Kady mill beating, fiber quality testing offer new insights into pulp evaluation.

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Fiber quality testing points to the desirability of a high shear laboratory beating procedure such as supplied by the Kady Mill Beater in order to properly assess the likely performance of pulps in commercial systems.

Conventional pulp evaluation, as currently conducted, examines the changes in the physical properties (e.g. tensile, tear, burst) of laboratory handsheets when produced from pulps beaten for different periods of time in a PFI mill. This is a time honored procedure, but how well does the response of laboratory handsheets to PFI mill beating predict the relative response of pulps to commercial refining and papermaking? Fiber quality testing brings new perspectives to that question.

Laboratory beating vs commercial refining.

In a previous paper *(1)* PFI-handsheet TAPPI tensile data (breaking length, Km) and TAPPI tear data (milliNewtons*sq. meters per gram) of three bleached kraft softwood pulps were assessed in relation to the Pulmac fiber quality numbers[1]. The characteristic response of the fiber numbers to laboratory beating using a PFI mill, presented in that study, are reproduced in Figure 1.

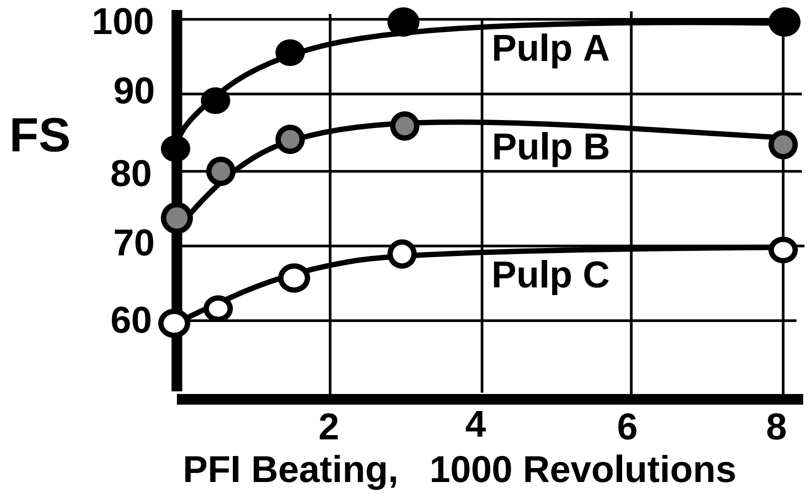
Commercial refining is readily characterized in respect to effect on fiber quality numbers only by comparing the refined with the unrefined pulp; i.e. the starting point (unbeaten) with the end point (after refining). An appropriate means to compare commercial data with laboratory beating is to examine the percentage change in the FS and L numbers as a function of the percentage change in the B number. The laboratory data in Figure 1 has been reframed in this manner to show these changes in the FS number (Figure 2) and in the L number (Figure 3). The results from a number of unconnected refiner studies are superimposed upon these graph with shaded squares representing northern bleached kraft softwood pulps and plain squares representing southern bleached kraft softwood pulps.

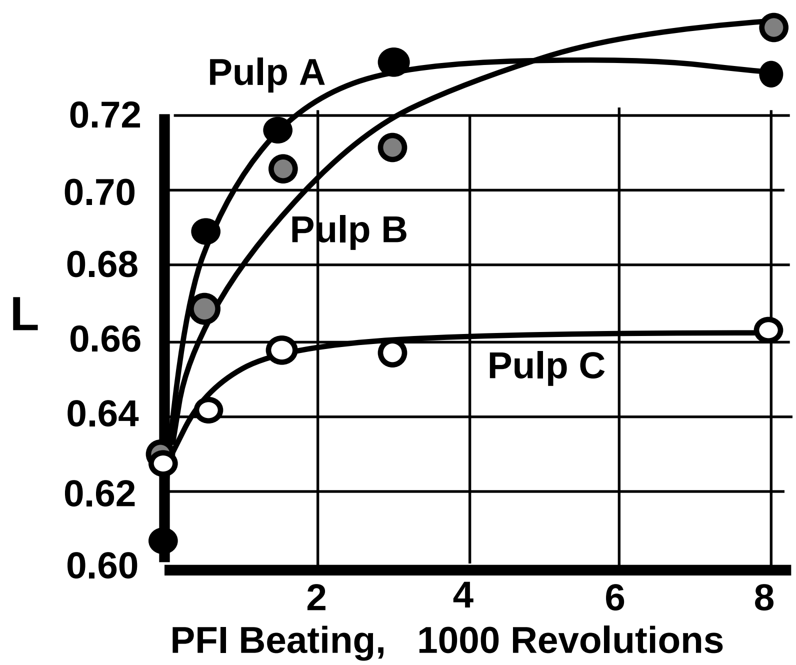
Clearly, commercial refining at the same percentage increase in the B number, yields pulps which show quite different FS and L responses for a wide range of different softwood pulps at different commercial locations. Commercial refining of northern bleached kraft softwood pulps typically does not produce the net increase in either the FS or L numbers that is characteristically achieved by PFI mill treatment. Southern bleached kraft pulps act similarly although the changes in the L number induced by commercial refining do not differ quite so dramatically from the PFI mill results.

