Application Note

AN 1034.00

Textile Sample Presentation

"There are a variety of techniques that can be used in presenting textiles samples to ensure valid, repeatable color measurements."

ABSTRACT

The goal of instrumental color measurement is to obtain repeatable numeric values that correspond to visual assessment. The method of sample preparation, sample presentation and instrument geometry used for measurement can impact measurement precision and the correlation of the measurement to visual assessment.

The world's true measure of color

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SAMPLE PREPARATION

One color measurement method for fiber or yarn wound on a cone or bobbin is to measure the fiber directly. In this case no sample preparation is required. However, a positioning device is typically used at the instrument measuring port to consistently present the wound fiber to the instrument (discussed further under Sample Presentation).

A second method is to prepare a wad of random fibers large enough such that light cannot penetrate through it and place it inside a container with a window in the bottom. Place a specified weight on top of the yarn and measure through the glass. A more consistent and optimal method would be to use a compression cell (Figure 2) in which a specified amount of yarn by weight is placed in a sample cup and a consistent air pressure is applied to a piston to compresses the yarn tightly against the cup window. Using consistent pressure is important since a consistent yarn density is needed for repeatable color measurements. As the yarn is being measured through a glass interface, the instrument will measure the sample as a duller color than it actually is. Methods of compensating for glass will be discussed in Sample Presentation.

Another method that gives measurements that correlate well with visual assessment is to wind the yarn closely and parallel on a card (Figure 3) to a sufficient thickness to prevent show-through. Commercial cardwinders are available for this purpose to ensure consistent tension and a constant number of windings. Tension must be consistent on the card but not so high as to cause the yarn to stretch. The card should have enough stiffness that it does not bend when the yarn is wound on it. If the card is bent when the yarn is wound, the front side will give a different measurement than will the back. The card can be made of paper board, plastic or metal and should be a uniform and neutral in color. Ensure that paper board or plastic cards do not contain UV fluorescing agents.

Figure 1. MiniScan EZ with bobbin adapter to consistently place the instrument flush on the curved surface of a textile cone or bobbin.

Figure 2. Compression Cell for pressing loose fiber flush against a sample cup window, minimizing light trapping by the loose fiber.

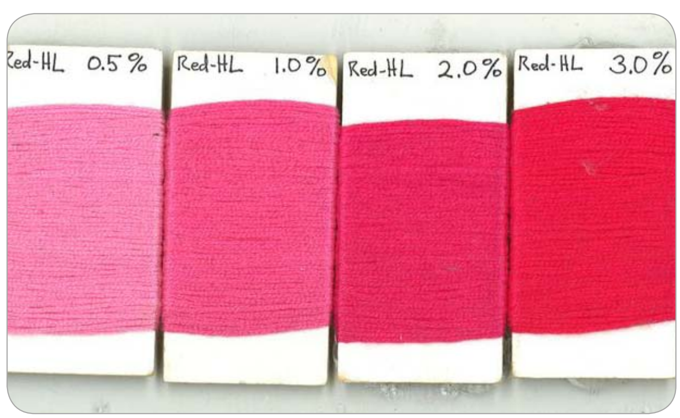

Figure 3. Card Wind of light yarn showing a dye concentration gradient.

Skeins of yarn can be prepared by clamping or taping one end to the edge of a rigid backing material, stretching the skein across the form keeping the strands of yarn parallel and clamping or taping to the other edge of the form. Commercially available skein holders (Figure 4) can be used for this purpose.

The yarn can also be knitted into a sock for measurement. Since a knitted sock is flat, it can be measured without a support or compression device. A disadvantage is that knits tend to easily stretch which causes the opacity of the fabric to vary. Variation in tension will cause the holes in the fabric to change size, and allow more or less light to pass through. When this occurs, the measurement instrument will "see" more or less of the sample backing material and will give varying measurement results. When necessary to increase the opacity of the sample,the knitted sock can be folded into multiple layers. The number of layers can be increased until the reading does not change significantly. An example is shown in Table 1. However as can happen with thicker socks, the sample may "pillow" or protrude into the measurement port of the instrument. In addition, Knitted socks may have distinct lines or textures which can effect measurement repeatability. Averaging techniques can be used to minimize this problem and will be discussed later in this paper.

Figure 4. Skein Holder to hold a yarn skein taut against a neutral background.

