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Prepared contribution

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As WITH all papermaking characteristics, the interpretation of observations on the behaviour of wood fibre networks is made more difficult by the heterogeneous nature of the fibres in a given pulp.

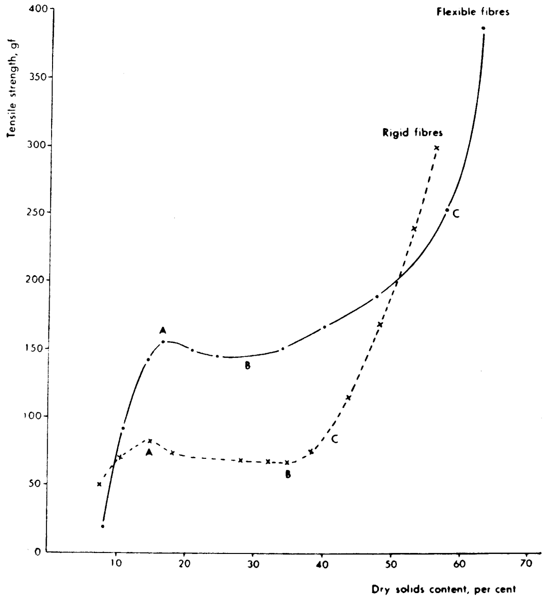
The fractionation of fibres by length indeed makes analysis of the phenomena easier, but the flexibilities of fibres of equal lengths in the same pulp are very varied and it is well known that this factor has a great deal to do with wet web formation and its strengthening during drying.

We were able to compare, for example, the development during slow drying of the strength of wet webs made of fibres from the same unbeaten pulp, fibres of the same length, but of different flexibility and wall thickness. The method for sorting pulp fibres by flexibility is a simple one that uses the differences in behaviour of these fibres in the networks while in motion. We shall say a few words about this method later, as we think it can make useful contributions in the field of papermaking fibrous networks.

Fig. 1 shows the variations in breaking length during slow drying of a wet web made of unbeaten bleached kraft fibres after screening on a 28 mesh wire screen. The upper curve corresponds to the fraction containing the most flexible fibres, which are also the widest and have the thinnest walls; the lower curve corresponds to the fraction containing the most rigid fibres, which have thick walls. In both cases, the fibre length is nearly the same.

Important differences are observed in the positions of the levels AB corresponding to the removal of capillary interfibre water. We find also a very distinct difference in shape, mainly in the last transition zone BC before the development of interfibre bonds. This transition zone, according to Robertson,(1) corresponds to the water associated with fibrils and lumens; it is distinctly shorter for the rigid fibres with narrower lumens.

A more detailed analysis of these curves provides us with other interesting aspects, an account of which will be given elsewhere. In Fig. 1, there is a table to show the distribution of fibres according to their flexibility for each of the fractions of pulps separated from the original pulp. This distribution has been established following the Pulp and Paper Research Institute of Canada method.[2] We note that the separation of flexible and rigid fibres is not absolute for the two pulps compared; nevertheless, the differences in behaviour for fibres of equal length are quite noticeable.



Distribution per 100 fibres, per cent	Fibre rigidity (PPRIC method)		
	High	Medium	Low
Rigid pulp	7	70	23
Flexible pulp	0	10	90
Initial pulp	3	35	62

Fig. 1—Development of sheet strength (100 g/m^2, width 2 cm) during drying for bleached kraft pulp retained on a 28 mesh screen

The graphs in Fig. 2 show the length and width distribution curves for each pulp fractionated from the original pulp and screened on 28 mesh wire. We note that the main difference is in the fibre width.

Other commercial pulps have been examined in the same way. Fig. 3 shows the results obtained with an unbleached sulphite softwood pulp. The differences in the behaviour between flexible, broad fibres on the one hand and rigid, narrower fibres on the other, all of them originating from the same

