Phichit Somboon, Juha Vuorela, Tuomo Pynnönen, and Hannu Paulapuro. 2009. Grit segments in TMP refining. Part 2: Potential for energy reduction. Appita Journal, volume 62, number 1, pages 42-45, 59.

Grit segments in TMP refining. Part 2: Potential for energy reduction

PHICHIT SOMBOON*[1], JUHA VUORELA[1], TUOMO PYNNÖNEN[1], AND HANNU PAULAPURO[2]

SUMMARY

The use of grit segments in thermomechanical pulp (TMP) refining and their effects on energy consumption, and pulp and paper properties have been studied. The refining was performed with a two stage process using a Sunds Defibrator RGP 44 single-disc refiner. The grit segments were installed in the first stage refiner, while the second stage refiner was equipped with reference segments. The results showed that when grit segments were used in combination with optimised refining conditions, the first stage pulp was found to have greater breakdown of the cell walls resulting in fast development of freeness in the second stage refining. Potential for reducing the energy consumption was at least 10% with minimal negative impacts on pulp and paper properties.

KEYWORDS

Refiner segments, thermomechanical pulp, refining, energy consumption, disruption, pulp and paper properties

INTRODUCTION

A new approach to reduce the energy consumption in TMP refining has been developed by applying a grit treatment to the surface of the refiner plate segments. Laboratory scale trials (*1*,*2*) showed that applying grit material to the segments enhanced the breakdown of the fibre wall structure during defibration and enabled a reduction in total energy consumption of up to 30 % without a significant loss of pulp quality. In this study, the grit treatment was used in an industrial scale refiner pilot plant. The experiment consisted of two trials. In the first trial (Part 1 of this work (*15*)), the process parameters were optimised for the grit segments. In the second trial, the potential for reducing the energy consumption and the effects on the properties of the resulting paper were examined.

In Part 1 of this work (*15*), the grit segment was tested using a Sunds Defibrator RGP44 single-disc refiner. The results showed that when the refiner was operated at a rotational speed of 2400 rpm, it produced pulp with a higher level of fibrillation, fibre flexibility and pore volume than refining with reference segments. The strength of long fibres was not affected by the grit segments. However, the grit segments did produce pulp with a shorter fibre length at energy inputs above 1.3 MWh/t. Based on this study it was found that to increase the disruption and opening of the fibre cell walls without reducing the fibre length, the first-stage refiner needed to be operated at a high rotational speed of 2400 rpm, a pressure of 300 kPa, and the specific energy consumption needed to be kept between 0.8-1.3 MWh/t.

In the present experiment, refining was conducted in a two stage process to evaluate the potential for energy reduction, and to examine pulp and paper properties at low freeness. The first stage refining was performed using the grit segments to increase the breakdown of fibre cell walls, while the second stage refining was carried out by using the reference segments.

EXPERIMENTAL

A two-stage refining process was carried out using a Sunds Defibrator RGP44 refiner in the pilot plant of the Finnish Pulp and Paper Research Institute (KCL). The experimental design of the refining trials performed with the grit and reference segments is shown schematically in Figure 1 with the operating conditions given in Table 1.

First-stage refining was performed using both grit and reference segments using both the optimised conditions (from Part 1 of this work (*15*)) and typical mill conditions (*3*). For the grit segment trials, the refiner was equipped with grit segments on both rotor and stator sides. The optimised conditions involved operating the refiner at a rotational speed of 2400 rpm, a refining pressure of 300 kPa, and specific energy inputs of 0.8 and 1.3 MWh/t (oven-dry weight). For the normal mill conditions, the rotational speed was 1500 rpm and the refining pressure and specific energy consumption were similar to the optimised conditions. The raw material was fresh chips made from Norway spruce (*Picea abies L. Karst*.). The chip feed was preheated under a pressure of 150 kPa with a steaming time of 45 seconds. The pulp was discharged at a consistency of 30%.

The second-stage refining was carried out by using a reference segment, a LE-segment (RG 4202) (*4*), and controlled under constant conditions. The refiner was operated at a peripheral speed of 1500 rpm. The refining pressure was 300 kPa. The total specific energy was raised in equal increments from 1 to 3 MWh/t (oven-dry weight). The consistency of the discharged pulp was controlled at 30%. Pulp samples were taken for testing fibre and paper properties. The potential for reducing the energy consumption was evaluated at a given pulp freeness.

