MECHANICAL PROPERTIES OF ACRYLONITRILE BUTADIENE STYRENE THERMOPLASTIC POLYMER MATRIX WITH CARBON NANOTUBES

VÁCHA Jan, BORŮVKA Martin

Technical university of Liberec, Liberec, Czech Republic, EU, jan.vacha@tul.cz, martin.boruvka@tul.cz

Abstract

This paper examines the mechanical properties of the composite of thermoplastic polymer matrix with carbon nanotubes. As the basic polymer matrix was used acrylonitrile butadiene styrene (ABS) to which were added the nanoparticles in a given percentage by weight in the form of nanotubes. Composite was injected into the Arburg injection molding machine. For evaluation were measured harness, impact and tensile test. These tests are compared with polymeric materials without added nanofiller. In conclusion is evaluated and compared influence on the mechanical properties of polymer matrix with carbon nanotubes and without fillers.

Keywords: Carbon nanotubes, nanocomposites, mechanical properties

1. INTRODUCTION

In the past ten years, extensive research and development have been carried out in the field of polymer composite production. On an industrial scale, melt processing has become the method of choice to incorporate color pigments or fillers. Nowadays, a wide variety of melt compounding technology is available which is applicable to polymer-CNT composite production [1]. Carbon nanotubes have a many properties (mechanical and physical) that make them attractive for use in a broad spectrum of applications, especially as filler for nanocomposites. There are two kinds of carbon nanotubes: single-walled carbon nanotubes (SWCNTs) with one graphene layer and multi-walled carbon nanotubes (MWCNTs) with many graphene layers wrapped onto themselves, see **Fig. 1**. They can be produced in various ways such as chemical vapour deposition (CVD) laser ablation, arc discharge, solar energy and molten salt electrolysis. The nanotubes are often with more or less impurity (metal catalytic particles, amorphous carbon, etc.) depending on the synthesis method used. The SWNTs are often in bundles of tens to hundreds of single SWNT. The MWNTs were reported to have lower mechanical performance than the SWNTs, but can be produced in much larger quantity and at a lower cost. They are individual in general and longer than the SWNTs. The MWNTs are also more rigid because their section is much larger compared to that of the SWNTs. Generally, an individual carbon nanotube is in a macromolecular structure with nanosized diameter and micrometer length. The diameter range for the SWNTs is between 0.4 and 5.6 (nm) [2], while that for MWNTs it is from several (nm) to several hundred (nm). The length of SWNTs was reported from several (mm) to several ten (mm), while that of MWNTs can be much longer up to several mm or even cm. Their morphology depends very much on the production method and the treatment (for example, for dispersion purpose) before being put into the matrix [1]. In this work are MWCNT used as a filler in acrylonitrile butadiene styrene polymer matrix and examined the effect on the nanocomposite using tensile test, hardness, flexural and impact test. Morphology is being examined using electron microscopy (SEM).

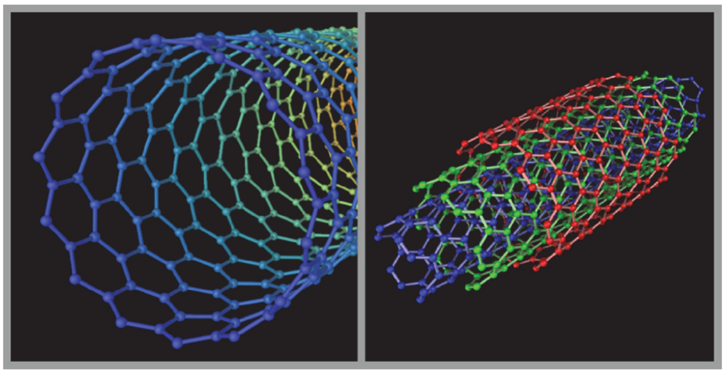

Fig. 1 Schematic diagrams of carbon nanotubes: single-wall SWCNT (left) and multi-wall MWCNT (right) [3]

2. MATERIAL AND EXPERIMENTAL

2.1. Material

For injection molding was used PLASTICYL ABS 1501 is a conductive masterbatch based on acrylonitrile butadiene styrene loaded with 15% of Nanocyl's MWCNTs (NC7000™). The masterbatch was used as the parent matrix from which mixed polymer blends. There was chosen 1, 2 and 5 weight ratio of carbon nanotubes. For mixing was used pure ABS with trade name ABS Magnum 3404 from Resinex Company. The result of surface resistivity of ABS without MWCNTs is 1 x 10^{13} Ohm·cm, melt flow index is 6.6 g/10min

