Modelling of Transport Phenomena in Laser Welding of Steels

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Introduction:

The role of Laser Welded Blanks in vehicles design is significantly increasing. The aim of present modelling is to carry out mechanism of formation of eddies in the laser weld pool by using specific tracers.

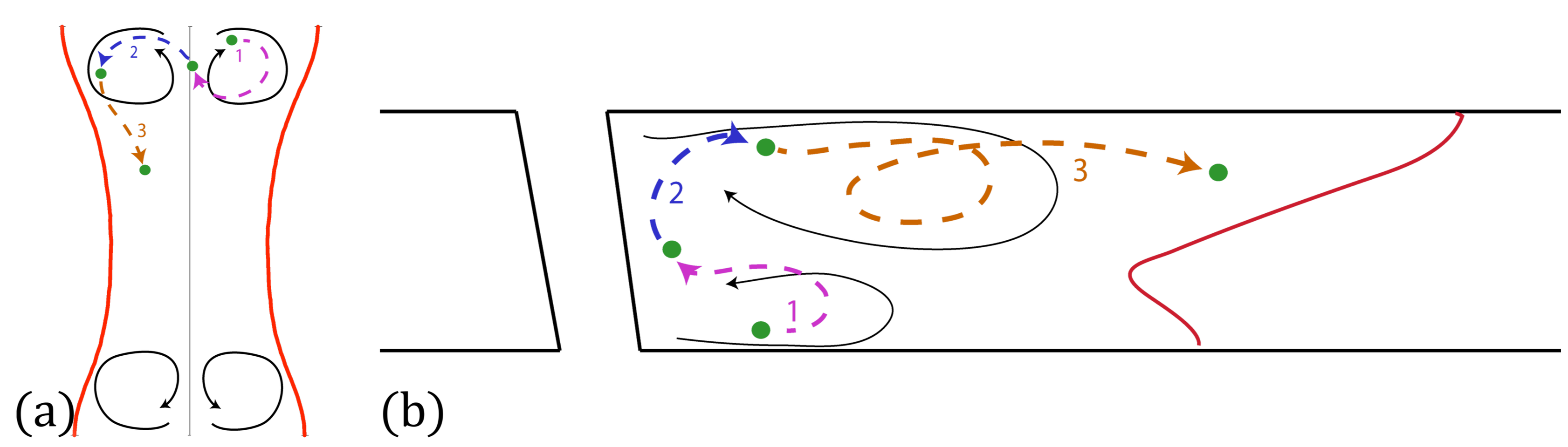


Figure 1. Particle tracing in cross (a) and longitudinal (b) sections

Experimental methods:

Present work approach is to add a foil of metal that can be used as a tracer. Experimental and numerical tests have been performed with pure nickel foil inserted in the joint plane. Nickel is a tracer having complete solubility in steel, it provides good global reflection of convection phenomena in the weld pool and allows flow optimisation by reverse engineering.

