Keyhole Behavior During Spot Laser Welding

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Abstract

Spot laser welding is largely used in industrial manufacturing, especially in the case of small penetration depth. In order to predict the dimensions of the heat-affected zones and to understand the formation of porosities after welding operations, a thermal-hydraulic model is developed.

The preponderant physical phenomena are firstly presented. Due to the large power density (>10^9 W/m^2), the metal reaches vaporization point in less than 1 ms. A "recoil pressure" is then generated and acts like a piston on the liquid/vapor interface. Multiple reflections of the beam occur that increase the applied power. A "keyhole" is generated, driven by the recoil pressure and the surface tension competition. When the laser power stops, the keyhole closure phase starts and porosity can be formed.

In order to understand the different mechanisms, a thermal-hydraulic model is then developed with COMSOL Multiphysics® software. Two numerical methods were previously tested to track the free-surface evolution [1]. In this work, the "Laminar Two-Phase Flow, Phase Field" is used to describe the flow of the liquid metal and "the Heat Transfer in Fluids" is used for the energy balance. The different steps of the keyhole evolution (birth, closure, solidification) are studied in a unique model.

Finally, the role of the recoil pressure is studied for the digging phase and numerical results are compared with experimental data from [2]. In Figure 1, the keyhole and the "heat affected zone" shapes are plotted for two different moments. Good agreements are obtained in terms of geometrical dimensions as well as digging kinetics. The closure phase is also studied to identify mechanisms responsible for the formation of porosities and to find out how the laser power can be adapted to optimize the process.

Reference

[1] V. Bruyere et al., Comparison between Phase Field and ALE Methods to model the Keyhole Digging during Spot Laser Welding, Proceedings of the 2013 COMSOL Conference, Rotterdam, (2013).

[2] C. Touvrey-Xhaard, Etude thermohydraulique du soudage impulsionnel de l'alliage TA6V. PhD thesis, Université de Provence (Aix-Marseille I), (2006).

Figures used in the abstract

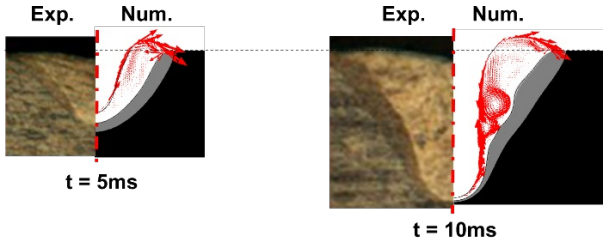

Figure 1: Comparison between experimental [2] and numerical results of melted zones.