Development of laboratory wet creping method to evaluate and control pulp quality for tissue

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ABSTRACT: The required properties of tissue paper including softness and liquid absorption are predominantly manipulated by the creping process, which cannot be simply produced in the laboratory. This causes problems in controlling the stock quality prepared using the various types of industrial pulps and consequently affects the creping operation and tissue quality. Our objectives were to develop a laboratory creping method and to apply it for the evaluation and control of the quality of pulp raw materials used in industrial tissue production. The experiment consisted of the development of a laboratory wet creping method and the study of the creping devices and the creping conditions, including basis weight of the base paper, sheet dryness, and degrees of pulp refining. The results showed that the method could produce crepes on laboratory sheets and the structures of the creped sheets could be engineered to improve their softness and liquid absorption. The tested pulps were found to produce significantly different responses to the laboratory wet creping, depending on their morphology and the mechanical treatments. The examination of industrial pulps found that eucalypt, bagasse, bamboo, and deinking pulps needed to be manipulated using different refining levels and required optimization among their softness, liquid absorption, and strength properties.

Application: A laboratory wet creping method could be used to evaluate the quality of pulp materials for tissue manufacture.

Creping is one of the most important processes in tissue manufacture. Mechanical force is applied on the tissue web by using the doctor blade to create small creasing lines on the tissue paper and to break down the bonding of the fiber networks [1,2].This produces internal structure changes in the tissue paper, enhancing its softness and liquid absorption but reducing its strength [3-5]. Industrially, creping can be performed under wet and dry conditions. In the dry creping process, the blade is applied on the dried web adhered on the surface of the dryer. In the wet creping process, a wet web (dryness of about 55%-80%) is then completely dried in the subsequent dryer [1,6,7]. In the creping process, the development of tissue properties, including softness and liquid absorption are fundamentally influenced by the creping conditions and the base sheet properties.

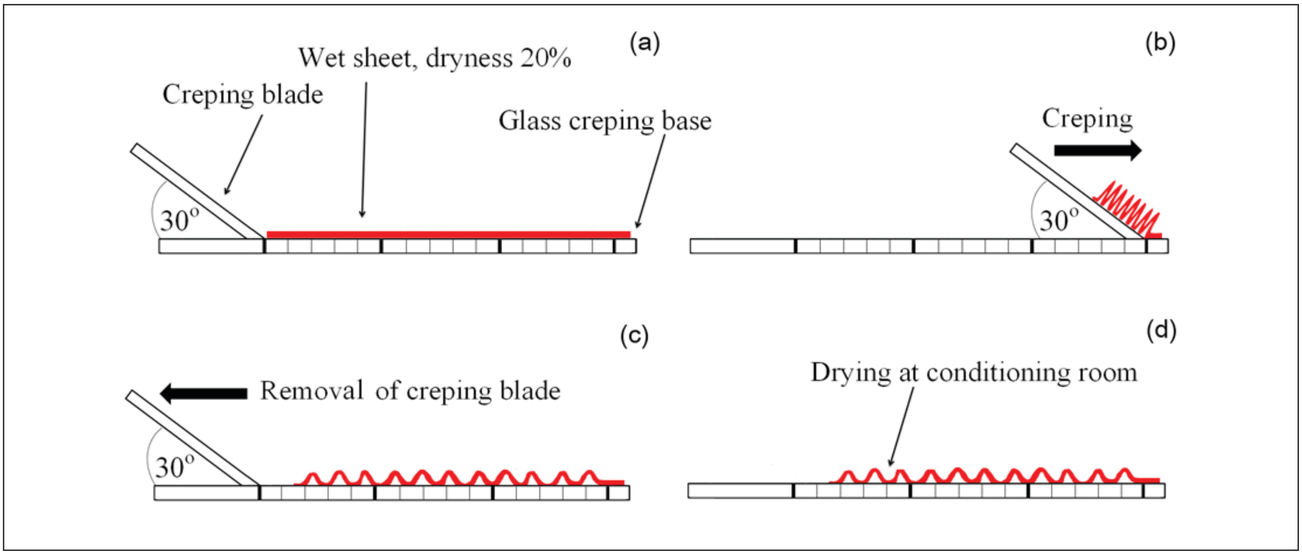
In creping conditions, it has been reported that the creping devices, the blade angle, the creping ratio, and the adhesive degrees of the base paper and the dryer surface have a strong effect on the creping results [8-10], while the base sheets properties including basis weight, degrees of pulp refining, and raw material uses are strongly related to the creped sheet properties [11,12]. Industrially, the tissue products are made using various types of raw materials, which cause difficulty in the control of stock quality, and consequently affect the creping operations and the required tissue qualities.