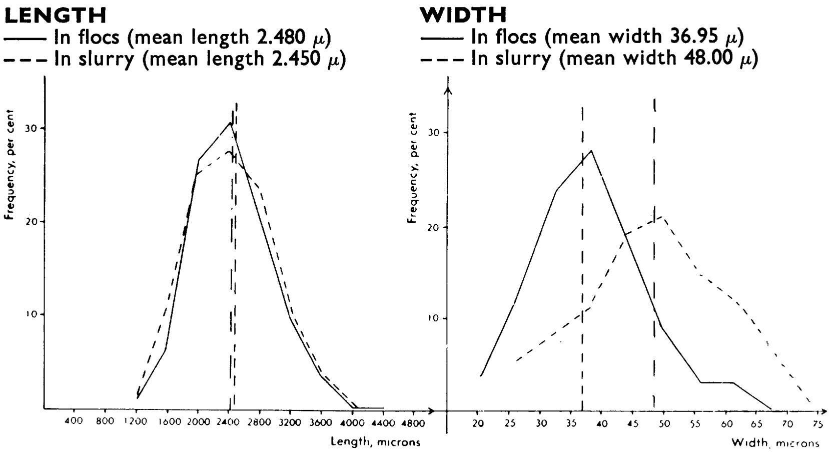
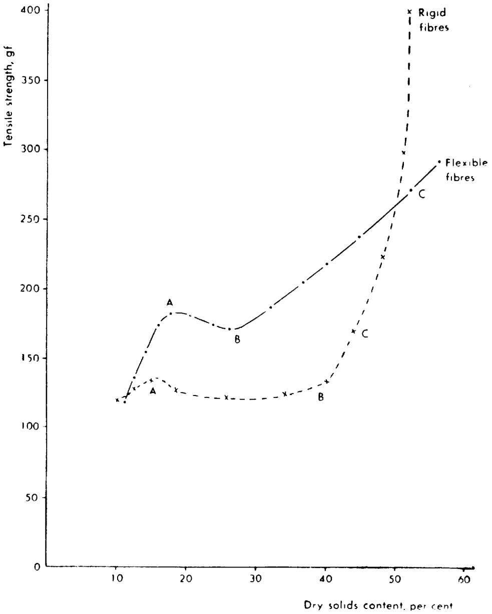


Fig. 2—Distribution of fibre lengths and widths for bleached kraft pulp retained on a 28 mesh screen



Distribution per 100 fibres, per cent	Fibre rigidity (PPRIC method)		
	High	Medium	Low
Rigid pulp	3	42	55
Flexible pulp	0	12	88
Initial pulp	1	23	76

Fig. 3—Development of sheet strength (100 g/m^2, width 2 cm) during drying for unbleached sulphite pulp retained on a 28 mesh screen

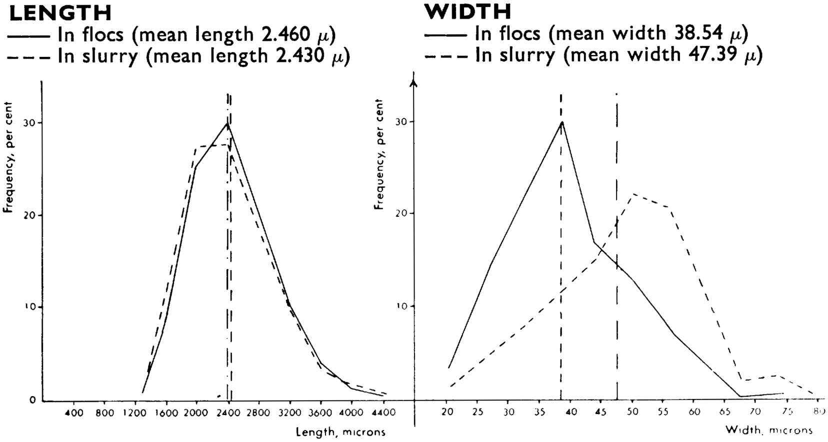


Fig. 4—Distribution of fibre lengths and widths for unbleached spruce sulphite pulp retained on a 28 mesh screen

pulp, are similar to those observed with the kraft pulp. The same remarks can be made as previously on the length and width distribution curves with respect to these pulps (Fig. 4).

Selection between flexible and rigid fibres in a pulp is made by treating the suspension. At certain consistencies and with a certain amount of stirring, it is possible to form within a papermaking slurry very individualised flocs regular in shape and quite coherent (Fig. 5). Fig. 6 and 7 show various kinds of these separated and dried flocs.