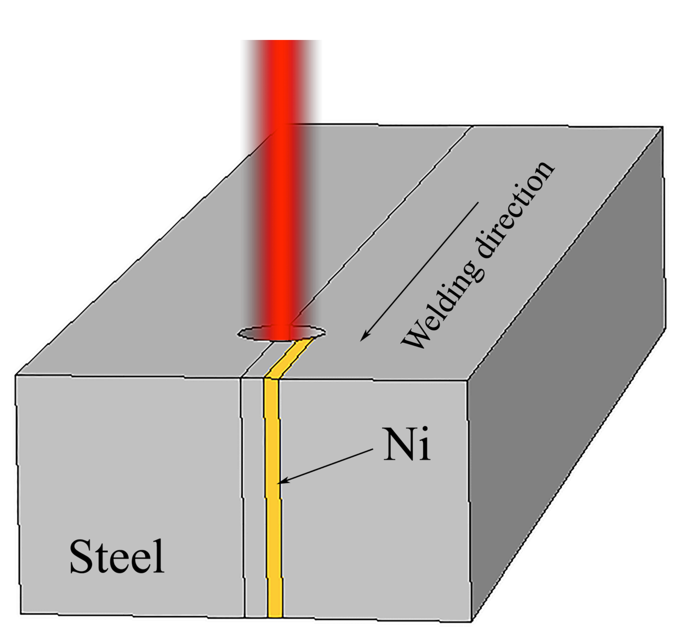


Figure 2. Schematic configuration with an off-set of 200 μm

Laser power: 4.0 kW
Scan speed: 6 m/min

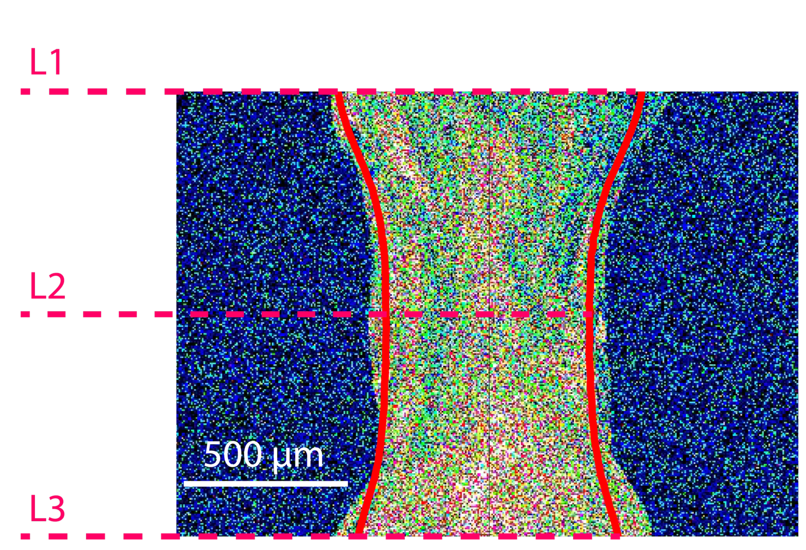


Figure 3. Experimental vs numerical melted zones

Computational Methods:

A 3D simulation of fluid flow, heat transfer and mass transfer has been performed to provide fusion zone shape and elements distribution map. Equations are solved in quasi-steady form.

- k-ω turbulent flow model was chosen
- Marangoni effect is applied to the top and bottom surfaces

$$\mu\frac{\partial u}{\partial z} = \frac{\partial \gamma}{\partial T}\frac{\partial T}{\partial x} \qquad \mu\frac{\partial v}{\partial z} = \frac{\partial \gamma}{\partial T}\frac{\partial T}{\partial y}$$

- Plume shear stress is introduced by weak contribution in keyhole.
- Fick law for diluted species is used to study transport species in weld pool

$$\nabla\cdot(-D_i\nabla c_i + \mathbf{u}c_i) = 0 \qquad D_i(T) = \frac{k_B T}{6\pi r_i \mu}$$

Results:

