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Effects of welding velocity on the impact behavior of droplets in gas metal arc welding

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ABSTRACT

The influence of welding velocity on the impact behavior of the globular metal transfer was studied by high speed video photography with a laser source during gas metal arc welding of E36 steel. The welding current and voltage were 180 A and 30 V during the welding process. The results indicated that the impact location of a droplet depended strongly on the welding velocity. There was a critical welding velocity (0.4 m/min) that when the welding velocity was lower than this value the droplet impacted inside the weld pool, while the welding velocity was higher than this value the droplet impacted outside the weld pool. The results showed that when a droplet impacted outside the weld pool it would rebound or adhere on the workpiece, which was depended on the kinetic energy of the droplet. The rebound percentage of droplets increased with increasing kinetic energy. With increasing welding velocity, the mass of droplets was not changed obviously, but the flight velocity of the droplet increased, i.e. the kinetic energy of droplets increased with increasing welding velocity. The results also showed that when a droplet impacted outside the weld pool, the droplet which rebounded away from the workpiece surface formed weld spatters, resulting in discontinuous weld appearance, while the droplet which adhered on the workpiece surface streamed to the weld pool and good weld joint would still be obtained. Molten metal decreases with increasing welding velocity. When the welding velocity increases from 0.4 m/min to 2.0 m/min, the weld width decreases from 12.9 mm to 6.3 mm and the weld penetration decreases from 5.4 mm to 2.1 mm.

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1. Introduction

Kou (1987) stated that gas metal arc welding (GMAW) was an electric arc welding process that produced coalescence of metals by heating them with a plasma arc established between a continuous, consumable electrode wire and the workpiece. In GMAW process, metal transfer describes the behavior of the droplet from the electrode wire tip to the workpiece. Kou (1987) concluded that there were three basic modes of metal transfer including the short-circuiting, globular and spray transfer in the GMAW process. Lancaster (1984) studied the physics of GMAW and concluded that metal transfer included three stages: detachment, transfer and impact on workpiece stage.

Metal transfer has been investigated by many experimental methods, including acoustical, electrical, spectral and optical technique. Saini and Floyd (1998) studied the correlations between sound signature and transfer mode in GMAW. Their results indicated that the sound signature was a usable, practical information source to predict transfer mode. In addition, Grad et al. (2004) monitored the GMAW process by measuring welding current and acoustic waveforms. Their results indicated that acoustic emission produced by metal droplet transfer seemed to be much stronger than the acoustic emission generated by microstructure changes. However, the acoustical method required very quiet work environment. Li et al. (2000) developed a neural network to output the metal transfer mode by collecting arc voltage data. Although accurate quality prediction was achieved, the neural network needed strict training during the welding process. Han et al. (2003) researched the connection between the arc spectrum and the droplet behavior. Various metal transfer modes could be recognized, however, a lot of calculations were involved and special training was needed in the pattern recognition system. Recently, Modenesi and Reis (2007) acquired the images of the droplet by an optical method which involved high speed video photography and laser-backlighted shadowgraphy technique. Ghosh et al. (2009) also used the optical method to study the behavior of metal transfer. Although clear images of droplet could be acquire directly by the optical method, these images displayed only two-dimensional information of the droplet. Li et al. (2010) studied the effects of different He–Ar ratios of the blowing gas on laser welding process.

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Table 1
Chemical composition of base metal (wt%).

Element	C	Si	Mn	S	P	Ni	Cu	Cr	Al	Fe
Content	0.15	0.606	1.45	0.006	0.01	0.223	0.193	0.221	0.125	Balance

Table 2
Chemical composition of electrode wire (wt%).

Element	C	Si	Mn	S	P	Ni	Mo	V	Fe
Content	0.08	0.90	1.46	0.015	0.013	0.01	0.04	0.01	Balance

Table 3
Processing parameters.

Processing parameters	Details
GMAW polarity	Direct current electrode positive (DCEP)
Contact tip-to-work distance	15 mm
Current	180 A
Voltage	30 V
Shielding gas	80% Ar + 20% CO_2
Shielding gas flow rate	25 l/min
Angle (α)	60°
Angle (β)	10° and 30°

Their results indicated that sound joints could be obtained even with 40% He + 60% Ar while no acceptable joint formed when using pure Ar. Staufer (2010) researched laser-arc hybrid welding in the automotive industry and claimed that the GMAW process was affected by the laser beam. Kaplan et al. (2010) studied the laser cladding and laser casting. Their results indicated that a transition from cladding to casting and vice versa could be achieved by proper control of the process parameters, both for preplaced and blown powder.

