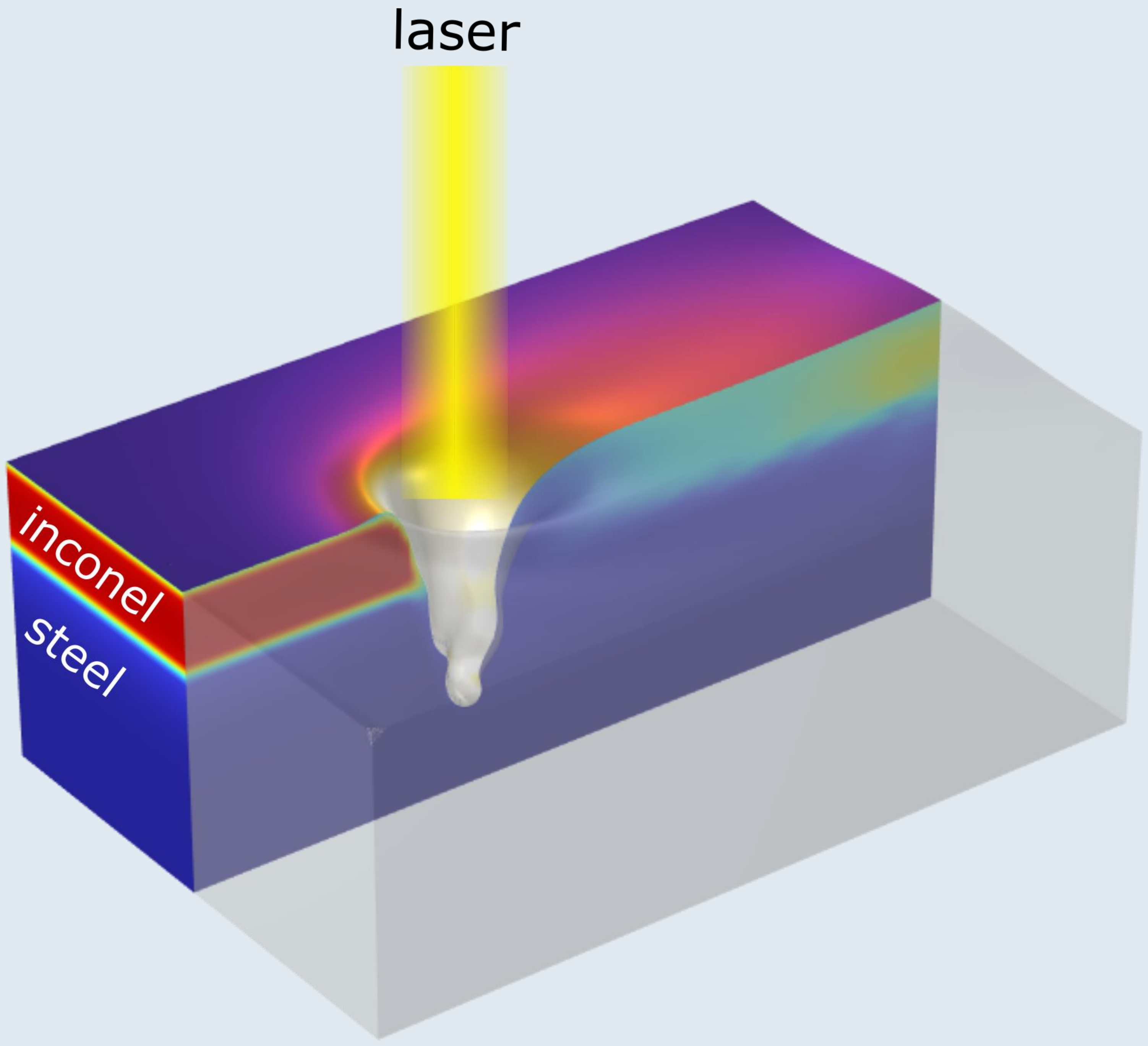

Heat Transfer and Fluid Flow Modeling During Dissimilar Laser Welding

Understanding defects in laser welding by predicting melt pool dynamics for a lap joint configuration with two different metals.