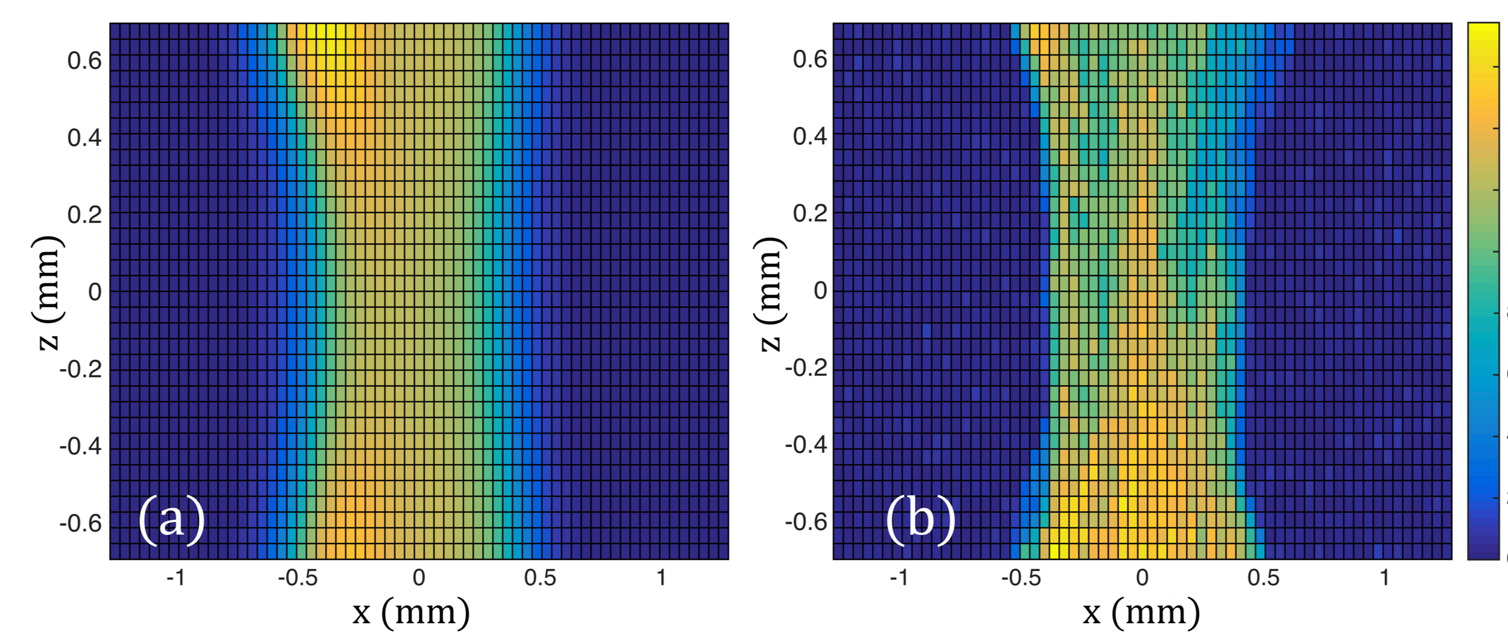
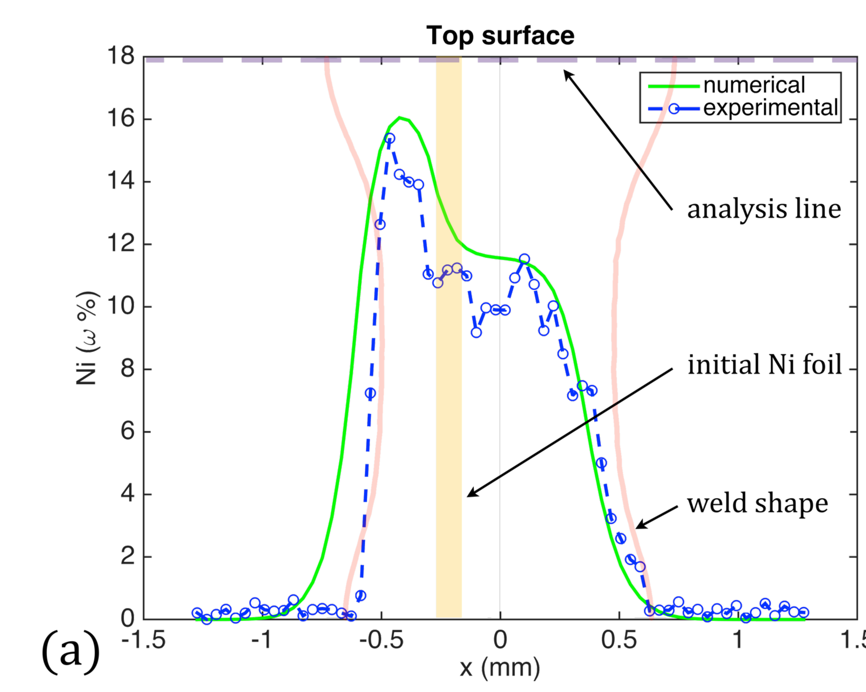


Figure 4. Nickel distribution (wt%) in cross-section, numerical (a) and experimental (b)

A relative error lower than 30 % has been found between experimental and numerical results.



