The measurement and significance of fines

Their addition to pulp improves sheet consolidation

By R.S. Seth

Abstract: Addition of fines to a chemical pulp significantly improves sheet consolidation and many dry-sheet strength properties. However, fines drastically decrease pulp freeness and sheet porosity; the pulp behaves as if highly beaten. Freeness drop results in poor dewatering. Reduced porosity retards moisture escape and slows the drying rate. Both factors contribute to decreased pulp or paper machine productivity. Fines accumulation in the furnish will cause such conditions. Being important for papermaking, fines should be measured accurately. Existing optical fibre length analyzers may not provide correct fines content.

The fines content of a material that has a particle size distribution is defined as its weight fraction that passes through an opening of a certain size. The size of the opening is arbitrary. Paper is made mostly from wood pulps. Pulp particles are distributed in size and consist of fibres and fines. For papermaking materials, generally particles that pass through a 75 µm-diameter round hole or a 200-mesh screen of a fibre length classifier are regarded as fines [1-3].

Small particles, originally present in wood, such as shortened fibres, vessel elements and ray and parenchyma cells are called primary fines. Their amount by weight in pulps is usually small. Pulps undergo considerable mechanical treatment during production and subsequent use in papermaking. The fiber-wall fragments produced during this treatment are called secondary fines. Their amount can be large, and depends on fiber morphology [4], pulping conditions and the extent of mechanical treatment.

Optical fiber length analyzers are now commonly used in the industry to obtain fiber length distributions in papermaking furnishes (see e.g. [5,6]). They also provide a count of particles shorter than a certain length, for example 0.2 mm. As detailed in the analyzer manuals, these counts are expressed either as a percentage of the population distribution, or more often as a percentage of the length-weighted distribution.

There is an impression in the literature (see e.g. [7]), and a perception amongst many users, that these optical fiber length analyzers provide a correct measure of fines content in papermaking furnish. In reality, they do not. Figure 1 shows, for a variety of chemical pulps, a comparison of fines contents measured as weight fractions that passed the 200-mesh screens of a Bauer-McNett classifier [1], and those provided by an optical fiber length analyzer. The optical measurements were the length-weighted percentages of fibres shorter than 0.2 mm. The pulps included both from softwoods and hardwoods, and were refined to various levels. The two measurements in Fig. 1 differ. The length-weighted measurements are generally gross underestimates, and relate poorly to the Bauer-McNett results. A similar conclusion was reached for mechanical pulp fines (See Fig A1).

There are two major problems with the measurement of fines with optical fiber length analyzers. The first is detection. Some analyzers are based on polarized light [5,6]. They detect the presence of a wood-pulp particle because cellulose in wood is birefringent. However, lignin is not. Even though cellulose is birefringent, small cellulose-containing particles may not produce sufficient birefringence to be detectable [8]. Furthermore, if the particles are lignin-rich such as the fines in mechanical pulp, they may not even be detected [9]. In other words, not all fines in papermaking furnishes can be detected by these analyzers.

Second, even if all fines were detected, there is no method to calculate their weight fraction in the population. Although the analyzers calculate a length-weighted percentage of particles below 0.2 mm length, the result is meaningless. This is because the calculation is based on an assumption that all particles in the population, both fibres and fines, have the same mass per unit length, i.e., coarseness (see analyzer manuals). This assumption is wrong, because pulp particles are distributed in coarseness [10].

Fines contents expressed as percentages of the population distributions are not meaningful either, because pulp fibers are used mostly by weight and seldom by number.

Thus, the existing optical fiber length analyzers cannot be relied upon to measure or even rank correctly the fines content in papermaking furnishes. Until more reliable and faster methods are available, the existing gravimetric methods should be used [1,2].

Significance of Fines

Fibre and fines fractions in chemical pulps have similar chemical compositions, however, the fines fractions are somewhat richer in hemicellulose and lignin than the fibre fractions [11]. Fibres and fines differ greatly in their physical proper-

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ties. Fines have much larger specific surface area or surface area per unit mass than fibres. They are more swollen as well. In fact, fines carry nearly twice the amount of water per unit dry mass than fibres, Fig 2 [12].

Because of their small size, large specific surface area, and higher swelling, fines affect paper sheet structure and properties in several ways. Fines fill inter-fibre spaces during sheet dewatering. They increase sheet wetness for given dewatering conditions. Fines increase fibre-fibre interaction by increasing the fibre-water-air interfaces where the surface tension force acts during sheet drying. Fines increase the shrinkage forces during sheet drying. Being hemicellulose-rich, fines probably improve fibre-fibre bond strength as well.

Several previous investigations have examined the effects of chemical pulp fines on paper properties — particularly the sheet structure. These results were obtained as follows.

