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APPLICATION OF IMAGE ANALYSIS TO PULP FIBRE CHARACTERISATION

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Abstract

Experimental and analytical techniques are discussed for the application of image analysis to the measurement of fibre length, width, coarseness, and curl. It is shown that automated and manual procedures agree well and the crossed fibre problem can be reduced to insignificance by appropriate sample preparation procedures and the use of a curl factor as a recognition function for crossings. Image analysis is used to characterise the introduction of curl in kraft pulp fibres by high consistency beating, and the removal of curl in the hot disintegration of refiner mechanical pulp.

Introduction

Quantitative microscopy has long proved a useful research tool in the study of pulp fibres. The long exacting hours at the microscope required by this process can take a formidable effort. Decisions are made about the number of fibres to sample and the sophistication of the measurement on each one to balance this effort with the significance of the data. By automating some part of this process, image analysis shifts this balance and permits more sophisticated measurements on each fibre, while imposing a higher practical limit on the fibre sample size.

The first part of this paper explains the instrumentation, and the experimental and analytical techniques, illustrated by comparisons between image analysis and manual results: the second part describes applying the technique to study fibre curl.

Image analysis system

We may consider a television camera as merely a device which converts a visible image into an electronic signal. An image analyser, then, is a research instrument which measures the size, shape, or arrangement of objects by viewing those objects with a television camera and electronically manipulating the resulting signal. The measurement process may be supervised by a dedicated computer which also compiles the results. Objects are represented inside the machine by the list of position co-ordinates at which the edges of each object intersect the scan lines (rasters) of the television picture.

One particular image analysis system is an Omnicon(TM) Pattern Analysis System made by the Bausch & Lomb Company. Its computer is a Nova 3/12 with a mapped memory of 64,000 words, hardware floating point arithmetic, and a ten million word capacity hard disk.

The image may be processed in two ways: it may be coded and transmitted directly to the computer for manipulation or measurement, or it may be fed to a fast processer which extracts the measurement under the supervision of the computer. When measuring many features, the speed of the second option is a great advantage. The calculation for a single field of view is complete in a fraction of a second. The measurements given in this report were all made with the faster option.

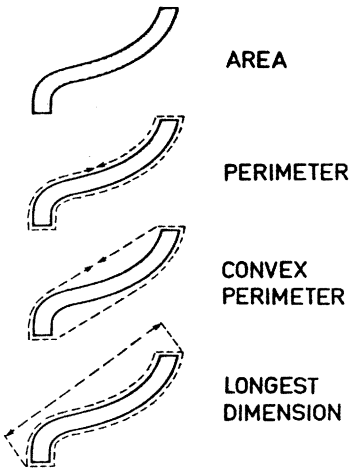

Fig 1—Four of the basic measurements that can be made using the fast logic circuitry.

In the first mode, with the coded image in the computer, we can make any calculations we wish from the co-ordinates, with appropriate programs. In the second mode, with the image going through the fast processor, we can choose from a repertoire of 13 basic measurements. The work of this report is derived from four of these measurements, illustrated in Figure 1 and listed below.

Area - the area of the object

Perimeter - the perimeter of the object including concavities.

Convex Perimeter - the perimeter of the object exluding concavities. It can be considered as the perimeter obtained by wrapping a string around the object.

Longest Dimension - the length of the projection of the object onto a line is determined. The orientation of the line is scanned at 2^{o} intervals over 180^{o}. The maximum projected length is termed the longest dimension.

Slide preparation

Slides which are excellent for human viewing may present problems for machine viewing, putting new constraints upon the slide preparation procedures. The prime problem is contrast. Inside the machine, the image is represented by a 512 x 1024 matrix of picture points and if the magnification is so chosen that the entirety of a 3 mm fibre is in the field of view then the fibre's 0.3 mm width will subtend only a few picture points. A weak contrast over a short run of picture points presents an ambivalent detection situation which can cause the machine to ignore a thin fibre end or treat some segments as separate

fibres. The solution is to dye the fibres intensely so that the lightest segment presents a formidable contrast to the machine.

The second problem is that of crossed fibres. The eventual solution lies in a computational algorithm which recognises and factors the image into its constituent fibres. We are working on this approach, but such an algorithm costs computer time. The obvious immediate solution is to reduce the occurence of crossed fibres to a minimum by preparing random distributions of fibres on the slide. If the occurence of crossings involves only a few percent of the fibres then a recognition and deletion algorithm should provide useful data.

It was soon recognised that standard methods of slide preparation were quite inadequate. The frequency of the fibre crossings was far greater than would be expected if the fibres were deposited randomly on the slide. The procedure adopted ensures that the fibre deposition is truly random and minimises the number of crossings.

About 0.25 g of pulp is added to 300 ml of deionized water and disintegrated with gentle shaking. The pulp is then screened using a 200 mesh screen and the moist remainder is dyed with a 2.5% solution of Chlorazol Black or Crystal Violet for half an hour. (The filtrate of fines may be collected and, if necessary, made into separate slides). After washing, the equivalent of 25 mg (oven dry) of dyed pulp is gently stirred into 25 l of deionized water. A plunger with 10 mm diameter holes is used to randomize the fibre suspension before sampling is taken with a 100 ml ladle. The contents of the ladle are poured into a Buchner funnel containing a 90 mm, 3 micron Nucleopore (TM) disk filter. Under gentle suction the fibres are deposited onto the filter with a random distribution. The wet Nucleopore filter is then removed and placed, fibre side down, onto a clean 75 x 50 mm slide and backed with a moist blotter. A stack of several slides is prepared and pressed at 60 $\pm$10 psi in a laboratory press to dry. When the Nucleopore filters are peeled away the fibres remain on the slide and can be covered with a permanent mounting medium and cover glass. About twenty slides per pulp are usually prepared.

