Flowing behaviors affected by different parameters and multi-materials in GTA weld pool hybrid a longitudinal electromagnetic field†

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1. Introduction

The electromagnetic field hybrid arc welding technique is applied in many manufacturing fields, however there is a lack of detailed understanding of flowing behavior of molten metal at a weld pool during GTA welding hybrid of longitudinal electromagnetic field (LMF-GTAW). For example, the impact of longitudinal electromagnetic field to the flowing behaviors of weld pool is not yet clear. Because the hybrid electromagnetic field can not only affect the behavior of the welding arc, but also change the driving force and flowing of molten metal at the weld pool.

In this paper, we focus on the need for understanding weld pool's flowing behavior affected by different parameters and multi-materials in LMF-GTAW using a numerical simulation research method.

2. A New Quasi-3D Transient Model

The weld pool is described relative to a cylindrical coordinate, assuming rotational symmetry around the arc axis owing to the fixed arc in GTAW. The flowing is assumed to be laminar, and a quasi-three-dimensional transient model is built up. The key additional electromagnetic driving body force expression and simulation procedure are given in our previous paper [1]. The typical materials, namely, AlCu4SiMg aluminum alloy, Q245R (STB42) carbon steel and 1Cr18Ni9Ti stainless steel are calculated. The different welding parameters, including surface tension coefficient welding current, magnetic induction and magnetic direction, are considered in the quasi-three-dimensional transient model and simulation procedure [2]. The basic welding current is 100 A and hybrid electromagnetic field is 0.01T in this paper.

Figure 1 shows that the LMF quells the molten metal motion on the depth direction (Z) and increases the radial motion(R), the velocity on the surface of weld pool and the width. Same conditions are carried out in GTAW and LMF-GTAW.

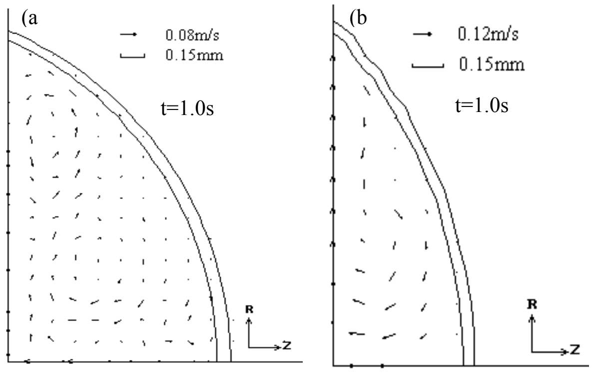

Fig. 1 The flowing at AlCu4SiMg aluminum alloy welding pool: (a) GTAW; (b) LMF-GTAW.

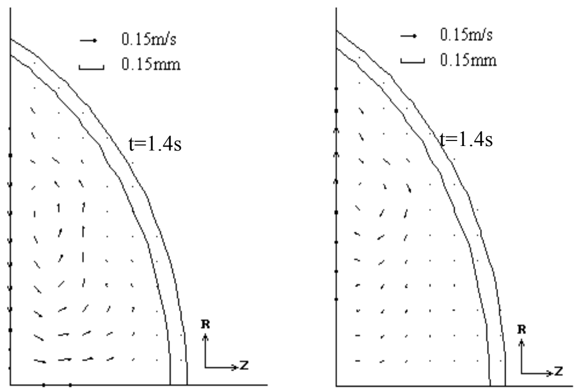

Fig. 2 The flowing affected by surface tension coefficient in LMF-GTAW: (a) 1.1×10^{-4}; (b) -1.1×10^{-2}.

3. Results and Discussion

Figure 2 shows the surface tension coefficient can change the flowing direction, the large surface tension coefficient (absolute value) makes the radius of the stable circular loop decrease. The centre of circular loop has also a general exodus, the flowing in homogeneity increases and the speed near the weld pool's surface is higher than that of

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other parts that are associated with surface tension coefficient absolute value.

Although a strong hybrid electromagnetic field can make a strong stirring motion, the increased magnetic induction has little change on the flowing mode or shape on the ROZ cross-section of weld pool. But the flowing velocity of molten metal is held in the ROZ plane, as shown in **Fig. 3**. The strong stirring behavior is one of reasons.

