

Increasing tensile strength without losing opacity

B. Alince

Paprican, Montreal, Que., Canada

KEYWORDS: Additives • Dry strength agents • Fiber bonding • Optical properties • Paper properties • Tensile strength

It is well known that refining of pulp fibers improves sheet tensile strength while decreasing printing opacity. Beating increases the number of bond-forming sites on the fiber surface, and tensile strength increases with the number of interfiber bonds. Tensile strength is often a linear function of the extent of the bonded area, as determined by nitrogen adsorption (1).

Light scattering—a measure of opacity—occurs at the interface of the fiber surface and air. Opacity decreases with increased beating because the increase in the interfiber-bonded area leaves less fiber-air interface available to scatter light. Light scattering is also linearly related to the bonded area, but in this case, it is an inverse relationship (2, 3).

Because both tensile strength and light scattering appear to be a function of the bonded area, a good way to evaluate a pulp is to plot the tensile strength of sheets formed from fibers beaten to different levels against the corresponding specific light-scattering coefficient. Such a plot is useful because it shows the trade-off between tensile strength and light scattering or opacity. This relationship has often been found to be linear (4-8).

Because these relationships are in good agreement, it is often assumed that the interfiber-bonded area responsible for the tensile strength is the same as that affecting the light scattering. However, the two areas of contact are not identical. For the fiber-fiber bonding via hydrogen

bonds, the contact between fibers must be on a molecular level, i.e., the surfaces must be closer than 1 nm. To affect light scattering, the fibers need only be in optical contact, which is in the order of the wavelength of light—several hundred nanometers, too far apart for any bonding to develop.

The difference in the distances required for molecular and optical contact suggests a potential method to improve tensile strength without losing opacity. Because of surface roughness, the fraction of surfaces in molecular contact at fiber crossing should be considerably smaller than that in optical contact. Introduction of additional bonding within the area of optical contact will strengthen the sheet without affecting the light scattering.

A synthetic styrene-butadiene polymer in the form of latex was used to accomplish this task. The latex particles were positively charged to promote their uniform deposition on fibers suspended in water (9). The fibers were unbeaten so that the development of tensile strength and opacity of handsheets caused by latex alone could be compared with that caused by beating.

Figure 1A shows the deposition of a monolayer of individual latex particles on fibers suspended in water as observed through a scanning electron microscope. The particles fill depressions, decreasing the microscopic roughness. Figure 1B shows the latex particles beginning to coalesce upon drying of the formed sheet. Finally, the particles form a film that follows the contour of the fibers, as seen in Figure 1C. During this process, the interfiber bonding is enhanced, likely the result of an increased fraction of surfaces brought into molecular contact. However, if the polymeric film

is thin, then the additional contact between fibers will develop within the area of optical contact and, consequently, the fiber-air interface responsible for scattering the light will remain the same.

Experimental data presented in Figure 2 illustrate the relationship between tensile strength and light-scattering coefficient for handsheets formed from unbeaten kraft softwood fibers treated with latex (used in the amount of 1-5% on pulp fiber). For comparison, Figure 2 also shows typical relationships observed for different pulp fibers subjected to beating. Improvement in tensile strength by beating is accompanied by decreased light-scattering, regardless of the type of fibers. However, addition of latex to improve the tensile strength of unbeaten fibers had only a marginal effect on the light-scattering efficiency. In fact, the printing opacity of the sheets containing latex-coated fibers increased with increased tensile strength, as seen in Figure 3.

The use of latex to improve tensile strength provides an additional benefit in the form of effective sizing. Handsheets become water repellent with as little as 1% latex, so the latex performs the functions of both a sizing agent and a binding agent. Normally, the use of conventional rosin-type sizing agents in larger amounts decreases the sheet's tensile strength.

