Development of an installation for the production of chemically activated materials for applications in additive techniques

Opracowanie instalacji do wytwarzania materiałów aktywowanych chemicznie do zastosowań w technikach addytywnych

mgr inż. Jakub Aniulis

Supervisor: prof. dr hab. inż. Krzysztof Marek Abramski

Auxiliary supervisor: dr inż. Grzegorz Dudzik

Department of Field Theory, Electronic Circuits and Optoelectronics (K35W12ND02)

Faculty of Electronics, Photonics and Microsystems

Wroclaw University of Science and Technology

With the accelerating pace of scientific research and technological advancement, there is a growing need for rapid prototyping in dedicated facilities using specific materials. Additive technologies, such as material extrusion 3D printing with a dedicated filament manufacturing facility, have become an economically viable solution to this need. The production of non-standard materials for this process often creates the need for installation in the form of a low-volume filament production line. A major challenge in such production processes is maintaining the quality of the filament throughout. This is because uncompensated variation in the properties of the material used in the 3D printing extrusion process is one of the factors leading to inconsistencies and defects in the parts produced. This creates a need for a low-cost, real-time filament quality monitor that can characterise the material properties of the filament along its entire length.

The thesis presents an installation for the production of chemically activated materials for additive technology applications, where automated longitudinal characterisation of filament properties has been applied. In order to ensure high quality filaments, it is necessary to monitor and manage a number of important properties including geometry consistency, volume variation, ovality, material homogeneity, blend ratio and the absence of internal and external defects such as air bubbles. To this end, a proprietary Real Time Filament Quality Monitor (R-FQM) has been implemented in the production installation to provide detailed insight into the characteristics of the filament during the production process. The R-FQM monitor implements the tracking of changes in the measured capacitance tube volume and diameter and other properties using different types of sensors for multiple selected axes and encoding the results to the specific piece of filament used in the 3D printing of the extruded material. The data collected made it possible to monitor factors such as material moisture content, roundness, material defects, component ratios, relative electrical permeability, Poisson's ratio or material type, among others. The first proprietary prototype of the instrument is presented and its operating principle is described in detail. Application examples include the identification of filament material type based on the characteristics of multiple material types from different manufacturers, the process of moisture absorption over time for selected filaments, and the detection of defects of varying severity.

R-FQM, combined with a proprietary multi-step process of drawing the filament through a wire drawing die, allows the properties of the filaments to be monitored and controlled during production. The innovative techniques were demonstrated in the production of polylactide-based composite filaments with the addition of nanohydroxyapatite. The diameter of the extruded material was reduced by pulling the resulting filament through a series of wire drawing dies of decreasing diameter in several stages. During the manufacturing process, the filaments were characterised at various stages of manufacture, including structural and thermal property analysis, as well as the proposed tensile test.