The major obstruction to the control of pulp quality is that the creped tissue paper is not easily produced in the laboratory and there is no standard method available for laboratory creping. Thus, laboratory testing sheets and creped tissues have totally different structures and physical and mechanical properties. Therefore, the objectives of this study were to develop a laboratory creping method; apply it for the evaluation of the quality of pulp raw materials including recycled pulp, wood pulp, and nonwood pulp; and apply the method for the control of stock quality in the production of the base sheets. The developed laboratory creping technique was focused on the wet creping process, for which the equipment and creping conditions were studied.

EXPERIMENTAL

Raw materials

The industrial pulps used in this study were bleached kraft hardwood pulps produced from eucalypt and bleached nonwood pulps produced from bamboo, bagasse, and deinking pulp obtained from a tissue paper manufacturer in Thailand. The tested pulps were manipulated to various degrees of drainability using a Valley beater according to ISO 5264-1 "Pulps—laboratory beating—part 1: Valley beater method."

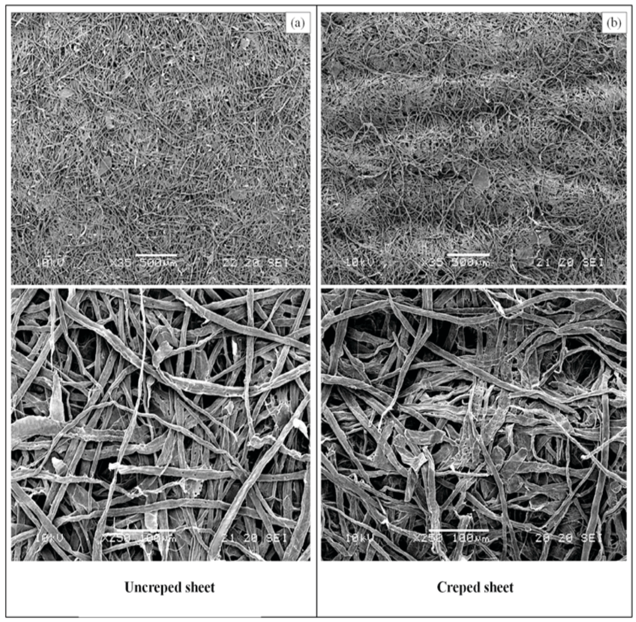


1. Schematic description of the laboratory wet creping method.

Development of laboratory creping method

The laboratory creping method was developed based on wet creping conditions. The creping equipment consisted of the glass creping base with a length scale and a steel creping blade with a thickness of 160 μm equipped on the holder with an adjustable angle. The base sheets were made without chemical use according to ISO 5269-1 "Pulps—preparation of laboratory sheets for physical testing—part 1: conventional sheet-former method" using a square former of 17 cm width, and the sheet basis weight was controlled at 30 g/m². The sheet dryness was controlled at about 20% to obtain the desired adhesion force between the wet sheet and the glass creping base.