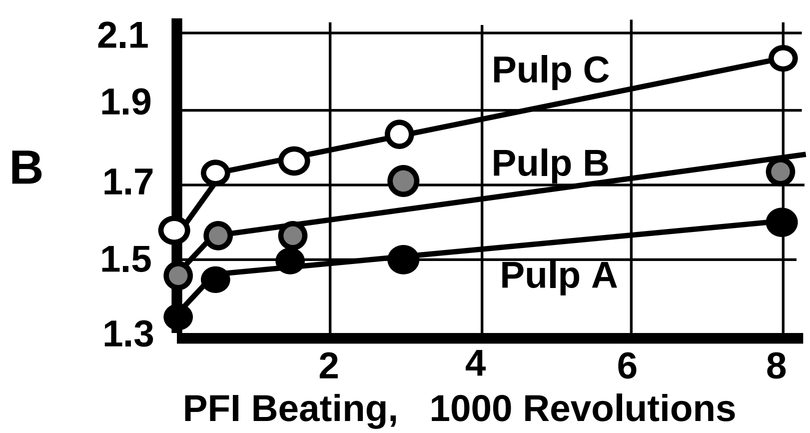
Why do pulp fibers respond so differently to commercial refining compared to PFI laboratory beating, and what significance might this have in respect to using PFI-handsheet data to predict commercial performance?

1. FS number (wet zero span value at 60 gsm); L number (ratio of wet 0.4 mm span value to wet zero span value); B number (ratio of dry to wet 0.4 mm span values)

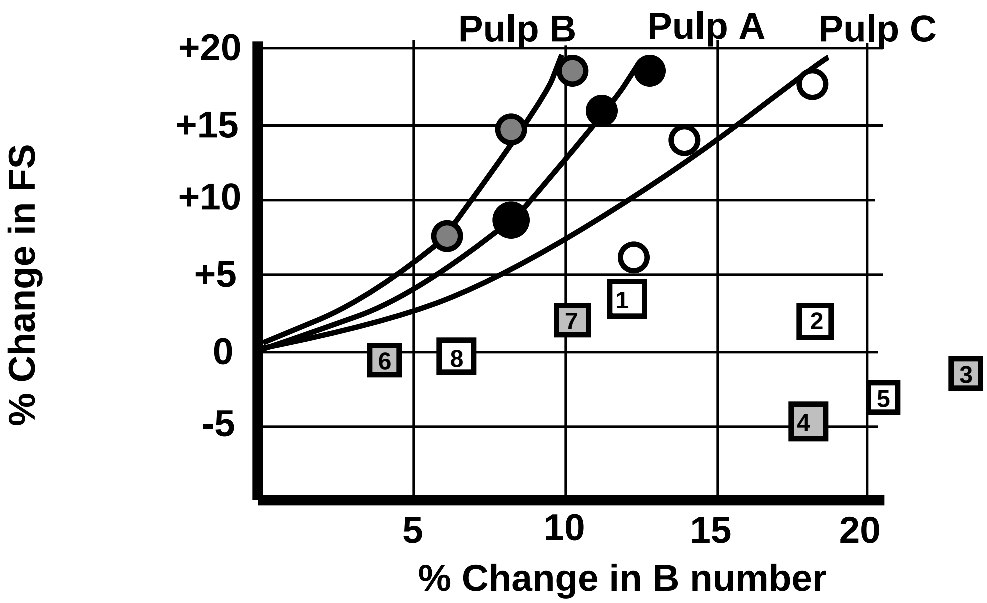
1. Fiber quality data for PFI handsheets



