

A CO₂ Gas Shielded Gas Tungsten Arc and Its Application to Welding of Steel Sheets

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Abstract. In order to develop a novel welding process with low costs and high productivity in comparison with the TIG welding process, the characteristics of a CO₂ gas shielded gas tungsten arc (GTA) are studied. A double gas shielded system which consists of CO₂ gas and inert gas is employed for the GTA welding torch due to avoiding the consumption of tungsten electrode. The arc voltage of the CO₂ gas shielded GTA in the conditions of arc current 150 A and arc gap 3 mm is about 19 V which is much higher than 12 V of TIG arc in the same conditions. The CO₂ gas clearly constricts the arc and the maximum heat intensity at the surface of a water cooled copper anode in the CO₂ gas shielded GTA becomes about 10 times larger than that of TIG arc. Furthermore, the CO₂ gas shielded GTA has very good performance in the traveling speed for welding zinc coated steel sheets in comparison with the TIG welding process.

Introduction

The tungsten inert gas (TIG) welding process has become indispensable as a tool for many industries because of the high quality welds produced and low equipment cost [1]. However, the principal disadvantages of TIG lie in the limited thickness of material which is able to be welded in a single pass with fully penetration and the low productivity. In order to improve the disadvantages of TIG,

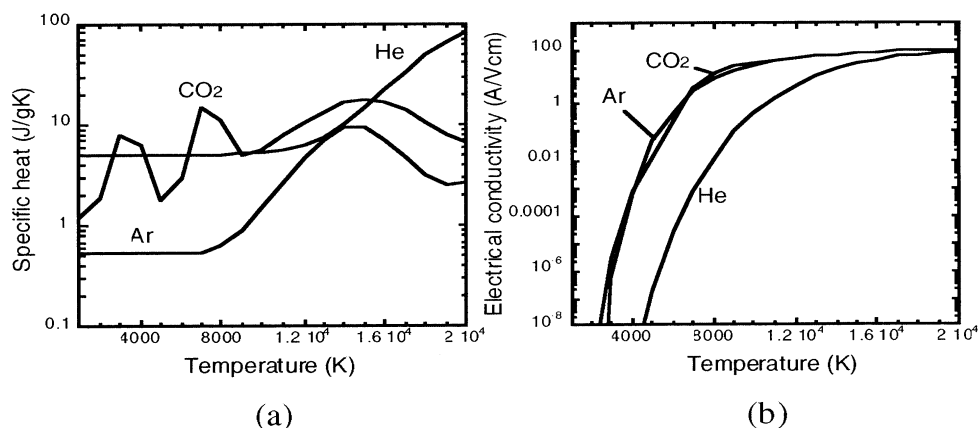


Fig. 1 Typical physical properties of (a) specific heat and (b) electrical conductivity for Ar, He and CO₂ at atmospheric pressure.

helium in the shielding gas has been used. For given values of arc current and arc gap, helium transfers more heat with its higher intensity into the material than argon [2]. The greater heating power of the helium arc can be advantageous for joining materials and for high speed welding required [1]. However, the cost of helium is higher than that of argon, specially, it is above twice as price in Japan. In the metal active gas (GMA) welding process, carbon dioxide (CO_2) or argon- CO_2 mixture has been generally used [3]. The cost of CO_2 is remarkably lower than that of argon, for example, it is below the half in Japan. Figure 1 shows typical physical properties of argon, helium and CO_2 which we calculated under the assumption of local thermodynamic equilibrium in the same manner with the literature [4]. The characteristics of CO_2 principally have high specific heat in lower temperature region, because helium effectively has the same specific heat with argon due to 10 % atomic weight of argon. The characteristics of helium principally have low electrical conductivity due to its higher ionization potential than argon. The low electrical conductivity of shielding gas in the welding arc leads to an arc constriction, because the arc current can exist only in the higher temperature region of the plasma. Therefore, helium contributes toward higher productivity in the TIG welding process [1] due to its high heat intensity at the material and high arc voltage [2]. On the other hand, the high specific heat of shielding gas should also lead to the arc constriction, because it limits the heat transfer in the arc fringes and then fixes an arc current pass in the arc axis area. The increase of arc current density due to the fixed arc current, specially, close to the cathode region will increase the electromagnetic force and, therefore, the cathode jet for cooling the arc column. The net effect of cooling the arc by the heat convection due to the cathode jet is an increase of its axis temperature [5]. It is frequently called *thermal pinch effect* in Japan [6]. The *thermal pinch effect*, also, would contribute toward higher productivity in the TIG welding process.

