Abstract

Topic – Modelling, simulation, and verification of the additive manufacturing process of 7xxx series aluminium alloys, in terms of minimizing material defects

Aim & scope – Development of additive manufacturing technology of 7xxx series aluminium alloys, using experiment modelling methods, thermodynamic simulations, and the use of high-temperature heating of the working platform to eliminate hot cracks.

Research plan – the aim of the work was achieved by completing the following research plan:

1. Characteristics of the powder feedstock, classification of its suitability for use in the LPBF technology, and changes in its parameters along with the processes.
2. Simulation of the solidification process of the AA7075 alloy during the LPBF process in order to optimize the parameters of the LPBF process in terms of eliminating hot cracks.
3. 3 Development of technological parameters of the LPBF process - optimization of parameters and parameters' importance on the porosity and susceptibility of the material to cracking.
4. Material tests after the LPBF process - analysis of the chemical composition, material continuity, the influence of the parameters of the LPBF technology, and heat treatment on the obtained microstructure.
5. Post-process treatment consisting of heat treatment (ASTM B211) and machining according to ASTM E8/E8M.
6. Mechanical testing of the material after the LPBF process - determination of hardness profiles and strength characteristics in a static tensile test.

Summary and main findings - the implementation of the research plan allowed to achieve the goal of the work and draw the following conclusions. During the LPBF process, AA7075 aluminium alloy powder is heavily degraded by oxidation and evaporation of Zn and Mg. With subsequent processes, the content of Zn and Mg in the powder increases, which affects the parameter window of the LPBF process, the stability of remelting, and the chemical composition of the obtained elements. The usefulness of thermodynamic simulations in modelling and designing experiments was determined, including the determination of the sequence of phases having an impact on liquation cracking and their chemical composition. The width of the scanned strips affects the total length and average crack width of the samples produced. The use of a high-temperature working platform promotes the formation of columnar porosity by the phenomenon of Ostwald ripening and coalescence of hydrogen or shielding gas particles. Low scanning speeds together with a high platform heating temperature allow to obtain samples free from cracks and with a porosity of <1%, thanks to the reduction of the temperature gradient, and cooling speed. The produced samples of Ø5 mm after T6 heat treatment are characterized by strength properties comparable to those of aluminium alloys of the 7xxx series with a similar chemical composition.

Keywords – Additive Manufacturing, laser powder bed fusion (LPBF), 7xxx series aluminum alloys, thermodynamic simulations, high-temperature working platform, mechanical properties, hot cracking