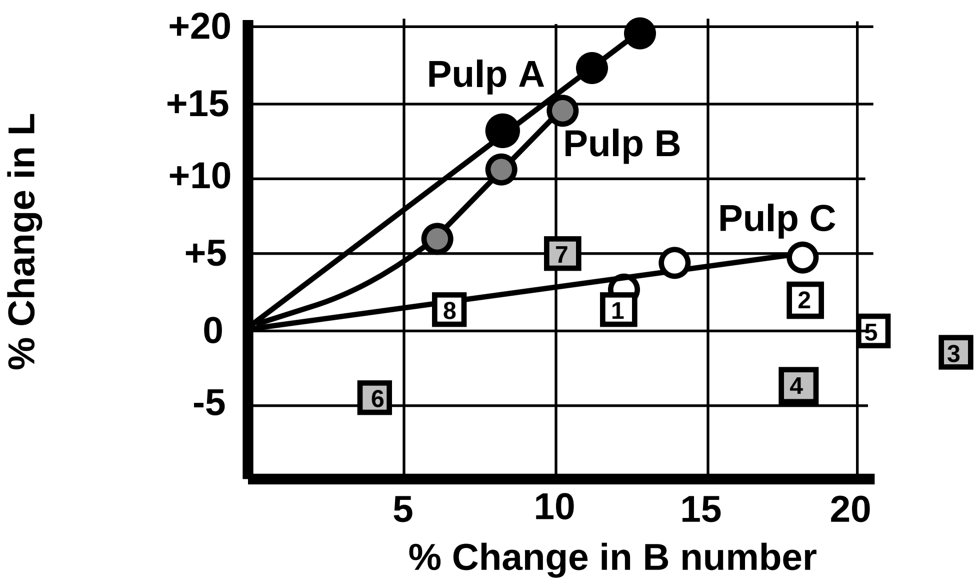




2. FS number response: Commercial refining vs PFI laboratory beating



3. L number response: Commercial refining vs PFI laboratory beating



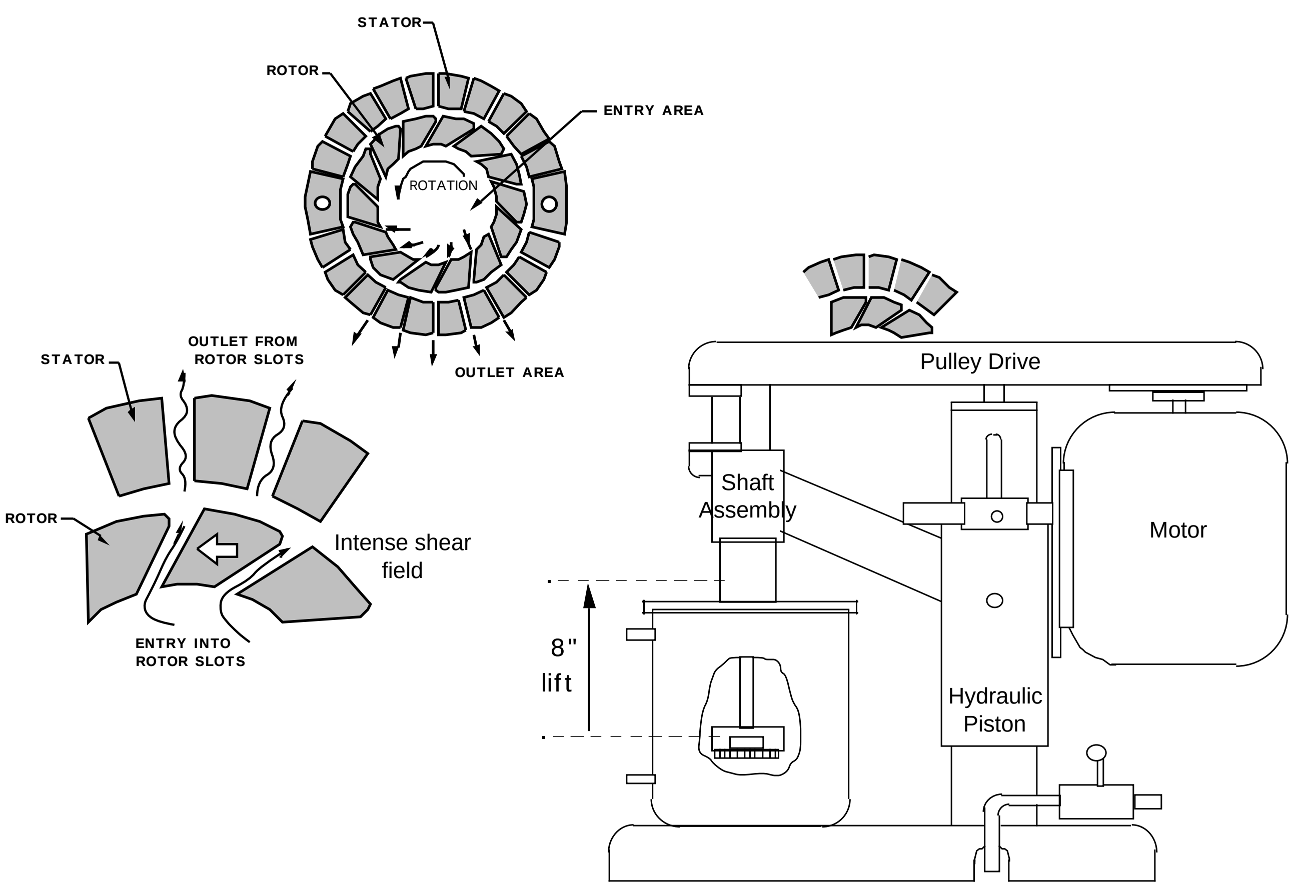
The Pulmac Kady Mill Beater.

