Determination the Specific Fibre Weight of Cellulose Fibres Using Fibre Length Analyser

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***Abstract*— Paper is reality in our everyday life. Modern paper production technology is divided into several sections, roughly corresponding to the processes involved in making handmade paper. In this scientific work we have elaborated a new specific quantity, measuring the weight and number of pulp single fibres in aqueous medium. The measurement has been fulfilled in a Kajaani FS 100 fibre length analyser.**

I. INTRODUCTION

Paper making processes cause the change of the length and weight of the cellulose fibres with a different order of magnitude. Fibre length is a fundamental property of pulp. The determination of the fibre length and fibre weight of pulp fibres is important in paper making technology and environmental protection as well because the effluents from paper mills contain solids and dissolved substances. Solids (fibres, fillers) are mostly removed from the effluent in a chemo-mechanical clarification process by the use of flocculants [1] [2].

It is important to emphasize the pollution in the waste water of a paper mill depends on the type of raw materials and the paper production processes. The arguments given above prove that it is important to measure these properties. [1].

Paper is a reality in our everyday life. Modern paper production technology is divided into several sections, roughly corresponding to the processes involved in making handmade paper.

Pulp is refined and mixed in water with other additives to make pulp slurry. In paper making, a dilute suspension of fibres (Figure 1) in water is drained through a screen, so that a mat of randomly interwoven fibres is laid down. Water is removed from this mat of fibres by pressing and drying to make paper. The water is acting as a binding agent between the fibres by forming molecular bridges with hydrogen bonds.

The properties of papers are highly depended on the quality of the included cellulosic fibres.

Interfibrillar and intermolecular actions occur during the papermaking process.

The first interaction among the fibres is the felting occurring in the sieve section whereas the second one is the forming of hydrogen bonds among the cellulose molecules during drying. Such fibres are needed for the procedure in which the ratio between the length and the width of the fibre is 70:1. The mass (grammage) and the strengths of the produced paper are characterized by those of the included single fibres.

Figure 1. Pine (picea abies) tracheids fibres

So, determination of the fibre length and fibre weight of different pulp fibres is fundamental. The earliest method to measure the fiber length, width and coarseness, was the microscopic method (Wilson, 1954). This procedure suffered from defects (fractionation of flat or collapsed fibers) that occur during measurements of the fibers. We also studied the morphological properties of fibres using WAT-250 D (W96P) video microscope (Figure 2.) before we used the fibre length analyser

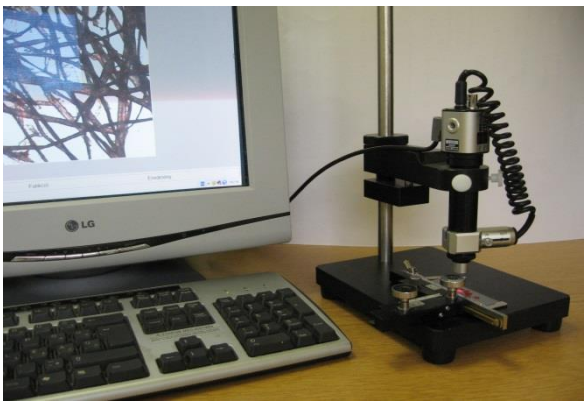

Figure 2. WAT-250 D (W96P) videomicroscope

Consequently new method has been elaborated by us for the measurement of the mass of the mentioned single

fibres. The measurement has been fulfilled in a Kajaani FS 100 fibre length analyser. This analyser is consisting of a capillary tube (0.2 mm) through which an aqueous suspension (density of suspension: 1 per thousand) of the fibres is passed.

The pulp and paper industry started to use the Kajaani FS-100 in the 1980s; this was the first automated fiber analyser [1]. "And is an optical device accepted as the method for laboratory fibre length measurements (Tappi T271) to measure fibre length and coarseness" [3]. This tool is ready for quick and one simple measurement procedure [4].

II. MATERIALS AND METHODS

Pulp Fibres

In scientific research we studied different cellulose fibres of different origin:

– sulphate pine cellulose: bleached or unbleached and dried or undried,

– mixed hardwood semi-chemical pulp: dried or undried,

– hardwood cellulose: bleached and dried,

– CTMP (Chemical Thermo Mechanical Pulp) pine: dried or undried.

These pulp fibres are obtained by chemical pulping from softwood, hardwood, and mechanical pulp is produced by mechanical defibration of wood. Pulping represents the process by which wood or other lignocellulosic material is reduced to fibrous mass, denoted as pulp [5][6].

During chemical pulping, most of the lignin is removed from the raw material.

