Effect of graphene content to the deformation components of basalt fiber reinforced nylon 6 hybrid composites

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STATEMENT OF PURPOSE

The main goal of the research was to investigate residual deformation of basalt fiber and graphene reinforced composites at different load levels with a simple cyclic test method.

INTRUDUCTION

In case of the engineering application it is important to create light-weighted materials with excellent mechanical properties. By the weight reduction the energy consumption can be reduced effectively. To achieve the high performance beside the low weight on reliable producing costs polymer composites can be used. These materials are consist of tough matrix and high-strength fibers. Application of nanoparticles in these composites can lead to high performance that can result in additional weight reduction possibilities.

Graphene is one of the last discovered nanoparticles which was invented by two Russian researchers in 2006. It is a single layer of carbon atoms packed densely in a honeycomb crystal lattice. It has great thermal- and electrical conductivity and has superior mechanical properties. However physical properties of graphene-like structures are explored deeply, their application as reinforcement in polymer composites is still under intensive research [1, 2].

Milani et al 0 used graphene created form expanded graphite to make composites. These particles were incorporated into polypropylene via in situ polymerization. In the composites the graphene content was varied between 0.5 wt% and 20 wt%. The results of X-ray diffraction studies demonstrated that by increasing the graphene content the dispersion is less proper, there are more graphene aggregates. This tendency reflected in in the mechanical properties, too. The tensile strength of composites reached the maximum 28 MPa at 4,8 wt.% graphene content, further nanoparticle addition lead to lower strength values.

Rafiq et al 0 used nylon 12 as a matrix material. They functionalized the graphene before the composite production. Composites were created in internal mixer at 210°C, with 0.1, 0.3, 0.6, 1.0 wt.% graphene contents. Ultimate tensile strength of composites increased to 43 MPa at 1 wt% graphene content, further addition of nanoparticles drastically decreased the strength.

Preparation of hybrid composites could be a feasible solution to break up the aggregates of nanoparticles. The presence of common fiber in the polymer melt can increase the apparent viscosity that can help to achieve better nanoparticle dispersion. This effect was proven for montmorillonite and basalt fiber containing polyamide 6 composite by cyclic tensile test [5].

In one of our previous research a special cyclic tensile was carried out for the characterization of the mechanical behavior of PA 6 matrix graphene containing nanocomposites. In the test the load was increased 100 N in every cycle, after the cycle 30 s relaxation time was applied. The higher elastic recovery of graphene containing composite was proved at 0.25 wt.% particle content.

In this study hybrid composites were produced with graphene and basalt fiber reinforcement. The goal was to enhance the dispersion of the nanoparticles therefore achieve better mechanical performance.

MATERIALS AND METHODES

For matrix material Schulamid 6 MV 13 type polyamide 6 (PA 6) from A. Schulman GmbH (Germany) was used. For micron-sized reinforcement basalt fiber (BCS KV12; Kamenny Vek Ltd, Russia) was applied. Graphene xGnP® Graphene Nanoplatelets - Grade H (GnP) supplied by XG Sciences, Inc. (USA) were used as nano-sized reinforcement. A Labtech Scientific twin screw extruder (L/D=44; D=26 mm) was used for continuous melt mixing. The screw speed was 12 1/min and the extrusion temperature was 240C°. For the composites 30 wt% BF and 0.5 and 1.0 wt.% graphene were used, respectively. The dried PA 6 granulates (80°C; 4 hours) were mechanically mixed with the reinforcing materials then extruded and granulated. Dumbbell type specimens (4 x 10 mm of cross section) were injection moulded on an Aurburg Allrounder Advance 370S 700-290 injection molding machine.

Before the mechanical tests, the specimens were conditioned under 50% relative humidity and 20°C for 48 h. Tensile tests were performed on a Zwick Z020 universal testing machine according to EN ISO 527. The load was increased in every cycle by 100 N. The up and down load speed was 100 N/s, in force-controlled mode. After down load 30 s relaxation time was applied in each cycle. The measuring procedure was set to be end when close to the maximum force at least 1 % additional elongation awaked and after it the force still could not achieve the previously set value. Latter phenomenon meant that the creeping behaviour begun to be dominant, that is far away from the pure elastic deformations.