The drainability of pulp fibres was tested using the whole pulp according to ISO 5267-2. Laboratory sheets were formed using the whole pulp with white water recirculation, and dried with a drying plate in a conditioning room at 23°C and 50% RH according to ISO 5263 and 5269-1. Basis weight, thickness, and density of laboratory sheets were tested according to ISO 536 and ISO 534. Tensile and tear strength of laboratory sheets were tested according to ISO 1924-2 and ISO 1974. Light scattering coefficient of laboratory sheets was tested according to ISO 2471. Fibre length was measured with the whole pulp using a Kajaani FS300 apparatus according to TAPPI T271 om-98. The length-weighted fibre length was used as an average length of fibres. The wet strength of fibres was determined based on derivation of the breaking stress of wet paper strips at a zero span and the number of fibres bearing the load (*5*). Disruption of fibre wall structure was measured based on the micropore volume in the cell wall and

[1]Researchers, [2]Professor
Laboratory of Paper and Printing Technology
Department of Forest Products Technology
Helsinki University of Technology
P.O. Box 6300, FIN-02015 TKK
Espoo, Finland
*Corresponding author (phichit.somboon@tkk.fi)

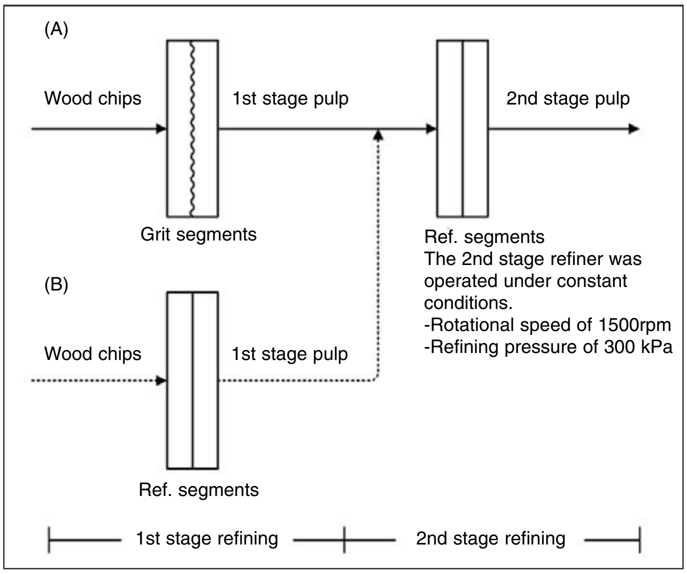

Fig. 1 Experimental schematic of TMP refining with the grit segments (A) and the reference line (B).

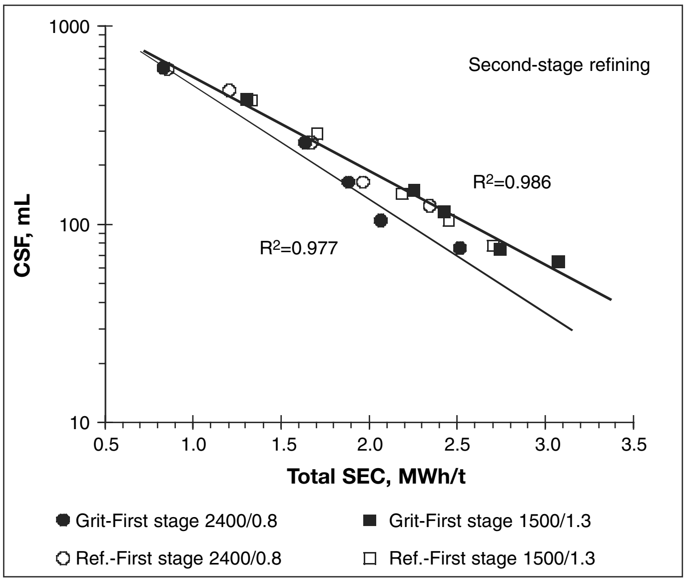

Fig. 2 Development of pulp freeness in second-stage refining as a function of total specific energy consumption. Comparison between grit and reference segments.