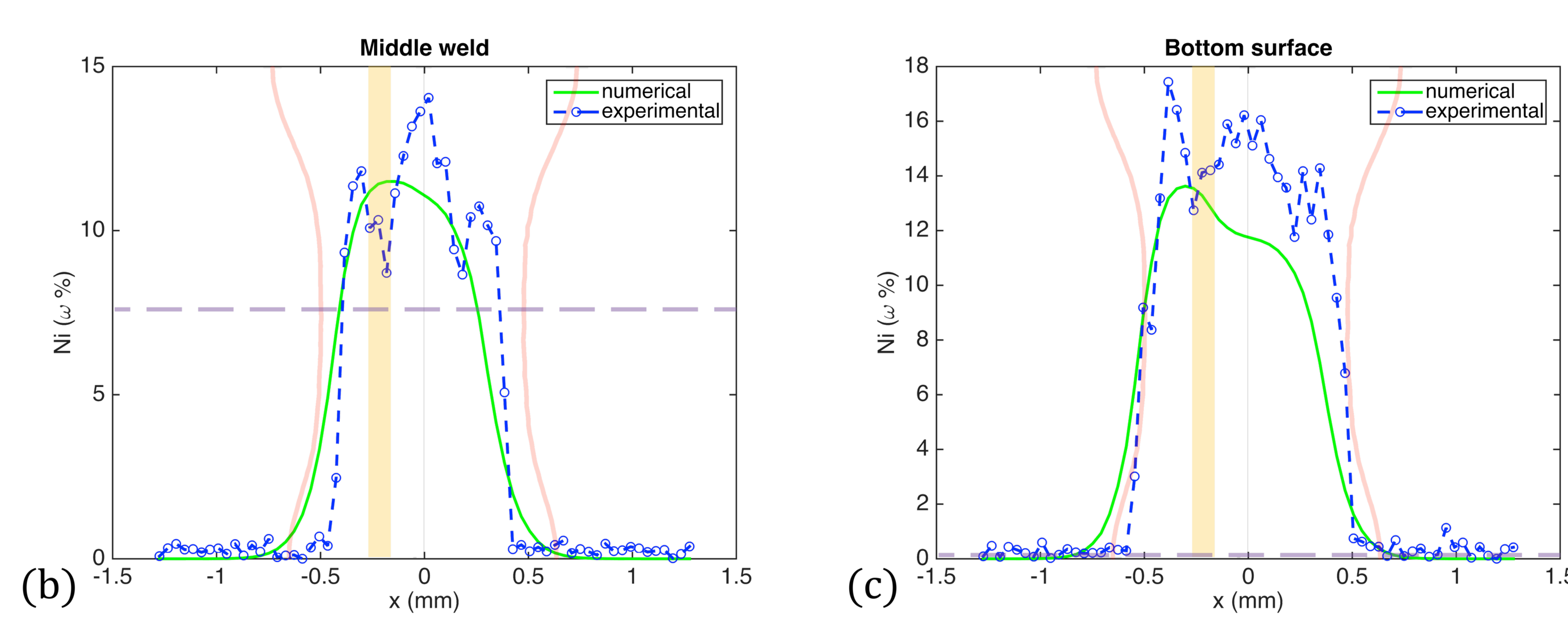


Figure 5. Experimental and numerical Ni distribution (wt %) along the line L1 (a), L2 (b) and L3 (c); numerical weld shape and initial position of nickel foil are provided.

Conclusions:

Current model gives an estimation of Ni mass distribution (wt%) in weld and main driving forces of convection.

These results could be used to improve laser weld mixing between dissimilar steels.

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