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Sustainpack

Innovation and sustainable Development in the Fibre Based Packaging Value Chain

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Dry refining of fibres

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Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
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ABSTRACT

The aim of the present study was to clarify possibilities to refine paper in high dry content without loosing the technical properties of paper. In addition, the effect of different process parameters on refining results as well as fibre level changes was also objectives of this study. Delivery of the dry refined fibres to other partners of the project was the main task.

Dry refining was carried out with both disk refiner and hammer mill. Results showed that refining of paper in high dry content succeeded. At their best results were close to the strength properties of the reference (wet disintegrated mass). However, in some tests strength properties were considerably lower compared to reference.

CONTENT

1. AIM OF THE STUDY

The aim of the study was to find out possibilities to refine fibres in high dry content without loosing the technical properties of paper. In addition, the effect of different process parameters on refining result as well as fibre level changes was also objectives of the present study.

2. MATERIALS

With disk refiner, materials used were unprinted newspaper and copy paper. Both of the materials were cut earlier into 30 * 30 mm paper flakes and copy paper.

Hammer mill tests were carried out with mixed bleached softwood and hardwood kraft, bleached softwood kraft and chemithermomechanical pulp (CTMP) from softwood. Bleached softwood kraft contained both spruce (44%) and pine (56%) fibres. Early wood content was 80%. Mixed softwood and hardwood kraft contained 20% of hardwood kraft. All the pulps were once dried.

3. METHODS

The first of the tested equipments was single disk refiner meant for reject refining of the thermomechanical pulp. Experiments were also carried out with hammer mill equipment meant for fluff manufacturing.

3.1 Disk refiner

30*30 mm paper flakes were fed between disks using conveyer belt and screw conveyer. Condition parameters were selected and paper was allowed to refine for couple of minutes before sampling. Experiments were carried out using single disk refiner with a diameter of 20”. There were two segment profiles tested in these experiments; fine (disk 1) and rough (disk 2) (Fig. 1). The studies were carried out with both pressurized (within steam atmosphere) and unpressurized (within air atmosphere). Conditions used were the rotation number of the disk, rough and fine segment profiles, gap and pressure (see Table 1). Specific energy consumption (SEC) of the dry refining was high varying between 50-500 kWh/t with an average of 200 kWh/t.

Table 1. Variables and parameters with disk refiner.

Variable	Parameter
Gap, mm	0.15-1.5
Rotation number of the disk, min^{-1}	1500
Segment profile	rough, fine
Pressure, kPa	0-180

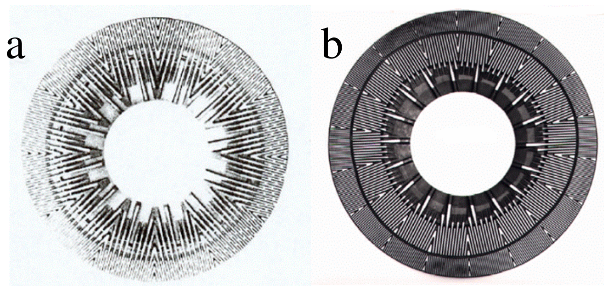

Fig. 1. Tested segment profiles; rough (a) and fine (b).

3.2 Hammer mill

Dry refining of the material was made also with hammer mill. The material was fed at the selected rate as a 14 cm wide strip. As the material was fed to the hammer mill, hammers shredded mechanically fibres from pulp sheet. Around the hammers there was a changeable screen basket with different hole diameters. Shredded fibres were refined against the screen basket profile until they were small enough to pass through the screen holes. Adjustable operating parameters allowed for precise control of pulp feed speed, hammer speed, air flow, feed rate and gap. Fig. 2 shows the principle of the hammer mill operation. The photographs of the hammer mill are shown in Figure 3. SEC varied between 70-110 kWh/t, which was clearly lower compared to disk refiner. However, it was significantly higher compared to SEC of pulping (10-40 kWh/t).

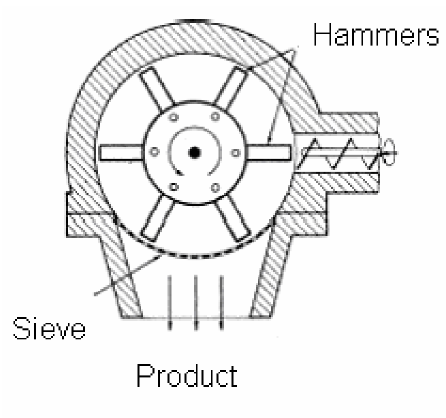

Fig. 2. Principle of the hammer mill operation.

Fig. 3. Open hammer mill (a) and feeding of the material to the hammer mill (b).

Parameters tested are shown in Table 2.

Table 2. Variables and parameters tested with hammer mill.