One obvious difference between commercial refining and PFI mill laboratory beating is the very much greater energy input and higher shear stresses applied by the commercial refiner. Our work with a new type of laboratory beater, the Pulmac Kady mill beater gave us the opportunity to explore the significance of shear stress in determining fiber behaviour during beating.

The Kady Mill Beater is a modified dispersion unit conventionally used for pigment and particle dispersion in the paint, coatings, and food industries. It produces very high shear rates with a high speed rotor pumping material across a narrow gap and through channels in a surrounding stator as illustrated in Figure 4. The rotor can be easily changed and by using different diameter rotors, the gap between rotor and stator can be varied, thus allowing the intensity of the shear field to be altered over a wide range.

Pulps in the Kady Mill are beaten at relatively low consistencies (ca. 0.5%) for periods up to 10 minutes. The resulting pulps are processed through the PQ System to characterize fiber FS, L and B numbers. Two different rotors are typically used in order to observe the effect of a moderate shear treatment (shear gap of 3.18 mm) and a very high shear treatment (shear gap of 0.45 mm). The high shear intensity is approximately 10 times that of the low shear value.

4. Pulmac Kady Mill Beater



Characteristic Kady Mill profiles and their meaning.

A typical Kady mill fiber quality profile for a bleached kraft softwood pulp is shown in Figure 5. The marked difference between the response to low and high shear Kady mill treatment is at once apparent. The low shear profiles look very similar to the PFI mill profiles shown in Figure 1 and discussed in detail in an earlier paper *(1)*. By contrast, with high shear Kady mill treatment a rapid rise in the FS and L values is followed by a marked decline in both numbers.

The explanation for this decline is that high shear treatment will at some point commence to break fibrils away from the parent fibers, producing fines, which cause the FS number to decline (the wet zero span test cannot clamp fines so that the test value will decline in direct proportion to the increase in fines content). Secondly, it will begin to cause fiber fracture which is witnessed by a decline in the L number. The B number for high shear treatment continues to illustrate the linear increase with beating, but the slope of the line is greater, reflecting the higher B number required to bond together increasing quantities of fines and shorter fibers.

High shear Kady mill beating thus reveals beating and refining as a competition between the beneficial effects of fiber swelling and the deleterious effects of fiber breakdown. Fiber swelling increases the load bearing capability of the fiber (increases the FS number) and by dekinking and decurling the fiber, enhances its effective length (increases the L number). Fiber breakdown produces fines (reducing the FS number) and induces fiber fracture (reducing the L number).

This picture of the beating process provides an explanation for the FS and L response of the commercially refined pulps as illustrated in Figures 2 and 3. The fact that they typically lie well below the levels retained by PFI mill treatment suggests the importance of fiber breakdown in commercial refiners. It also suggests that an important characteristic of a pulp from the perspective of commercial quality might well be its *resistance* to fiber breakdown.

