ABTCP 2002
35º Congresso e Exposição Anual de Celulose e Papel
35th Annual Pulp and Paper Congress & Exhibition
14 a 17 de Outubro 2002 - São Paulo - Brasil
October 14-17, 2002

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ABTCP Associação Brasileira Técnica de Celulose e Papel 35 anos

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Summary

Seven different bleached pulps (using different bleaching sequences) from a common unbleached eucalyptus hardwood pulp, were developed. Each of these pulps was examined by using of a standard PFI mill beating plus handsheet production and conventional physical property testing. All pulps were also tested for viscosity and fiber characteristics using the Pulmac Z-Span 3000 System to determine Z-Span numbers: fiber strength (FS number), length (L number), and bonding (B number). The goal of any pulp or fiber evaluation procedure is to "predict" the performance of the pulp when used in the commercial production of a particular paper grade. The changes in quality are the inadvertent consequences of variations and interaction effects when pulping and bleaching processes are nominally constant. Changes in fiber properties define the non-uniformity produced by a fixed sequence of pulp mill processes applied to a particular wood supply. The variation in the fiber quality of the pulps for this particular study, on the other hand, is not an expression of processing non-uniformity, but of deliberate changes in the chemical processing employed to bleach a constant quality unbleached pulp. When fiber strength declines due to chemical action, the fiber also gets more "limp" and the pulp gets "softer". The consequence is that (1) fibers appear more curled and kinked when examined under a microscope, and (2) the fibers flatten out and develop more bonded area when made into a sheet of paper. Since viscosity measurements reflect the average polymer chain lengths of the “cellulose molecules” within the fiber, they are considered to be related to fiber strength to the extent that changes in this average length effect overall fiber strength. However, the viscosity number is an empirical, rather than a fundamental predictor of fiber strength. Laboratory beating plus handsheet production and testing is currently the normal approach to assessing the performance capability or machine runnability of a pulp. This approach is frequently associated with the development of calculated parameters (viz. tensile at some constant freeness, or tear at some constant tensile value, etc) which experiences has correlated to operational performance. The experiment allowed the conclusion that the handsheet physical strength data, both for an unbeaten condition and when PFI beaten to 400 CSF, can be "explained" as an inter-action of the three parameters derived from Z-Span testing: the FS, L, and B numbers. The predictability of Z-span testing was found to be better than the conventional pulp viscosity test. The evaluation suggests a number of avenues where interpretation of z-span numbers might be useful in more fully understanding the impact of different bleaching sequences on the fiber structure and papermaking quality of fibers.

Resumo

Sete diferentes polpas branqueadas por diferentes seqüências de branqueamento foram preparadas em laboratório a partir de uma única amostra de celulose de eucalipto. Cada uma dessas amostras foi examinada e testada quanto sua refinação e resistências físicas e mecânicas utilizando-se o moinho PFI. As polpas foram também testadas quanto à sua viscosidade e quanto às propriedades intrínsecas das fibras, valendo-se do sistema Pulmac Z-Span 3000. Os testes medidos pelo sistema Pulmac foram: resistência da fibra (FS), comprimento (Número L) e Ligação (Número B). O objetivo básico de qualquer procedimento para avaliação de uma polpa é predizer sua performance em operação industrial e produção comercial. Quando o processo de produção é mantido estável, as variações na qualidade são devidas às alterações nas propriedades das fibras. Por outro lado, nesse estudo, a matéria prima fibrosa foi mantida constante e as alterações de qualidade induzidas foram as variações na forma de se branquear a mesma celulose marrom. Quando a resistência da fibra individual é diminuída, a fibra se rompe mais facilmente e ela também se colapsa durante o processamento industrial. A conseqüência é que as fibras ficam mais encurvadas, enroladas e dobradas, quando olhadas ao microscópio. Elas também se colapsam e se juntam mais, aumentando a ligação entre fibras. Uma vez que a viscosidade da polpa se relaciona com o comprimento das cadeias de celulose, ela tem sido utilizada como um parâmetro indicativo da performance em resistência das polpas. Como esse índice é muito empírico, as avaliações não escapam de se testar também as polpas em ensaios de refino e testes de folhas laboratoriais. O experimento em questão permitiu concluir que os testes físico-mecânicos das polpas podem ser explicados muito bem pelos três parâmetros de qualidade derivados da operação do teste de zero span das fibras: os números FS (resistência da fibra), número L (comprimento) e número B (ligação). A pesquisa indica uma série de oportunidades que podem ser melhor apreciadas na avaliação de materiais fibrosos. Isso é válido tanto para a definição desse material fibroso, como para interpretar efeitos de processo sobre a performance comercial das polpas.