Fines were produced by extensively refining a sample of pulp A and separating from it the fraction that passed through a 100-mesh screen of a Bauer-McNett fibre length classifier. Different amounts of this fine material were then added to the original pulp. Pulps were given extra disintegration to ensure mixing. Table I. Pulp A was a bleached, never-dried, commercial softwood kraft. Fines were produced by refining extensively a sample of pulp A and separating from it the P-100 Bauer-McNett fraction. Different amounts of those fines were then added to the original pulp. Pulps were given extra disintegration to ensure mixing.

Fibre length of the furnish (see Table I), the possible loss in sheet strength properties due to loss in fibre length seems to be more than compensated.

As fibre length and bonding do not affect zero-span tensile strength [24], it remained unchanged for all pulps (Fig. 5). It is instructive to examine in Figs. 5 to 7 results obtained at 414 kPa wet-pressing pressure, and compare them with those in Table II. While the addition of 8.2% fines to pulp A increased the sheet density of pulp C by about 5%, the elastic modulus increased by 22%, tensile strength by 48%, and folds nearly 3.5 times. The results in Table II show that similar improvements in the strength properties of the original pulp can be obtained by a modest amount of PFI mill beating — about 160 revolutions. On the other hand, fines produced a dramatic decrease in the pulp
FIG. 2. Cross-sections of dry sheets showing improved sheet consolidation with increasing amount of fines. The sheets were made at 35 kPa wet-pressing pressure. Their apparent density values were: A – 0.429 g/cm³, B – 0.469 g/cm³, C – 0.521 g/cm³. The procedure for obtaining cross-sections is described elsewhere [22].

FIG. 3. Cross-sections of dry sheets showing improved sheet consolidation with increasing amount of fines. The sheets were made at 35 kPa wet-pressing pressure. Their apparent density values were: A – 0.429 g/cm³, B – 0.469 g/cm³, C – 0.521 g/cm³. The procedure for obtaining cross-sections is described elsewhere [22].

FIG. 4. Scattering coefficient against sheet density for the pulps of Table I. The arrows in this and subsequent Figures 5 to 9 indicate results obtained at 414 kPa wet-pressing pressure. The scattering coefficient was measured at 681 nm.

FIG. 5. Finite- and zero-span tensile strengths against sheet density for the pulps of Table I.

FIG. 6. Elastic modulus vs. sheet density for the pulps of Table I.

FIG. 7. MIT double folds vs. sheet density for the pulps of Table I.

FIG. 8. Scott internal bond strength vs. sheet density for the pulps of Table I.

FIG. 9. Scott internal bond strength vs. sheet density for the pulps of Table I.

freeness (Table I), and the air permeability of the sheet (Fig. 9). The addition of 8.2% fines to pulp A dropped its air permeability to one-thirtieth. To achieve an equivalent drop in these two properties, the original pulp would have to be beaten to about 6,000 revolutions (see Table II). In other words, as far as pulp freeness and sheet porosity are
concerned, the pulp behaved as if highly beaten. These observations accord with earlier work by Tasman [15].

In conclusion, the addition of fines to a chemical pulp improves sheet consolidation and many dry-sheet strength properties, and the improvements can be significant. However, fines drastically decrease pulp freeness and sheet porosity; the pulp behaves as if highly beaten. Freeness drop results in poor dewatering. Both factors contribute to decreased pulp or paper machine productivity. Fines accumulation in the furnish will cause such conditions.

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Résumé:
L'aïage de fines à une pâte chimique permet d'améliorer considérablement la consolidation de la feuille et un bien nombre de caractéristiques de résistance de la feuille. Les fines du rapport des fibres. Les fines sont donc considérées comme de l'eau très refiée. La baisse de l'aïage entraine un mauvais assour- dissement. Une faible pourcentage de fines dans le savon réduit la viabilité de la gamme. Ces deux facteurs contribuent à réduire la productivité de la pâte ou de la machine à papier. Une accumula- tion de fines dans la composition de fabrication entraîne des situations. Les fines sont importantes dans la fabrication du papier et elles doivent être mesurées avec précision. Les ana- lyseurs spéciques des longueurs de fibres actuelles ne peuvent pas indiquer la teneur en fines appropriées.

LITERATURE
1. TAPPI Test Method T 233 cm-95. Fiber length of pulp by classification.
2. TAPPI Test Method T 261 cm-94. Fines fraction of pulp by screen sieving.

END NOTES
1. Mechanical pulp fines, however, behave differently. Being lignin-rich [25], they are relatively much stiffer. They do not bond well that well to fibres, and do not lose their free surface as much. Therefore, they contribute greatly to light scattering.
2. The changes in strength properties with fines addition can be relatively small if the pulp is already beaten for high sheet consolidation [13-15].