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Grit segments in TMP refining. Part 1: Operating parameters and pulp quality

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SUMMARY

An energy efficient technique to produce pulp fibres in TMP refining was developed by using grit material to disrupt and open the outer layers of fibres. The grits were made from self-fluxing tungsten-carbide powder and a Ni-base alloy powder, which were laser-cladded on the bar surface of a refiner segment to direct energy sharply to breakdown wood and fibres structures. The trial of grit segments was carried out on a Sunds Defibrator RGP 44 single-disc refiner performed in the first stage refining. The results showed that in the first stage refining, grit segments can disrupt and open the fibre cell walls efficiently when operated at a high refiner rotational speed of 2400 rpm. However severe shortening of the pulp fibres occurred when the energy input was above 1.3 MWh/t. The refiner equipped with grit segments operated smoothly without any adverse effects on the motor load or feeding system.

KEYWORDS

Refiner segments, thermomechanical pulp, refining, energy consumption, disruption, pulp quality

INTRODUCTION

The repeated viscoelastic deformation of wood material and the low friction force on refiner bars potentially cause considerable energy losses in TMP refining (*1-6*). Innovative refiner segments with abrasives on the surfaces, called abrasive segments (abrasive plates), are a practicable approach to develop an energy-efficient refining process. Different designs of abrasive surfaces have been made, for example, flat abrasive segments where the plate consist of breaking bars and an abrasive surface on the outside (*7,8,9*), filled grove segments where the groves of the segments are filled with a pulpstone-like matrix (*9,10*), and other designs, bar surface roughness where the segment bars are coated or deposited with abrasive materials (*9,11*). These abrasive segments have been tested on both the first and second stage refiners using laboratory and pilot scale TMP refining equipment. The results indicate that abrasive refiner segments are superior to conventional segments. However, the low load capacity of the refiner, the limited durability of abrasive surfaces, and the shortening of pulp fibres are serious problems with abrasive refiner segments.

In previous studies (*9,10*), abrasive segments have been used under intensive refining conditions to develop the pulp to target freeness which is likely to cause difficulties in refiner operation and severe damage to pulp fibres. In a new approach, the focus is on the application of grit treatment to enhance the breakdown of fibre cell walls before the fibrillation stage. It was hypothesized that applying grit material to the refiner segments used in the defibration stage would promote the development of pulp fibres and reduce energy consumption in the fibrillation stage by increasing the disruption and opening of the fibre wall.

The hypothesis was tested at laboratory scale by using high-freeness TMP collected from the first refining stage and the reject lines as raw material. The pulp was disrupted with a special grit material and subsequently refined under TMP refining conditions. The results showed that disruption allows a reduction of total energy consumption up to 30 % in without a significant loss of pulp quality (*12,13*).

In this research work, the application of grit treatment to industrial TMP refining was studied. Refiner segments were redesigned as a means to bring about a disruption of fibre cell walls and the new segments were tested at pilot scale.

EXPERIMENTAL

The experiment consisted of two trials. This paper (Part 1) presents the results from the first trial that was carried out to analyse the process parameters and pulp quality obtained using a refiner fitted with grit segments. The second trial evaluated the potential for using these segments to reduce the energy consumption and examined the properties of the resulting paper. This information is presented in part two of this work. (*22*).

Applying grit to the segments was carried out in cooperation between the Helsinki University of Technology, Tampere University of Technology and Metso Paper. LE-segments (RG 4202) (*14*), manufactured by Metso Paper, were used in the trial. The grits were made from self-fluxing tungsten-carbide powder and a Ni-base alloy powder, which were laser-cladded on the bar surfaces of refiner segments (*15,16*). A modified segment, having grits on the bar surfaces, is shown in Figure 1.

The trial of grit segments was performed on a Sunds Defibrator RGP44 single-disc refiner in the pilot plant at the Finnish Pulp and Paper Research Institute (KCL). The grit segments were mounted on the first-stage refiner, both on the rotor and stator sides. The key process parameters of the first-stage refiner, i.e., peripheral speed, refining pressure, and specific energy consumption were optimised. The peripheral speed was tested at 1200, 1500, and 2400 rpm and refining pressures at 100, 300, and 500 kPa. The specific energy input was controlled incrementally from 0.8 to 1.5 MWh/t (oven-dry weight). The raw material was fresh chips made from Norway spruce (*Picea abies L. Karst*.) produced at UPM-Kymmene in Finland. The chip feed was preheated under a pressure of 150 kPa with a steaming time of 45 seconds. The consistency of the discharged pulp was controlled at 30%. The pulp samples were taken for measuring pulp freeness and fibre length, and for analysing the breakdown of the fibre cell walls.

