FIBER MEASUREMENT

Measurement of fiber coarseness with optical fiber length analyzers

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ABSTRACT

An important issue in measuring fiber coarseness with optical fiber length analyzers is the accuracy of the mass of the pulp on which one makes measurement. The authors describe a method that allows delivery of a small, debris-free pulp sample of known mass to the analyzer. The method meets the needs for chemical wood pulps.

Application: *Optical fiber length analyzers can provide consistent and meaningful results on pulps by considering mass, arithmetic mean length, and number of fibers, but samples must be debris-free.*

THE COARSENESS OF PULP IS THE mass of fibers per unit length. It is an important property of papermaking fibers. Coarseness affects the response of fibers to papermaking treatments and most product properties—structural, strength, and optical *(1)*.

Accurate determination of fiber coarseness has always been a challenge *(2)*. One common method relies on the measurement of the total projected length of a known mass of pulp fibers with an optical fiber length analyzer such as a Kajaani FS-100 or FS-200 *(3)*. Coarseness results from dividing the pulp mass by the total measured length of the fibers. In practice, the following equation provides a calculation of coarseness:

$$C = m/n\,\bar{l} \qquad (1)$$

where

C = coarseness
m = a very small, o.d. mass of fibers supplied to the analyzer
$\bar{l}$ = arithmetic mean length of the fibers
n = total number of fibers in the mass m.

The analyzer provides the length, $\bar{l}$, and the number, n. The accuracy of coarseness determined from Eq. 1 depends on the accuracy of measurement of the three factors in the equation. If one assumes that the analyzer provides accurate fiber length, then the accuracy of C will depend on the accuracies of m and n.

To obtain consistent and meaningful measurements on pulp samples, one must consider all issues related to the measurement of m and n. For instance, how representative is the mass, m, of the total pulp sample? Other than the fibers whose coarseness is of interest, what else is present in the pulp sample? The presence of debris such as fibrils, fiber fragments, ray cells, etc., can interfere with the measurement of both m and n. How accurate is the moisture content of the sample? How is the mass, m, determined? One usually obtains a small mass from a pulp slurry by sampling a small volume from it and knowing the consistency of the slurry. How representative is this small volume? How homogeneous is the slurry? How accurate is the knowledge of the slurry's consistency? Is n the actual number of fibers in the mass, m, or simply an estimate? How good is this estimate?

To minimize some errors in coarseness measurement, we have adopted a method for specimen preparation and have used it for several years for chemical wood pulps. The purpose of this report is to describe this method.

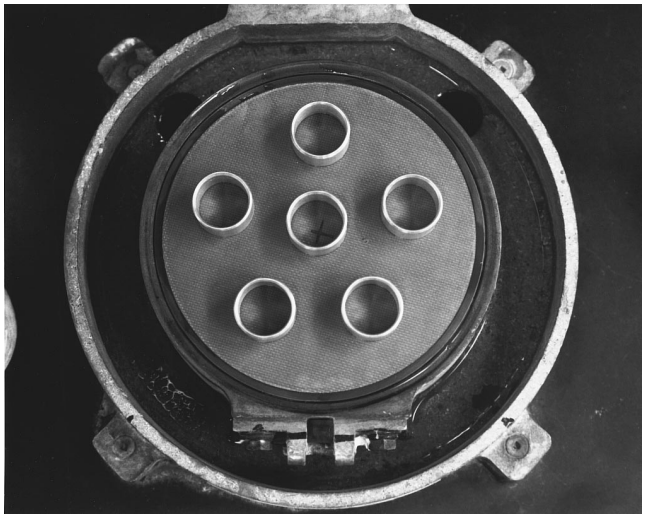
THE METHOD

We use a representative sample of the pulp weighing approximately 24 g. Where necessary, we follow recommended sampling procedures *(4)* by taking a small sample from each pulp sheet in the shipment. The pulp undergoes disintegration following the standard procedure until clear of fiber bundles *(5)*. We take a sample of approximately 1.2 g of the disintegrated pulp. Where possible, one can take a similar sample while making standard test sheets.

