

Physical testing: A fresh look at old habits

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IN THE PULP AND PAPER INDUSTRY, physical testing provides reliable information on the physical properties or characteristics of a product. During the production of pulp and paper, physical testing plays an important role in the control of manufacturing processes and product quality. Furthermore, evaluation of the finished product is necessary to determine whether the required quality specifications have been met.

Pulp and paper products are generally bought and sold using quality specifications defined by functional or end-use requirements. Agreement between manufacturer and customer using the customer's experience with the product's use establishes these specifications. The use of physical quality specifications requires the following:

- Knowledge of the physical properties needed to satisfy the functional requirements of the product
- Test methods to determine these properties with adequate accuracy and precision
- Limits on the values of these measurements to provide criteria for rejection.

Before the 1920s, the influence of scientific testing on pulp and paper producers was negligible. Qualitative tests that evaluated products by appearance, feel, and other subjective observations commonly judged the quality of a product. These tests often bore no relation to the functional requirement of the product. We can only speculate on

the time and material waste resulting from decisions made using such inappropriate or unreliable test information. Eventually routine test procedures using more rigorous scientific principles and careful quantitative measurement came into wide use.

For approximately 75 years, many tests and variations of tests have evaluated pulp and paper quality and determined product specifications. Many test methods have made significant contributions to the better understanding of pulp and paper processes and the improvement of product quality. They continue to be valid and useful today. Some methods, however, had limited application or use for the evaluation of a narrow range of products. Over time, the original arguments behind these test methods became forgotten or ignored. These test methods may still find universal application, however. This may be inappropriate and have serious consequences.

Another concern involves the lack of consideration sometimes paid to measurement uncertainties when evaluating physical test data. Users of pulp and paper products will sometimes express apprehension over small differences in a measured test property value when the uncertainty of the measurement may be the same order of magnitude as the difference measured. For another test, they may express little concern over measurement differences that are truly significant.

The inappropriate application of test methods and disregard for test measurement uncertainties presents potential obstacles to reliable, effec-

ABSTRACT

Many test methods for routinely evaluating the physical properties of pulp and paper have become entrenched in testing programs. They have contributed to the better understanding of processes and the improvement of product quality. Some test methods, however, were for limited application or for specific product grades. Time has seen these tests applied universally and sometimes inappropriately. Some test methods even find application without regard for their limitations or level of measurement uncertainty. Blind application of test methods can lead to unnecessary testing, incorrect interpretation of results, and the setting of irrelevant or unrealistic specifications.

Application:

Use of test data must recognize the limitations of the test method. The significance of differences in test results is necessary.

tive, and timely product quality information. Insufficient consideration of these issues can lead to unnecessary testing, the faulty interpretation of test results, and the setting of irrelevant or unrealistic product specifications.

In pulp and paper testing, there are a variety of examples of the inappropriate application of test methods and dubious interpretation of test data. Test methods are sometimes applied to types of samples for which they were not optimized or designed. In addition, product quality specifications often require test methods and properties only remotely connected with end use. They ignore more important tests and properties. Finished products are still often wrongly accepted or rejected using statistically highly variable data. A few examples will illustrate these points.

PULP TESTING ISSUES

The CSF test has wide use as an index of the drainage behavior of pulp suspensions. The current test procedure (1) was originally designed more than 50 years ago to control manufacture of groundwood pulp. Standard test conditions require obtaining a test reading for a pulp suspension adjusted to a stated consistency and temperature. The test method also suggests it is not necessary to use the exact consistency and temperature, since correction tables are available that permit correcting the result to that of standard conditions. The method also warns that the correction tables were developed for groundwood pulp and the accuracy of the correction tables is unknown for other pulp grades. Corrections may be low for chemical pulps (2). For pulps other than groundwood, the test method recommends adjusting consistency and temperature to standard conditions. A recent survey of testing practices in the pulp and paper industry noted that the freeness test now has more use on chemical pulp rather than mechanical pulp (3). Therefore, one may suspect that the accuracy of freeness measurement is often subject to compromise.

Another example of pulp test methods applied to samples for which they were not designed or optimized are laboratory pulp screening tests. Most mechanical pulps contain a portion of incompletely defibrated material consisting of wood slivers and fiber bundles called shives. The presence of shives has a negative impact on paper machine and pressroom runnability and on print quality. Laboratory screening test methods therefore provide indices of mill screening operation efficiency. Somerville proposed a standardized screening procedure in 1932 (4). Later improvements in the equipment and procedure (5) form the basis for the test

method widely used today. Test conditions were again determined using the predominant mechanical pulp of the day—groundwood.