Undoubtedly, the increased welding current can lead to fast flowing, shown in **Fig. 4**. It is also contribute to the stable flowing path and uniform circular loop. The "step-style" about the flowing loop disappears at the developing period of the weld pool. A stable even flowing status is formed at the welding pool with the big welding current, as a result of higher temperature.

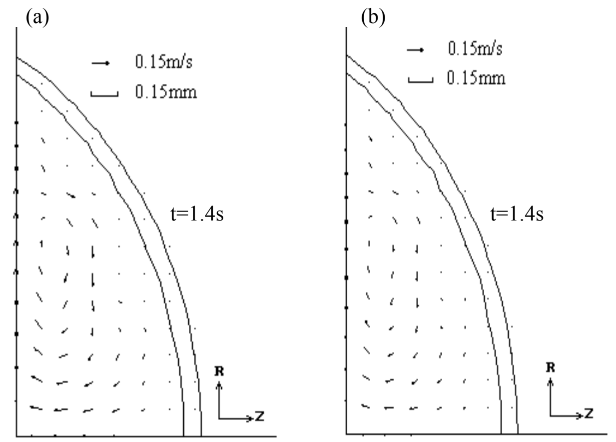

Fig. 3 The flowing affected by magnetic induction in LMF-GTAW: (a) B=0.02T; (b) B=0.03T.

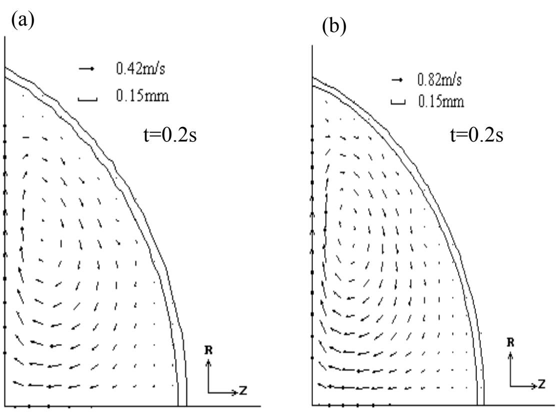

Fig. 4 The flowing affected by welding current in LMF-GTAW: (a) I=150A; (b) B=180A.

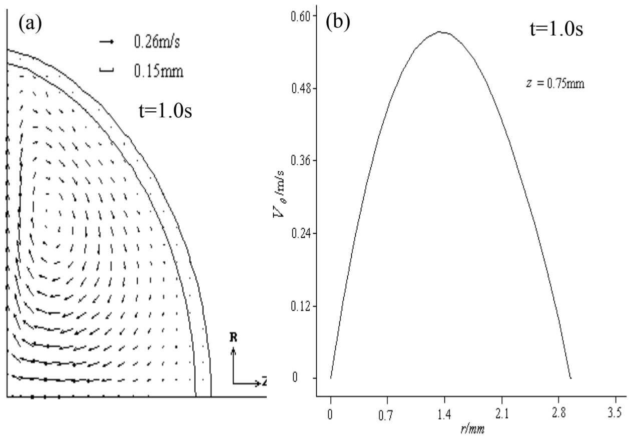

Fig. 5 Flowing at STB42 carbon steel LMF Weld pool: (a) ROZ cross-section; (b) stirring rotation motion.

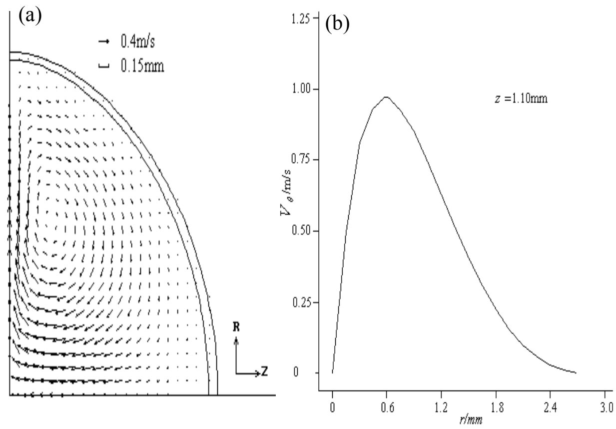

Fig. 6 Flowing at 1Cr18Ni9Ti stainless steel LMF weld pool: (a) ROZ cross-section; (b) stirring rotation motion.

