The operating regime in mechanical pulps - the significance of fiber failure

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Introduction

It has generally been assumed that mechanical pulps operate in a domain where fiber breaking has an insignificant effect on the fracture mechanism in tensile and tear test, and the main failure is believed to occur through the bonds between the structural elements in the sheet /1, 2/. There are, however, indications that modem mechanical pulps, which are mainly composed of fines (P200) and long fiber (R48) with a u-shaped Bauer-McNett classification distribution, undergo significant fiber failure in tensile and tear testing /3-5/.

Several authors have investigated this problem. However, the experimental approach has been limited by the fact that bonding in mechanical pulps cannot be significantly increased without changing the sheet composition /2, 6/. Refining as a means to increase bonding in mechanical pulps produces significant amount of additional fines which alters the composition of the sheet /7/. Wet pressing has limited effect on mechanical pulps, increasing bonding slightly in some cases, and having no effect at all in others. This is likely due to the fiber rebound after the pressure is released /8, 9/. Thus, most of the studies have relied on artificial blends, where bonding was increased by increasing the fines content. To maintain the fiber length constant, the R28, R48 and R200 composition of the sheet is adjusted/2, 6/. This approach has provided significant results, and has altered the perception about the operating domain, however, it has not been able to provide unambiguous proof of the significance of fiber failure on strength properties in mechanical pulps.

In order to circumvent the problem of altering the sheet composition to increase bonding, in this study the bonding was increased by wet pressing and press drying sheets to various levels of RBA. The operating regime problem was then studied by interpreting the tear relative to bonding (where bonding is measured as T/Z, Tensile index/Zero span tensile index) relationship in whole TMP, its fractions and mixtures of these fractions. In addition the effect of fiber length on the tear strength at various bonding levels was studied using the data obtained from the mixture studies.

Experimental

Fiber middle and fines fractionation: The Bauer McNett apparatus was used to fractionate a hot disintegrated 110 CSF Norway spruce (Picea abies) TMP. The R48 (all above R48), R200 and P200 fractions were collected. The P200 fraction was collected using the sedimentation method. The R48 fiber fraction was fractionated twice in order to achieve a near pure fiber fraction without any fines present. *Handsheet forming:* Handsheets were formed using a 150 mesh screen and recirculation of white water. Fines handsheets were formed on a dense glass fiber filterpaper. All handsheets were restraint dried if not dry after pressing. The target handsheet basis weight was 60 g/m^2 O.D. *Wet pressing:* Couched handsheets were not pressed. Wet pressing was conducted at 65, 489 and 978 psi's and 23°C using a Carver press and 3 blotter papers on the one side and a chrome plate on the other side of the handsheet. Wet pressed handsheets were pressed for 1 minute. *Press drying:* Press drying was conducted at 6 pressing levels 0, 0.8, 8.1, 16.3, 48.9 and 163 psi's. Individual handsheets were pressed between hot plates heated to 120°C using a sandwich that consisted of a felt, wet blotter (to increase drying time and humidity above 100°C), handsheet, chrome plate, and a filter paper (to protect the chrome plate). All handsheets were pressed until completely dry. *Testing:* Tensile and Tear strengths were measured using the Tappi standardT-494, with exceptions of a reduced span length (2 inches), and 0.5 inches/min strain velocity in the tensile test. Zero span tensile strength was measured using a Pulmac zero span tensiletester.

Results and Discussion

Figure 1 depicts the decrease in Tear index as the bonding (Tensile index / Zero span tensile index) is increased by wet pressing and press drying of whole pulp TMP sheets. The whole pulp TMP is already at maximum Tear index without significant pressing, and decreases as pressure is increased independent of the pressing procedure used (wet pressing or press drying). This distinctly shows, that a modem whole pulp TMP even at fairly high freeness (110 CSF), operates at a domain where fiber breaking can be considered a significant factor. The point where the domain changes from negligible fiber breaking to significant fiber breaking is approximately at 0.3 T/Z. A similar relationship was obtained when tensile index was plotted against the Tear index, the domain change point being approximately at a Tensile index of 30 Nm/g.

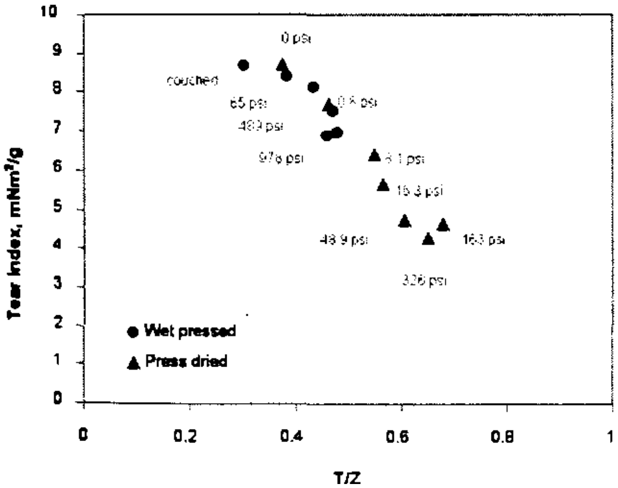

Figure 1. Tear index at various levels of bonding (Tensile index / Zero span tensile index) of TMP (110 CSF) wet pressed and press dried to various levels of bonding

The Tear index vs. Bonding index (Tensile index divided by Zero span) for fiber (R48) and fines (P200) mixed sheets is shown in Figure 2. The shape of the relationship is similar to that of a refining series or a pressing series in chemical pulps. In Figure 2 the second order fits are plotted for each fiber (R48) –fines (P200) mixture. These were also constructed for all mixtures used in this study. The second order coefficients for all the mixtures are summarized in Table 1.