Figure 5. Loose yarn can be knitted into a sock for color measurement.

TABLE 1. EXAMPLE OF KNITTED SOCK READINGS AS RELATED TO NUMBER OF LAYERS*			
Color Scale	**2 Layers**	**4 Layers**	**8 Layers**
L*	52.11	50.78	50.70
a*	4.14	3.84	3.80
b*	11.28	10.75	10.74

*(Average of 4 Readings, White Backing)

SAMPLE PRESENTATION

Sample presentation to the instrument can effect the measurement results in terms of both the measurement value obtained as well as the repeatability of the measurement. In the case of yarn measurement the primary areas of concern are consistency of sample presentation, sample pillowing and sample directionality.

TABLE 2. EXAMPLE REPEATABILITY DATA FOR YARN CONE MEASUREMENT*

Color Scale	Without Positioning Device	With Positioning Device
L*	0.20	0.07
a*	0.06	0.07
b*	0.05	0.07

*(Standard Deviation of 20 Readings)

If a cone or package of yarn is being measured directly with a portable or bench instrument (Figure 1), it is important that a positioning device be used to reproducibly position the sample at the instrument measuring port. This is because the sample is curved and does not lie flat on the sample port and thus does not completely fill the port. Any position change by rocking the cone slightly in either direction would cause a reading change. By using a cradle-shaped positioning device at the instrument sample port, having a radius similar to the cone or bobbin, will position the sample consistently for measurement.

When measuring yarn wound on a card or skein holder, measuring a knitted sock of the yarn sample and in some cases measuring the yarn cone or package, sample pillowing may occur. This occurs when the sample is so thick and soft that it protrudes into the instrument sample port causing poor measurement repeatability. The magnitude of this problem depends on the optical characteristics of the instrument being used as well as the sample being measured. When pillowing is a problem the sample can be measured by pressing it against the instrument equipped with a glass sample port. This will typically give more repeatable results. As previously mentioned, since the yarn is being measured through a glass interface, the instrument will measure the sample as a duller color than it actually is. This is because glass causes low reflectance values to be higher, and high reflectance values to be lower. For quality control applications when the color difference is being measured and the "standard" was measured the same way, the error introduced by the glass is less significant. However accuracy can be improved by calibrating the instrument through glass, or when a higher absolute accuracy of measurement is desired, a glass correction can be used. This equation is for sphere (d/8°) geometry instrumentation with the specular component included.

$$\textbf{Glass Correction Factor} = R\lambda = (R_g + T_c - 1.0)/(R_g + T_c - 1.0 - (T_d * R_g) + T_d)$$

WHERE:

- R_g = measured %R behind glass
- T_c = transmittance of glass to collimated light (normally equal to 0.92 for glass with a refractive index of 1.50 and no absorption)
- T_d = transmittance of glass to diffuse light (nominally equal to 0.87 for glass as described above)
- $R\lambda$ = corrected % reflectance with no glass

Most yarn samples will have some level of directionality. Directionality is when the sample has distinct lines or texture that when measured at different angles of rotation, yield varying results. Averaging multiple placements of the sample with a 90 degree rotation between readings will minimize the effect of directionality.

TABLE 3. EXAMPLE READINGS BEHIND GLASS*

Scale	Without Glass	No Glass Correction	With Glass Correction
L*	51.41	48.89	50.83

*(Knitted Sock, Average of 4 Readings, White Backing)

SAMPLE AVERAGING

Averaging multiple readings of samples can compensate for variations in pillowing, directionality, nonuniformity as well as other variables that occur when measuring yarn. Ideally, multiple preparations of the sample will be measured and averaged. However in production environments the ideal approach is not always followed. As a minimum, one production sample should be measured and averaged in groups of 2 (2, 4, 6...) for each measurement with a 90 degree rotation between each reading.

For card wound and knitted samples it is not suitable to simply place the sample on the port and rotate the sample without removing it as there will be no averaging of the variation in pillowing and non-uniform color within the sample. The best approach is to take and average several readings of the sample for multiple preparations or at multiple positions and at multiple angles of rotation. An appropriate sampling number for each significantly different yarn type should be determined. One approach is to determine a statistically-sound sampling number. This can be done by first selecting a representative sample of the product.

