Resistivity behavior of leather after electro-conductive treatment

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ABSTRACT

Measurement of electrical resistance of textile materials, fiber and fabrics included, remains always an engaging task due to sensitivities to interference of multiple factors. Difficulty stands on both finding a method of measurements that fits the requirements of samples to be tested and the most appropriate indicator describing this property. Numerous methods and indicators are used for different sample content and shape (fibers, roving, yarn or fabric, etc.), even when the material tested is the same. Different methods usually use indicators that produce results difficult to compare or to interpret, or do not express intrinsic qualities of their constituent materials. The situation is the same for leather materials. In this paper, we propose a new method, multiple steps method, and a new indicator, electrical resistivity, which takes into consideration compressional properties of leather sample and produce results independent from the amount and form of the sample. Electrical resistivity of conductive leather, as defined below, is shown to be an inherent indicator of bulk conductivity of leather assembly and is not influenced by sample form or the way it is placed within the measuring cell. The method is used for the first time to evaluate changes in electrical resistivity of leather after various chemical processes to make it electro-conductive. The data provide important information about the evolution of electro-conductive properties of leather at different stages of processing, as well as the influence of environmental conditions.

KEYWORDS

Conductive leather, electrical resistivity, multiple step method

INTRODUCTION

A touch screen display is a primary input device of a smart phone, a tablet computer, etc. While there are many tough technologies in existence, resistive and capacitive technologies are dominant and leading the touch-screen panel industry. Moreover, a capacitive touch screen panel widely used in smart phones is coated with a material that stores electrical charges. In the cold climate or other specific conditions when the use of gloves is necessary, gloves with electro-conducting leather are a tool to operate a touch panel screen. Therefore, electrically conductive materials can be applied to the surface of leather to be used as a touching operator for capacitive touch screen panel. Consequently, the treated leather samples show electrical conductivity and reasonable working performance. [1-3].

Investigation of conductivity of textile materials and leather is a very challenging field because of its complexity. Difficulties arise from a multitude of shapes (fibers, roving, yarn, fabric, sheet, foil, etc.), structures, fiber content, etc., of textile assembly and leather. Various methods and standards have been devised to measure the electrical resistance of different kinds and forms of textile assemblies, leading to a situation where indicators used for evaluation of the conductivity of a specimen, even where composed by the same material, are unmatchable and not easy to compare.

Moreover, measuring surface resistance of flat shape textile samples is difficult because of current flowing into the shape cannot be isolated only in the surface, but a part of it can penetrate through the volume. Numerous methods and standards can be found in literature [4-20]. For example, two and four probe electrical resistance measurement methods, where the most accurate and widely used methods are four probe placements. Initially proposed by van der Pauw [21], surface resistance of any arbitrary shape was determined by the ratio of applied voltage over two electrodes to the current flowing on the two other opposite electrodes placed around sample circumference. Likewise, Tokarska [15-16] has used Van der Pauw method for surface resistance measurement and anisotropy evaluation of conductive textile samples. Another approach for measuring surface resistance is applied by Yang and Wang [22], where they develop a novel circular probe.

The abovementioned methods crucially focus on measurement of textile samples resistance by considering them thin films, but taking into account their drawbacks, we have proposed a new method for measuring the electrical resistivity of textile assemblies [9-10] that tends to eliminate many of the problems associated with current methods. It is a multiple-step method based on a new definition of electrical resistivity of textile assemblies and takes into consideration their compressional properties. The new parameter seems to be an inherent property of fiber composition not influenced by the form of the sample and the geometry of the measuring set-up. This method was successfully used, for the first time, to check the effect of the spinning process on the electrical resistivity of fiber assemblies and to use the result for different practical evaluations of the process itself. In this paper, we are trying to expand the use of this method in testing electrical resistance of conductive leather.