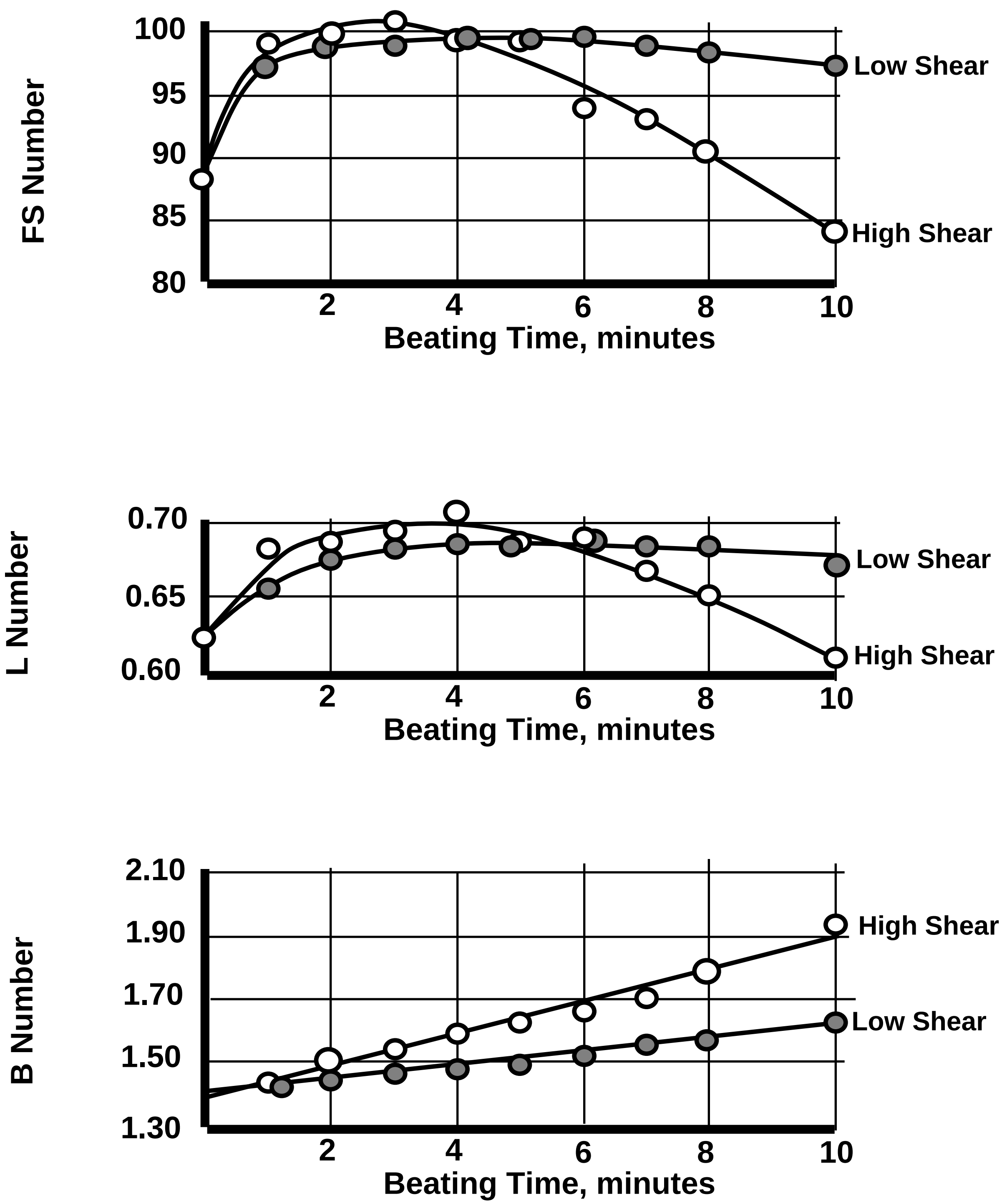
Comparison of PFI and Kady mill treatment of the same pulps.

The bleached Kraft softwood pulps discussed in the earlier paper *(1)* and whose PFI fiber quality numbers are reported in Figure 1, were also tested in the Kady mill. The comparative FS, L and B number profiles shown in Figures 6, 7, and 8, are expressed in terms of relative change from zero beating. They are shown in relation to beating time expressed as a percent of the maximum beating time. In the case of the PFI mill data this was 8000 revs (approximately 1 hour). For the Kady mill it was 8 minutes.

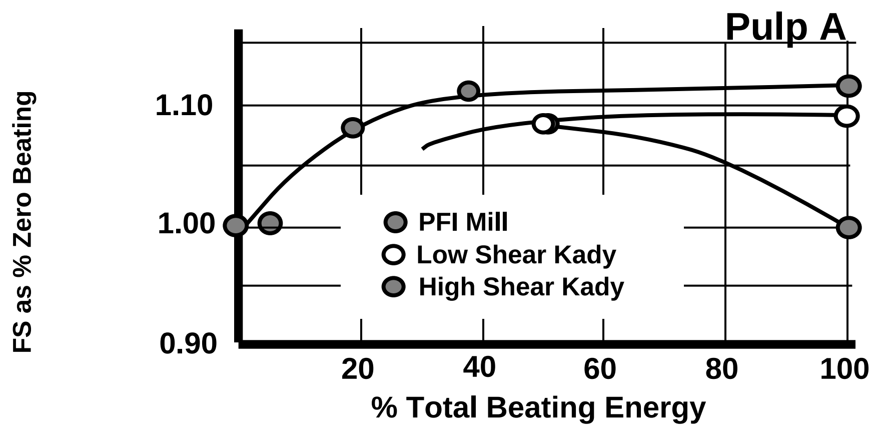
The differences in the relative FS and L number changes after 100% beating are shown in Table I. The changes in the FS value for high shear Kady mill treatment are zero or negative in distinction to the substantially positive values for both PFI and low shear Kady mill treatment, indicative of fiber breakdown. The extent of this fiber breakdown under high shear Kady mill treatment, differs for the three pulps, suggesting that they may well differ in respect to their resistance to fiber breakdown.