Keywords: fiber, pulp, strength, z-span, evaluation, eucalyptus, zero-span

Palavras-chave: fibras, polpa, celulose, resistências, Zero-span, avaliação, eucalipto

INTRODUCTION

Seven different bleached pulps (using different bleaching sequences) from a common unbleached eucalyptus hardwood pulp, were developed. Each of these pulps was examined by using of a standard PFI mill beating plus handsheet production and testing. All pulps were also tested for viscosity and the fiber characteristics using the Pulmac Z-Span 3000 System to determine Z-Span numbers: fiber strength (FS number), length (L number), and bonding (B number). The goal of any pulp or fiber evaluation procedure is to "predict" the performance of the pulp when used in the commercial production of a particular paper grade. The changes in quality are the inadvertent consequences of variations and interaction effects when pulping and bleaching processes are nominally constant. Changes in fiber properties define the non-uniformity produced by a fixed sequence of pulp mill processes applied to a particular wood supply. The variation in the fiber quality of the pulps for this particular study, on the other hand, is not an expression of processing non-uniformity, but of deliberate changes in the chemical processing employed to bleach a constant quality unbleached pulp.

This report discusses the relation of these fiber quality numbers to the handsheet data.

TEST PROCEDURES

Each unbeaten pulp sample was thickened and fluffed in the Z-3 System Dewatering Device and Fluffer, respectively. The appropriate weight of the fluffed pulp was diluted in the Z-3 System Beater jug and given the standard Z-3 System beating treatment (5 minutes in the Pulmac Beater). This pulp was processed in the Z-3 System Automated Sheet Former (ASF) to produce standard test sheets. These sheets were aimed to be as close as possible as 60 gsm on their basis weight. They have been tested for fiber strength (FS number), length (L number), and bonding (B number) using the Z-Span Tester. Each of the beaten samples was diluted in a bucket and the appropriate volume added to the ASF, producing test sheets as above and tested for the FS, L , and B numbers according to equations in Table 1. The same unbeaten and beaten pulps were also evaluated according to TAPPI Standards to determine their physical testing data. The results of these tests are numerically presented in IS0 units.

Table 1: Tensile strength measurements generated by the Z-Span 3000

FS[1] (N/cm)	=	Zo	=	wet[2] zero span tensile strength
L (%)	=	Z+ / Zo	=	wet short span[3] tensile strength / wet zero span tensile strength
B[4] (%)	=	Zd / Z+	=	dry short span tensile strength / wet short span tensile strength

[1]See ISO 15361 Pulps – Determination of zero-span tensile strength, wet or dry (ISO 15361:2000 (E))

[2]wet zero span tensile strength testing randomly oriented pulp fibers that have been rewet to under 50% concentration such that all fiber-to-fiber bonds are eliminated.

[3]Short spans are set to 0.400 mm.

RESULTS AND DISCUSSION

The data presented in Table 2 include the basic handsheet physical test data for both the unbeaten and PFI mill beaten pulps as well as the Z-Span numbers for all pulps.

The goal of any pulp or fiber evaluation procedure is to "predict" the performance of the pulp when used in the commercial production of a particular paper grade. Most of the Pulmac experience is associated with the effect of changes in the Pulmac Z-Span numbers (FS, L, B) of a pulp from a given pulp mill or on papermaking quality on a given paper machine. These changes, however, are the inadvertent consequences of variations and interaction effects when pulping and bleaching processes are apparently constant. Changes in fiber properties define the non-uniformity produced by a fixed sequence of pulp mill processes applied to a particular wood supply. The variation in the fiber quality of these pulps supplied to perform the study, on the other hand, is not an expression of processing non-uniformity, but of deliberate changes in the chemical processing employed to bleach a constant quality unbleached pulp. The following analysis applies generalized knowledge of the impact of fiber quality changes on paper machine performance to draw conclusions in respect to how "different" rather than "non-uniform" pulps will interact with commercial operation. This means that the purpose was to explore a variability domain for which we lack on extensive directly applicable data, and therefore, on experience.