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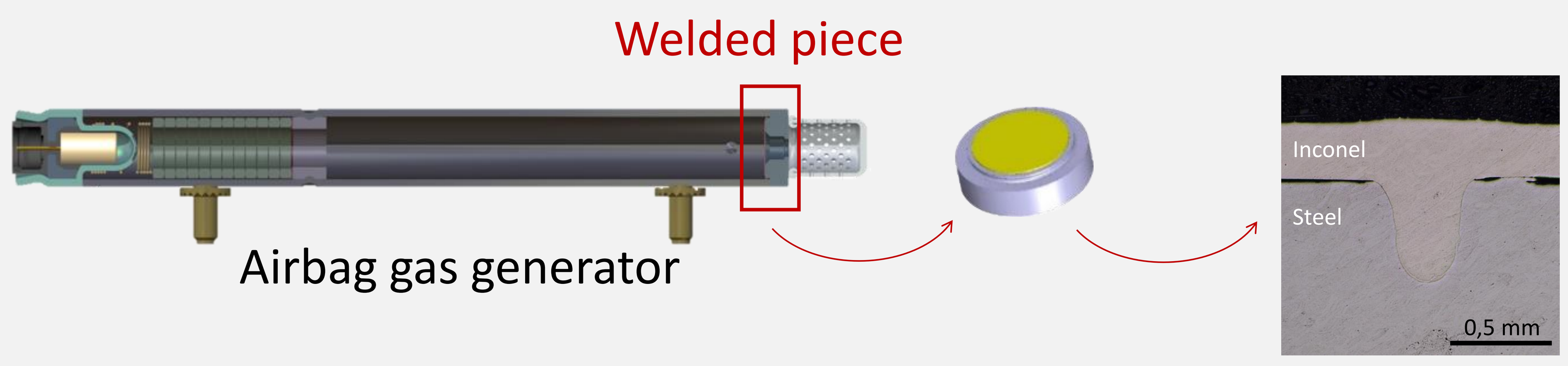
Introduction and Goals

- Context : Gas generator for airbags developed by Autoliv Livbag.
- Lap joint configuration : thin disk of metal welded on the nozzle of an inflator by keyhole laser welding.
- Two metals in solid, liquid and gaseous states.
- Multiphysics simulation to understand and improve the operating parameters of the welding process.



Cross-section micrography of a weld bead

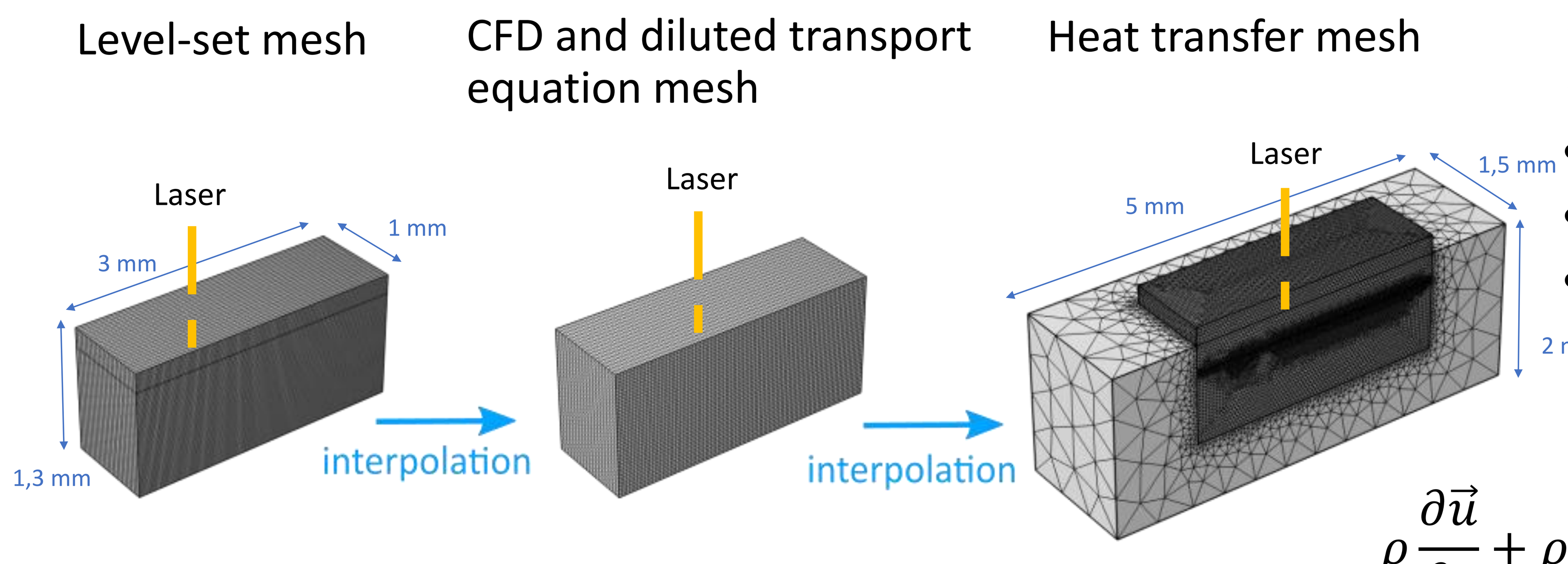


FIGURE 1. A specific mesh for each physics

Methodology

- 3D-model, half of the weld bead with symmetric condition.
- Multi-mesh method used to reduce computation time[2].
- Energy and momentum equations computed :

