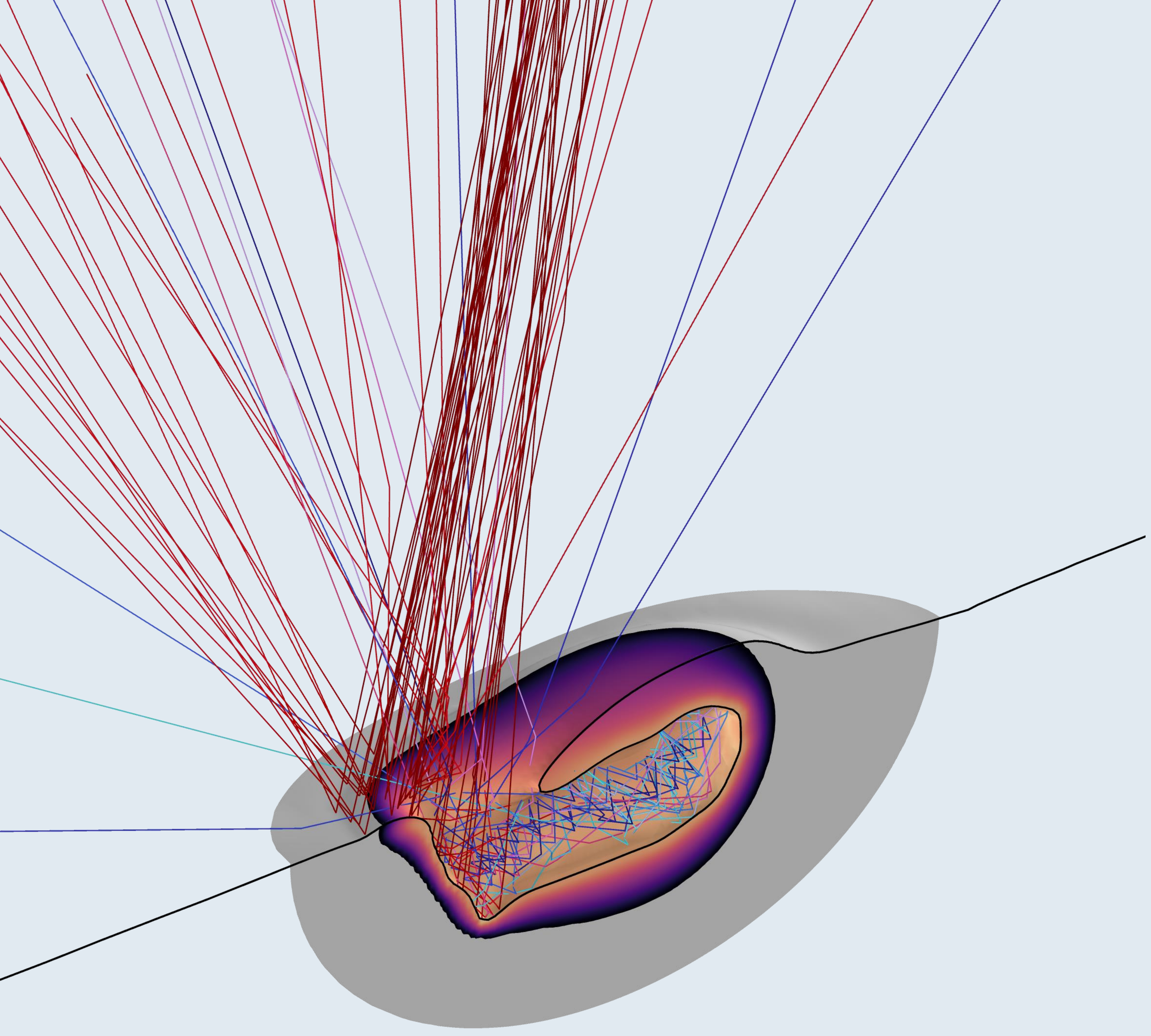

RayOptics and Mesh Adaptation for the Study of Copper Laser Welding Process Stability Using COMSOL® Application Builder

