Study of conduction mechanisms in antistatic felts at the mesoscopic scale

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ABSTRACT

This work is part of a project that deals with the optimization of the quantity and the nature of conductive fibers in antistatic felts used for filtering and sieving powders. Our research concerns the electrical properties at the mesoscopic scale. It aims at determining the conduction mechanisms and the distribution of the electric potential at the scale of the distance between the conductive fibers. In this paper, current-voltage (I-V) measurement results are presented and discussed. X-ray microtomography is used to obtain the geometry of the conductive fibers inside the felts before and after these I-V tests. The studied textile material is based on polyester fibers and stainless steel conductive fibers.

INTRODUCTION

Antistatic felts are often subjected to electrostatic charges liberated by contacts occurring by frictional forces while filtering or sieving powders. The accumulation of these charges can cause sparks and lead to an explosion in the presence of flammable substances or combustible dusts. Moreover, this risk increases with the reduction of the powder particle size [1]. To avoid this danger, it is important that these felts should be able to drain the accumulated charges to a grounded point. A classical way to handle this consists in incorporating conductive fibers into the filter media. However, one major bottleneck in optimizing the antistatic felt performances is the poor understanding of its conduction mechanisms when draining out the accumulated electric charges.

In this paper, the electrical properties of antistatic felts are considered at the mesoscopic scale, the objective being the investigation and elucidation of the conduction mechanisms. Particular emphasis is given to the current-voltage (I-V) measurement results. X-ray microtomography, a non destructive imaging technique, is used to determine the geometry of the conductive fibers inside the felt samples before and after these I-V tests. These experimental methods are applied to felts based on polyester fibers and stainless steel conductive fibers.

SPECIMENS

The polyester felts used in this research were provided by the company SIOEN Felt & Filtration, Liège, Belgium. Stainless steel conductive fibers are incorporated in these felts. The rectangular samples have a typical area of few square centimeters with a thickness of 2 mm. Given this geometry, an electrical conductive silver paint is used to ensure the electrical contact between wires and both felt sample extremities. Due to the anisotropy of the properties of this textile material, its electrical properties are highly sensitive to fiber orientation; therefore all the experiments were carried out in both machine direction (MD) and cross directions (CD). Furthermore, all the specimens are tested in a controlled environment in terms of relative humidity and temperature.

EXPERIMENTAL METHODS

The circuit shown in Fig. 1 is used to obtain the I-V curve associated with a felt sample. The voltage between the electrodes of the latter is denoted U_x and is swept between 0 and 1000 V. Note that a resistor of 1MΩ is added to protect the high-voltage generator.

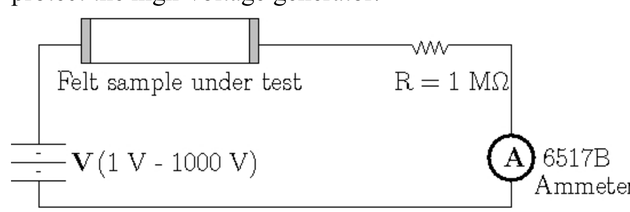

FIGURE 1. Felt sample test circuit to record the I-V curves.

The X-ray microtomographic tests are performed by the using the Skyscan-1172 device (Skyscan, Kontich, Belgium), available at the Laboratory of Chemical Engineering. This microtomograph gives 2D cross section images of the felt samples with a high resolution. The specimens were fastened to an adapted sample holder minimizing the mechanical vibrations. A standard image thresholding technique [2] was then used to convert the felt images to binary images. If a pixel in the image is above a given global threshold then it is converted to white (polyester fibers or air) otherwise it is converted to black (stainless conductive fibers). From each binary image, a set of parameters associated to the conductive fibers were extracted, namely: their total number; the smallest distance between them; the coordinates of the global centroid and the variance of the relative distance to this centroid. The objective was to assess whether the location of the conductive fibers changes after a I-V test or not. This result can support or disprove a conduction mechanism based on an electromechanical activation.

RESULTS AND DISCUSSION

The method has been applied to a polyester felt sample with the stainless steel fibers in the (CD) direction. Its geometry and associated system axis are shown in Fig.2.