$$\nabla . \vec{u} = 0 \qquad \rho C_p \left[\frac{\partial T}{\partial t} + \vec{u} \cdot \nabla T\right] + \nabla \cdot (-\lambda \nabla T) = (Q_{laser} + Q_{vap})\delta(\phi)$$

$$\rho \frac{\partial \vec{u}}{\partial t} + \rho(\vec{u} \cdot \nabla)\vec{u} = \nabla \cdot [-pI + \mu(\nabla \vec{u} + (\nabla \vec{u})^T)] + \overrightarrow{F_{recoil}}\delta(\phi) + K\vec{u} + \rho\vec{g} + \overrightarrow{F_{ST}}\delta(\phi)$$

- Interface between gas and solid/liquid metals ➔ Level-set method.

$$\frac{\partial \Phi}{\partial t} + \vec{u} \cdot \nabla \Phi = \gamma_{ls} \nabla \cdot \left(\varepsilon_{ls} \nabla \Phi - \Phi(1-\Phi)\frac{\nabla \Phi}{|\nabla \Phi|}\right)$$

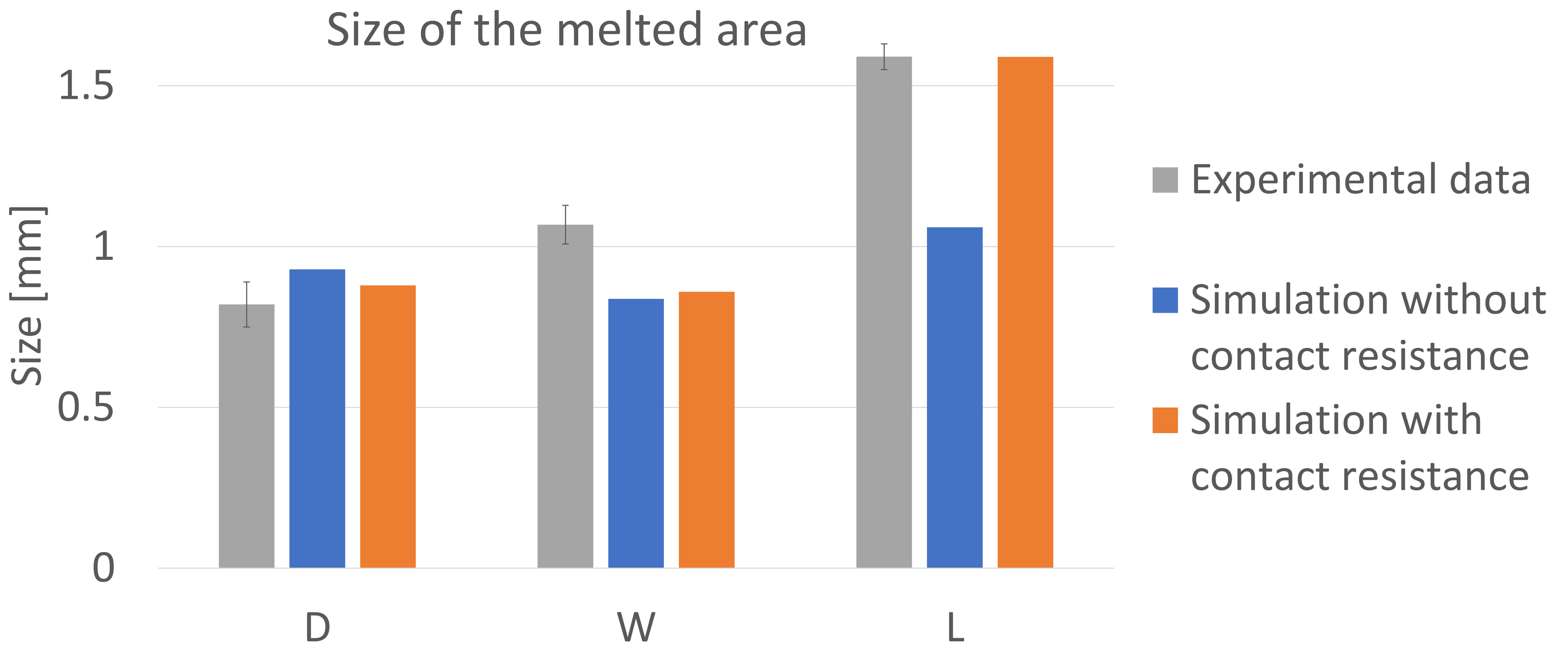
- Distribution of the two metals ➔ diluted transport equation

$$\frac{\partial c}{\partial t} + \nabla \cdot (-D_c \nabla c) + \vec{u} \cdot \nabla c = 0$$