The drainability of pulp fibres were tested according to ISO 5267-2. Fibre length was measured with the whole pulp using a Kajaani FS300 apparatus according to TAPPI T271 om-89. The length-weighted fibre length was used as an

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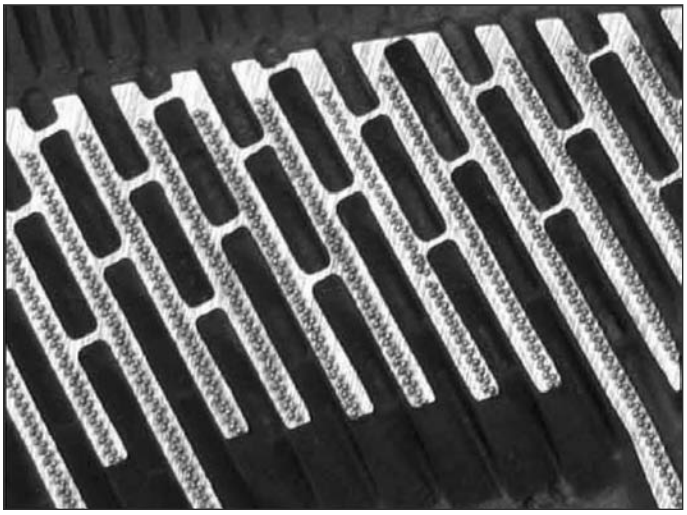

Fig. 1 Grit segments with LE-segment base.

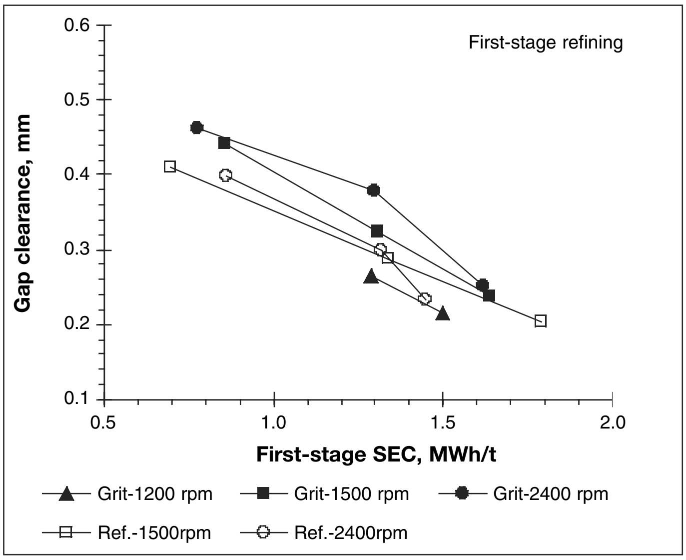

Fig. 2 Plate clearance of first-stage refiner equipped with grit and reference segments operated under various levels of rotational speeds as a function of specific energy consumption.

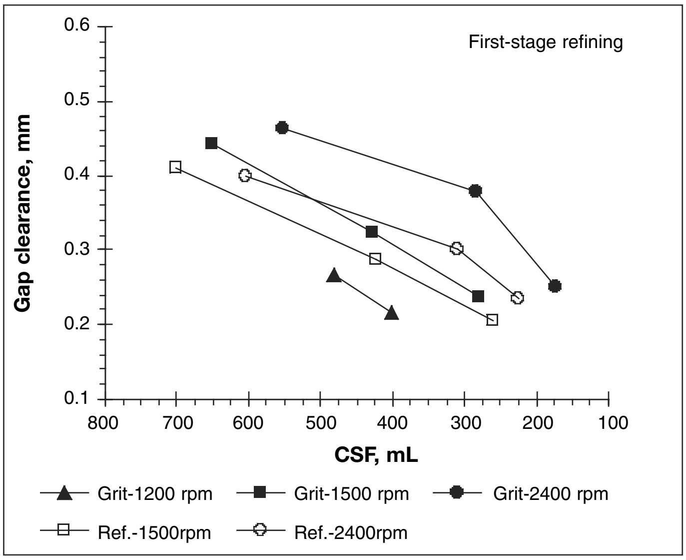

Fig. 3 Plate clearance of first-stage refiner equipped with grit and reference segments operated under various levels of rotational speeds as a function of development of pulp freeness.

average length of fibres. The strength of wet 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 (*17*). The flexibility of long fibre fraction was analysed based on the hydrodynamic method (*18*). Disruption of fibre wall structure was measured based on the micropore volume in the cell wall and 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 (*19*). External fibrillation and splitting of long fibres were analysed based on an image analysis method, which was developed by the KCL (*20*).