Table 2 Pulp fiber quality and handsheet data on physical tests

Sample	Pulmac Z-2 Data FS	L	B	Physical Data CSF	Bulk	Tens.	Burst	Tear	TAPPI Visc.	PFI Revs	Air Res.	Opa-city
#1*	90.5	0.37	2.01	572	2.07	35.8	1.5	7.4	16.2	0	0.8	80.8
#2	88.0	0.32	3.25	405	1.47	94.4	6.0	12.2	16.2	2500	12.7	73.7
#3	85.5	0.35	2.17	563	2.12	36.0	1.4	6.4	15.5	0	0.8	81.3
#4	86.5	0.29	3.62	424	1.55	87.1	6.2	12.0	15.5	1800	10.7	75.5
#5	89.3	0.35	2.19	582	2.09	35.5	1.4	7.0	14.1	0	0.8	80.5
#6	88.9	0.29	3.47	405	1.51	92.0	6.4	13.3	14.1	1850	21.6	74.8
#7	89.4	0.36	2.13	572	2.08	36.1	1.6	7.2	14.3	0	0.9	80.1
#8	83.3	0.30	3.56	396	1.49	89.1	6.3	12.3	14.3	1900	24.2	74.8
#9	78.9	0.34	2.31	544	2.06	38.8	1.6	6.9	11.2	0	1.0	80.2
#10	80.8	0.29	3.76	396	1.47	93.7	6.7	11.9	11.2	1950	24.4	74.1
#11	72.1	0.34	2.79	544	2.04	41.2	1.8	8.0	8.7	0	1.0	80.4
#12	68.2	0.32	4.06	424	1.54	87.4	6.1	10.8	8.7	1350	11.6	75.8
#13	51.9	0.34	3.63	526	1.92	44.7	2.0	7.5	8.0	0	1.6	80.3
#14	47.9	0.29	5.47	405	1.46	88.3	5.6	8.7	8.0	1300	25.6	75.6

- Sample Description

(bleaching sequence and beating)

O-D-Eo-D	#1- Unbeaten	#2-PFI to ~ 400 CSF
O-D/C-Eo-D (DC=75:25)	#3- Unbeaten	#4-PFI to ~ 400 CSF
O-D/C-Eo-D (DC=50:50)	#5- Unbeaten	#6-PFI to ~ 400 CSF
O-C-Eo-D	#7- Unbeaten	#8-PFI to ~ 400 CSF
O-A-Z-Eop-D1-D2	#9- Unbeaten	#10-PFI to ~ 400 CSF
O-A-Z-Q-P	#11-Unbeaten	#12-PFI to ~ 400 CSF
O-A-Z-Xq-P	#13-Unbeaten	#14-PFI to ~ 400 CSF

WHAT ROUTINE GENERATION OF Z-SPAN DATA TELLS US

One of the most simple test procedure for pulp evaluation is to determine the Pulmac fiber quality numbers using the standard Z-3 System procedures on the unbeaten pulp. This is the procedure employed for routine testing in a number of commercial pulp mill applications.

A selection of data were extracted from Table 2 and presented in Table 3. The data have been ordered in terms of declining FS number. Former experience with variability in pulp mill fiber quality suggests that it takes a decay of some 5% in the FS number of a pulp to measurably increase the probability for reduced performance on the paper machine. From this experience, a first criterion of "difference" between pulps is that their FS numbers differ by at least 5%. Accordingly, with reference to Table II, Criterion 1 labels pulps #1, 7 , 5 as one category, with the other pulps being in different categories. A significant decline in the FS number of a pulp induced by the chemical action of cooking or bleaching has been found to signal other significant changes in the character of the fiber.

