How near infrared measurements are taken around the world in textile plants

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Introduction

The application of near infrared (NIR) spectroscopy methods to the characterization of textile fibers, yarns and fabric has shown a steady growth during the past few years. NIR methods have replaced several chemical and physiochemical tests that are routinely performed in textile plants. NIR techniques are used to replace both environmentally unfriendly and time-consuming test procedures. This paper describes two applications, giving particular attention to the practical aspects of the test procedures, that are currently used in textile plants.

Analysis of union fiber

In order to enhance aesthetics and properties of fabrics, often more than one generic fiber is used in textile manufacturing. The most common example of blended fibers is polyester/cotton. Polyester provides easy care properties and durability, while cotton contributes to the natural look and comfort of the fabric. It is important that the concentration of each fiber in the blend is maintained within a narrow tolerance to maintain quality. Moreover, US law requires that the garment must maintain a fiber blend ratio within 3% of the stated blend. The conventional method is a gravimetric procedure where the cotton portion of the blend is dissolved in concentrated H_2SO_4. The blend percent is calculated from the weight difference between the original and the treated fabric. The complete procedure takes about four hours. NIR spectroscopy is the most suitable method for this application because all textile fibers are either natural or synthetic polymers of hydrocarbons with wide differences in structure that produce easily distinguishable spectra, as seen in Figure 1. Normal blends are polyester/cotton, polyester/acrylic, wool/polyester, wool/cotton, rayon/polyester, acrylic/cotton etc. As seen in Figure 2, the spectra of polyester, cotton and polyester/cotton showing several distinguishable bands and a combination of these wavelengths can be used to develop a prediction model for polyester or cotton. This application is currently being used by approximately 75 textile plants in the USA. A similar subject has been published elsewhere,[1] but the current article discusses the practical problems associated with blend measurement.

While the application is straightforward, there are a few practical problems often encountered in this method because textile samples are obtained in various physical configurations and also in various colours. As seen in Figure 3, samples may be obtained in raw fiber form, sliver (intermediate product in yarn manufacturing), roving or in yarn form. In addition, fabrics are often submitted for analysis in garment form, as illustrated in Figure 4.

Figures 5–8 show the usual sample presentation techniques used in textile plants. Calibration modifications are often necessary for different types of samples. Homogeneity of the blends of different fibers is also another problem that must be carefully considered. If the fiber is intimately blended at the beginning of the process, usually the blend is highly homogeneous, however, in the

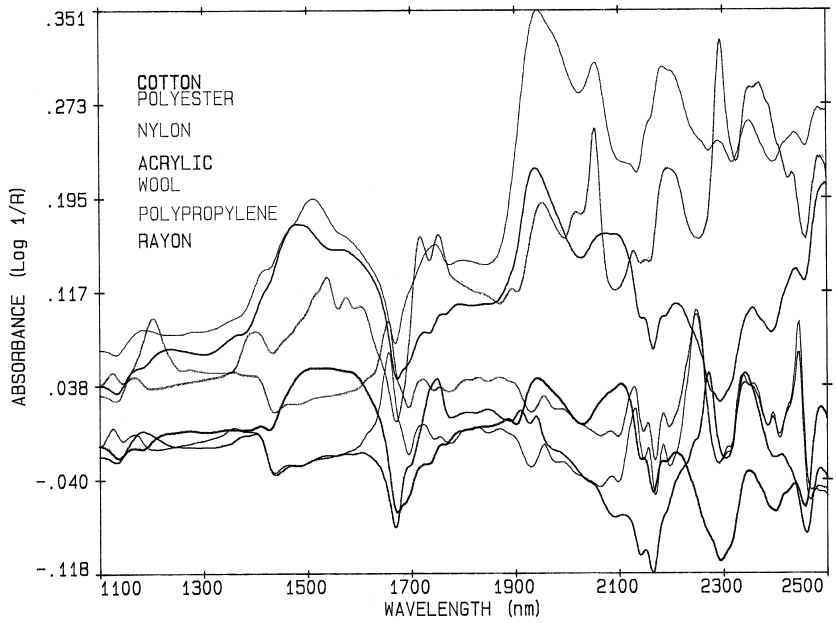

Figure 1. NIR spectra of various textile fibers.

