A simple device to measure the electric charges accumulating on textile fabrics

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A simple device to detect and measure the electric charges accumulating on textile fabrics is described. The device measures the magnitude of the charge without touching the charged fabric and functions similar to an electroscope. Preliminary measuring trials with a group of apparel fabrics have demonstrated the feasibility of the device.

Keywords: Electroscope, Synthetic fibres, Static electricity

1 Introduction

Specifically engineered textile products, made possible by the availability of a wide range of synthetic fibres, have changed the traditional image of the textile industry in recent years. Weaving and knitting are no longer the only fabric manufacturing technologies, and apparel use is no longer the only application for textile fabrics. Engineered fabrics are used in dozens of new applications, including life-saving, life enhancing and injury preventing. Because of the critical role played by the fabrics in some of the new end-uses, strict control and regulation of their properties, including charge accumulation, assumes importance.

Early references to static electricity date as far back as 600 BC, and the first understanding of the nature of electricity is believed to have come from the study of the phenomena of static electricity. Static electricity, however, became a major issue in the textile industry only after the advent of synthetic fibres. By accumulating charges more readily than many natural fibres, synthetic fibres cause a variety of problems in the yarn and fabric manufacturing processes, and in the end-use.

The production of static electricity on a fabric is believed to be the result of frictional rubbing of the fabric against another surface. Mere separation of the two surfaces after contact produces a static charge. The simplest explanation of the phenomenon is that there is a transfer of electrons from one surface to the other, and that the transfer is influenced by the relative affinity of the surfaces to electrons. Thus, if metal is rubbed against wool, the metal acquires negative charge because of its greater affinity to electrons, and wool becomes positively charged as a result of losing some electrons to the metal. Of course, the presence of charge on a surface can be detected only if the conductivity of the surface is low enough for the charge to remain on the surface for an appreciable period of time. Many synthetic textile fibres, especially those that absorb very little moisture, have low electrical conductivity even at high humidities, and these are the ones that cause many problems to fabric manufacturers and their end-users.

As a result of charge accumulation, the fabric can be expected to stick to body hair, and if the stock fabric is forcefully separated from the hair, it may cause physical discomfort to the wearer. The wearer of two oppositely charged garments may feel embarrassed as the garments slide on one another during movement. Charged fabrics also attract dust and dirt particles, thus increasing the soiling tendency of the fabric. The soiling is believed to be worse when the fabric is positively charged owing to the preponderance of negatively charged dust particles in the atmosphere. When high enough charge accumulates on the fabric, discharge in air follows, often with accompanying sparks. It is not uncommon to notice mild sparking while taking off certain garments during the winter season. The sparks emanating from clothing are certainly a fire hazard in the presence of inflammable vapours. Surprise electric shocks on the first contact of charged garments are also not uncommon occurrences in winter.

While the problems caused by static charges are just a nuisance value in most apparel end-uses, the consequences can be much more serious in case of certain patients who carry electronic devices under the garments. Implantation of a number of these devices...
to monitor and regulate certain failing/malfunctioning internal organs is one of the growing trends in the medical practice today, and the trend may assume much greater importance in the future as a result of stunning advances in biology and medical instrumentation. Interaction of the static charge on the fabric with any internal or external electronic device that monitors body functions can prove to be catastrophic in nature. Thus, there is an increasing need today to understand and control charge accumulation by the apparel fabrics, and certainly to develop reliable and inexpensive measuring devices that can be readily used by consumers who cannot afford to carry charges on their garments. By accurately measuring the nature and amount of charge accumulation, it should be possible to re-apply suitable antistatic treatments to the garment to reduce the tendency for charge accumulation. This paper describes the working principles of a simple instrument that has been developed to detect and quantify the charges accumulating on textile fabrics.

2 The New Device and Its Functioning

2.1 Description of the Device

The device (Fig. 1) works very similar to that of the well-known electroscope and it consists of two thin strips of electroplated gold foil mounted at the bottom end of a metal rod. A metal knob rests on the top of the rod, and transparent side plates, preferably of a lightweight polymeric material, can be used to enclose the leaves within the metal casing. An airtight design of the enclosure would ensure that the disturbance suffered by the metal strips due to air currents is minimal. An insulating rubber plug can be used to separate the metal rod from the metal casing so that any charge accumulation on the rod would tend to remain on the rod itself, without being leaked to the metal casing.