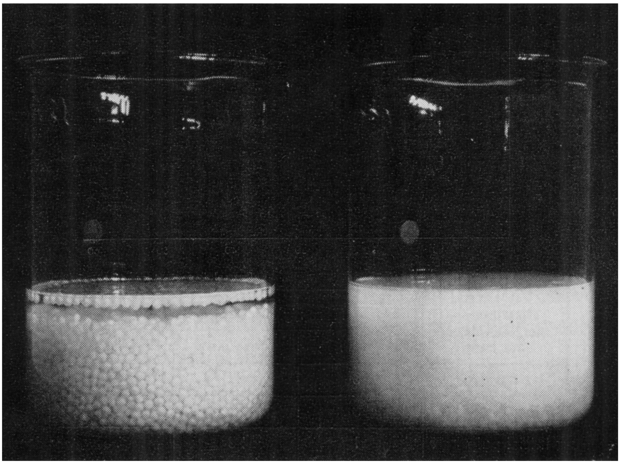


Fig. 5—Pulp flocculated by means of a stirring process

The fibres most suited to form these flocs in the slurry are those having some rigidity and elasticity, which are able to store energy after being bent. Very soft and flexible fibres or fibres that are too rigid (like mechanical pulp) are less liable to aggregate in these networks and they remain mostly between the flocs in a more individualised state.

We consider these observations to fit in well with the hypothesis presented this morning by Steenberg and his collaborators about the mechanism of fibre network formation. Following the preceding discussion between Nissan and Steenberg, however, we may consider this special organisation of fibres so obtained in water (Fig. 5), after the washing out of unagglomerated fibres, as a heap of separated networks of fibres. This concept might be of value for evolving better models for papermaking fibre networks in liquid suspension. Within a certain range of fibre concentration, up to the sediment concentration, we have to consider that the application of shear strength results in rapid entanglement of groups of fibres, giving local variations of concentrations and producing discontinuities inside the network. At this early point, therefore, we must consider the pulp suspension behaving as a random assembly of more or less separated deformable groups of entangled fibres and no more as a random, three-dimensional continuous network. The continuous methodical stirring of the suspension in our process allows separation of 'active' and 'passive' fibres, in Thalén's sense of these terms;(3) the former fibres remain mostly in the flocs, the latter float between the flocs.

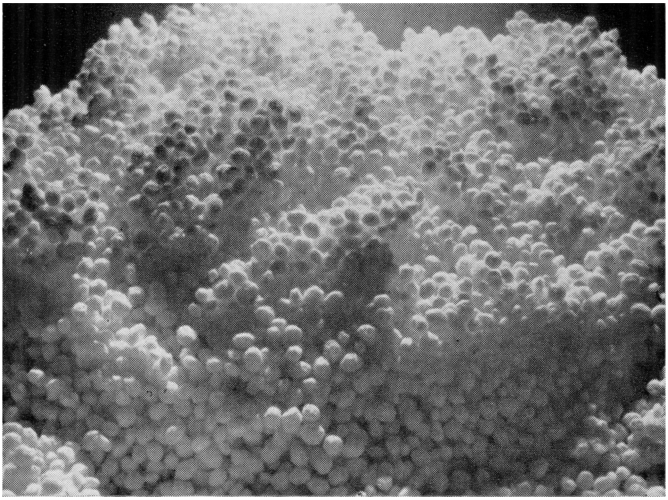


Fig. 6—Dried separated flocs of various pulps

To make the treatment more selective, it may be repeated separately on each fraction after a new dispersion at the proper consistency of the separated flocs on the one hand and of the unagglomerated fibre on the other. The curves in the illustrations were obtained with pulps after the third cycle of treatment. One of the pulps is very rich in springwood fibres and the other, the more rigid, in summerwood fibres. These particular flocculation phenomena will form the subject of subsequent publications. This behaviour of fibres and this method of selection seem to us interesting for the study of fibre network properties; therefore, we considered it advisable to give a brief account of them here.

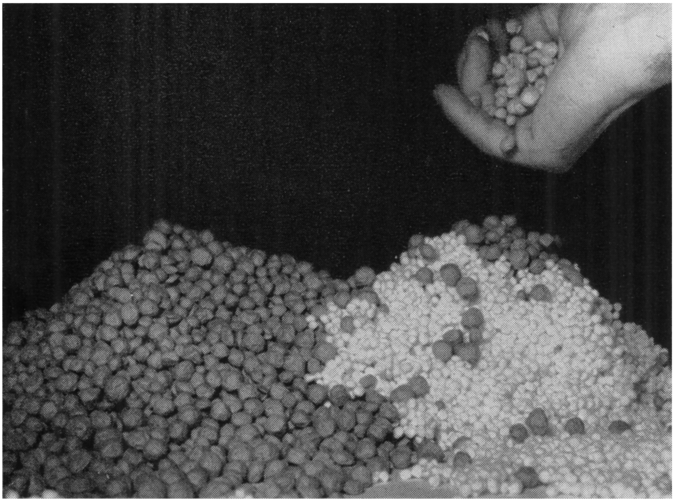


Fig. 7—Dried separated flocs of various pulps

References

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2. Robertson, A. A., Meindersma, E. and Mason, S. G., *Pulp & Paper Mag. Can.*, 1961, **62** (1), T3–T10
3. Thalén, N. and Wahren, D., *Svensk Papperstidn.*, 1964, **67** (5), 186–195