This paper presents the characteristics of a CO_2 gas shielded gas tungsten arc (GTA) in order to develop a novel welding process with low costs and high productivity in comparison with the argon TIG welding process. A double gas shielded system which consists of CO_2 gas and inert gas is employed for the GTA welding torch due to avoiding the consumption of tungsten electrode. We give arc appearances with arc voltages in the same arc current and also heat intensity distributions at the surface of a water cooled copper anode, in comparison with the argon TIG arc. Furthermore, the performance of the CO_2 gas shielded GTA which welds a zinc coated steel sheet is presented.

Experiments

Figure 2 shows the appearance of a torch for the CO_2 gas shielded GTA and its schematic illustration. A double gas shielded system which consisted of CO_2 gas and inert gas was employed for the torch due to avoiding the consumption of tungsten electrode. The small amount of inert gas like a argon, helium or their mixture was supplied to an inner copper nozzle, but the CO_2 gas was principally

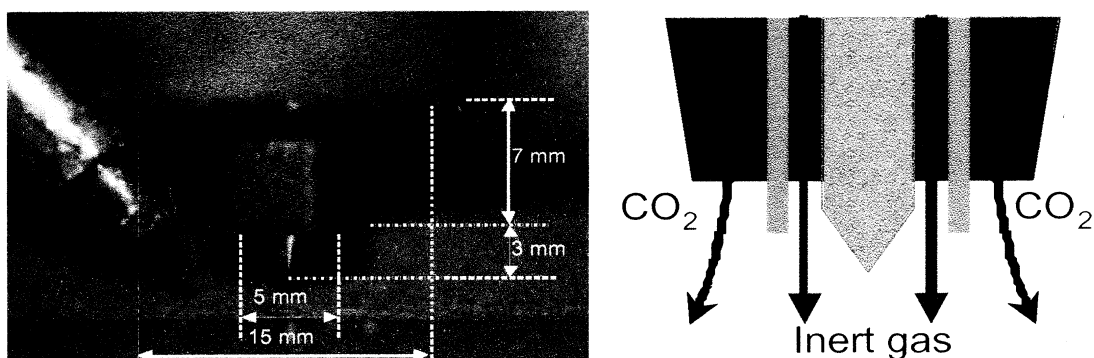


Fig. 2 A torch for the CO_2 gas shielded GTA and its schematic illustration.


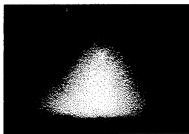
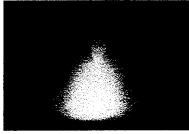


supplied to an outer ceramic nozzle. The gas flow rates of the inert gas and the CO₂ gas were set at 5 L/min and 10 L/min, respectively. We defined an electrode extension as a distance from the tip of the inner copper nozzle to the tip of the tungsten electrode. The electrode extension was set at 3 mm. The CO₂ gas shielded GTA achieved equivalent arc stability to TIG arc under the above conditions. A filler metal can be supplied to the weld pool as shown in Fig. 2.

We observed arc behavior of the CO₂ gas shielded GTA by using a digital camera and measured its arc voltage, in comparison with the conventional TIG arc. The experimental method proposed by Nestor [7] was used to determine the heat intensity into the anode. The experimental procedure is given in detail in our previous paper [8]. We also measured axis arc pressures at the anode surface of water cooled copper with a small hole of 1 mm in diameter, by using a digital monometer (Yokogawa, MT110).