2.2 Operation of the Device

In trial experiments, a fabricated device similar to the one described above was used. A negatively charged ebonite rod (the negative charge on the rod was obtained by rubbing the rod against fur) was moved close to the top surface of the metal knob as shown in Fig. 2a. As can be expected, the leaves started spreading apart under the influence of the repulsive force, which is brought about by the negative charge that dissipated over the leaves. Next, the positively charged fur was moved close to the metal knob without touching it. As seen in Fig. 2b, the leaves partially collapsed as a result of some of the electrons being drawn off the leaves and onto the metal knob. The loss of negative charge caused a reduction in the repulsive force between the leaves, which resulted in their partial collapse.

When the positively charged fur was brought very close, but still not touching the knob as shown in Fig. 2c, the leaves first collapsed and then showed a divergence. The collapse of the leaves is not difficult to understand. As the positively charged fur comes closer and closer to the knob, more electrons are drawn off the leaves and onto the knob. There comes a point when all the excess electrons are removed from the leaves, at which point the leaves collapse fully, as a result of becoming electrically neutral. But why should the leaves diverge as the fur comes even closer? The divergence certainly must be due to the presence of a like charge on the leaves, and the like
charge this time is a positive charge. The leaves become positively charged as a result of the fur drawing more electrons from the neutral leaves, and the repulsive forces that the positively charged leaves exert on each other cause them to spread apart. A similar behaviour of the leaves (collapse followed by a divergence) was observed when the negatively charged ebonite rod (in place of the positively charged fur) was pushed closer and closer to the knob. The reasons for this sequential collapse and divergence are of course not any different from those described above.

The above trials were carried out under the standard ambient conditions (65±2% RH and 21±1°C). The charged object was moved close to the device immediately after rubbing and separation. Once the charged object was positioned at a fixed distance from the device, it was left undisturbed in that position until the displacement of the leaves is fully reversed. The time taken for the reversal gave an idea of the rate of discharge. In addition to the fur (100% wool), the woven fabrics made of 100% polyester, 100% nylon, 100% silk and 100% cotton were also used in the experiments and it was observed that the displacement of the leaves, and hence the charge produced by a particular fabric, was not consistent over repeated rubbing trials. However, the rate of discharge was more consistent over repeat trials than the measured charge density. When the displacement of the leaves was normalized with respect to fabric weight, it was found that wool gives the maximum displacement, followed by polyester, nylon, silk and cotton. Cotton fabric failed to show any noticeable displacement of the leaves. The fabrics used were all commercial fabrics and no information was available on the finishes, if any, carried by the fabrics.

2.3 Application of the Device for the Measurement of Electric Charges on Textile Materials

The device can be used to determine if a textile material is charged and, if so, whether the charge is positive or negative. To determine the polarity of the charge, it is necessary to make use of standard reference materials such as ebonite and fur or any other similar combination that produces a negative charge on one and positive charge on the other as a result of surface rubbing and separation. If the leaves that are separated by a known negative charge (such as the one on the ebonite rod) are further separated by the accumulated charge on a textile material, the charge carried by the material is a negative charge. On the contrary, if the leaves separated by a known negative charge are brought together by the charge accumulated on the textile material, the material carries a positive charge.

The test parameter that relates to the amount of charge carried by the textile material is the distance of separation between the metal leaves. The magnitude of charge on the material can thus be measured by measuring the distance between the knobs when a charged textile material of known weight and fixed size is positioned at a fixed distance from the metal knob of the device, or alternatively when the metal knob of the device is positioned at a fixed distance from the charged textile material. Since the charged objects tend to lose charge into the atmosphere and since the rate of discharge depends on the ambient conditions, among others, it is necessary to carry out the magnitude test in a controlled atmosphere.

3 Conclusions

The device can be used not only to measure the amount of charge carried by the fabric but also to check the polarity of the charge. It requires the positioning of the charged material at a fixed distance from the device to provide an indication of the amount of charge. The wearer of a charged garment can obtain a quick estimate of the amount of charge held by the garment by simply walking towards the device and standing at a fixed distance from it. While the device is designed to measure the charges on fabrics in a non-contact mode, it can be used to measure the charges on any sheet-like material.

The primary aim in this work was concept verification and it is believed that the trails carried out with the prototype device have demonstrated the feasibility of the device. The optimum dimensions of the device have, however, not been worked out, and the specifications of the leaves to obtain an acceptable measuring sensitivity, that can facilitate reliable measurements on the whole range of textile fabrics, are not defined. Also, no attempt has been made to define the standard test procedures or to calibrate the instrument for magnitude measurements.

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References