Title	Numerical simulate on the coupled arc and pool for GTAW using a unified mathematical model
Author(s)	Yongping, Lei; Yaowu, Shi; Jian, Lin et al.
Citation	Transactions of JWRI. 2010, 39(2), p. 215-217
Version Type	VoR
URL	https://doi.org/10.18910/12119
rights	
Note	

Numerical simulate on the coupled arc and pool for GTAW using a unified mathematical model†

LEI Yongping*, SHI Yaowu*, LIN Jian *, LU Zhenyang **, XIAO RONGSHI*** and MURAKAWA Hidekazu****

KEY WORDS: (Numerical simulation) (Unified mathematical model) (Coupled arc and pool) (Boundary-fitted coordinate system) (GTA) (Welding)

1. Introduction

It is well known that in tungsten arc (GTA) welding process, the formation of weld is accompanying the interaction between the weld arc and pool. The arc heat melts the work-piece and forms a pool. Once the molten pool begin to form, several important physical chemistry phenomena, such as depression of weld pool surface, radiation and convection heat loss from the free surface, will simultaneously take place at the pool surface. These phenomena turn back again to influence the arc thermo-fluids phenomena. Therefore, the weld arc and pool essentially compose of an integrated system. But in the most of numerical simulation models, the weld arc and pool are deal with as an independent model, or the weld pool surface is assumed as flat [1], or specified weld pool shapes were used [2].

In this paper, a unified mathematical model for a stationary Gas Tungsten Arc (GTA) welding was developed. The model was composed of two sub-models describing the heat transfer and fluid flow in weld arc and pool respectively.

2. Numerical Solution Strategy

As we know, the welding arc and pool constitute a whole system, but they have different physical characteristics. Therefore, this system can be divided into two sub-systems which connected by a variable common interface. The unified computational model is schematically illustrated in **Fig. 1** in which the different driving forces, the coordinate system and computational regions of welding arc and weld pool are shown. The two set of governing equations and auxiliary formulas, controlling the welding arc and pool respectively, were solved separately by a finite difference method. In the calculation, the interface profile between welding arc and pool is updated dynamically in a small time step until it satisfied the convergence criterions, and then the calculating regions for the two sub-models are re-meshed. A boundary-fitted coordinate system was adopted to precisely describe the cathode shape and weld-pool free-surface profile as well as the unknown molten shape of work-piece during welding. This calculation method has a "clear" interface characteristics, and is different from the whole model with a "fuzzy" interface.

The detailed governing equations, auxiliary formulas, boundary conditions and numerical method are given in the paper [3].

This model is also can be used for the situation of a water cooled cupper work-piece. In that cases the arc physical phenomena can be study deeply.

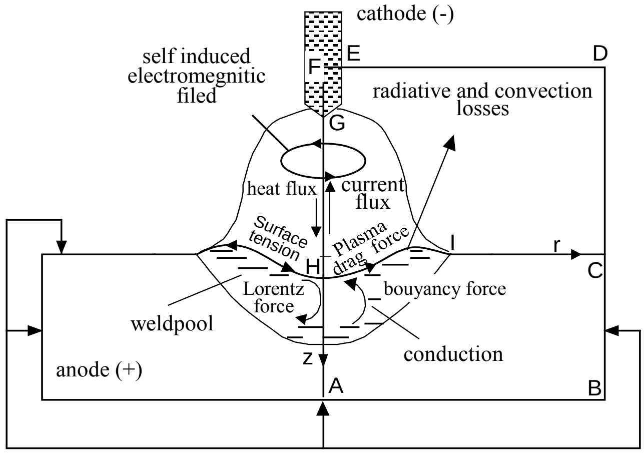


Fig.1 Schematic diagram of stationary GTA welding with computational regions and driving forces

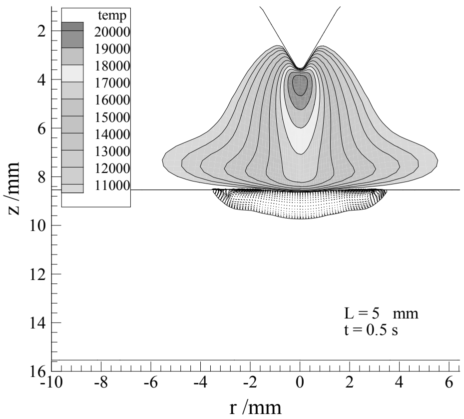
3. Results and Discussion

The material used for calculation was AISI 304 stainless steel. The shielding gas used for calculation was pure argon and the thermo-physical properties of the argon plasma at atmospheric pressure are obtained from Murphy [6]. The calculation conditions are 5mm arc length and 60° cathode vertex degree, 200A welding current, 14V welding voltage, 3.2mm the cathode diameter, 10.0 L/mm^{-1} shielding gas flux.

