

Experimental research on single pass GTAW process with use of different shielding gas for austenitic stainless steel SA 240 type 304H

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Abstract

deep penetration GTAW for high efficiency has long been of concern in industry. An autogenously gas tungsten arc welding process was used on austenitic stainless steel SA240 type 304H to produce 10 mm thick butt weld. Experimental results shows that small addition of carbon dioxide or oxygen to shielding gas can increase the oxygen content in weld pool. If we control the oxygen content perfectly then we can change weld shape from wide shallow to narrow deep. Marangoni convection is one of the effective force for deep penetration and oxygen content of weld pool over critical range can directly effect on weld penetration. When the value of oxygen content is over ppm, an inward marangoni reaction is occurred which gives narrow deep weld pool. Hydrogen addition in argon based shielding gas is also worked out in this study. Hydrogen changes the static characteristic of arc. Hydrogen addition increases arc power and consequently the quantity of the material melted. Hydrogen addition also increase the thermal efficiency as well as melting efficiency of welding arc too.

Introduction

Gas tungsten arc welding is the most important welding process in almost all type of manufacturing industries. GTAW mostly used for austenitic stainless steel, titanium alloys and other nonferrous metal for high quality welds. However the shallow penetration makes the productivity relatively low, other side, compared to high energy welding method such as laser beam welding, plasma welding and X or V groove are necessary in welding thick plate which makes productivity low. Surface active elements are very critical for weld penetration in GTAW process. Surface active elements like oxygen, sulphur can give its significant effect on the welding characteristics. Controlling of these surface active elements is very critical and complex process. After decades of developments, it is possible to control the surface active elements in weld pool. There are several ways to change the surface active elements in weld pool. A-TIG process is developed for full penetration in which smearing of flux which contain the surface active elements which is required for welding and adjusting the gaseous mixture of shielding gas will change the surface active elements. Flux spreading is not easy in automatic welding and also difficult for the operator to control the effective quantity of the flux used. Productivity is also decreased because it is very time taken process. There have been four proposed mechanism of A-TIG welding. First is based on the surface tension of molten pool decreased and pool surface go down due to arc pressure, resulting in arc concentration at bottom bottom of the pool. This process is known as keyhole TIG process. Second mechanism is considered that vaporised flux molecules contract the welding arc. Third is inward marangoni convection by change of temperature coefficient of the surface tension ($d\sigma/dT$) from negative to positive when the concentration of surface active elements in the weld pool exceeds a critical value. Fourth mechanism is insulation mode. Compared to A-TIG welding, the investigation on effect of gaseous addition to argon based shielding gas on the weld penetration and weld shape is very limited.

Former research showed that, by smearing oxide fluxes or adding small amount of active gas oxygen or carbon dioxide to argon shielding gas meaningfully increase the GTAW penetration into stainless steel. This finding makes it possible to improve an advance automatic TIG welding process because the regulated by adding active gas into shielding gas than by placing oxide flux on plate as is done in the conventional A-TIG process. When the oxygen content is the reverse marangoni convection is induced and deep narrow weld shape is obtained.

Experimental Procedure

A 10 mm thick austenitic stainless steel SA 240 type 304H with sulphur content of 0.0300 wt% and oxygen content of 0.0038 wt% was selected for the square butt welding experiment. The detail composition of plate is given in table 1.

A direct current electrode negative polarity power source was used with autogenous TIG torch. The 2% thoriated tungsten electrode gap was measured for each new bead before welding to ensure that the bead was made under the same conditions except for the shielding gas concentration.

To modify the argon based shielding gas, controlled levels of oxygen or carbon dioxide were added to the argon-based shielding gas. Argon-hydrogen mixture also were prepared for these experiments. Mixture of Ar-Co₂, Ar-O₂ and Ar-H₂ were 0.6% Co₂, 0.4% O₂ and 10% H₂ by volume, respectively.

