Characterizing The Electrostatic Charging Of Plastics

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A measuring setup to characterize plastics can be used to monitor the electrostatic charging of materials.

INTRODUCTION

The use of plastic components for moving parts in equipment and machines becomes more and more standard in mechanical design and construction processes. Examples are wheels for chairs and transportation carriages, movable equipment, and moving parts in machinery. Plastics can become electrostatically charged. It is not the purpose here to describe this phenomenon, because it is well-known and discussed in literature. These charges attract dust, but can also cause an electrostatic discharge. This is normally an unpleasant experience for the human being, and can disturb and even damage electronic circuits and components.

The effect can be avoided by making conductive plastics. However, it is necessary to have a simple, easy-to-use and low-cost testing and measurement setup for the characterization of this electrostatic charging mechanism. In this way, materials can be compared and even optimized for their anti-static properties. This article describes the mechanical and electrical construction of the measurement setup.

MECHANICAL CONSTRUCTION

The mechanical part of the setup consists of a piston, driven by pressurized air. The piston has two end-of-loop microswitches, which are connected to a PC. In this way, the PC is able to control the linear movement of the piston in both directions or can command a stop/start of the piston. The range of the piston is 20 cm in length. The piston is connected to a sample holder by a rigid arm. On this arm, a small plateau is constructed such that an extra weight can be placed on the construction. In this way, the pressure of the sample on the reference material during movement can be controlled and/or changed according to the test requirements (Figure 1).

The sample can be moved over a reference plate. The base of this 'floor' is made of copper, and is connected to the earth. It is also the local ground (GND) reference of the system. On top of this base, a reference plate of about 25 cm x 15 cm can be placed. Different materials can be used for this reference plate. As a typical example, glass, on the extreme position in the triboelectric series, can be used as an insulating material. In order to have a metal and grounded reference, a copper plate can be installed. The composition depends on the test application and the test requirements. The base has an open construction in order to also allow the installation of non-flat reference samples such as part of a box or curved surfaces.

The samples of the material under test (MUT) can be fixed to the rigid extended arm of the piston. In this way, the samples are moved over the reference plane, and can be charged up electrostatically, due to the friction between both materials. MUT samples can be small wheels; flat samples or parts of boxes or other components can also be tested.

Two noncontacting charge transduc-

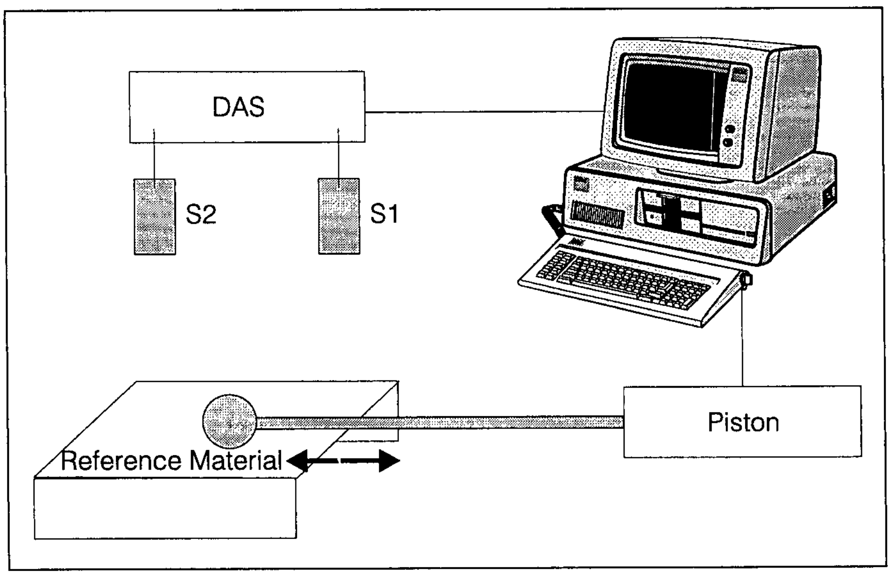

Figure 1. *Mechanical Construction of Setup.*

ers (S1 and S2 in Figure 2) can be positioned over the reference plate. Normally, they are positioned in such a way that S1 senses the charge of the MUT at its reference position. Transducer S2 senses the charge of the reference plate near the end-position of the MUT sample. When using MUT samples that are flat and relatively thin, S2 can be positioned at the end-position. But when samples are used which are relatively big, the distance between S2 and the reference plate becomes too big, and S2 is then positioned near this location (Figure 2).