The yield of the pulp is, therefore, only 45 to 55%. Two main industrial processes of chemical pulping are used:

– the sulfate process with sulfate pulp as product,

– the sulfite process with sulfite pulp as product.

The alkaline sulfate process uses sodium sulfide and sodium hydroxide as pulping chemicals. The acidic sulfite process is based on calcium, magnesium, and sodium or ammonium bisulfide. Worldwide, the sulfate process is used in up to 90% of cases.

Softwood is composed of two types of cells: tracheids (90-95%) and ray cells (5-10%). Softwood fibres are by definition wood tracheids. Tracheids give the softwood mechanical strength (particularly thick-walled latewood tracheids) and transports water. Softwood fibres are closed at both ends.

The median fibre length of Finnish pine and spruce is approximately 3 mm. Due to their long fibres, softwood pulps are often referred to as long fibre pulps[7][8].

Kajaani FS 100 Fibre Length Analyser

The main part of the device is a capillary tube (0.2 mm) through which the thin suspension of the fibres is conducted. On one side of the capillary (Figure 3.) a lamp is positioned and on the other, opposite side, is a detector. When a fibre goes through the capillary, the polarized picture of the single fibre is transmitted into the detector and from this we can calculate the length of the fibre. "A low-pressure vacuum pump and chamber collects the analyzed fibres. The measurement range is between 0-6.79 mm, divided into 24 classes, of which the first 12 classes are resolved to 0.2 mm lengths and the last 12 have a resolution of 0.4 mm (for the 0-0.7 mm range)" The fibre counting is manually with a keyboard. The fibre suspension is diluted (0.0004% consistency). [9][10][11][12].

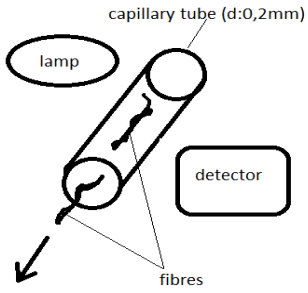

Figure 3. Fibre Length Analyser

Methods

In our method for the establishing of the mass of cellulosic single fibres the following 4 steps should be fulfilled:

1. Determination of the dry matter content of the sample.
2. Cellulose sample with 0.1-0.2 g absolute dry fibre content should be pulped in 1000 ml distilled water.
3. 100 ml of the above mentioned suspension should be diluted to 1000 ml by distilled water.
4. 100 ml of the suspension should be filled into the Kajaani 100 fibre analyser to determine the average fibre length (laf) and the total number of the included fibres (tn).

Average single fibre mass (masf) can be calculated by dividing the included mass of the fibers (mf) by their above gained number (tn):

$$m_{asf}(g) = \frac{m_{af}(g)}{tn} \quad (1)$$

The above discussed data enable the calculation of the specific mass (mspec) in g/mm of the single fibre:

$$m_{spec}(g/mm) = \frac{m_{asf}(g)}{l_{af}(mm)} \quad (2)$$

Initially the impact of the grinding of different ECF bleached pine fibres in Jokro mill has been determined on the mass of the single fibre. 5 samples of different freeness (12, 18, 24, 32, 60 °SR) have been produced by grinding in Jokro mill.

5 Bauer McNett fractions have been separated (mesh: 14, 30, 50, 100, 200) from each mentioned samples of different freeness respectively. The average mass and length of single fibre of mentioned samples have been determined and compared with each other.

The average mass and length of single fibres of dried and never dried pine sulphate celluloses respectively after

grinding in PFI mill have been determined and compared with each other thereafter.

Further experiments have been performed with Chemical Thermo Mechanical Pulp (CTMP) single fibres.

Finally the average mass and length of single fibre of 9 different cellulosic fibres of the same freeness have also been studied.

III. RESULTS AND DISCUSSION

Obtained data in the 1st set of experiments are summarised in Figure 4 and 5.

The first observation from the obtained data is that the grinding practically does not decrease the average length (Figure 6) of single fibres but it significantly decreases their mass.

From this it might be concluded that the grinding keeps the lengths of the fibre practically unchanged but does sensitively decrease its cross section.

Final conclusion is that in the length, acting binding forces are strong primary ones whereas in the cross sections acting ones are much weaker secondary forces.

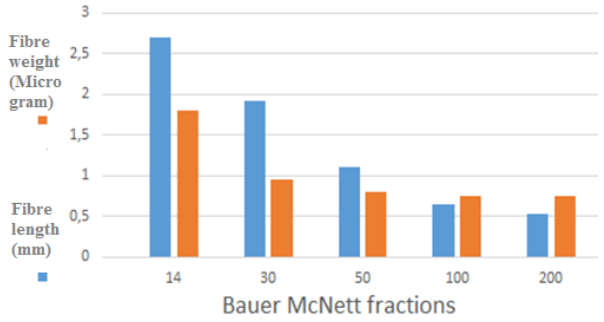

Figure 4. Average fibre length and weight of ECF bleached pine fibres of 12 oSR freeness (after grinding in Jokro mill) and 5 Bauer McNett fractions.

