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Characteristics of ionized gas metal arc processing

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ABSTRACT

This paper presents characteristics of ionized gas metal arc processing which consists of a torch, a consumable electrode wire, shielding gases and two power sources. One of the power sources ionizes the shielding gases before supplying into the arc region and another stably produces the gas metal arc. The degree of ionization in the shielding gas is well regulated by the primary power source, and then the secondary power source is able to control the arc, including a weld pool formation, a growth of molten droplet at the electrode wire tip and its detachment. It is concluded that the ionized gas metal arc can make a stable processing of welding without spatters and fumes in comparison with the conventional gas metal arc processing. Furthermore, it is suggested that the ionized gas metal arc is very useful for not only welding but also thermal spraying for producing a fine coating of metal surface.

1. Introduction

Gas metal arc (GMA) processing has been the most dominant welding processes in various industries of automotive, steel making, shipbuilding, bridges, building construction, pipelines, chemical plant, power generation and so on, because this processing has the advantages of very high productivity and low equipment cost [1]. However, spatters and fumes are markedly appeared during the gas metal arc welding and then are not appropriate for the factory environment and the health of workers.

In the gas metal arc process, the arc current and the arc voltage are mainly assumed to be a control parameter, and the transportation of filler materials from an electrode wire to the base metal are controlled so that a suitable welded joint is efficiently formed. On the other hand, the shielding gas can be considered to be another control parameter of the gas metal arc process, although the shielding gas is generally assumed to be a just protection gas from the air. Electric arcs are the base of the gas metal arc processing and are usually ignited in gases at room temperature in atmospheric pressure for the welding [2,3]. All gases at room temperature are excellent electrical insulators, and then a sufficient number of charged particles such as electrons and ions have to be generated in order to make gases electrically conducting due to the dielectric breakdown [4]. To ionize the gases is primarily necessary for such a gaseous discharge but needs large values of energy. The calculated results from numerical simulations for a gas tungsten arc in the real argon and for a gas tungsten arc in the imaginary argon with larger specific heat are shown in Fig. 1 [5]. In the imaginary argon with larger specific heat, the arc is markedly constricted due to the thermal pinch effect [6]. Fig. 1 clearly suggests that the heat source properties of the arc for the welding could be greatly changed if the shielding gas is ionized before feeding into the arc region in advance [7,8] and also the degree of ionization is controlled in the gas metal arc process where argon, helium, hydrogen, nitrogen, oxygen, carbon dioxide and those mixtures are used as a shielding gas. From this view, it is deduced that the flexibility of the arc heat source control improves greatly.

We are advancing the development of the ionized gas metal arc (i-GMA) process. In this paper, the welding arc phenomena in the i-GMA process are presented in comparison with the conventional GMA process.

2. Experimental apparatus and method

Figs. 2 and 3 show an equipment system of the i-GMA process and its torch structure. The inverter controlled DC power source with a constant voltage characteristic was used for gas metal arc, but the inverter controlled DC power source with a constant current characteristic was used for the generation of ionized gas.

Pure Ar (10 L/min) was supplied to a center gas, and Ar+20% CO_2 (15 L/min) was supplied to both the plasma gas and the shielding gas as shown in Fig. 3. The mild steel plate with a thickness 4.5 mm was employed as the base metal, and the solid electrode wire (YGW15) of 1.2 mm in the diameter was also employed as the filler material. The distance between the nozzle tip

