The effects of humidity on surface resistance of magnesium catalyzed cast polyamide 6

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Abstract

The magnesium catalyzed polyamide 6 can absorb the humidity of air. Due to this the surface resistance, i.e. the antistatic characteristic changes. In our material developing program a special grades were produced, which have appropriate antistatic characteristics under dry conditions, too. With graphite additive having conductive characteristics it could be reached that the surface resistance of new material did not depend on moisture content. It was found also that surface resistance – in general – can change with order of magnitude within few hours after production.

Keywords

cast polyamide 6, humidity, surface resistance,

1. Introduction

In the industrial and agricultural machines, plastic parts are used in several cases. It is known that plastics due to their good insulating characteristics are able to be charged, which increases the pollution. With antistatic parts this effect can be avoided, moreover, it provides more advantages during the operation. Antistatic plastics are not charged, therefore discharge will not develop (e.g. by accident a person to earth it), and sparks will not emerge (which may cause in special cases an explosion or blast eg. in agriculture the phenomenon of powder blast). Other advantages of antistatic or electrically conductive plastic parts are the easier and cost saving storage and material handling and maintenance orders.

As a part of the present material developing process, cast PA 6 with antistatic characteristics were produced. The humidity absorption of the base matrix has an effect on the grade of the antistatics, therefore the experiments on humidity effects are necessary.

2. Characteristics of base matrix

The material is produced by Quattroplast Kft, under the name DOCAMID 6G-H. This material can not be compared directly to other polyamide 6 products in the

world because of the magnesium catalyser used for the production. In general, polyamide 6 (PA6) type plastics are made with polycondensation, but for casting purposes the ring opening polymerization is used. The advantage of the latter is the fact that the chain formation takes place without water in a few minutes, which enables a faster production contrary to the conventional polycondensation technology. For starting the ring opening polymerization, usually natrium catalyser is used, but by the present material magnesium catalyser was used. The characteristics of DOCAMID 6G-H is summarized in table 1.

Separate examinations were made to explore the humidity content of the base matrix as different machine parts made of polyamides that were able to absorb the humidity content of the air. The absorption follows the law of diffusion. The outer surface layer is able to bound humidity fast, but this humidity content reaches the lower layer very slowly. On figure 1 the humidity absorption of samples, soaked in 20°C water, is shown in the function of time.

Table 1. Characteristics of DOCAMID 6G-H base matrix

Density	1,15 g/cm^3
Tensile strenght	85 MPa
Elongation at break	60%
Elastic modulus	3300 MPa
Charpy impact strength	>8 kJ/m^2
Shore D hardness	83
Volume resistance	10^{15} Ω·cm
Surface resistance	10^{13} Ω
Heat Distortion Temperature (HDT)	95°C

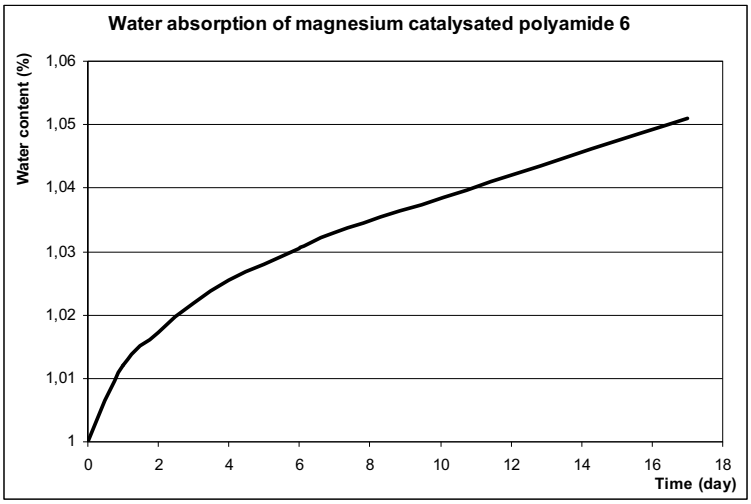

Figure 1. Water absorption of magnesium catalyzed polyamide 6

It can be seen on the figure that after 17 days the samples still not reached the impregnation level, only the speed of absorption became constant (0,2 %/day≈0,02 g/day). This experiment proves also the slow impregnation process, though machine parts usually do not cope with water for such a long time. However they cope with the humidity of air, therefore it is reasonable to take the possible impregnation into consideration. Impregnation due to air humidity content means an even slower process.