Discussion

Mr B. Radvan—How is the forming consolidation derived? If I understood correctly, what happens is that, if one measures the breaking length against increasing consistency, the conventional breaking length decreases; but, if an allowance is made by using a notched specimen, then the breaking length remains constant and can be derived as a specific breaking length. This is not always so and, when not, this departure is called forming consolidation. Is it not possible that this departure arises simply from the fact that, for example, different form factors apply to flocculated sheets or something similar? Is there any independent information that consolidation takes place, for instance, from measurements of density?

Dr R. J. Norman—Yes, there are in fact small but significant density changes, which reflect that there has been a change in the consolidation of the sheet.

Dr O. J. Kallmes—Could you enlarge on how you reinforce sheets? I find it difficult to believe that to add more substance, the sheet becomes weaker. How did you characterise the structure of these sheets? Are you sure you have a lower degree of bonding in these sheets than those you started with?

Dr Norman—Spotted handsheets were constructed, firstly by making a standard handsheet and couching this from the machine. Then, after inserting a thin perforated plastic sheet over the wire and forming substance spots that had the standard substance, these were wet couched on to the first sheet. Thereafter, the spotted sheet received the same treatment as the standard handsheets, also the same treatment as a sheet formed at perhaps 0.12 per cent consistency and that was a flocculated sheet. It is clear that the type of substance variability present is very different in the spotted handsheet from that in the sheet formed at high consistency. Yet the similar pattern of change in test properties suggests that the substance variation alone has been the major factor.

Dr Kallmes—Would you say that, in wet pressing the sheet, the spots were under greater pressure than the thinner remainder of the sheet? Therefore, the thin parts of the reinforced sheet might be weaker than a sheet with the thickness of the thinner parts over its entire area.

Dr Norman—We attempted to clarify this point, firstly, by using the standard pressing technique, then using a greater number of blotters so that there would be a greater cushioning effect and a more uniform pressure. We found this made no difference to the results. In any case, the differential pressing would have taken place equally as much on the flocculated handsheet as it does on the spotted sheet.

Mr P. A. Tydeman—Firstly, to comment on Kallmes' points, I think the real significance of Norman's work on the effects of substance spots is that it emphasises the importance that formation has upon paper properties. To what extent the spots are bonded and of precise simulation is not of great relevance. Was the specific breaking length calculated by using the substance in the waist itself or the average substance of the paper?

Dr Norman—The specific breaking length is calculated from the average substance. The use of a constant value for the substance is the main reason for the wide scatter in test results.

Mr Tydeman—Presumably, the individual values of specific breaking length vary according to the amount of material in the waist. If you happen to have selected a waist with a high amount of material in it, it is going to be somewhat stronger. Is there a distribution of values and can any information be derived by comparison with the distribution of conventional breaking length?

Dr Norman—Yes, there is quite a wide distribution of specific breaking length values. As one might expect, the breaking load values are spread over the entire range of strength and substance variations within the sheet for this type of test, but the scatter of values that one has with the standard breaking length is very much less, since they represent a scatter about the weaknesses in the sheet.

Dr J. A. Van den Akker—Have you attempted to rationalise your results with regard to the shortness of span and flocculation by means of the Peirce*

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* Peirce, F. T., *J. Textile Inst.*, 1926, **17**, T 355–T 368

weak-link theory? I believe this theory generally accounts for the dependence of the tensile strength of paper on the variance of the material.

Mr G. F. Underhay—Firstly, my immediate reaction to Norman's very interesting presentation was to be a little worried by the straight line obtained by using the waist-line method of testing. On reflection, however, one realises that the marked difference between the straight line and the dropping curve as the consistency goes up is one that has revealed the inadequacy of our testing and not one that discounts the desirability of dilution.

I am reminded that under the direction of Arthur Baker (whom we are delighted to see here), the original sheetmachine grew in height from 8 in to about 16 in entirely from such experimentation to find out how much better sheet uniformity can be by diluting the stock to the standardised consistency of 0.017 per cent.

My second comment concerns some information that Wrist gave us on a slide (I think, in Oxford), the implications of which I regarded as rather shattering. He showed that, if fibres could be distributed in a completely random manner, as calculated by statistical methods, the look-through of the sheet would be extremely disappointing.