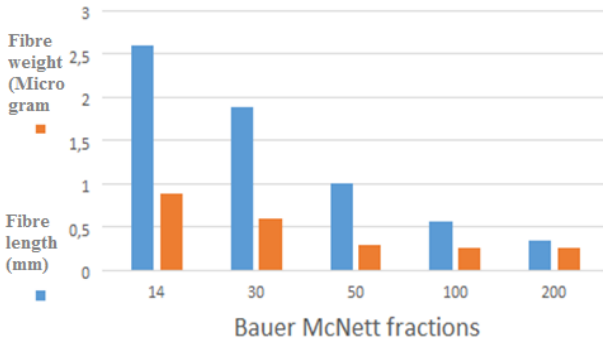

Figure 5. Average fibre length and weight of ECF bleached pine fibres of 60 oSR freeness (after grinding in Jokro mill) and 5 Bauer McNett fractions

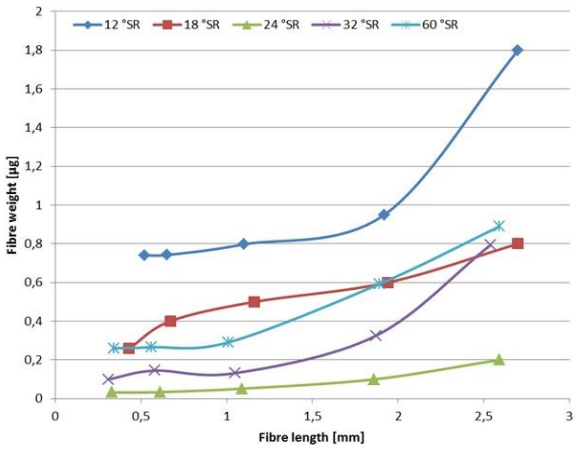

Figure 6. Average fibre length and weight of ECF bleached pine fibres of 5 different freeness and 5 Bauer McNett fractions of each freeness.

Obtained data in the 2nd set of experiments are summarised in Tables 1 and 2. Concerning changes in fibre length and fibre mass after grinding leading to freeness form 13 °SR to 57 °SR

TABLE I.
CHANGES IN AVERAGE FIBRE MASS, AVERAGE FIBRE LENGTH AND SPECIFIC FIBRE MASS OF NEVER DRIED PINE SULPHATE CELLULOSE SINGLE FIBRE IN THE FUNCTION OF FREENESS AFTER GRINDING IN PFI MILL.

Bleached never dried sulphate pine ground in a PFI mill			
Freeness (SR°)	**Fibre length (mm)**	**Fibre weight (µg)**	**Specific fibre weight (µg/mm)**
13	2,27	0,303	0,133
22	2,26	0,298	0,131
33	2,23	0,295	0,132
47	2,21	0,295	0,133
57	2,19	0,289	0,131

The changes in specific fibre mass (Table 3) are nearly

TABLE II.
CHANGES IN THE AVERAGE FIBRE MASS, AVERAGE FIBRE LENGTH AND IN THEN SPECIFIC FIBRE MASS OF DRIED PINE SULPHATE CELLULOSE SINGLE FIBRE IN THE FUNCTION OF FREENESS AFTER GRINDING IN PFI MILL.

Bleached never dried sulphate pine ground in a PFI mill			
Freeness (SR°)	**Fibre length (mm)**	**Fibre weight (µg)**	**Specific fibre weight (µg/mm)**
13	2,3	0,381	0,165
20	2,27	0,314	0,138
32	2,25	0,283	0,125
45	2,08	0,273	0,131
54	2,04	0,268	0,131

neglectable in both samples because the loss in fibre length and fibre mass are proportional.

Both the length and the mass of CTMP (Table 4) single fibres decreased in the function of the increased freeness

TABLE III.
CHANGES IN AVERAGE FIBRE MASS, AVERAGE FIBRE LENGTH AND SPECIFIC FIBRE MASS OF NEVER DRIED CHEMICAL THERMO MECHANICAL PULP (CTMP) SINGLE FIBRE IN THE FUNCTION OF FREENESS AFTER GRINDING IN PFI MILL.