Operating procedure

In operation, the microscope slide containing fibres is placed on an automated stage with a 50 mm range, and viewed either through a Zeiss photomicroscope or a trans-illuminated Zeiss Tessovar. The image is presented to a Vidicon or a Newvicon video scanner which acts as the eye of the image analyser. A contrast criterion is used to identify the fibres from the background and the edges of the fibres are automatically delineated at the midpoint of the contrast jump. Under program control the stage steps from one field of view to the next as measurements are accumulated.

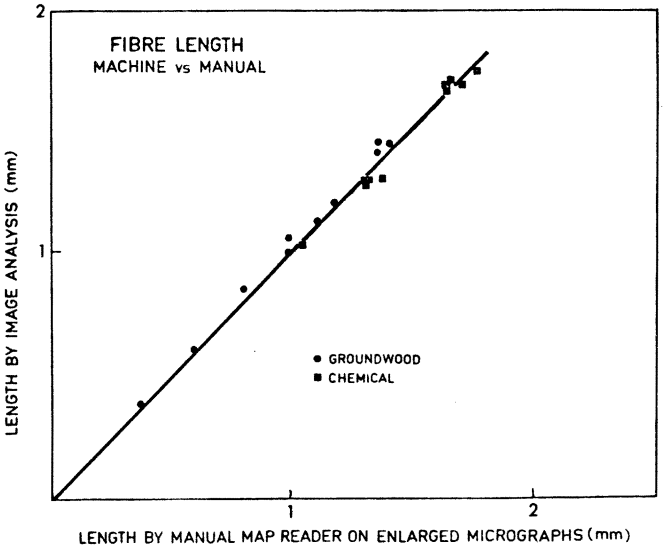

Fig 2—Comparison of the length of some chemical and mechanical pulp fibres measured by image analysis and by manual procedures.

Determination of fibre length

Individual Measurements

As discussed earlier the image analyser can determine, for each feature, certain basic quantities such as perimeter and area. From these basic useful fibre parameters may be derived. For example, fibre length can be considered as half the perimeter, and mean fibre width as its area divided by its length. As a refinement, for square-ended fibres, length may be considered as half the perimeter minus the width.

In Figure 2 we show a comparison between lengths of individual fibres measured automatically in this way, and manually. The correspondence is excellent.

Determination of weighted average fibre lengths

There is general agreement[1-3] that, for characterising fibre pulp the weighted average fibre length is more useful than the number averaged length. It is popular to use the constant coarseness approximation in which the weight is assumed proportional to the length. In this approximation the weight averaged length $\langle l \rangle_{wt}$ is the ratio of the number average of the square of the length $\langle l^2 \rangle$ and the number average length $\langle l \rangle$ or

$$\langle l \rangle_{wt} = \langle l^2 \rangle / \langle l \rangle \qquad (1)$$

where the unsubscripted brackets indicate a population average. What is not often exploited is the relationship between the standard deviation of the length distribution and the weighted average. It follows from the definition[4] of the standard deviation that, provided the population is large,

$$\sigma^2 = \langle l^2 \rangle - \langle l \rangle^2 \qquad (2)$$

which may be combined with (1) to give

$$\langle l \rangle_{wt} = (\sigma^2 + \langle l \rangle^2) / \langle l \rangle \qquad (3)$$

This can also be turned around and used to extract σ from the number and weighted average lengths in the literature. The weighted averages in this paper were calculated with eqn. (3).

Fibre length measurements on pulps

Bauer McNett Fractions

A laboratory pulp of unbleached kraft black spruce was fractionated in a Bauer McNett classifier and the R 14, 14/28, 28/48, and 48/100 fractions were collected and prepared on slides as described above. Figure 3 shows the measured length distributions for the four fractions.

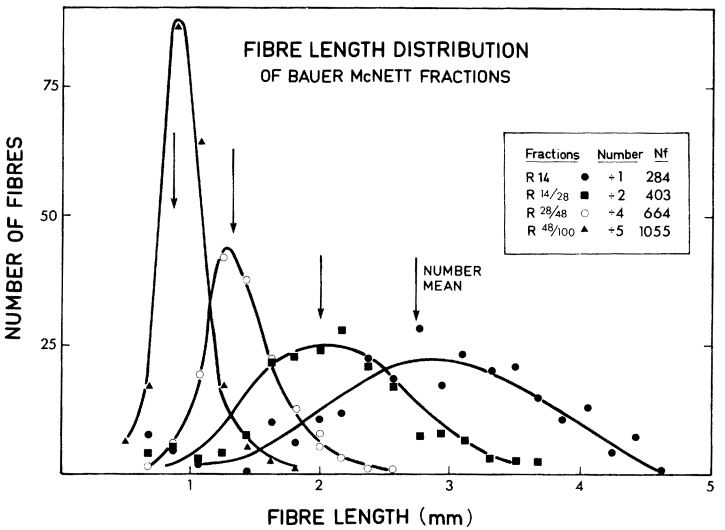

Fig 3—The fibre length distributions for four Bauer McNett fractions. The arithmetic mean (as opposed to weighted mean) is indicated by the arrows. The legend indicates the total number of fibres in the sample (N_f) and the scale factor.

