Multiphysical Modelling of Keyhole Formation During Dissimilar Laser Welding

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Abstract

The development of melted zone during high power laser welding of metallic materials is strongly affected by shape and dimensions of vapor-filled keyhole that forms during laser-matter interaction. In case of bimetallic joining of metals and alloys, the discontinuity of physical properties (like laser absorption coefficient, thermal diffusivity, phase change temperatures etc.) may lead to the dissymmetry of the keyhole relatively to joint line. Very few experimental and numerical studies deal with this phenomenon, which is quite important for control of chemical composition and, consequently, of tensile properties of dissimilar welds.

In the present study, time-dependent multiphysical simulation of pulsed and continuous laser welding of dissimilar metals, based on Moving Mesh approach, is proposed. Strong coupling between heat transfer, laminar compressible flow and ALE is used. The model allows following the thermal field, free surface deformation and convection phenomena during melting and solidification of the weld.

In the first place, the model was applied to a case of single material (Ti6Al4V alloy) and successfully validated by comparison with experimental weld dimensions. Next, the model was applied for studying of keyhole dynamics and melted zone development in a case of dissimilar materials, in pulsed and continuous laser mode. The effect of discontinuity of physical properties across the joint line on keyhole behavior was studied for dissimilar couple Ti6Al4V/stainless steel (Figure 1).

The model showed that in the beginning of laser-matter interaction, the difference of absorption coefficient of two solid metals (30% for stainless steel and 40% for titanium) leads to the mismatch in keyhole drilling rate. Formation of the keyhole and ejection of melted matter initiate on titanium side, that is first to reach vaporization temperature, even when laser beam is centered on joint line. Then, keyhole wall propagates in melted stainless steel, but the root the keyhole remains at titanium side. The mismatch in thermal diffusivities and shift of the keyhole from joint line conduct to highly asymmetric melted zone. Understanding of phenomenology of keyhole formation was helpful for adjusting laser welding conditions in view to obtain defect-free Ti6Al4V/stainless steel joint.

Figures used in the abstract

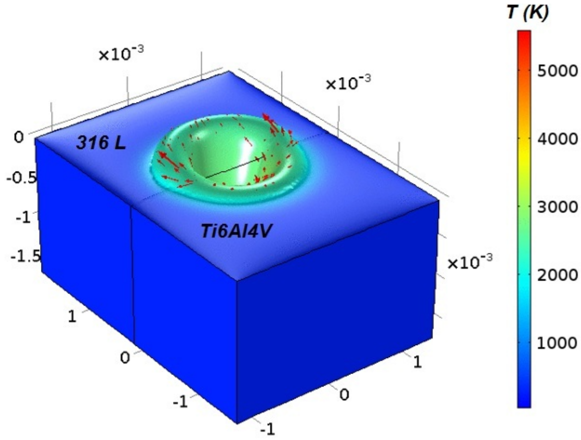

Figure 1: Figure 1. The development of melted zone at the interface between Ti6Al4V and 316 L stainless steel (laser power of 1500W, pulse duration of 9 ms).