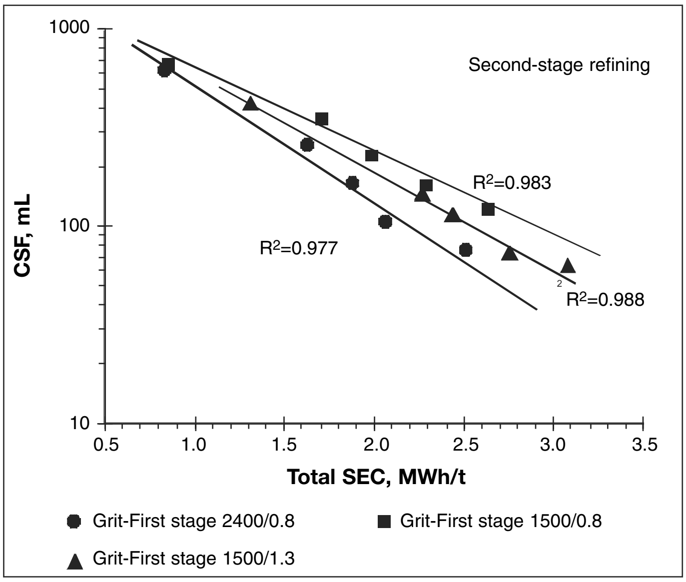

Fig. 3 Development of pulp freeness in second-stage refining as a function of total specific energy consumption. Comparison between grit segments performed at various levels of operating conditions in the first stage.

degrees of fibrillation of fractionated fibres (R30). The micropore volume was measured using a differential scanning calorimeter based on the thermoporosimetry method with an isothermal step melting technique (*6*).

RESULTS AND DISCUSSION

Effect on energy consumption

In the optimised conditions, the first-stage pulp refined using grit segments and the optimised process conditions (a rotational speed of 2400 rpm) required less energy in second-stage refining to reach a given freeness, as shown in Figure 2. After discussion with industrial partners who are most interested in this technology for SC and LWC production. The potential for reducing the energy consumption was calculated (by extrapolation) at a 50 mL CSF, the freeness typical used for SC or LWC paper (*7,8*). It was found that grit segments reduced the energy demand by up to 10% compared to the reference segments. For the normal mill refining conditions, the first-stage refiner was operated at rotational speed on 1500 rpm. The results showed that there was no difference in the total energy consumption required to produce pulp to a certain freeness for the grit and reference segments.

Figure 3 shows that when using grit segments, both increasing the rotational speed from 1500 to 2400 rpm and increasing the energy input from 0.8 to 1.3 MWh/t promote the development of pulp freeness in second-stage refining. However, the rotational speed has a greater effect on the energy reduction when refining with grit segments.

The results concerning the effect of impact frequency and peripheral speed on energy consumption are somewhat conflicting. According to Salmén et al. (*9*),

Table 1
Refining conditions used in a two-stage process performed with grit and reference segments.

	The first-stage refining			The second-stage refining			Remark
Test points	Types of segment	Speed (rpm)	Pressure (kPa)	Types of segment	Speed (rpm)	Pressure (kPa)	
1	Grit	2400	300	Ref.	1500	150	Optimised conditions
2	Ref.	2400	300	Ref.	1500	150	Reference conditions
3	Grit	1500	300	Ref.	1500	150	Normal mill conditions
4	Ref.	1500	300	Ref.	1500	150	Reference conditions

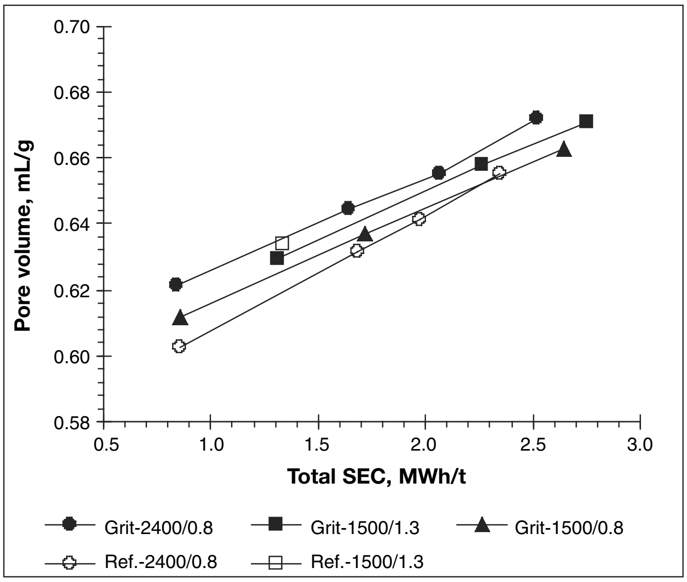

Fig. 4 Pore volume of fibre cell walls as a function of total specific energy consumption.

