Thermo-Mechanical Simulation of Dissimilar Titanium Alloys Laser Welding

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Abstract

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 of 2 mm and 1.8 mm thickness made in Ti50 (R50400 UNS code) and Ti 6Al 4V (R56400 UNS code) are welded using, continuous wave, solid state Yb:YAG disk-type Laser. After passing through a 600 micrometers core diameter optical fiber, the Laser beam is focused using an optical head composed of a 200 mm focal length collimating lens and a 200 mm focal length focusing lens. Laser spot diameter intercepted by workpiece surface can be estimated to 0.6 mm diameter. The welding optical head is displaced by a CNC-controlled machine on a 100 mm distance to create a junction between the two dissimilar workpiece with 100 mm by 40 mm dimensions. Welding speed is 2 m/min for a Laser power set to 3 kW. Dissimilar welding simulation presents some difficulties related to lack of knowledge about high temperature material properties and behaviors. This lack of knowledge imposes to adopt strong assumptions. Real welding conditions are difficult to be taken into account, especially fastening conditions. In this work, these conditions are neglected because, laser weld is established very quickly, and flanges, grounding workpieces, are removed immediately after welding.

A 3D unsteady numerical simulation was developed using COMSOL Multiphysics software, Structural Mechanics and Heat Transfer modules. The totally penetrating laser beam is represented, analytically, as a volumic heat source with a bi-elliptical cross-section. According heat source developed by Goldak [1], a Gaussian heat distribution within the cross-section of the heat source is adopted. A strong coupling is established between equations governing heat diffusion and mechanic through introduction of a coefficient of linear expansion within the thermal stress (ts) physic. A plasticity model with isotropic hardening based on a small strains assumption is chosen as behavior for each material of the assembly. Influence of mushy and liquid zones induced by the welding are neglected in this work.

The numerical simulation allows us to predict an angular distortion and a longitudinal shrinkage as a consequence of laser welding (figure 1). These results are compared to displacements measured by Digital Image Correlation method (figure 2).

Reference

1. J. Goldak et. al., A new finite element model for welding heat sources, Metallurgical Transactions B, Volume 15B, 299-305 (1984).

Figures used in the abstract

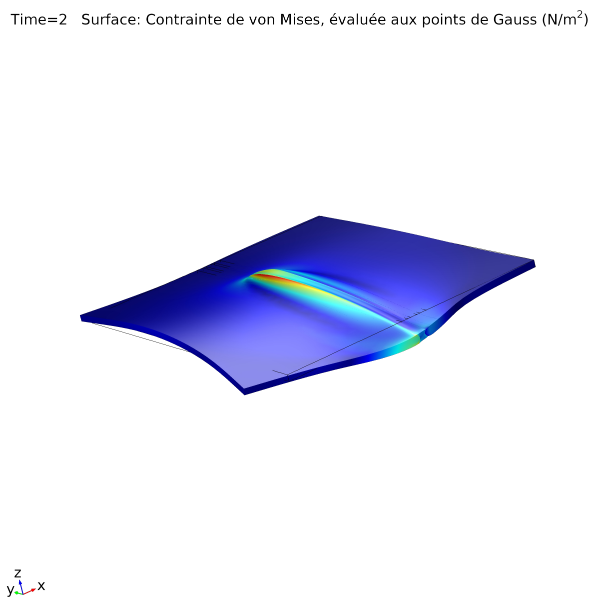

Figure 1: Deformed shape 2 s after welding start

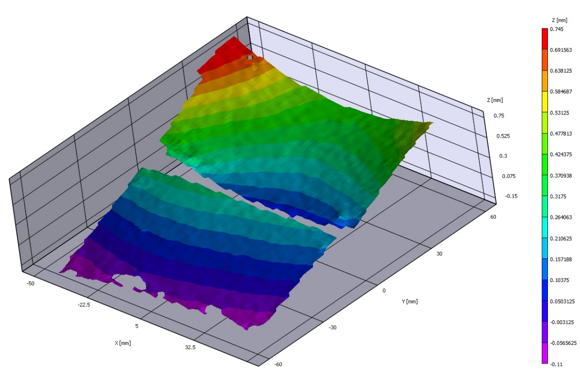

Figure 2: out-of-plane displacement measured by DIC 3D method

Figure 3

Figure 4