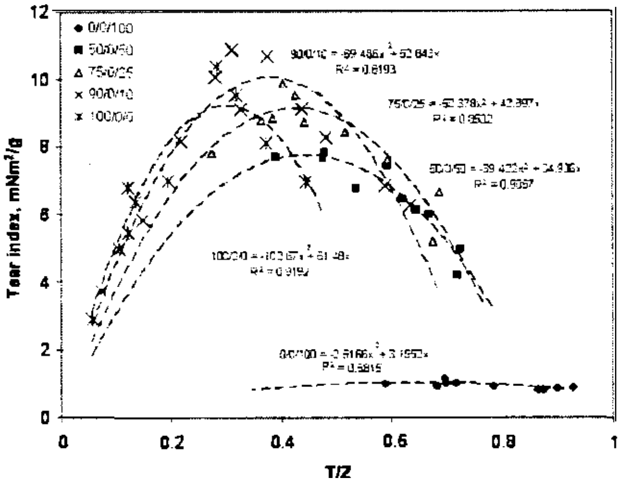

Figure 2. Tear index vs. Bonding index (T/Z) of Fiber (R48) aid Fines (P200) mixed sheets.

Table 1. Second order coefficients for mechanical pulp **mixtures.**

Mixture	Tear vs. T/Z			Bauer-McNett
R48/R200/P200	a (x^2)	b (x)	R^2	Fiber length, mm
0/0/100	-2.5166	3.1952	0.5816	0.100
50/0/50	-39.422	34.936	0.9067	1.054
75/0/25	-50.378	42.897	0.8532	1.515
90/0/10	-69.486	52.843	0.8193	1.791
100/0/0	-102.67	61.48	0.9192	1.984
0/100/0	-11.01	11.104	0.4769	0.500
50/50/0	-54.691	41.666	0.9265	1.250
72/25/0	-58.644	45.761	0.9232	1.625
90/10/0	-103.4	62.74	0.8153	1.850
37/37/25	-45.374	35.318	0.8859	0.963
25/25/50	-33.253	26.646	0.8038	0.675
0/33/66	-10.311	8.4793	0.5063	0.233
0/66/33	-7.2919	8.327	0.7703	0.367

The maximum Tear index was obtained for sheets containing R48 fiber fraction at a fairly constant bonding index between 0.3-0.4 depending on the sheets composition, lowest for the pure fiber sheets, and increasing slightly as fines or middle fractions were added. The maximum Tear index correlated well with the Bauer-McNett based calculated fiber length, as shown in Figure 3.

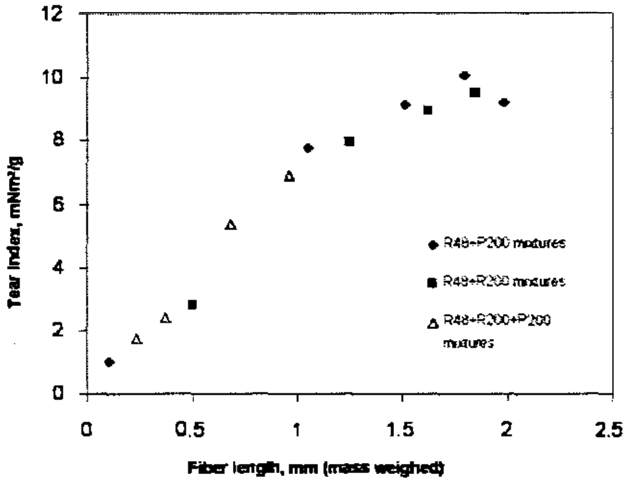

Figure 3. Maximum Tear vs. Fiber length

In addition the fiber length dependency of the Tear index increased as the bonding was increased at a bonding level below the maximum Tear index (Figure 4). However, at higher bonding levels, beyond the Tear maximum, the fiber length dependency of Tear strength decreased. This is likely due to the increasing effect of fiber strength on the Tear strength.

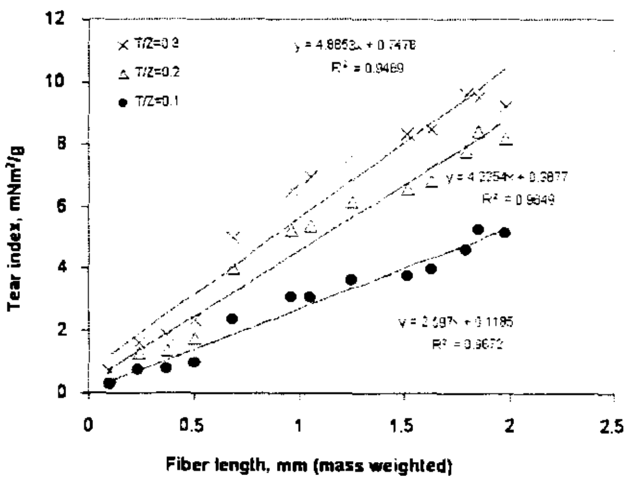

Figure 4. Fiber length dependency in the low bond strength region

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