Variable	Parameter
Gap, mm	1.2, 1.4
Feed rate, m/min	18, 20
Rotor speed, rpm	600, 2500, 2900
Screen basket aperture, mm	3.2, 4, 6 and without screen basket
Blast air, m^3/s	0.3

All the materials delivered to the project participants were dry refined using parameters presented in Table 3.

Table 3. Parameters of the hammer mill.

Variable	Parameter
Gap, mm	1.2
Feed rate, m/min	18
Rotor speed, rpm	2900
Screen basket aperture, mm	3.2
Blast air, mPPP^{3P}/s	0.3

3.3 Analyses

Before analyses, samples containing chemical pulp were wet disintegrated and mechanical pulp containing samples were hot-disintegrated. Both the original material (sheet) and the dry refined fibres were wet disintegrated and these samples were compared to find out proceeding of fibre properties.

All the standards used in the analyses are presented in Table 4.

Table 4. Analyses and standards.

Analysis	**Standard**
Dry content	SCAN-C 3:78
Hot-disintegration	SCAN-M 10:77
Consistency	SCAN-M 1:64
CSF, Canadian Standard Freeness	SCAN-M 4:65
Laboratory sheets	SCAN-C 26:76
Basis weight	SCAN-P 7:96
Tensile strength	SCAN-P 16:76
Tear strength	SCAN-P 11:73
Burst strength	SCAN-P 24:77
Pulp sheet	SCAN-CM 11:95
Brightness	SCAN-P 3
Optical properties	SCAN-C 27:76

4. RESULTS

4.1 Disk refiner

In these experiments with disk refiner, the considerable amount of the material did not refined completely. Instead, after disk refining there was paper flakes and fibre bundles, so called knots, left. For newspaper, the unrefined fraction varied between 20-90%. For newspaper it was affected by gap, segment profile, and refining phase (air or steam) (Fig. 3). In refining, a small amount of unrefined material is desired. However, decreased amount of unrefined fraction led to fibre cutting and decreased strength properties. This is perceivable in Figs. 4 and 7. With fine segment profile the amount of unrefined fraction was the lowest, but fibres tended to cut and due to this also strength properties were decreased. For copy paper, the amount of unrefined fraction as well as fibre length seemed to vary mainly as a function of gap (Figs. 5 and 6).

The strength properties with pressurized single disk refiner within steam atmosphere were obtained to be better compared to tests carried out with unpressurized single disk refiner within air atmosphere. For newspaper, the tensile and tear strength were close to results of wet disintegrated paper (reference) (Fig. 7). There were not any differences between optical properties. For copy paper, the strength potential was significantly weaker compared to reference (Fig. 8).

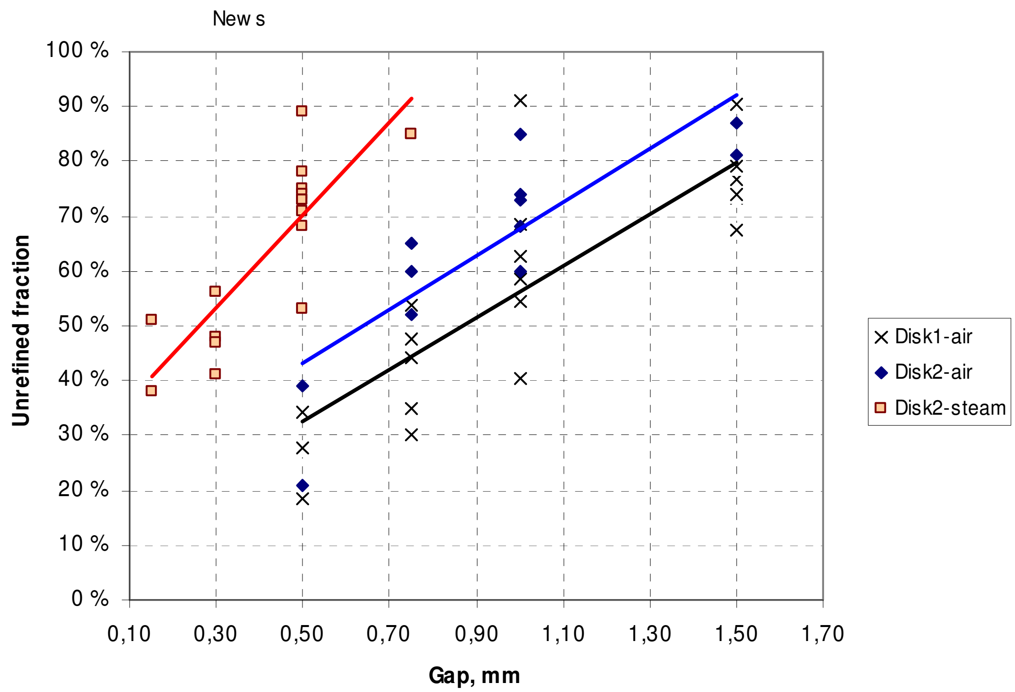

Fig 3. Unrefined fraction as a function of gap for newspaper.

