Modeling of thermal behavior, stress distribution, and microstructure fields during laser deposition of a Ti-6Al-4V alloy

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Macroscopic finite element (FE) simulations were conducted to model the time-dependent thermal profile development during laser deposition of a Ti-6Al-4V alloy. In a sequential analysis, maps of stress distribution and thermal distortions were generated in the specimen geometry by using finite element structural analysis that employed the non-uniform distribution of the temperature field obtained from the prior heat transfer analysis. By estimating the solidification temperature and velocity fields from the macroscopic FE calculations, the evolution of prior columnar β phase, interface L phase, and α phase during directional solidification of a Ti–6Al–4V melt pool was studied with a phase field model. The formation of the columnar prior-β(Ti) phase was predicted by this model. During the solidification of the β phase from an undercooled liquid, the residual liquid below the solidus temperature within the β columns results in the α phase. The FE simulated stress and strain fields were correlated with the length scales and volume fractions of the microstructure fields. In a recent study, modeling of fluid flow due to the effects of shrinkage and natural convection driven by surface tension and buoyancy forces was conducted to provide an accurate description of thermal profile near the liquid melt pool. The above analyses can be used for proactive control of the subsequent modeling of the heat treatment processes.