Weld pool development and stirring behavior of AlCu4SiMg aluminum alloy during GTA welding hybrid a longitudinal electromagnetic field†

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KEY WORDS: (Welding pool) (GTAW) (Magnetic field) (Aluminum alloy) (Development) (Stirring motion)

1. Introduction

In GTA Welding with a longitudinal electromagnetic field (LMF-GTAW), the formation, microstructure and mechanical properties of aluminum alloy are studied. However, there is still a lack of practical or numerical detailed understanding of the formation of the welding pool during LMF-GTAW. For example, the effect of the longitudinal electromagnetic field on the formation of the weld pool is not clear yet. The additional electromagnetic force can not only affect the behavior of welding arc, but also change the force balance state and heat transfer of metal molten body of the weld pool.

In this paper, we focus on the need for understanding the weld pool's formation is AlCu4SiMg aluminum alloy during LMF-GTAW by a new mathematic model and finite element method (FEM).

2. A New Quasi-3D Transient Model

The welding arc and weld pool are described relative to a cylindrical coordinate, assuming rotational symmetry around the arc axis owing to the fixed arc in GTAW. The flow is assumed to be laminar, and a quasi-three-dimensional transient model is built up. The detailed governing equations, additional electromagnetical driving body force expression, boundary conditions and numerical method are given in our previous paper [1]. The governing equations are solved