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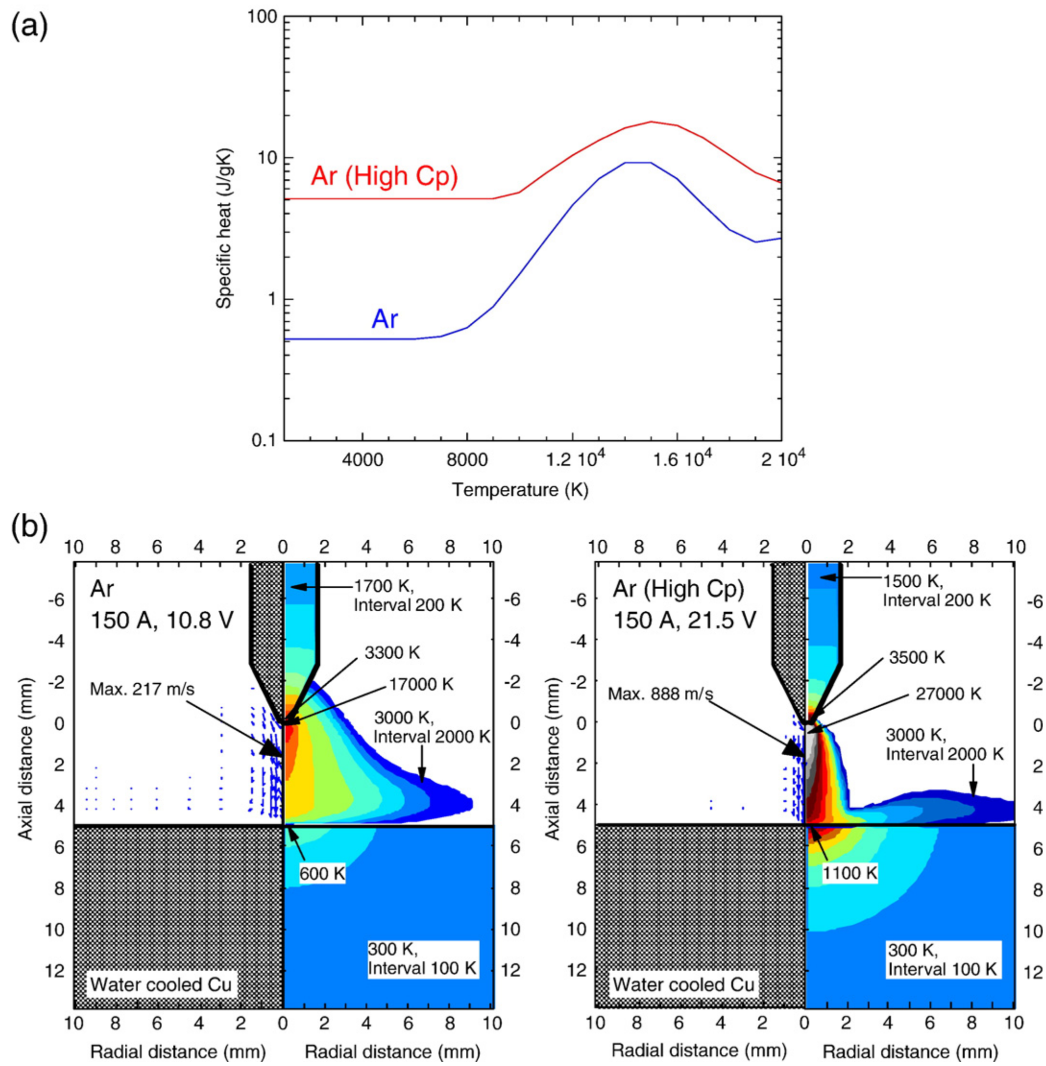

Fig. 1. (a) Specific heat of the real argon and an imaginary argon, and (b) calculated results for gas tungsten arc in the real argon and in the imagination argon with larger specific heat at 150 A in arc current.

and the base metal was a 10 mm, and the welding speed was a 60 cm/min. A bead on plate welding was conducted, and the welding arc phenomena were observed with a high-speed digital video camera.

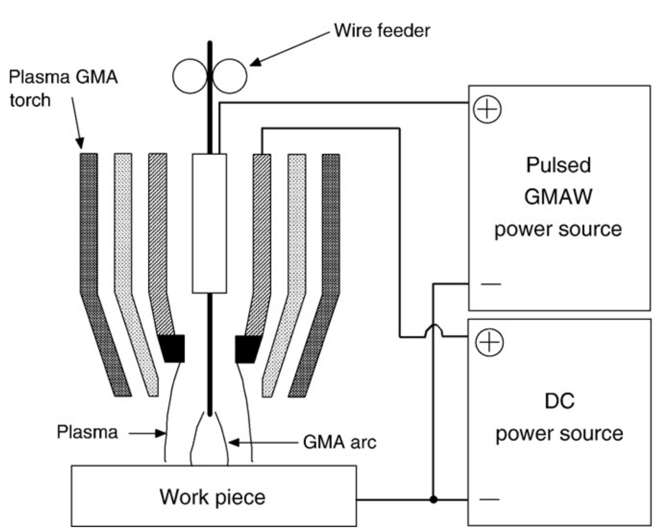

Fig. 2. Schematic diagram of an equipment system for ionized GMA process.