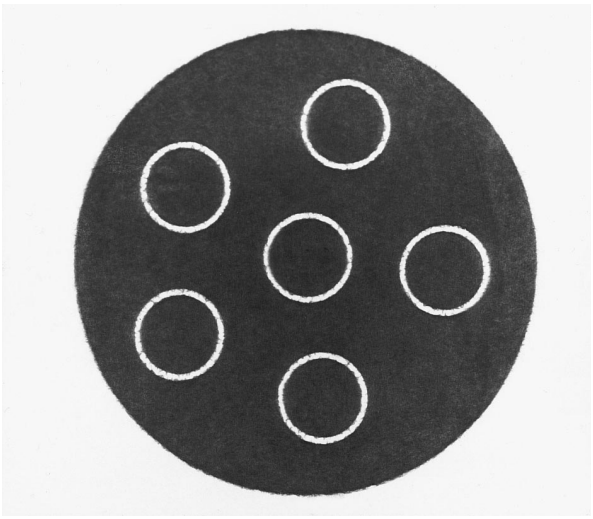
Figure 1 shows the placement of six equally sized rings at random on the screen of the British handsheet machine. Rings should be approximately 2 cm from the screen edge, spread out, and uncrowded so the flow through the screen remains even. The rings were machined from a stainless steel tube. Inner and outer diameters of each ring are 27 and 31 mm, respectively. The height of the rings is 15 mm. The bottom surface of the ring wall is flat and the top has undergone chamfering to minimize fiber catching. Dimensions of the rings are not critical, but it is important that they are all the same size.

The handsheet machine is filled gently with water, and the 1.2-g disintegrated pulp sample is poured into it. The pulp slurry is stirred and drained followed by sheet formation using a standard procedure *(5)*. The rings are removed, and the sheet is couched in the standard manner *(5)* to give six mini sheets as **Fig. 2** shows.

Most debris in pulp is removed during drainage at low consistency through the standard 150-mesh screen of the sheet machine. To ensure that the sample is debris free



1. Six rings of equal size placed on the screen of a British handsheet machine



2. Six mini-sheets after couching

before forming the mini-sheets, one can fill the sheet machine, stir the slurry, and drain it followed by a repeat operation. One could also make the mini-sheets twice using half the original weight each time. This is because the ability of sheets to retain debris diminishes with decreasing weight. These methods of debris removal are similar to those of Clark *(2)*. The amount of debris depends on the origin of the pulp. For consistent comparisons, one should similarly treat all pulps. Gentle filling of the sheet machine and stirring do not usually disturb the rings.

Immediately after couching, we transfer three of the mini-sheets selected at random to a container with 4 L of water for redispersing. We place the other three sheets in a weighing jar and determine their o.d. mass using a standard procedure *(6)*. Because of the similarity of the two sets of mini-sheets, we can use this mass to determine the consistency of the 4-L slurry as Appendix I indicates.

We gently peel the mini-sheets from the couch blotters with a pair of flat-tipped tweezers. If the pulp sticks to the blotter, one can line the blotter with a Whatman No. 4 filter paper.

The 4-L pulp stock slurry undergoes agitation to ensure homogeneity. An appropriate, carefully measured volume of this homogenized stock goes to the fiber length analyzer for coarseness measurements as Appendix II indicates. In this way, an accurately known, small, o.d. mass of debris-free fibers goes to the analyzer.

Three mini-sheets will typically weigh nearly 100 mg. One should use a balance with 0.1-mg accuracy or better for weighing. A pulp of 150 µg/m coarseness having a mean fiber length of 2.5 mm contains nearly 2.7 million fibers per gram. A 100-mL sample from the 4-L stock slurry will contain nearly 7000 fibers. This number is appropriate for coarseness determination with a Kajaani FS-100 fiber length analyzer or similar unit. For fibers of different length or coarseness, it is possible to vary the method appropriately.

Appendix III shows the effect of debris and its absence on coarseness measurement. Coarseness measurements can be uncertain if debris is present in the pulp sample.

KEYWORDS
Denier, fiber dimensions, fiber length, fineness, mass, measurement, optical instruments, optical measurement, pulps, sample preparation.