Bleached never dried sulphate pine ground in a PFI mill			
Freeness (SR°)	**Fibre length (mm)**	**Fibre weight (µg)**	**Specific fibre weight (µg/mm)**
26	2,2	0,628	0,285
35	1,81	0,537	0,296
40	1,73	0,401	0,231
54	1,44	0,366	0,254
26	2,2	0,628	0,285

as well for dried as for never dried samples. No such tendency could be concluded in case of specific fibre mass data. Obtained data in the 4th set of experiments are summarized in Figures 6 and 7.

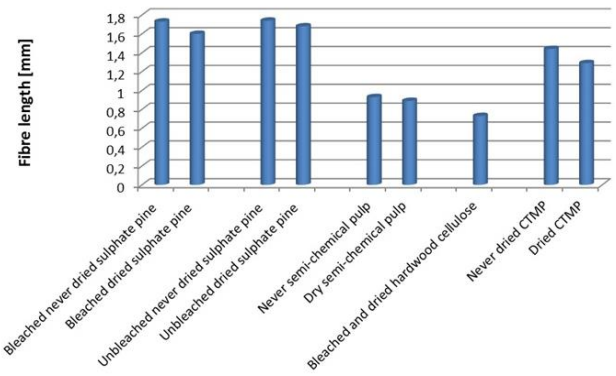

Figure 7. Changes in the average fibre length of cellulose single fibre of different prehistory at the same freeness (50 °SR).

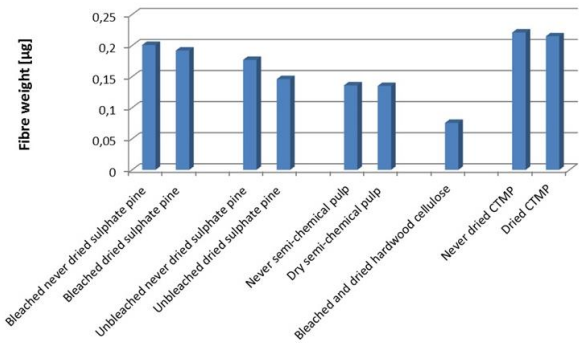

Figure 8. Changes in the average fibre mass of cellulose single fibre of different prehistory at the same freeness (50 °SR).

When comparing the average fibre length it could be concluded that the unbleached never dried pine sulphate cellulose has the highest value and the bleached hardwood cellulose has the lowest one.

IV. CONCLUSIONS

The elaborated method by us for the determination of the average single fibre mass for cellulosic fibre of different origin could be successfully used for a wide range of cellulosic fibres.

When comparing the results of average fibre mass it could be concluded that the unbleached never dried pine sulphate cellulose has the highest value and the bleached hardwood cellulose has the lowest one.

REFERENCES

[1] Bichard, W. and P. Scudamore: "An evaluation of the comparative performances of the Kajaani FS-100 and FS-200 fiber length analyzers". *Tappi J.*, 1998, 71: 149-155.

[2] Jackson, F.:"Fiber length measurement and its application to paper machine operation". *Appita*, 1968, 41: 212-216.

[3] Yalcin Copur and Hannu Makkonen: "Precision and Accuracy Studies with Kajaani Fiber Length Analyzers". Journal of Applied Sciences, 7: 1043-1047. (2007)

[4] Piirainen, R.:"Optical method provides quick and accurate analysis of fiber length". *Pulp Paper*, 1985, 59: 69-71.

[5] TAPPI T 271 "Fiber Length of Pulp and Paper by Automated Polarized Optical Analyzer Using Polarized Light."

[6] Yalcin Copur and Hannu Makkonen, Precision and Accuracy Studies with Kajaani Fiber Length Analyzers. *Journal of Applied Sciences*, 2007, 7: 1043-1047.

[7] Anderson, O., An investigation of the hillbom and bauer mcnett fiber classifiers. *Svensk Papperstid*, 1953, 56: 704-709.

[8] Bentley, R.G., P. Scudamore and J.S. Jack, A comparison between fiber length measurements. *Methods Pulp Paper Mag*. Canada, 1994, 95: 41-45.

[9] Bichard, W. and P. Scudamore, An evaluation of the comparative performances of the Kajaani FS-100 and FS-200 fiber length analyzers. *Tappi J*., 1998, 71: 149-155.

[10] Butler, W.T., 1948. The use of the bauer mcnett fiber classifier. Pulp Paper Mag. Canada, 49: 133-136.

[11] Clark, J.D.A., The measurement and influence of fiber length. *Tappi Techonol. Assn. Papers*, 1942, 25: 556-562.

[12] Copur, Y., D. Kiemle, A. Stipanovic, J. Koskinen and H. Makkonen, HNMR spectroscopic determination of carbohydrates and yield in pine and maple pulps. *Paperi Puu*, 2003, 85: 158-162.