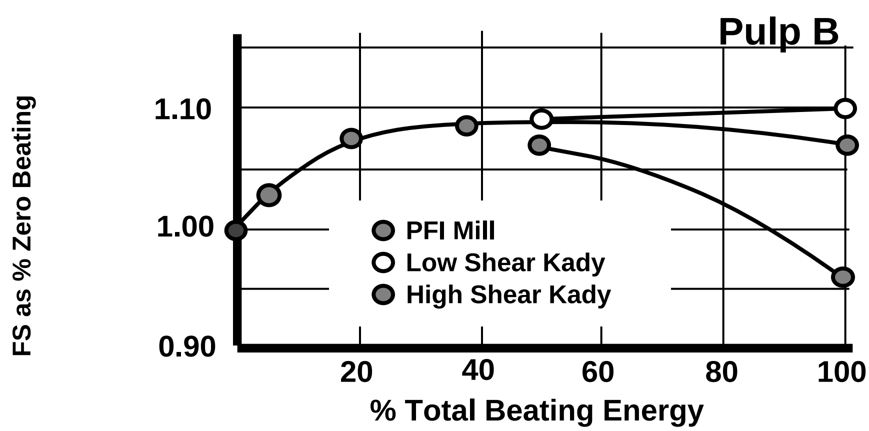
The L number profiles do not show as sharp a distinction between the high and low shear beating processes, but do reflect differences between pulps subjected to high shear beating which mirror the FS results; i.e. suggesting that Pulp A is the most resistant and Pulp C the least resistant to fiber breakdown.

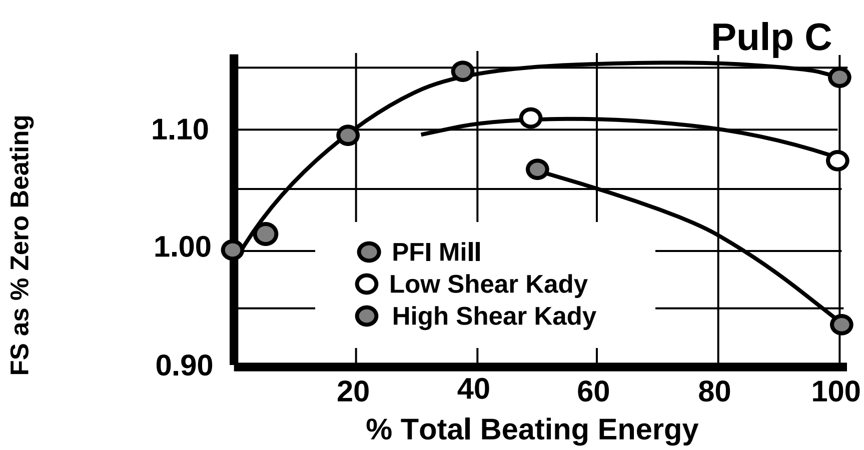
5. Kady Mill fiber quality profiles



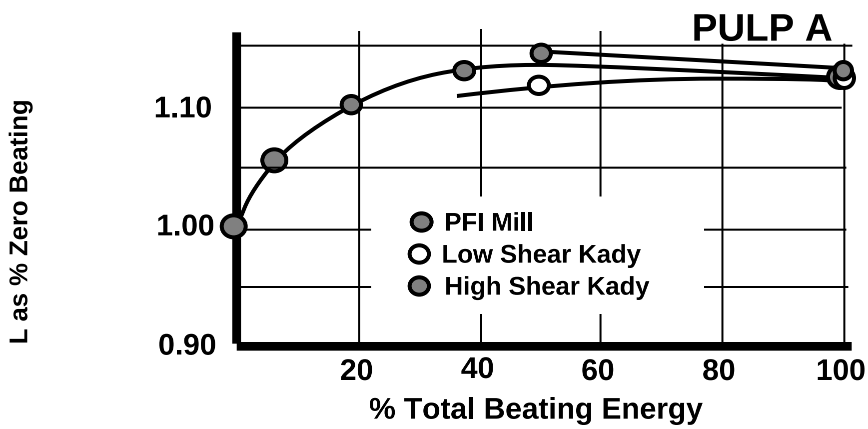
6. Comparative FS numbers: PFI and Kady mill treatments