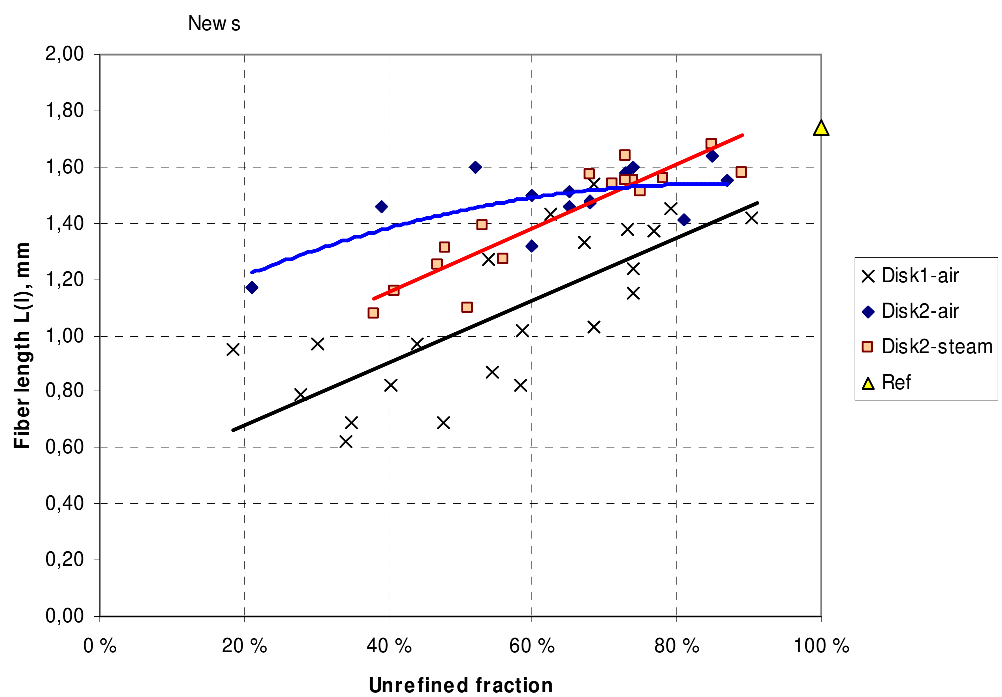

Fig. 4. Length weighted fibre length as a function of unrefined fraction for newspaper.

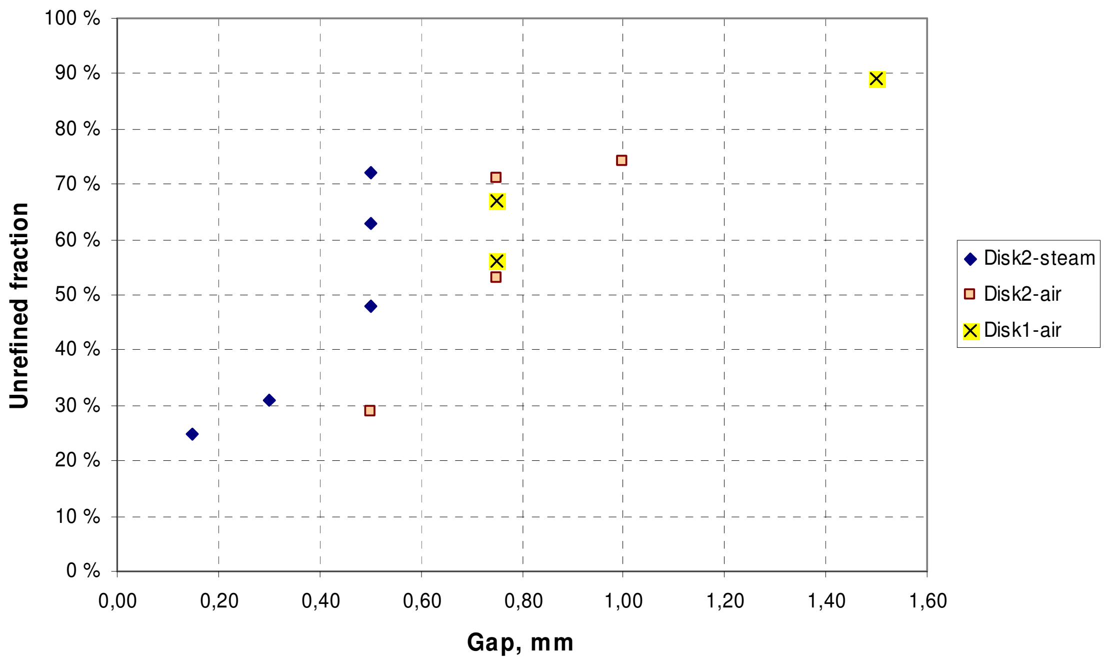

Fig. 5. Unrefined fraction as a function of gap for copy paper.