OTHER CONCERNS

A properly operated Kajaani FS-100 analyzer provides an accurate count, n, of the fibers in the pulp mass, m, needed for Eq. 1. This is because the operator who physically transfers the fibers to the analyzer ensures sufficient slurry mixing, slow pouring, and complete transfer. This is not true with the Kajaani FS-200 analyzer. That analyzer controls those operations. After delivering the pulp mass, m, to the analyzer, the analyzer dilutes the sample to a fixed volume. It then aspirates a proportion, k, of this volume for the coarseness measurement. Equation 1 must then include the factor, k. The accuracies of m and n depend greatly on the accuracy of the proportion taken and the homogeneity of the slurry sampled. It is notoriously difficult to maintain homogeneity in pulp slurries. In addition, fibers can segregate at the inlet orifice of a narrow tube when aspirating a pulp slurry through it. This is because fibers of different sizes have different mobilities. Shorter fibers are more mobile. Doubts therefore arise on the accuracy of coarseness measured with the Kajaani FS-200 analyzer. Measurements with this unit were higher

than those obtained with the Kajaani FS-100 analyzer. Operating the analyzer in a mode similar to the manual mode of the Kajaani FS-100 analyzer—where all the fibers are transferred—can rectify this situation. Because of this uncertainty, we prefer to use a Kajaani FS-100 analyzer for our coarseness measurements.

CONCLUDING REMARKS

Accurate measurement of coarseness of wood pulp fibers is difficult. Consistent and meaningful results are possible with pulps using optical fiber length analyzers provided one pays attention to the important factors in Eq. 1. These are $\bar{l}$, m, and n. If the analyzer provides accurate l and n, our work suggests a method for delivering an accurate small mass, m, of debris-free pulp fibers to the analyzer. The method meets the needs for chemical wood pulps.

Because of the considerable fiber fragments and fines in mechanical pulps, it is more meaningful to measure and compare the coarseness of various Bauer-McNett fractions than those of the whole pulps *(7)*.

One can adapt the method of forming mini-sheets to provide small pulp samples of known, similar masses where necessary *(8)*. **TJ**

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APPENDIX I

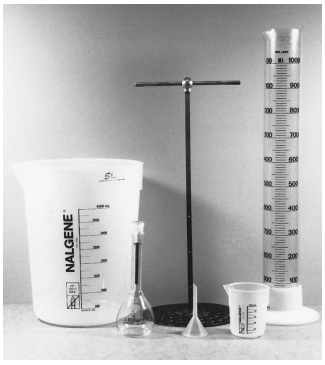
This appendix shows that the mass difference between the heaviest and the lightest sets of three mini-sheets is almost 3% or less. The masses of the two sets are therefore similar within 3%.

We made ten sets of mini-sheets with the six-ring method and determined their o.d. mass. **Table I** shows the analysis.

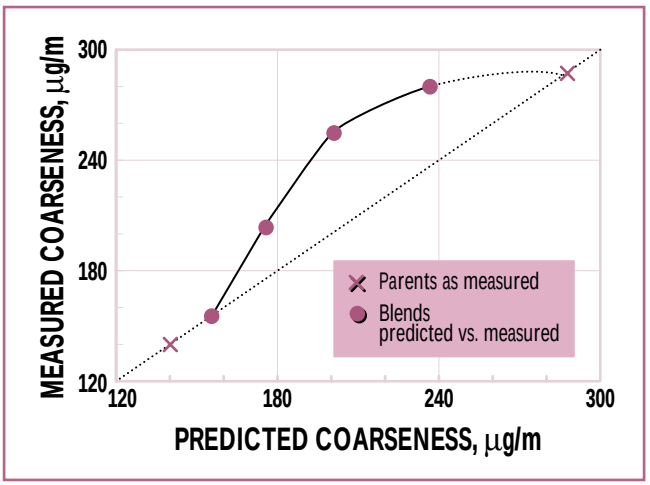
APPENDIX II

Stock slurry preparation consists of dispersing three randomly selected mini-sheets in 4 L of water. A 1-L graduated cylinder measures the water. The standard British sheet machine stirrer disperses and homogenizes the slurry as in handsheet making. The container for the slurry is sufficiently wide for the stirrer to fit as **Fig. 3** shows. While the homogeneous slurry undergoes stirring by the up-and-down motion of the stirrer, we take an approximate 20-mL sample of the slurry with a 100-mL beaker and transfer it to a 100-mL volumetric flask. While the slurry continues stirring, we transfer further small samples to the flask until reaching exactly 100 mL of the slurry. Then we transfer the contents of the flask to the analyzer.