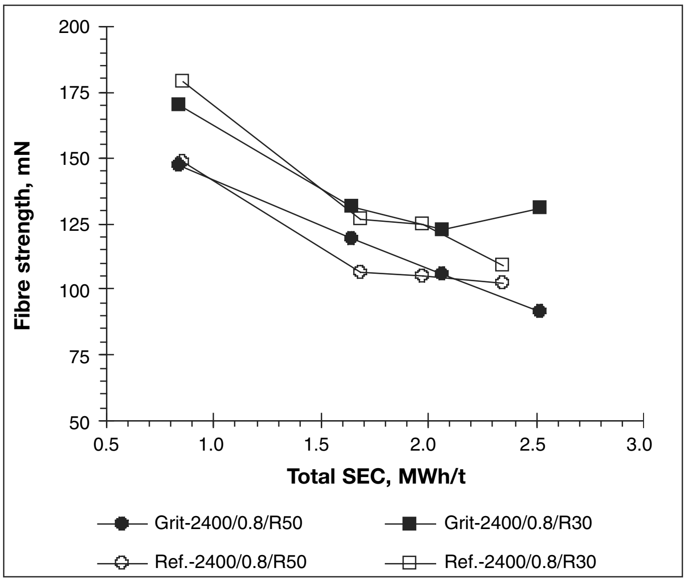

Fig. 5 Strength of wet fibres as a function of total specific energy consumption.

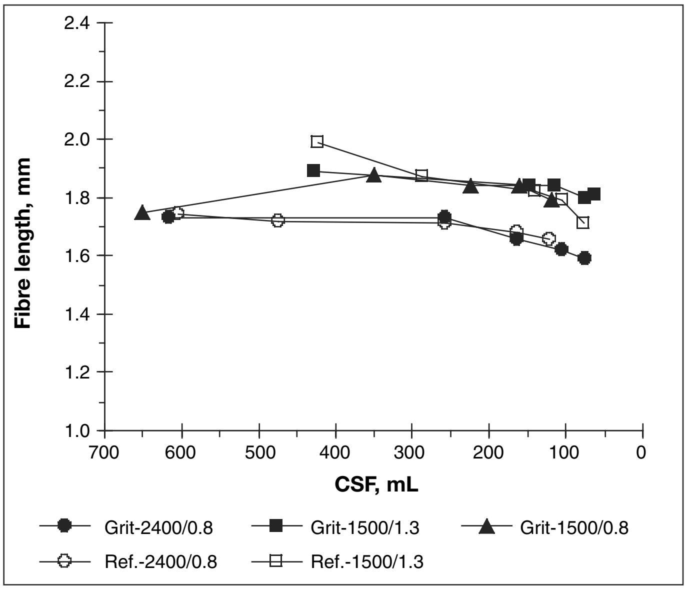

Fig. 6 Length-weighted fibre length measured with the whole pulp as a function of pulp freeness.

the mechanical properties of wood are dependent on the frequency of the mechanical action, with decreasing frequency lowering the softening temperature. This is favourable for the structural breakdown of wood (*9,10*). In the grinding process, reducing the peripheral speed of the grinding stone, i.e. reducing the deformation frequency caused by the grits and results in a clear reduction in energy consumption (*9*). Contradictorily, in the refining process, increasing the rotational speed reduces the energy consumption (*11,12,13*), which is in agreement with the results of the present experiment. According to Sundholm et al. (*12*), changing the rotational speed of the refiner affects bar impact frequency and impulse momentum of the bars. The frequency does not have a significant influence on the energy reduction, but the impulse momentum of the bars is an important factor affecting the energy consumption. Miles et al. (*13,14*) described the effect of rotational speed on amount of energy transferred at each impact, called refining intensity. Increasing the rotational speed of the refiner increases the intensity of refining and results in fast development of fibres. Regarding the grit segments (Part 1 of this work (*15*)), increasing the bar velocity increases the impulsive momentum and the energy transfer; this could explain why the grits of the segments break down fibre cell walls efficiently at high rotational speed.

