Two-Phase Modeling of Conduction Mode Laser Welding Using Smoothed Particle Hydrodynamics

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ABSTRACT

Laser welding is widely applied in industry due to several advantages compared to conventional arc or gas welding: high welding speed, a small heat affected zone, ease of automation, and weight savings. Depending on the absorbed radiation intensity from the laser beam, laser welding may be classified into conduction mode welding and deep penetration welding. Conduction mode laser welding is a preferred manufacturing method to obtain visually appealing weld seams without further grinding or finishing. It is suitable for joining thin sheets and tubes, e.g. visible surfaces of device housings or stainless steel sinks. The process is characterized by high quality welds without defects like pores or spatter, and low mechanical and thermal distortions in the work piece. During the welding process, a laser beam melts the parts to be welded along a common joint, while the maximum temperature stays below evaporation temperature. The energy is transferred to the work piece merely through heat conduction and thus, the weld depth is limited by the heat conductivity of the material. The molten materials coalesce and solidify to form a weld, whose width is greater than its depth.

To gain insight into the influence of process parameters on the melt flow and resulting weld, the conduction mode laser welding process is simulated using Smoothed Particle Hydrodynamics (SPH) [1]. As a meshless Lagrangian method, it has the ability to accurately describe the free surface melt flow by fulfilling the continuity equation at the same time. The underlying heat transfer phenomena including the solid-liquid interface and the occurring phase transitions, melting and solidification, are modeled based on the works of Cleary and Monaghan [2, 3]. Temperature-dependent material properties are taken into account to gain more precise results. As an example, the temperature-dependent surface tension gradient is considered in order to describe the Marangoni convection which dominates the weld pool. The energy input from the laser beam is approximated as a moving heat source acting on the material surface.

For the simulations, the software package Pasimodo [4] is used. The obtained numerical results of the temperature distribution are validated by comparison to solutions of point sources, line sources and surface sources in the semi-infinite domain which are given in [5]. The change of process parameters like welding speed and laser power, and their respective effects on the weld pool dimensions are investigated. Furthermore, the use of different lasers and materials to be welded is examined. The simulation results are compared with experimental data to identify strengths and further improvements of the model.

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