THE WELD POOL DYNAMICS IN THE TANDEM WELDING

Hong Wang[1], XiangZhang[2], XingChen[3], Zhiwei Liu[4]

[1,2,3,4]*School of Materials Science and Engineering, Taiyuan University of Science and Technology*

[1]***bwd1963@163.com***

Abstract

The tandem welding process establishes a means for increasing both the travel speed and deposition rate. Electromagnetic force models of the tandem weld pool are developed. Thermal fields and flow fields under tandem heat sources are simulated. Simulation results show that flow characteristics of the weld puddle are affected by source process parameters.

Key words: *Temperature field; Flow field; Welded pool; Model; Tandem welding*

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INTRODUCTION

Welding is the most important process in manufacturing industry. In today's economic climate, fabricators are increasingly under pressure to reduce costs and substantial benefit can be achieved by increasing productivity. One of the most versatile arc welding processes is MIG/MAG welding, and in recent years, there have been a number of process developments to enhance deposition rate, and hence productivity. Tandem gas metal arc welding (GMAW) differs from conventional GMAW as two welding wires are passed through the same welding torch. A single torch with two contact tips is used to feed both wires into a single weld pool.[1] Tandem welding is a welding technology featured by that two independent electrodes are arranged parallel to weld line and that welding is performed by controlling them individually under separate welding conditions while keeping the distance between the two electrodes at constant[2-7]. Usually using more current to get higher productivity will cause the change of welded pool and arc shape. The fluid flow of the welded pool of the tandem welding processing is one of the most important factors affecting weld quality. The heat flux in the tandem welding and its effects on melt pool are studied in the paper.

MODELING OF WELDING HEAT SOURCE IN THE TANDEM WELDING

Fig.1 is the tandem welding diagrammatic sketch. The leading and trailing arcs play welding heat source roles in tandem welding. The heat flux from the leading arc acts on top surface of the welded workpiece, the temperature of the metal heated rise. While the temperature comes to melting point, a melt pool is formed. Simultaneously, the trailing arc acts on the melt metal, the welding pool sizes such as its depth and width changed. In the other hand, the pointed end of the filler metal is also melt by the tandem welding arc, a droplet is formed. There is a lot of heat in the droplet. When the melt metal droplets enter into welding pool, the mass transfer and heat transfer will affect the temperature distribution and the fluid flow of the welding pool. In tandem gas metal arc welding, there is a electromagnetic interference between the two adjacent arcs. Hence welding heat source is made of two parts including arc heat and droplet heat, and the interaction between leading arc and trailing arc can be taken into account by a arc deflection parameter.

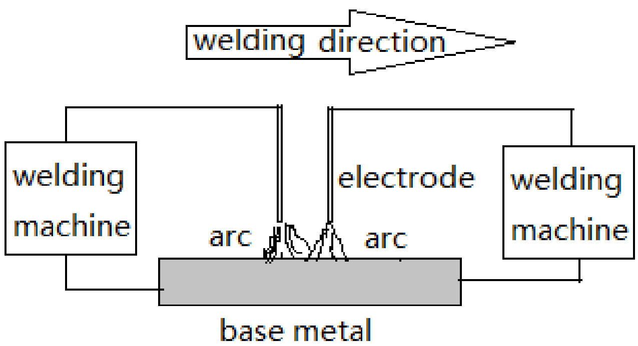


Fig.1 The diagrammatic sketch of the tandem welding

For determination of the fluid flow in the welding pool and temperature field in the entire workpiece, the equations of energy, mass, momentum conservation were solved in order to obtain the temperature distribution in the entire workpiece and the welding pool dimensions.

MATERIALS PROPERTIES FOR THE WELDING POOL

Table 1 lists the transport properties of low carbon steel Q235. The size of the plate used in this paper is a rectangular block (90 × 60 × 6mm). The heat source is assumed to be located at the center of the plate. The materials properties of the low carbon steel Q235 can be see the reference [8].

