EVALUATION OF ELECTRICAL PROPERTIES OF INJECTION MOLDED POLYPROPYLENE MATRIX WITH CARBON NANOTUBES

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Abstract

This work examines the electrical properties of composites with thermoplastic polymer matrix and carbon nanotubes. As a basic matrix was used polypropylene, to which were added nanoparticles in the weight percentage in the form of nanotubes. The composite was made by the injection molding machine Arburg. For evaluation of electrical properties was measured resistivity of the final polymer composite material with added nanofiller and without it. In this paper are also described injection parameters.

Key words:
Carbon nanotubes, nanocomposite, surface resistivity, mechanical properties, injection molding

1. INTRODUCTION

Nanotechnology is nowadays one of the most developing technology. Now it consists of four main areas - nanomaterials, nanoelectronics, molecular nanotechnology and microscopes working in the scale of nanometers. Using structure and nanoparticles properties is epochal and hi-tech technology, that is possible to use in wide range of different areas and branches of human activity, and which exceeds delimitation of individual branches of science and technical research. The same use is also in the high tech of nanocomposite materials, which today has properties that we previously could not imagine [1]. As one of the first nanomaterials were in the early of 90’s discovered spherical carbon molecules (so-called fullerenes), which started nanotechnology conception. In the 1991 Japanese scientists found out that it is possible also to produce fullerenes with the cylindrical shape. These are very long and narrow carbon nanotubes which can reveal mechanical strength 50 up to 100 times higher then has considerably heavier steel. They can conduct electric current and also heat. These are so far the most perspective material which is used by nanotechnology. Moreover it was proved that some nanotubes can reveal behavior close to semiconductors which served as a basic for production of molecular transistor which can serve already at room temperature. Due to such reality there was opened way to molecular electronics, miniaturization of information techniques and increase computer speed [2]. Carbon nanotubes (CNT) are elongated systems whose wall are created by carbon atoms (similar to spherical fullerenes) with the diameter from 1 up to 100 nanometers and length up to 100 μm. They can be found as single-wall (SWCNT) or multi-wall (MWCNT) see fig.1. Nanotubes were produced at ratio length: diameter - 132000000:1 that is much higher than any other material. These cylindrical carbon molecules have special properties which are highly valuable for nanotechnologies (electrical, optical,...). Mainly due to their thermal conductivity, mechanical and electrical properties have found these material uses as fillers for different structural materials [3]. In this work are MWCNT used as a filler in polypropylene polymer matrix and examined the effect on the nanocomposite using tensile test, electron microscopy and measurement of surface resistivity. Within the tensile test is specimen stressed in the direction of the...
axis with increasing force until it breaks. During the test is recorded strength and elongation of ensemble.

2. MATERIAL AND EXPERIMENTAL

2.1. Material

In this paper was as a parent composite matrix used polymer polypropylene (PP) from the company Nanocyl (Sambreville, Belgium) with trade name Plasticyl PP2001. Into PP composite was added 20% weight percentage of nanoparticles in the shape of multi-wall carbon nanotubes (MWCNT) also from the company Nanocyl. There was chosen 20% weight ratio cause seems to be the best in light of mechanical properties and reveals optimal brittleness. The composite has density 0.872 g/cm³. Melting temperature varies about 170 °C.

2.2. Machine and moulds

For injection was used standard column-mounted injection machine ARBURG 270S 400-100. Injection moulding technological parameters had to ensure partly samples production and there was necessary to avoid nanotubes structure degradation, too. Mainly with regard to thermal and shear loading was crucial to set proper plastication and injection moulding parameters (see tab. 1). For injection mould tempering was used aggregate TA3. Temperature of melt was 190 °C. Injection rate was 30 cm³/s and size of holding pressure 1.200 bar. Holding pressure time for the samples for measuring tensile test was 35s and samples for measurement resistivity was 20s. For production testing samples for tensile test from composites with carbon nanotubes was used injection mould with central ejector which had exchangeable plates according to requirements and individual ISO standards. A sample for the measurement of resistivity was used form of plates with dimensions 120x120x2 mm with conical inlet in the middle. Both forms have cooling circuits both on the part of die and part of punch. Mold was cooled to a temperature of 60 °C for both the two halves of injection mold.