Experiments determined the shortest time needed to give a satisfactory separation of the shives. Based on these experiments, a screening time of 20 min was chosen. The test method is proper and valid. With the advent of new mechanical pulping processes, however, the test method is now blindly applied to other pulps—including chemical pulps—with some significant consequences. Fiber flexibility strongly influences the efficiency of pulp screening. Shives from inflexible fiber furnishes such as groundwood are more readily separated than those of more flexible fibers such as chemical or chemi-mechanical pulps. Flexible fibers have a greater tendency to become intertwined with other fibers or with shives. They are unable to pass through the screen plate or have difficulty doing so. Close examination of the rejected material collected by the Somerville test for flexible fiber pulp furnishes often shows a significant quantity of acceptable fibers that contribute to erroneously high shive content values. It is possible to realize improvements in separation by extending screening times. Then the test becomes undesirably long, and there may still be acceptable fiber trapped with the shives.

The determination of fiber length is an important pulp test property measurement. Although highly automated optical analyzers are frequently employed today to measure pulp fiber length distributions, traditional screen classification methods such as Bauer-McNett fractionation are also still widely used. In this method, a dilute suspension of fibers circulates at high velocity parallel to screen slots. A much slower velocity passes through the slots. In this way, the fibers are presented lengthwise

to a series of screens with successively smaller mesh openings. Only fibers short enough not to bridge the openings pass into the next chamber. As with several other pulp screening test methods, the standard testing procedure was originally designed with groundwood pulp in mind. For reasons similar to those advocated for the Somerville shive test, this technique is better for pulp furnishes comprising inflexible fibers. The method still finds use for a variety of pulps including chemical pulps. The quality of the separation of fibers into uniformly narrowly distributed length fractions is often diminished. Reproducibility of test results between different classifiers is generally poor or only fair. An earlier, unpublished investigation by this author, however, indicates good reproducibility is possible, if the test conditions are controlled and the dimensional specifications of the screens are well maintained. Reproducibility of test results declined, however, when using the method with chemical pulps. This is likely due to the reduction in the probability of flexible chemical pulp fibers presenting themselves lengthwise to the screens.

Users of test data often ask the operators of testing laboratories to comment on the significance of observed differences in average test values. A common error of test data users is the incorrect presumption of the accuracy and precision of a test method. There is often a tendency to expect more from a test method than its realistic capability. The Somerville shive test illustrates this point. When this test was first developed, the definition of an acceptable level of shive content for a market pulp was high by today's standards. Improvements in quality have seen the acceptable quantity of shives drop to very low levels. As a result, the test is very often applied to samples that contain little or no

shives. With the difficulties alluded to earlier, the level of uncertainty of the test values is higher. It is common to see Somerville test values as low as 0.005% reported on specification sheets. In absolute terms, this corresponds to a shive weight of 0.001 g. Even a reported value of 0.100% requires accurately determining a shive weight of 0.025 g. The weight of a single shive particle may fall within this weight range. The potential weighing errors alone therefore can be significant. Reported low Somerville reject values are questionable at best. Pulp producers continue to set Somerville reject specifications at these uncertain measurement levels and express great concern when they are not met.

PAPER TESTING ISSUES

Paper testing also has its share of ambiguously applied methods. Fracture toughness is the ability of a material to resist propagation of a preexisting crack. It is a fundamental mechanical property of the material. The Elmendorf type tear test routinely measures the resistance of a sheet of paper to crack propagation. This applies tearing forces out of the sheet's plane. During paper manufacturing, printing, and many converting operations, however, crack propagation failures are due to stresses applied in the plane of the sheet. In-plane mechanical properties therefore should be more relevant to end use than out-of-plane tear tests. A previous investigation (6) on newsprint showed that pressroom runnability correlated with in-plane fracture toughness of the sheet but not with Elmendorf tearing resistance. This assertion challenges the relevancy of the industry standard tear test for evaluating fracture toughness that relates to end-use failure. In addition, pulp strength is generally assessed in the laboratory by beating the pulp and then determining the Elmendorf tearing resistance of handsheets at a

given tensile strength. Beating increases the degree of bonding between the fibers. It therefore increases the tensile strength of the sheet. At moderate to high degrees of bonding where the tensile strength potential of pulp is best realized, however, most softwood pulps display a decrease in tearing resistance with bonding. A papermaker wanting to increase tearing resistance therefore must compromise the tensile strength of the sheet. This casts doubt on the usefulness of conventional tearing tests for evaluating the reinforcing potential of softwood pulps. The in-plane fracture toughness of a sheet depends strongly on its tensile strength. It has been proposed as a criterion for evaluating and optimizing reinforcement pulps (7).

