Multiphysical modelling of keyhole formation during dissimilar laser welding

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Introduction: The present numerical study aims to reproduce the development of melted zone between dissimilar materials, that is strongly affected by shape and dimensions of vapor-filled keyhole forming during laser-matter interaction. In case of bimetallic joining of metals and alloys, the discontinuity of physical properties may lead to the dissymmetry of the keyhole relatively to joint line.

Computational Methods: Strong coupling between heat transfer and Navier Stokes is applied :

$$\rho\, c_p{}^{eq}\left(\frac{\partial T}{\partial t}+\vec{u}.\vec{\nabla}T\right)=\vec{\nabla}.\left(\lambda\vec{\nabla}T\right)$$

$$\rho_l\left[\frac{\partial\vec{u}}{\partial t}+\left(\vec{u}.\vec{\nabla}\right)\vec{u}\right]=\vec{\nabla}.\left[-pI+\mu(T)\left(\vec{u}.\vec{\nabla}+\left(\vec{u}.\vec{\nabla}\right)^t\right)\right]+\vec{F}$$

$$\vec{\nabla}.\vec{u}=0$$

Laser beam is introduced as Gauss distribution :

$$q_{pulsed}=\frac{P_L A}{\pi r_0^2}e^{\left(-\frac{x^2+y^2}{r_0^2}\right)}\cdot\left(t<t_{pulse}\right)$$

where A - laser absorption coefficient :

$$A=A_{solid}+(A_{liquid}-A_{solid})\cdot flc2hs(T-T_m,\Delta T)$$

$$A_{liquid}=A_{surf}+(A_{kh}-A_{surf})\cdot flc2hs(z-z_c,\Delta z)$$

Considered convection phenomena :

- Marangoni convection
- surface tension force
- natural convection
- recoil pressure

$$p_r=a\cdot e^{-\frac{b}{T}+c}$$

Resulting velocity field is injected in ALE moving mesh module.

Results: For couple Ti6Al4V/stainless steel, good correspondence between numerical and experimental shape of melted zone was observed. Keyhole dissymmetry took place only for low impulse duration (t<3ms).

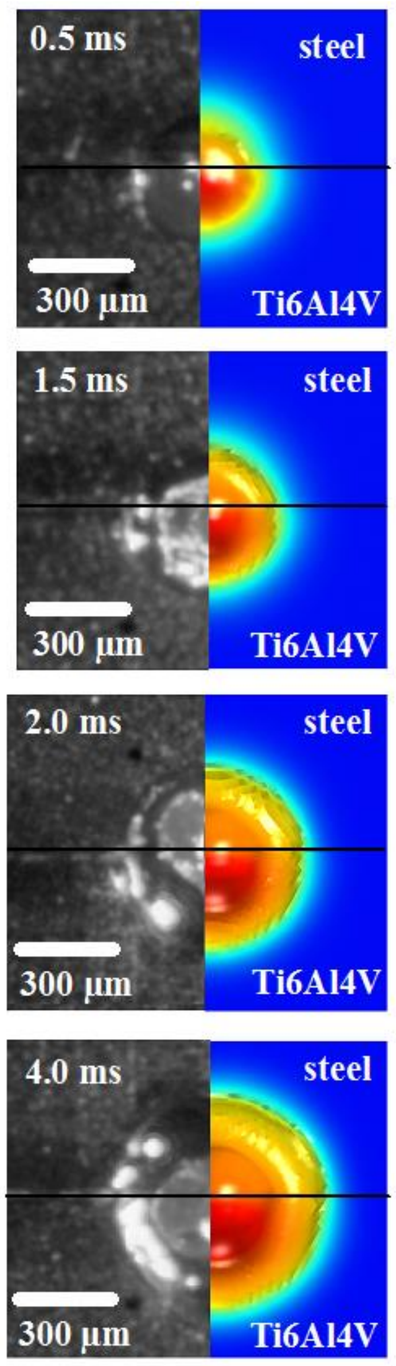

Figure 1. Impact surface at Ti6Al4V/steel interface: comparison between calculation and rapid camera image (top view).

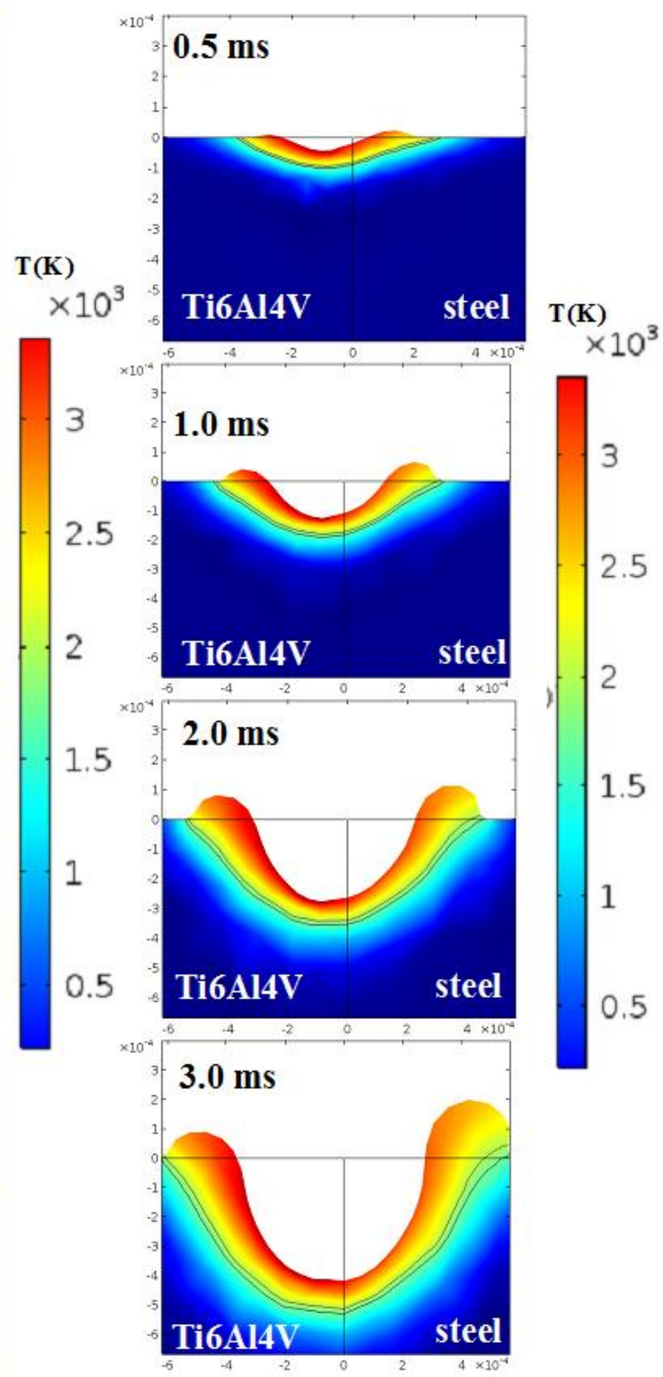

Figure 2. . Keyhole development in Ti6Al4V/steel joint (cross view).

Conclusions:

- Approaching realistic representation of melted zone
- As a perspective of this work, the interdiffusion of species during melting and solidification of the weld will be introduced, which will allow taking in account local variation of thermophysical properties.