Table 1: Chemical composition of austenitic stainless steel SA240 type 304 H

Alloy element	C	Mn	P	S	Si	Ni	Cr
Content (wt%)	0.058	1.9480	0.0316	0.0020	0.333	8.011	18.015

Conceptual discussion

Marangoni force is the dominant force in weld pool shaping. The Marangoni effect is the effect of mass transfer of fluids due to surface tension gradient. The major point of focus is, with higher surface tension would pull more strongly on the surrounding liquid than the one with lower surface tension, this surface tension gradient would cause the liquid to flow from regions of lower surface tension. [4] The Marangoni number is a dimensionless number describing the relative importance of surface tension force to viscous force. It is illustrated as

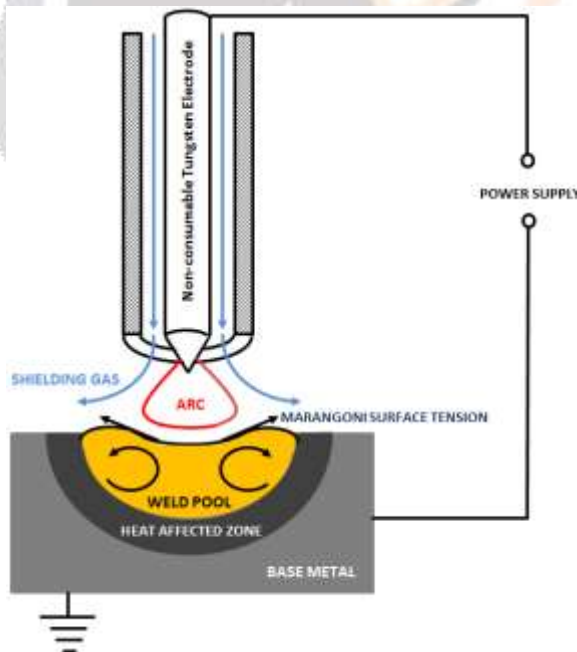


Fig. 1 negative

Schematic diagram of GTAW process with surface tension temperature gradient

$$-\frac{dy}{dT} \cdot L \frac{\Delta T}{\delta \alpha}$$

where y is surface tension, T the temperature of the weld pool, L the characteristic length, α the thermal diffusivity of the workpiece, and δ the dynamic viscosity of material. The weld pool shape is believed to be very dependent on Marangoni convection, in the centre of it all, is the surface tension temperature gradient. For welding processes, the workpiece would contain some degree of impurities, such as oxygen and sulphur found in steels; during welding, these impurities were discovered to be very 'surface active', altering the surface tension gradient together with temperature, thus making the term extremely complex to formulate. There are three different effects of surface tension temperature gradient.

1- When surface active element concentration is low, gradient is negative it lead to surface temperature grater than the critical temperature. Thus surface tension is lower in the high temperature region, the pool centre; therefore according to Marangoni convection theories, liquied metal would experience outward flow from the centre.[3]

2- When the surface active element concentration is increased, gradient can be positive and negative both. In this situation, critical temperature is between pool centre and boundary. By combining this two flow patterns, 'W' shaped pool would be created. When it increased further, gradient value is positive.

3- Now if the surface active element concentration is high enough, that the entire surface temperature is now lower than the critical temperature, then surface tension is now higher in the high temperature region, the pool centre; this would reverse the flow pattern completely to inward flows to the pool centre.