RESULTS AND DISCUSSION

The results of the tensile tests showed that the presence of 0.5 wt.% graphene nanoparticle did not change the tensile strength significantly (*Table I.*). At 1.0 wt.% particle content of nanoparticle the tensile strength decreased. On the other hand the presence of nanoparticles increased the Young's modulus in both cases.

Materials	Tensile strength [MPa]	Young's modulus [MPa]
PA 6/30BF	99.0 ± 0.3	4419 ± 154
PA 6//30BF0.50GnP	99.9 ± 0.2	4902 ± 124
PA 6/30BF/1.00GnP	94.0 ± 0.6	4858 ± 2

Table I. Mechanical properties of polyamide 6 matrix hybridcomposites (BF – Basalt fiber, GnP – Graphene nanoparticle)

The main goal of this research was to study the deformation components of hybrid composits, focused mainly on the residual deformation component and the elastic deformation (sum of instantaneous and viscoelastic deformations) of the materials.

In case of hybrid composites it was found that there is a moderate decrement is the residual deformations in case of 0.5 wt.% containing hybrid but at 1 wt.% GnP content showed higher redisual deformations at each load levels. (*Fig. 1.*).

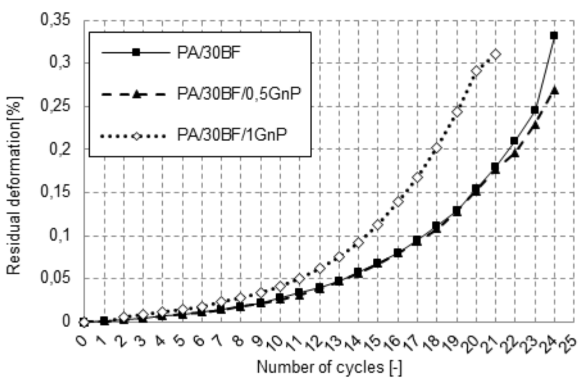

Fig. 1. Effect of the graphene content to the residual deformation during cyclic test after 30 s relaxation time

The increment of residual deformations in each cycle ($\Delta\varepsilon_{30}$) were also calculated (*Fig. 2.*). It is revealed that 0.5 wt.% GnP content can have greater influence on the properties at higher load levels.

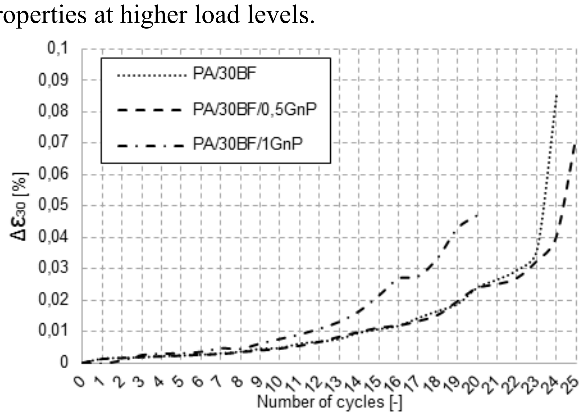

Fig. 2. Increments of residual deformation in each cycle after 30 s relaxation time

CONCLUSIONS

The presence of 0.5 wt.% graphene did not change the tensile strength significantly, but the Young's modulus increased. At 1.0 wt.% graphene content the mechanical properties were less favorable. Similar effects occurred in case of the cyclic investigations: the presence of 0.5 wt.% nanoparticle could slightly decrease the residual deformation. Overall it can be concluded that the presence of basalt fibers can only help in the dispersion of nanoparticles at low nanoparticle contents.

FUTURE WORK

At the $\Delta\varepsilon_{30}$ results on each curve a shoulder can be observed. As these shoulders are consequently present they can refer to some morphological change inside the materials. The investigation of this phenomenon can be a topic for a further research work.

KEYWORDS

nylon 6, graphene, basalt fiber, hybrid composite

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