EXPERIMENTAL

Materials and Methods

The leather used is white sheep crust leather of Albanian origin, 8 x 8 cm in size and 0.97 ± 0.2 mm thick. The leather is chrome tanned and dried but not dyed. The chemicals used were pyrrole, ferric chloride, anthraquinone -2- sulfonic acid sodium salt monohydrate of laboratory grade and high purity [23]. The leather has good tensile and tear strength characteristics. These good characteristics make leather a unique and desirable product to be used in daily life. Moreover, it has good heat insulation which makes itr very useful for winter season products.

When considering the electrical resistance of a textile material, the situation complicates due to the influence of shape and compression parameters on the I-V (current-voltage) characteristics. All existing methods for measurement of the DC resistance of textile are based on data obtained from a single test which excludes the possibility of acquiring any information about compressional behavior of the fiber assembly. In order to take compressional behavior into consideration, we have proposed a multiple step method which is described in literature in details [9-10]. This method consists of measuring the electrical resistance of the sample compressed to different volume – fractions within measuring cell. The dependence of the electrical

resistances of textile material on its volume-fraction (Vf) within the measuring cell is then approximated by a reciprocal power function

$$R = C \bullet Vf^{b} \quad (1)$$

- where C and b are constants to be defined experimentally, while *Vf* is the volume fraction of textile material within the measuring cell. Volume-fraction of textile material is defined as the ratio between the volume of textile sample *V= m/d* and apparent volume of the cell V_0:

$$Vf = V/V_0$$

- where m is the mass of textile sample and d is the density of textile material.
Assuming this relationship holds over the entire range of volume fractions, we can obtain presumed resistance R_o of textile material compressed until it is transformed into a compact homogenous mass by:

$$Ro = (R) = C \quad (2)$$

- the resistivity, *ρ* in the case of a parallelepiped cell is calculated by:

$$p = Ro \frac{m}{d \cdot a^2} \quad (3)$$

- where *a* is the length of the sample, i.e., the distance between electrodes of the cell. Equation 1 equation 3 can be transformed into a more convenient form for calculations:

$$p = R * \left[\frac{m}{d \cdot a^2}\right] * Vf^{-b} \quad (4)$$

The main objective of the current study is to find out if the above testing method can be applied to testing conductivity of conductive leather. White sheep crust leathers were treated chemically in order to make them conductive. Two different coating methods were used: single in-situ polymerization of pyrrole and double in-situ polymerization of pyrrole.
Single in-situ polymerization method was used for increasing conductivity of white sheep crust leather [1]. Leather samples were treated with single in-situ polymerization of pyrrole. For single in-situ polymerization, leather (8 x 8 cm) was first treated with a pyrrole/AQSA mixed solution for 1 hour, at room temperature, rotating manually at 10 rpm. Then ferric chloride solution, which plays the role of the oxidant, was added to the mixture to initiate the polymerization which lasted 2 hours, at 5°C, rotating manually at 10 rpm. Finally, the polypyrrole coated leather samples were washed with distilled water and dried at 35 °C. The concentration of monomer (pyrrole), AQSA as a dopant, and FeCl3 as oxidant were varied and optimized in order to provide the maximum conductivity of leather.
For double in-situ polymerization, the leather was initially treated as in the first method, in single in-situ polymerization method containing half of the concentration of reactants. The sample was then treated again in a second bath containing half of the concentrations of reactants following the same procedure to obtain double in-situ polypyrrole coated leather. Finally, the coated leather was washed 4 times with distilled water and dried at 35°C.
It was observed that the color of the sheep leather samples treated with two methods changed into black at the end of the experiments. The treated leather samples were cut in square shapes. The electrical resistance of the compressed sample was measured with a Tektronix DMM4050 Multimeter and the voltage used was 10 volts DC. The test procedure involved measuring the electrical resistance of samples for at least ten different volume-fractions within the cell (Figure 1). The mass of samples varied between 2.8 to 6 grams according to their dimensions, and thickness was measured for each sample. The density of the leather was 0.86 g/cm^3. Each sample was first tested in its initial square sheet shape and then cut into thin

threads, after which it was again tested for electrical resistance (Figure 2). This procedure eliminates any influence of sample differences on measurement results. In each case, samples were randomly placed within the measuring cell.

