Modeling of Substrate Plate Preheating to Predict Efficiency in the Electron Beam Melting Process

M. Michatz[1], S. Janson[2], G. Schlick[3], I. Kühne[4], A. Frey[5]

[1]University of Applied Science, Faculty of Mechanical Engineering, Augsburg, Germany; Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV, Augsburg, Germany
[2]iwb Application Center Augsburg part of the Technical University of Munich (TUM), Augsburg, Germany
[3]Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV, Augsburg, Germany
[4]Heilbronn University, Faculty of Technology and Economics, Künzelsau, Germany
[5]University of Applied Science, Faculty of Electrical Engineering, Augsburg, Germany

Abstract

Additive Manufacturing is revolutionizing the industrial sector for complex and individualized metallic components. The most limiting factor of the widely established laser beam melting technology is the scan velocity due to inertia of the mirrors [1]. In electron beam melting (EBM), this aspect is not relevant because electromagnetic coils are used for the deflection. To ensure a stable process a narrow range of the beam focus temperature (TBF), on the upper side of the substrate plate, must be maintained. Direct measurement of TBF would allow for immediate control of the output power via the EBM electronics, but this measurement is not trivial due to the process conditions. A thermocouple on the bottom side is currently used to determine a substitute temperature supporting the experience-based adjustment of the output power for the generation of TBF. When the build job progresses and the plate is lowered precise adjustments are impossible. Knowledge of specific loss coefficients would lead to enhanced modification options. This paper describes a model based approach to extract them by replicating the preheating process. Hereby the EBM output power acts as a boundary heat source on the plate surface. The simulated transient temperature field is calibrated through experimental data extracted centrally at the bottom of the plate.
The model setup is based on the Heat Transfer in Solids interface. The 3D-model is defined by the plate geometry imported with the CAD Import Module. Different surface finishes are mapped by corresponding values of the emissivity. A Heat Flux boundary condition is used for the energy input of the heating capacity. In order to achieve a homogeneous temperature, the local distribution of the power input is of high importance. In the test setup a camera captures near-infrared images of the focus area and converts them into grayscale images to evaluate the qualitative temperature distribution. This data is used to iteratively generate gradient images which are applied in the EBM control to reduce heat accumulation by optimizing the local beam intensity. The final image is imported with the COMSOL Image Function. It is then used in the Heat Flux settings field Heat rate to provide

a realistic spatial distribution. Two Diffuse Surface boundary conditions are applied to model cooling in different plate regions. Natural convection was neglected due to the prevailing high vacuum. A User controlled mesh is set up for numeric efficiency followed by a mesh refinement study.
The beam power is varied in the model by a Parametric Sweep until the simulated and measured values correlate. A loss coefficient of 0.64 for the preheating procedure is found. This corresponds to the values given in [2]. Since the value depends on geometry, material and temperature, the loss coefficient cannot be stated generally [1, 2]. However, the simulation model offers a simple instrument for the tailored determination of further coefficients.

[1] ZÄH, Michael F. ; LUTZMANN, S.: Modelling and simulation of electron beam melting. In: Production Engineering 4 (2010), Nr. 1, S. 15-23
[2] SCHULTZ, Helmut: Electron beam welding: Elsevier, 1994

Figures used in the abstract

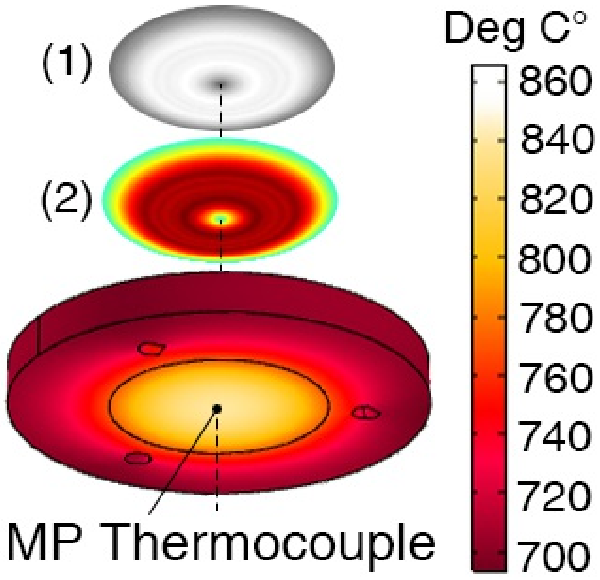

Figure 1: Simulated temperature at the measurement point (MP) of the substrate plate, display of the image conversion (1) gradient image, (2) applied image function.