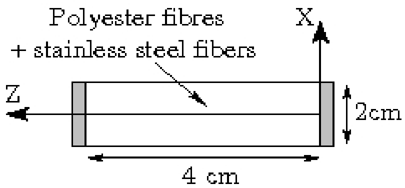

FIGURE 2. Geometry of the studied felt sample.

The specimen was conditioned environmentally at relative humidity of 35% and at temperature of 25°C during all the experimental tests.

Two successive microtomographic investigations were first carried out without any intermediate I-V test in between, but the sample was removed and placed in the sample holder between the first two tests. The objective was to analyze an eventual impact of the operator manipulation on the location of the conductive fibers. An I-V test up to 1000 V was then recorded before the third microtomographic test. The microtomograph gives the cross-section images parallel to the X,Y-plane with a pixel size of 7 µm.

As depicted in Fig. 3, the I-V curve of the felt sample exhibits a non-linear and hysteretic behavior. Note that a log-log system axis is used. First, it can be seen that the current increases with the voltage flowing almost the Ohm's law. After a voltage threshold (here 825 V), the current rises suddenly and becomes 100 times higher than its previous value (from 10^{-7} A to 10^{-5} A). The associated power is in the range of 80-100 µW. The I-V curve becomes finally linear with a very small resistance (R∼100 kΩ) compared to the initial one (R∼4.5 GΩ).

Fig. 4 shows the evolution of the total number of stainless steel conductive fibers for each of the three microtomographic tests, the I-V curve being recorded after the second one. The results are given for a distance of z = 9.5 mm. The comparison of the curves (1) and (2) shows that the operator manipulation does not perturb the location of the conductive fibers significantly. However, applying an I-V test to the felt sample yields deviations of the value of the total crossing points of these fibers in a given plane perpendicular to axis z (here z = 9.5 mm).

These results suggest that the stainless steel conductive fibers may move inside the polyester felt when subjected to a continuous voltage. Moreover, the sudden transition noticed in the I-V curve could indicate a contact between these conductive fibers.

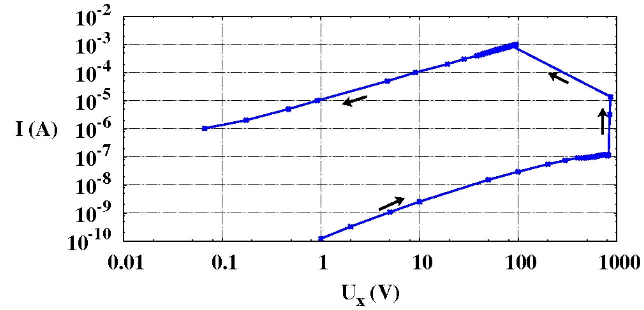

FIGURE 3. I-V curve of the felt sample, U_x being the voltage between its electrodes.

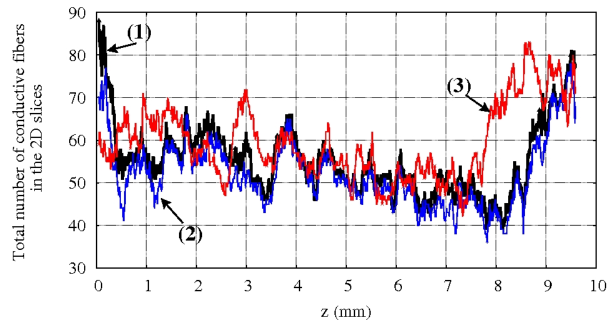

FIGURE 4. Total number of conductive fibers along the distance z = 9.5 mm. The two first microtomographic acquisitions (1) and (2) are done successively without an intermediate I-V test.

CONCLUSIONS AND FUTURE WORK

In this paper, the conduction mechanisms of an antistatic felt at the mesoscopic scale are considered. Current-voltage measurements results are presented and discussed. X-ray microtomography is used to obtain the geometry of the conductive fibers inside the felts before and after these I-V tests. The results suggest that the stainless steel conductive fibers may move inside the polyester felt when subjected to a continuous voltage. Moreover, the sudden transition noticed in the I-V curve could indicate a contact between these conductive fibers.

Details on the proposed method and the experimental setup, more results and discussion on the conduction mechanisms in the antistatic felts at mesoscopic will be included in the extended paper.

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