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Section 6 - Optical Testing Application Information for Paper and Paperboard

Introduction

Optical properties are important to the manufacturer, vendor and user of paper and board because they are a major factor in the appearance and appeal of the product. This is true not only for the paper and board itself, but also its conversion. For example, increasing gloss by varnishing the highlights of a selected area causes it to stand out from the background. Optical properties relate to all aspects of the product appearance including whiteness, brightness, color, opacity and gloss.

In terms of the paper constituents, these properties are affected by all stages of the pulp and paper production processes. There are trade-offs to be considered, since changing parameters to enhance one property may be detrimental to another. For example, increasing bleaching to improve brightness will reduce opacity.

The pulping and bleaching processes are responsible for the whiteness of the fibers while the ultimate brightness of a paper or board is governed by the light scattering effect of furnish constituents, formation, loadings and coatings and any optical brightening agents which may be applied.

Color may appear as a shade of whiteness due to chemicals remaining in the fibers after processing, or as a color from dyes added to the pulp or applied to the surface.

Opacity is initially governed by the translucency of the fibre furnish where the needleshaped hardwood fibers are more opaque than the ribbon shaped softwood fibers. Formation has an influence but the loading and coating is the dominant factor in the final opacity of the sheet.

Gloss is a complex optical property, which is not easy to define accurately or to measure in terms of the appearance to the naked eye. Physically, it is connected with the reflection of a collimated light beam that falls upon a paper surface. In uncoated papers, some of the light is reflected from the fibers in the surface as if they were an assembly of miniature mirrors. This is specular reflection. The rest of the light penetrates more deeply into the paper and is reflected and refracted in many directions. This is diffuse reflection. The total light reflected is comprised of specularly and diffused reflected components which are not easy to differentiate.

The relative components will also change according to the angle of incidence at which the light strikes the paper. Increased coating weight and calendering causes the surface to become smoother and more reflective; the specular reflection increases accordingly. When light falls on a matte surface the reflected light is diffused in all directions. At near glancing incidence, some of the light is specularly reflected causing a lustre sometimes called sheen. The angle of incidence used in the measurement of gloss therefore varies according to the type of paper being measured and the chosen standard method, which is to be applied.

Brightness, Color and Opacity

Application

To satisfy the industry's need for a single value to denote brightness, a very specific spectral distribution of light has been chosen by the Standards Organizations for illuminating the paper under test. Most white or near-white papers have a reflectance curve which is relatively flat from 550 to 700 nanometers, but which slopes down in the blue region of the spectrum. Hence, the specific area of the spectrum to indicate the whiteness of a sheet has been chosen in the blue band, specifically 457 nanometers, with a spectral range of 400 to 500 nanometers. As the sheet becomes more yellow, the blue reflectance increases.

To achieve the single value measurement of brightness, the yellow and red area of the visible spectrum has been ignored. Thus, colored or tinted papers cannot be fully described by this single number. For example, a paper with a reddish tint could have the same brightness as a neutral white paper. The complete and absolute characterization of a tinted sheet can therefore only be achieved using a three-color method of measurement. However, brightness measurements are more easily understood and provide a quick and easy method of checking the optical appearance under most manufacturing conditions. It should be noted that the actual spectral response of the instrument used to measure brightness is affected by

- the lamp used as a light source
- the focusing lens
- the filters
- the characteristics of the photo sensor

Thus, changing any of these components, such as the lamp, can change the spectral response.

In some applications, measured brightness does not correlate well with the visual assessment of whiteness. This is due to variation in areas outside the blue band of the spectrum. It may therefore be necessary to obtain whiteness and yellowness indices using a colorimeter. The values obtained are not the tri-stimulus values needed for the complicated measurement of color, but use simple formulas to assess separately the degree of whiteness and yellowness.

Brightness is often enhanced by the introduction of optical brightening agents. These cause the paper to fluoresce. This is a process where light energy of one spectral region is absorbed and re-emitted at other (usually longer) wavelengths. For some materials, the level of reflected light is higher than the incident light at certain wavelengths. The measurement of the fluorescent factor is made by inserting a UV filter in the incident light path and subtracting the resultant brightness from the value obtained without the additional filter.

There are several systems available for measuring color. All use numbers measured by a tristimulus colorimeter based on the internationally accepted CIE standard observer. The three most commonly used systems are:

- CIE, L*a*b (CIELAB or STARLAB)
- Hunter L, a, b, system
- CIE, Dominant wavelength, purity and luminosity

The L value relates to lightness/darkness of the color.