There is a need to deal with humidity absorption due to other reasons of design, too. Humidity causes the change of dimensions of the polyamide parts and mechanical properties, too.

3. Surface resistance measurement

Among electrical tests the surface resistance measurement is widely used to check the antistatic characteristics of the materials. Surface resistance measurement is standardized. Now the standard called „IEC 60093 Methods of Test for Volume Resistivity and Surface Resistivity of Solid Electrical Insulating Materials" and pusblished in 1980 is in use.

For the research the GIGALAB Digital Mega-Ohmmeter, produced by ITECO, was used. The diameter of the used rubber electrodes were Ø63 mm, their width were 4 mm. For the measurement 100 V potential was used, which means a measurement range of 10^5 - $2 \cdot 10^{11}$ Ω. This range is just appropriate for antistatic measurements, as above 10^{12} Ω the polymers are insulators, below 10^6 Ω the polymers are conductive. During the research the required antistatics was defined in 10^9 Ω surface resistance. The measurement accuracy in this range was in ±5 %. The measurement settings can be seen on figure 2 (the distance maker should be taken away after the setting of the two electrodes).

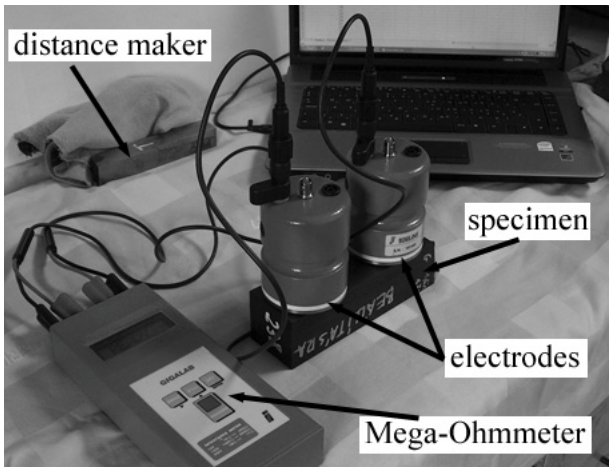

Figure 2. Setting of surface resistance measurement

4. The surface resistance in time

The working conditions of different machines are often changed. These changes can have an influence on parts, therefore on plastic parts as well. Therefore the change of surface resistance was examined in time. During the experiment that outstanding case was taken, when the absolutely dry sample was put into water. The results are shown in table 2.

Table 2. Surface resistance change of originally dry sample put into water in the function of time

Conditioning	0 hour	24 hours	48 hours	72 hours	96 hours	120 hours
Surface resistance (Ω)	$7.58 \cdot 10^{10}$	$5.8 \cdot 10^{7}$	$3.96 \cdot 10^{7}$	$3.92 \cdot 10^{7}$	$3.33 \cdot 10^{7}$	$3.35 \cdot 10^{7}$

It can be seen that surface resistance changes basically during the first 24 hours. This means that the value of surface resistance reacts fast to the modified conditions. The more humid air is able to change the antistatic characteristics of the dry material in a few hours. The experienced material behaviour suggests to select the proper antistatic characteristics valid under dry conditions as well.

5. Effects of humidity content on surface resistance

For reaching antistatic characteristics the applied additives in base PA 6 matrix enhance the existing humidity effects. The surface resistance is decreased furthermore. On figure 3 the behaviour of TA52 composites (material softening additive) can be seen. Three main stages are compared: dry, normal (RH 50%) and wet (saturated in water) samples.

In present case the additive can not absorb humidity just the base matrix. In case of sample containing 10 % additive, depending on the stages, the surface resistance changes between 10^{11} and 10^{7} Ω. This means that the originally good insulator (10^{13} Ω) plastic, depending on the surroundings, can have worse or even better antistatic characteristics. However in case of 20 % additive, independently from surroundings, the antistatic characteristics are good (below 10^{9} Ω).

The independence of polyamide parts from the environment has several advantages, e.g. no need for conditioning, or the maintenance can be held in regular periods (e.g. the stuck contamination is not changing according to the environment).