Table 1 shows the width corrected average length and other statistics.

Fraction	Number of Fibres N_f	$\langle l \rangle$ (mm)	Std. Dev σ (mm)	$\langle l \rangle_{wt}$ (mm)	$\sigma/\langle l \rangle$
R 14	284	2.27	0.90	3.06	0.32
R 28/14	403	2.05	0.68	2.28	0.33
R 28/48	664	1.42	0.44	1.56	0.31
R 48/100	1055	0.87	0.94	0.94	0.29

Table 1

It is interesting to note that the ratio of the standard deviation to the mean remains rather constant at an average of 0.32. If one calls this ratio a and enters

$$\sigma = a\langle l \rangle \tag{4}$$

into equation (3) then

$$\langle l \rangle_{wt} = (1 + a^2) \tag{5}$$

As early as 1942 it was suggested by Clark[2,3] that one could get an approximation to the weight averaged length for a Bauer McNett fraction by increasing the number average by 12.5%. For Clark's approximation to work we see from (4) and (5) that the ratio a must be a constant. The 12.5% he suggests reduces to avalue for a of 0.3, similar to ours.

From the work of Forgacs[3] we can deduce a values of 0.39 $\pm$0.08 for a 48/100 fraction, and 0.40 $\pm$0.10 for a 100/200 fraction.

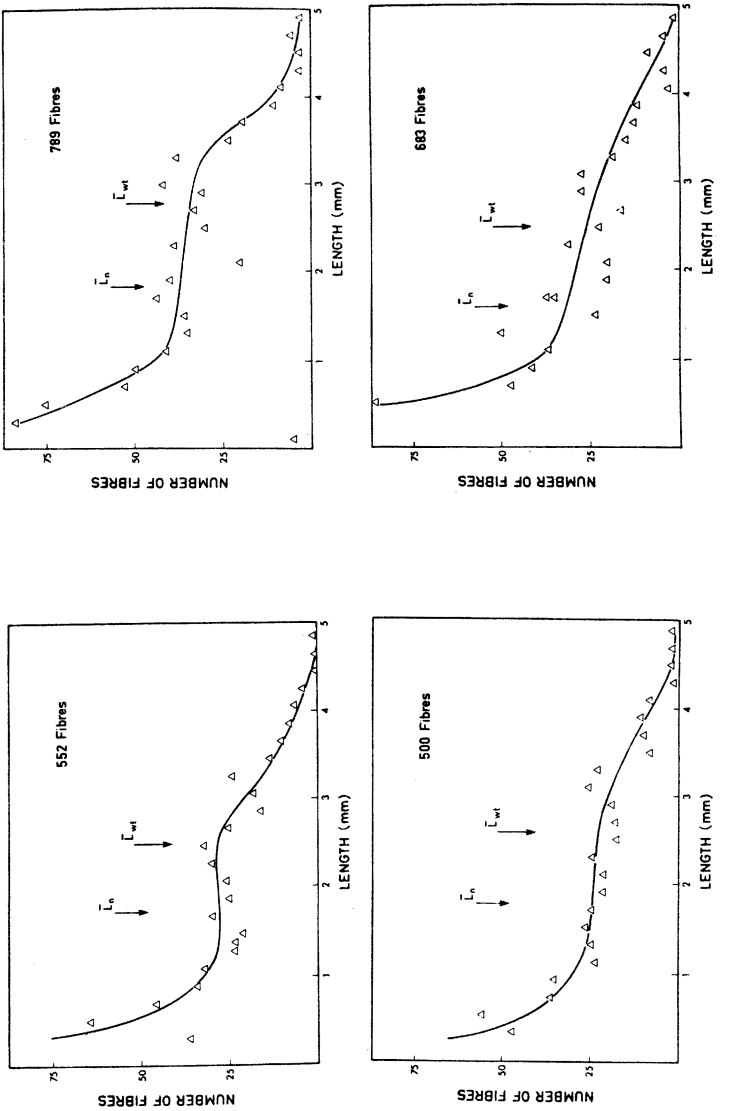

Fig 4—The length distributions for four commercial bleached kraft pulps. The weighted and number average lengths are indicated by the arrows.

Whole Commercial Pulps

Commercial bleached kraft pulps of predominantly spruce content were chosen from a collection that had previously been manually characterised at Paprican. The pulps were re-examined by image analysis and the results are shown in Figure 4. Table 2 shows a comparison with the manually acquired data. The `manual' weight averaged lengths were determined from fibre lengths of the fractionated samples [5].

Number of Fibres	<l> (mm)	Std. Dev. (mm)	$\langle l \rangle_{wt}$ (mm) Image Anal.	Manual[5]
782	1.85	1.30	2.73	2.71
500	1.78	1.20	2.53	2.58
552	1.78	1.15	2.48	2.30
683	1.61	1.20	2.45	2.37

Table 2

Determination of fibre width

The mean width of each fibre is obtained from its area divided by its length. For measurement of fibre length the entire fibre must be within the field of view but at that magnification the instrumental resolution is inadequate to measure width precisely; a higher magnification is needed and the requirements that the entire fibre be sampled must be relaxed. Two complementary measurement strategies are available: in the first strategy (Width I) a fibre is measured only when its lower left extremity is within the defined portion of the picture called the measurement frame. This ensures that each fibre contributes only once to the average fibre width, but has the disadvantage that the fibre ends are preferentially sampled.

