C. Modeling – a path to prevent defect formation at high welding speeds during gas tungsten arc welding

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Introduction

Productivity improvement in gas tungsten arc (GTA) welding is often achieved by increasing welding speed. However, in many cases, high welding speed can affect the quality and integrity of the weld. Currently, there is no unified model to predict the formation of weld defects such as humping and undercutting that typically occur at high welding speeds by considering various welding variables, electrode geometry and workpiece properties. What is needed is a model that can predict the initiation of these weld defects based on scientific principles. The goal of this presentation is to demonstrate a new computational model that can predict the initiation of humping considering the values of arc current, welding speed, shielding gas, electrode geometry, sulphur content in workpiece and electrode to work-piece distance in GTA welding.

Procedure

The flow of shielding gas over the weld pool surface generates high shear force which leads to formation of surface waves in the weld pool. These waves are driven by a balance between molten metal's inertia, surface tension and gravity force. In the work, we developed an analytical model based on Kelvin-Helmholtz instability theory to predict the welding parameters which initiate defects at high speed in the weld bead. This model calculates the instability of free surface in the weld pool by considering kinematic surface condition, surface tension and pressure balance on free surface. The stability of this wave or free surface depends on shielding gas velocity, density of the molten metal and shielding gas, weld pool size and surface tension of the molten metal. In the model, shielding gas velocity and density were calculated using empirical relations and the experimental data. The approximate weld pool size and shape was calculated by solving three dimensional equations of conservation of mass, momentum and energy with appropriate boundary conditions.

Results and Discussion

The effects of various welding variables, electrode geometry and weld metal composition on humping were examined. It was found that the threshold value of welding speed for the defect formation decreases with increase in current. The addition of helium in argon expands the range of operating conditions in which sound welds are produced. This behavior results from the low molecular weight of the mixed gas compared to argon that affects the arc pressure and gas velocity. Presence of sulfur in the weld metal affects the flow in the weld pool, surface tension of the molten metal and weld pool size. All these variables have non-linear interaction on each other and affect the initiation of humping. These results obtained from the model agree well with the available independent experimental data.

Conclusions

The results from the proposed model indicate that the initiation of humping is affected by the values of arc current, welding speed, nature of the shielding gas, electrode geometry, sulphur content of the steel and electrode to work-piece distance during GTA welding. Good agreement between the model predictions for the initiation of humping and the independent experimental data for various welding conditions show that the model can be used for the prevention of weld defects that occur typically at high welding speeds.