Effect on pulp and paper properties

Figure 4 and 5 show the development of the pore volume of fibre cell walls and the strength of the wet fibres produced in second-stage refining. Increasing the rotational speed of the first-stage refiner appeared to increase the breakdown of fibre cell walls in the second-stage refining. Fibre cell walls with the highest pore volume values were produced during second stage refining when grit segments and the optimised 2400 rpm conditions had been used during first stage refining. Under these operating conditions, There were no distinct differences in fibre strength properties of the second stage pulps produced with the grit and reference segments when compared at a given refiner rotational speed. This indicates that the grit segments produced more broken fibre cell walls, but did not weaken or cause severe shortening of pulp fibres. Because of limitation of cost and time we were forced to restrict the number of interesting measurements that for the pulp of Ref-1500/1.3 was not carried out. It would have been interesting indeed to have this result as its absence somewhat reduces the confidence in our overall conclusion. However, we believe that the general trend line in pore volume supports our general conclusion.

The length-weighted fibre length measured with the whole pulp is shown in Figure 6. The fibre length is less affected by the segments, but it is dependent on the refiner rotational speed. The fibre length was reduced by about 0.2 mm examined at a CSF of 50 mL, when the speed was increased from 1500 rpm to 2400 rpm.

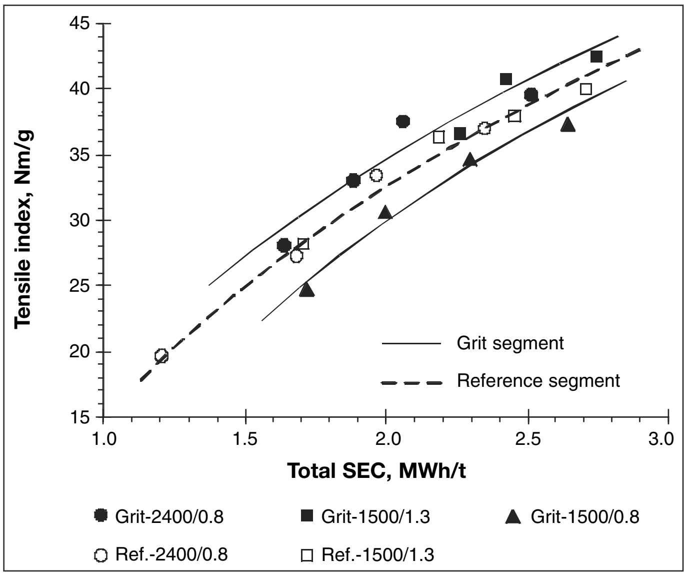

Fig. 7 Tensile strength of laboratory sheets as a function of total specific energy consumption. Comparison between grit and reference segments performed at various levels of operating conditions in the first stage.

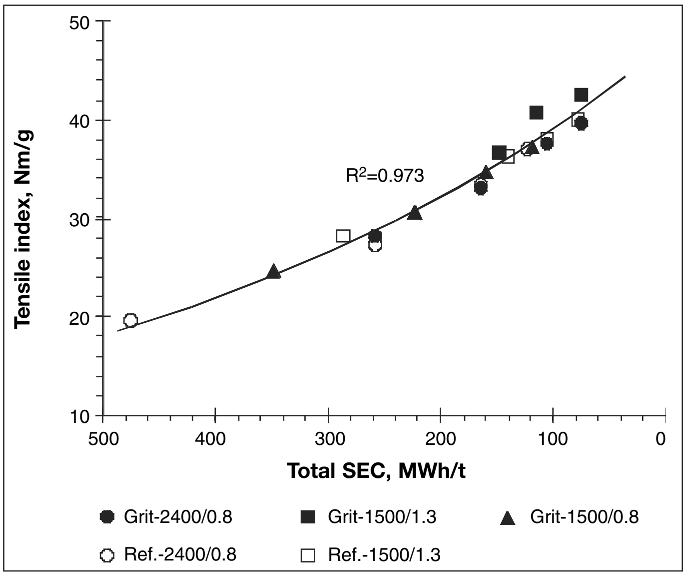

Fig. 8 Tensile strength of laboratory sheets as a function of pulp freeness.

