TIG-MIG Hybrid Welding

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Tungsten inert gas-metal inert gas hybrid welding (TIG-MIG) combines the advantages of tungsten and metal inert gas welding. It can efficiently produce high-quality weld joints that meet modern manufacturing quality and efficiency requirements. Based on heat transfer, fluid dynamics, and electromagnetic theory, a three-dimensional coupled transient model of arc-droplet interactions in TIG-MIG hybrid welding was established. In this study, the temperature field, flow field, electromagnetic force, pressure, and current density parameters were analyzed in the arc space. The results show that introducing TIG welding has a significant impact on MIG welding.

TIG-MIG hybrid welding numerical simulation arc behavior metal transfer

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1. Development of TIG-MIG hybrid welding

To develop TIG-MIG hybrid welding, Yang et al. [1] used PID closed-loop control to regulate interactions between two arcs and develop the thermomechanical balance of the molten pool. It was found that using direct-current electrode-positive mode with both TIG and MIG helped to increase weld bead penetration, while using the direct-current electrode negative mode with both TIG and MIG made cleaning the oxide film from the workpiece and suppressing spatters easier. Kanemaru et al. [2] found that there was more metal vapor in TIG-MIG arcs than in single-MIG arcs. This might change the electrical potential inclination of the arc. Moreover, some of the MIG current flowed directly into the TIG electrode from the MIG wire without flowing through the workpiece. This current-divided flow in the hybrid arcs produced a lower total heating efficiency with TIG-MIG than with the single-TIG or -MIG method, and the life of the tungsten in the two arcs was very short as a high welding current was needed to keep the TIG arc (leading arc) straight. To decrease the current-divided flow in TIG-MIG and increase the lift of tungsten, Ding et al. [3] decreased the total welding current to 134A and successfully jointed ferritic stainless steel and magnesium alloys via the TIG-MIG welding-brazing method. Few pores or spatters appeared because of the stable droplet transfer during this welding-brazing process. However, the extremely low heat input decreased the effectiveness of the TIG-MIG hybrid welding. Zong et al. [4] inclined the TIG torch backwards to decrease the TIG current, as the leading TIG arc would be straightened by the repulsive force of the MIG arc. The distance between TIG and MIG arcs was increased to 5.0 mm to avoid current-divided flow in the TIG-MIG method. Experimental temperatures and fluid flows on weld pool surfaces showed that hybrid arcs tend to encourage high-temperature molten metal to move transversely and decrease the backward velocity of molten metal. All of the results mentioned above indicate that the arc and droplet behaviors are key factors that affect heat and force distributions on the weld pool surface, affect the welding process stability, and affect the weld microstructures [5][6][7]. Therefore, it is important to study the interaction mechanisms among the two arcs and the droplet, as these redistribute arc heat and electromagnetic forces on the workpiece and change the droplet trajectory in the arc.

2. Numerical Simulation of in TIG-MIG Hybrid Welding Behaviors

A numerical si[8][9][13,14]. This is also an economic way to provide the quantitative results for heat and mass transfer in the arc and weld pool, which are barely detected when using only experiments. Moreover, building a simple and reliable simulation model is one of the key issues in implementing digital twin technology in the manufacturing industries [10]. Mishima et al. [11] developed three-dimensional TIG-MIG numerical models to study the effects of torch angles on two arcs behavior. The arc plasma temperature changed with the included angle of the two arcs. The lowest heat input occurred when the TIG torch was at 0° and the MIG torch was at 60°. However, the influence of droplet transfer on the arc behavior remains to be studied. Zhou et al. [12] utilized a Gauss heat source model to analyze the heat transfer process during double-sided TIG-MIG processes. It was easier to achieve full penetration using these processes than with the single-MIG method, as the TIG arc increased the MIG arc heating effect during double-sided welding. Chen et al. [13] developed adaptive models of hybrid TIG-MIG arcs to predict the effects of inclined arcs on the workpiece temperature distribution and weld bead geometry. When the distance between the two arc centers was 10.0 mm on the workpiece, heat from the trailing TIG arc did not change the weld pool width because the TIG current was only 125 A. The studies by Zhou and Chen et al. were done to develop the classic heat source models, which could not provide the quantitative distribution of the current density, fluid flow, and electromagnetic force in the two arcs. As a result, the coupling mechanism of the two arcs still needed to be studied. Lou et al. [14]simulated workpiece temperature fields at various electrode distances. The best distance between TIG and MIG electrodes was 10.0 mm because of the preheating effect of the leading TIG arc. The weld pool could be separated into two parts when the electrode distance exceeded 12.0 mm. At this point, the synergistic effect of using two arcs on the workpiece disappeared. In fact, the attractive or repulsive electromagnetic forces produced during TIG-MIG processes not only change arc plasma behavior [15], but also affect droplet behavior. As a result, heat and mass transfer in the weld pool change dramatically, thus influencing the welding process and bead formation [16].

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