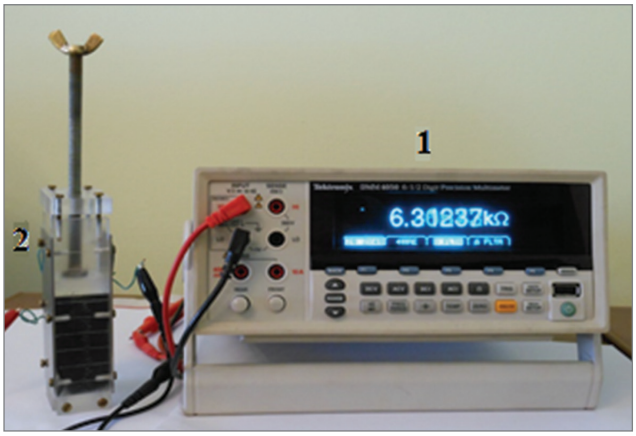

Figure 1. Measuring setup. 1-Multimeter, 2-Measuring cell

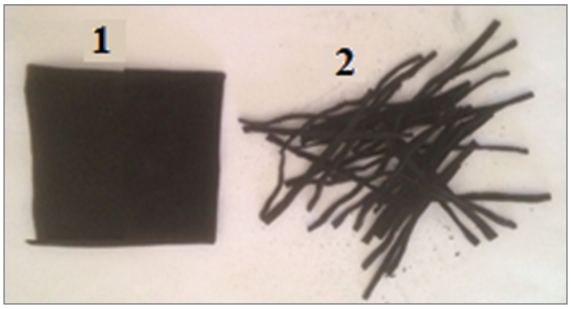

Figure 2. View of two shapes of samples:
1-Square shape [8cm x 8cm], 2-Thin stripes shape

EXPERIMENTAL VERIFICATION OF THE METHOD

In this section, experimental data is presented to show how the new parameter, the electrical resistivity of a leather sample as defined above, is influenced by the shape of samples (sheet and stripe), as well as by observation of environmental effects on resistance.

Initially, the taken volume fractions varied from 0.16 to 0.46 with a step of 0.01. The data received were used to define the power function in equation (1).

Figure 3 shows a typical dependence of results of measured resistance of the sample on volume fraction and its corresponding curve of approximation. The correlation coefficients of approximations vary from 0.9 to as high as 0.99. This is an indicator of suitability of chosen function of approximation.

Table 1, shows three typical results of experiments carried out with leather samples made conductive by using both methods of chemical treatments:

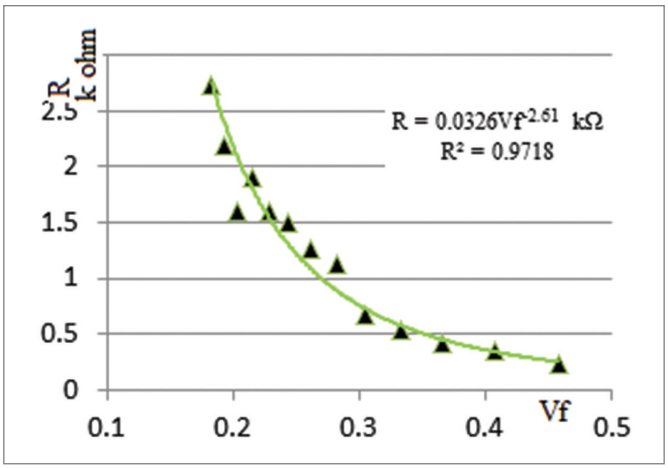

Figure 3.T ypical dependence of results of measured resistance of the sample on its volume fraction and its corresponding curve of approximation

method 1, single in-situ polymerization of pyrrole, and method 2, double in-situ polymerization of pyrrole coating. The following conclusions can be drawn from the data:

Table 1. Three typical results of experiments carried out with leather samples made conductive by using both methods of chemical treatment