The alternative strategy (Width II) is to measure that segment which falls in each field of view. The probability of sampling is then proportional to fibre length with the short fibres counted at least once. This results in a weighted fibre width distribution. We find 4X objective gives a workable resolution and still samples enough fibres that the fibre end preference in the first option is less significant.

Although sensitive measurements can be made which expose trends within a set of pulps which are treated in the same way, caution is needed in the comparison of absolute values for the fibre width measured with different preparation procedures.

Determination of coarseness

The coarseness of a pulp is defined as the weight of fibre per unit length and is regarded as an important basic measurement. Because the method of preparation transfers known weights of fibres to each slide, the coarseness may be calculated from the total length of fibre on each slide divided by this weight.

Fraction	Number of Fibres	Coarseness µg/m Mean	95% Limits
R 14	284	213	26
R 14/28	403	198	20
R 28/48	664	173	14
R 48/100	1055	177	11

Table 3

In Table 3 we show coarseness values obtained on Bauer McNett fractions of a laboratory pulp of unbleached kraft black spruce. The data indicate, as found by Clark[6], a decrease in coarseness towards the shorter fractions. No independent

measures of coarseness have been made but the values obtained here are clearly similar to those reported elsewhere for similar pulps[7,8].

Determination of curl

Definition and Measurement of Curl

Fibres in pulp suspensions are not straight but rather are curled to a greater or lesser extent. This curl has a significant influence on paper properties but no satisfactory technique exists for its measurement. Although we have in our image analysis system the wherewithal to extract the detailed shape of a fibre and study its curvature distribution, we have thus far concentrated on single number curl factors which are measured by the fast logic circuitry.

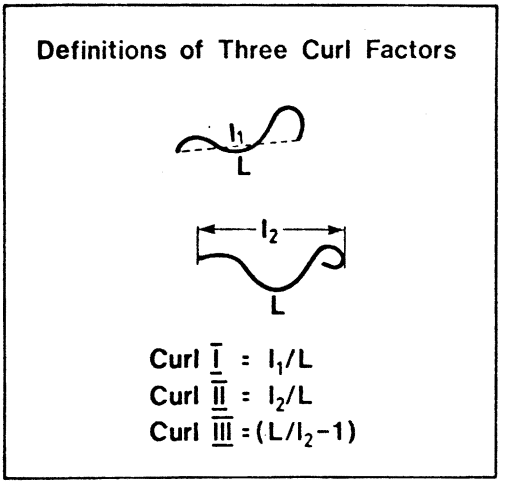

Fig 5—Definition of three curl factors.

One curl factor used in polymer theory[9] and discussed by Perez and Kallmes[10] is the ratio of the true length to the linear end-to-end distance. We designated the reciprocal of this ratio, Curl I (Figure 5). The fast logic is not capable of determining this parameter because it cannot recognise fibre ends. It can be shown however that for fibres that are not too curly, Curl I can be obtained approximately from measurements of simple and convex perimeters according to the following equation:

Curl I = 2 x Convex Perimeter/Simple Perimeter - 1

The ratio of the longest dimension to the fibre length can also be considered as a curl factor and has the advantage that it is rigorously obtained from the fast logic circuitry. This curl factor Curl II, may be considered as related to the ratio of the length over which the fibre has influence in a paper sheet to its potential length. A third curl index, Curl III, which is a transformation of Curl II, as defined in Figure 5, is a measure of the fractional increase in the linear extent of a fibre that would result if the fibre were forcefully uncurled but not stretched.

In textile research it is called the 'crimp ratio' and is measured by pulling the fibres straight, one at a time[11]. It is considered that this curl factor may have relevance to the extensibility of wet webs, since curled fibres in such sheets may be straightened to a considerable extent. Curl III numerically increases with curliness, being zero for a straight fibre, whereas Curl I and Curl II decrease with curliness, being 1.0 for a straight fibre.

Comparison of Curl I and II

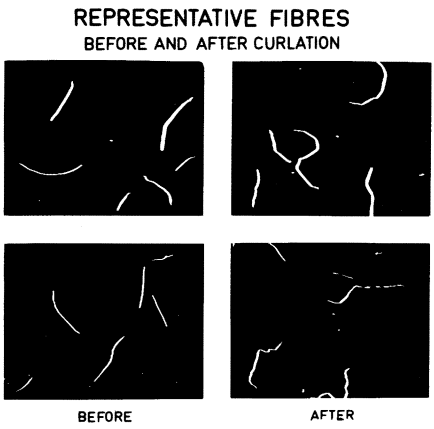

Fig 6—Fibres before and after curlation, photographed from the screen of the image analyzer.

An unbleached laboratory kraft black spruce pulp in which the fibres are fairly straight was subjected to six hours of curling in a Hobart kitchen mixer at 20% consistency. Figure 6 shows representative fibres before and after treatment. The mean value of Curl I for the fibres is 0.88 before curling, and 0.79 afterwards.