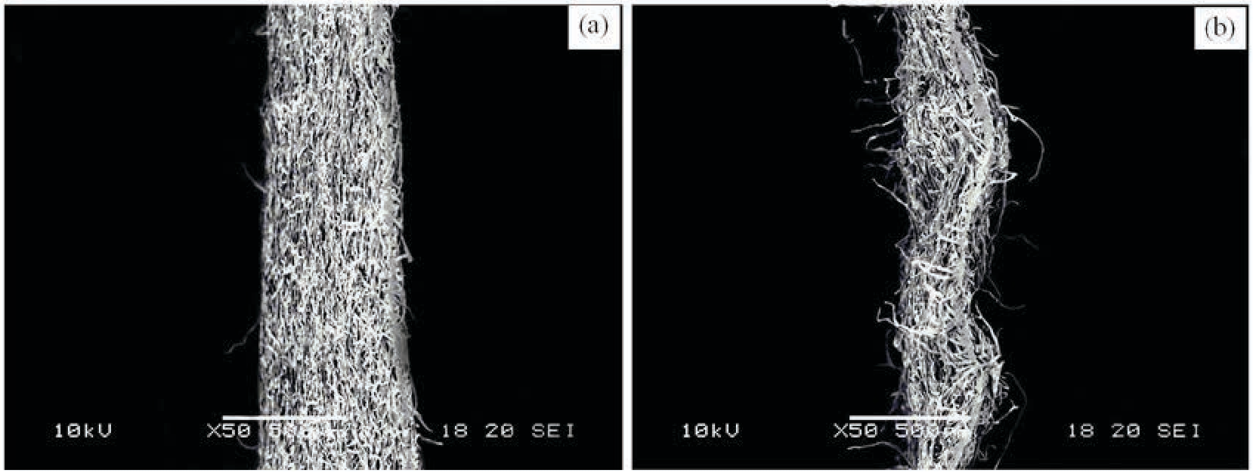
In the creping process, the prepared wet sheet including the couch blotter was placed on the glass creping base with the top side of the wet sheet fixed onto the couch blotter and the wire side of the wet sheet attached on the creping base. When the wet sheet was completely attached on the creping base, the blotter was removed, leaving the wet sheet attached on the creping base. The wet sheets were creped by the blade at an angle of about 30° to produce folded samples and subsequently stretched backwards close to the beginning position according to the length scale as shown in **Fig. 1**. The creped sheets were dried at a temperature of 23±1°C temperature and room humidity of 50±2% according to ISO 187 "Paper, board and pulps—standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples." Finally, the dried creped sheets were scraped by the blade on the top and wire sides to produce the flat sheets without the changes of the creped structure before testing.



2. Scanning electron microscope (SEM) images of (a) uncreped and (b) creped sheets made from eucalypt pulp.

Sample testing

The physical properties including basis weight, thickness, and density were tested according to ISO 534 "Paper and board—determination of thickness, density and specific volume." The tensile strength was tested according to ISO 1924-2 "Paper and board—determination of tensile properties—part 2: constant rate of elongation method (20 mm/min)" with a sample length of 50 mm and a testing speed of 50 mm/min. The water absorbency rate was tested according to ISO 8787 "Paper and board—determination of capillary rise—Klemm method," and the water holding capacity was tested according to ISO 5637 "Paper and board—determination of water absorption after immersion in water." The softness was tested by using a Clark softness-stiffness tester (Thwing-Albert Instrument; West Berlin, NJ, USA) according to TAPPI Standard Test Method T 451 cm-84 "Flexural properties of paper (Clark stiffness)."



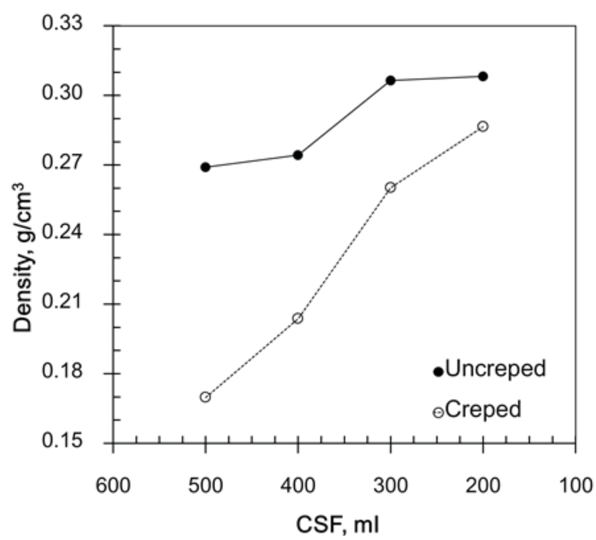
3. SEM images of (a) uncreped and (b) creped sheets in thickness direction.