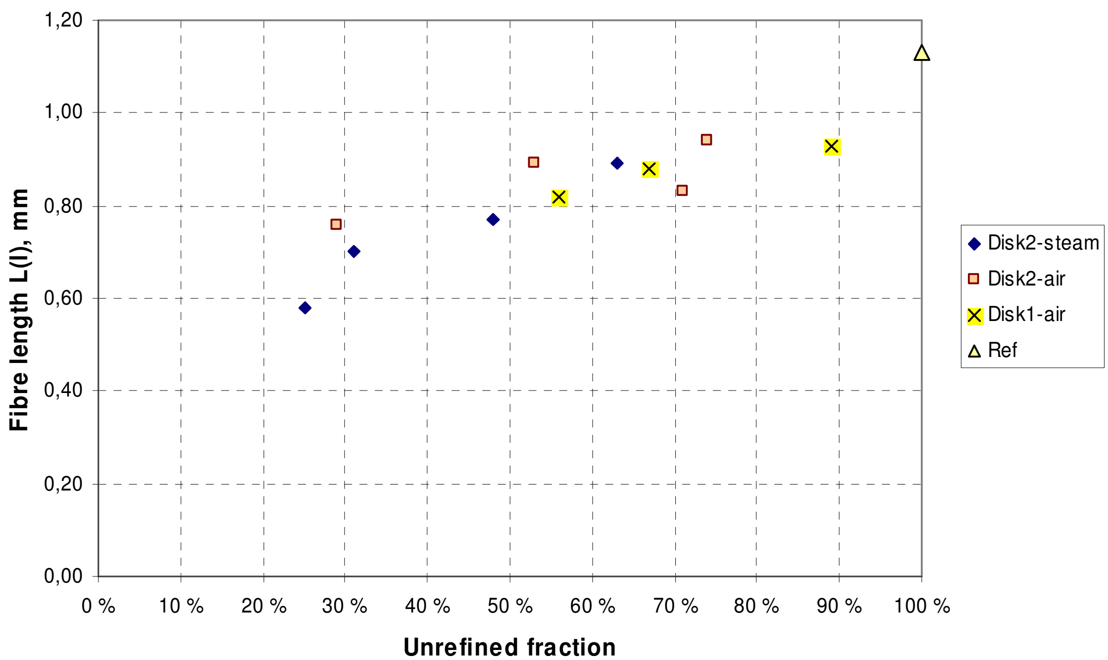

Fig. 6. Fibre length as a function of unrefined fraction for copy paper.

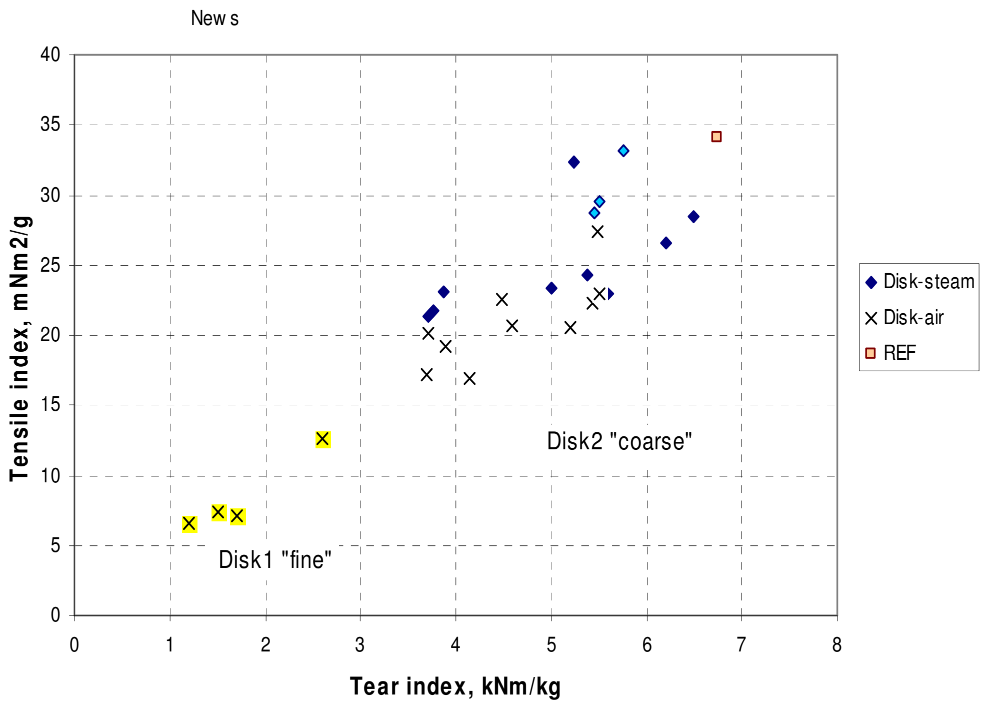

Fig. 7. Strength potential of the dry refined newspaper.