Figure 7 shows the Curl I distribution before and after curling and Figure 8 shows the same for Curl II. These figures

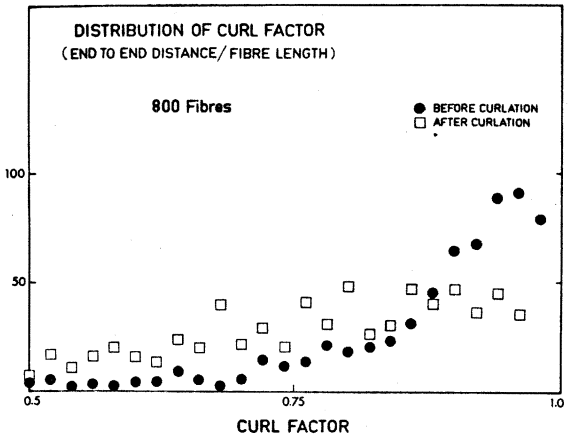

Fig 7—The distributions of Curl factor I for the same pulp before and after curlation.

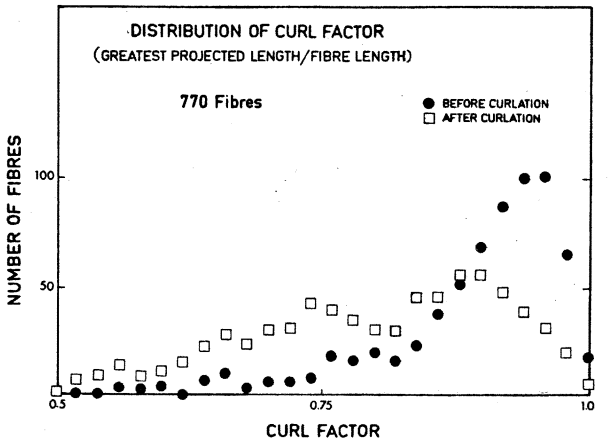

Fig 8—The distributions of Curl factor II for the same pulp before and after curlation.

show that Curl I and Curl II are both sensitive measures of curl but that neither is decidedly superior to the other.

Use of Curl I for Detection of Fibre Crossings

The fast logic is incapable of separating two crossing fibres. It sees them as a single X-shaped fibre. Although the slide preparation procedure greatly reduces the frequency of crossings, the residue could cause errors in certain determinations, for example, of fibre length. Curl I helps us to recognise crossings. Its value for a pair of crossed fibres is much lower than that for each fibre separately. On one set of slides we therefore entered as a selection criterion that Curl I should be greater than 0.5. About four out of five pairs of crossed fibres were recognised and rejected. There were about half as many false rejections as false acceptances. The data in this report were taken using this screening factor for crossed fibres. In our specimen preparations, only about 2% of the total fibre content was rejected using this criterion.

The Development of Curl by Hobart mixing at 20% Consistency

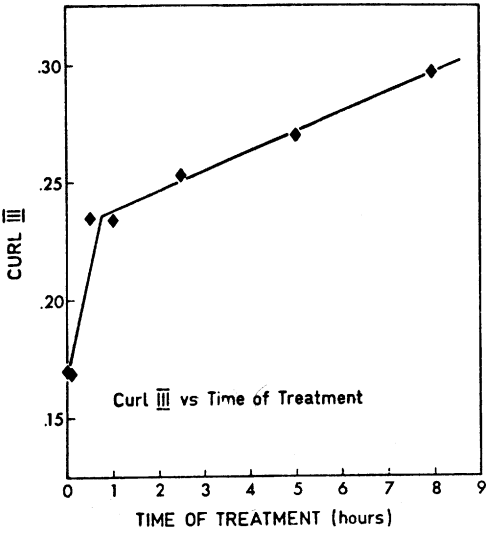

Fig 9—The mean Curl III value of a kraft pulp — freely dried in a handsheet and never dried — as a function of beating time at 20% consistency.

A commercial predominantly spruce, kraft pulp was beaten to 1000 Rev. in a PFI mill and then subjected to curling at 20% consistency in a Hobart kitchen mixer. After various times of treatment, samples were withdrawn and prepared for image analysis. Figure 9 shows the change in Curl III with time of treatment. We see that the curl increases dramatically in the first half hour and then

begins a slow and approximately linear ascent right through eight hours of treatment.

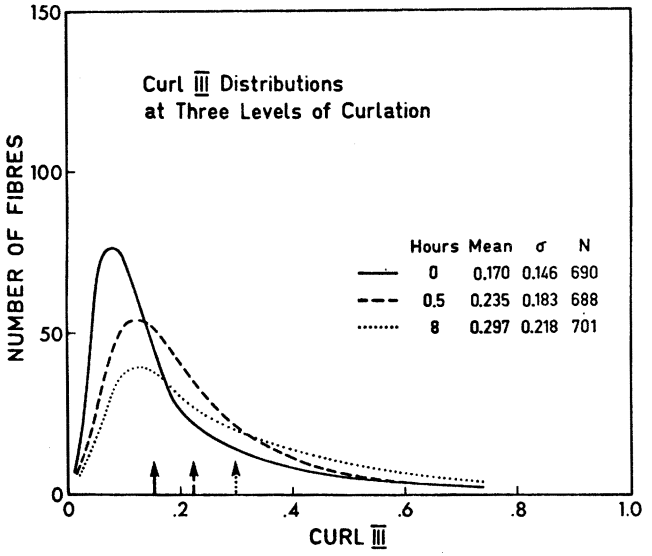

Fig 10—The Curl III distributions of the never dried pulp from three representative intervals in Figure 9.