An important, desirable characteristic of a test method is that it should generate test results that are highly repeatable. Although the repeatability of replicate measurements for a given sample strongly depends on the uniformity of the sample itself, some test methods stand out as inherently generating variable results. There are many tests used to evaluate performance and set product specifications that exhibit a high degree of variability. Folding endurance is an important end-use requirement for security papers or other paper grades subject to repeated folding. The MIT folding tester has wide use to measure this property. The test result is the number of double folds that a strip of paper undergoes before failing. Folding endurance is a primary product specification for security papers. It is common to observe coefficients of variation of 10–25% or even higher for replicate determination of the number of double folds, however.

DISCUSSION AND CONCLUSIONS

The issues here provide only a few examples of the difficulties that

plague pulp and paper physical testing. Everyone involved in physical testing has his or her share of problem issues. Are we using too many tests and variations of tests to reliably define product quality? How meaningful are the tests we use? Are we putting too much emphasis on test methods of limited relevancy?

It is difficult to reconcile the desire for fewer tests with the wide variety of sample grades the industry now produces. Ideally, the number of routine physical test methods should be a small, manageable number of meaningful, general test methods. Ideally these could apply to a wide range of samples and provide sufficient information to control manufacturing processes, satisfy functional requirements, and set appropriate product quality specifications. Unfortunately, it is not easy to meet these criteria.

Physical testing procedures typically have well defined and precisely controlled conditions. The objective often is to determine if there are differences between products rather than to predict behavior under simulated operating conditions. Test equipment cannot duplicate the extensive variety of processing conditions found in modern pulp and paper mill operations. Test procedures that attempt to simulate mill operations are inherently narrow in scope and are not particularly adaptable to general use. Standard testing procedures should use established scientific principles and generate reproducible results. They must provide reliable and accurate results and distinguish between small differences in the property being measured. Suitable industry testing standards should ensure that the customer can establish realistic specifications and the manufacturer can attain them.

Many standard testing methods use the requirements of older technology and now may be irrelevant.

KEYWORDS

Materials testing, paper tests, physical properties, properties, pulp tests, test methods.

Unfortunately, some test methods still have routine use simply because there is a historical precedence—"It's always been done that way"—or a perception that certain tests must be done even if the user really is not sure why. Part of the problem lies in our inability or reluctance to stop some traditional tests although they may not be giving information value for the effort expended. This is understandable, although not justifiable. Large databases of operating data have accumulated over time involving certain test methods. It is not easy to dismiss these. When a new and improved test method comes to replace an old one, it often simply is added to the already long list of tests routinely performed.

A discrepancy may exist between the necessary tests and the performed tests. This arises mostly because the requirements of the needed tests may be more time consuming or involve more sophisticated and costly test equipment. It is often for such reasons that a test as

easy as burst is very popular, while adoption of more complex and time-consuming tests such as in-plane fracture toughness has been slow.

Some solution lies in educating users of test data. Official test method organizations can contribute by evaluating the legitimacy of existing test methods. If appropriate, they can consolidate duplicate methods and reclassify or eliminate the more ambiguous ones. For example, some investigations have demonstrated there are precise mathematical relationships between certain common tests that might be independent of the type of fiber and the method of mechanical treatment. It therefore may be possible to eliminate some tests that can be reliably predicted from other tests. This would save valuable testing time.

Users of test data also must realize the limitations of the test methods they use and develop a knowledge of the significance of differences in test results. Users subsequently should review product specifications to determine their relevancy and initiate appropriate changes.

More resources need to be directed toward test method development and the transfer of new testing methods and technology to test-

ing laboratories. In particular, test method development should focus on the reduction of empirical methods and the augmentation of fundamental property measurement. TJ

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