2.2. Machine and mould

For injection molding 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. It was crucial to set proper plastication and injection moulding parameters (see **Table 1**) mainly with regard to thermal and shear loading. Aggregate TA3 was used for injection mould tempering. Temperature of melt was 260 (°C). Injection rate was 30 (cm3/s) and size of holding pressure 600 (bar). Holding pressure time for the samples was 10 (s). For production testing samples for tensile and impact test was used injection mould with central ejector which had exchangeable plates according to requirements and individual ISO standards. The mould has cooling channels both on the part of die and part of punch and it was tempered on the temperature 60 (°C) for both sides of injection mould.

Table 1 Injection moulding parameters

Barrel Temperature (°C)					Injection Speed	Mold Temperature	Holding pressure
Zone 5	**Zone 4**	**Zone 3**	**Zone 2**	**Zone 1**	**cm^3/s**	**(°C)**	**bar**
260	255	255	245	230	30	60	600

2.3. Tensile test, hardness, flexural test, impact test

Measure Multipurpose Hounsfield H10KT tensile machine with the sensor head measuring power up to 10 (kN) was used to perform measurement of tensile and flexural properties of test samples. The measurement procedure for tensile properties was in accordance with standard ČSN EN ISO 527-1, 2 and for flexural properties was in accordance with standard ČSN EN ISO 178. Measurements were taken to the point of test specimen breakage. The loading speed for tensile test was 50 (mm/min) and for flexural test was (10mm/min).

Shore test was used for evaluation the hardness. The value is subtracted from the scale of hardness after 15 seconds. Measurements were carried on the Shore D hardness test machine. The measurement procedure was carried out according to standard ČSN EN ISO 868. The tip has a cone shape, type D for harder type of materials.

Izod method has been chosen to determine the impact properties of test samples. Measurements were carried on impact test machine CEAST Resil impactor 6967.000. The measurement procedure was in accordance with standard ČSN EN ISO 180/A. Nominal energy of hammer was 2.75 (J).

3. RESULT AND DISCUSSION

Composite Plasticyl ABS 1501 in the form of granulates was after drying processed by injection moulding technology to produce testing samples which were evaluated on surface and volume resistivity. At composite processing there was presumption that distribution of the carbon nanotubes is homogenous as it is written in [4- 10]. We can see fracture surface of test specimen after cryogenic freezing and after fracture on **Fig. 2**.

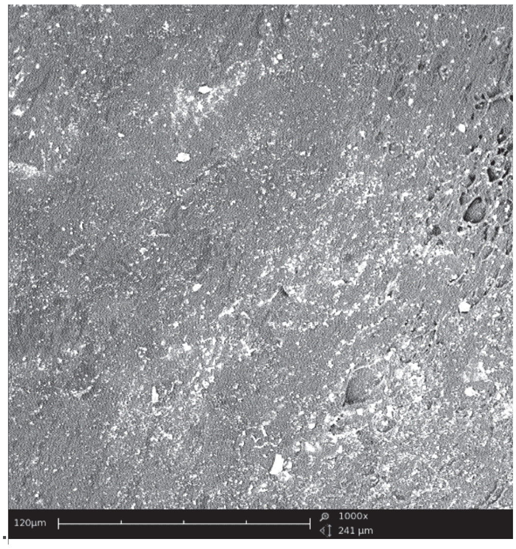

Fig. 2 The homogeneous dispersion of nanotubes in ABS matrix with 5% wt. ratio MWCNT [4]

With regard to fact melt flow index MVR decrease from 36 cm^3/10min for pure material to 1 cm^3/10min for 5 % wt. ratio MWCNT, were pressure parameters during filling phase and pressure phase for commonly adjusted temperature conditions at injection quite too high: holding pressure was 600 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]. Due to the higher viscosity of composite was necessary to increase the melt temperature of 230 °C to 260 °C. The structures not degrade at this temperature. The production parameters were the same for all polymer blends.

Measurement of tensile, flexural, hardness, impact and impact test were performed on 10 specimens for 1, 2, 5 % weight ratio of carbon nanotubes and pure ABS. The resulting values of tensile test we can see in **Table 2**. The tensile strength of ABS without carbon nanotubes as fillers is 40.12 MPa, with 1 % wt. ratio CNT´s is 45.28 MPa, 2 % wt. ratio CNT´s is 46.24, 5 % wt. ratio CNT´s is 46.25 MPa. The loading speed was 50 mm/min. The measurement procedure was in accordance with standard ČSN EN ISO 527-1, 2.