The development of curl is better appreciated from the complete Curl III distributions of these samples, shown in Figure 10. Up to the first half hour of curling the curl index increase is caused by a rather mild curling of the originally straight fibres. Subsequently the entire pulp becomes more grossly curled.

Effect of Fibre Length on Curl of Kraft Pulp

Curl III has been measured on two Bauer McNett fractions of a kraft pulp as shown in Table 4. The longer fibres are significantly curlier. We have used this effect to demonstrate here a further power of the image analyser.

Fraction	Curl III Mean	Curl III Std. Dev.	Number of Fibres	Std. Error $\sigma/N^{1/2}$
R 14	0.126	0.132	547	.006
R 28/48	0.103	0.117	544	.005

Table 4
Curl III for two Bauer McNett fractions of an unbleached kraft spruce pulp

It is possible to make similar determinations on a whole pulp without resorting to mechanical fractionation. Since Curl III and fibre length can be determined individually for each fibre, values of Curl III can be obtained for any designated length interval, as shown for a different pulp in Table 5. This shows that for this pulp the longer fibres are also the curliest.

Length Interval (mm)	Curl III Mean	Curl III Std. Dev.	Number of Fibres	Std. Error $\sigma/N^{1/2}$
(1.87, 12)	0.298	0.249	505	0.011
(1.27, 2.73)	0.227	0.204	370	0.011
(0.98, 1.86)	0.200	0.166	289	0.010
(0.62, 1.07)	0.197	0.171	145	0.014

Table 5
Curl III for Four Length Classifications on a Dried Kraft Pulp

Curl and Latency Removal

Refiner mechanical pulp fibres have curls and crimps which can be straightened by hot disintegration[12]. Figure 11 shows the Curl III distributions for hot and cold disintegrated refiner groundwood.

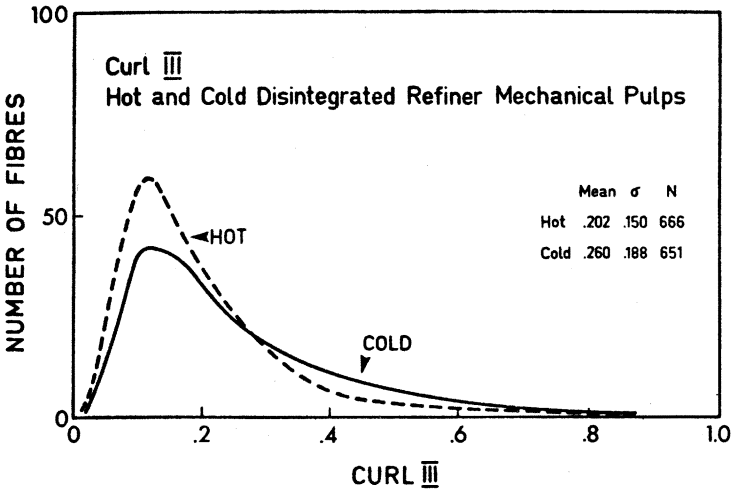

Fig 11—The Curl III distributions of a hot and a cold disintegrated refiner mechanical pulp.

The refiner pulp differs markedly from the kraft in the variation of curl with fibre length. We have shown that the longer kraft fibres are curlier. We find here that for both the hot and the cold disintegrated refiner pulp, there is no significant difference in curl between the largest four length classifications. These results are shown in Figures 12 and 13.

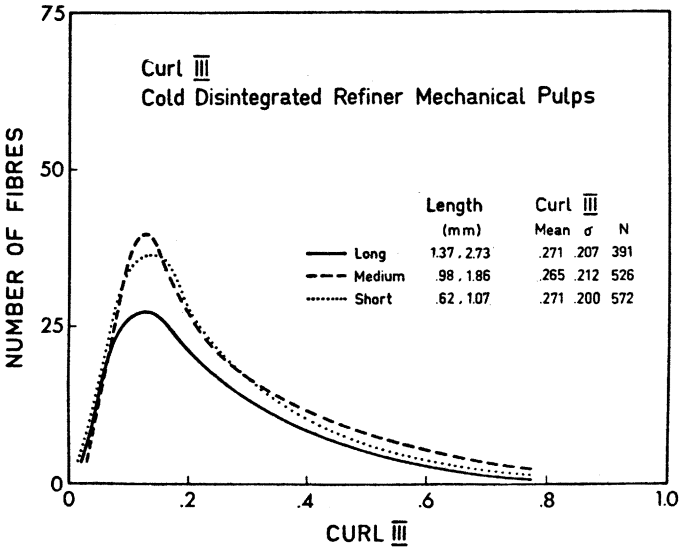

Fig 12—The Curl III distributions for three length classifications of the cold disintegrated refiner mechanical pulp.