When fiber strength declines due to chemical action, the fiber also gets more "limp" and the pulp gets "softer". The consequence is that (1) fibers appear more curled and kinked when examined under a microscope, and (2) the fibers flatten out and develop more bonded area when made into a sheet of paper. These changes are reflected in fiber quality measurements by a decline in the L number, due to increased fiber curl (the L number measures the probability that a fiber will span a fixed gap and this probability is lower for a curled fiber relative to the same fiber when straight), and an increase in the bonding or B number. These trends are clearly displayed by the data in Table 3.

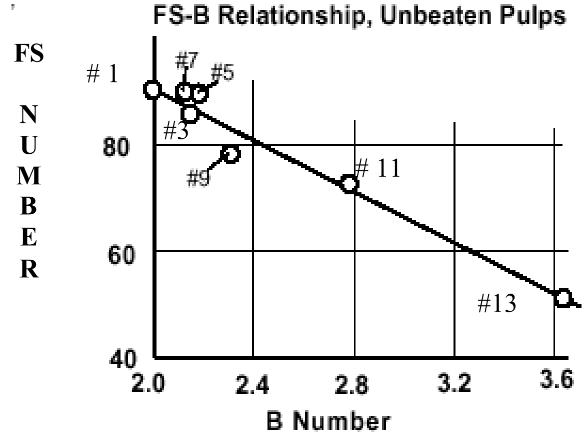
Table 3: Routine Fiber Quality Tester (FQT) data

Sample	FS	L	B
#1*	90.5	0.37	2.01
#7	89.4	0.36	2.13
#5	89.3	0.35	2.19
#3	85.5	0.35	2.17
#9	78.9	0.34	2.31
#11	72.1	0.34	2.79
#13	51.9	0.34	3.63

Since in the case of this particular study, the changes in the fiber properties are due to significant changes in the nature of the chemical environment during bleaching, it is possible that in addition to the physical changes discussed above, that the following phenomenon may be happening: fibers' surface chemistry and fiber wall structure are sufficiently altered to influence the bonding ability; e.g. an increase in retained hemicellulose would enhance the bonding process. Also, a weakening on fiber wall speeds up the fiber collapsing to a ribbon-like structure, improving bonding. Another effect of preserving hemicellulose is the light effect on fiber coarseness (+) and fiber population (-). This would be reflected in discrepancies in the FS - B relationship. Figure 1 illustrates this relationship. Perhaps pulps #7 and 5 show marginally superior bonding potential, and # 9 somewhat lower bonding potential, but these discrepancies are not glaring.

Based on this general preamble pulps #1, 5, and 7 are expected to have a comparable response to any given beating or refining treatment, and in a given papermaking environment to act comparably and yield papers with comparable physical properties. Pulp # 3 is also relatively close to this trio. The rest of the pulps will tend to "wet out" and "break up" more readily during beating and refining as their FS number declines. Physical handsheet properties will tend to decline due to the increasing decline in the strength of the fibers, and can only be restored by a deliberate increase in the bonding potential of the pulp, producing a steady decline in sheet bulk and opacity and an increased "tininess" of the sheet. The possibility of this recovery of physical properties will be significantly diminished in commercial systems, where the refining action is sufficiently harsh to offset gains in bonding potential by a greater fiber break up, reducing fiber length and increasing the production of fines.

FIGURE 1
FS-B Relationship, Unbeaten Pulps



Laboratory PFI beating and handsheet production represent one predictive laboratory mode of converting pulp to paper and it is interesting therefore to see how well the "predictions" developed from "routine" fiber quality measurements apply to these papers. In Table 4 the fiber quality data given in Table II is extended to show the papermaking consequence using laboratory equipment.. The PFI beating strategy employed was to adjust the amount of beating in order to cause all pulps to exhibit a CSF - Canadian Standard Freeness of about 400.