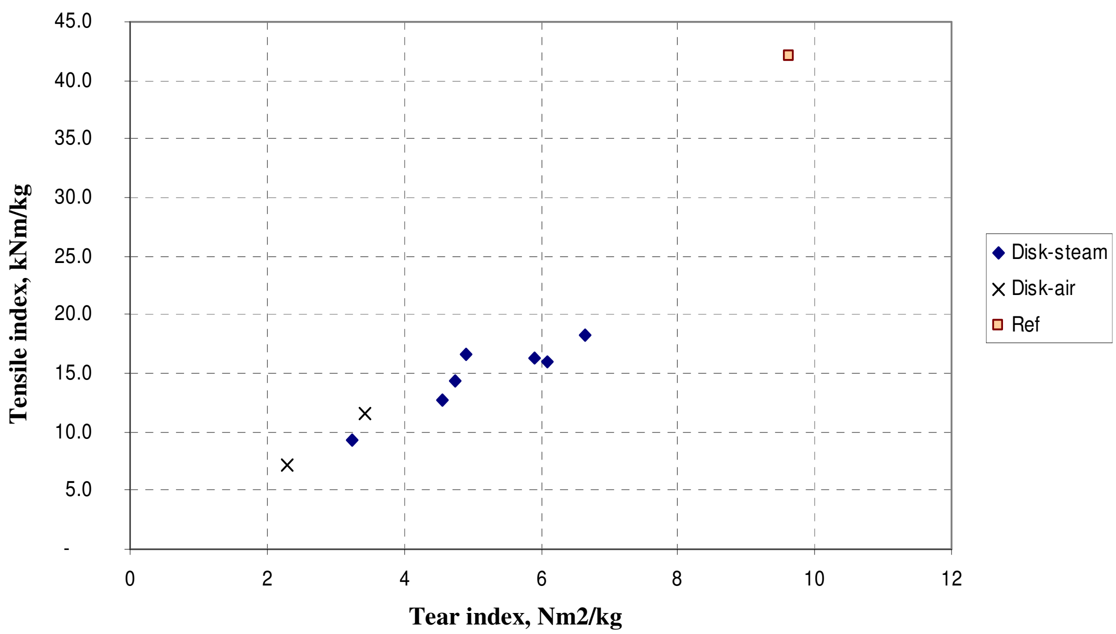

Fig. 8. Strength potential of the dry refined copy paper.

4.2 Hammer mill

Screen aperture was the most significant parameter affecting amount of unrefined fraction (Fig. 9). With increased screen aperture the amount of unrefined fraction increased. The relative humidity was also observed to affect strongly; with increased relative humidity from 30% to 39%, the amount of unrefined fraction decreased from 35% to 25%. The other process parameters had minor effect on refining result.