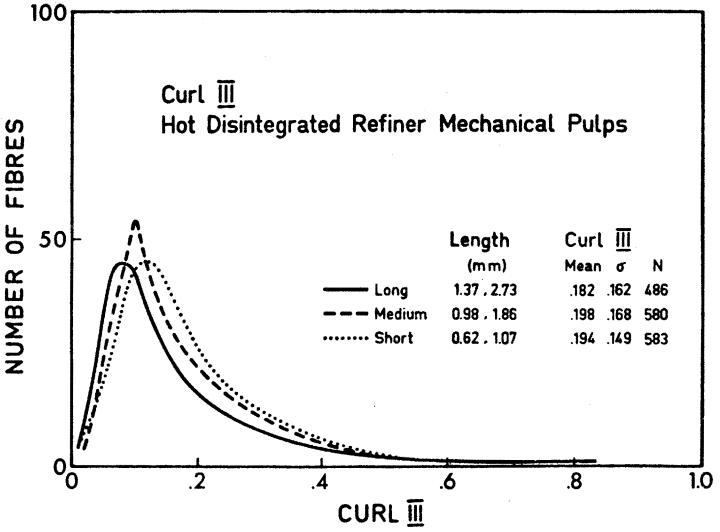

Fig 13—The Curl III distributions for three length classifications of the hot disintegrated refiner mechanical pulp.

Conclusions

We have discussed the instrumentation, and experimental and analytical techniques for applying image analysis to the measurement of fibre length, width, coarseness, and curl. The automated and manual approaches agree, whether the comparison is done fibre by fibre or on whole pulps. We have shown that with appropriate sample preparation procedures and the use of a curl factor as a recognition function for crossed fibres, the problem of crossed fibres can be reduced to insignificant proportions.

We have applied image analysis to characterise the introduction of curl to kraft fibres by beating at 20% consistency, and to the reduction of curl as latency is removed from refiner mechanical pulp.

Acknowledgements

We are indebted to George Williams of MacMillan Bloedel Research Ltd. for a discussion on slide preparation that led to the development of the technique discussed here, and to Michel Barbe of Paprican for collaboration in the curl studies that were undertaken as a part of his work on the properties of wet webs.

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Discussion

Panel Discussion following papers presented by Dr. Jordan, Prof. Kropholler and Dr. Taylor.

Dr. B. Jordan

I have a question for Prof. Kropholler. Several years ago Rosenfeld[1] published a note in which he claimed that if one worked with Fourier transforms locally in texture analysis then the edge effects were so pronounced that it made the Fourier or power spectrum useless as a local image-segmenting technique. Hence he favoured run-length statistics. Do you agree with this?

Prof. H. Kropholler

I agree with the comments that you just made. We are not seriously using Fourier techniques, in texture analysis.

Dr. L. Eriksson, STFI, Sweden

I have a question regarding sample preparation. Fibres are three-dimensional in terms of curl. Presumably during analysis the fibres are stationary and thus restrained in some way by external forces. How is sample preparation carried out so as to reflect the true curl?

Dr. B. Jordan

We use a projection technique. There is the underlying assumption that a fibre with say, helical structure is not straightened by squashing it down onto a plane, it will maintain curliness. A straight fibre on the other hand will remain straight on projection.

Mr. B. Klowak, American Can Corporation, Wisconsin, USA

I understand that Dr. Jordan used a proportionality with length to estimate fibre weight. I would like to ask why he did not use a proportionality to area?

Dr. B. Jordan

That is a good question. Actually we have used both methods and there is no great difference.

We have also used, as I mentioned, a method where we take a calibration curve of weight as a function of length.

Mr. B. Radvan, Wiggins Teape, UK

Dr. Jordan, the histograms of radii of curvature which appear in your contribution always had a high population at low radii which you have ascribed to kinks. Do you think this could be used as a measure of damage to the fibres?

Dr. B. Jordan

Yes. There is a great deal of information in these histograms and what we have to do is to find appropriate weights between the high frequency and the low frequency contributions to try to extract something meaningful. Obviously, there is added information if you used both the curvature and the curl. The question remains: what is the paper-making significance of the added information, and is it worth the extra effort? This is the subject of our activities at present.

Dr. C. J. Taylor

We also use curvature measurements similar to those described by Dr. Jordan. We have found that this allows us to differentiate between asbestos and other types of fibres by using syntactic analysis of the resulting histograms.

Prof. K. I. Ebeling, Helsinki University of Technology, Finland

I would like to ask what resolution is possible with the technique. Could you for example analyse the effect of strain on bonded area response, particularly with respect to the effect on the centre area of a bond?

Dr. B. Jordan

The largest problem is one of getting an appropriate image. This is always a problem in image analysis.

I think we have enough contrast to look at local deformations at bond sites, but we have not done it at present.

Dr. M. B.Lyne, Paprican, Canada

Many people could be considering the purchase of an image analyser. It would be of interest to know what hardware is required with the analytical equipment that you have described today in order to guarantee inter- and intra-laboratory agreement. In particular, reproducibility of the detection criteria and sample illumination are required.

Dr. B. Jordan

For print quality applications, this is adequately discussed in our paper in Tappi[2].

Illumination is important for fibres also, though not as critical as one might suppose.

Dr. C. J. Taylor

There is generally a better chance of getting good agreement between different sites if the image analysis method used represents some physical model of the subject under consideration. In other words, sample-related techniques are likely to lead to a failure to agree. For example, specific effects or tricks are difficult to reproduce.

