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Measuring Fabric Moisture Content with Improved Wheatstone Bridge

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Abstract

Use of improved Wheatstone bridge in measurement of fabric moisture content as well as its measurement principle is introduced in this paper. A new detection circuit of fabric moisture content based on improved Wheatstone bridge is designed, and its measurement result is standardized by oven method. The fitted curves representing fabric moisture content of different materials are plotted after the experimental data is processed. Compared with oven method, errors are analyzed. The results reveal that the detection circuit can accurately measure the changes in fabric moisture content and errors are small (within 1% for cotton), which can meet the need of fabric moisture content detection online system.

Keywords: Moisture Content; Improved Wheatstone Bridge; Detection Online; Fabric Resistance

1 Introduction

The moisture content is a fundamental parameter of fabric textile dyeing process, which directly affects the textiles processing quality. Moisture content is defined as the ratio of the weight of the water that fabric absorbs and the weight of dry fabric. Namely moisture content = (the weight of wet fabric –the weight of dry fabric) / the weight of dry fabric [1].

Top measurement methods of moisture content are oven drying, infrared hygrometry, capacitance method, microwave method, and resistance method. The oven method holds the highest accuracy, and it can be used to calibrate the results measured via other measurements. However, it can't be achieved online, because the time it takes is too long [2]. Infrared and microwave test methods are non-contact measuring methods, their biggest strength is that measurement does not require to be in touch with fabric and detection-online is easy to be achieved. However, they are born with deathful disadvantage that they have many demands from the external environment and the radiation may affect workers health or interfere with other equipments [3, 4]. Capacitance method and resistance method are electrical measurement method; they obtain fabric moisture content indirectly by measuring the conductivity of fabrics. Currently capacitance method is not yet mature because of its instability. And owing to easier implementation, low cost, and support for online testing, the resistance method is widely used in textile industry [5]. A new method

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of measuring fabric moisture content based on resistance method will be introduced in which Wheatstone bridge is improved to effectively solve the problem of the wide resistance change range of fabric with different moisture. And stably output current signal after conversion and conditioning. The relationship between the output current and fabric moisture is fitted after cotton, denim, linen and chiffon samples are tested by circuit designed, which is applied on the setting machine for testing moisture of fabric online. After theoretical analysis and experimental testing, this method is confirmed with feasibility.

2 Measurement Principle and Realization

2.1 The Effect of Fabric Hygroscopicity on the Electrical Conductivity

Most of the textile materials inherently possess a certain degree of hygroscopicity, mainly manifested as moisture content of textile materials varies with the changes of exterior ambient humidity. Place drying fabrics in a highly humid air or directly into a liquid solution, the moisture content of textile materials will increase. Similarly, place the fabric with higher moisture content in a relatively arid environment, the water will gradually decrease [6]. Whether absorbing water or releasing water, in certain conditions, the moisture content of the fabric will gradually become steady; this phenomenon is called moisture balance. When it reaches moisture balance, the moisture content that the fabric possess depends on the external environmental factors such as relative humidity and temperature [7, 8].

After absorbent of textile materials, its electrical properties will change a lot, in order to describe the specific nature of conductive textile materials, the model similar to textile material geometry and various technical indexes must be introduced, and are defined as follows:

Definition: R is the resistance value (Ω) of fabric material, L is the length (cm) of fabric material, S is the cross-sectional area (cm^2) of fabric material and ρ_v is volume resistivity of fabric material. Then,

$$\rho_{\mathrm{v}} = \frac{R \cdot S}{L} \tag{1}$$

From the formula (1), ρ_m is the resistivity of material, and its unit is $\Omega\cdot$cm. In value, it is equal to the resistance value of fabric material with the length of 1 cm and the cross-sectional area of 1 cm^2.

Definition: d is the density of fabric material (g/cm^3), ρ_m is mass resistivity. Then,

$$\rho_m = d \cdot \rho_v = d \cdot \frac{R \cdot S}{L} \tag{2}$$

It is easy to know from formula (2) that ρ_m in value is equal to the resistance value of fabric material with the mass of 1 g and the length of 1 cm, and its unit is $\Omega\cdot$g/cm^2. Mass resistivity can reflect material conductive properties. For textiles, length and mass is easier to measure than the cross-sectional area and volume, and the error is relatively small. Hence, mass resistivity is often utilized to indicate the conductive properties of materials [9, 10].

Textile materials are important electrical insulating materials [9, 11]. Generally textile materials are polymers; they have a high electrical insulation property thanks to special molecular structure.