Modeling of Transport Phenomena in Laser Welding of Steels

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Abstract

Nowadays, laser welding is commonly used in automotive field due to its high level of efficiency for welding of dissimilar steels comparing to other welding technologies. In order to control the quality of laser welding of dissimilar materials, a good knowledge of convection phenomena in the weld pool became essential.

For better understanding of convection-diffusion process in case of full penetrated laser welding, a 3D simulation of fluid flow, heat transfer and mass transfer has been performed to provide fusion zone shape and elements distribution map. Heat transfer and fluid flow equations were strongly coupled, and diffusion of alloying elements was calculated basing on resulting position of solid/liquid interface and velocity field. In parallel, a number of experiments using pure Ni foils as tracers has been performed. Mapping of Ni distribution in the melted zone provided necessary validation basis for simulation of convection-diffusion process.

The model has been developed basing on approximation of a steady keyhole and solved in quasi-stationary form in order to reduce computation time. The energy transferred by laser spot was taken into account by application of vaporization temperature to the wall of the keyhole.

Turbulent flow model was used to calculate velocity field. Solid-liquid interface was introduced through changing fluid viscosity. Buoyancy force was applied as volume force to the melted zone. Marangoni effect and vapor plume stress were applied to melted zone limits in form of weak contribution.

Fick law for diluted species was used to simulate the transport of alloying elements in the weld pool. According to the literature, mixing of molten metals in fusion zone happens in a few milliseconds. Thus the convective term of the Fick law happens to be predominant.

The results of simulation have been found in good agreement with experimental data.

Figures used in the abstract

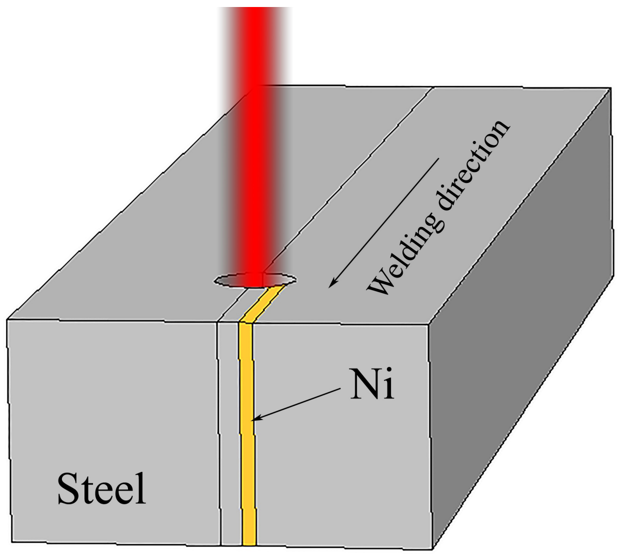

Figure 1: Schematic configuration

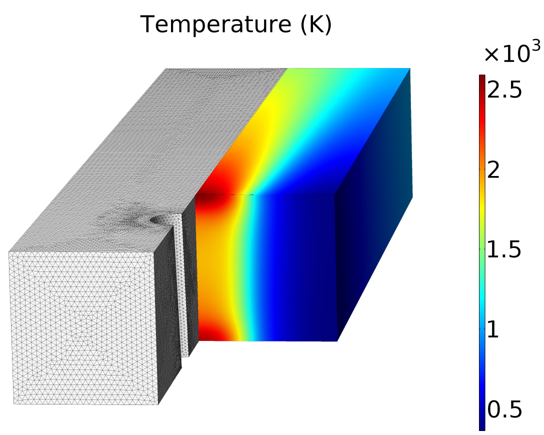

Figure 2: Mesh and thermal field

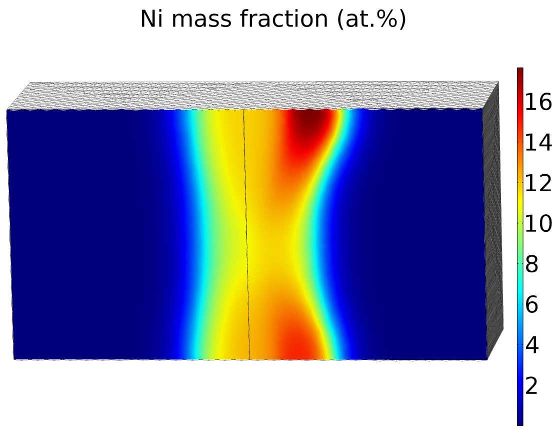

Figure 3: Mass fraction of nickel

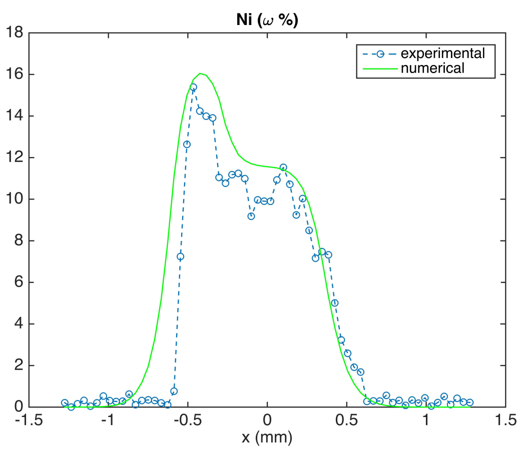

Figure 4: Mass fraction of Nickel below the top surface