The a factor refers to chromaticity on the red/green axis.

The b factor refers to chromaticity on the blue/yellow axis.

All systems are mathematical in nature and do not specify the use of a particular instrument. However, correlation between them needs to consider the geometry, photometry and spectral response. Using these systems, the magnitude and direction of color differences between a sample and standard can be determined and understood.

It should be noted that there are fundamental differences on the optical geometry of instruments used for the determination of optical properties according to TAPPI or ISO. In either method the sensor views the sample perpendicular to the surface.

The TAPPI method illuminates the sample with a light beam angled at 45° to the surface. The inherent disadvantage of angled beam illumination is that the amount of light reflected varies according to the orientation of the fibers in the sheet. This requires sample measurements to be taken in both machine and cross-direction.

The ISO method uses diffuse illumination. The lack of any directional effect in ISO instruments means that they are more readily adapted to automated strip feed systems than equivalent TAPPI instruments.

Opacity

The Opacity of paper is often of interest, particularly for printing papers. It may be determined by:

1. Measuring the reflectance of a single sheet of paper at a certain wavelength (usually 457 nm) when held a non-reflective black background.
2. Measuring the reflectance of a single sheet of paper when held against a standard white background (TAPPI method) or a pad of the same paper thick enough to prevent light transmission. The opacity is the ratio of the two reflectance values, expressed as a percentage.

All optical measurements are normally carried out on a single instrument such as Brightness & Color Meter. The necessary wavelengths are controlled by a series of filters to facilitate brightness and opacity measurement.

STATISTICS IN GLOSSMETERS

Application

The two most important contributors to the appearance of a paper are fiber formation and gloss. The former will also influence the latter.

When considering the appearance of paper, changes in the treatment applied to the base paper result in a wide variation from matte finish (minimal light reflectance) to the high gloss finish of cast coated, lacquered, metallic and plastic laminated papers. In between are:

- wash and lick coated papers
- various medium and heavily coated papers
- papers with loadings ranging from chalk to titanium dioxide
- papers subject to calendering and supercalendering

The appearance resulting from these variables has to be measured to ensure conformability with the specification and consistency with the product. Equally important is the need for appearance in the printed paper. Print gloss depends on

- fiber formation
- the properties of inks applied
- the interaction between ink and paper, where color and intensity can vary according to the penetration and absorption of the ink vehicle

Due to the changes in specular and diffuse reflection in different types of paper and its uses and the difficulty in correlating with the human eye, it has been found necessary to apply different geometries to gloss meters in order to obtain the best correlation with certain specific groups of product. This particularly applies to the angle at which the light beam strikes the paper and at which the reflected light is measured, these two angles usually being the same. For papers with very high gloss, e.g. wax papers, an angle of 20 degrees to the vertical is the standard applied since there is a high proportion of specular reflection. The angle used for the greater majority of papers, however, is 60 or 75 degrees, according to the chosen standard. This is to account for the greater amount of diffuse reflection in these types of paper.

The design of glossmeters varies according to needs, and to those of relevant standard methods as shown below.

Specification

Glossmeters for 20, 60 and 85 Degrees

This range of instruments is a portable unit that charges its batteries with the line adapter power supply. Accuracy and repeatability are within 0.5 gloss units. They have a 24 character, two line digital display featuring a high contrast, wide angle display. With the button depressed, continuous readings assess the variation across a surface. Calibration is

certified and traceable to BAM, the International Authority. Intermediate calibration standards enable linearity to be checked down to 0.5 and up to 950 gloss units. The instrument also features auto-calibration. The light source is tungsten halogen, filtered to illuminate C with infrared compensation. Drift is minimized with opto-electrical compensation for lamp aging.

Up to 999 readings for each angle may be stored in memory and which may be transferred to data acquisition systems such as TestLink or to a printer via the RS-232 port. Statistics, in the form of maximum, minimum, average, number of readings and standard deviation are presented. False readings may be deleted with automatic recalculation of the remaining statistics.

Operational Characteristics

The most important features of these statistical glossmeters include reliability, ease of use, reproducibility and traceability of calibration. All functions are push button and include on/off control, delete/reset, statistics, angle, read, output and calibration buttons. The instrument is portable and can be operated hand-held. It is supplied with a cased high gloss calibration standard and zero reference, power adapter/charger, cleaning kit, spare lamp, and an RS-232 connection cable, all in a sturdy carrying case.