Application of Spectroscopy Technology in Textiles

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***Abstract*—Spectral analysis has a very high sensitivity and accuracy, widely used in qualitative and quantitative analysis of textile fibers. This paper described the mechanism of spectroscopy in qualitative identification of textile fibers. Then it gave a systematic review and summary on the research of qualitative or quantitative analysis of textile fibers. It discussed the mechanism of spectroscopy in silkworm cocoon sex identification. And then it summarized the research status of spectroscopy in silkworm cocoon sex identification. It analyzed the existing problems and deficiencies of spectrometry in testing. Finally, it put forward the further research direction of spectroscopy detection and composed out the outlook of the application of hyper spectral in silkworm cocoon sex identification.**

Keywords-spectrum; textile fiber; silkworm cocoon; sex identification

I. INTRODUCTION

With the concept of ecological textile is becoming more and more thorough popular feeling, the qualitative and quantitative analysis of textile fiber is increasingly important. To seek a rapid and convenient detection method has been on the agenda. With the development of the spectral analysis technology, it has the advantages of no pretreatment, short test time, no chemical reagent in the process of analysis. Near infrared diffuse reflection spectroscopy, infrared spectroscopy, raman spectroscopy, and terahertz spectroscopy are increasingly researched in the qualitative identification of textile fiber. Compared with the female cocoon, the male cocoon has some advantages, which include superfine filament size, good cohesive force and high grade raw silk. It is an ideal raw material of high grade raw silk reeling. Therefore, to realize the distinction between male and female silkworm cocoon, using respectively, can improve the quality of silk products and improve the added value of silk products without increasing the production input [1]. Spectroscopy and spectral analysis are extensive researched in the field of textile fiber qualitative identification and silkworm cocoon sex identification, having a broad application prospect.

II. APPLICATION OF THE SPECTROSCOPY TO THE QUALITATIVE IDENTIFICATION OF TEXTILE FIBER

A. Study on the Mechanism of Spectroscopy in Qualitative Identification of Textile Fibers

After the study confirmed that the spectrum produced by different groups on the absorption peak position and intensity is different. Different textile fibers have different spectrum absorption peaks. According to the Lambert Beer's law, as the change of the sample content, the spectral feature will also change. The peaks in the spectra provides a certain theoretical basis for qualitative or quantitative research on the textile fibers [2].

B. Research Status of Spectroscopy in Qualitative Identification of Textile Fiber

Spectroscopy technology obtained spectral information after continuous scanning of the sample, and can predict the sample's physical and chemical parameters from the simple spectrum. This technology is widely applied in textiles field.

Tomomi Dozono et al [3, 4], using cotton, polyester and wool as the research object, collected its infrared spectrum, and used the method of diffuse reflection to obtain spectrum of the mixed fiber. They used the characteristic spectrum of each fiber, through the soft independent modeling classifying sample. Fiber composition of the mixed fiber were studied by the partial least squares regression method.

Jin-chao Chai et al [5], using cotton, polyester blended fabrics as the research object, used near infrared diffuse reflection spectrum combined with partial least squares method to establish the quantitative calibration model. Then they analyzed the influence of different spectral preprocessing method of calibration model. The results showed that the model based on Vector normalization method had the best effect. This method verified the possibility of quantitative analysis of fiber mixtures by near infrared spectrum.

Li-zhen Tao et al [6], gathered polyester, cotton and different proportion of polyester/cotton mixture infrared spectra, and then selected 2900cm-1, 1717cm-1, 721cm-1 as the quantitative analysis of the characteristic absorption peak and peak area ratio as the characteristic value. They obtained the fitted equation of characteristic value and polyester content in polyester/cotton mixture by using Origin software. This method can achieve quickly and accurately quantitative analysis of polyester/cotton mixture.

Min Wang [7] elaborated the qualitative and quantitative study on the infrared spectrum of blended fiber in detail. They used a method of combined infrared spectra, two derivative infrared spectroscopy and two-dimensional correlation infrared spectroscopy achieve qualitative analysis of single component fiber. Two order derivative infrared spectrum peak height ratio in the spectroscopy and the difference spectrum were used for qualitative analysis of hybrid fiber. With this method, they obtained the general content of a component in hybrid fiber. A quantitative analysis model of the wool/acrylic blended ratio was established combined with chemometrics methods.