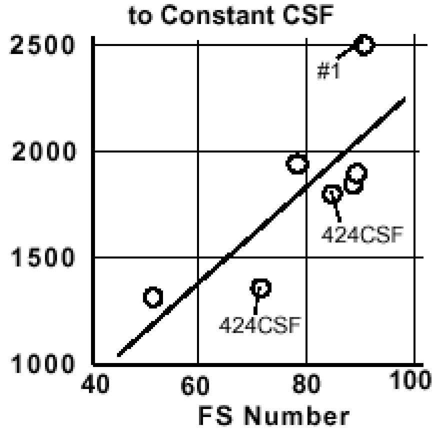
Table 4: Routine FQT data & PFI handsheet quality

Sample	FS	L	B	CSF	Revs	Burst	Tensile	Tear	Bulk	Air Res.	Opa city
#1,2	90.5	0.37	2.01	405	2500	6.0	94.4	12.2	1.47	12.7	73.7
#7,8	89.4	0.36	2.13	396	1900	6.3	89.1	12.3	1.49	24.2	74.8
#5,6	89.3	0.35	2.19	405	1850	6.4	92.0	13.3	1.51	21.6	74.8
#3,4	85.5	0.35	2.17	424	1800	6.2	87.1	12.0	1.55	10.7	75.5
#9,10	78.9	0.34	2.31	396	1950	6.7	93.7	11.9	1.47	24.4	74.1
#11,12	72.1	0.34	2.79	424	1350	6.1	87.4	10.8	1.54	11.6	75.8
#13,14	51.9	0.34	3.63	405	1300	5.6	88.3	8.7	1.46	25.6	75.6

The prediction that pulps wet out and break up more readily as FS number declines, broadly characterizes the reduction in beating time from 2500 to 1300 PFI revolutions to produce nominally the same freeness. This is illustrated in Figure 2.

The prediction that pulps #1, 5, and 7 should be comparable with respect to rate of beating and paper properties, seems to apply more to pulps #5 and 7, with pulp #1 showing greater resistance to beating and a somewhat higher handsheet tensile value. The lower B number and higher L number recorded for this pulp may be relevant to this observation. The prediction in respect to the other pulps is generally borne out. By adjusting the amount of beating the physical properties (burst, tensile, and tear) have been evened out, although the lowest FS number pulps still show a deficit. It is known that the paper strength is a combination of fiber strength and bonding. More bonding do not necessarily means better tensile or burst, because the fiber may be weaker.

FIGURE 2
FS correlation with PFI Revs to Constant CSF



It is possible to conclude that the logic of the predictions based on FS number for beating ability is sound, assuming that in a commercial environment adjusting refining treatment would not produce the evening out of physical properties as achieved in the laboratory. That is, in the commercial environment the papers produced from these pulps would more strongly reflect the limits imposed by the large differences in fiber strength.

It is important to emphasize the fact that the pulps # 1, 5 and 7 were proved to be similar in fiber quality and handsheet properties. They were bleached, and also pulp # 3, using a similar family of bleaching sequences, ODEoD ; OD/CEoD ; OCEoD.

On the other hand, the pulps showing lower FS, higher B values, lower pulp viscosities, lower energy to beating, lower strengths, and better opacity, are those bleached by TCF sequences (OAZQP ; OAZXqP). Curiously, the opacity for these TCF pulps was good, better than the obtained in the first family of bleached pulps. A possible explanation is that the removal of chemicals along the TCF bleaching sequences reduced the individual fiber weight, and fiber population could be more numerous (number of fibers per gram of pulp). As a consequence, the opacity increased even considering the increasing on the B value. The reduced fiber and handsheet strengths for samples # 11 and #13 give good indications that the fiber walls were damaged.

HOW "PREDICTIVE" ARE THE PFI-HANDSHEET DATA?

The general conclusions developed in the prior section bring into question the ability of this PFI-handsheet data to correctly predict commercial quality of these various pulps. Certainly the physical test data are more difficult and time-consuming procedures to be performed in routine analysis than the analysis of Z Span numbers.

