Characterization of residual strain relaxation and preferred grain orientation of additively manufactured Inconel 625 by in-situ neutron imaging

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The presence of residual stress and unintended distribution of texture in metal components printed by metal additive manufacturing (AM) methods is a well-known phenomenon. In many cases, the residual stresses in these materials are released by post-build annealing. In this study we investigated experimentally the variation of residual stresses during a vacuum stress relief heat treatment of Inconnel 625 samples, printed using the powder-bed metal laser melting additive manufacturing technique. Although post-built annealing can reduce or eliminate the residual stress, other undesirable effects can also happen during annealing, e.g., formation of new phases. With the help of energy-resolved neutron imaging we measure, in-situ, the strain map distribution and the uniformity of preferred grain orientation within as-built samples and during their subsequent stress relief annealing in a vacuum furnace at 700°C and 875°C. These distributions (averaged through the sample thickness) were measured across the entire 25 x 15 mm^2 sample with sub-mm spatial resolution. Despite the limited accuracy of in-situ lattice strain reconstruction during sample annealing, the results indicate that most of the strain relaxation occurs at 700°C within the first 2-3 hours. Relaxation of the strain at 875°C happened at a much faster rate. In addition, energy-resolved neutron imaging demonstrates the possibility to correlate the uniformity of grain orientation and the degree of texture variations with printing parameters, in particular the laser translation speed. Simulations of the AM build process were also carried out to predict the residual stress distributions within the samples as a function of the build process parameters. The simulation results are in a good agreement with the experimental measurements, confirming the usefulness of the experiments for validating simulation. Results of this study demonstrate that energy resolved neutron imaging can be used as a guide for the optimization of the heat treatment cycle and for validations of microstructure simulation results.