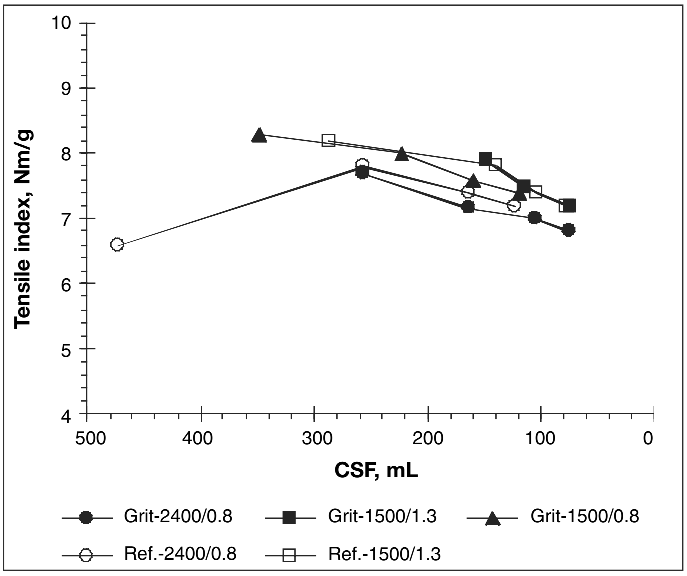

Fig. 9 Tear strength of laboratory sheets as a function of pulp freeness.

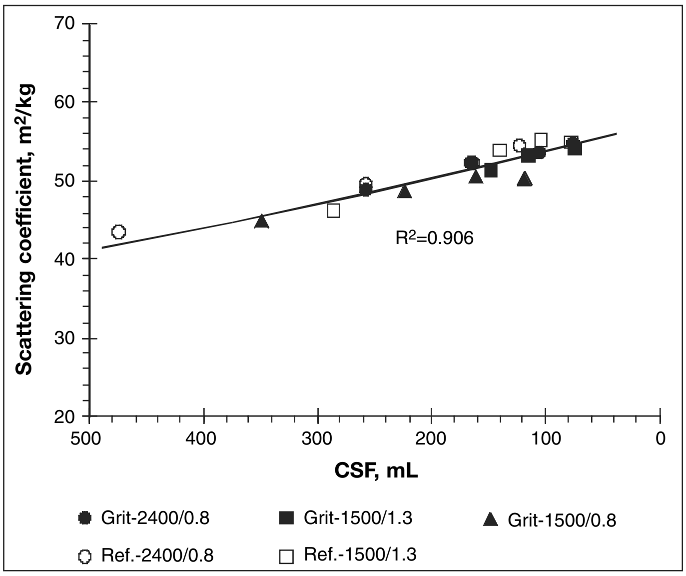

Fig. 10 Light scattering coefficient of laboratory sheets as a function of pulp freeness.

The effect of segment type and operating conditions on tensile strength is shown in Figure 7 and 8. The tensile strength of the second stage pulp was found to increase when the first-stage refining was performed with grit segments using a rotational speed of 2400 rpm and a SEC of 0.8 MWh/t, and when using a rotational speed of 1500 rpm and a SEC of 1.3 MWh/t. This shows that the grit segments can produce pulp of a given tensile index with a lower energy consumption than the reference plates. However, when comparing at a given freeness, there were no differences in tensile strength between the pulps produced with different segments and under different operating conditions.

Figure 9 shows the effect of segment type and operating conditions on tear strength. The tear strength was less affected by the segment type. It was somewhat lower under the operating conditions with a high rotational speed of 2400 rpm. However, at a CSF below 100 mL, there were no distinct differences.

The light scattering coefficient was not affected when using different segments between the grit and reference segments and different operating conditions, as shown in Figure 10.

