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Physical area of sub-visible contraries in pulp, paper and paperboard by image analysis

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1. Introduction

The level of sub-visible contraries, such as microscopic ink particles, present in pulp, paper or paperboard can impact its usefulness in a specific end-use application. For someone controlling or monitoring the de-inking process, the absolute physical area of ink coverage, or the number of ink specks present in an inspection area may be of greatest importance.

2. Scope

2.1 This method uses image analysis to determine the level of sub-visible contraries in pulp, recycled pulp, paper, and paperboard in terms of Equivalent Physical Diameter (EPD) of contraries within the EPD range of 8 micrometers to 160 micrometers, reported in parts per hundred as well as the number of specks per square centimeter of sample. Extension to other speck sizes (for example those greater than 160 micrometers), may require changes in equipment, calculation procedures, or both, and is not covered in this test method.

2.2 Paper and board surfaces are far from uniform below 100 micrometers (1). To obtain the truest physical size distribution of the sub-visible contraries requires the specific illumination and optics described in this method.

2.3 The specimen to be evaluated must have a brightness, as determined by TAPPI T 452 “Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm),” of approximately 20% or greater. It may be necessary to reform some pulp sheets into handsheets if the surface is too rough or textured to obtain a sharp image over the entire viewing area. Reforming the sheet may result in the loss of some ink particles.

2.4 Specks larger than 160 micrometers, and of sufficient contrast, are considered visible and should be measured according to TAPPI T 563 “Equivalent Black Area (EBA) and count of visible dirt in pulp, paper and paperboard by image analysis”.

3. Significance

3.1 Cleanliness and shade are two appearance attributes influencing the marketability of recycled paper. Any particles of residual ink too small to be seen with the naked eye could still influence the shade of the sheet. In principle, one might want to control the deinking process completely from these two attributes; however, greater insight can be obtained from the direct measurement of changes in the particle-size histogram (2, 3).

3.2 The measurement of sub-visible residual ink specks differs in several ways from the measurement of cleanliness with a standard dirt counter as described in T 563. The standard dirt count incorporates the visual impact of different colored specks with the calculation of equivalent black area, EBA. The physical size of residual (sub-visible) ink specks, rather than their psychophysical impact, is of interest. Secondly, visible dirt counting is performed at such low magnification that the reflectance variation associated with formation requires a special center surround filter described in T 563. This surround filter is not required at sub-visible dimensions when employing the optics described in the apparatus section of this method.

4. Related documents

TAPPI T 452 Brightness of pulp, paper and paperboard (Directional reflectance at 457 nm)
TAPPI T 563 Equivalent Black Area (EBA) and count of visible dirt in pulp, paper and paperboard by image analysis

5. Definitions

5.1 *Sub-Visible Contraries* - any foreign matter embedded in or on the sheet, which, when examined by reflected light has a darker contrast relative to the sheet surface and has an equivalent physical diameter of 8 micrometers or greater as determined by this test method.

5.2 *The Equivalent Physical Diameter (EPD)* - the shape of ink specks, and other sub-visible contraries, is irregular. The EPD is the diameter of a circle equivalent in area to the area of the detected speck. The EPD of a speck is calculated from the total area of all adjacent and contiguous pixel areas below the detection threshold. The EPD is calculated according to:

$$EPD = 2 (\text{speck area}/\pi)^{1/2}$$

5.3 *Gray Level* - Image analyzer detectors digitize the signal of each picture element (pixel) into discrete values called gray levels. The upper and lower limits of the gray level scale can be adjusted to arbitrary settings to achieve calibration to established reflectance scales. The gray level scales are frequently calibrated against an absolute scale such as the percent reflectance at specific wavelengths.

5.4 *Detector Integration Time* - the amount of time, in milliseconds, for the image detected by a CCD sensor to reach a mean gray level (GL) of 180.

5.5 *Percent Coverage* - is the summed area of all the detected specks, expressed in mm², taken as a ratio over the examined area normalized to 1 cm² and multiplied by 100%. Percent coverage can also be expressed as parts per hundred (PPH).

6. Apparatus

6.1 *Description of the apparatus:*

6.1.1 *Detector:* The detector consists of a CCD sensor matrix, optics, illuminant and specimen stage. The sensor matrix is densitometric with at least 256 gray levels (G.L.) of sensitivity with the physical pixel resolution having an effective diameter of 5 µm or less (see Note 1). The detector must view the specimen perpendicular to its surface. The illumination is diffuse, un-polarized and is concentrated in the portion of the spectrum such that 95% of the spectrum will be between 650 nm and 710 nm. The illumination must be uniform such that the illumination at the specimen stage, before any software corrections, must be within ± 3% coefficient of variation (COV). The specimen stage must be shielded to prevent influence from ambient light, be matte, and have a reflectance exceeding 90% between 380 nm and 750 nm.

NOTE 1: Imaging precision improves with resolution. Therefore it is advisable to have as high a pixel resolution as is practical for the smallest dirt specks. However, the pixel resolution must not be less than 1.5 µm (i.e. twice the peak wavelength of the illuminant). The practical limit of resolution will be limited by the quality of the near IR optics used. Frequently, this is several times greater than the wavelength of illumination.

6.1.2 *Analyzer:* An analyser incorporating the EPD calculations and using a specified thresholding technique (3, Appendix A.1).

6.1.3 *The calibration plates* must be matte, blemish free, nonfluorescent at the wavelengths of measurement, and have at least one solid white area and one solid black area. Additionally the calibration plates must meet the specifications in Appendix A.2 and the white plate must have a reflectance greater than 80% at 660 nm.

6.2 *Calibration:* Turn on the apparatus and light source. Allow the equipment to warm up and adjust the hardware settings according to the manufacturer's instructions or recommendations.