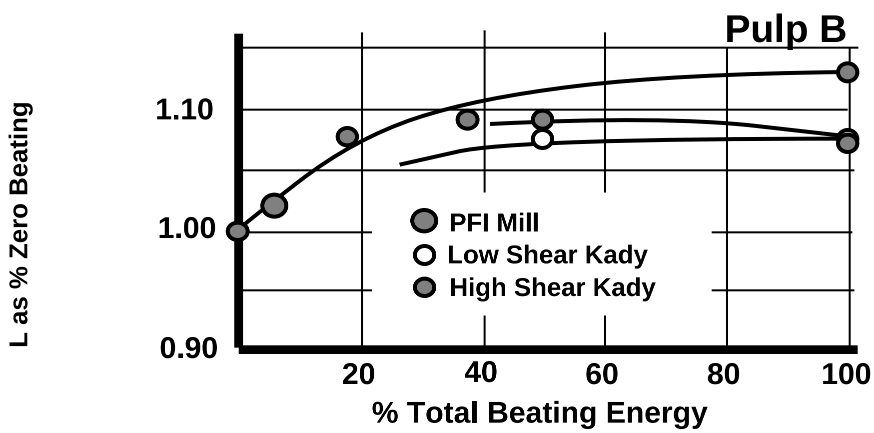


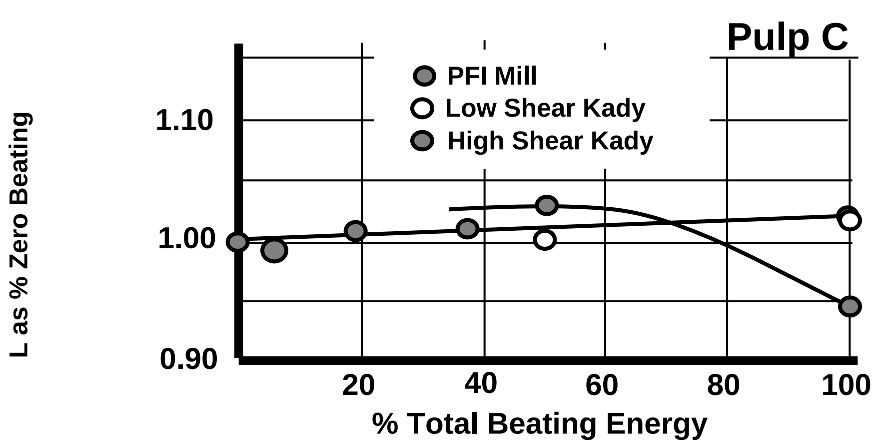




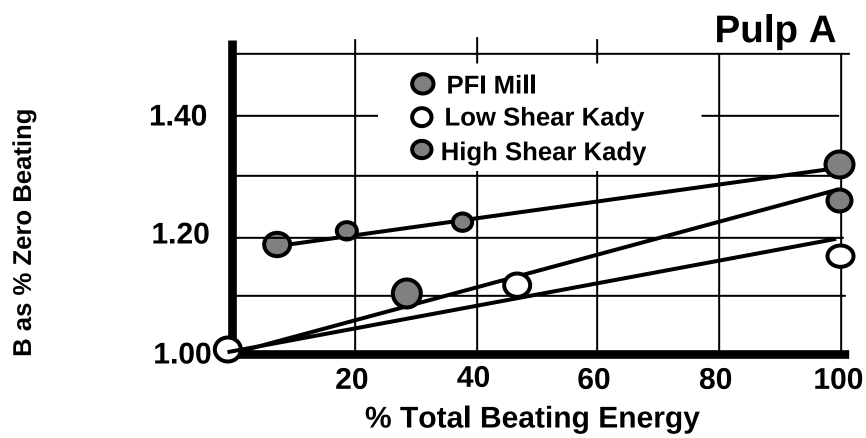
7. Comparative L numbers: PFI and Kady mill treatments