The butt welding was conducted with zinc coated steel sheets (SHGA440-45). The plate size was 300 mm in length, 50 mm in width and 1.8 mm in thickness. The arc gap was set at 3 mm but the arc current was changed for taking a fully penetration at each different welding speed.

Results and Discussion

Figure 3 shows the appearances and arc voltages of CO₂ gas shielded GTA using argon, argon-hydrogen mixture and helium as inert gas from the inner copper nozzle for the same 150 A arcs. Figure 3 also shows the appearances and arc voltages of conventional TIG arcs in argon and helium. All arcs were operated on the water cooled copper anode at 3 mm in arc gap. The arc constriction for CO₂ gas shielded GTA is clearly observed compared with the conventional TIG arc. The CO₂ gas shielded GTA remarkably increases arc voltage and, specially, reaches 18.9 V for argon-hydrogen mixture as the inner nozzle gas. The value of 18.9 V is equivalent to that for helium TIG arc. Figure 4 shows the heat intensity distributions at anode surface for CO₂ gas shielded GTA using argon as the inner nozzle gas and for argon TIG arc at 50 A in arc current and 3 mm in arc gap. The CO₂ gas clearly constricts the arc due to the *thermal pinch effect*, and the maximum heat intensity for the CO₂

TIG arc	CO ₂ gas shielded GTA
 Ar (11.8 V)	 Ar-CO ₂ (15.0 V)
	 Ar+10%H ₂ -CO ₂ (18.9 V)
 He (18.8 V)	 He-CO ₂ (19.6 V)

Arc current: 150 A, Arc gap: 3 mm, Cathode: 2%La₂O₃-W (2.4 mmφ), Anode: Water cooled Cu

Fig. 3 Appearances and arc voltages of CO₂ GTAs using Ar, Ar-H₂ mixture and He as inner nozzle gas, in comparison with conventional TIG arcs in Ar and He.

gas shielded GTA becomes about 10 times larger than that for argon TIG arc. The greater heating power of the CO₂ gas shielded GTA due to increase of arc voltage and also heat intensity will be advantageous for joining material and for high speed welding. Figure 5 shows the maximum arc pressures for the same arcs in Fig. 3 at axis of copper anode surface which is cooled by the water. The maximum arc pressures for CO₂ gas shielded GTAs with argon or argon-hydrogen mixture are larger than the pressure for argon TIG arc and increase with the arc current. However, the pressure for CO₂ gas shielded GTA with helium has similar or less value to the pressure for helium TIG arc at the same arc current.

Figure 6 shows bead appearances of butt welds for zinc coated steel sheets, which were conducted for taking a fully penetration in variable welding speeds, namely, 50, 100, 150 and 200 cm/min, respectively, and then the arc current was chosen for each condition. A melt-through is observed for CO₂ gas shielded GTA with argon-hydrogen mixture at 150 cm/min because the arc current reaches 240 A for its welding speed and then the higher arc pressure produces the melt-through. This result suggests that the maximum welding speed with fully penetration is from 100 to 150 cm/min for the CO₂ GTA with argon-hydrogen mixture. A melt-through is also observed close to the end of weld bead for CO₂ GTA with argon at 100 cm/min due to higher arc current which is the just same value, 240 A. Therefore, it is suggested

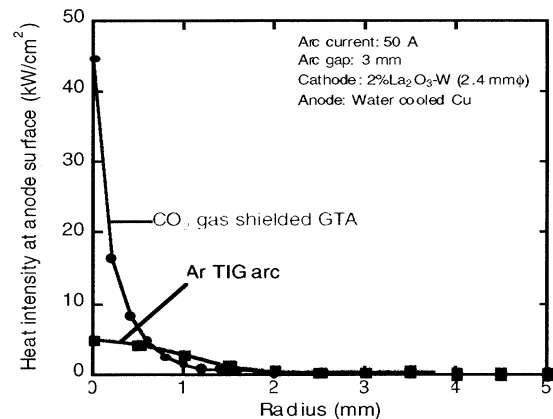


Fig. 4 Heat intensity distributions at anode surface for CO₂ GTA using Ar and for argon TIG arc.