RESULTS

Laboratory creped sheets

The creped sheets produced from the eucalypt pulp and then treated by the laboratory wet creping method are shown in **Fig. 2**. The laboratory creping produced buckling on the base sheets within a crepe size of 300-600 μm. Along the creasing lines, the fiber network was loosened and delaminated, which increased the pores in the creped sheets. Microscopic examination of the creped sheets in the thickness direction found that the sheets were delaminated, which had created micro cracks as shown in **Fig. 3**.

The physical and mechanical properties of the creped sheets are shown in **Figs. 4-6**. The laboratory creping produced test sheets having various densities depending on the refining level. The density was in the 0.17-0.24 g/cm^3 range with the pulp freeness reduced from 500 mL to 200 mL as shown in Fig. 4. The tensile strength of the creped samples was analyzed in two directions: across the crepe and in the crepe direction. It was found that across the creped sheets had lower tensile strength, which indicated that the laboratory creped sheets had an anisotropic structure where the across crepe direction resulted in greater loosening of the structure of the fiber network as shown in Fig. 5.



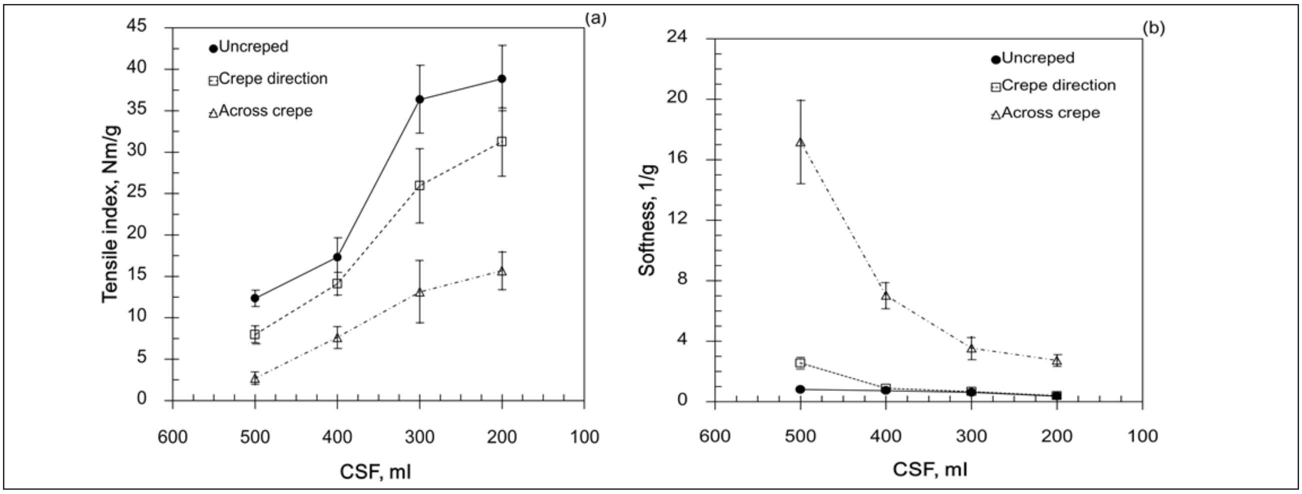
4. Density of uncreped and creped sheets as a function of pulp freeness.

The softness of the creped sheets measured using the Clark softness-stiffness tester was about 3-17 1/g and for the standard sheets it was 0.4-0.8 1/g with no distinct differences in the pulp freeness, which ranged from 200 mL to 500 mL as shown in Fig. 5. The liquid absorption speed was about 0.5-1.3 mm/s and the water holding capacity was about 137-210 g/m^2 with a higher value than for the uncreped sheets, as shown in Fig. 6.

