Thermo-Mechanical Simulation of Dissimilar Titanium Alloys Laser welding

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Introduction: Present work covers topic of strains and stresses prediction in case of Laser welded dissimilar titanium alloys structures. Dissimilar welding is used for weight and cost reduction considerations in the frame of aeronautic construction. Two dissimilar titanium alloys sheets (40 mm × 100 mm) made in Ti50A and Ti6Al4V (Fig.1) are welded using a Nd:YAG continuous Laser source. A 3D unsteady numerical simulation was developed in order to assist in prediction of distortion for this kind of welded structure.

Figure 1. Cross-section of a Laser welded flat joint (Welding Speed = 2 m/min, Laser Power = 2 kW)

Computational Methods: the time-dependant partial equation (1) is used to simulate conductive heat transfer within a metal medium:

$$\rho C_P \frac{\partial T}{\partial t} + \rho C_P u \nabla T = \nabla\left[k \nabla T\right] + Q \qquad (1)$$

A strong coupling is established between equations governing heat diffusion and mechanics assuming a linear coefficient of thermal expansion (2) and (3):

$$s = S_0 + C : \left(\varepsilon - \varepsilon_0 - \alpha\left(T - T_{ref}\right)\right) \qquad (2)$$

$$-\nabla s = Fv \qquad (3)$$

A plasticity model with isotropic hardening based on a small strains assumption is chosen as mechanical behaviors for each material of the assembly [1-2].

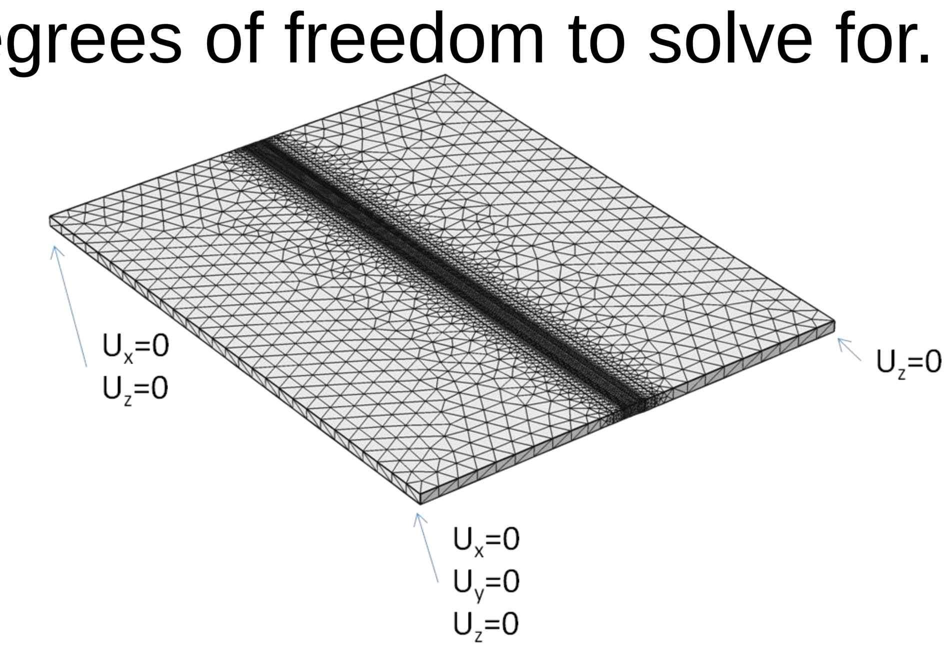
A volumic heat source based on Goldak's model [3] is identified analytically, see (4) and (5):

$$\begin{cases} \dfrac{6\sqrt{3}\times f\times P}{a\times 2h\times c_1\times \pi\sqrt{\pi}}\, e^{\left(\frac{-3x^2}{a^2}\right)} e^{\left(\frac{-3\times(y-V_s\times t)^2}{c_1^2}\right)}\left(1-0.9\times e^{\left(\frac{(z+0.0009)^2}{h^2}\right)}\right) \\ y \ge V_S \times t \end{cases} \qquad (4)$$

$$\begin{cases} \dfrac{6\sqrt{3}\times r\times P}{a\times 2h\times c_2\times \pi\sqrt{\pi}}\, e^{\left(\frac{-3x^2}{a^2}\right)} e^{\left(\frac{-3\times(y-V_s\times t)^2}{c_2^2}\right)}\left(1-0.9\times e^{\left(\frac{(z+0.0009)^2}{h^2}\right)}\right) \\ y \le V_S \times t \end{cases} \qquad (5)$$

P is an absorbed power and $f=2-r$, a, h, c_1 and c_2 are coefficients adjusted to simulate the moving molten pool crossing the workpiece.

