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Tensile properties of paper and paperboard (using constant rate of elongation apparatus)

1. Scope

1.1 This test method describes the procedure, using constant-rate-of-elongation equipment, for determining four tensile breaking properties of paper and paperboard: tensile strength, stretch, tensile energy absorption, and tensile stiffness.

1.2 This procedure is applicable to all types of paper and paperboard within the limitations of the instruments used, whether the instruments perform horizontal or vertical tests or whether they are manually operated or computer controlled. It is also applicable to handsheets, with modifications, as specified in TAPPI T 220 "Physical Testing of Pulp Handsheets." It does not apply to combined corrugated board.

2. Definitions

2.1 *Tensile strength*, the maximum tensile force developed in a test specimen before rupture on a tensile test carried to rupture under prescribed conditions. Tensile strength (as used here) is the force per unit width of test specimen.

2.2 *Stretch*, the maximum tensile strain developed in the test specimen before rupture in a tensile test carried to rupture under prescribed conditions. The stretch (or percentage elongation) is expressed as a percentage, i.e., one hundred times the ratio of the increase in length of the test specimen to the original test span.

2.3 *Tensile energy absorption* (TEA), the work done when a specimen is stressed to rupture in tension under prescribed conditions as measured by the integral of the tensile strength over the range of tensile strain from zero to maximum strain. The TEA is expressed as energy per unit area (test span $\times$ width) of test specimen.

2.4 *Tensile stiffness*, the ratio of tensile force per unit width to tensile strain within the elastic region of the tensile-strain relationship. The elastic region of the tensile-strain relationship is the linear portion of the load-elongation relationship up to the elastic limit. The elastic limit is the maximum tensile force above which the load-elongation

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relationship departs from linearity. (Tensile stiffness is numerically equivalent to $E \cdot t$, where E is the modulus of elasticity and t is sample thickness.)

2.5 *Breaking length*, the calculated limiting length of a strip of uniform width, beyond which, if such a strip were suspended by one end, it would break of its own weight.

2.6 *Tensile index*, the tensile strength in N/m divided by grammage.

NOTE 1: ISO/TC6 recommends the use of tensile index over breaking length. See TAPPI T 1210 or TIP 0800-01 "Units of Measurement and Conversion Factors."

3. Significance

3.1 Tensile strength is indicative of the strength derived from factors such as fiber strength, fiber length, and bonding. It may be used to deduce information about these factors, especially when used as a tensile strength index. For quality control purposes, tensile strength has been used as an indication of the serviceability of many papers which are subjected to a simple and direct tensile stress. Tensile strength can also be used as an indication of the potential resistance to web breaking of papers such as printing papers during printing on a web fed press or other web fed converting operations. When evaluating the tensile strength, the stretch and the tensile energy absorption for these parameters can be of equal or greater importance in predicting the performance of paper, especially when that paper is subjected to an uneven stress such as gummed tape, or a dynamic stress such as when a sack full of granular material is dropped.

3.2 Stretch (sometimes evaluated in conjunction with bending resistance) is indicative of the ability of paper to conform to a desired contour, or to survive nonuniform tensile stress. It should be considered important in all papers, but is of particular importance in papers where stress-strain properties are being modified or controlled. This includes creped paper, pleated paper, air-dried paper, and paper that has been made extensible through mechanical compaction. Stretch is evaluated in decorative papers and certain industrial grades such as paper tapes and packaging papers, both as an index of how well the paper will conform to irregular shapes and, along with tensile energy absorption, as an indication of the paper's performance under conditions of either dynamic or repetitive straining and stressing. Stretch has also been found important in reducing the frequency of breaks on high-speed web fed printing presses such as are used to print newspapers.

3.3 Tensile energy absorption is a measure of the ability of a paper to absorb energy (at the strain rate of the test instrument), and indicates the durability of paper when subjected to either a repetitive or dynamic stressing or straining. Tensile energy absorption expresses the "toughness" of the sheet. An example of this is a multi-wall sack that is subject to frequent dropping. In packaging applications such as multi-wall sacks, favorable drop tests and low failure rates have been found to correlate better with tensile energy absorption than with tensile strength.

3.4 Tensile stiffness tells of the stiffness of the sheet and often gives a better indication of the mechanical response of the sheet to converting forces than does failure criteria.

4. Apparatus

4.1 *Tensile testing machine*¹, a constant-rate-of-elongation type, meeting the following requirements:

4.1.1 Two clamping jaws, each with a line contact for gripping the specimen, with the line contact perpendicular to the direction of the applied load and with means for controlling and adjusting the clamping pressure.

NOTE 2: "Line contact" describes the clamping zone resulting from gripping the specimen between a cylindrical and a flat surface or between two cylindrical surfaces whose axes are parallel (1).