Copper laser welding is a challenging process. This study aims to developed numerical tools to better understand physical phenomena leading to instabilities and defects

J. Daligault[1], M. Dal[1], S. Touzouirt[1], M. Sawannia[2], C. Hagenlocher[2], R. Weber[2]

1. PIMM Laboratory, Arts et Métiers Institute of Technology, CNRS, CNAM, HESAM University, Paris, France
2. Institut für Strahlwerkzeuge (IFSW), University of Stuttgart, Stuttgart, Germany

Abstract

A numerical model of laser welding process applied on highly optically reflective and thermally conductive materials such as copper has been developed. The latter considers multiphysical couplings of CFD, heat transfers and Phase-field representation to account for topological deformation of the liquid-gas interface. In addition, a dedicated JAVA® method has been setup thanks to COMSOL® Application Builder to implement a new coupling between Phase-field description and geometrical optics, allowing self-consistent computation of the well-known « beam trapping effect » in laser processes. Hence, heat source induced by laser-matter interaction is updated correspondingly to liquid-gas interface fluctuations (Ref 1). Moreover, an adaptative refined mesh (AMR) method is considered to conteract the high numerical complexity of such a model. Numerical results are compared to x-ray measurements of keyhole dynamic formation (Ref 2).

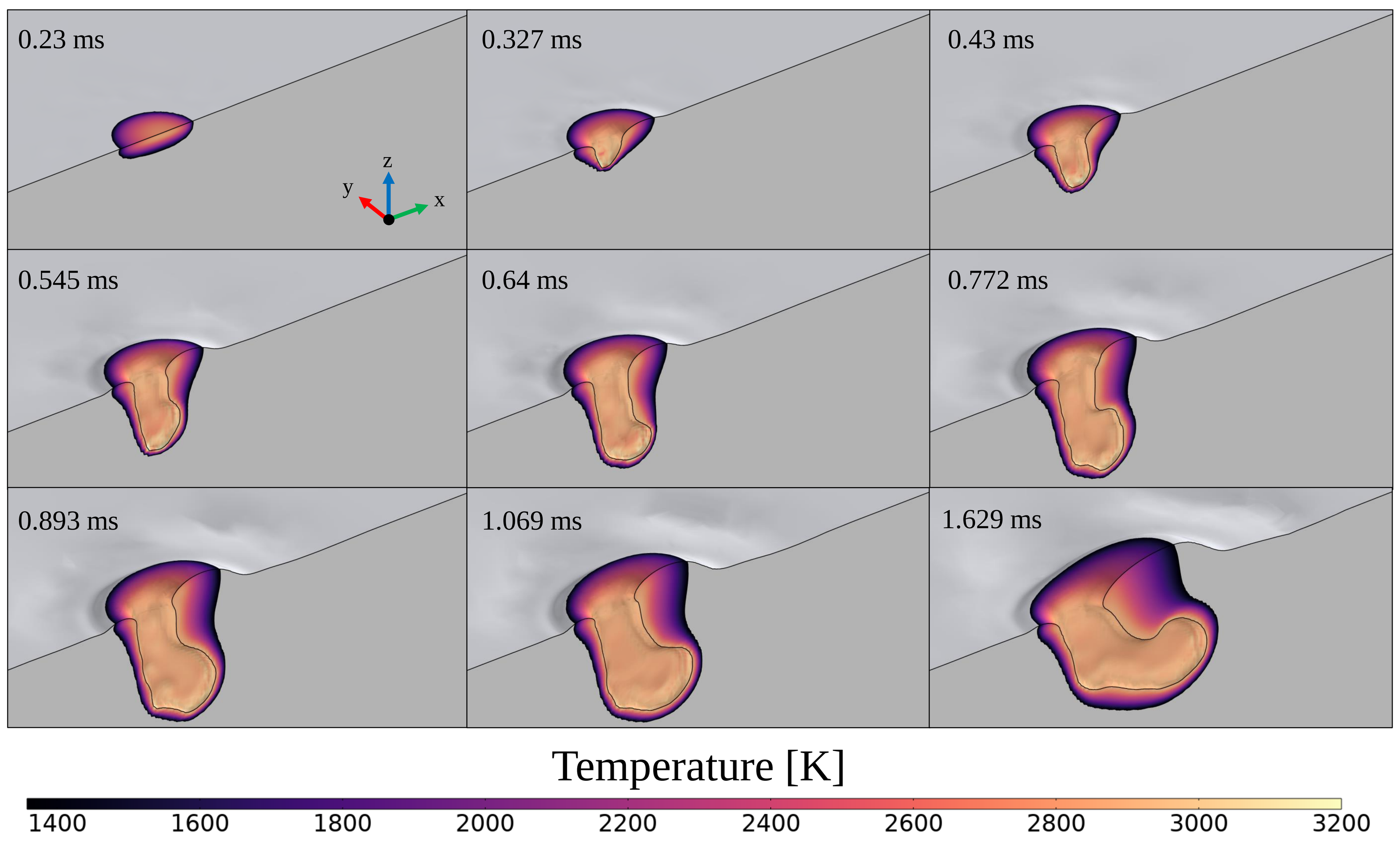

FIGURE 1. Evolution of the free boundary and molten pool during copper laser welding.

Methodology

A multiphysical model coupling heat transfers, computational fluid dynamics and interface tracking (phase-field) is developed to simulate the formation of the molten pool and vapor capillary.

The free boundary is extracted regularly as a .stl file and used to reconstructed a physical boundary. A geometrical optics (gop) is introduced to model rays propagation and multiple reflections. The resulting irradiance computed along the keyhole wall is introduced as volume heat source is the next multiphysical computation. The method allows the representation of complex keyhole configurations unobtainable with classical formulation, such as analytical heat sources.

Results are compared to dynamic observations of in-situ X-ray measurement realized at IFSW (FIGURE 3).

Adaptative Mesh Refinement (AMR)

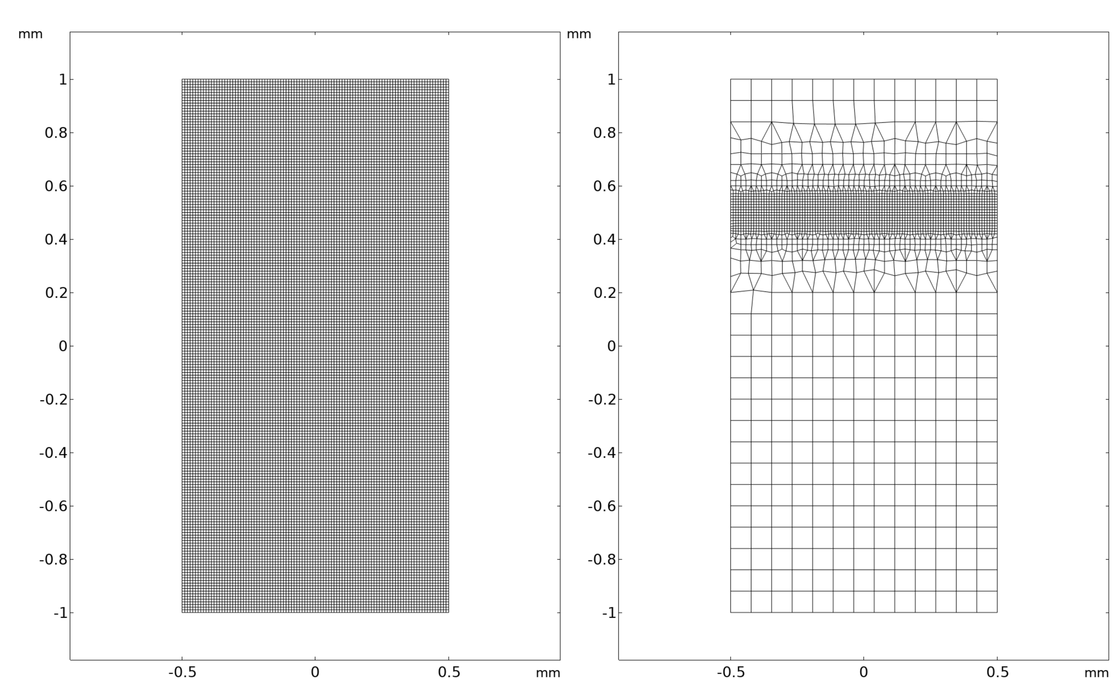

FIGURE 2. Mesh without AMR (left) and with AMR (right).