The figure 2 shows geometry, meshing and boundary limit conditions. The problem consists of 535k degrees of freedom to solve for.



$$\begin{cases} -n\cdot\left[k\nabla T\right] = h\cdot\left(T_{ext} - T\right) \\ h = 5 \quad W/\left(m^2\cdot K\right) \\ T_{ext} = 293.15 \quad K \end{cases}$$

Figure 2. Mesh and boundary limits

Results: The numerical simulation allows us to predict an angular distortion and a longitudinal shrinkage as a consequence of laser welding (figure 3). These results are compared to displacements measured by Digital Image Correlation method (figure 4).

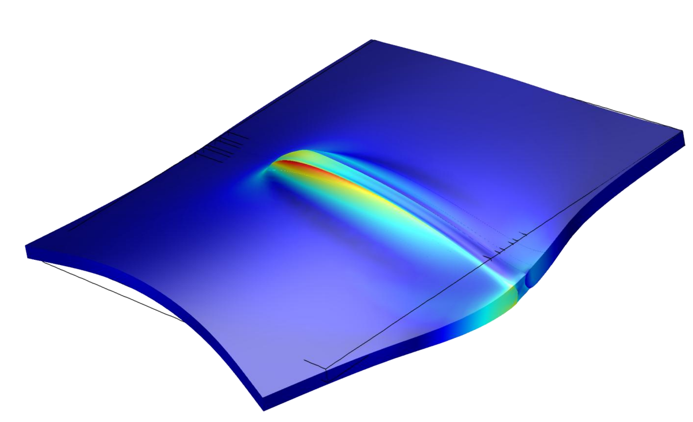


Figure 3. calculated displacement

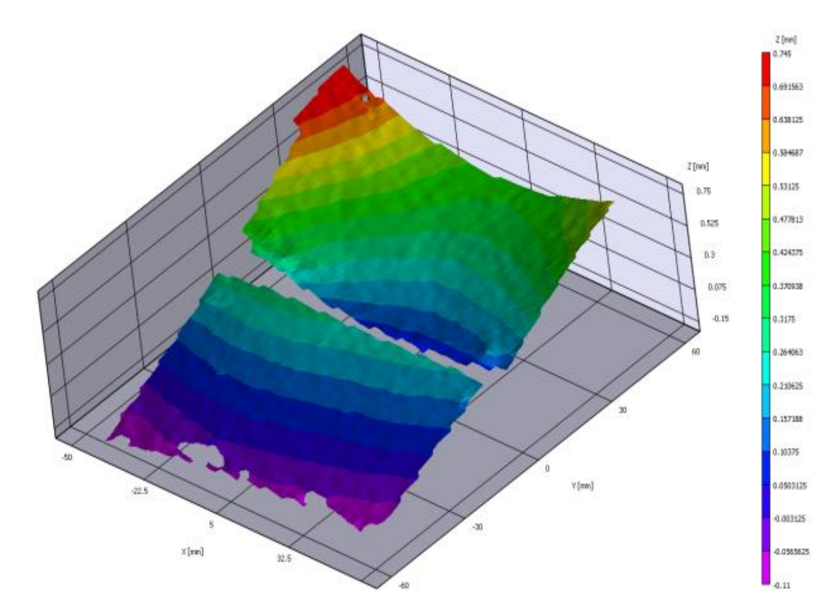


Figure 4. out-of-plane displacement measured by DIC 3D method

Conclusions: Dissimilar welding simulation presents difficulties related to lack of knowledge about high temperature material properties and behaviors. Real welding conditions, especially clamping conditions, are neglected because laser weld is established very quickly. Further works will concern introduction of more realistic boundary limits, introduction of metallurgical phenomena occurring during welding, and, identification of an elastoviscoplastic strain behavior .

References:

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