Abstract of the PhD thesis

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Title:
"Hybrid composite materials used for machine elements in the automotive industry"

The aim of the work entitled "Hybrid composite materials used for machine elements in the automotive industry", was the development of innovative composite materials used for the production of gears, obtained by injection, and testing their functional properties for use in the automotive industry.

The literature review presents the characteristics of selected materials: POM, PA 6, PA 6.6, PA 4.6, PPA and PEEK, as well as their previous research results focusing on polymer toothed gears. This chapter describes the methods of modifying the mechanical properties of plastics using such additives as: glass or carbon fibers, lubricants and carbon nanofillers. Injection molding technology was also characterized and process and design factors affecting strength, quality and performance parameters of structural injection molded elements were discussed. Differences between gears made of polymer and metal materials used in the automotive industry were also analyzed.

As part of this work, a number of mechanical and structural properties were obtained for selected polyamides and their composites. Based on the obtained results, two proprietary composite materials based on polyamide 4.6 were developed. For durability tests, a single-stage gear was selected, consisting of two gears with the number of teeth 17 and 25, module 2 mm and pressure angle 20°. Simulations of the analysis of the filling of molding cavities, fiber orientation, places of joining lines and volumetric shrinkage distribution were presented. Selected elements of the construction of molding cavities and the adaptation of gear wheel models to the injection molding process are discussed. The actual production problems encountered during a series of supervised injections of gears were indicated and the process of optimizing the injection parameters in order to obtain the desired element was discussed. Deviations of gear geometry and their accuracy classes according to DIN 3962 were determined.

An original test stand was developed, the main purpose of which was to compare the durability of the tested gears. The assumed measurement parameters were rotational speed, braking torque and gear operation time. The strength of the tested gears was measured by the increase in the temperature of the tooth's mating surface and the generated sound pressure. Durability boundary conditions for gears made of unmodified PA6 and PA66 were established. Types of tooth wear and causes of failure of the tested drive systems made of materials modified with glass fiber and Teflon were discussed. Among the tested gears, three materials PA46, PA46/PTFE and PA66/6T/35GF were selected, for which the impact of processing shrinkage and the phenomenon of prolonged lapping of the tooth side surface were examined. The additional lapping stage was carried out using gears obtained by sintering DMLS metal powders. On the basis of the test results obtained, the materials characterized by the best durability strength in the previous tests were selected - PA46 and PA46/PTFE. Using the extrusion technology, two new hybrid polymer composites based on PA46 and PA46/PTFE were obtained. In order to improve the mechanical properties of PA46/PTFE, new hybrid

polymer composites were obtained using the extrusion technology, with multi-walled carbon nanotubes and an organic lubricant in their structure. After completing four series of durability strength tests, a toothed gear made of PA46/CNT/SM composite was selected, characterized by a slight wear of the side surface of the teeth and the lowest increase in their contact temperature.

The obtained research results will allow to accelerate the process of refining innovative compositions of polymer gears. The test results are used in the development work of Splast, related to high-precision structural elements in the automotive industry.