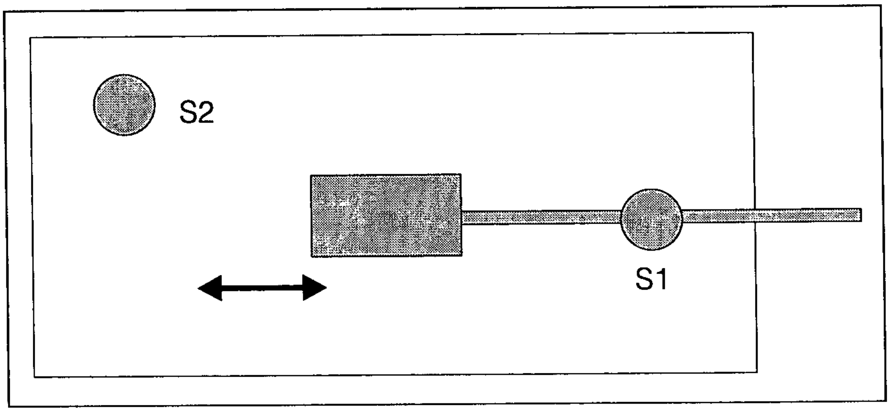

Figure 2. Top View of the Measuring Setup.

ELECTRONIC CONSTRUCTION

The electronic construction consists mainly of three parts: the non-contacting capacitive transducer, the charge-amplifier, and the filter.

The non-contacting capacitive transducer consists of a small metallic, hollow cylindrical construction, which is connected to the local ground-reference (Figure 3). At the top, a BNC connector is mounted, so that this ground is also taken as the signal reference. The inner tip of the BNC connector is wired to the internal capacitor of the transducer. This internal capacitor is made by an insulated metal plate inside the hollow cylinder. In this case, a double-sided PCB has been used, where one side of the PCB is also connected to the ground (over the cylinder).

The bottom end of the transducer has a type of window which can be covered by a small metal plate for the reference measurements.

The equivalent diagram of this system is also sketched (Figure 3). It can be seen that the charge of the MUT sample or the reference plate forms the second capacitor, and that the complete system is equivalent to a capacitive voltage divider. However, this type of transducer has a very high impedance level, so care should be taken for the first stage of the measuring amplifier. Special operational amplifiers with a high input impedance, a low input bias current (on the order of pA) and a very low offset drift must be used. Special care should also be taken for the design of the PCB for these measuring amplifiers so that no leakage between input and output section can occur.

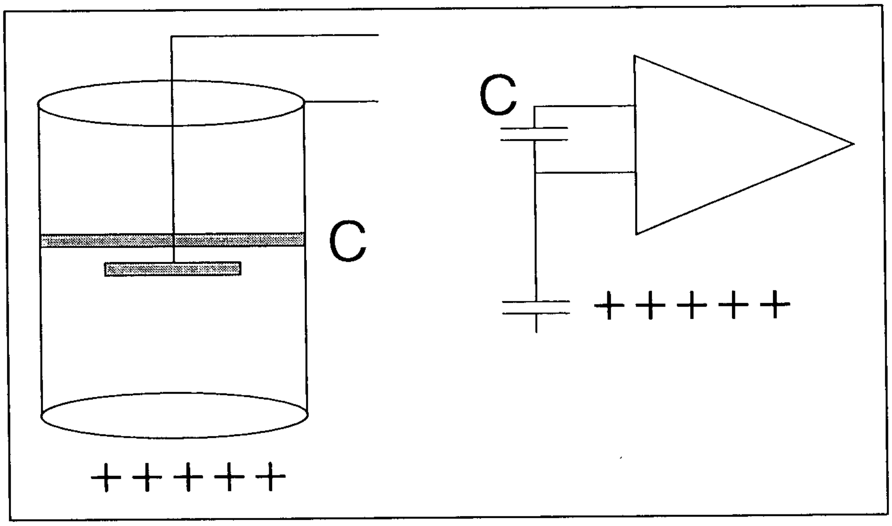

Figure 3. Equivalent Diagram of Capacitive Transducer.

Due to some fluctuations on the measured signals, a first-order RC low-pass filter was added at the output of the measuring amplifier in order to stabilize the measured data. However, this filter introduces some delay in the measurements.

For calibration purposes, the window of the sensor can be covered by a metal plate. In this way, the transducer is directly referenced to the ground, and its output should be zero level. During the measurements, the output dc offset drift can be canceled by adjusting the offset control at regular moments.

The transducer can be calibrated by adjusting the distance of the sensor to the MUT sample and by adjusting its amplification. For this purpose, a metal foil is placed over the MUT sample, and a 1 kV reference voltage is applied to this foil. The output of the transducer can be adjusted to 100 mV so that there is a 1:10,000 ratio for the measuring results.

