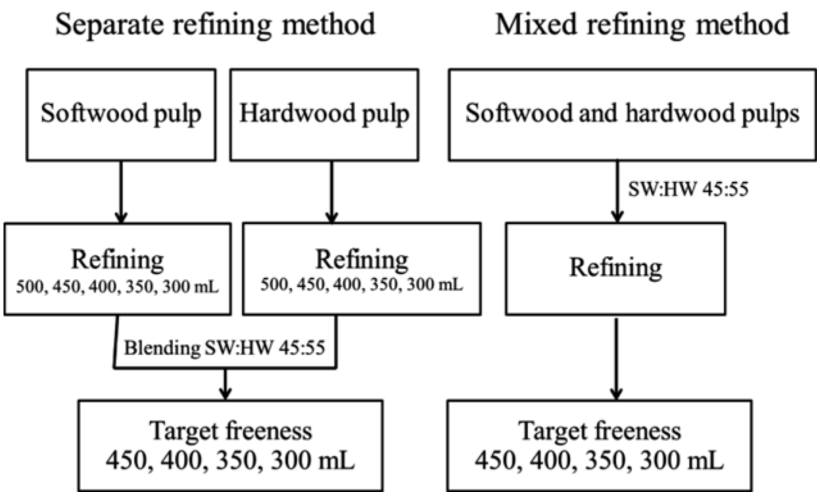

Figure 1 Pulp treatment with separate and mixed refining methods. (SW = Softwood; HW = Hardwood.)

(Montgomery, 2009). In the mixed refining method study, the softwood and hardwood pulps were blended in the same proportions as in the separate method, and subsequently treated with the Valley beater to the target freeness levels of 450, 400, 350 and 300 mL.

Pulp and paper properties measurement

Determination of pulp drainability was measured using the Canadian standard freeness apparatus according to the ISO 5267-2 standard method (International Organization for Standardization, 2011). The water retention values of treated pulp were measured according to the SCAN C-62 standard method (Scandinavian Pulp, Paper and Board Testing Committee, 2003) where the pulps were fractionated using a dynamic drainage jar with a screen number of 100 and 150 mesh. Fiber length was measured using a Kajaani FS300 (Metso Automation Co. Ltd. Hakkila of Vantaa, Finland) according to ISO 16065-1 (International Organization for Standardization, 2011). Fiber length distribution was classified using the Bauer-McNett classifier according to the TAPPI T-233 standard method (Technical Association of the Pulp and Paper Industry, 2001). The laboratory sheets consisting of the softwood and hardwood pulps with a weight ratio of 45:55 were prepared at a basis weight of 60 g.m^{-2} according to the ISO 5269-1 standard method (ISO, 2011). The tested sheets were conditioned and tested at 23 ± 1°C and room humidity of 50 ± 2% according to the ISO 187 standard method (ISO, 2011). The tensile strength of the laboratory sheets was measured following the ISO 1924-2 standard method (International Organization for Standardization, 2011). The tear resistance was measured according to the ISO 1974 standard method (International Organization for Standardization, 2011). The light scattering of the tested sheets was determined according to the ISO 9416 standard method (International Organization for Standardization, 2011).

RESULTS AND DISCUSSION

Fiber fractionation analysis

The results of the examination of the fiber length distribution of the softwood, hardwood and mixed pulps are shown in Figure 2. The fractionation of tested pulp based on the Bauer-McNett classifier consisted of the long fiber fractionation retained on a screen of 50 mesh, the middle fractionation retained on a screen of 100 mesh, the short fiber fraction retained on a screen of 200 mesh and the fines fraction passed through a screen of 200 mesh, which corresponded to a fiber length longer than 1.33 mm, 1.33-0.75 mm, 0.74-0.32 mm, and less than 0.16 mm, respectively (Heinemann and Vehniäinen, 2009).

It was found that the softwood pulp with an average fiber length of 2.16 mm and a freeness of 740 mL consisted of a long fraction of 94.0%, a middle fraction of 3.8%, a short fraction of 0.9% and a fines content of 1.3%. The hardwood pulp with an average fiber length of 0.70 mm and a freeness of 500 mL consisted of a long fraction of 51.0%, a middle fraction of 29.0%, a short fraction of 5.6% and fines content of 14.4%. When the softwood and the hardwood pulps were blended