Table 2 Tensile strength of pure ABS and ABS with MWCNT

ABS	Pure polymer	1 % wt. of CNT´s	2 % wt. of CNT´s	5 % wt. of CNT´s
Tesile strenght [Mpa]	40.12	45.28	46.24	46.25

We can see increase young modulus on **Table 3** and **Fig. 3**. The increase of flexural modulus we can see on **Table 4** and **Fig. 4**. Due to the continually decreasing cost of a CNT perhaps be in the future use of these fillers to improve the mechanical properties.

Table 3 Young’s Modulus of pure ABS and ABS with MWCNT

ABS	Pure polymer	1 % wt. of CNT´s	2 % wt. of CNT´s	5 % wt. of CNT´s
Young’s Modulus [Mpa]	2532.314	2882.695	3377.025	3888.561

Table 4 Flexural modulus of pure ABS and ABS with MWCNT

ABS	Pure polymer	1 % wt. of CNT´s	2 % wt. of CNT´s	5 % wt. of CNT´s
Flexural modulus [MPa]	2100	2441.45	2502.47	2742.65

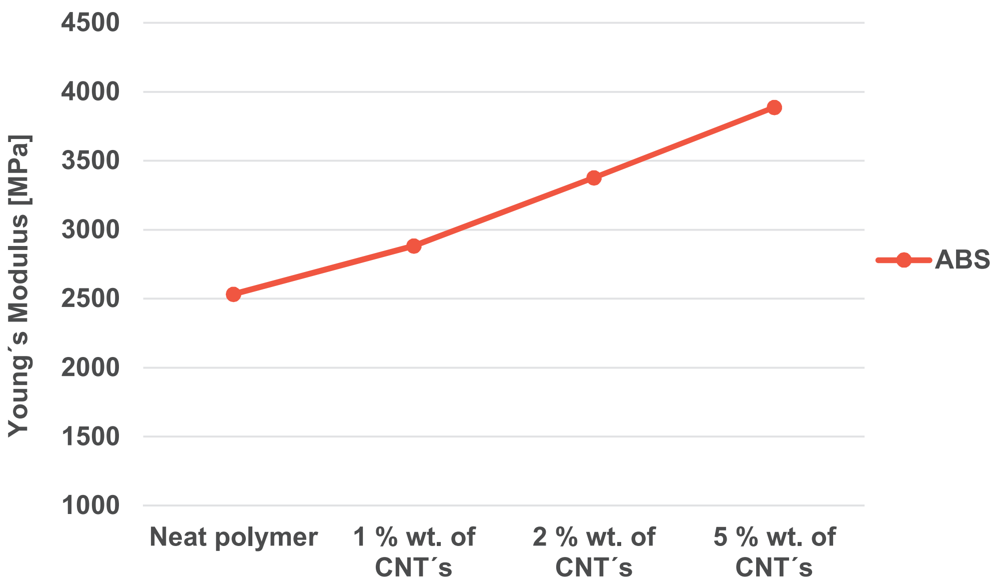

Fig. 3 Comparison of young´s modulus of pure ABS and ABS with MWCNT

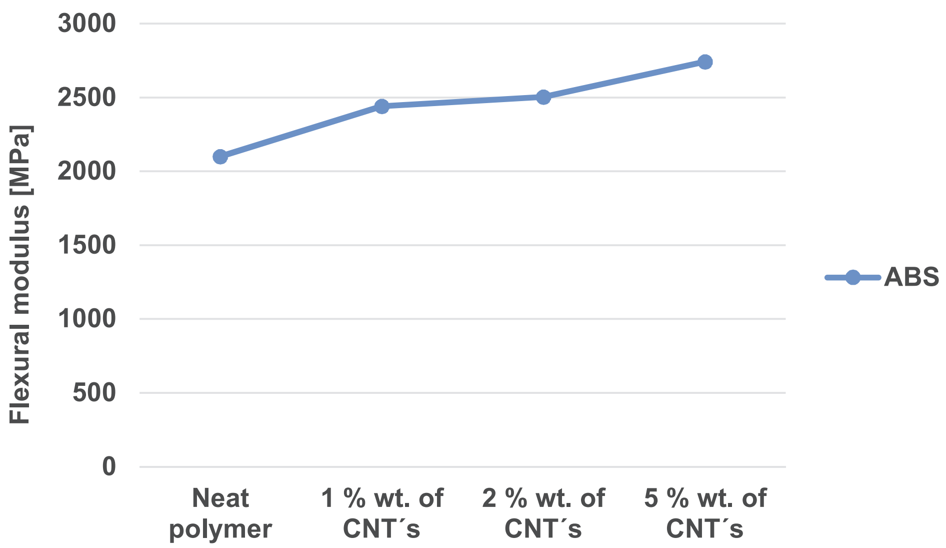

Fig. 4 Comparison of flexural modulus of pure ABS and ABS with MWCNT

Hardness test by Shore-D showed an increase from 71.84 [-] for pure material to 74.28 [-] for ABS with 5% MWCNT, see **Table 5**. The impact strength showed a decrease from 15.142 for pure ABS to 3.322 for ABS with 5% MWCNT, see **Table 6** and **Fig. 5**. From results, we see an increase in tensile strength. We also reduce the ductility, resulting in increased hardness and brittleness of the final composite.

