Abstract

In recent years there are efforts to use polymer nanofibers and their properties in polymer composites. The aim of such efforts is to develop composites with nanofibers fillers which would be able into a great extend to take advantage of any unique properties of polymer nanofibers. Such area of research belongs into the research project whose part is also to incorporate nanofibers and nanoparticles into composite with thermoplastic matrix. The important part of research represents also finding the suitable additives to ensure sufficient adhesion between filler and polymer matrix which is crucial for the final composite properties.

Keywords: Polymer nanocomposites, Nanofibers PA6, Injection moulding Additive

1. INTRODUCTION

During the last years there is intense research of nanofibers and nanofibers structure and these are tendencies to use these nanofibers and their in many spheres unique properties in composites with thermoplastic matrix. Such effort has to face many problems and complications linked with batching nanofibers which is very complicated with regard to fibres dimensions. Moreover it is very complicated to ensure sufficient dispersion and mixing of nanofibers in polymer thermoplastic matrix. Own thermoplastic matric has to be selected in such manner to ensure sufficient adhesion of matrix on polymer nanofibers and that temperature which is necessary to melt matrix is not too high thus there is no damage of nanofibers. However own research of nanocomposites thermoplastic matrix properties and preparation is still in the beginning and that is why this paper deals with the preparation and subsequent measurement of nanocomposites properties with polymer nanofibers and thermoplastic matrix.

2. EXPERIMENTAL

2.1 Matrix

As a composite matrix there was used semi-crystalline thermoplastic, polypropylene Thermofil PP E020M from company Sumika. It has excellent flow properties and low melting point. These properties are particularly suitable for used nanofibres, which reduce flowability of the melted polymer.

2.2 Nanofibers PA 6

Polymer nanofibers from polyamide 6 used in this experiment reveal many unique properties including low diameter (so that high specific surface), highly-oriented crystal structure (thus high final ultimate strength). These nanofibers were produced by technology Nanospider which was developed at the Technical University of Liberec. Image of these fibers from scanning electron microscope is shown in Fig. 1. For the experimental measurement was used material Nanofibers from PA6 from company Nanovia s.r.o. Percetage volume of nanofibers was 2, 4 and 6 %.
2.3 Additives

Quality adhesion between fibres and synthetic matrix has a great influence on the final properties of any composites. That is true mainly about mechanical properties but adhesion can influence also better dispersion of fibers. Chemical method represents one of the most used ways to ensure compatibility and connection on the interphase among fibers and matrix. Effectiveness of fibers surface modification by means of chemical compatibility additives is influenced by chemical composition of polymer and type of fiber. Chemical modification of fibers can activate hydroxyl groups are can create new functional groups which can effectively react with polymer. For preparation of composites there were used two compatibilities agents. As a first additives there was Fusabond from company DuPont, the second additives was Priex 20097 from company Addcomp. Additives was always added in the amount of 4%.

2.4 Preparation and production of composite materials

For fabrication composite pellets was used twin-screw extruder (Fig. 2) flowed by water bath and pelletizer. Parameters of compounding process are shown in Table 1. Coupling agents and nanofibers was dosed directly into the melting chamber of extruder in the recommended position by external device. The reason for dosing fibres in the front parts of the extruder (near granulation head) is to prevent excessive shear stress of fibres during compounding melt composite and thus their damage or thermal degradation.

![Schematic of compounding procedure](image-url)
For injection was used standard column-mounted injection machine ARBURG 270S 400-100 (see Fig. 3). Injection moulding technological parameters had to ensure partly samples production and also there was necessary to avoid nanofibers structure degradation. Mainly with regard to thermal and shear loading was crucial to set proper plastication and injection moulding parameters (Table 2).

For production testing samples from composites with polyamide nanofibers was used injection mould with central ejector which had exchangeable plates according to requirements and individual ISO standards. Thus it was by very easy manner possible to exchange plates for testing samples production according to testing methods. The mould has cooling channels both on the part of die and part of punch and it was tempered on the temperature 40°C for both sides of injection mould by means of aggregate TA3.

### Table 2 Injection moulding parameters

<table>
<thead>
<tr>
<th>Zone 5</th>
<th>Zone 4</th>
<th>Zone 3</th>
<th>Zone 2</th>
<th>Zone 1</th>
<th>Injection Speed [cm³/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>175</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>165</td>
<td>30</td>
</tr>
</tbody>
</table>

### 3. RESULTS AND DISCUSSION

The final properties of composites are not influenced only by technological conditions of their preparation and production but there is also strong influence on the final properties by adhesion nanofibers into PP matrix. The aim of this paper was research of additives different types influence on the chosen composite properties (melt flow index, tensile modulus of elasticity), which were prepared under the truly same technological conditions (Table 1 and Table 2) and by using the identical devices. Composites with nanofibers (Fig. 1) were after drying (as pellets) processed by injection moulding technology on the testing samples which were subsequently used for normalized tests and examinations. With regard to reality that composite viscosity due to addition of nanofibers is different than viscosity of pure PP, the adjusted technological parameters of injection testing samples were chosen from several tested variants of technological parameters so that there is not degradation of additive with regard to temperature and compression (shear) loading of composite melt. Before the own testing were materials microscopically evaluated both from the uniform distribution and dispersion of nanofibers point of view and also with regard to check sufficient nanofibers wettability by polymer matrix (Fig. 4).

On the injected samples were carried out complex tests of rheological, physical, mechanical and temperature properties accor. to standards for evaluation plastics and composites. On the following images are shown just selected properties of composites with PA6 nanofibers with different additive types – results...
of measuring melt flow index accor. to ISO 1133-1 are in the Fig. 5, results of bending modulus of elasticity according to ISO 178 are in the Fig. 6.

![Image of composite PP fracture area with 6% of nanofibers PA 6 (SEM)](image)

**Fig. 4** Microscopic image of composite PP fracture area with 6% of nanofibers PA 6 (SEM)

![Bar chart showing melt flow rate for composites with different additive type](chart)

**Fig. 5** Melt flow rate [g/10min] for composites with different additive type

Results in the Fig. 6 prove that adding nanofibers into thermoplastic matrix does not dramatically decrease melt flow index so also material with the highest filling ratio (6%) keeps almost initial processability. From the graphs is also evident that additive Priex more increases melt flow index than additive Fusabond.
Fig. 6 shows changes in the values of bending modulus of elasticity which are given by adding polyamide nanofibers into thermoplastic matrix. From graph is evident that additive Fusabond ensures good adhesion because according to presumption, bending modulus of elasticity is increasing with increasing filling ration. By contrast additive Priex is increasing bending modulus of elasticity itself and other filling has no influence on the modulus.

4. CONCLUSION

Development of composites with thermoplastic matrix is continual and still developing process which in the near future will lead to the development of composite materials those properties will be not influenced just by type of nanofiller, percentage filler volume, shape and size of filler but also by type and sort of compatibilizing additives. Such study lead to conclusion that till today we are not able by present technologies for plastic processing (granulation, injection moulding) to produce such composite with polymeric nanofibers which would be markedly different by its properties from the present composites (polymer nanofibers with glass fibres, natural fibers, mineral fillers and so on). With regard to price of nanofibers and present properties of such composites, it will be quite difficult to find their wide utilization in the near future.

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LITERATURE