An adaptative mesh refinement method is added to the simulation to counteract the high numerical cost.

A global decrease of up to 70% computation time was obtained.

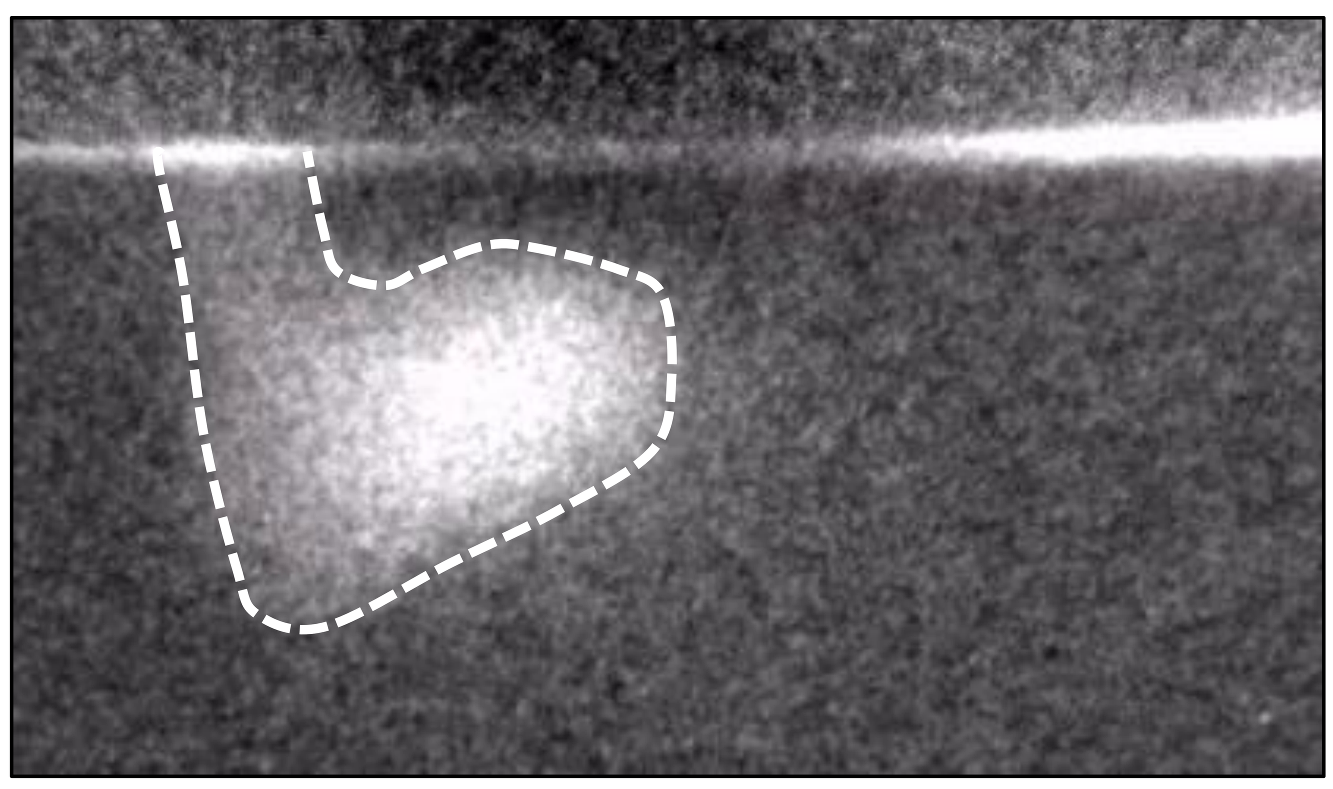

FIGURE 3. In-situ X-ray observation of the capillary during copper laser welding. Captured at IFSW (Stuttgart).

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