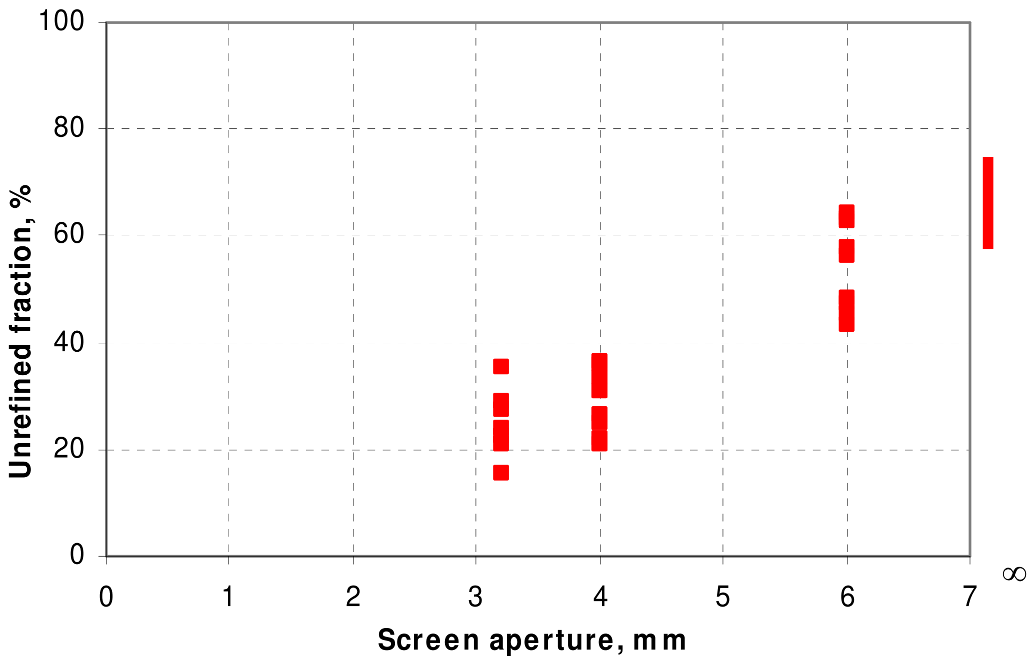

Fig. 9. Effect of screen aperture on unrefined fraction. "∞" means experiments carried out without screen basket. Experimental material was mix of softwood and hardwood.

It was observed, that with chemical pulps the fibre length (Fig. 10) and the most strength properties (for example tensile strength, Fig. 11) remained. Only tear strength (Fig. 12) was observed to decrease compared to reference. The decrease in internal strength of the fibre might be the reason for that because there was not any significance difference in fibre length.

With CTMP, the fibre length and strength properties decreased significantly compared to reference (Fig. 10, 13 and 14). The stiffness of the fibres might explain the differences between chemical pulp and CTMP; more flexible chemical fibres are able to resist the mechanical stress better compared to stiffer CTMP fibres. Probably due to this the fibre length of the CTMP decreased. Decreased fibre length was perceivable in decreased tear strength. Also tensile strength of the CTMP was lower compared to reference.

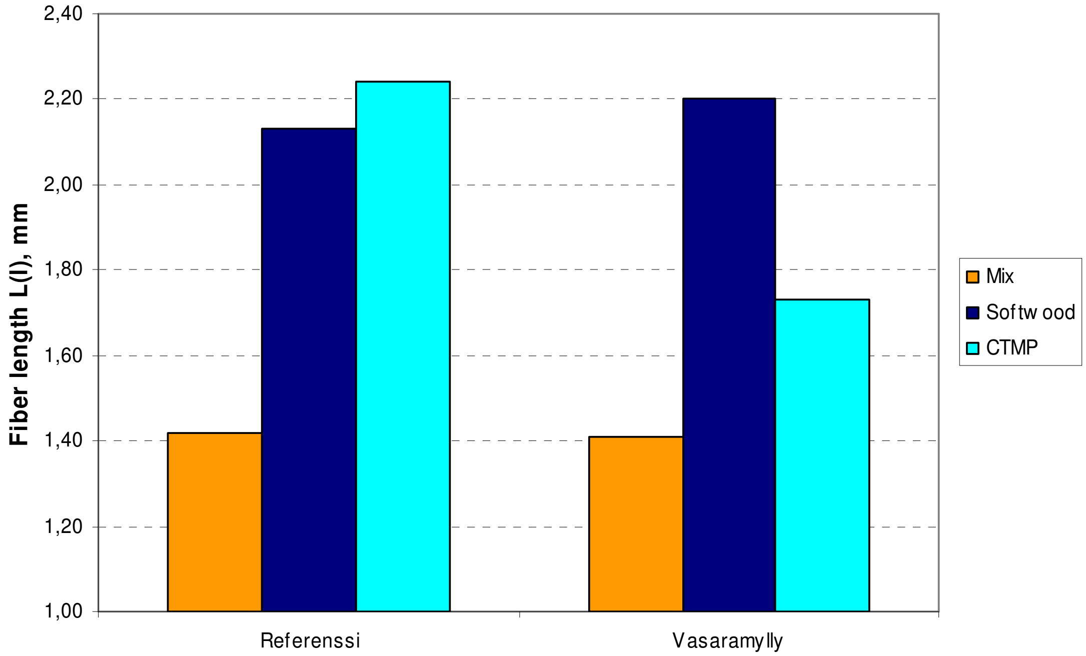

Fig. 10. Fibre length after the wet disintegration (reference) and dry refining with hammer mill.