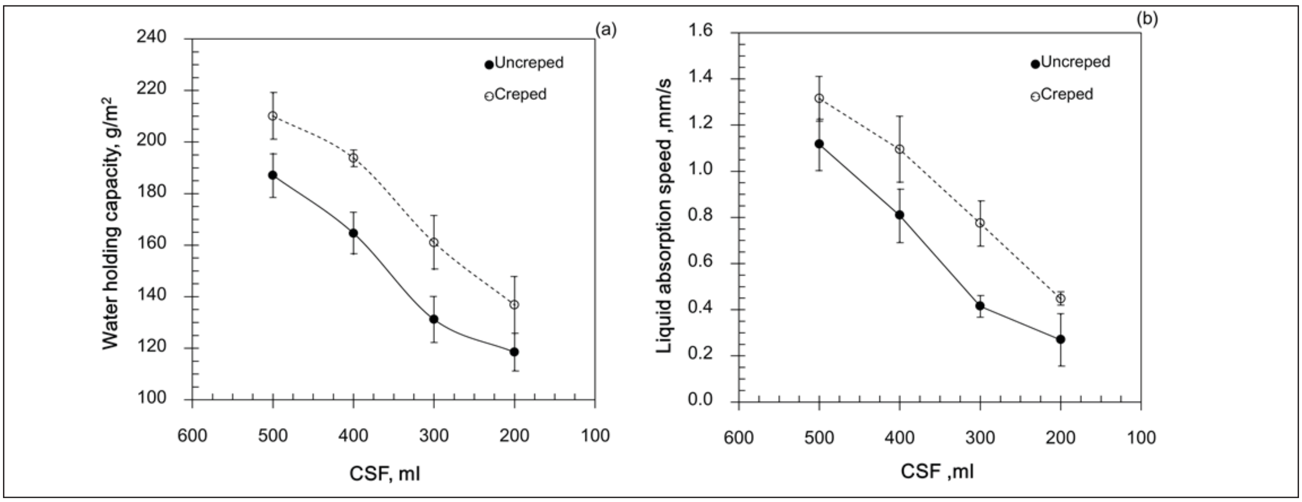
Evaluation of industrial pulp quality

The pulps used in this study were obtained from a tissue manufacturer using deinking pulp, bleached eucalypt pulp, bleached bamboo pulp, and bleached bagasse pulp. Their fiber morphologies were analyzed using a Metso FS5 (Metso; Helsinki, Finland) automated fiber analyzer. The fiber surface energy was analyzed using a fiber potential analyzer. The tested pulps had freeness of 300-500 mL, with a length-weighted average fiber length of 0.651-1.147 mm, coarseness of 0.05-0.086 mg/m, and zeta potential of -35 to -95 mV, as shown in **Table I**. The bamboo pulp was found to be different from the other materials, having longer fiber length and lower zeta potential, while the other pulps showed no large differences in fiber lengths and coarseness.

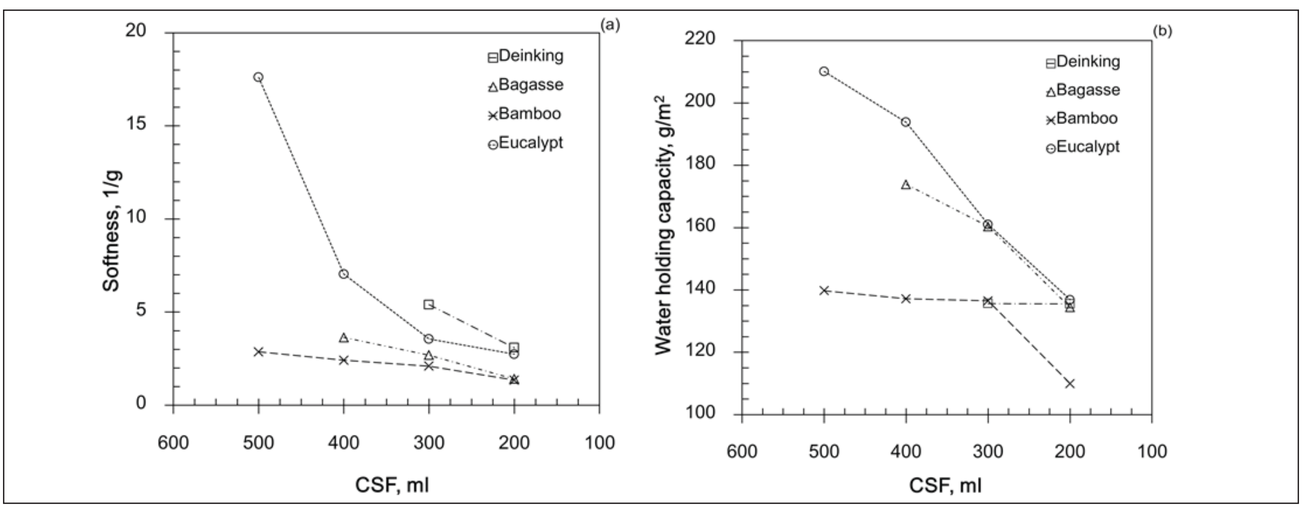
The creped sheets produced from the various pulps at a high level of pulp freeness showed clearly different levels of sheet softness; however, for freeness below 300 mL there were no clear differences in softness. At a given pulp freeness,