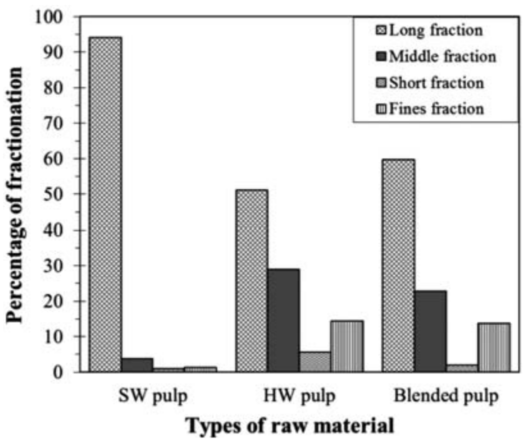

Figure 2 Fiber fractionation of the softwood pulp (SW), the hardwood pulp (HW) and blended pulp analyzed using the Bauer McNett classifier.

in the ratio 45:55, the average fiber length was 0.87 mm, the freeness of the mixed pulp was 575 mL, the long fiber fraction was 59.6%, the middle fraction was 22.7%, the short fraction was 2.0 % and the fines content was 13.7%.

Drainability analysis

Table 1 shows the drainability based on the Canadian standard freeness (CSF) measurement of the mixed pulp produced from the softwood and the hardwood pulps, which were separately treated using the Valley beater. It was found that the blending of treated pulps at the same level of freeness gave a mixed pulp with a lower freeness than the initial pulps. This indicated that the fiber distribution of the mixed pulp had a strong impact on the water passing through the fiber mat formed on the device wire during the drainability measurement. In addition, it was found that the hardwood pulp which contained short fibers had a more important role in the reduction of the drainability of the blended pulp.

Figure 3 shows the calculated beating time of blended pulps at a given proportion indicating the levels of the electrical energy used in beating process. In linerboard production, the required freeness of the mixed pulp was about 350 mL. It was found that at the target freeness of 350 mL, the softwood pulp with freeness levels of of 450 and 500 mL blended with the hardwood pulp under the various levels of treatments with a shorter treatment time. This implied that less energy was consumed and the hardwood pulp could be treated to a freeness of 320 mL to achieve the target freeness of the final blended pulp (Figure 3 and Table 1). Comparing the separate

Table 1 Freeness of blended pulp for softwood pulp and hardwood pulp with a given blending ratio with the pulps separately treated under various levels of drainability.

Hardwood pulp freeness (mL)	Softwood pulp freeness (mL)			
	500	450	400	350
500	440	420	418	391
450	436	400	398	382
400	410	384	371	348
350	369	354	337	320
300	337	310	302	286

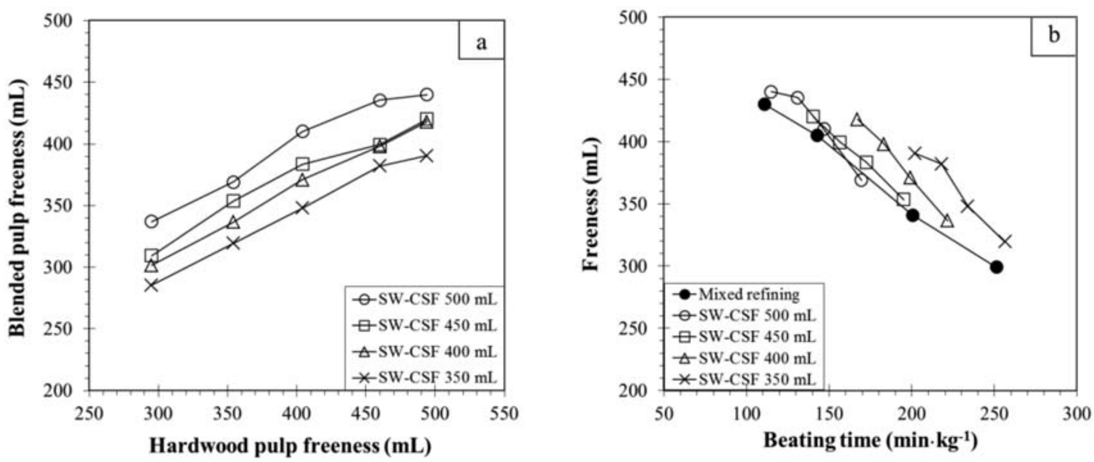

Figure 3 Drainability of blended pulps as a function of hardwood pulp freeness (a) and calculated beating time (b).

and mixed treatments, it was found that there was no difference in the beating times between the treatments where the softwood pulp was treated at freeness levels of about 450–500 mL. However, the higher beating of softwood pulp at freeness levels of 400 and 350 mL required a longer beating time than for the mixed refining method indicating a lower energy efficiency.