From the above review, many researches focused on the detachment and transfer stages of metal transfer. However, little attention has been devoted to the impact on workpiece stage of metal transfer. Fan and Kovacevic (1998) claimed that the impact of droplets had an important influence on the flow pattern in the weld pool. Rao et al. (2010) also considered the impact on workpiece stage of metal transfer in their research and claimed that the shape of droplet was effected by the helium content. However, in both of the researches, they only considered the situation that the consumable electrode wire was vertical to the workpiece and the droplet always impacted inside the weld pool. Actually, the impact on workpiece stage of metal transfer is a complicated physical process, especially at high welding velocity in the GMAW process. In some situations, the angle between the electrode wire and the workpiece is acute and the droplet does not always impact inside the weld pool. Therefore, further studies are still necessary to investigate the impact on workpiece stage of metal transfer.

In this paper, the angle between the electrode wire and the workpiece is acute and we focus on the impact on workpiece stage of globular metal transfer at various welding velocities in the GMAW process. The impact location, diameter, kinetic energy and rebound percentage of droplets are measured by the three-dimensional information which is obtained by high speed video photography with a laser source. Furthermore, the influence of the droplet behavior on the weld morphology is also analysed.

2. Experimental

The schematic of gas metal arc welding experimental system is shown in Fig. 1. The system was composed of three parts, including a welding system, a frame acquisition system and a welding current and voltage collection system. The welding system: a welding machine (YD-500AG) with 500 A current rating was used in the GMAW process. The GMAW is used in the direct current electrode positive (DCEP). The welding current and voltage were 180 A and 30 V, to get globular metal transfer. The frame acquisition system: a high speed video (Camrecord 5000 × 2) with a frame

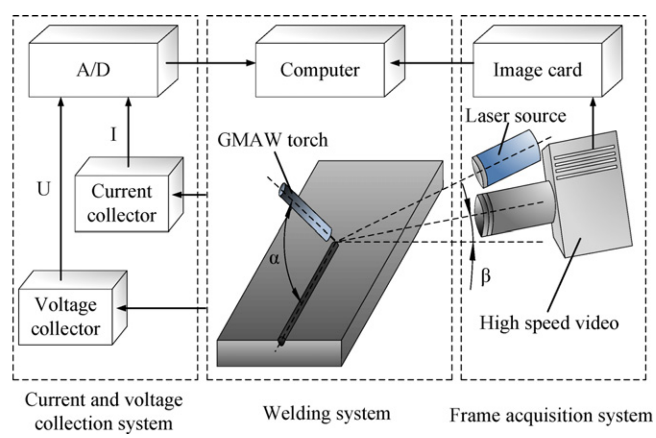

Fig. 1. Schematic of gas metal arc welding experimental system.

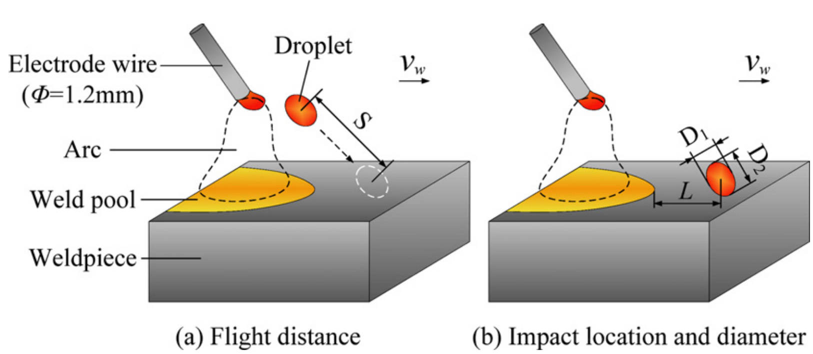

Fig. 2. Schematic diagram showing measurement of characteristics of a droplet. (a) Flight distance and (b) impact location and diameter.

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