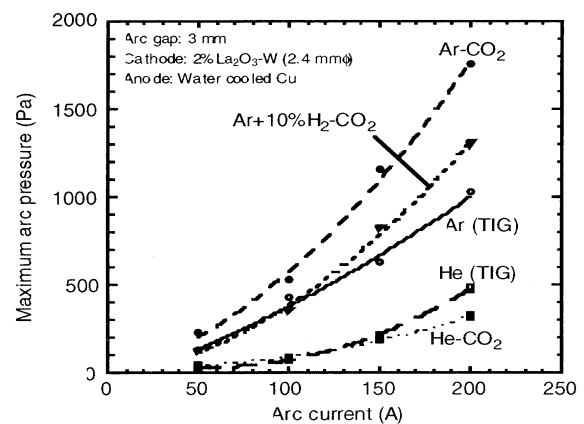


Fig. 5 Maximum arc pressure for CO₂ GTAs using Ar, Ar+H₂ mixture and He, in comparison with conventional TIG arc in Ar and He.




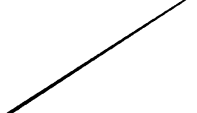

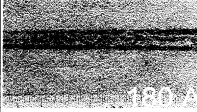
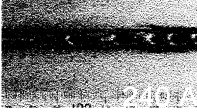




Speed Gas	50 cm/min	100 cm/min	150 cm/min	200 cm/min
Ar-CO ₂				
Ar+10%H ₂ -CO ₂				
He-CO ₂				

Fig. 6 Bead appearances of butt welds for zinc coated steel sheets by using CO₂ GTAs.

that the maximum welding speed with fully penetration is from 50 to 100 cm/min for the CO₂ GTA with argon. On the other hand, the CO₂ GTA with helium produces the fully penetration even at 200 cm/min due to its obvious lower arc pressure at higher arc current than 300 A, as shown in Fig. 5. We measured oxygen content in the weld metal by using an Oxygen/Nitrogen analyzer. The oxygen contents for CO₂ gas shielded GTA using argon, argon-hydrogen mixture or helium were ranged 170-280 ppm, 110-120 ppm and 170-280 ppm, respectively, but that for the base metal was 16 ppm.

The conventional argon TIG arc was able to produce the fully penetration only at 30 cm/min. From these results, we think that CO₂ gas shielded GTA can produce the fully penetration at welding speed of three times higher than the conventional one and then give the high productivity of welding steel sheets without spatters to the industries.

Conclusions

The conclusions in the present paper are summarized as follows.

- (1) A CO₂ gas shielded gas tungsten arc (GTA) was developed. A double gas shielded system which consists of CO₂ gas and inert gas was employed for the GTA welding torch due to avoiding the consumption of tungsten electrode.
- (2) The arc voltage of the CO₂ gas shielded GTA at 150 A in arc current and 3 mm in arc gap reached about 19 V which was much higher than 12 V of argon TIG arc in the same conditions.
- (3) The CO₂ gas clearly constricted the arc and the maximum heat intensity at the surface for the CO₂ gas shielded GTA became about 10 times larger than that for argon TIG arc.
- (4) The maximum arc pressures for CO₂ gas shielded GTAs with argon or argon-hydrogen mixture were larger than the pressure for argon TIG arc and increased with the arc current. However, the pressure for CO₂ GTA with helium had similar value to the pressure for helium TIG arc at the same arc current.
- (5) The CO₂ gas shielded GTA could produce the fully penetration at welding speed of three times higher than the conventional one for argon TIG arc and then gave the high productivity of welding steel sheets without spatters to the industries.

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