Industrially, the refining of softwood pulp from a freeness level of 700 to 500 mL consumed electrical energy of about 150-180 $kWh.t^{-1}$ while the refining of the hardwood pulp from freeness 500 to 320 mL consumed 80-120 $kWh.t^{-1}$ (Lumianen, 2000). According to the current results, the total refining energy consumption of the blended pulp at freeness of 350 mL was approximately 120–150 $kWh.t^{-1}$ which is within the normal operational range of industrial work.

Pulp and paper properties

Figure 4 shows the water retention values indicating the changes in the fiber cell wall structure and shows that at a given drainage value, a lower refined softwood pulp of 500 mL blended with hardwood pulp of various freeness levels had a higher water retention value than the blended pulps with a higher treated softwood pulp. The higher water retention value possibly resulted from the hardwood pulp. This indicates that at a given freeness, the pulps made from blended softwood and hardwood pulps under various treatments gave different levels of water remaining in the fiber cell walls, and consequently affected the operation of wet pressing (Laivins and Scallan, 1994) and web drying, and the physical and mechanical properties of the final paper products (Wang, 2006).

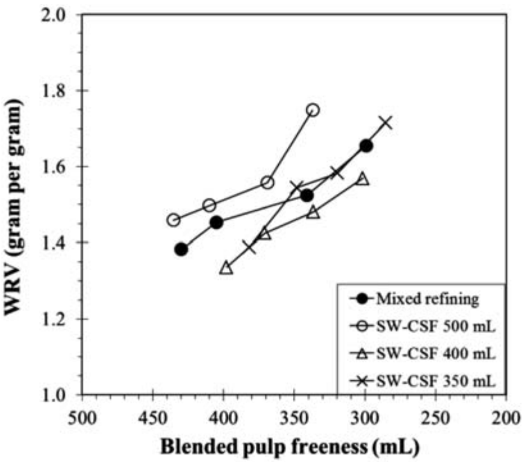

Figure 4 Water retention value (WRV) of blended pulps under mixed and separate refining methods as a function of pulp drainability.

Comparing the separate and mixed refining methods, it was found that at the high treatment level of softwood pulp with a freeness level of 400 and 350 mL, there were no obvious differences in the changes in the fiber cell walls (Figure 4). This might have been because the laboratory beater obtained a homogenous treatment under both conditions. However, this information could not be directly used to indicate industrial refining results because the industrial operations consist of many controlled variables such as the refining energy, refining intensity, gap distance and pulp consistency. In addition, the pulp is retained on the refiner plates for a few seconds which produces a nonhomogeneous treatment (Somboon, 2011). According to the results, the mixed and separate refining methods would possibly produce treated pulp with differences in the fiber cell wall structure.

Figure 5 show the properties of the laboratory sheets made from the treated pulps based on the mixed and separate refining methods. It was found that at a given freeness, the sheets produced from the mixed refining method had a lower density indicating less change in the structure of the fiber cell walls and thus lower collapse during drying. This could imply that the pulp obtained from the mixed refining method produced a lower homogenous treatment on the softwood and the hardwood pulps than did separate refining.

Examination of the mechanical properties of the laboratory sheets was carried out based on their tensile strength and tear resistances as shown in Figures 6 and 7. The study found that the mixed refining method produced treated pulp with a superior tensile strength, while the tensile strength in sheets from the separate refining depended on the levels of softwood and hardwood pulp contained in the blended pulp. With separate refining, it was found that the blended pulp with a softwood pulp freeness of 500 mL resulted in superior tensile strength, while the high treatment levels of softwood with pulp freeness of 400 and 350 mL produced a lower tensile strength. At the softwood pulp of freeness 500 mL, the increased tensile strength due to the blending of high treatment hardwood pulp rapidly reduced the tear resistance of the tested sheets as shown in Figure 7. Figure 8 shows clearly that the softwood pulp having a freeness of 500 mL required a lower beating time and obtained test sheets with high strength. This could indicate that treatment under these conditions consumed less energy while producing high levels of mechanical properties in the tested sheets.