RESULTS AND DISCUSSION

Effects of grit segments on the first-stage refiner

First-stage refining with grit segments was tested with a Sunds Defibrator RGP44 refiner operated in single-disc mode. The refiner can be loaded up to a specific energy consumption of 1.8 MWh/t and a production rate of 550 kg/h, which was equal to of that reference segments. The loading capacity was similar to of that reference segments. There was no contact of the grits between rotor and stator during calibration of the plate gap clearance measurement and refining. The durability of the grits was examined after the experiments and it was found that no grits had been removed from the bars. Unfortunately, this trial was a relatively short period of operation. It is impossible to predict a long term durability of the grit segment. This is to be investigated in forthcoming mill trials.

Figure 2 and 3 show the gap clearance of grit and reference segments at different degrees of refining for rotational speeds from 1200 to 2400 rpm. At rotational speeds of 1500 and 2400 rpm, the plate equipped with grit segments required a wider gap to maintain the desired level of specific energy. However, at energy consumption above 1.5 MWh/t, there were no differences. When comparing the gap clearance at a given pulp freeness, it was also found that the grits plates have a wider gap to produce the pulp at the desired freeness level. This indicates that the grits might have an effect on the performance of refiners and the development of pulp fibres, but do not impact on the motor load.

Effect of rotational speed on pulp freeness and fibre length

The effect of rotational speed on the development of CSF and fibre length is shown in Figure 4 and 5. When the refiner was operated at a constant refining pressure of 300 kPa and a low level of specific energy consumption of 0.8 MWh/t, the pulp freeness and fibre length were not affected by changes in the rotational speed of the refiner plate. At higher levels of energy input, increasing the rotational speed up to 2400 rpm resulted in fast development of pulp freeness. There were no differences in the freeness values obtained from the grit and reference seg-

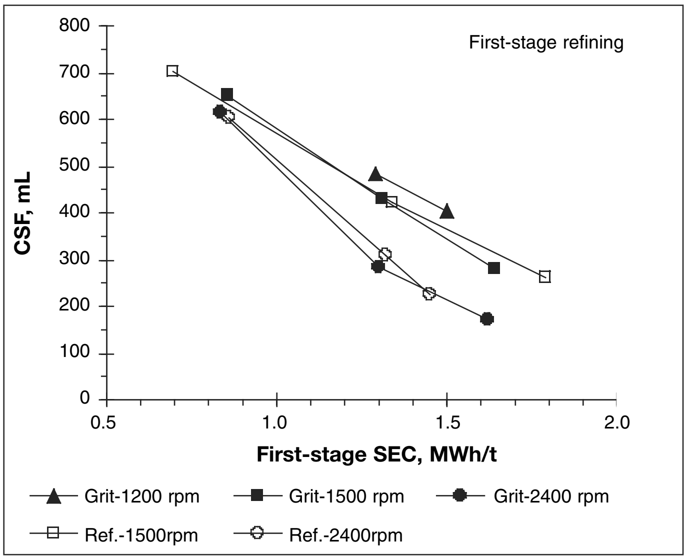

Fig. 4 Development of pulp freeness as a function of specific energy consumption in first-stage refining. The refiner was equipped with grit and reference segments and controlled under various levels of rotational speed.