To ask an omnibus question, how far are we getting in this symposium in finding out (if, indeed, a statistical distribution fails to give a good sheet of paper) how to produce a good sheet of paper? We have been talking a great deal about factors that affect uniformity of dispersion: even if we achieve an ideal distribution of fibres in paper, according to the statistical information of four years ago, we end up with a sheet that still has a poor look-through.

My last point is that, at the British Association meeting only a fortnight ago here, in Cambridge, Sir Cyril Hinshelwood, in his presidential address, emphasised the great importance of fundamental research. He also brought in the old story of the lack (in this country, at any rate) of nearly enough technological application of fundamental research. Here, I suggest, is an urgent need for us to combine this work on dispersion with the practical objective of producing much improved sheet formation. Personally, I do not yet know how to do it.

Dr N. Hartler—During the discussion, our chairman brought up the question of the relationship between stiffness and nodes. Some fundamental facts are known and I would like to call your attention to them. From Fig. B, we can discuss the fibre stiffness (as measured by bending) and the quantity of kink-bands (as measured in polarised light) as distortions of fibrils in the fibre wall (kink-band is a better word than node). Fibres that have been very carefully removed from delignified, undamaged woodchips contain no kink-bands and would therefore have appeared at the extreme left in the graph. Such fibres are so sensitive, however, that they cannot be mounted and measured by bending. Therefore, no data is available for the interval to the left in the graph. (My articles in *Svensk Papperstidning*, 1963 could be consulted for further information.) As the right of the graph shows, in the early stage of beating, the stiffness decreases with an accompanying increase in kink-bands. Whether or not the flexibilisation of fibres during mechanical handling and beating is a result of preferential banding in the kinks is an open question. During bending, the fibres assumed the shape of a continuous curve, not that of the circumference of a polygon. (Observations were made using only low magnifications.)

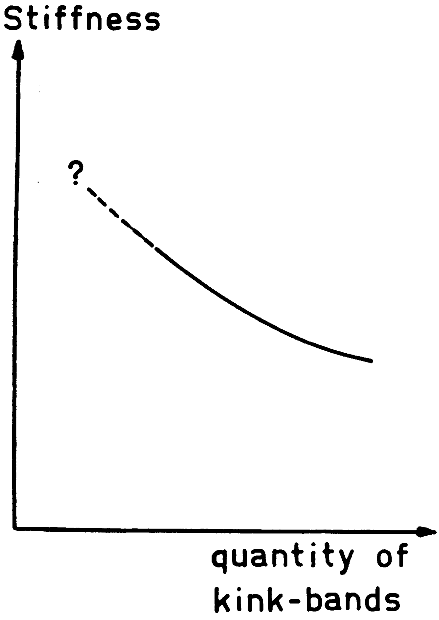

Fig. B

Dr J. Grant—I was very struck by Jacquelin's flocs, because they bear a striking resemblance to the phenomenon known as ricing, a property peculiar to esparto pulp, in mill usage at any rate. One associates it with overdigestion and overagitation by pumping or beating. It appears therefore that esparto pulp is an excellent material for further work, if he wishes to pursue his experimentation. My immediate question is do the known properties of esparto pulp fibres support his theory of the flexible and rigid constituents of a pulp slurry?

Mr G. Jacquelin—We have compared the ability of many pulps to give that kind of floc and have seen that esparto pulp very easily gives a high yield of these flocs. This is probably correlated with the special morphology of these fibres, giving them a certain rigidity. We have compared pulps originating from the same plant material, but with different kinds of cooking. It is the cooking that gives more flexible fibres, which in turn provide the lower yield of flocs. I think it is not only a question of morphology, but also one of degree of cooking of the fibres.

Dr L. J. Groen—I made a small calculation, which might be a bit overdone. We learned from this paper that, in testing handsheets, one should rather use the specific breaking length, which turns out to be roughly 10 per cent higher than the usual average breaking length. The non-ideal formation of machine-made paper gives about another 10 per cent loss in strength values, owing to flocculation (generally accepted experience corroborated by Higgins' paper). According to Schwalbe, the use of alum and rosin size decreases the strength values by roughly 20 per cent. If we take into account that the anisotropy of machine-made paper introduces another 10 per cent strength loss compared with isotropic paper, the paper strength would be about 50 per cent of the pulp (stock) strength potentialities. I do not believe this and I do not think that I am the only one. It means that we have to be very careful in describing the different effects independently and we must be realistic in trying to apply our knowledge to practice, which in fact is our ultimate object.