B. Statistical and Numerical Analysis for Optimization of Aluminum Pipe Welding

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Introduction

Porosity is a significant issue for qualifying welding procedures for thin wall aluminum pipe to ASME codes. In this work, numerical and statistical modeling was carried out to assist in the optimization of a variable polarity GTAW process for welding of 2-inch Sch 10 6061 aluminum pipe.

Procedure

The statistical modeling was accomplished using results of designed experiments. The experimental parameters included: variable polarity waveform EN-EP time (25-2, 12-2, DCEN), K2: pulse frequency (H,L), electrode stickout (0.1, 0.5, 1 electrode diameters), K3: gas flow rate (H,L), wire and tube high temperature/humidity exposure times (0,2,4 hrs.) and pipe fitup gap (0,0.05, 0.1 in). The numerical simulations were carried out using a Volume of Fluid simulation code with a Gaussian heat input distribution based on this efficiency. Arc surface pressure and current were also simulated with Gaussian distributions, and the heating, melting, melt flow and solidification of the weld metal were predicted.

Results and Discussion

The statistical analysis summarized in Figure 1 showed that, surprisingly, the variable polarity procedures tended to produced more porosity than DC current procedures. It was conjectured that the welding arc fluctuations introduced by the variable polarity processes promoted aspiration of atmospheric oxygen, hydrogen and moisture into the welding arc. Also surprisingly, the presence of a small joint gap significantly reduced the amount of porosity in the welds. Exposure either welding wire of prepared tube assemblies in a high humidity, high temperature environment for only 4 hours resulted in large increases in porosity.

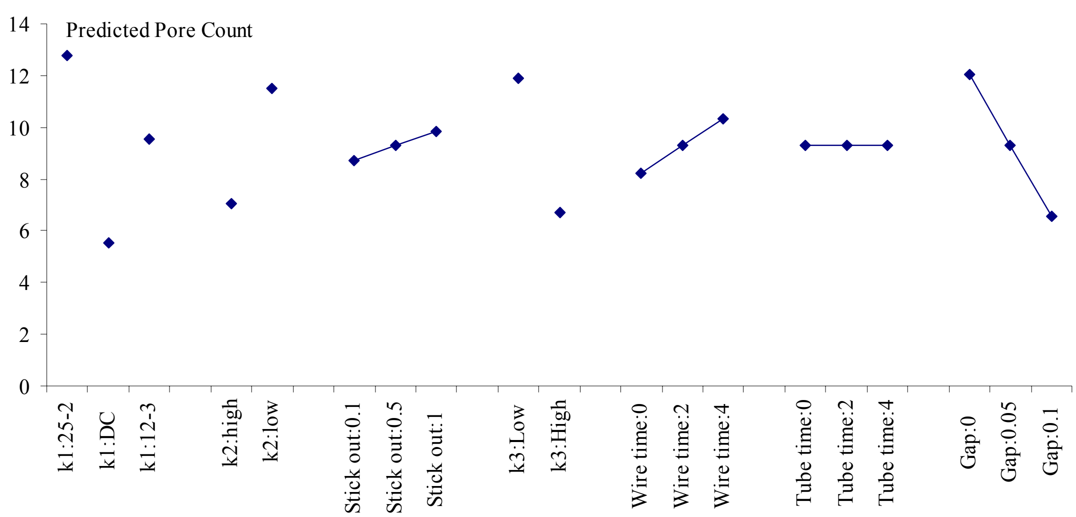

Figure 1. Main effects plot for count of pores

The heat input of the variable polarity and DC GTA welding processes as measured using liquid nitrogen calorimetry is shown in Figure 2. The heat inputs of all processes was found to be in the range of 55%. The surprisinging low DCEP heat input was thought to be due to the very low current required for this experiment. The EP current was much higher in the 10-4 variable polarity waveform used to measure the efficiency of that process.