Results

- State changes and keyhole creation correctly modelled.
- Specific shape of melted zone : larger in Inconel layer

➔ Need to model a thermal contact resistance



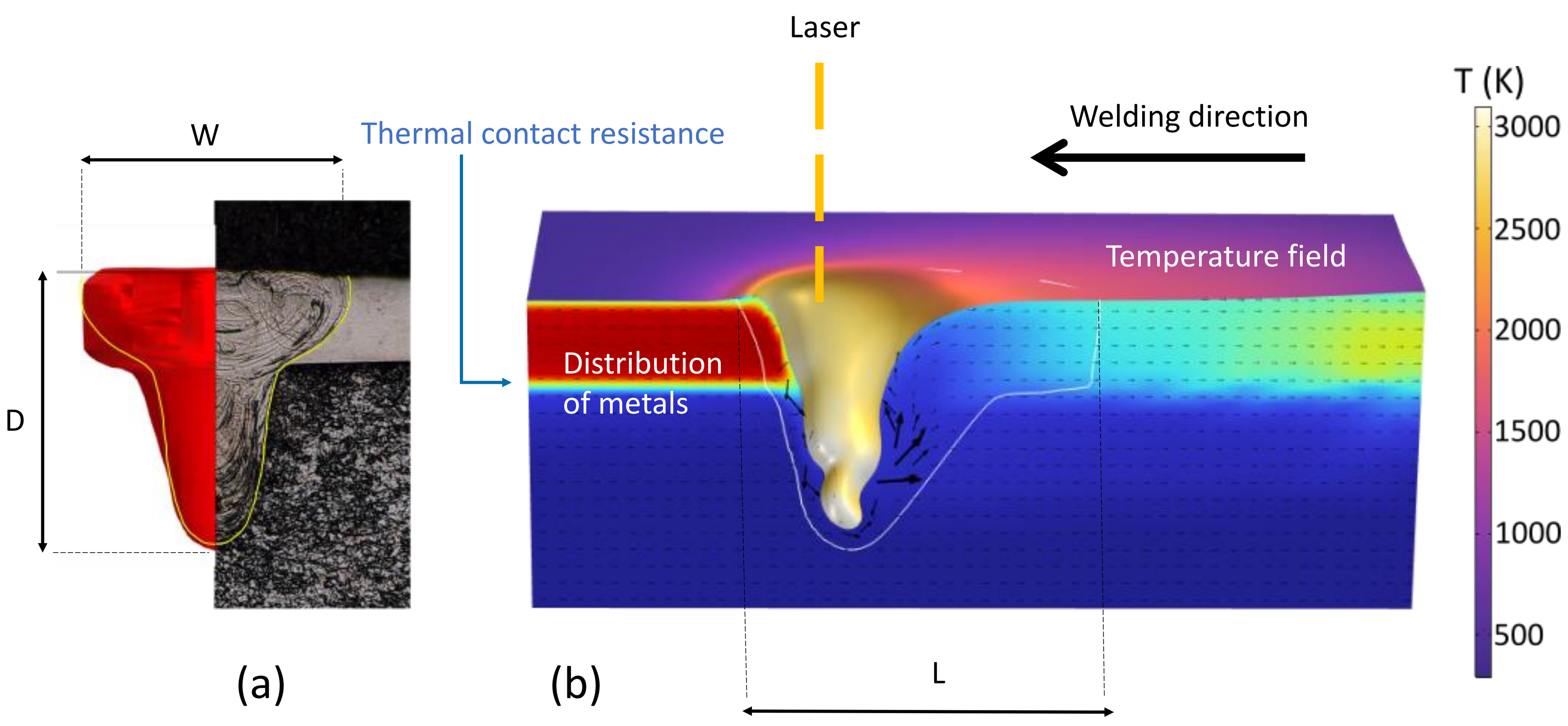


FIGURE 2. (a) Comparison between the computed melted zone (red) and the experimental data. (b) Computed field of temperature, isotherm of fusion (white), velocity vectors, and distribution of Inconel (red) and steel (blue)

REFERENCES

1. M. Dal & R. Fabbro. "An overview of the state of art in laser welding simulation". *Optics & Laser Technology*, vol. 78, pp. 2-14, 2016
2. M. Courtois, M. Carin, P. Le Masson & S. Gaied. "Complete 3D heat and fluid flow modeling of keyhole laser welding and methods to reduce calculation times". *Math. Model. Weld Phenom*, vol. 12, 2018

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