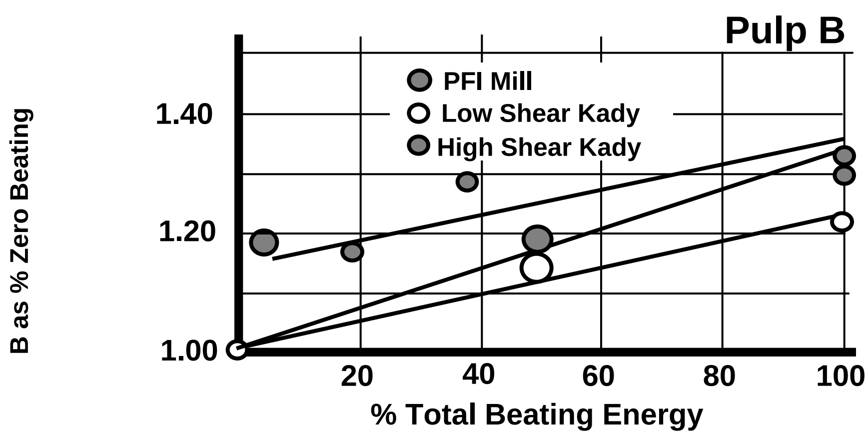


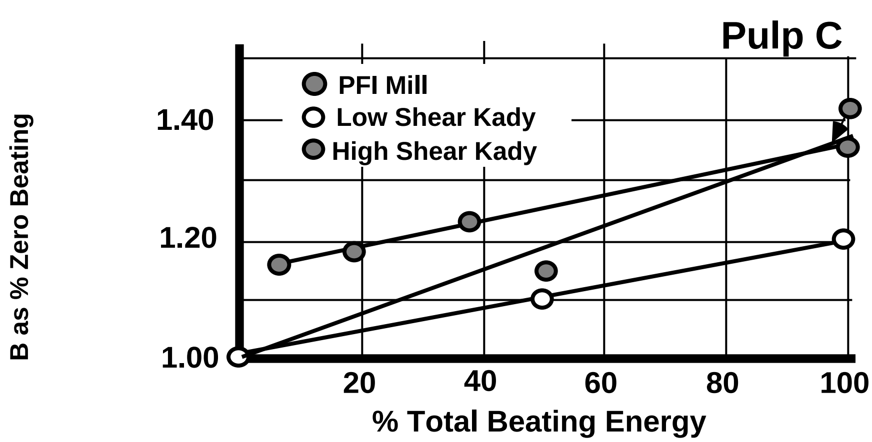




8. Comparative B numbers: PFI and Kady mill treatments







1. Laboratory beating end-point data for FS and L numbers.

100% Beating Data	PFI Mill	Kady Mill LoShear	Kady Mill HiShear
FS Number			
Pulp A	+12%	+9%	0 %
Pulp B	+7%	+10%	- 4%
Pulp C	+14%	+7.5%	- 6.5%
L Number			
Pulp A	+12.5%	+12.5%	+13%
Pulp B	+13%	+7%	+7%
Pulp C	+2.5%	+2.5%	- 6%

The B number profiles indicate that both the PFI and low shear Kady mill pulps exhibit about the same slope for the linear growth in the B number, with the high shear Kady mill pulps showing a greater slope. This reflects the increased B number associated with pulps as fiber breakdown is experienced. The fact that the PFI, B number profile is displaced upward relative to the Kady mill profiles reflects a particularly low B number for the unbeaten PFI pulp. The fiber quality numbers for unbeaten pulps are very sensitive to actual slurrying procedures employed. The PQ system standard (a 25 second, low consistency, low speed treatment in a modified Waring blendor) differs from the normal TAPPI standard method, which may account for the observed displacement.

Conclusion

By measuring fiber quality numbers it becomes apparent that the 5 -15% increase in the FS and L numbers typically produced by PFI mill laboratory beating is not what happens in commercial refiners. Fiber quality data obtained on pulps treated in a high shear Pulmac Kady mill beater suggest that the reason for this discrepancy is due to fiber breakdown. It is posited that some degree of fiber breakdown is the norm when pulps are subjected to the harsh conditions associated with commercial refining. Further, the data presented in this study imply that different pulps exhibit different breakdown tendencies.

These results amply illustrate why interpretation of PFI-handsheet data has proved unable to offer more than a rough guide when assessing how pulps will perform in particular commercial environments. The fiber quality assessment of Pulmac Kady mill beating offers important advantages in assessing pulp quality not available to current standard procedures. Future work will determine whether these advantages materially improve the precision with which a pulp's commercial performance can be predicted.

Literature cited

1. Wavell F. Cowan, Tappi, 2nd paper in the current series.