In general, the evening out of the physical properties by using of different PFI beating times, clearly implies significant differences in the bonding levels achieved by the various pulps. This is demonstrated by comparing the tensile values with a measure of the *dry* zero span test value for the same pulps. The air dry zero span test measures the maximum possible tensile strength of the bonded network, a value which can be approached by increasing interfiber bonding , but never exceeded. So, the ratio of the observed tensile strength to the dry zero span value (T/DZS) will increase as bonding levels increase. These data, obtained from Table I with the dry zero span values being expressed in the same units (N.m/g) as the tensile values, are presented in Table 5. The variability of the ratio values is evidence of the variability in interfiber bonding. This is also reflected in the B number derived from these pulps, which correlate strongly with the T/DZS ratio.

Table 5: Tensile / Dry Zero Span Ratios

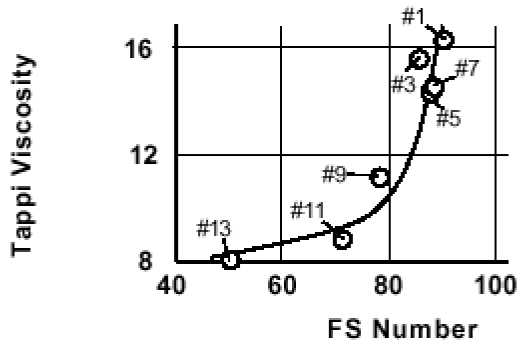
Sample	Tensile	Dry ZS	T/DZS	B
#2	94.4	189.2	.499	3.25
#8	89.1	182.5	.488	3.56
#6	92.0	189.0	.487	3.47
#4	87.1	183.3	.475	3.62
#10	93.7	185.5	.505	3.76
#12	87.4	176.2	.496	4.06
#14	88.3	153.3	.576	5.47

For this series of bleached eucalyptus pulps, interpreting physical properties of laboratory handsheet at a PFI nominally constant freeness of 400 CSF as being indicative of relative paper machine performance is at odds with fiber quality testing. As an illustration, pulps 2 and 14 are derived from pulps with FS numbers of 90.5 and 51.9 respectively, representing a decline of more than 50%. Yet, these pulps show a decline of only 6% in hand-sheet tensile, 7% in burst, and 29% in tear. This result is very much associated with the particular PFI mill treatment accorded to the pulps. It is likely that in any commercial environment, where refining was an important process element, the suggested distinctions (tensile, tear, burst) between pulps would prove grossly understated.

HOW "PREDICTIVE" IS VISCOSITY?

Viscosity measurements reflect the average lengths of "cellulose molecules" within the fiber wall. The viscosity measurement will relate to fiber strength to the extent that changes in this average molecule chain length effect overall fiber strength. However, structural effects like changes in kinks, crimps and micro compressions (which determine the way load flows through the network of molecules) can compensate for losses in molecular length, or themselves cause a net decline in fiber strength. So, the viscosity number is a partial, rather than a fundamental predictor of fiber strength. In addition, varying residual chemistry associated with different bleaching processes and the statistical noise of the actual test method limit the usefulness of the viscosity test measurement. For the pulps produced by this series of different bleaching sequences, this empirical relationship is shown in Figure 3. It is apparent that the decline in viscosity for a number of the pulps exaggerates the impact on fiber strength, although the general trend for a decline in viscosity to correspond to a decline in fiber strength is clearly evident.

FIGURE 3
The Viscosity - FS Relationship



DO Z-SPAN NUMBERS "EXPLAIN" HANDSHEET STRENGTH PROPERTIES?

Since the actual PFI pulps treated to produce a nominally constant 400 CSF, were tested both for handsheet properties and for Z-Span numbers, as were the unbeaten pulps (see Table 2), all these data were examined statistically by multiple regression to assess the extent to which the variation in handsheet physical strength properties could be attributed to changes in the fiber quality numbers.

A logarithmic model was chosen for this assessment of the form:

$$\textbf{Handsheet property} = (FS^a \times L^b \times B^c) \div K$$

where a, b, and c, are empirical indexes, and K an empirical constant. The results are shown in Table 6.

Table 6: PFI handsheet quality and fiber quality relationships

Handsheet Property	Multiple Regression Equation	R^2 Value
Tensile	$\frac{FS^{1.7} \times L^{0.8} \times B^{2.2}}{139}$	0.98
Burst	$\frac{FS^{2.8} \times L^{1.4} \times B^{3.5}}{70600}$	0.99
Tear	$\frac{FS^{1.45} \times L^{0.84} \times B^{1.41}}{111}$	0.95

These multiple regression equations yield "predictions" relative to actual measurements which are compared for all three sets of physical handsheet test data in Table 7.