NOTE 3: For certain grades of paper "line contact" jaws may not be appropriate and it may be necessary to substitute flat gripping surfaces. Certain grades are damaged by the "line contact" loading between cylindrical and flat surfaces. The use of emery cloth on flat gripping surfaces will help minimize slippage for some board grades.

4.1.2 The clamping surfaces of the two jaws shall be in the same plane and so aligned that they hold the test specimen in that plane throughout the test. The clamping lines shall be parallel to each other within an angle of $\pm 1^\circ$, and

¹ Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list, available as part of the CD or printed set of Standards, or on the TAPPI website general Standards page.

shall not change more than 0.5° during the test. The applied tensile force shall be perpendicular to the clamp lines within $\pm 1^\circ$ throughout the test.

4.1.3 The distance between line contacts at the start of the test shall be adjustable and resettable to ± 0.5 mm (nominally 0.02 in.) for the specified initial test span (6.4). (See 11.3.)

4.1.4 The rate of separation of jaws shall be 25 ± 5 mm/min (nominally 1.0 in./min), or as otherwise noted (6.5) and once set shall be resettable and constant to $\pm 4\%$. (See 11.3.)

4.1.5 Recorder or indicator capable of indicating the actual force on the specimen within 1% or 0.1 N, whichever is greater.

4.1.6 Recorder speed or indicator shall be adjustable to provide a readability and accuracy of $\pm 0.05\%$ stretch.

4.2 *Alignment jig* (optional) (1) to facilitate centering and aligning the specimen in the jaws, so that the clamping lines of contact are perpendicular to the direction of the applied force and the center line (long dimension) of the specimen coincides with the direction of applied force.

4.3 *Planimeter* or *integrator*, respectively, to measure the area beneath the load-elongation curve or to compute directly the work to rupture, with an accuracy of $\pm 1\%$.

4.4 *Specimen cutter*, for cutting specimens of the required width, with straight parallel sides (5.3).

NOTE 4: Fully automated laboratory management and/or data acquisition systems are available which perform several functions such as: automatic calibration check, pre-setting and storing a variety of test programs, cutting the test strip, acquiring test data, and accurately determining the tensile breaking properties of paper and paperboard. These tests may be performed with the test strip horizontal or vertical by such equipment. Such equipment may be suitable for use in performing this method; however, the user is responsible for making independent assessment of this fact on the basis of data generated using specific equipment.

5. Sampling and test specimens

5.1 For sampling for acceptance of a lot of paper, paperboard, related product, without prior agreement between buyer and seller, use TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product."

5.2 For sampling for quality control and other purposes, use accepted and agreed upon company and laboratory sampling practices.

5.3 Precondition, then condition, the sample in accordance with TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products" prior to cutting the specimens.

NOTE 5: The exposure of the paper to a high relative humidity before preconditioning and conditioning can lead to erratic results varying from a decrease in stretch and tensile to a substantial increase (30% increase in stretch not uncommon) in these properties. Consequently, TEA is similarly affected. Careful protection of the sample from the time of sampling until testing is therefore very important.

5.4 Cut 10 test specimens from each test unit of the sample in each principal direction of the paper 25 ± 1 mm (nominally 1.0 in.) wide with sides parallel within 0.1 mm (nominally 0.004 in.) and long enough to be clamped in the jaws when the test span is 180 ± 5 mm (nominally 7.0 in.), leaving enough length so that any slack can be removed from the strip before clamping. (See 11.3.) Insure that strips are free from abnormalities, creases, or wrinkles. In some cases, it may be impossible or impractical to obtain a test specimen having a length long enough to be clamped in the jaws having the test span specified here. In such cases, see Appendix A.3.1 for special considerations and procedures required for testing samples at smaller test spans.

6. Procedures

6.1 Perform the test in the testing atmosphere specified in T 402.

6.2 If the test specimen width is not known to 0.1 mm (nominally 0.004 in.) (i.e., if a previously evaluated precision cutter is not used), determine width and parallelism using magnifier and scale. Lack of parallelism is indicated by a difference in width of the two ends of the specimen.

6.3 The testing machine shall be calibrated and adjusted as described in Appendixes A.1 and A.2.

6.4 Set the clamps to an initial test span (distance between line contacts) of 180 ± 5 mm (nominally 7.0 in.). Determine and always reset this distance within ± 0.5 mm (nominally 0.02 in.). (See Appendix A.1.3.)

6.5 Set the controls for rate of separation of the jaws to 25 ± 5 mm/min (nominally 1.0 in./min). (See 11.3.) In cases where the time required to break a single strip exceeds 30 s, a more rapid rate of jaw separation shall be used,