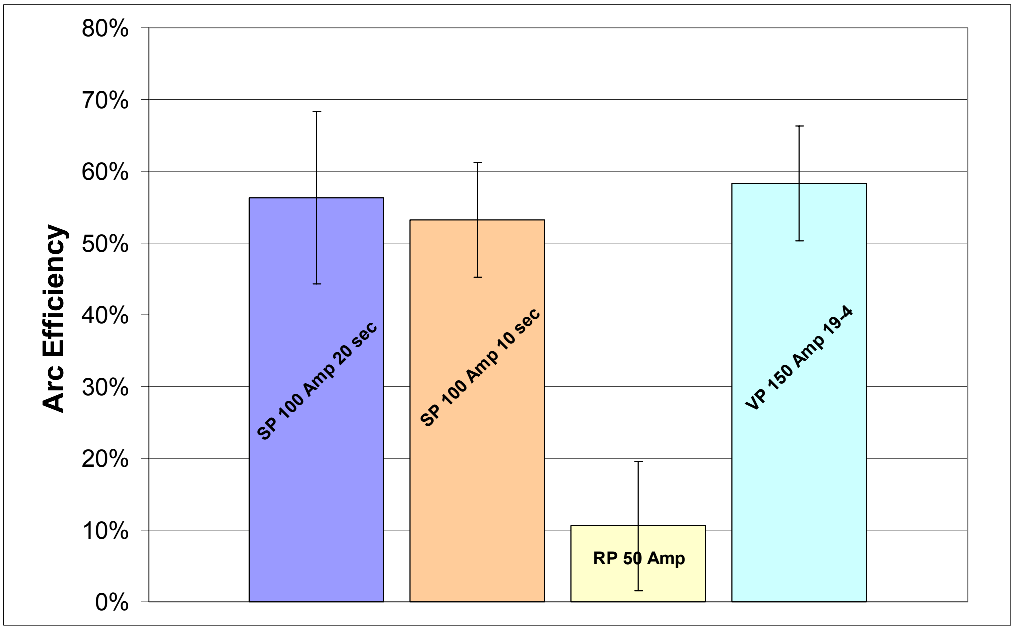

Figure 2. Arc efficiency of GTAW welding

With the measured heat inputs, the simulations adequately predicted weld penetration and back bead width. As an illustration of its usefulness, the simulation was used to optimize the heat input profile around the tube circumference for varying travel speeds (Fig. 3).

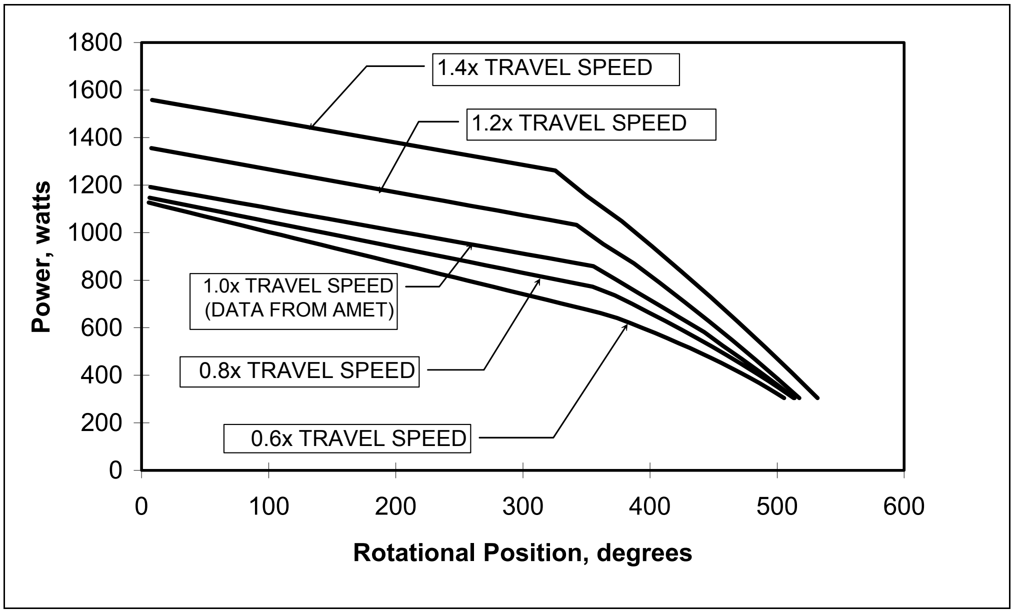

Figure 3. Heat input profiles that produce a constant weld back bead width along the entire weld, plotted for 5 different travel speeds.

Conclusions

In this research, a variable polarity GTAW process was optimized for porosity-free welding of aluminum piping. The welding parameters were varied according to a designed experiment and the results were analyzed to determine the optimum settings. In addition, a numerical simulation of the process to optimize the heat input so as to obtain consistent penetration profile around the tube and in the weld overlap area.