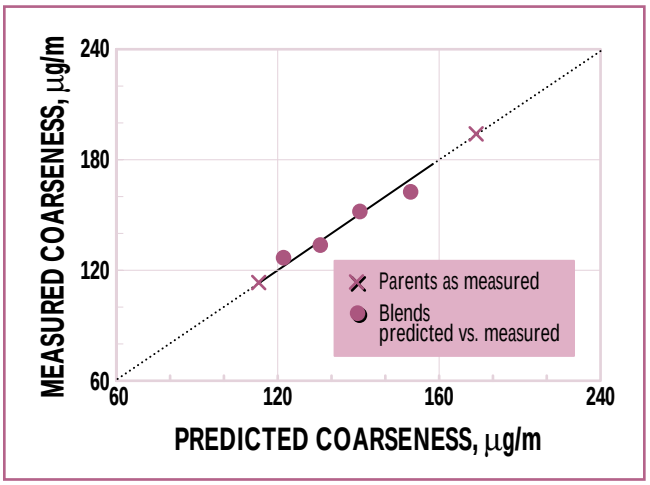
Table II shows the reproducibility of sampling and coarseness measurement. The measurements on twenty 100-mL samples used a Kajaani FS- 100 analyzer. The pulp was an undried, unbleached, laboratory kraft of softwood.



3. Laboratory ware used for making and sampling the stock slurry with baffles from the stirrer removed to facilitate sample taking while stirring



4. Predicted vs. measured coarseness for pulp blends when debris was present made in Laboratory 1



5. Predicted vs. measured coarseness for pulp blends when debris was absent made in Laboratory 2

Sheet number	Mass of each mini-sheet, g		Mean mass of a mini-sheet, g	Standard deviation, g	Difference between heavy and light groups of three mini-sheets, %
1	0.0312	0.0299			
	0.0308	0.0303			
	0.0308	0.0299	0.0305	0.0005	3.0
2	0.0302	0.0308			
	0.0302	0.0308			
	0.0291	0.0301	0.0302	0.0006	2.7
3	0.0303	0.0314			
	0.0303	0.0315			
	0.0300	0.0308	0.0307	0.0006	3.4
4	0.0315	0.0320			
	0.0321	0.0320			
	0.0316	0.0318	0.0310	0.0002	1.3
5	0.0297	0.0300			
	0.0304	0.0292			
	0.0304	0.0298	0.0299	0.0005	2.4
6	0.0295	0.0306			
	0.0310	0.0300			
	0.0304	0.0303	0.0304	0.0005	2.1
7	0.0304	0.0310			
	0.0303	0.0309			
	0.0317	0.0314	0.0310	0.0006	2.7
8	0.0309	0.0318			
	0.0302	0.0310			
	0.0318	0.0309	0.0311	0.0006	2.8
9	0.0302	0.0311			
	0.0309	0.0298			
	0.0301	0.0298	0.0303	0.0006	2.8
10	0.0314	0.0309			
	0.0322	0.0318			
	0.0315	0.0311	0.0315	0.0005	2.2

I. Results of sample analysis

APPENDIX III

We blended two laboratory made, undried, unbleached kraft pulps in proportions of 80/20, 60/40, 40/60, and 20/80. One had high fiber coarseness (Douglas-fir), and the other had low fiber coarseness (western red cedar). Two different laboratories measured the coarseness of the parent pulps and their blends. In one case, the debris remained in the samples. For the other case, the samples underwent drainage over a 150-mesh screen. Consistency measurements determined the sample masses for both cases. A Kajaani FS-100 analyzer measured the coarseness.

One can predict the coarseness of a blend using the following equation:

$$C_b = C_1C_2(M_1 + M_2)/(M_1C_2 + M_2C_1) \quad (2)$$

where

C_b= blend coarseness
C_1= coarseness of parent 1
C_2= coarseness of parent 2
M_1= mass of parent 1
M_2= mass of parent 2.

Figures 4 and 5 show results for the two sets of pulps. In each case, we measured the coarseness values, C_1 and C_2, on the parents and predicted the coarseness of each blend using these measurements in Eq. 2. We also measured the coarseness of each blend comparing the values against these predictions in Figs. 4 and 5. Obviously the coarseness results in Figure 4 are in error. The reason may be that both $\bar{l}$ and n become uncertain when debris is present in the pulp sample.

Sample number	Coarseness, µg/m
1	145
2	149
3	137
4	142
5	147
6	149
7	145
8	143
9	144
10	144
11	142
12	134
13	143
14	142
15	146
16	144
17	151
18	147
19	150
20	149
Mean	145
Standard deviation	4

II. Reproducibility of sampling and coarseness measurement