3. Experiment results and discussion

Fig. 4 shows the wave forms of an arc current and an arc voltage, and the feature image obtained from a high-speed video shooting in case of the conventional gas metal arc process. On the other hand, Fig. 5 shows the case of i-GMA process. The wire feeding rate was controlled to be 10 m/min in both cases. The average of the gas metal arc current is 284 A for the conventional GMA process but 190 A for the i-GMA process, and then the i-GMA process can achieve a higher melting rate of the wire for the same gas metal arc current in

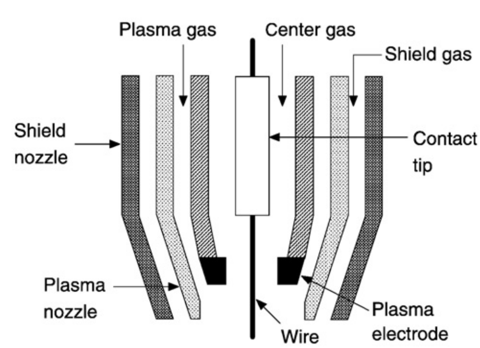

Fig. 3. Schematic diagram of a torch structure for ionized GMA process.

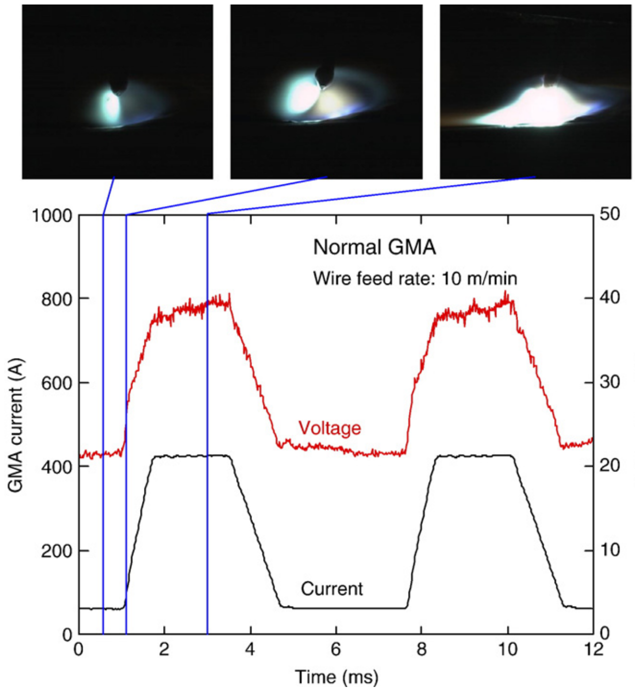

Fig. 4. Arc phenomena with wave forms of arc current in conventional GMA process.

comparison with the conventional GMA process. Therefore, the i-GMA process suggests the possibility of the high efficient welding. In general, the melting rate of the electrode wire is subjected to the heat input from the arc and the joule heating in the wire [9]. However, in the i-GMA process, the heating of the electrode wire due to the ionized shielding gas, namely, the plasma is added, and then it is considered that the same rate of the wire feeding can be obtained at clearly lower current value for the i-GMA process than the conventional GMA. In the i-GMA welding of thick steel plates, the efficiency improvement can be expected compared with the conventional GMA welding.