Table 5 Hardness Shore-D of pure ABS and ABS with MWCNT

ABS	Pure polymer	1 % wt. of CNT´s	2 % wt. of CNT´s	5 % wt. of CNT´s
Hardness [-] Shore D	71.84	72.97	74.37	74.28

Table 6 Impact test - IZOD method of pure ABS and ABS with MWCNT

ABS	Pure polymer	1 % wt. of CNT´s	2 % wt. of CNT´s	5 % wt. of CNT´s
a_{in} [kJ/m2]	15.142	9.513	7.1	3.322

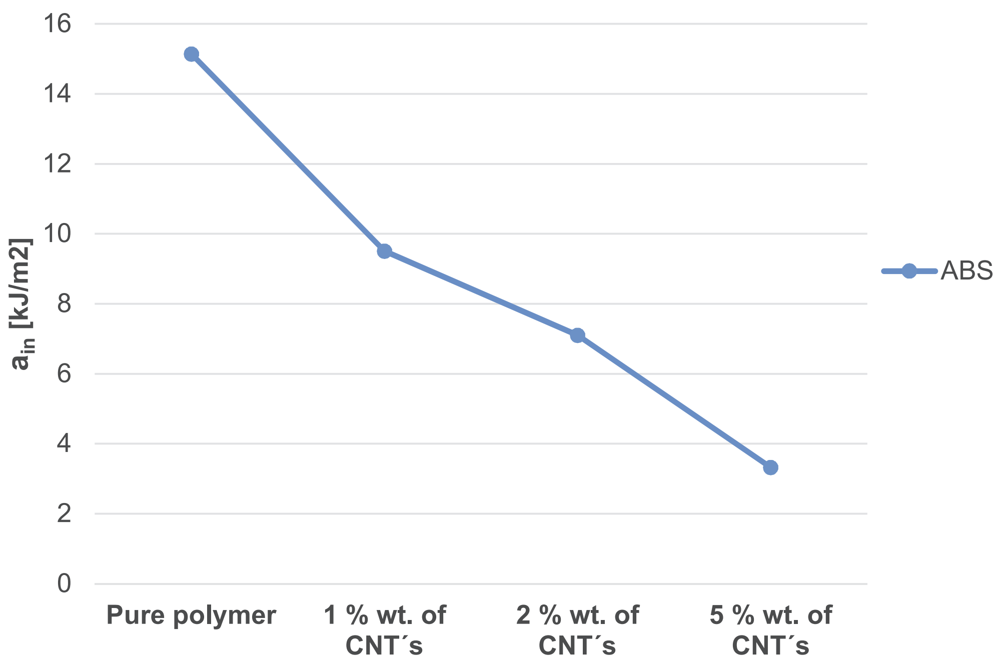

Fig. 5 Comparison of impact strength of pure ABS and ABS with MWCNT

4. CONCLUSION

The evolution of composites with thermoplastic and carbon nanotubes is a constantly progressing process that will be influenced by expanding number of application possibilities. The results showed increase of tensile strength, young's modulus and hardness. Elongation of test specimens and Izod impact notched strength has decreased. Molecular structure of polymer becomes denser. A carbon nanotube has integrated into the chain of a macromolecule. With increase of content of CNT we can presume increase in not only mechanical, but also electrical properties. Due to the continually decreasing cost of a CNT perhaps be in the future use of these fillers to improve the mechanical properties. Influence of change of processing parameter on mechanical properties will be examined in the near future.

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