The data presented here were obtained using an experimental cationic styrene-butadiene latex. The positive charge of latex particles was obtained by introducing amino groups into the polymer, and the average particle diameter was approximately 0.1 μm . *continued next page*

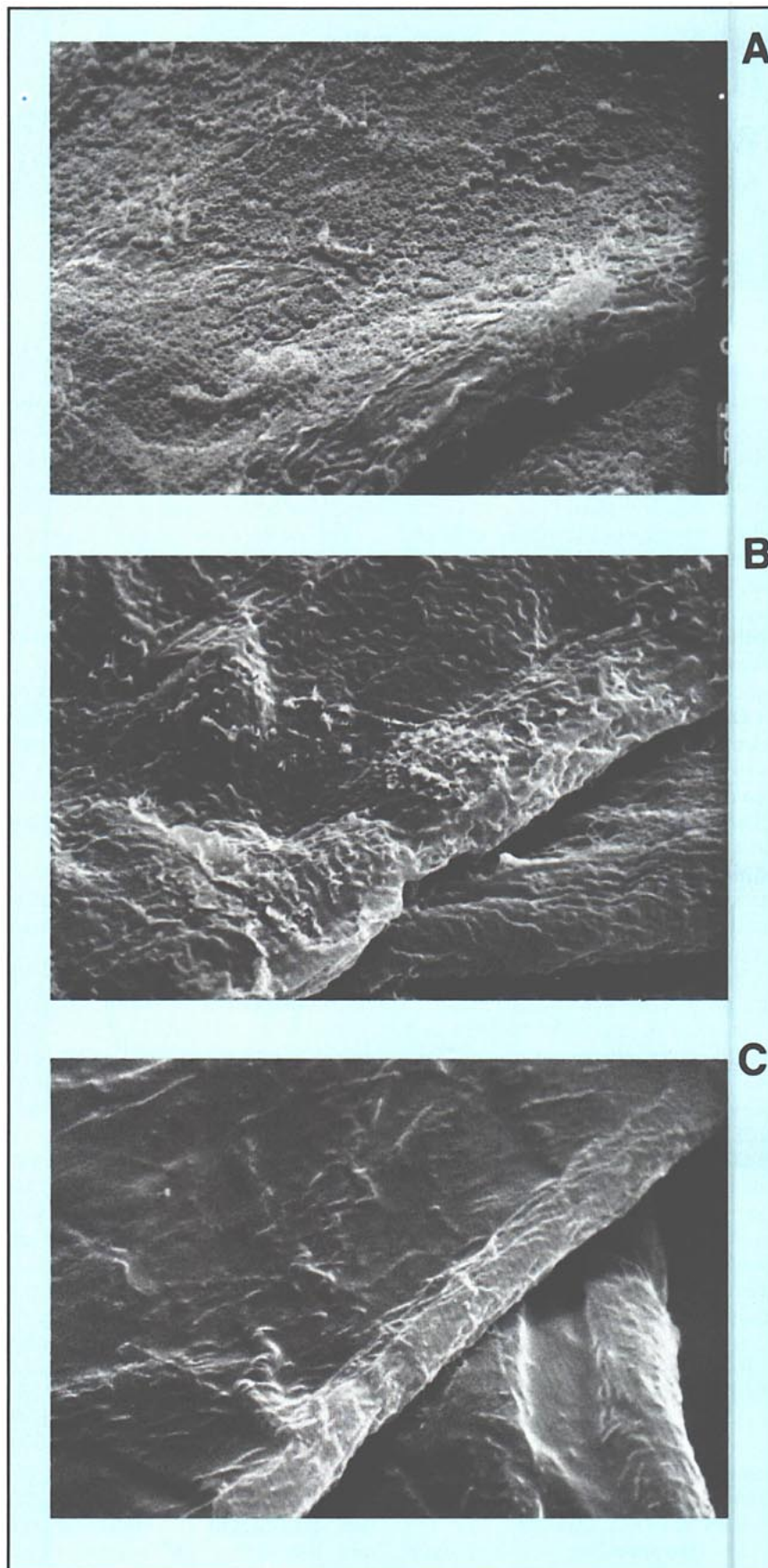
Literature cited

1. Rennel, J., *Svensk Papperstid.* 72(1): 1(1969).
2. Haselton, W. R., *Tappi* 38(12): 716(1955).
3. Rennel, J., *Tappi* 52(10): 1943(1969).
4. Hartler, N., and Rennel, J., *Svensk Papperstid.* 72(1): 9(1969).
5. Davidson, R. R., *Paper Technol.* 6(2): 107(1965).
6. Bown, R., *Papermaking Raw Materials* (V. Punton, Ed.), Vol. 2, Mech. Eng., London, 1986, p. 543.
7. Bovin, A., and Carno, B., *Svensk Papperstid.* 80(15): 483(1971).
8. Alince, B., and Lepoutre, P., *Tappi J.* 68(4): 122(1985).