Table 7: Predictability of multiple regression for handsheet physical strength and Z Span numbers

	Tensile		Burst		Tear	
Sample	Actual	Predicted	Actual	Predicted	Actual	Predicted
#1	35.8	34.5	1.5	1.4	7.4	7.1
#2	94.4	84.2	6.0	5.6	12.2	11.9
#3	36.0	35.4	1.4	1.4	6.4	7.0
#4	87.1	95.5	6.2	6.8	12.0	12.5
#5	35.5	38.9	1.4	1.7	7.0	7.5
#6	92.0	91.3	6.4	6.4	13.3	12.2
#7	36.1	37.5	1.6	1.6	7.2	7.4
#8	89.1	89.2	6.3	6.1	12.3	11.9
#9	38.8	34.5	1.6	1.4	6.9	6.6
#10	93.7	92.4	6.7	6.4	11.9	11.9
#11	41.2	44.8	1.8	2.0	8.0	7.6
#12	87.4	88.6	6.1	6.0	10.8	11.3
#13	44.7	45.5	2.0	2.0	7.5	6.8
#14	88.3	86.1	5.6	5.5	8.7	9.5

These data generally bear out our qualitative conclusion that the level of bonding is a major variable and accounts for a significant component of the variability in handsheet strength properties. This is not only true for the difference between unbeaten and beaten, but also for the variability within constant freeness pulps, as witness the generally comparable quality of the prediction for these latter pulps compared to the unbeaten pulps.

EFFECT OF PFI BEATING ON Z-SPAN NUMBERS

In Table 8 are illustrated the changes induced in the fiber quality numbers when the unbeaten pulps are PFI beaten to ca. 400 CSF.

Table 8: Effect of PFI beating to 400 CSF on fiber quality data

	Unbeaten			PFI	PFI to 400 CSF			% Change			Change/1000revs		
Sample	FS	L	B	Revs	FS	L	B	FS	L	B	FS	L	B
#1,2	90.5	0.37	2.01	2500	88.0	0.32	3.25	-2.8	-13.5	61.7	-1.1	-5.4	24.7
#3,4	85.5	0.35	2.17	1800	86.5	0.29	3.62	+1.2	-17.1	66.8	+0.7	-9.5	37.0
#5,6	89.3	0.35	2.19	1850	88.9	0.29	3.47	-0.4	-17.1	58.4	-0.2	-9.2	31.6
#7,8	89.4	0.36	2.13	1900	83.3	0.30	3.56	-6.8	-16.7	67.1	-3.6	-8.8	35.3
#9,10	78.9	0.34	2.31	1950	80.8	0.29	3.76	+2.4	-14.7	62.8	+1.2	-7.5	32.2
#11,12	72.1	0.34	2.79	1350	68.2	0.32	4.06	-5.4	-5.9	45.5	-4.0	-4.4	33.7
#13,14	51.9	0.34	3.63	1300	47.9	0.29	5.47	-7.7	-14.7	50.7	-5.9	-11.3	39.0

Laboratory studies have demonstrated that in the very early stages of beating the fracture of the thin outer wall of the fiber permits fiber swelling to occur. This swelling tends to eliminate dislocations and constrictions in the main body of the fiber allowing a more uniform transfer of load. For this reason, the early initial period of laboratory beating is normally accompanied by an increase in the FS number (5-15%). Fiber swelling also causes a dekinking and decurling of the pulp fibers, causing them to straighten out. For this reason, the initial period of laboratory beating is generally accompanied by an increase in the L number (5-20%). Later stages of beating can initiate fiber fracture. Under such conditions, the L number is observed to decline. Such beating can also generates fines whose appearance forces a decline in the FS number. Fines are too small to be clamped by the zero span jaws, but contribute to sheet weight thereby reducing the FS number in proportion to their presence. Beating enhances interfiber bonding, which is the dominant goal of the process. A continuous increase in the B number with beating reflects this reality.