SIGNAL PROCESSING AND SYSTEM CONTROL

As can be seen from Figure 1, the system is controlled by a PC and a data acquisition system (DAS). The DAS not only has analog inputs, but also has digital I/O possibilities. They can be used for sensing the end-of-loop switches, and for the command of the start/stop control of the piston, and the direction of movement. PC and DAS are connected over an IEEE 488 bus.

The control program of the system allows the following parameters to be set:

- Number of actions, where an action consists of a start, number of movements (backwards and forwards), stop and a measuring period (Na)
- Number of movements during one action (Nm)
- Total time elapsed during the measuring period (Tp)
- Interval time for data sampling during the measuring period (Ti)

This method allows a lot of flexibility for the measuring system. Two examples are given.

EXAMPLE 1

When the parameters are set as Na = 50, Nm = 2 and Ti = Tp = 1 second, the charging of the material is monitored. Indeed, one action consists of only 2 movements, after which the charge is measured for one monitoring moment. This action is then repeated 50 times.

An example of this type of measurement for a nonconductive plastic material is given in Figure 4.

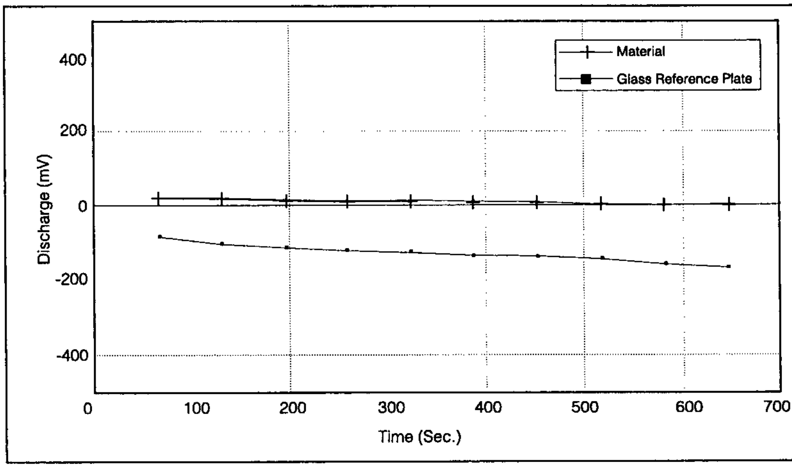

Figure 4. *Example of Charging Up of Nonconductive Plastic Material.*

EXAMPLE 2

When the parameters are set as Na = 1, Nm = 1000, Ti = 1 second and Tp = 600, only one global action is performed, which now consists of 1000 movements, so that the materials are really charging up to their final values. Afterwards, these final charges are monitored, as is the discharge process. The measuring interval is 1 second, and the discharge is monitored over 10 minutes time. An example of this type of measurement for a nonconductive plastic material is given in Figure 5.

The measuring data are taken from the DAS to the PC over the IEEE 488 bus. They are stored as an ASCII file, and can be introduced in any spreadsheet for further processing.

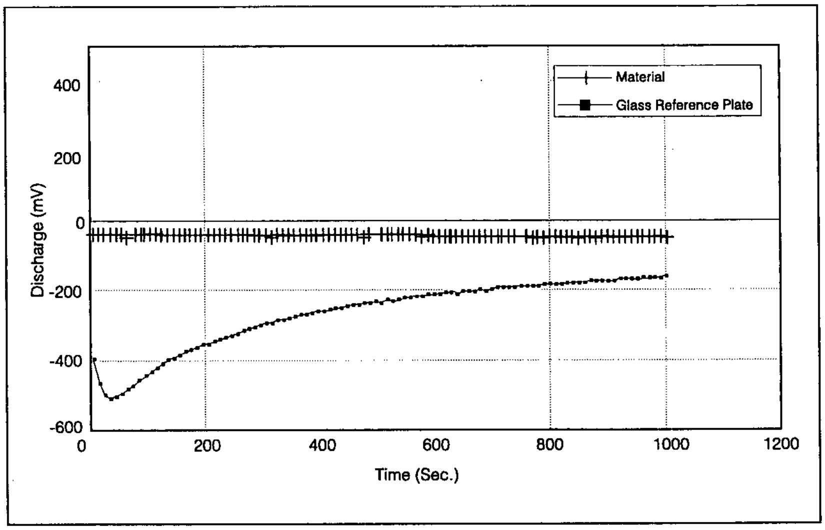

Figure 5. *Example of Discharging Behavior of Nonconductive Plastic Materials.*

CONCLUSIONS

This article presented a very easy-to-handle and low-cost measuring setup. It allows the characterization of the electrostatic charging of different (conductive) plastics and materials under different constraints or reference conditions. The software control of this setup allows a flexible use of the setup for monitoring both the charging and the discharging phenomena.

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