The spectrum produced by different groups on the absorption peak position is different. This is the basic theory

of infrared spectroscopy used for substance identification. Under normal circumstances, as long as the two kind of textile fibers composition is different, the distinction between both is possible. But structure similar to that of the infrared spectrum of textile fiber, the difference is not big. Therefore it is difficult to accurately identify, which puts forward a new challenge for spectroscopy applied in textile field.

Natural bamboo fiber and flax fiber have similar morphology structure, physical and chemical properties. Their diffuse near infrared spectroscopy have almost the same strength and location of absorption peak. Therefore, Wei-dong Li et al [8], after the first derivative spectra and vector normalization processing, established hierarchical cluster analysis model for the samples with Ward' salgorithm, realized the effective rapid identification of two kinds of fibers.

The present study shows that the terahertz spectroscopy is very sensitive to small changes of the material structure and the environment. Terahertz spectrum of the material that has similar structure also has a big difference, giving material unique fingerprint spectrum.

Si Chen [9], using three kinds of different processing technology of polyester fiber, gathered their terahertz and infrared spectrum. The results showed that infrared spectrum can identify three kinds of polyester fiber by absorption peak area size difference. Terahertz spectrum directly distinguish by the differences in crystallinity and orientation degree of three kinds of polyester fiber from the absorption spectra.

Toru Kurabayashi et al [10], proposed a method based on terahertz spectrum to distinguish textiles. The results showed that terahertz spectrum are sensitive to the difference between the fibrous structure. Terahertz absorption spectra of same type or category of fiber are also different. They implemented qualitative analysis of several common synthetic fibers, verified the possibility of this method.

III. Spectroscopic Applications In Silkworm Cocoon Sex Identification

A. *Study on the Mechanism of Spectroscopy in Silkworm Cocoon Sex Identification*

Shen-yuan Pan, Tong-ming Jin et al, compared second order derivative average spectrum of silkworm chrysalis, cocoon layer with silkworm cocoon'. They came to the conclusion that the different of near infrared absorption, reflection characteristics caused by the different natures of the silkworm chrysalis, and had little to do with nature of cocoon layer but not rule out comprehensive influence of other factors. And other research proved that when using spectrum detection cocoon of male and female, silk protein groups of hydrogen molecules can absorb on the near infrared spectrum. The composition of spectrum can reflect the composition of silk cocoons. The same species of cocoon has the similarity between the same sex, but there is difference [11] between male and female. Although the silk fibroin molecules is a variety of amino acid composition of the peptide chain, different kinds of silk molecules have different amino acid content and sequence [12]. And this is the fundamental reason for the differences in the spectra of silk.

B. *Research Status of Spectroscopy in Silkworm Cocoon Sex Identification*

Spectral analysis technology can make full use of spectral data of multiple wavelengths for the qualitative or quantitative analysis. To distinguish between male and female cocoons, researchers had done many exploration using spectroscopic techniques. In 2008, Hui Yan, Bin Chen et al [13], extracted the principal component of near-infrared diffuse reflectance spectra of silkworm cocoon, and then established prediction model combined with support vector machine. The recognition rate is up to 94.7%, but there are some technical problems worthy of further study, such as the error caused by different curvature of cocoon surface, environments and species. In 2008, Yu-pin Li, using partial least squares method combined with BP neural network method, established the forecast model of silkworm cocoon sex identification. Prediction accuracy has a certain reliability, but the number of samples is less, still need to validate the accuracy of the model in the cases of large sample, multispecies.

C. *Application Prospects of Spectrum Analysis Technology in Textile Field*

Spectrum analysis technology had been widely used in the textile field, achieved a certain degree of qualitative and quantitative analysis. Some key technologies, such as spectral acquisition, spectral preprocessing, feature extraction, the establishment of prediction model, got different degrees of development and research. And spectral analysis techniques got a certain degree of applications in silkworm cocoon sex identification, verified the possibility of this method. But they had some defects and shortcomings to some extent, unable to realize the automatic determination. Therefore, to explore a new silkworm cocoon sex identification with spectrum technology is the key technical points in the study of silkworm cocoon. At present, the rapid development of image recognition technology provides a wealth of theoretical analysis and algorithm improvements, widely used in industrial production. Hyperspectral image contains not only the two-dimensional image information of sample in each band, also contains spectral information of each pixel of the phase. Hyperspectral image technology is the integration of the spectrum analysis technology and the image processing technology at the lowest level of data. With the advantages of the two technologies, the external features of the research objects are visualized, and the effective components of internal are quantitatively predicted [14]. Hyperspectral technology provides new research direction and technical support for quality identification of textile fiber and silkworm cocoon sex identification.

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