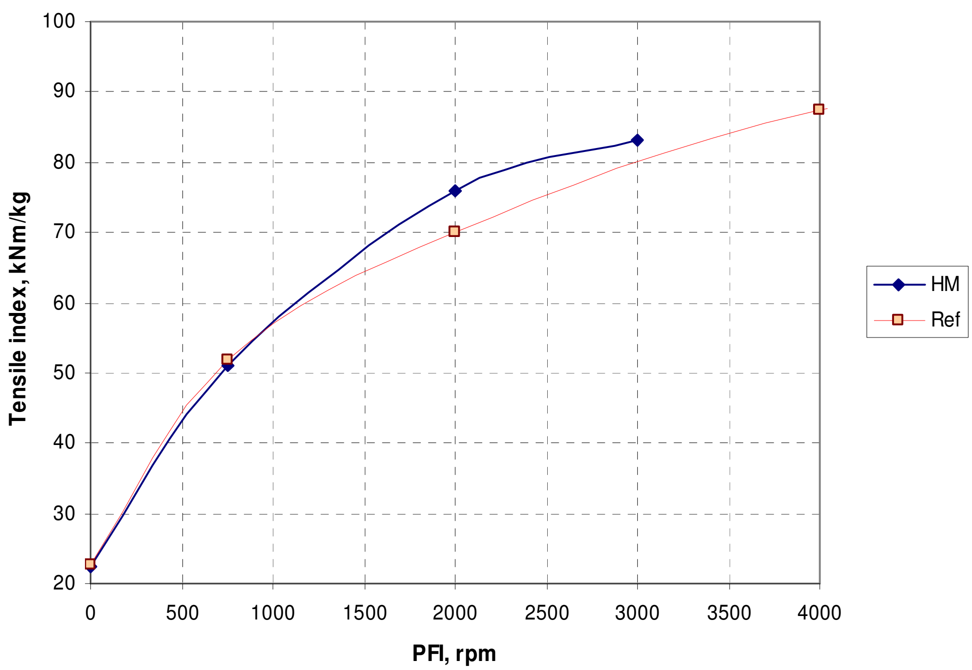

Fig. 11. Tensile index as a function of PFI for softwood. HM: hammer mill refining; Ref: wet disintegrated mass.

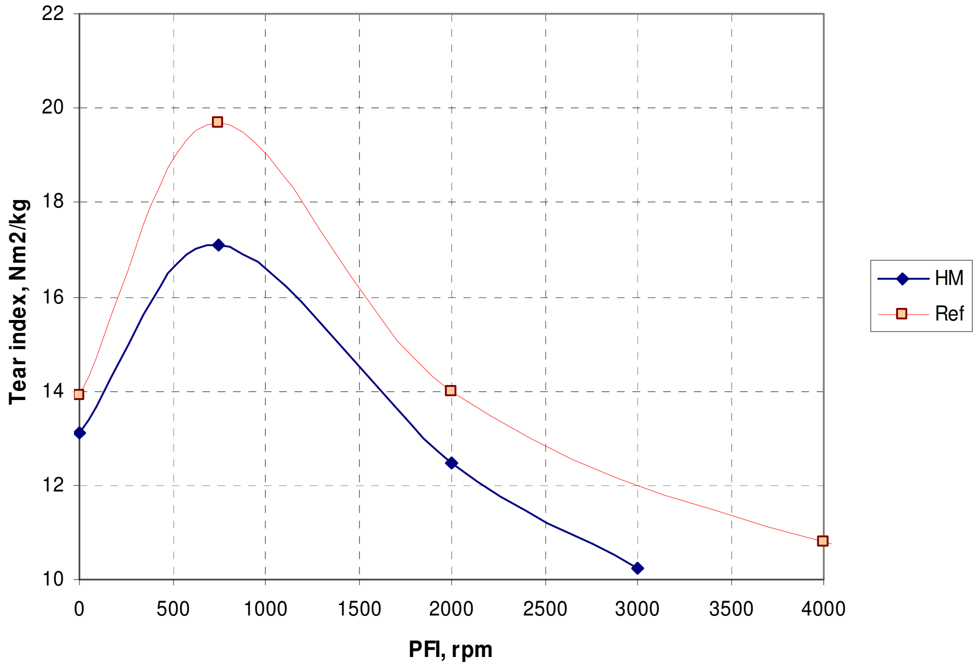

Fig. 12. Tear index as a function of PFI for softwood. HM: hammer mill refining; Ref: wet disintegrated mass.