In Table 8 although we use the description "unbeaten" to describe the initial condition of the fibers, they have actually been treated for 5 minutes in the Pulmac Z-3 System Beater. This treatment is effective in swelling and decurling the fibers. For this reason, the expected effect of PFI beating on the Pulmac fibers strength number is not significantly observed. However, significant negative numbers for L changes due to beating do reflect break-up of the fiber due to fracture and fines production.

Past evidence indicates that as the FS number of a pulp from the same wood species and general pulping condition declines, that the decline in FS for a constant amount of beating increases, as does the decline in L number and the gain in B number. Applying this general observation to the changes in the Pulmac fiber numbers per 1000 revs of PFI beating as given in Table 8, suggest anomalies which may be relevant in respect to specific bleaching applications. For instance, applying the above trend we note the % decline in FS going from near 0 (+1% to -1%) to -5.9% as FS declines from 90 to 52. Pulp # 7, 8 shows a significantly greater % FS decline than implied by this trend, and Pulp # 9, 10 shows a significantly lower % FS decline. Similarly for the % decline in L, we can define a trend from -5% to -11% over the FS range from 90 to 52, with Pulps # 5, 6 and # 7, 8 showing a significantly greater % L decline and Pulp #11, 12 a significantly lower % L decline than implied by this trend. For the %B increase there is significant scatter about the trend line from +25% to +39% (for FS 90 to 52), with Pulp #11,12 having the most significant departure with a substantially lower gain in %B than expected based on its FS number. From this rough assessment we can note that Pulp #7,8 shows a greater %FS and %L decline than expected, and Pulp #11,12 shows a reduced decline in %L and increase in %B than expected. Perhaps these two pulps are responding to the particular bleaching sequences employed in the most "unexpected " manner.

CONCLUSIONS

Laboratory beating plus handsheet production and testing is currently the normal approach to assessing the performance capability of a pulp. This approach is frequently associated with the development of calculated parameters (viz. tensile at some constant freeness, or tear at some constant tensile value, etc) which experiences have correlated to commercial performance.

Z-Span numbers developed from standard Z-3 System pulp testing provide three directly measured parameters which can also be empirically correlated to commercial pulp performance.

Finally, mill practice frequently involves the measure of pulp viscosity as the parameter which is empirically correlated with runnability performance.

In this report, data from each of these three different pulp quality assessment measurements are compared in respect to "predictability" of commercial performance of pulps produced using different lab bleaching sequences on the same unbleached eucalyptus pulp. Based on our interpretation of how people normally use viscosity and beater/handsheet parameters (i.e. pulp performance is assessed in respect to linear changes in the observed parameters) we conclude that viscosity measurements would tend to overestimate the predicted physical testing decline in commercial pulp quality of pulps #3 through #7 relative to Pulp #1. From beater/handsheet testing, the use of physical property data at 400 CSF as the criterion, would badly underestimate the decline in commercial pulp quality of Pulps #9 through#13 relative to Pulp #1.

Based upon these analyses, the viscosity data was proved not to be a powerful predictor of the 400 CSF physical test data for the quality of these pulps.

The data presented allow the conclusion that the handsheet physical strength data, both for an unbeaten condition and when PFI beaten to 400 CSF can be "explained" and “predicted” as an interaction of the three parameters derived from Z-Span testing, the FS, L, and B numbers.

The evaluation in general suggests a number of avenues where interpretation of fiber quality numbers might be useful in more fully understanding the impact of different bleaching sequences on the fiber structure and quality. It also provides information about bleaching sequence effects on fiber qualities, such strength and bonding. Conventional sequences with chlorine dioxide, chlorine and caustic extractions have yielded better fiber quality results (and also handsheet strengths), in comparison to the sequences containing ozone, with lower viscosity and lower fiber strength.

Our final conclusion is that these data fit well into the much larger body of data that have been acquired over the years, exhibiting comparable explanatory power, and continuing to support the conclusion that fiber quality testing using the Z-Span tester provides an economical and rapid system for pulp quality evaluation.

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