1. *Measure the sample at various positions or for multiple preparations. At least twelve readings should be made. For a better characterization, do 30 to 50 readings. Those readings need to be evenly apportioned between sample orientations of 0°, 90°, 180°, and 270°. Determine the color difference for each of the scale values (for example dL*, da*, db*). The color difference values are determined by using the average reading as the "standard" and the individual readings as the "sample" data.*

2. *Calculate the mean ($\bar{x}$) for each of the scale values. The mean is the average of the color difference readings taken on the sample as compared to the "standard". To determine, add together the color difference values for all readings and divide by the total number of readings. This will determine the center point around which all the readings are grouped.*

   The equation for the mean is:

$$\bar{X} = \frac{1}{N_a}\left(\sum_{\lambda=1}^{N_a} X_i\right)$$

where, $\bar{X}$ *= mean of* N_a *readings*
N_a *= total number of readings*
X_i *= ith reading for each color difference scale*

3. *Calculate the standard deviation (S). The standard deviation of the color difference readings is used to determine how closely grouped the readings are about the mean.*
   The equation for standard deviation is:

$$S = \sqrt{\left[\frac{\sum_{\lambda=1}^{N_a} (x_i - \bar{x})^2}{N_a + 1}\right]}$$

where, S *= Standard deviation*
N_a *= total number of readings*
$\bar{X}$ *= mean of* N_a *readings*
X_i *= ith reading*

4. *Calculate the tolerance range and the standard error goal. The tolerance range is the upper tolerance minus the lower tolerance for each of the color difference parameters. Multiply the range by 0.1 and compare this to 0.2 scale units. The larger of 0.2 scale units or the product of the tolerance range multiplied by 0.1 will be equal to the standard error goal (*$S_{e,g}$*).*

5. *Determine the sampling number. The minimum number of sample readings to be made is the largest of the three color scale values rounded to a whole number that is divisible by 4. This means that a minimum of 4 readings per measurement is needed but it could be higher depending on the variability in the measurement method.*
   The calculated sampling number is:

$$N_c = \left(\frac{S}{S_{e,g}}\right)^2$$

where, N_c *= calculated sampling number*
S *= standard deviation*
$S_{e,g}$ *= standard error goal*

GEOMETRY

Color measurement instrument geometry generally falls into one of two categories - a diffuse d/8° sphere geometry or a directional 45°/0° or 0°/45° geometry. For sphere instruments, the source light is projected into the sphere and is diffused by the sphere coating. This diffused light is incident on the sample and the light reflected at 8° is measured. Typically sphere instruments include the specular component in the measurement and have a 25 mm (1 inch) diameter sample port. For 45°/0° geometry instruments the light source illuminates the sample at 45° and the light reflected at 0° (normal to the surface) is measured. The 45°/0° geometry excludes the specular component and frequently have measurement ports that are 50 mm (2 inch) in diameter giving a better optical average of the sample. The following table gives the recommended instrument geometry for the various yarn sample preparation methods.

Cone or Bobbin Package	Directional 45°/0° or 0°/45° geometry
Loose Fiber Compressed Against Glass	Diffuse d/8° Sphere or Directional 45°/0° or 0°/45° geometry
Card Wind	Diffuse d/8° Sphere or Directional 45°/0° or 0°/45° geometry
Skein Holder	Diffuse d/8° Sphere or Directional 45°/0° or 0°/45° geometry
Knitted Sock	Directional 45°/0° or 0°/45° is best; Diffuse d/8° Sphere is suitable

CONCLUSION

When measuring yarn it is important to select samples appropriately, use an established measurement method, and handle the sample in a consistent manner.

1. *Choose samples that are representative of the product*
2. *Prepare samples in the same manner each time*
3. *Present the samples to the instrument in a repeatable manner*
4. *When possible make multiple preparations of the sample and average the results*
5. *Remember that the measured results depend on sample preparation and presentation of the sample as well as the instrument geometry*

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ABOUT HUNTERLAB

HunterLab, the first name in color measurement, provides ruggedly dependable, consistently accurate, and cost effective color measurement solutions. With over 6 decades of experience in more than 65 countries, HunterLab applies leading edge technology to measure and communicate color simply and effectively. The company offers both diffuse/8° and a complete line of true 45°/0° optical geometry instruments in portable, bench-top and production in-line configurations. HunterLab, the world's true measure of color.

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