CONCLUSIONS

The use of grit segments in first-stage TMP refining at high rotational speed, followed by treatment with standard segments operated under normal mill process conditions in the second stage, can reduce the total energy consumption at least 10% with minimal negative impacts on pulp and paper properties. However, great care needed to be taken when using high rotational speeds to minimize fibre shortening and lowering the tear strength.

Further work is now being planned to study the girt geometry and its placement on the refiner segment. Mill scale trials are also being planned to evaluate the performance of grit segments over a longer operating period.

Continued on page 59

Continued from page 45

ACKNOWLEDGEMENTS

The authors would like to thank the Finnish Funding Agency for Technology and Innovation (TEKES), Metso Paper, UPM-Kymmene and Stora Enso for financial support of this research work. Research partners, i.e., the Finnish Pulp and Paper Research Institute (KCL), and the Technical Research Center of Finland (VTT) are gratefully acknowledged for providing useful information for this work. We would like also thank Tampere University of Technology for working on gritting process.

REFERENCES

(*1*) Somboon, P., Kang, T., and Paulapuro, H. – Disrupting the wall structure of high-freeness TMP pulp fiber and its effect on the energy required in the subsequent refining, *Pulp Pap. Can.* **108**(10):30-34 (2007).

(*2*) Somboon, P. and Paulapuro, H. – Surface mechanical treatment of TMP pulp fibers using grit material, *Proc. Intl. Mechanical Pulping Conf.,* Minneapolis, USA, 8 p. (2007).

(*3*) Somboon, P., Vuorela, J., Pynnönen, T. and Paulapuro, H. – Application of grit treatment to industrial thermomechanical pulp refining, *Proc. 6th Biennial Johan Gullichsen Colloquium*, Espoo, Finland, p.59-65 (2007).

(*4*) Bergquist, P. and Vuorio, P. – LETM segments-new technology for reducing electrical energy consumption, *World Fiber Process*, no.2:40-45 (1998).

(*5*) Somboon, P. and Paulapuro, H. – Measuring wet strength of wood fibers with a combination of a zero-span tensile apparatus and an automated optical analyzer, *Proc. Progress in Paper Physics Seminar,* Oxford, Ohio, USA, p.45-48 (2006).

(*6*) Maloney, T. C. and Paulapuro, H. – The formation of pores in the cell wall, *J. Pulp Pap. Sci.* **25**(12):430-436 (1999).

(*7*) Paulapuro, H. and Laamanen, J. – Papermaking properties of mechanical pulps, *Proc. 19th International Symp. at Miami University*, USA, 43 p. (1988).

(*8*) Haarla, A. – Printing and writing papers, In Paulapuro, H. (ed.) **Paper and board grades**, Fapet Oy, Finland, p.14-52 (2000).

(*9*) Salmén, L., Lucander, M., Härkönen, E. and Sundholm, J. – Fundamentals of mechanical pulping, In Sundholm, J. (ed.) **Mechanical pulping**, Fapet Oy, Finland, p.35-61 (1999).

(*10*) Salmén, L. – The effect of the frequency of a mechanical deformation on the fatigue of wood, *J. Pulp Pap. Sci.* **13**(1):J23-J28 (1987).

(*11*) Nurminen, I. – High strength TMP with 25% lower energy consumption by changing only fiber separation conditions, *Proc. Intl. Mechanical Pulping Conf.,* Helsinki, Finland, vol.1, p.167-173 (2001).

(*12*) Sundholm, J., Heikkurinen, A. and Mannström, B. – The role of rotation and impact frequency in refiner mechanical pulping. *Pap. Puu*, **7**(5):446-451 (1988).

(*13*) Miles, K.B. – A simplified method for calculating the residence time and refining intensity in a chip refiner, *Pap. Puu*, **73**(9):852-857 (1991).

(*14*) Miles, K. B., May W. D. and Karnis, A. – Refining intensity, energy consumption and pulp quality in two-stage chip refining, *Proc. 1990 Pulping Conf.,* Toronto, Canada, Book 2, p.681-690 (1990).

(*15*) Somboon, P., Vuorela, J., Pynnonen, T. and Paulapuro, H. – **Grit segments in TMP refining. Part 1: Operating parameters and pulp quality**, *Appita J.* **62**(1):37(2009)

Original manuscript received 20 February 2008, revision accepted 25 July 2008