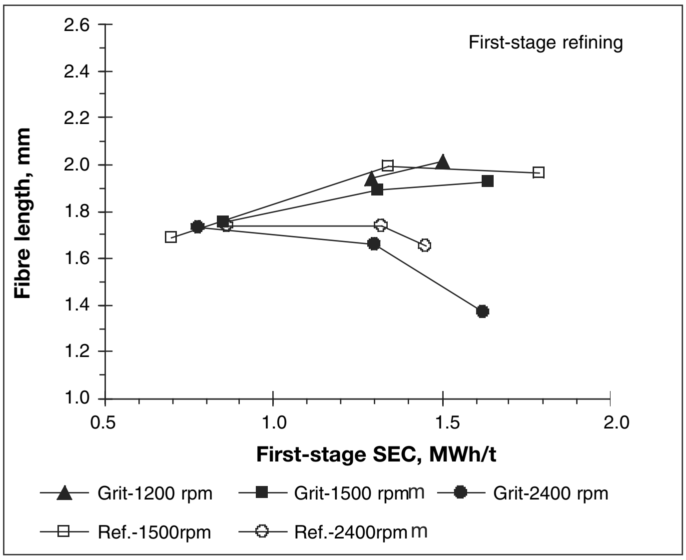

Fig. 5 Length-weighted fibre length as a function of specific energy consumption in first-stage refining. The refiner was equipped with grit and reference segments and controlled under various levels of rotational speed.

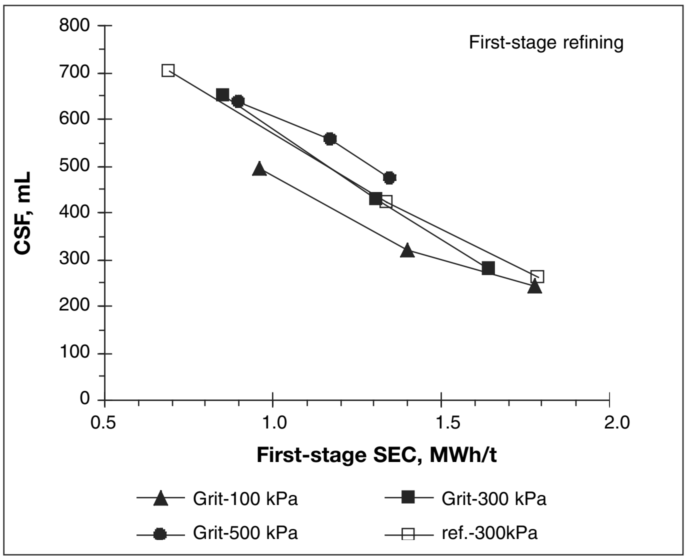

Fig. 6 Development of pulp freeness as a function of specific energy consumption in first-stage refining. The refiner was equipped with grit and reference segments and controlled under various levels of refining pressures.

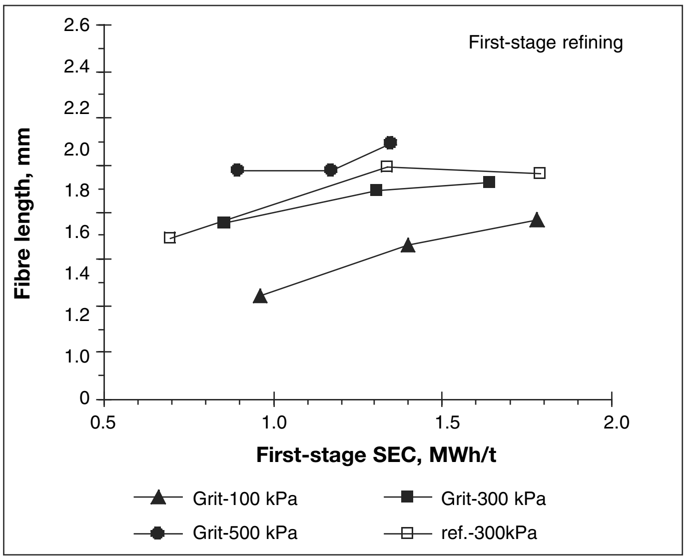

Fig. 7 Length-weighted fibre length as a function of specific energy consumption in first-stage refining. The refiner was equipped with grit and reference segments and controlled under various levels of refining pressures.

ments, but there were distinct differences in fibre length. The grit segments produced a shorter fibre length at a given specific energy input and caused a faster drop in fibre length at an energy input above 1.3 MWh/t. To maintain the fibre length, we suggest that the specific energy consumption in first-stage refining should be kept below 1.3 MWh/t at high rotational speed of 2400 rpm.