5. (a) Tensile strength and (b) softness of uncreped and creped sheets as a function of pulp freeness. Creped sheets were cut and tested in across crepe and crepe directions, while uncreped sheets had no crepe direction. Error bars represent the standard deviation of tensile index values in a range of 0.76–4.44 Nm/g and the standard deviation of softness values in a range of 0.39–2.76 1/g.



6. (a) Water holding capacity and (b) liquid absorption speed of uncreped and creped sheets as a function of pulp freeness. Error bars represent the standard deviation of water holding capacity values in a range of 3.10–10.90 g/m² and the standard deviation of liquid absorption speed values in a range of 0.026–0.142 mm/s.



7. a) Softness and (b) water holding capacity of creped sheets produced from industrial pulps as a function of pulp freeness.

the eucalypt pulp had a higher degree of softness and water holding capacity, while the bamboo pulp had poor softness and lower water holding capacity. In addition, the bamboo pulp produced creped sheets with less change in softness and water holding capacity under various degrees of refining, as shown in **Fig. 7.**

Figure 8 shows the inverse correlation between softness and tensile strength of the creped sheets produced by various pulps. The softness was strongly correlated with the tensile strength, where higher softness was obtained at lower tensile strength. To obtain a given softness, the pulps needed to be refined to different levels to produce the desired fiber bonding correlated to sheet softness (Fig. 8 and **Fig. 9**). This indicated that for the production of tissue at a given pulp freeness, the use of bamboo pulp might result in a lower sheet softness.

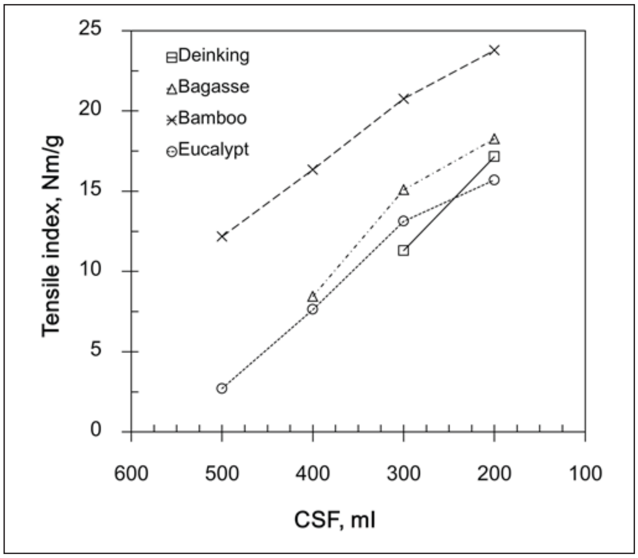
At a given sheet strength, the water holding capacity of the eucalypt and bagasse pulps was higher while for the bamboo and deinking pulps it was lower, as shown in **Fig. 10**. The study found that the creped sheets produced from the bamboo and deinking pulps were less sensitive to an improvement in the water holding capacity.