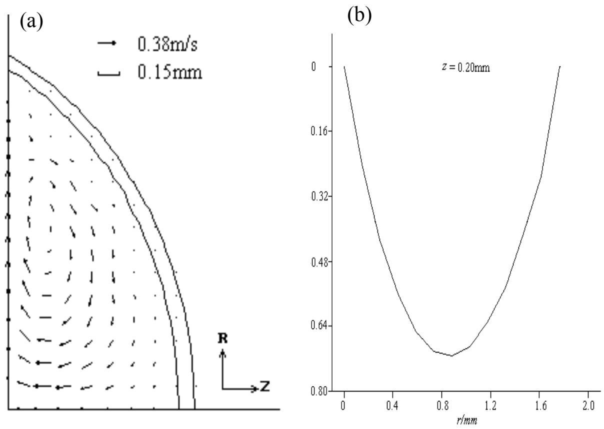

Fig. 7 Flowing at AlCu4SiMg aluminum alloy LMF weld pool: (a) ROZ cross-section; (b) stirring rotation motion with an inverse direction of magnetic field.

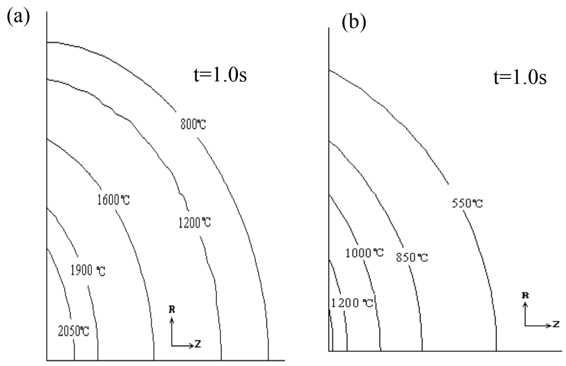

Fig. 8 The temperature field of LMF-GTAW: (a) STB42 carbon steel; (b) AlCu4SiMg aluminum alloy.

Figures 5, 6 and 7 shows the flowing at the LMF-GTA welding pool with different materials, including STB42 carbon steel, 1Cr18Ni9Ti stainless steel and AlCu4SiMg aluminum alloy respectively. The 1Cr18Ni9Ti stainless steel has the highest flowing velocity due to the lowest thermal conductivity properties.

Under the influence of hybrid magnetic field, the maximum stirring speed of 1Cr18Ni9Ti stainless steel is not present at the middle of the radius with the 1.10mm depth shown in Fig.6b. The curve of stirring velocity is also not of the symmetry shape. The peak is close to the welding seam's centre because of the thermo-physical properties.

Compared to the ferrous materials, the non-ferrous metal (such as aluminum alloy) also has an obvious stirring rotation motion around their symmetry axis (oz axis). In particular, the direction of stirring rotation motion is also changed, but the stirring strength is not changed, while the direction of the hybrid electromagnetic field changes at LMF-GTA welding pool, shown in Fig.7b.

Figure 8 shows the temperature field at LMF-GTA welding pool of AlCu4SiMg aluminum alloy and STB42 carbon steel respectively, when the welding time is 1.0 second. The STB42carbon steel has a higher temperature than that of AlCu4SiMg aluminum alloy, resulting from material properties about the heat transfer on traditional or LMF welding process.

4. Conclusions

The LMF quells the molten metal motion on the direction of depth, increases the radial motion and the velocity near the surface of weld pool. The surface tension coefficient can change the flowing direction. The increased magnetic induction can hold the flowing velocity of molten metal on the ROZ plane. The 1Cr18Ni9Ti stainless steel has the highest flowing and stirring velocity due to the thermal physical properties in the material.

References

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[2] Luo J, Jia CS, Wang YS, Xue J and Wu YX: Acta Metall. Sin., 37(2001), pp212-219.