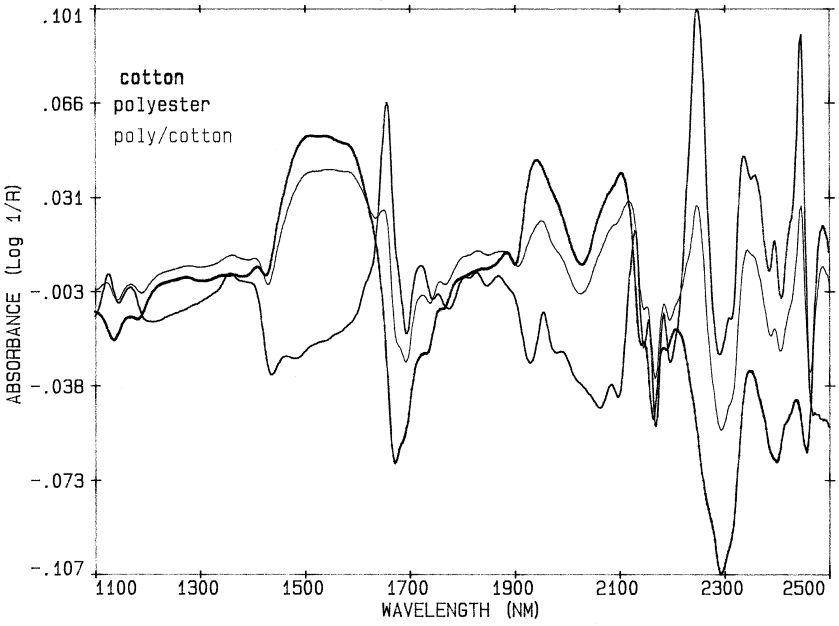

Figure 2. NIR spectra of polyester (PET), cotton and polyester/cotton blends.

Figure 3. Fiber, sliver, roving, yarn: products from different stages of yarn manufacturing.

Figure 4. Textile fabrics and garment samples.

Figure 5. Presentation of garment sample to InfraAlyzer.

Figure 6. Presentation of fiber, sliver and roving sample to InfraAlyzer.

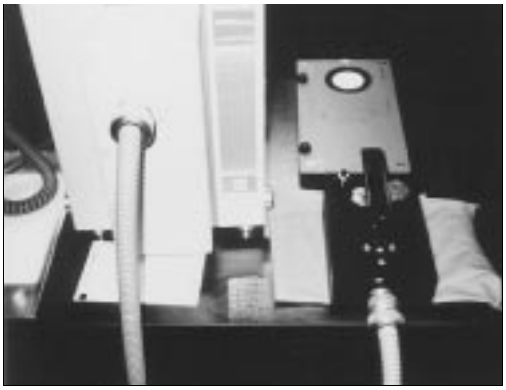

Figure 7. Presentation of fabric sample to NIRS 6500 with fiber optic cable.

Figure 8. Presentation of fiber, sliver and roving sample to NIRS 6500.

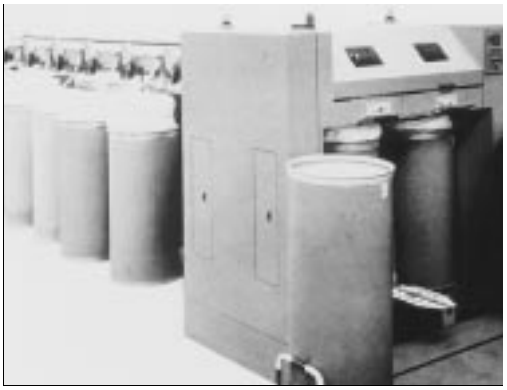

Figure 9. Identifying processing step where intimate blending occurs.

Figure 10. Identifying processing step where draw blending occurs.

case of draw blending where different fibers are mixed in an intermediate processing stage of yarn manufacturing, the blend is not homogeneous and additional blending is often required before presenting the sample to the NIR instrument. The two blending methods are illustrated in Figures 9 and 10.

Thermal history of carpet yarns

The majority of synthetic carpet yarns are produced from nylon (polyamide). In order to develop bulk yarn, it is heat set, which provides fullness and resiliency to the carpet. Synthetic fiber properties are highly sensitive to heat because it affects the fine structure and morphology of the fibers, which ultimately influence dyeability of the yarn. Uneven heat treatment has been the major cause of sub-standard carpet quality. As illustrated in Figure 11, yarn is taken up from the creel and is conveyed through a hot air oven at approximately 200ºC. After exiting the oven, the yarn, which is then wound up on the tube, is ready for tufting into carpet (Figure 12).

