Simple Model for Optimizing Laser Welding Properties

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This work describes a simple heat conduction model for optimizing the laser welding process. The model is compared to experimental results obtained on welding of AA6013 aluminum alloy using an Yb-fiber laser. A very good agreement had been obtained by adjusting the plasma power attenuation and material thermal conductivity coefficients.

In laser beam welding, metallurgical defects can be reduced with a fine control of the heating input and cooling rates. This control is determined mainly by the laser beam intensity hitting on the workpiece surface, the welding speed and by the thermomechanical and optical properties of the material. In addition, the flow and type of the shielding gas influence the attenuation of the incident beam intensity caused by the plasma/vapor plume formed above the keyhole. Finally, the absorption of laser radiation inside the keyhole depends on the actual location of the focal plane and on the laser beam quality, which has been continuously improved in new high brightness fiber and disc lasers. Improvements on the beam quality are responsible for increasing penetration depth and welding speed using these new lasers. At the same time, the improved laser beam quality modifies the heat input profile and thus the thermal gradient and solidification rates within the weld bead. It is well known these parameters influence metallurgical defects. Understanding the effect of these new laser sources on the welding is then fundamental to determine the optimal range of the process parameters.

In this work, we propose a simple but effective heat conduction model that is adjustable with experimental results. Several parameters process could be tested in order to obtain the actual profile of the heat input within the weld. Three different regions were considered in the model: the plasma plume just above the surface, the top of the weld and the keyhole inside the weld. The attenuation of laser intensity was taking into account only the plasma-forming region, considering an effective attenuation coefficient. In the top of the weld, convection and capillary flow increases the apparent heat conduction, which is tuned here by increasing the thermal conductivity coefficient. Inside the weld, the absorption of laser energy is strongly increased by the multiple reflections at the keyhole wall. In our model, we demonstrate that the total number of multiple reflections depends on the local laser beam divergence. This simple modification allows describing correctly the focal position influence on the weld depth. The effective attenuation and thermal conductivity coefficients were adjusted comparing the theory and the measured values of weld dimensions as shown in Fig. 1. These experimental results were obtained on bead-on plate welding of an AA6013 aluminum alloy using a 2 kW Yb-fiber laser. A correct fit between the model and the experimental results was attained by increasing of the aluminum alloy conduction thermal coefficient by 30 % and by assuming a plasma-attenuation coefficient of 3 m^{-1}.

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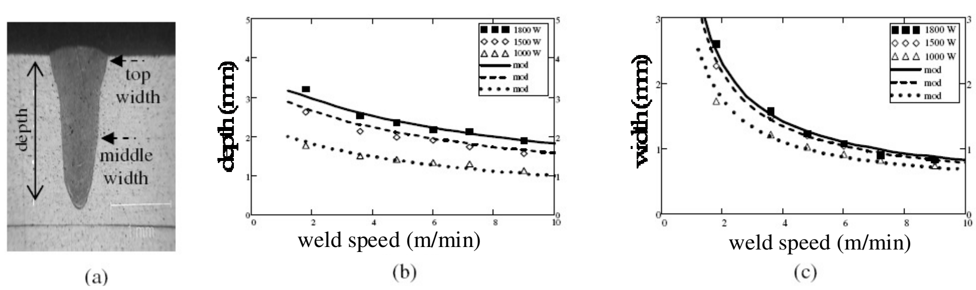

Fig. 1. (a) Weld cross section view. Model (lines) and experimental results (symbols) for weld depth (b) and top weld width (c) as function of welding speed for laser powers of 1000 W, 1500 W and 1800 W.

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