Sample	Chemical treatment	T ºC	RH %	T. Test	Resistivity of different shapes of leather samples Ω·m			
					Sheet		Thread	
					Resistivity	Standard deviation	Resistivity	Standard deviation
1	Method 1	15.0	61	0.89	0.990	0.42	0.980	0.23
2	Method 1	28.6	54	0.79	0.880	0.43	0.980	0.28
3	Method 2	27.4	43	0.96	0.372	0.06	0.374	0.03

a. Within experimental error, the change in sample type from sheet to thread does not affect the calculated resistivity of conductive leather samples.

b. Power index b of power functions used for approximation varies with sample type, sample composition, and placement of the sample within the cell. The range and magnitude of the variation of power indexes is quite wide, from 1.4 to 3.8, but within the margins of standard deviation, this does not affect the results of calculated resistivity.

c. Standard deviations in case of leather samples treated with the first method are very high, varying from 19 to 46 %, while in the case of samples treated with second method it varies from 16 to 19 %. These are indicators of unevenness of effect of treatment on samples conductivity. It has to be noted that samples treated with method 1 show a distinct deference between resistivity of two sides of samples, while samples treated with method 2 show no such difference

In general, electrical properties of textile materials change with air humidity. In this paper, we decided to apply the above mentioned method for studying the influence of air humidity on the electrical resistivity of conductive leather. To minimize the distribution of data due to unevenness of chemical treatment, as tested above, we decided to test a sample treated by the second polymerization method (double in-situ polymerization) using leather threads as sample shape. The sample was conditioned for 24 hours in different air humidity and almost the same air temperature (Table 2).

Table 2. Measured electrical values in different environmental conditions

Ta °C	RH %	ρ Ωm
24.9	23	1.36
25.2	31	1.06
25.0	36	1.10
25.5	42	0.93
24.6	44	0.92
25.1	50	0.75
24.8	55	0.66
24.9	57	0.58
25.1	63	0.48

Mostly interested in effects of humidity, we observed experimentally that the electrical resistivity of conductive leather changes linearly with air humidity. As the humidity increases, leather electrical resistance decreases as shown in Figure.4.

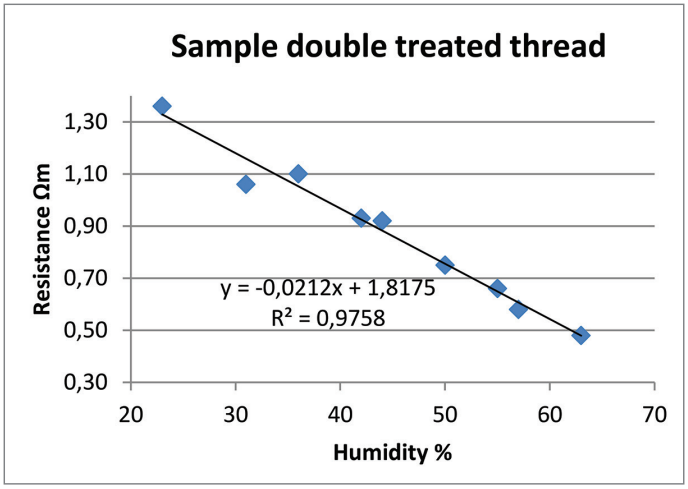

Figure 4. Relation between electrical resistivity and air humidity

CONCLUSION

Compressional properties of conductive leather play a crucial role in the measurement of their electrical resistance. The use of a multiple-step method for measuring electrical resistance of conductive leather, together with a new definition of electrical resistivity, takes into consideration the compressional properties of leather.

Electrical resistivity of conductive leather, as defined above, unlike the methods and standards used nowadays for measuring surface resistance, is shown to be an inherent indicator of bulk conductivity of leather assembly and is not influenced by sample form or the way it is placed within the measuring cell.

Electrical resistivity of conductive leather is a property, which strongly depends on environmental conditions, especially air humidity.

This method is used for the first time to evaluate changes in electrical resistivity of the leather after different chemical processing to make it electro-conductive. The data provide important information about evolution of electro-conductive properties of leather at different stages of processing and how it is influenced by environmental conditions.

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