Prof. H. Krophollor

I would add that the problems of repoducibililty are even present within one laboratory. On texture-type problems it is imperative to have some calibrating sample included with the samples. Work on fibres can be easier since dyeing the fibre can often result in enough contrast. The physical characteristics that one is looking for can be simpler.

Dr. C.J. Taylor

With some types of image grey-level thresholding can be applicable to asbestos fibres. The problem with this technique is that it is totally variable and different answers are obtained on different occasions since even automatically self-adjusting systems have considerable arbitrariness.

The model we have used supposes a consistently lower optical density related in a linear fashion and a measurement of that is made. The results on the final count don't alter under an order of magnitude change in the illumination on the slide.

Dr. B. Jordan

In situations where the signal - to-noise ratio is very critical then the precise grey-level threshold can be very important. However, in most situations a response plateau is reached, and large changes of illumination are possible without any significant effect on the results.

Dr. C. J. Taylor

Certainly in our experience edges are rarely sharp enough in microscope images and I would have expected that a change in threshold would be expected to give a significant change in the fibre width that you observe.

Dr. B. Jordan

This can be a problem, but the threshold setting that we use is the mid-point of the edge and thus symmetrical broadening from whatever cause, such as the optics, will not have much effect. We have, to date, found reasonable reproducibility over many samples.

Mr. A. de Ruvo, STFI, Sweden

What kind of TV camera is recommended for use on printability studies, where grey-scale measurements are all important.

Dr. C. J. Taylor

We always use a Chalnicon tube because in practice all other tubes are fragile. It has high resolution on near-linear intensity response, and good sensitivity. If you are interested in looking at complete images with a wide intensity range, and you need information from the low intensity areas without saturating the high areas, then a Vidicon with $\gamma = 0.7$, whose response slopes off at high levels, might be more appropriate.

Prof. P. Luner, ESPRI, USA

Returning to the question of the move away from using Fourier transforms to describe structure, is there any problem with the type of signal and its processing or does the problem lie in the paucity of information gained?

Dr. B. Jordan

The computational demands for handling the grey-level occurrence matrices and other real space statistics are just as large as for the Fourier transform. The problem with the Fourier transform lies in its local application and in the presence of edge effects. The finite Fourier transform assumes that the signal is reproduced over and over again outside the sampling region. This small sampling causes errors, as pointed out by Rosenfeld.

Dr. C. J. Taylor

From our experience of using Fourier methods, even when they are not applied locally, the Fourier transform of anything looks much like the Fourier transform of anything else.

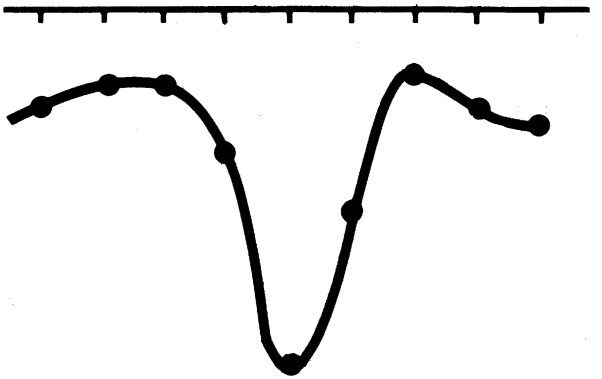
Fourier has some nice properties, for example, it is not dependent on translation, and orientation can be removed. Unfortunately, it tends to mask phenomena which human observers see.

Dr. F. El-Hosseiny, Weyerhaeuser, USA

A few years ago I was trying to measure the radii and diameters of textile fibres and I found that there was an observable change with a change in refractive index of the immersion fluid. The difference was very high particularly when trying to measure small objects. I would like to draw attention to this fact as it might not be well known.

Dr. C. J. Taylor

This problem can be extreme with asbestos fibres which are at the limit of resolution of the optical microscope. We use phase contrast images and so the image looks as shown below.



The question that then arises is whether any one pixel forms part of the fibre image or not. We look at the intensity values of the individual cells and fit a curve through these points. If we know the response function of the microscope then a proper measurement of width can be derived though the arguments are complex.

Dr. B. Jordan

This is a serious problem with phase-contrast work. The transfer function of phase-contrast is asymmetric.

Dr. C. J. Taylor

This is true, I was, of course, just citing one example. The main point is that at high magnification it is important to take account of the microscope optical transfer function during the measurement and analysis phases.

Dr. B. Jordan

One can generalise this by saying that one must be very careful with the optics of the image. It is like the old computer saying "garbage-in:garbage-out". If you have poor quality images or if you are working at the limit of your optics then this has to be attended to: you are quite right.

Dr. R.P. Taylor

I believe you are using raster-scan, high-resolution image tubes. For images of fibres where there is a high length to diameter ratio would it be possible to use a non-raster type tube where a spot is made to follow an image under computer control? This may be a more efficient technique.

Dr. B. Jordan

Image dissector camera systems are available on the market which do just as you say: Lamont make one example.

Dr. C. J. Taylor

The problem is one of process speed. Devices which track images can only integrate photons from that one point. A raster system integrates photons for the whole of a frame. The time economics of raster-scan devices is superior to random-access devices.

If image storage were a problem then tracking devices may be used but this is not usually the case.

B. Attwood (Chairman)

This was a very interesting session and it could well provide the basis for an interesting one-or two-day seminar.

REFERENCES

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