ELASTIC RECOVERY AT MONTMORILLONITE AND CARBON NANOTUBE REINFORCED PA6 NANOCOMPOSITES

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1. Introduction

In technical life the utilization of polymer matrix nanocomposites gradually spreads because of their special characteristics like conductivity, enhanced gas-barrier properties, flame retardancy, etc. but their application as structural materials is still not reached the level that would be expected based on to their mechanical performance [1]. The main reason of it is the viscoelastic properties of the polymer matrix. At neat polymers and at polymer matrix microcomposites there is now sufficient knowledge to take the time-dependent behavior into account at the design of a new product. At nanocomposites - where the nanoparticles also can have strong effect on the viscoelasticity – this knowledge is still incomplete. As the viscoelastic properties of a polymer matrix composite depend on the applied loads on every load level there has to be made a one cycle test to characterize the instantaneous elastic, the time-dependent viscoelastic and the time-dependent viscous (or relaxation) deformation components. This characterization method can be quite long, therefore the researchers introduced rate of elastic recovery. At this cyclic measurement the tensile load increased by the cycles but between each cycle a certain time is applied for the recovery of the time-dependent viscoelastic deformations (elastic deformation). The elastic recovery can be calculated as the rate of the elastic deformation and the total deformation (Fig. 1.) [2].

In this study there were made cyclic tensile tests on polyamide 6 (PA6) matrix nanocomposites with 1 wt% nanoparticle content. The applied nanoparticles were: montmorillonite (MMT); montmorillonite modified by (2-hydroxyethyl)-methacrylate (HMMT) and multi-wall carbon nanotubes (MWCNT). The sample preparation was carried out according to a previous research [3].

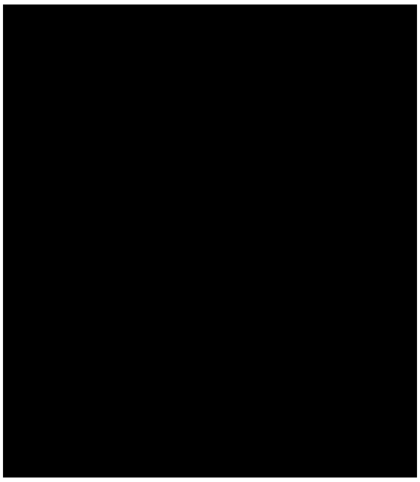

Fig. 1: Strain-stress curves for cyclic loading, at increasing load levels.

The cyclic tensile tests were performed on a Zwick Z020 (Germany) universal testing machine. The relaxation time was set to be 30 s and the load was increased by 100 N in each cycle. The machine was used in force-controlled mode, the up and the down load speed was set to 100 N/s. The measurement ended when close to the maximum force at least 1% additional elongation awaked and the force still could not achieve the maximum value. This phenomenon meant that the creeping behavior begun to be dominant that is far away from the elastic deformations.

2. Experimental Results

The residual strain measured after the relaxation time (plastic deformation) was marked as ε_{30s}. Fig. 2. shows the ε_{30s} values as a function of the cycles (viz. the stress: as there was no notable differences between the specimen geometries). It is visible that at nanocomposites higher residual strains appear at higher cyclic numbers. That means the deformation behaviour is closer to the linear than at the neat matrix. It can also be concluded, that the HMMT containing nanocomposite showed the most elastic properties.

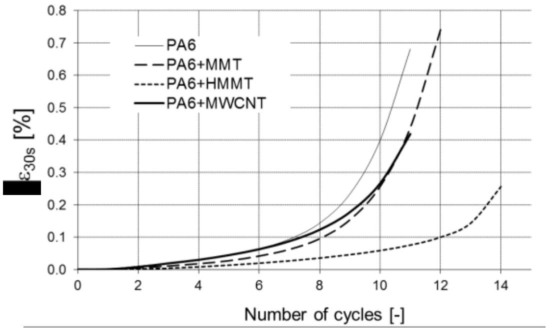

Fig. 2: The residual strain measured after the relaxation time (30 s).

Based on the measurements the percentages of the elastic recovery of the materials were calculated (Fig. 3.).

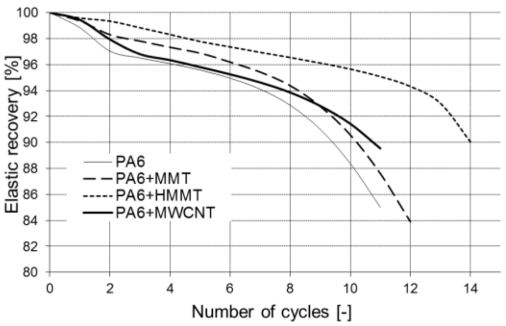

Fig. 3: Elastic recovery of nanocomposites

At the neat matrix and at the MWCNT containing one the elastic recovery decreases intensively at low cycles than gradually changed were observed. This can be explained by the orientation of the amorphous phase of the matrix. This phenomenon was less characteristic for the MMT containing composite and not occurred in case of the HMMT containing nanocomposite. Overall it means that in the last cases the amorphous region became more elastic, therefore the residual deformation was not considerable. At the HMMT containing nanocomposites after 10 cycles (i.e. 1000 N load) the elastic recovery was still around 95% while the others have remarkable residual deformations. At this nanocomposite the decrement of the elastic recovery is approximately linear in a wide cycle range that means the deformation can be relatively easily calculated. Based on the results it can be stated that by incorporating nanoparticles into the PA6 matrix at tensile loads the elastic region can be widen. This means that the nanocomposites can be used safely at higher loads compared to the neat matrix.

3. Acknowledgements

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4. References

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