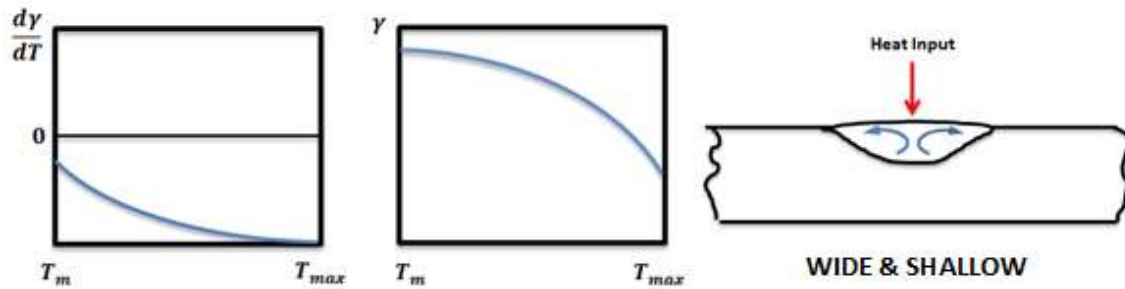


Fig. 2- Wide and shallow pool by negative gradient

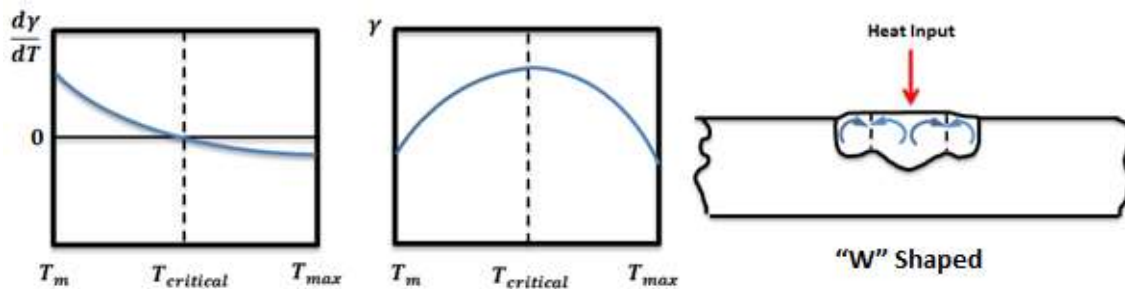


Fig. 3 - "W" shaped pool by pool boundary not yet surpassing the critical temperature

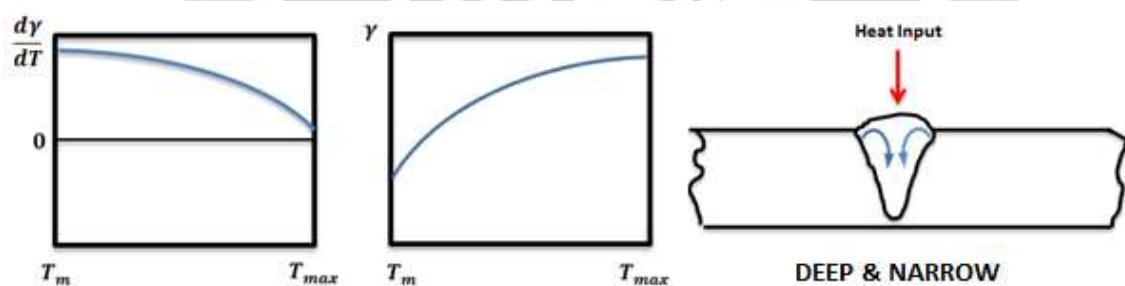


Fig. 4 Deep and narrow pool by positive gradient

The effect of the torch gas CO₂ and O₂ concentration on the weld metal oxygen content. The weld metal oxygen content initially increases with the CO₂ content up to 0.6% and O₂ content upto 0.2-0.4% then maintains a nearly constant value around 200 ppm for a CO₂ content up to 2.0%. In the GTA welding process, the weld shape and weld D/W ratio depends to a large extent on the liquid pool convection, which is driven by the surface tension (F_y), electro-magnetic force (F_{em}), buoyancy force (F_b) and arc plasma drag force (F_p). Among them, the surface tension is one of the main driving forces affecting the liquid pool convection. surface active elements, such as oxygen, sulfur, selenium and tellurium can change the temperature coefficient of the surface tension for iron alloys. When the surface active element is low in the weld pool, the temperature coefficient of the surface tension is negative, and the Marangoni convection on the pool surface is in an outward direction. Therefore, the heat flux is easily transferred to the edge and the weld shape is wide and shallow.[3]

When the surface active elements are high and over a critical value, the temperature coefficient of the surface tension is positive, and the Marangoni convection is inward on the pool surface. In this case, a deep and narrow weld shape forms.

