Abstract

Influence of printing parameters in SLM technology and of post-processing treatments on the structure and properties of selected copper alloys

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The main aim of this work was to develop sets of printing parameters in the SLM technology which would enable the creation of parts from three copper-based alloys: CuSn10P, CuNi2SiCr, and CuCr1Zr, with their relative density reaching 99 ± 1%. Moreover, the goal was to establish the parameters of suitable post-processing treatments, which would improve the final material properties of the specimens.

The dissertation begins with a literature review presenting the main groups of AM technologies, their market relevance and proliferation, serving as an economic and scientific background for the conducted research. Next, a printing strategy is defined, and its implementation in the software provided by the producer. The physical aspects of the SLM technology are described – the heat source characteristic, and its interaction with the feed material, from which the acquired properties are derived. In further chapters, the attention is shifted towards the available literature regarding the state of additive manufacturing from copper and copper alloys. The literature review ends with the description of selected post-processing methods reported to be successfully used on AM products, and with the assessment of their utility in the doctoral project.

The practical chapters start with the formulation of the aim of the study, research thesis, and research questions. Afterwards, the methods are described – the design of experiment, the preparation of the production process, the post-processing treatments, and the measurements of the final material properties. For each alloy, a design of experiment is devised, aiming at establishing the relation between the processing parameters (such as laser power, scanning speed and hatch distance) and the resulting microstructure. The final goal was to acquire the samples of maximal, near-theoretical density. In the case of CuNi2SiCr alloy, there was an attempt to explore alternative

optimization approaches including an introduction of purposefully introduced porosity, or a minimal feature size optimization. An equally important aspect of the research was measuring the influence of powder recirculation on the process quality, and also the examination of post-processing treatments, including traditional heat treatment, hot isostatic pressing, chemical polishing, and vibratory finishing, which are the main ways of improving mechanical properties, and of lowering the roughness of 3D-printed objects. In the case of CuCr1Zr alloy optimization, Python programming language was used to create DoE matrix, carry out the statistical analysis, and build a regression model describing the influence of the process parameters on the final density of the samples. The major highlight of the work was finding a set of printing parameters for each of the examined copper alloys, that allows for creation of samples of at least 99.40% relative density, measured using the hydrostatic method. For the CuNi2SiCr alloy, an additional printing strategy was devised for printing porous, periodic cellular structures, and an alternative printing strategy for manufacturing walls of under 100 μm thickness. Moreover, for the precipitation hardenable alloys, methods of heat treatment and chemical polishing were established, which raised the mechanical properties, and conductivity while lowering their roughness. For the CuCr1Zr alloy, a model of linear regression was devised to describe the influence of the printing parameters on the density with an R^2 value of 0.918.

In the conclusion of this work, an extensive description of the practical applications was provided, such as printable and stackable radiator prototypes, catalytic supports, and EMI shielding elements. One of the more significant results of the project was a prototype of a measurement cell for a dielectric spectrometer with a documented radiation attenuation effect, and also a technology of ultrasound-assisted chemical polishing which was the subject of a patent application. The proposed technological solutions have a high technology readiness level and constitute a significant contribution to the technological portfolio of the unit employing the author.

Keywords: additive manufacturing, selective laser melting, laser beam - powder bed fusion, copper alloys, technological process optimization, post-processing.