Numerical Modelling of the Plasma Discharge During Electron Beam Welding

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Abstract

One specific effect of the interaction of the intense electron beam with the metal during electron beam welding (EBW) is plasma formation in the zone affected by the beam. The parameters of the plasma are closely connected to the characteristics of the thermal action of the electron beam on the welded metal, which allows operational control and study of EBW. The plasma charge current is widely used as signal for regulating EBW.

This work describes a model for plasma formation in the crater in the liquid metal and above the EBW zone. The model is based on the solution of two equations for electron density and mean electron energy. The mass transfer for heavier particles in the plasma (neutral atoms, excited atoms and ions) is taken into account in the analysis through the diffusion equation for the multicomponent mixture. The electrostatic field is calculated using Poisson's equation. Thermionic electron emission is calculated for the crater wall. The ionization intensity of the vapour due to beam electrons and high-energy secondary and back-scattered electrons is calibrated using plasma parameters when there is no polarized collector electrode above the welding zone.

The data calculated using COMSOL Multiphysics® are in good agreement with experimental results. The plasma parameters for the excitation of a non-independent discharge are given. It is shown that there is a need to consider the effect of a strong electric field in the crater near the crater wall on electron emission (the Schottky effect) when calculating the current of a non-independent discharge. The calculated electron drift velocities are much higher than the velocity at which the current instabilities arise. This confirms the assumption for the beginning of ion-acoustic instabilities, which was also observed experimentally.