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Effect of Laser Beam Scattering in SPH-Simulation of Deep Penetration Laser Beam Welding

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The effect of laser beam scattering on capillary stability and melt dynamics is investigated simulatively for deep penetration laser beam welding. The process is strongly dependent on the absorbed laser energy on the capillary surface. To estimate the locally absorbed energy, multiple reflections of the laser beam on an ideally smooth surface are often assumed. For a better understanding of the process, it is important to examine the effect of surface scattering due to surface roughness, and volume scattering due to condensed droplets or local changes of the complex refractive index in the vapor plume.

The mesh-free Lagrangian Smoothed Particle Hydrodynamics (SPH) method is coupled with a ray-tracing scheme. The SPH model covers fluid and thermodynamics, including temperature-dependent surface tension, recoil pressure, heat conduction, and phase transitions. The ray tracer models the laser-material interaction by tracking the propagation of light rays within the capillary according to the laws of geometrical optics, and taking into account multiple reflections and scattering. Surface and volume scattering are evaluated separately. For surface scattering, the reflections at the material surface are divided into a specular part and a diffuse part with randomly reflected rays. For volume scattering, the Henyey-Greenstein model is used to specify the angular distribution of the scattered light ray.

The effect of scattering is examined for laser beam welding of aluminum and titanium. The results show that volume scattering has a stabilizing effect on the capillary for the highly reflective material aluminum, while the effect of surface scattering is small for both materials.