Thermo-Fluiddynamic Modeling of Laser Beam-Matter Interaction in Selective Laser Melting

K.-H. Leitz[1], P. Singer[1], A. Plankensteiner[1], B. Tabernig[1], H. Kestler[1], L.S. Sigl[1]

[1]Plansee SE, Metallwerk-Plansee-Straße 71, 6600 Reutte, Austria

Abstract

In Selective Laser Melting (SLM) a laser beam is applied to build up a workpiece by melting up powder layer by layer. The technology offers great potential for future manufacturing technology, as it allows unique design possibilities at short process chains and small lot sizes. Whereas for materials like aluminum, steel, titanium, nickel and cobalt chromium alloys SLM is already well established and commercial fabrication systems are available, its application for the processing of high melting metals like molybdenum and tungsten requires a fundamental process understanding as the processing window is significantly narrower. In order to extend the applicability of SLM to those materials, multi-physical simulations are a versatile tool as they allow a look into the process and to identify relevant process parameters.

In this contribution a multi-physical simulation model for laser beam-matter interaction based on the computational fluid dynamics and the Heat Transfer Module of COMSOL Multiphysics® is presented and applied for an analysis of the SLM process. The model includes the absorption of laser radiation on the surface of the metal powder, conductive and convective heat transfer in the metal and the ambient atmosphere as well as melting, solidification, evaporation and condensation processes. It uses a coupled thermo-fluid-dynamical description of metal and ambient atmosphere based on the phase field approach. Depending on the temperature of the metal phase it is distinguished between solid, liquid and vapor phase state. The solid is treated as a high viscous fluid and the surface tension is restricted to the liquid phase. The density change during evaporation is taken into account by source terms in the continuity and the Cahn-Hillard equation. Based on the model a material specific comparison of SLM of steel and molybdenum is performed. Simulation results for the both materials are shown in Figure 1. Whereas for steel a long melt pool and a significant amount of evaporation is found, for molybdenum the melt pool is restricted to the size of the laser beam and no evaporation is observed. The presented results demonstrate that the coupled thermo-fluid-dynamical simulation model is able to describe the process dynamics of SLM as well as the material specific process characteristics. As the core of the model is the description of the laser beam-matter interaction, its applicability is not restricted to SLM. It can easily be adopted for a simulation of other laser based manufacturing processes.

Figures used in the abstract

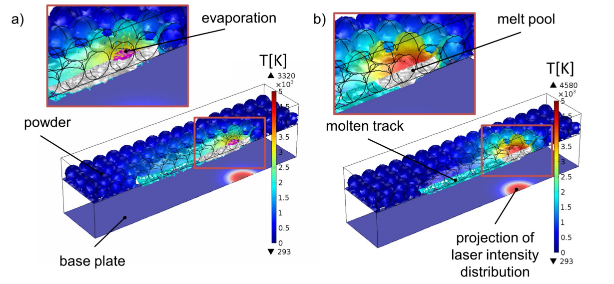

Figure 1: Multi-physical simulation of SLM: a) steel, b) molybdenum.