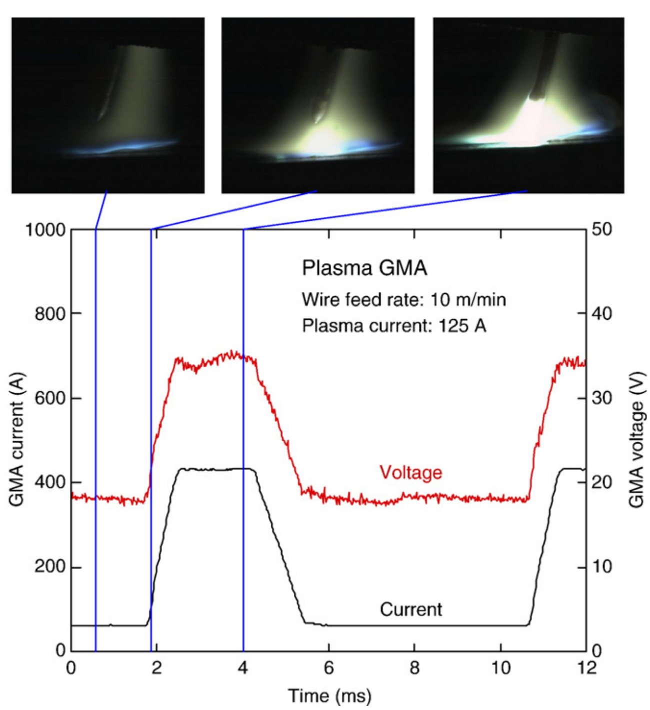

Fig. 5. Arc phenomena with wave forms of arc current in ionized GMA process.

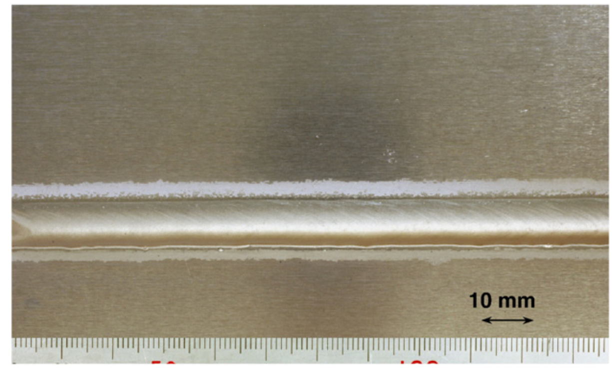

Fig. 6. A weld bead appearance for aluminum alloy (A5052) by ionized GMA process.

In the conventional GMA process in Fig. 4, the arc swings intensively and becomes unstable as the arc is in a period of the base current, and another current path is generated momentarily at the time of rise from the base current to the peak current, and then this becomes an initiation of the spatter generation from tip of the electrode wire. Moreover, the arc pressure close the wire tip is supposed to be high because the edge of arc flame is very plain in the peak current. The higher arc pressure works as one of the obstruction factors of the droplet detachment from the wire tip and leads to another initiation of the spatter generation, namely, the exploding metal transfer [10]. On the other hand, in the i-GMA process in Fig. 5, the arc brightness of the gas metal arc in a period of the base current is weak, and the plasma is clearly supplied from the nozzle. Especially, the change in the arc flame from the base current to the peak current is extremely smooth, and the characteristic of the plasma as the ionized shielding gas functions well. In addition, the diffused edge of arc flame is found in Fig. 5, and the smooth droplet detachment can be obtained in the peak current. The decentralization of the repelled force for droplet detachment is achieved due to a diffused arc route at the wire tip because the ionized shielding gas covers the whole surface of the droplet at the wire tip, and then the droplet with the stable plasma atmosphere is seceded by the electromagnetic pinch effect at the peak current.

Fig. 6 shows a weld bead appearance when the fillet weld of an aluminum alloy (A5052, 3mmt) as the base metal is conducted. However, pure argon was used for all gases in three systems. The current of plasma was set at 100 A, the wire feeding rate was set in 8.5 m/min, and the welding speed was set in 50 cm/min. The average current was 56 A, and it is possible to weld by a current that is much lower than the conventional GMA process. In addition, generations of the spatter and the smut are very few, and the beautiful weld bead is obtained.

The i-GMA process suggests the possibility of a clean arc welding process with high efficiency in comparison with the conventional GMA process. Furthermore, it is also suggested that the i-GMA process is very useful for not only welding but also thermal spraying for producing a fine coating of metal surface.

4. Conclusions

The conclusions in this paper are summarized as follows.

(1) In the i-GMA process, heating of the electrode wire due to the ionized shielding gas, namely, the plasma was added, and the same amount of the wire feeding rate was obtained at a low current value compared with the past GMA process.
(2) The stable droplet transfer from the wire tip to the base metal could be obtained because the change in the arc flame from the base current to the peak current was extremely smooth, and the characteristic of ionized shielding gas functioned well.
(3) The achievement of a clean arc welding process with high efficiency was suggested by the i-GMA process.

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