Abstract

The main goal of this doctoral dissertation was to investigate the influence of different types and shapes of fillers on selected physical properties, usability, and the structure of composites based on polypropylene (PP). Understanding these relationships is crucial for optimizing production processes and expanding the applications of these materials in industry. Polypropylene, as one of the most commonly used polymers, is valued for its properties such as low density, chemical resistance, and good mechanical properties. With the possibility of almost unlimited modification, polypropylene is used in many industries, and the introduction of fillers can significantly affect its mechanical, thermal, and usability properties.

The literature review discusses various methods of modifying polymer materials and the characteristics of fillers used in these materials. The modification of polymer materials can be carried out in many ways, including by adding stabilizers, plasticizers, and various types of fillers such as glass fibers, carbon fibers, glass microspheres, talc, and various nanomaterials. Each of these fillers can uniquely affect the properties of composites, opening up new possibilities for applications and material optimization.

The research conducted as part of the dissertation included three main stages: mechanical testing, structural testing, and thermal and flammability testing.

In mechanical tests, special attention was paid to the impact of various fillers on tensile strength, stiffness, and other mechanical properties of PP composites. The static tensile test allowed determining the maximum strength of the composites, while dynamic mechanical analysis (DMA) provided information on their behavior under dynamic loads. Creep and relaxation tests enabled the assessment of the long-term mechanical stability of the composites under different operating conditions.

Structural testing using scanning electron microscopy (SEM) allowed for a detailed analysis of the composites' microstructure, including the distribution and adhesion of fillers in the polymer matrix. Differential scanning calorimetry (DSC) enabled the assessment of the impact of fillers on the crystallinity and phase transition temperatures of the composites. Optical microscopy provided additional information on the morphology and internal structure of the studied materials.

The UL 94 test and measurements of the limiting oxygen index (LOI) allowed for the assessment of the flammability of PP composites with various fillers, which is crucial for applications requiring high fire resistance. Thermogravimetric analysis (TGA) provided information on the thermal stability and degradation of the composites at high temperatures. Thermal imaging studies during injection molding enabled the assessment of heat flow and thermal stability during material processing.

The results of the studies showed that the type and shape of the filler have a significant impact on the properties of PP composites. For example, adding glass fibers increased the tensile strength and stiffness of the composites, improving their mechanical properties and thermal resistance. Glass microspheres reduced the density of the composites. Talc increased the stiffness and crystallization temperature of the composites, although it did not always translate into a significant improvement in mechanical strength.

The analyses showed that the appropriate selection of the type and shape of the filler can significantly improve the mechanical, thermal, and usability properties of PP composites, increasing their range of applications in the automotive, construction, and electrical industries. For example, composites with glass fibers can be used in constructions requiring high mechanical strength and dimensional stability, such as electronic enclosures or vehicle structural components. Composites with glass microspheres can be used in products requiring lightness, while composites with talc can be used in applications requiring high stiffness and resistance to high temperatures.

The dissertation makes a significant contribution to understanding the impact of various fillers on the properties of polypropylene composites and provides valuable insights for further research and the development of material technologies. This will enable not only the creation of new, more efficient, and sustainable materials but also the optimization of existing production processes and industrial applications. The development of polypropylene composites with improved properties can lead to their wider use in various industries, which in turn can contribute to improved efficiency and sustainable development in many sectors.