9. Alince, B., *Tappi* 60(12): 133(1977).

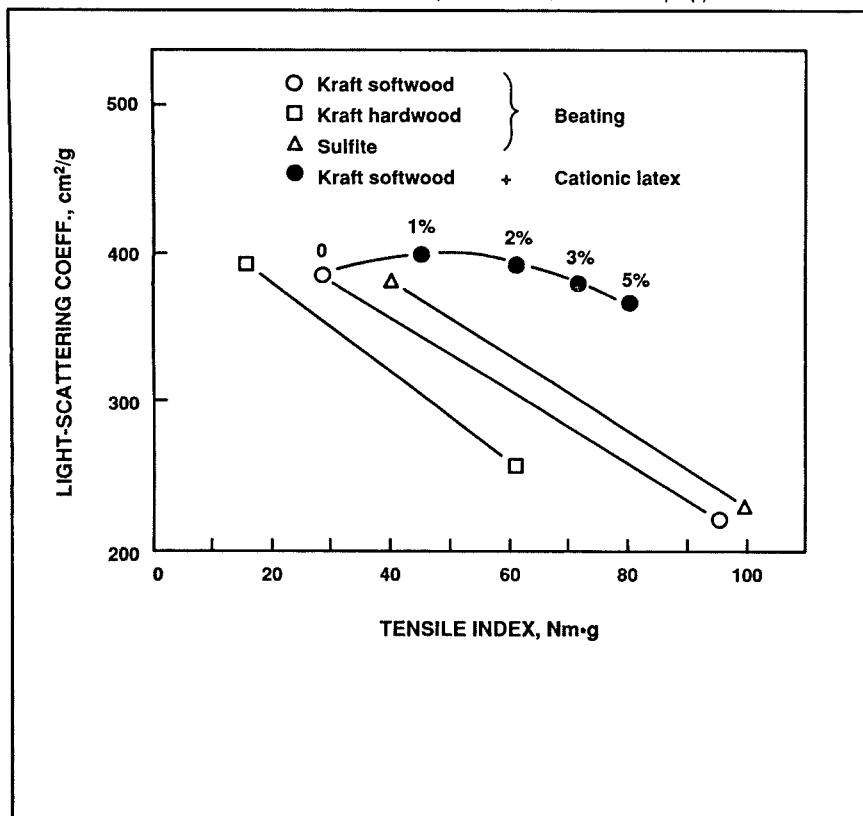
Received for review Feb. 6, 1991.

Accepted Feb. 14, 1991.

1. (A) Positively charged latex particles deposit on fibers suspended in water as a monolayer of individual particles. (B) As the sheet is formed and begins to dry, the particles start to coalesce until (C) a film is formed.



2. Relationship between tensile index and specific light-scattering coefficient for handsheets formed from three typical pulps (tensile strength increased by beating) and from unbeaten kraft softwood pulp strengthened with cationic latex (1%, 2%, 3%, and 5% on pulp)



3. Opacity vs. tensile index for handsheets formed from kraft softwood pulp subjected to a range of beating and from unbeaten kraft softwood pulp treated with cationic latex (1%, 2%, 3%, and 5% on pulp)