Effect of refining pressure on pulp freeness and fibre length

The effect of refining pressure on the development of pulp freeness and fibre length is shown in Figure 6 and 7. The testing pressure was 100, 300 and 500 kPa, corresponding to a saturated steam temperature 120, 143 and 158°C, respectively (*21*). The refiner was operated at a constant rotational speed of 1500 rpm. It was found that at the typical refining pressure of 300 kPa, there are no distinct differences in the development of pulp freeness and fibre length between grit and reference segments. Regarding grit segments, refining at a lower refining pressure yields faster development of freeness.

Depending on the viscoelastic properties of the wood raw material, lower temperature provides easier breakdown of the cell wall structure. However, at lower refining temperature (refining pressure of 100 kPa), a shorter fibre length down to 1.4 mm was obtained. This suggests that if grit segments are to be used at a high rotational speed of 2400 rpm to achieve a fast development of CSF, then a refiner pressure of 300 kPa needs to be used to maintain the fibre length at an acceptable level.

First-stage TMP pulp

Figure 8, 9 and 10 show the external fibrillation, the flexibility, and the pore volume of fibre cell wall of the first stage

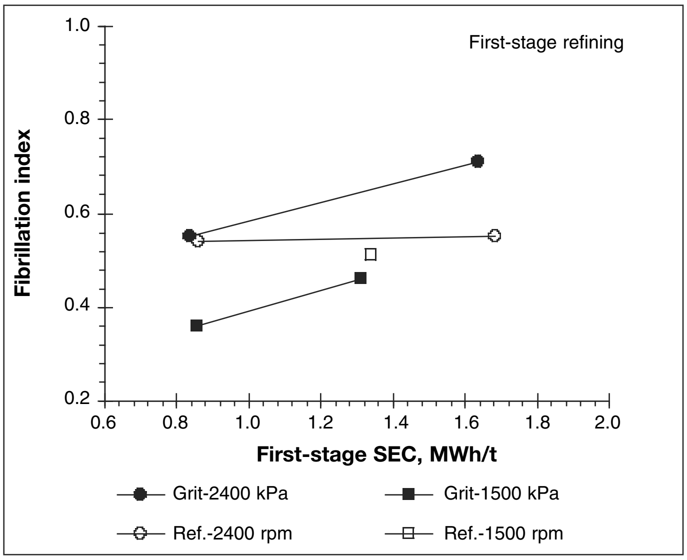

Fig. 8 External fibrillation of long-fibre fraction (R30) in first-stage refining as a function of specific energy consumption. Refining pressure was controlled constantly at 300 kPa.

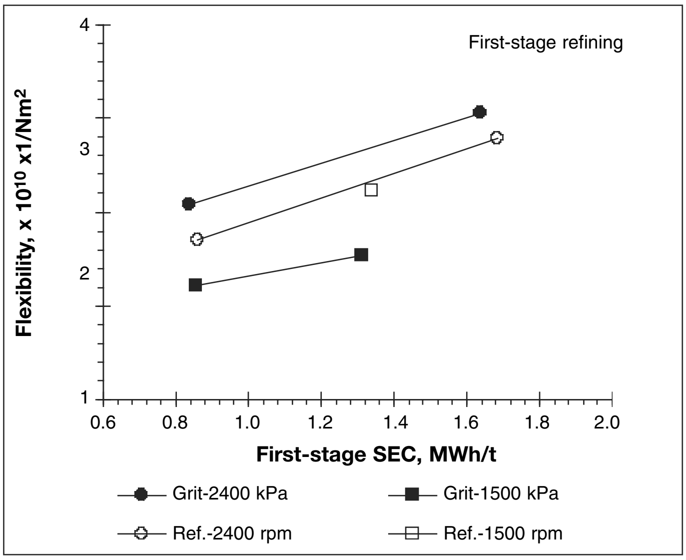

Fig. 9 Fibre flexibility of long-fibre fraction (R30) in first-stage refining as a function of specific energy consumption. Refining pressure was controlled constantly at 300 kPa.