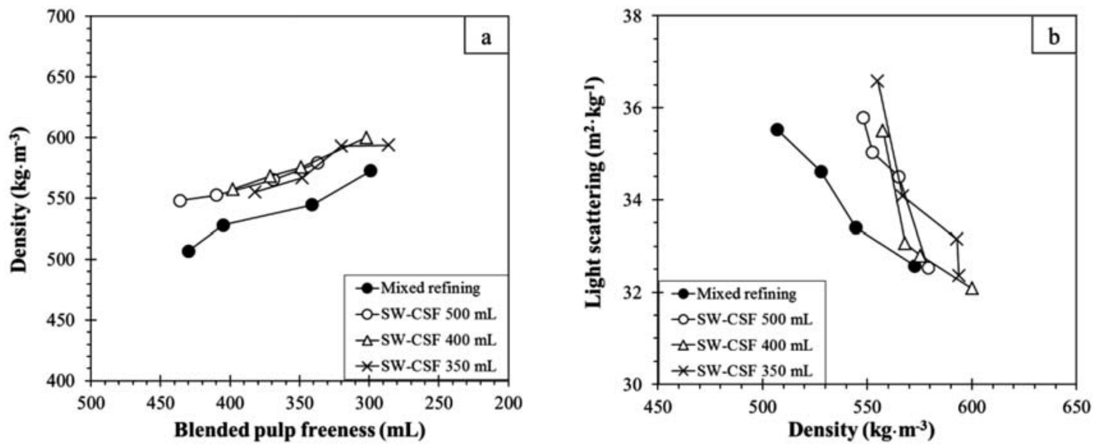

Figure 5 Density (a) and light scattering coefficient (b) of the sheets produced from the pulps under mixed and separate refining methods.

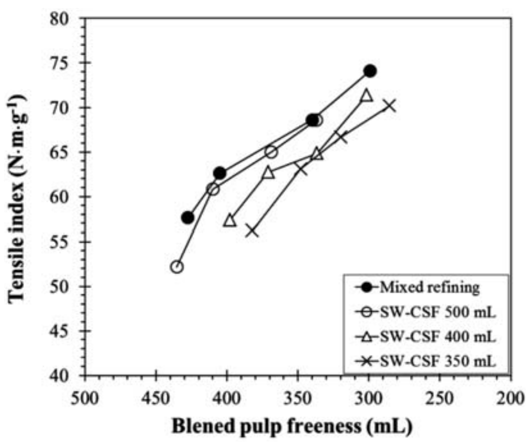

Figure 6 Tensile strength of sheets produced from pulps under mixed and separate refining methods as a function of drainability.

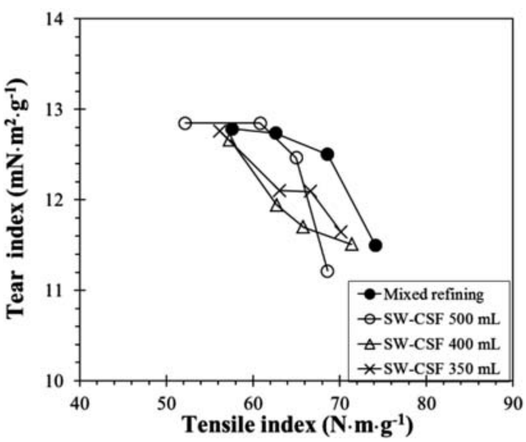

Figure 7 Tear resistance of the sheets produced from the pulps under the mixed and separate refining methods as a function of tensile strength.

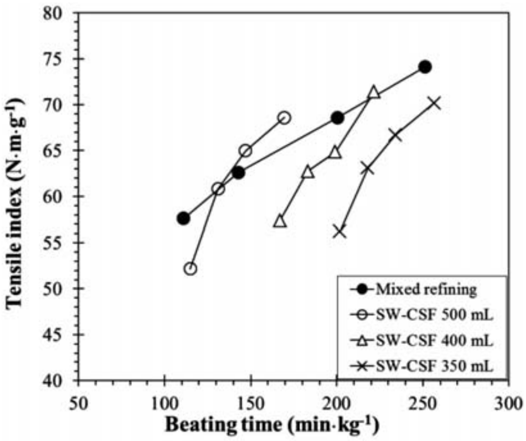

Figure 8 Tensile strength of sheets produced from pulps under mixed and separate refining methods as a function of beating time.

CONCLUSION

The study involved pulp refining using separate and mixed refining methods with unbleached kraft softwood and bleached kraft hardwood pulps to produce final blended pulps with a given blending ratio at a target freeness of 350 mL. It was found that these methods produced different qualities of final blended pulps resulting from the different directions of softwood and hardwood pulp development. In separate refining, the softwood pulp needed to be refined to a freeness of 500 mL and the hardwood pulp required refining to a freeness of 320 mL and obtained superior strength in the laboratory sheets. The wrong treatment of softwood and hardwood pulps produced severe degradation in the sheet quality. The efficiency of treatments using the laboratory device was not clear; however in separate refining, the results showed clearly that a very high level of softwood refining gave a lower energy efficiency. The results from the study could be applied to industrial refining as criteria to control the refining levels of pulp materials in separate refining, while the energy efficiency could be further studied using a pilot refiner.

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