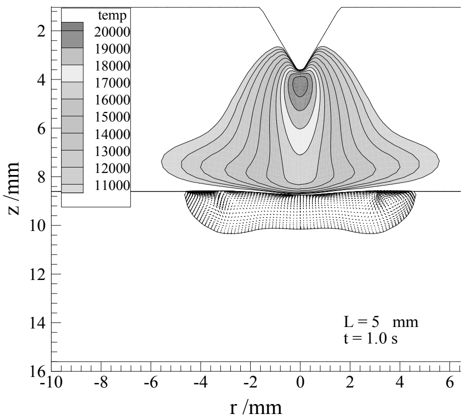
Figure 2 shows a set of typically calculated results. The arc temperature fields, the fluid flow in the weld pool and the weld pool shapes at different welding time. It can be

† Received on 30 September 2010
* School of MSE, Beijng University of Technology, China
** School of MS&AET, Beijng University of Technology, China
*** LERI, Beijng University of Technology, China
**** JWRI, Osaka University, Japan

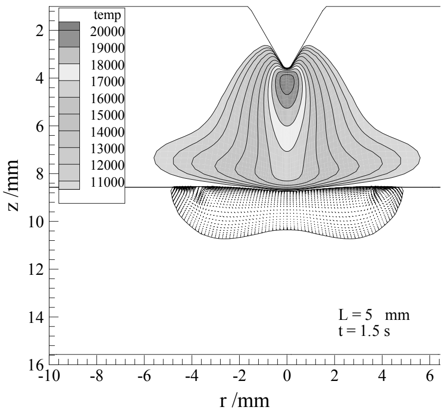
Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan



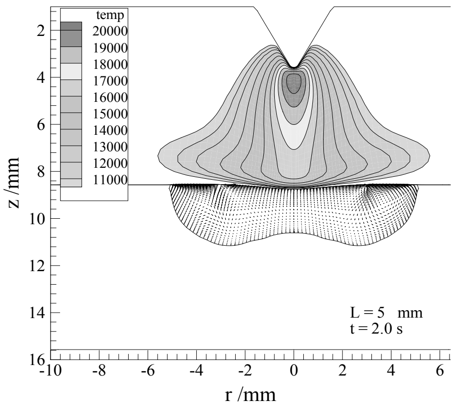
(a) heating time is 0.5 second



(b) heating time is 1.0 second

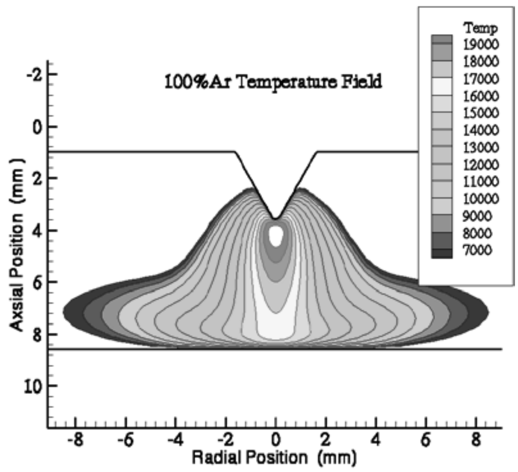


(c) heating time is 1.5 second

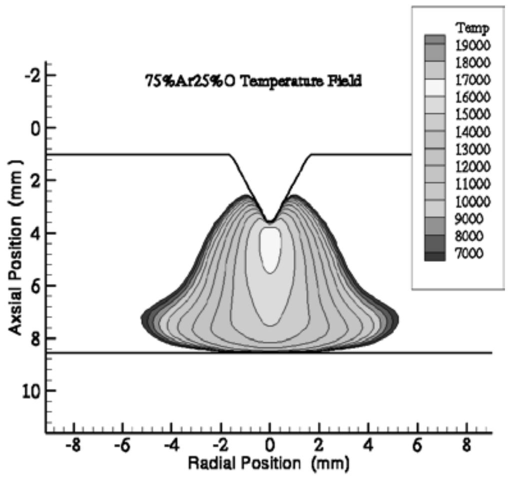


(d) heating time is 2.0 second

Fig.2 Weld arc temperature distribution and weld pool shape and size under different heating time



(a) 100% Ar shielding atmospheres



(b) 75%Ar25%O shielding atmospheres

Fig3 Temperature fields in two kind of shielding atmospheres.

seen that the volume of the weld pool is increasing with the welding time extending, but the change of arc temperature distribution is slight.

Figure 3 shows the temperature fields in two kind of shielding atmospheres. It can be see that the highest temperature decrease and the high temperature area is contracted into the arc center.

4. Conclusions

(1) The developed model is suitable to describe the behavior of the integrated welding arc and pool system.

(2) The two-way interaction of the arc and pool subsystems can be calculated by the two sub-model with “clear” interfaces.

(3) The influence of weld pool deformation on the arc temperature fields is very small when the welding current is 200A.

Acknowledgment

This work was supported by the Beijing Nature Science Foundation under grant No.3102002 which is gratefully acknowledged. The author also thanks Prof Murphy A.B, CSIRO Division of applied physics, Australia, for his supplying the thermo-physical properties of the argon plasma.

References

[1] Lowke J.J., *Proceedings of International Symposium on Theoretical Prediction In Joining and welding*, Editor M.Ushio, JWRI, Osaka University, 1996, 1-9

[2] Choo R.T.C., Szekely J., Westhoff R.C., *Metall. Trans. B* ,1992, 23B: 357-369

[3] Lei Y.P., Gu X.D., Shi Y.W. and Murakawa H., Acta Metallurgica Sinica (Chinese), 2001, No.5, 537-542.