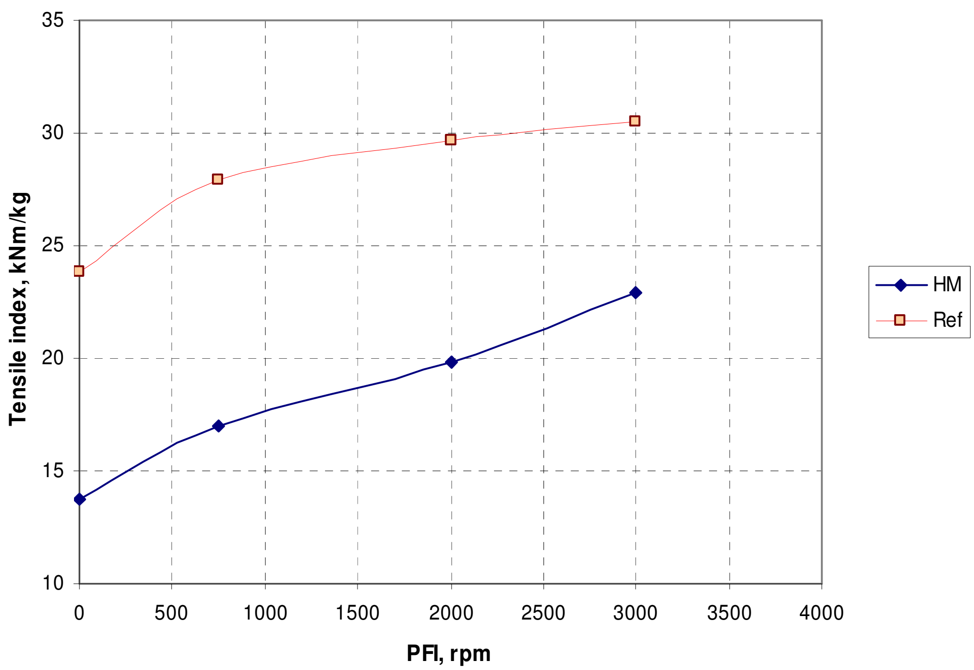

Fig. 13. Tensile index as a function of PFI for CTMP. HM: hammer mill refining; Ref: wet disintegrated mass.

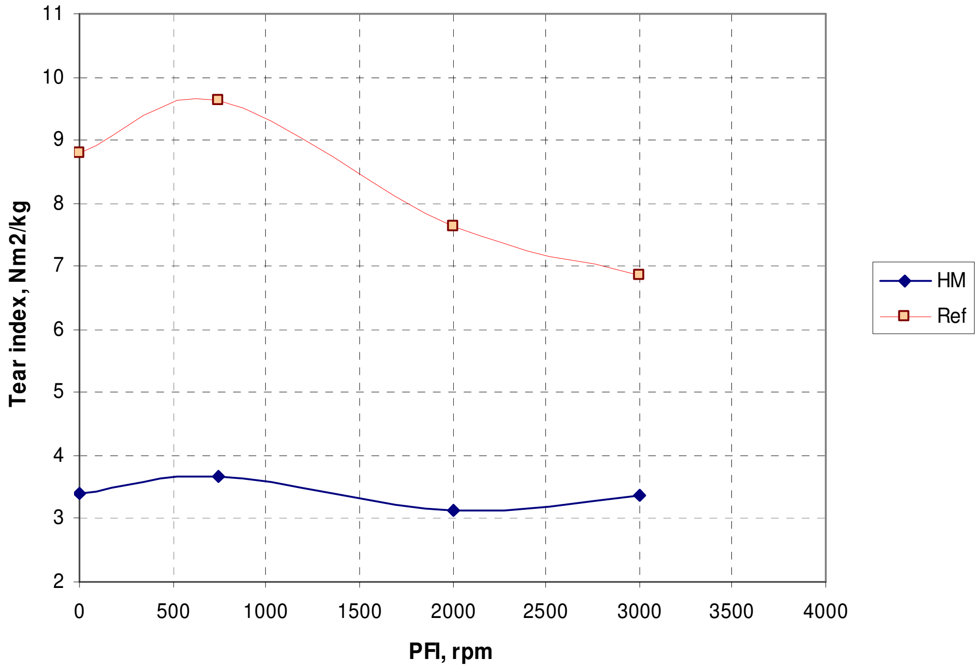

Fig. 14. Tear index as a function of PFI for CTMP. HM: hammer mill refining; Ref: wet disintegrated mass.

5. SUMMARY AND CONCLUSIONS

With disk refiner, the gap and segment profile was observed to have significant effect on dry refining result. The optimisation of segment profile would probably decrease the amount of unrefined fraction and would enhance fibre properties. Better mass properties were obtained with pressurized disk refining within steam atmosphere compared to the tests carried out with unpressurized disk refiner within air atmosphere. With single-stage disk refining the yield varied between 10-80%. The yield was observed to increase with decreasing gap. However, with increasing yield the fibre length tended to shorten. Some strength properties were lost in dry refining, but at its best results were close to reference. With copy paper, strength properties were much lower compared to reference. Optical properties were studied to be close to reference.

Hammer mill tests were carried out with chemical pulps and with CTMP. It was observed the screen aperture to be the most significant parameter affecting the amount of unrefined fraction. However fibre length did not correlated with the diameter of tested screen apertures. With screen aperture of 3.2 mm the amount of unrefined fraction was about 35%. Gap, rotor speed and feed speed of the material did not affect significantly refining result. Fibre length and paper technical properties remained with chemical pulps although minor weakening was observed in tear strength. This might be due to the weakening of the internal strength of the fibres. With CTMP (softwood), the fibres tended to shorten and strength properties decreased. Probably long and stiff fibres were unsuitable for hammer mill refining. The amount of unrefined fraction was higher than it was expected, which probably was due to the low relative humidity.