<table>
<thead>
<tr>
<th>Table 1 Injection moulding parameters</th>
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<tr>
<td><strong>Barrel Temperature [°C]</strong></td>
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<td>Zone 5</td>
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<td>280</td>
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</tbody>
</table>

2.3. Surface resistivity

Resistivity measurement was carried out according to ČSN EN 61340-5. On test samples was measured surface resistivity of the device consisting by two circular electrodes which comply with the standards, see fig.2, and measuring instrument High Resistance Meter 4339B Hewlett Packard, see fig.3. To measure the surface resistivity is necessary to know the value of secondary circuit electrodes and distance of electrodes. Measurements were carried out at a voltage of U = 100 mV, the electric current was I = 10 mA. The temperature was 23 °C and relative humidity in the room was 51%.
2.4. Tensile test

Measuring tensile properties of test samples were performed on a multipurpose Hounsfied H10KT tensile machine with the sensor head measuring power up to 10 kN. The measurement procedure was in accordance with standard ČSN EN ISO 527-1, 2. The loading speed was 50 mm/min.

3. RESULT AND DISCUSSION

Test specimens were injection molded from granulate Plastycyl PP2001. Testing samples were evaluated on surface resistivity. At composite processing there was presumption that distribution of the carbon nanotubes is homogenous as it is written in [5-9] and shown in the Fig. 4.

With regard to fact that composite viscosity was greatly higher then PP viscosity with carbon nanotubes, were pressure parameters during filling phase and pressure phase for commonly adjusted temperature conditions at injection quite too high: pressure at switch-over was 1500 bars, holding pressure was 1200 bars. Adjusted technological parameters for testing samples production were tried out, and were chosen from several testing variants of the technological parameters and they had to ensure partly samples production and there was necessary to avoid nanotubes structure degradation mainly with regard to temperature and pressure (shear) loading of composite melt. Samples for analysis were taken from the batches after stabilizing of injection moulding parameters [4].
Test samples (produced by injection molding) composite Plasticyl PP2001 were evaluated how they antistatic grade by measuring the surface resistivity. Commonly used to evaluate the measurement of surface resistivity, volume resistivity measurement is applied only in cases of dispute. How good antistatic grade is, we can see in Table 2 [10]. Measurement of surface resistivity was performed on 15 specimens PP with MWCNTs and without fillers. The resulting values of resistivity we can see in Table 3.

<table>
<thead>
<tr>
<th>Antistatic grade</th>
<th>Surface resistivity [Ω]</th>
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<tr>
<td>excelent</td>
<td>$10^6 + 10^7$</td>
</tr>
<tr>
<td>very good</td>
<td>$10^7 + 10^8$</td>
</tr>
<tr>
<td>good</td>
<td>$10^8 + 10^9$</td>
</tr>
<tr>
<td>average</td>
<td>$10^9 + 10^{10}$</td>
</tr>
<tr>
<td>barely satisfactory</td>
<td>$10^{10} + 10^{11}$</td>
</tr>
<tr>
<td>unsatisfactory</td>
<td>$10^{11} + 10^{13}$</td>
</tr>
</tbody>
</table>

The resulting samples PP with MWCNTs indicates that this composite has very good antistatic grade and is capable of excellently drain off static charge to the area. These results indicate that there was a homogeneous dispersion of MWCNTs and the injection molding had not a great influence on the conductivity of the composite. Results PP without added nanofillers are not recorded, because the device is not able to measure. This is because the basic polymer matrix has a higher resistance than the device can detect. It cannot be used as a conductor of static charge.

The tensile strength of PP without carbon nanotubes as fillers is 24.3 MPa, with carbon nanotubes is 40.52 MPa. Ductility decreased from 75 % to 3.75 %. From results, we see an increase in tensile strength, but we can also see a reduction in ductility, resulting in increased hardness and brittleness of the final composite. Higher material costs do not compensate for the increase in mechanical properties.

### 4. CONCLUSION

The development of composites with thermoplastic matrix and carbon nanotubes is a constantly evolving process that will be influenced by expanding number of application possibilities, using not only excellent electrical properties of such composites. These properties and application potentials will be influenced not only by the type and form of nanotubes, their percentage by volume, but also the type and kind of the polymer matrix. The test results show increase in the mechanical properties. Because of the higher price of the composite is not expected wider use in this area. Rating resistivity is a good pointer to determine how well the composite drains static charge. The results show that the composite PP2001 has excellent drain off
static charge. These properties enable him wide use, such as applications in explosive environments. It also shows the possibility of using this composite as a conductor of electric charge, which will be the subject of further research. Influence of change of percentage amount nanotubes with regard to resistivity and conductivity will be examined in the near future.

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REFERENCES