Heat source equations have been used to solve just the energy balance equation with appropriate initial and boundary conditions. The tandem MIG welding is somewhat more complicated than just the single MIG welding because of interaction between the leading arc and trailing arc. The volumes' heat source equation can be expressed as

$$q_L(x,y,z)=\begin{cases} x-\frac{D_E}{2}+l_L-vt\geq 0 \\ \frac{6\sqrt{3}U_L I_L f_f\eta\cdot\cos^2\alpha_L}{\pi\sqrt{\pi}a_1 bc}\exp\left(-\frac{3(x-\frac{D_E}{2}+l_L-vt)^2}{(\frac{a_1}{\cos\alpha_L})^2}-\frac{3y^2}{b^2}-\frac{3z^2}{(\frac{c}{\cos\alpha_L})^2}\right) \\ x-\frac{D_E}{2}+l_L-vt\leq 0 \\ \frac{6\sqrt{3}U_L I_L f_r\eta\cdot\cos^2\alpha_L}{\pi\sqrt{\pi}a_2 bc}\exp\left(-\frac{3(x-\frac{D_E}{2}+l_L-vt)^2}{(\frac{a_2}{\cos\alpha_L})^2}-\frac{3y^2}{b^2}-\frac{3z^2}{(\frac{c}{\cos\alpha_L})^2}\right) \end{cases} \quad (1)$$

where U_L、U_T、I_L、I_T are the leading electrode arc voltage, the trailing electrode arc voltage, the leading electrode arc current and the trailing electrode arc current, respectively. D_E is the distance between the leading wire and trailing wire， l_L ,l_T are the deviation of the leading arc and trailing arc, respectively. V is welding speed， t is welding time, ηis welding heat efficiency. a_1， a_2， b， c are double ellipsoidal leading semi-major axis， trailing semi-major, minor semi-axis and depth, respectively. α_L， α_T are the leading arc deflection angle and the trailing arc deflection angle, respectively[9].

$$\alpha_L=\arctan\left(\frac{l_L}{L_L}\right), l_L=\frac{I_T L_L^2}{2I_L D_E}, \alpha_T=\arctan\left(\frac{l_t}{L_T}\right), l_T=\frac{I_L L_T^2}{2I_T D_E} \quad (2)$$

RESULTS AND DISCUSSIONS

The numerical package FLUENT was used to solve the transport equations. The three dimensional code is based on the SIMPLE algorithm[10].

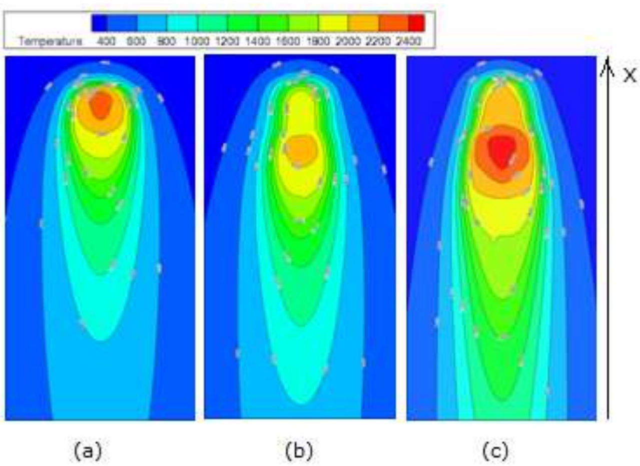
Control volume method is employed to solve the discrete governing equations. Dynamic evolutions of the geometrical profile, dimension and fluid flow for the molten pool have been simulated.

Table 2 lists single MIG welding parameters and tandem welding parameters.

Table .2. Welding parameters used in the simulation

Case	Welding method		Weld current (A)	Heat input (W)	Wire feed Rate (mm/s)	Weld voltage (V)	Welding speed (mm/s)
a	Single MIG		350	7000	9	20	15
b	tandem	leading	200	4000	5		
		trailing	150	3000	4		
c	tandem	leading	370	7400	10		30
		trailing	330	6600	8		