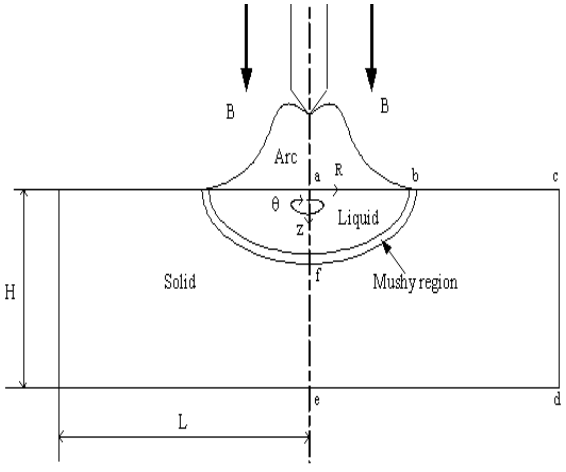

Fig.1 Diagram of FEM model in LMF-GTAW

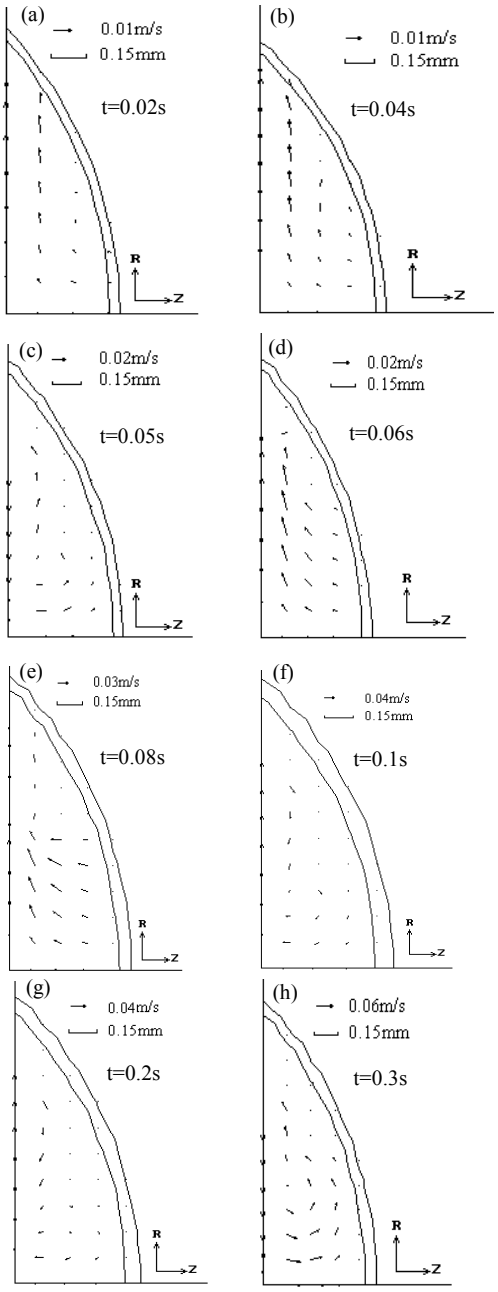

Fig.2 The gestation period of the LEM-GTA Welding pool

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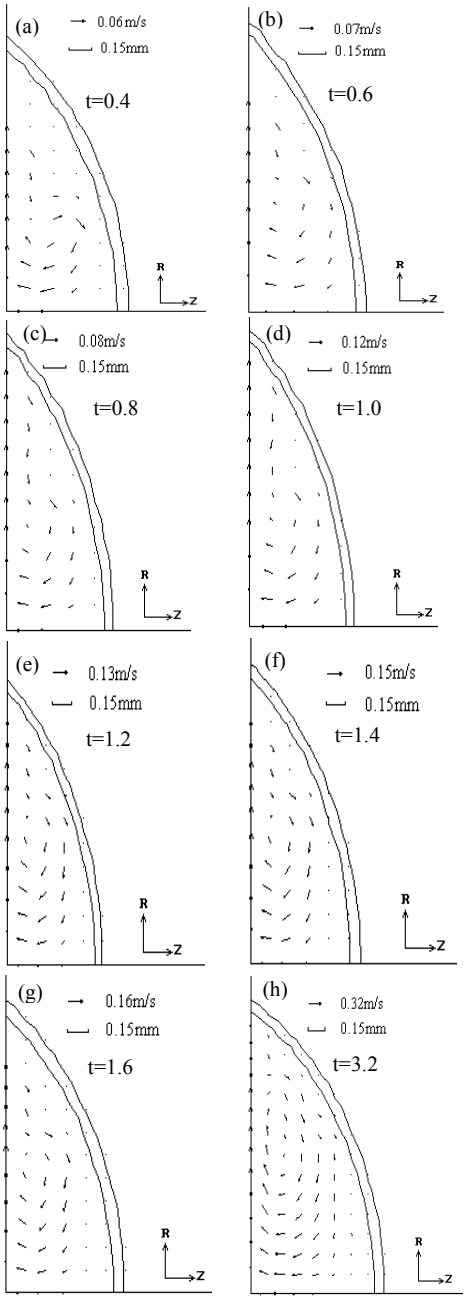

Fig.3 The developing period of LEM-GTA Welding pool

iteratively by the FEM numerical procedure. The type of material, namely, AlCu4SiMg aluminum alloy (3.9~4.8% Cu, 0.4~0.8% Mg, 0.4~1.0% Mn, 0.6~1.2% Si, Al balance) is calculated. The physical parameters given to a quasi-three-dimensional transient model are from the literature [2].

3. Results and Discussion

Figures 2 and 3 show the two-dimensional fluid flow velocities of LMF-GTAW pools during the gestation period and at the developing period respectively, the welding current is 100 A and the hybrid electromagnetic field is 0.01T. The direction of molten metal flowing is random in Fig.2.

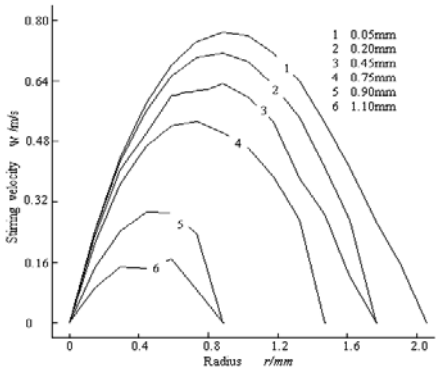

Fig.4 The stirring speed of LEM-GTA Welding pool depending on the depth of welding seam

The flowing characteristic of molten metal becomes a stable circular loop at the end of the gestation period, and the welding time is about 0.3s. The "step-style" flowing shape appears in welding pool, as shown in Fig.2h.

The direction of molten metal flowing remains constant throughout the developing period, shown in Fig.3. The stable flowing path is from the center of welding pool to the edge of welding seam, which means the shape of welding seam is the flat, so called “wide and shallow”. The “step-style” is disappears at the end of the developing stage. A stable flowing is formed in welding pool.

The flowing state of welding pool is locally affected by the additional electromagnetic field. Specially, a stir driving force forms a stir action in welding pool, shown in **Fig. 4**. Compared to the traditional GTAW welding process, LMF-GTAW has a significant rotation motion about the symmetry axis (oz axis, θ direction, shown in Fig.1).

Although the molten or solid state aluminum alloy is not a ferromagnetic material, there also exists the distribution of welding current flux in the welding pool, so the molten metal in the welding pool is carried in response to the additional electromagnetic forces imposed upon it. Under the influence of the hybrid magnetic field, the maximum stirring speed is present at the middle of the radius with the same depth. The radius center region has a stronger electromagnetic driving force in comparison with the others, due to the fact that the bigger zonal components of welding current flux is perpendicular to LFM and a lower viscosity or flowing resistance at higher temperature, which then produces strong stirring behavior at the middle of radius, resulting the electromagnetic stir in welding pool.

4. Conclusions

Based on the numerical calculation of a hybrid electromagnetic field in the molten metal flowing unified model, we conclude that LMF affects the flowing state of molten metal at the welding pool. The welding current fluxes, direction of hybrid electromagnetic and local temperature of molten metal determine the stirring behaviors of the LMF attachment during the GTAW process.

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