DISCUSSION

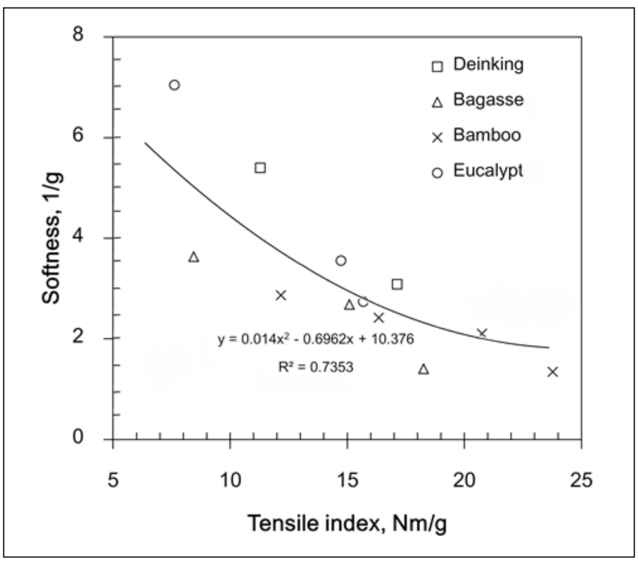
Because standard laboratory sheets cannot be used to test the softness and water holding capacity as the pulp is developed in the refining process, the creping method was developed. The test sheet was attached onto the creping glass base with the optimum adhesive force between the wet sheet and the glass base. The adhesion force and creping size were controlled by the sheet dryness, the basis weight, and the blade angle. In this experiment, the parameters were kept constant to minimize their effect on the creped

Pulp Types	Freeness, mL	Fiber Length, mm	Coarseness, mg/m	Zeta Potential, mV
Deinking pulp	272	0.858	0.075	- 43.9
Eucalypt pulp	485	0.651	0.057	- 95.5
Bagasse pulp	492	0.734	0.086	- 38.6
Bamboo pulp	651	1.147	0.071	- 35.4

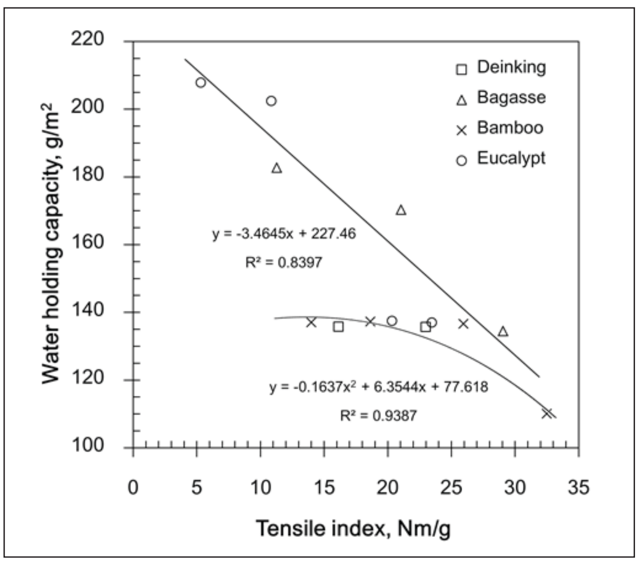
I. Pulps obtained from tissue manufacture and their fiber morphology.



9. Tensile strength of creped sheets produced from various types of pulp material as a function of pulp drainability.



8. Softness of creped sheets produced from various types of pulp material as a function of tensile strength. The regression equation with a correlation coefficient was formulated from softness values of all pulp types.



10. Water holding capacity of the creped sheets produced by various types of pulp materials as a function of tensile strength. The regression equations were separately formulated from eucalypt and bagasse pulps and deinking and bamboo pulps.

structures, whereas the pulp types and refining levels were changed for analyzing their performance. The laboratory wet creping method could produce crepes on the base sheets, causing changes in their structure (Figs. 2 and 3). In comparison with the industrial creped tissues [4], the laboratory creped sheets showed a lower level of broken fiber networks. Also, the base sheets were an isotropic structure of fiber orientations, which might produce the properties of creped sheets different from the industrial products. However, the results of the developed method clearly showed that important properties (i.e., softness, liquid absorption, and tensile strength) could be determined and optimized while the standard uncreped sheets showed indistinct results for these properties. The obtained softness and water holding capacity were correlated to the development of pulp fibers under refining in a pulp freeness range of 200–500 mL. According to these results, the method could be applied to evaluate the quality of the various pulps used in tissue manufacture.