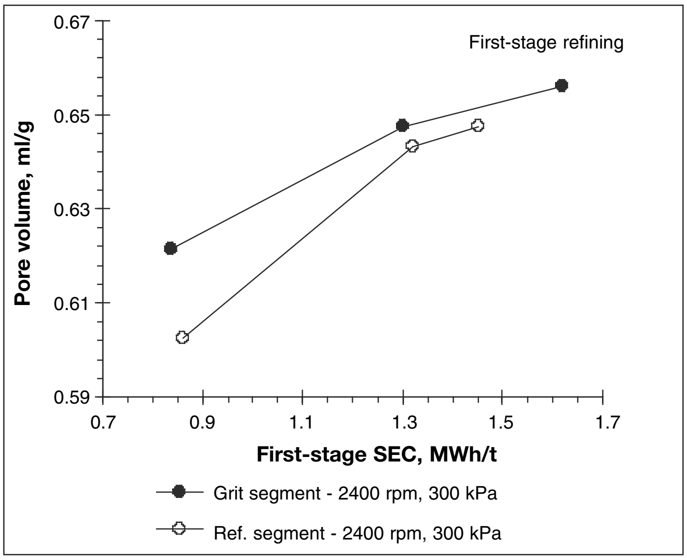

Fig. 10 Pore volume of fibre cell walls as a function of specific energy consumption in the firs-stage refining.

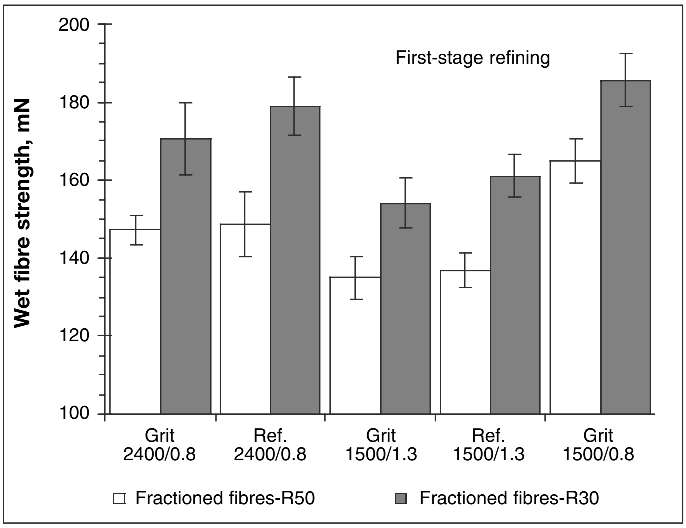

Fig. 11 Strength of wet fibres in the first stage refining. Refining pressure was controlled constantly at 300 kPa.

fibres. The results showed that a grit segment operated at a high rotational speed of 2400 rpm gives a higher level of fibrillation, fibre flexibility and pore volume than refining with the reference segments. This indicates that a possibly high level of fibre cell wall disruption could be achieved during first-stage refining when using grit segments. However, when the refiner equipped with grit segments was operated at a normal rotational speed of 1500 rpm, the degree of external fibrillation and flexibility were found to be lower than that obtained with the reference segments. Although the results presented are based on averages of only two or three points. We believe that they can be relied upon for general trends. The apparently abnormal results for 1500 rpm may be due to the particular design and the cladded position of the grits. This is being investigated by the suppliers.

Figure 11 shows the strength of wet fibres collected from 30- and 50-mesh screens determined based on a zero-span tensile test (*17*). The strength of first-stage pulp fibres was found to be important for the resistance of fibres to damage in the second-stage refining, as shown in the previous study (*12*). In the present trial, the strength of long fibres was found to be mainly affected by the specific energy input. There are no differences in the strength of wet fibres obtained with grit and reference segments. A wet strength of long fibres (R30) was about 150-180 mN at specific energy of 0.8 MWh/t obtained with both grit and reference segments.

CONCLUSIONS

Grit segments fitted to a Sunds Defibrator RGP 44 single-disc refiner during first stage refining operated smoothly without any adverse effects on the motor load or feeding system. Its operation at a high rotational speed also gave good performances. When operated at a rotational speed of 2400 rpm the grit segments produced the pulp with a higher level of fibrillation, fibre flexibility and pore volume than refining with the reference segments. The strength of long fibres was found to be not affected by grit segments. However, the grit segments produced a shorter fibre length and caused a faster drop in fibre length at an energy input above 1.3 MWh/t. It is therefore recommended that to increase the disruption and opening of the fibre cell walls without reducing the fibre length, the first-stage refiner should be operated at high rotational speed of 2400 rpm, pressure of 300 kPa, and the specific energy consumption should be kept between 0.8-1.3 MWh/t.

In Part 2 of this study, the potential for reducing energy consumption will be discussed in more detail.

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