When synthetic polymer is heated, the crystalline fraction of the material increases by converting gauche configuration of the polymer chains into *trans* conformation. Nylon crystallinity is linearly correlated to its thermal history. The mid-infrared method of measuring polymer

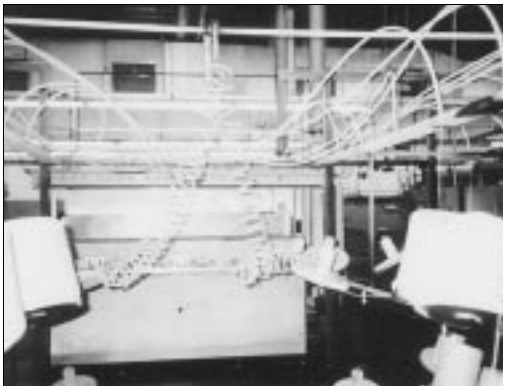

Figure 11. Yarn entry to heat setting range.

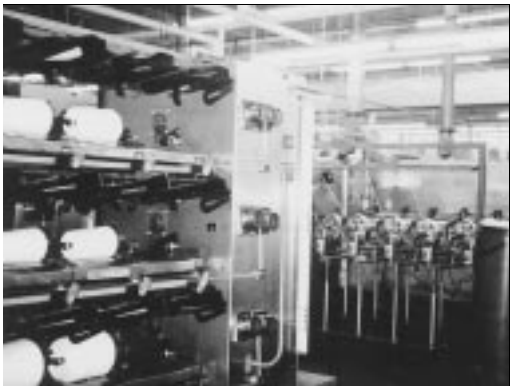

Figure 12. Yarn exit and package formation at the heat setting range.

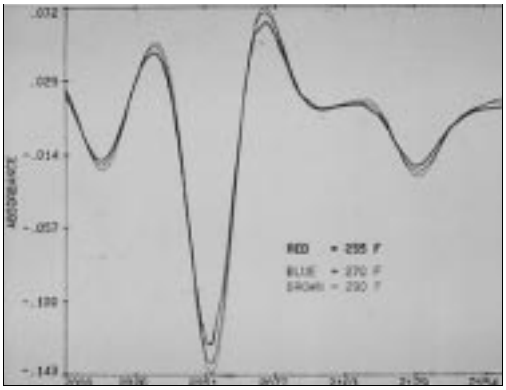

Figure 13. NIR spectra of heat set nylon.

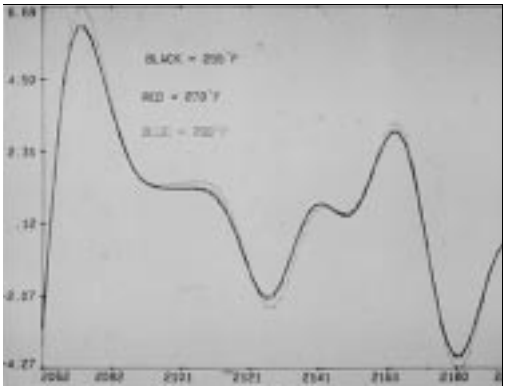

Figure 14. NIR spectra of heat set nylon.

crystallinity is a well-established procedure. The NIR method of determining nylon heat history was developed by the author in collaboration with Dr James E. Rodgers, Monsanto Chemical Company. The 2nd derivative absorbance spectra of nylon samples annealed at different temperatures are shown in Figures 13 and 14. Absorbance changes arising from the thermal history differences of the fiber can be noticed in the region near 2130 and 2180 nm that are usually assigned to C=O stretch/C–H stretch combination and amide III/N–H deformation combination bands of nylon. Since thermal treatment increases molecular order, crystallinity is expected to influence C=O and N–H groups involved in the protein-like linkages (C=O - - N–H) in nylon structures. More details about the mechanism of measuring nylon heat history have been published elsewhere.[2]

This application can be used at-line to check heat set packages in the manufacturing location as the package is removed from the winding machine and, hence, off-quality yarn can be identified immediately. Figure 15 illustrates the measurement of thermal nylon yarn at the manufacturing location using a fiber optic cable.

Figure 15. At-line heat history measurements.

Conclusions

The near infrared spectroscopy method of characterizing raw material, in-process stock and finished products has been well established. Two examples provided here illustrate the wide range of application of this technology in the textile industry. The textile industry utilizes high speed, sophisticated process technology to achieve high productivity and to continually improve quality. The near infrared method provides an excellent method for textile manufacturing to obtain real-time process/product information that is absolutely necessary to control manufacturing.

References

1. S. Ghoah and J. Rodgers, "NIR Analysis of Textiles", in *Handbook of Near Infrared Analysis*, Ed by D.A. Burns and E. Circzak. Marcel Dekker, New York (1992).
2. S. Ghosh and J. Rodgers, "Determining Heatset Temperature by Near Infrared Reflectance Spectroscopy", *TRJ*, **SJ (9)** (1985).