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Study of Thermo-electronic Characteristics of Woven Heating Fabrics Embed with Silver Filaments Based on Infrared Images

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Abstract

In the paper, two kinds of Woven Heated Fabrics (WHFs) were prepared and evaluated. WHFs were fabricated by integrated silver filaments into fabrics with the same interval distance, and silver paste was coated on the crossing points of some WHFs to decrease contact resistance. Subsequently, surface infrared temperature images and temperature simulated by finite element method were utilized to evaluate the performance of WHFs. Experimental results showed surface temperature of WHFs is non-linear correlation with time when voltage was loaded on two ends of WHFs, but the surface equilibrium temperature of WHFs is linear correlation with loaded voltage and power consumption. However, simulated surface temperature is highly consistent with the measured surface temperature of silver filaments by adjusting the Heat Transfer Convection Coefficient (HTCC) at different loaded voltage. WHFs have wide application prospect in Electric Heating Garment (EHG) in the future. Infrared temperature images and finite element simulation can decrease the cost and enhance design efficiency of WHFs.

Keywords: Active Warming; Thermo-electronic Behavior; Woven Heating Fabric; Infrared Temperature Image; Silver Filament

1 Introduction

Smart textiles and garments that can monitor change of environment parameters, such as temperature and press, etc, and make timely response to protect human body will have wide application prospect in the future. Metals and conducting polymers filament or yarn have already been widely applied in many smart textiles and garments, for example, heating garment, antistatic materials, electromagnetic interference shielding, transport of electrical signals, sensors, etc [1-7]. Heating fabrics and heating garments were paid increasing attention by many researchers in the last decades. F. W. Hewitt [8] fabricated a flexible electric heating pads by using resistance wire

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and a flexible fabric support as early as 1929, André B. [9] developed a heating fabric by arranging non-conductive threads as warp, and non-conductive threads strip and conductive threads strip as weft alternately, more and more heating fabrics and heating garments were springing up, especially in recent years. N. V. Bhat [10] fabricated a cotton fabric which can possess electric conductivity by impregnating polypyrrole. Such fabrics can be used as heating pads and integrated into the apparel to keep the wearer warm. Performances of the heating garments were evaluated on a thermal mannequin in cold weather environments [11]. Electrical characterization of heating fabric with stainless steel yarns was investigated, and results showed performances of the heating fabric were closely correlative with power supply and current amount [12]. S-tainless steel yarns with comb structure were arranged in cotton yarn fabric during the weaving process to acquire heating element [13]. Liu Hao et al. [14] integrated superfine silver filament in woven fabric and fabricated a resistance adjustable flexible heating fabric, subsequently, the performance of heating fabric was investigated in detail by experiments. Result showed strong positive linear correlations are between rated power and utmost ascending temperature of flexible heating fabric and between power consumption and presetting equilibrium temperatures of flexible heating fabric. Syed Talha Ali Hamdani [15] conducted on a study of the thermo-mechanical properties of knitted structures, the methods of manufacture, effect of contact pressure at the structural binding points and on the degree of heating, and utilized infrared images to study the heat distribution over the surface of the knitted fabric. In this paper, thermo-stability test of non-conductive yarns were investigated by a series of ageing tests. Simultaneously, two kinds of heating fabrics which are Woven Heating Fabric (WHF) without silver paste on crossing point and Woven Heating Fabric with Silver Paste on crossing point (WHF-SP) will be developed and their properties will be measured and analyzed by temperature measurement system and power consumption measuring system developed in our laboratory.

2 Experimental Method and Principle

2.1 Thermo-stability Test of Non-conductive Yarns

Application security is the crucial performance index for heating fabrics and heating garments. When a big current was loaded on silver filaments in heating fabric, surface temperature of silver filaments will be very high, but the non-conductive yarns which comprise main support of heating fabric can't withstand so high temperature. Therefore, study of correlation between thermo-stability of non-conductive yarns and surface temperature is very important for designing and using heating fabrics. In this section, polyester yarn with 22.5 tex was selected as warp yarn and weft yarn of heating fabric, environment temperatures of 3 ageing oven were set at 80, 100 and 120 degrees Celsius respectively. 120 polyester yarns with 80 cm length were put into each ageing oven and performed ageing testing of 264 hours, two ends of each yarn were fixed on a wood board by adhesive tape to avoid back-twisting, 10 yarns in each ageing oven were token out and performed strength testing on universal strength tester (Instron 3369, US-A) after 24 hours ageing testing. Breaking strength and elongation at break of each yarn were acquired and utilized to analyze the correlation between mechanical properties and ageing temperature.