Interesting behavior of polymers containing multiwall carbon nanotubes

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Abstract. Mixing is a very important polymer process. Nanocomposites were made by a new type of shear mixer, IDMX. The nanocomposites contained different amount of multiwall carbon nanotubes. Test pieces were prepared by injection moulding method. Thermal, flowing and mechanical properties were measured.

1. Introduction
Nowadays polymers have important rule in the field of technological researches. They are used instead of metals or ceramics. Polymeric materials are used to very different purposes. Sometimes we have to produce products with interesting properties and however there is no material which fulfills all of the requirements. In these cases we can produce composites. Composites consist of different types of materials, for example polymer – fiber, polymer – glass, polymer – wood, polymer - ceramics composites.

The new researches are focused on nanomaterials, nanocomposites. The most interesting features can be reached when we produce nanocomposites. Polymer nanocomposites consist of two different parts: the polymer matrix and the nanoparticle. The nanoparticle is often the carbon nanotube. The carbon nanotubes belong to the family of fullerenes. There are single wall and multiwall carbon nanotubes (Figure 1 and 2).

Figure 1. Three different types of single wall carbon nanotube [14]  
Figure 2. TEM image of multiwall carbon nanotube [15]
The diameter of the nanotubes is 1-50 nm, the length of them can be longer than 10 μm. The carbon nanotubes were discovered by Iijima in 1991 when he produced fullerenes[1]. From that time carbon nanotubes are in the focus of the researchers of every science. The carbon nanotubes have very interesting mechanical and conductive properties [2-13]. Carbon nanotubes can be used in nanoelectronics and they can be used as detector of trace elements because the conductivity of the nanotube changes when elements are adsorbed on them. They have special mechanical properties; their Young modulus is about 1 TPa which is a higher value than the modulus of steel (about 200 GPa). The carbon nanotubes are very flexible; they can be used as reinforcement in composites.

2. Experimental

During our research we used reground polycarbonate (ANJALON J100V, J&A Plastics GmbH), ABS (POLYMAN HH3, Polyman Plastics Inc.) and multiwall carbon nanotube master blend (MB-3020-01 Hyperion Catalyst, USA). The master blend contained 15% multiwall carbon nanotube and 85% polycarbonate as matrix. Concentration series were produced. The composites contained 1% and 1,5% multiwall carbon nanotubes.

The composites were produced by a new type of shear mixer, called IDMX mixer (Figure 3). Because of its specific geometry this mixer is very efficient. The mixer has got stators (Figure 4) and rotors (Figure 5) which provide dispersive and distributive mixing as well.

Test pieces were injection molded by Arburg Allrounder Injection molding machine.

The mechanical (Charpy and tensile properties) and the flowing (MVR) properties of the nanocomposites were investigated. The structures of the nanocomposites were investigated by SEM and LP-FTIR methods.
3. Results and Discussion
The change of the impact strength of the nanocomposites is shown in Figure 6. It was found that the impact strength of the composites is worse than the impact strength of polycarbonate. The impact strength of the composites containing carbon nanotube was at a lower level than the value of the reference composites. The difference between the 1% carbon nanotube and the 1.5% carbon nanotube containing nanocomposites was not high. The multiwall carbon nanotube content causes lower impact strength.

In Figure 7 we can see the change of the yield strength of the nanocomposites. The yield strength of every composite is lower than the pure polycarbonate has. In our experiments, there is no significant difference between the blends having different carbon nanotube content. The change of the yield stress vs. ABS content of the blends it was found that more or less linear correlation exists.

In Figure 8 and Figure 9 the MVR value and the hardness of the different composites are shown respectively.

The flow properties of the blends change according to the composition. It was found that the carbon nanotube content slightly decreases the MVR value of the blend; however this change is not too much.
The hardness of the blends shows only a slight change. Increasing the PC content the hardness increases. However the change in the range up to 20% PC is negligible. The measured hardness is practically the same as the hardness of the pure ABS.
In Figure 10-12 the SEM images of the raw materials and the SEM images of two nanocomposites are shown.

![Figure 10. SEM image of polycarbonate. Experiment.](image1)

![Figure 11. SEM image of ABS. Experiment.](image2)

![Figure 12. SEM image of nanocomposite containing 1% MWCNT, 89% PC, 10% ABS. Experiment.](image3)

![Figure 13. SEM image of nanocomposite containing 1% MWCNT, 19% PC, 80% ABS. Experiment.](image4)

It can be seen that the structure of the raw materials and the nanocomposites are very different. The carbon nanotube can be seen on the fractured surfaces. It is important to emphasize that the distribution of the nanotube in the matrix material is more or less uniform. We did not find agglomerates in the materials. Having smaller magnification, it is clear from the SEM investigation that the structure of the pure materials has changed.

We investigated the inner structure of the nanocomposites by LP-FTIR method. We used CO$_2$ laser and the structure of the remaining material was studied by SEM method. The SEM images of a nanocomposite can be seen in Figure 14 and 15. We found that the remaining structure is different. The structure of the nanotubes can be seen. A continuous physical network can be investigated. This network means a cohesion force in the matrix.
4. Conclusion

Polycarbonate – ABS – multiwall carbon nanotube nanocomposites were prepared by IDMX mixer. Test pieces were injection moulded and investigated. Multiwall carbon nanotubes were mixed in two-phase system, the mixing was efficient. Mechanical and flowing properties were determined. It was found that the carbon nanotube increases slightly the surface hardness of the materials. Using SEM technique we found that the prepared carbon nanotube composites show more or less uniform distribution of the components. This structure was supported by the change the yield strength of the nanocomposites. Using LP-FTIR method it was found that the carbon nanotubes continuous physical network.

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