Model-Based Power Profiles for Control of Melt Pool Volume in Laser Powder Bed Fusion

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During the powder bed fusion process, a laser is scanned back and forth along a build plan. At the beginning of each scan vector within the build, the laser is inputting energy into the same vicinity as the previous scan vector, from which the heat has not yet dissipated. This immediate reheating effect causes higher temperatures and larger melt pools at the beginning of each scan, which may lead to more extreme defects such as keyholing. In this work, two simulation-based strategies are investigated to maintain constant melt pool volume by reducing the laser power at the beginning of each scan. In a benchmark finite element simulation with constant power, the melt pool volume in a return scan increases by 312% compared to the steady-state melt pool volume of the previous scan. In the first strategy, a proportional-integral controller is applied to the simulated laser power which reduces the melt pool perturbation to 72% and significantly quickens the return to steady-state. A second strategy iteratively simulates each time increment of the analysis and uses a root-finding algorithm to find a power which maintains constant melt pool volume. This iterative method always converges to within 1% of the target melt volume. With the extra computational steps, the iterative method has CPU wall times roughly 3 times longer than the constant power and proportional-integral control simulations.