Genetic Algorithm-based Optimization of Laser Beam Path in Additive Manufacturing

Primož Potočnik, Andrej Jeromen, Edvard Govekar

University of Ljubljana, Faculty of Mechanical Engineering, Aškerčeva 6, SI-1000 Ljubljana, Slovenia
E-mail: primoz.potocnik@fs.uni-lj.si

This study presents a methodology of genetic algorithm-based optimization of laser beam path for improving laser-based additive manufacturing (AM). The study focuses on AM with direct laser deposition (DLD) process. A simple thermal model is developed to simulate the effects of laser-induced heat input on the temperature distribution within the substrate during the process of deposition of one layer. The optimization approach aims to find solutions with more homogeneous temperature properties that minimize the thermal gradient on the substrate during the laser deposition process. This presumably results in lower residual stress and deformations of the substrate and more accurate 3D metal printing. The tool-path planning is formulated as the search for the optimal sequence of cell depositions that minimize the fitness function, which is composed of two primary components, i.e. thermal fitness, and process fitness. Thermal fitness is expressed as the average thermal gradient, and process fitness regulates the suitability of the proposed tool path for the AM process implementation. Various tool path generators are proposed to initialize the initial population of tool-path solutions. Generators are designed to implement standardized tool-path generators (such as raster, spiral, etc.), and a specialized stochastic-based path generator. Genetic algorithm-based tool-path optimization is proposed, where custom initialization, crossover and mutation operators are developed for application in laser-based AM. Simulation studies demonstrate the effectiveness of the genetic algorithm-based optimization in finding solutions that minimize the fitness function and therefore provide both thermally and for the AM process implementation more suitable laser beam path solutions. Compared to the traditional trial-and-error tool path formulations, the proposed approach offers an improved and automated solution for an efficient laser beam path in laser-based AM.