When the peak temperature is high and over a critical value for a weld pool containing a certain active element, such as during stationary GTA welding and laser spot welding, the outward Marangoni convection pattern in the pool center area will coexist with the inward Marangoni convection in periphery area on the pool surface. For this case, the Marangoni convection on the pool surface is complex.[2] However, for the moving GTA welding, this phenomenon seldom happens. provides a significant source of oxygen absorption for the molten weld metal in these experiments. Former research has shown that oxygen is an active element in pure iron and stainless steel in the range of 150–350 ppm and 70–300 ppm respectively. In these ranges, Oxygen from the decomposition of CO₂ the temperature coefficient of the surface tension of the welding pool is positive, while outside of these ranges, the temperature coefficient of the surface tension becomes negative or nearly zero as shown in for the Fe-O system. The experimental results from this study are consistent with the former research. When the oxygen content is over 100 ppm in the weld, the Marangoni convection mode is suddenly changed from outward to inward and the shallow-wide weld shape (low D/W ratio) changes to a narrow-deep weld shape (large D/W ratio) as shown in However, it is interesting to find that the weld D/W ratio decreased suddenly though the oxygen content in the weld is nearly constant at around 200 ppm when the CO₂ addition is between 0.6 and 2.0% as shown in fig. 5

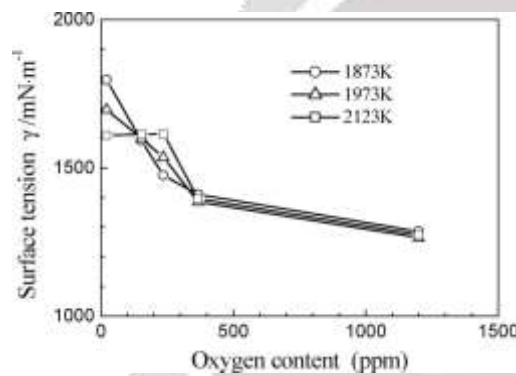


Fig. 5 Effect of oxygen content on surface tension of liquid iron

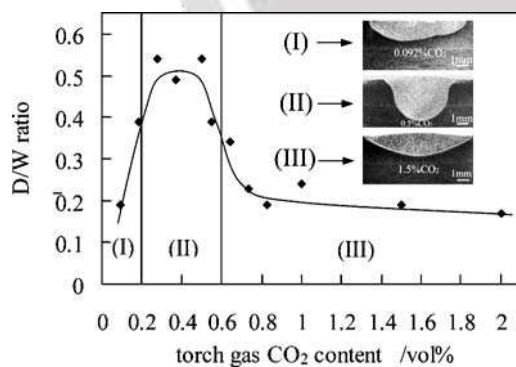


Fig.6 Weld shape and weld depth/width ratio under different CO₂ additions.

Increasing the hydrogen content of in the shielding gas contributed to an increase in penetration depth and in the cross-sectional area of the weld metal, both with and without an activating flux. The penetration capability of the activating flux GTAW was always higher than with the argon-hydrogen gas mixtures.[1] The ferrite content decreased with an increase of hydrogen in the shielding gas with both the conventional GTAW and activating flux GTAW processes. However, the activating flux GTAW had a higher heat input than the conventional GTAW because the arc voltage increased; therefore, the activating flux GTAW weld had a lower ferrite content. Deep penetration welds with a high depth-to-width ratio significantly reduced the angular distortion of stainless steel weldments. Activating flux GTAW increased the energy density of the heat source, resulting in constricting the plasma column, which caused a particularly deep and narrow weld.

Conclusion

From above discussion we can conclude that shielding gas can give its effect on weld penetration. Mixture of Argon carbon dioxide can increase the oxygen content in weld pool and it also can give more depth to width ration in compare to simple argon as shielding gas. Hydrogen also make the hotter arc which gives more penetration. So by using these essentials we can get more deep penetration and overcome the problem of lesser productivity of GTAW welding.

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