Fig.2 is the temperature distribution on the top surface of the melt pool at different welding heat input. The welding heat source is moved in the direction X.The liquidus temperature of welded materials low carbon steel Q235 is about 1793K. The welding pool shape can be attained by the temperature field of low carbon steel Q235. When the heat input is 7000W for the single MIG welding, egg-like melt pool is formed, the maximum temperature is at about 2400K, and at the same heat input for the tandem MIG welding, the maximum temperature is about 2100K, its pool shape looks like a bowling，a thin and elongated melt pool. When larger power heat of tandem MIG welding is used at higher welding speed, the melt pool shape lookslike a white gourd, a thick and strong melt pool. Fig.2(b) and (c) shows that the position of the maximum width of the welding pool in the tandem MIG welding is at the centre of the trailing heat source, larger heat input and higher welding speed make welding pool wider and longer. Fig.2 shows that depth of the melt pool when heat input and/or welding speed are changed. The accumulative energy from the leading heat source and the trailing heat source make the position of the maximum temperature and the maximm depth close to the trailing heat source, but there is a nonsequent folding in the isothermal curve at 1900K.Fig.3 is the velocity vector distribution in the welding pool. Fig.3 shows that there are three vortexes in the tandem welding pool than that in the single MIG welding pool. There is a more obvious nonsequent folding in the fig.3(c) at the isothermal curve of 1900K. there is a more intense convection in the welding pool of the tandem MIG welding. The vortex formation in the welding pool strengthens the fluid flow in the convection.



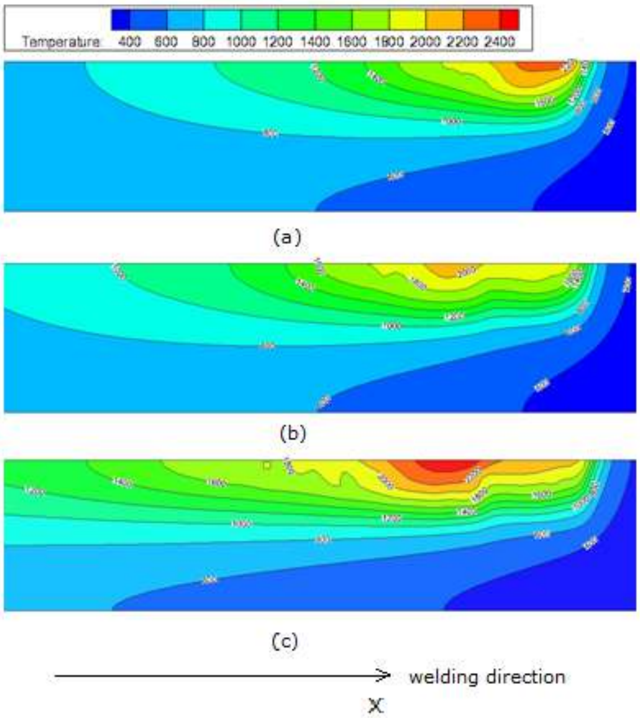
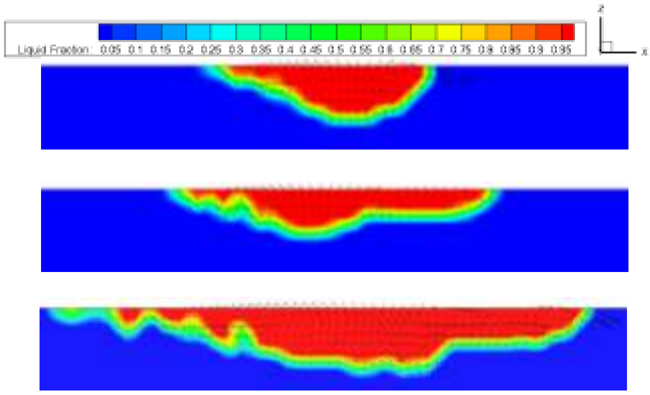


Fig.2. The temperature distribution of the melt pools

(a) Single MIG(7000W),

(b) Tandem (7000W),

(c) Tandem(14000W)



（b）2 组 双丝焊

(a) Single MIG (heat input 7000W)

(b) Tandem MIG (heat input 7000W)

(c) Tandem MIG (heat input 14000W)

Fig.3. The welding pool dimension at different welding conditions

CONCLUSIONS

(1) The revised double ellipsoidal model for the tandem welding is proposed. The deflection angle of welding

arcs effects heat flux and welding temperature field and the convection in the welding melt pool.

(2) There are more vortexes in the tandem welding pool than that in the single MIG welding. Higher speed and larger power in the tandem welding make the fluid flow of the melt pool complicated. There is a obvious heat flow accumulation in the tandem welding. The position of the deeper in tandem melt pool is near the trailing heat source.

Acknowledgments

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