The study of the deinking pulp, eucalypt pulp, bamboo pulp, and bagasse pulp found that the creped sheets produced from these pulps had differences in softness, water holding capacity, and strength properties at a given pulp drainability. The eucalypt and bagasse pulps were found to be of a superior quality and produced creped sheets with high softness and water holding capacity at a given tensile strength. The bamboo pulp could be blended with other pulps to improve the strength of tissue paper, but it might reduce the sheet softness and water holding capacity.

CONCLUSIONS

A wet creping method was developed in the laboratory and the creped sheets were engineered to improve their softness and liquid absorption. The results showed that the creping caused breaking of the fiber bonding in the creped structure and created small pores in the creped sheets. The application of this creping method to the evaluation of industrial pulps determined that the eucalypt pulp and bagasse pulp produced creped sheets with higher softness and water holding capacity. The bamboo pulp had lower water holding capacity similar to that of the deinking pulp, but produced high strength creped sheets. **TJ**

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ABOUT THE AUTHORS

Tissue products are made using various types of raw materials, which causes difficulty in the control of stock quality. Furthermore, laboratory testing sheets and creped tissues have totally different structures and physical and mechanical properties, and there are no standard methods available for laboratory creping. Previous research could not be carried out in the laboratory, as creped sheets had to be made using a high speed creping machine and adhesive chemicals. Our work differs because we developed a simple method to make the creped sheets in the laboratory and to analyze the performance of pulp raw materials without the use of chemicals.

The greatest difficulty we encountered was to make consistent creped sheets under various conditions because the creped structures were affected by the raw material type, degree of refining, basis weight, and dryness of base sheets. It was necessary to produce consistent creped sheets so the physical and mechanical properties of samples could be analyzed.

Surprisingly, the creped laboratory sheets can be made with softness close to industrial products. Also, physical and mechanical properties can be differentiated between the different pulps used and various degrees of refining. The developed laboratory wet creping method could be used to evaluate the quality of pulp materials for tissue manufacture and could be applied to examine the development of pulp quality under refining.

Our next step is to work with tissue mills to evaluate the performance of all raw materials used in tissue manufacture. We will also further develop the laboratory creping devices for other laboratories.

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LITERATURE CITED

1. Norris, von F.H., *Paper and Paper Making*, Oxford University Press, London, 1952, pp. 205-218.
2. Ramasubramanian, M.K., Sun, S., and Gupta, S., "Modeling and simulation of the creping process," *PaperCon*, TAPPI PRESS, Atlanta, GA, USA, 2011, p. 1203.
3. Furman, G.S., "Adhesive testing of chemical additives applied to Yankee dryers," *Nonwovens Conf.*, TAPPI PRESS, Atlanta, 1990, p. 271.
4. Ramasubramanian, M.K., *Handbook of Physical Testing of Paper, Vol. 1*, (R.E. Mark, C.C. Habeger, J. Borch, et al., Eds.), 2nd edn., Marcel Dekker, New York, 2002, pp. 661-698.
5. Ramasubramanian, M.K., Sun, Z., and Chen, G., J. *Manuf. Sci. Eng.* 133(5): 1(2011).
6. Ingvar, K., *Papermaking Science and Technology, Book 9: Papermaking Part 2, Drying*, Fapet Oy, Helsinki, 2000, pp. 147-185.
7. Raunio, J.P. and Ritala, R., *Nord. Pulp Pap. Res. J.* 27(2): 375(2012).
8. Kuo, L.S. and Cheng, Y.L., *TAPPI J.* 83(12): 1(2000).
9. Hollmark, H., "Study of the creping process in an experimental paper machine," *STFI* Research Report No. 144, Series B, Swedish Forest Products Research Laboratory, Stockholm, 1972.
10. Choi, D. and Patterson, T., "Predicting the performance of creping adhesives," *PaperCon*, TAPPI PRESS, Atlanta, 2010, p. 11.
11. Uesaka, T., Retulainen, E., Paavilainen, L., et al., *Handbook of Physical Testing of Paper, Vol. 1*, (R.E. Mark, C.C. Habeger, J. Borch, et al., Eds.), 2nd edn., Marcel Dekker, New York, 2002, pp. 873–900.
12. Kimari, O., *Papermaking Science and Technology, Book 18: Paper and Board Grades*, Fapet Oy, Helsinki, 2000, pp.75–94.

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