In figure 3 it also can be seen that the surface resistance of normal samples (RH 50%) are between the wet and dry samples' values but are closer to the dry ones. The working condition of cast polyamide parts is usually air (not water), that's why the dry and normal stage curves are suggested to be taken into account during design with cast polyamide parts.

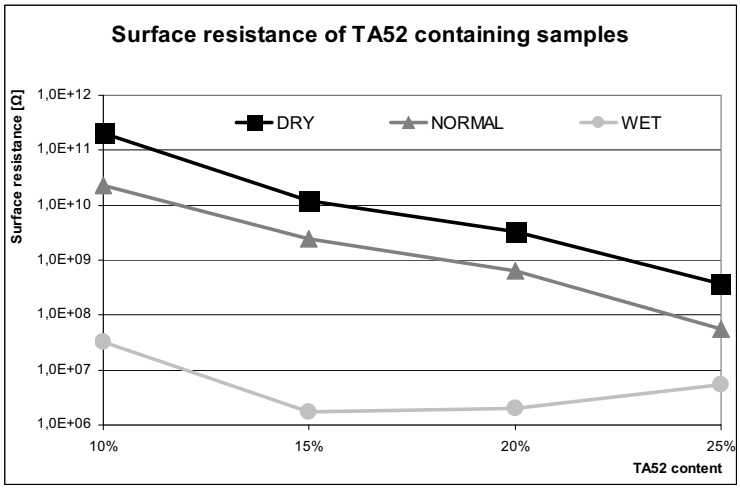

Figure 3. Surface resistance of PA6 composites in different stages

6. Effects of humidity content on the under-surface layers

In case of cut of the given polyamide 6 part, the humidity content and the resistivity will be different. The humidity content of the deeper or under-surface layers are important during machining. Due to the slow impregnation process lower humidity content is expected, i.e. their surface resistance is going to be higher. For testing this, a sample with 1% graphite content was examined conditioned in RH50%. The surface resistance of the layers was examined.

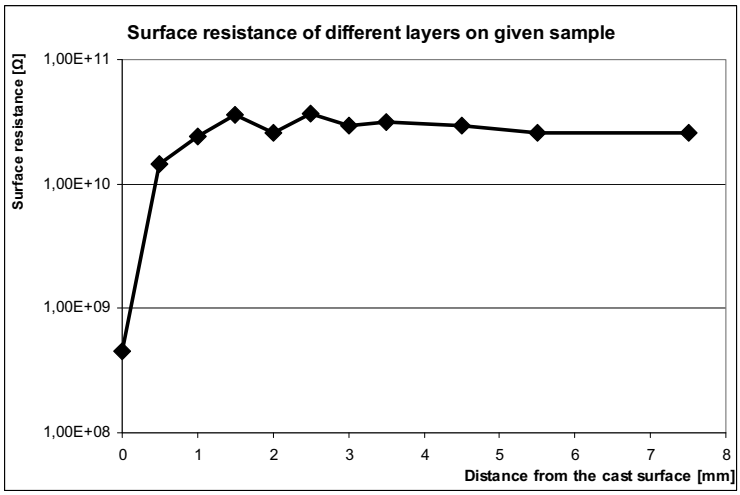

Figure 4. Surface resistance of different layers on given sample.

On figure 4 it can be seen that in the near-surface zone (original cast surface) the humidity content results smaller surface resistance that it was found for dry material (eg. after removing 2.5 mm). From the experiments it was found that 5 months conditioning is enough for humidity to diffuse into 0.5 mm depth. The measurements show that in layers deeper than 1 mm the sample is nearly dry. Further resistance values are influenced only by the distribution of additives. However these variations are negligible. On the basis of these it can be stated that after sudden material detachments dry condition surface resistance can be expected, though the new surface can became to the state of humid surface resistance in 24 hours.

7. Summary

There is an increasing need for using antistatic polyamide 6 versions. Those materials react fast to the environmental effects, i.e. their surface resistance (antistatics) can change significantly. For stable working performance of natural cast polyamide 6 material, which is generally used as an isolator material, the needed surface resistance should be taken as the possible most wet condition sample having lowered resistance. In case of antistatic composite version of cast PA 6 the dry sample's value should be taken into consideration as a critical values. The different composites have different sensitivity to the humidity, but the dry ones have higher surface resistivity.

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