Study for TIG-MIG Hybrid Welding Process
- Experimental Consideration for Optimum Torch Configuration -

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On TIG-MIG hybrid welding process, the MIG arc can keep stability even in pure inert shielding gas by the effect of hybridization with TIG arc and it becomes possible to achieve the both merits of high quality as well as TIG and high efficiency as well as MIG. In this report, we considered about optimum torch configuration on this process for practical application. As a result, following findings were obtained:
(1) More than +45° MIG torch angle is needed to keep forehead angle of MIG arc under condition that quite large repulsion occurs. (2) Although there is not seen deciding difference for bead shape and penetration by the change of torch angle, TIG 0°/MIG+45° is the best configuration relatively for the penetration shape and flatness of bead shape. (3) Based on the consideration, original torch for TIG-MIG hybrid welding process was produced and it was confirmed the good weldability on practical joint.

Key Words: (TIG welding), (MIG welding), (Pure Argon shielding gas), (Hybridization), (High efficiency), (High quality)

1. Introduction

We study about TIG-MIG hybrid welding process which can stabilize MIG arc even in pure Ar shielded condition thus it is possible to achieve the both merits of high quality as well as TIG and high efficiency as well as MIG. On the base of experimental and numerical simulation, we showed the results as follows in previous reports.
(1) The condition that TIG current is larger than MIG current is needed for arc stability and it is expected that the additional TIG current can control penetration in this process1).
(2) The direct current path generates between TIG and MIG electrodes through high temperature arc plasma depends on its electro conductivity, and there is the possibility that this phenomena contributes to stabilization of the pure Ar shielded MIG arc2-3).

(3) For the torch angle and distance, it is necessary to position nearby distance and cross each other in suitable condition range for keeping arc stability1).

Determination of the optimum configuration for the torches to obtain the good weldability is very important. It is needed the rich tolerance of the condition range for the variable welding conditions such as thickness and type of joint, inclined position for multi-pass welding of practical application. Generally, in the many case of the hybrid welding process which combines several heat sources, includes this process, the parameter of hybridization tends to increase much rather than ordinary process. As a result, the influence of parameter becomes complicated and decision of suitable condition becomes difficult. Therefore, determination of the suitable configuration of torches is important to treat useful the hybrid process4).

In this report, we investigated the influence of torch angle of TIG and MIG on the welding property such as the arc shape, bead appearance, and penetration shape. Because the complication of hybrid process increases with the number of treated parameter, it is important to narrow down the parameter for purpose of consideration. The purpose of this consideration is the determination of optimum configuration which has compact structure and tolerance for the certain range of current condition. Therefore, the distance between TIG and MIG arc was fixed to 4mm as basic parameter in previous reports1) for compact structure and the influence of torch angle and current condition was discussed mainly. Based on the results, the optimum configuration for practical execution was decided. At last, the original torch which has unified and fixed structure on decided torch angle for TIG-MIG hybrid welding process was produced and its weldability was confirmed on practical joint.

2. Experimental procedure

Fig. 1 shows the sizes, configuration of the experimental apparatus including position from front to rear, and polarity of TIG and MIG electrodes. Table 1 shows the welding conditions in this study. The configuration of the torches were set up based on the distance between the crossing positions of electrodes-axis and surface on base metal shown as “Distance between TIG and MIG arc”, thus the leading TIG and trailing MIG were configured. Concerning the arc ignition steps, TIG arc was started first and weld pool was formed on the surface of base metal, and then MIG arc was started. Stable arc is obtained even in pure inert shielding gas by hybridization of TIG and MIG arc on suitable condition.

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The experiment was performed in order to consider the optimum configuration of TIG and MIG torches. TIG torch angle was set vertical and the distance between TIG and MIG arc set 4mm to constitute the structure to simple and compact. TIG vertical configuration also seems to be desirable for control of torch axis in the case of automation. MIG torch angle changed in the range of $+30^\circ$ to $+60^\circ$ and MIG current was fixed on about 290A to set the metal transfer mode to splay transfer which can be expected the large stiffness of arc for the repulsion from TIG arc.

The experimental results were considered about the influence on the welding property such as degree of repulsion, bead shape, and penetration. To compare with the case of symmetrical TIG and MIG torch angle TIG-$30^\circ$/MIG+$30^\circ$ (Fig.3) as basic condition in previous reports, the results of this condition was also confirmed.

Based on above mentioned matter, we decided the torch angle and produced the original torch for TIG-MIG hybrid welding process which has fixed and unified structure. At last, we confirmed that it is possible that good weldability is obtained on application for practical joint including inclined position such as multi pass fillet weld by this original torch.

3. Results and Discussion

Fig.4 shows the image of high speed camera picture and the bead appearance under each condition of MIG torch angle. In these conditions, TIG torch angle was fixed vertical. The direction of MIG arc changed from axis of MIG wire electrode due to effect of repulsion between TIG and MIG arc, and it directed to backward on the torch angle TIG$0^\circ$/MIG+$35^\circ$. It is thought that direction of MIG arc is determined by the balance between the two forces described below:

1. Force to backward from repulsion effect caused by electromagnetic interaction with leading TIG arc.

2. Force to backward from aerodynamic effect due to repulsion force between TIG and MIG arc.
(2) Force to forward from stiffness of trailing MIG arc having forehead angle.

It seems that the direction of MIG arc, namely melting zone of MIG wire, influences droplet transfer and bead formation. In the previous reports for multiple electrode welding processes such as the tandem GMA\(^5\) and multiple electrode submerged arc\(^6\), it is shown that trailing MIG arc is desired to direct forward in order to avoid formation of humping bead. The humping bead is formed by irregularly backward flow of weld pool in the conditions of high speed and high current welding, and then, trailing MIG arc prevents the formation of it by easing the flow by its arc force and filling the weld metal to molten pool.

penetration depth was almost same about 1.5mm in the range of TIG current 300\(^\circ\)A. The value of penetration depth was large as MIG torch angle was small and the maximum depth was obtained on condition TIG0\(^\circ\) / MIG+30\(^\circ\) on the each condition of TIG current.

Fig.6 shows the change of size for bead shape by TIG current under the each condition. To evaluate the extent of flatness for bead shape, H/W was compared on each condition. Although there was not significant difference, the most flat shape was obtained on torch angle TIG0\(^\circ\) / MIG+30\(^\circ\) due to increase of bead width (W) and decrease of reinforcement height(H). The results of TIG-30\(^\circ\) / MIG+30\(^\circ\) also behave like the results on torch angle TIG0\(^\circ\) / MIG+30 \(\sim\) 60 \(^\circ\) without significant difference.

Fig.7 shows the picture of cross section under the each condition. The finger-like penetration was obtained on torch angle TIG0\(^\circ\) / MIG+45\(^\circ\) especially, which has the largest value of penetration depth in the results showed above. It seems that extreme finger shape is not suitable to avoid the defect such as lack of fusion. On the other hand, the broad shape of penetration was obtained on torch angle TIG0\(^\circ\) / MIG+60\(^\circ\). However, there was the deviation for center of penetration. This deviation seems to be caused by deflection of MIG wire and it is expected to improve from the effect that the direction of MIG arc is fixed by the force balance between the repulsion from TIG arc and the stiffness of MIG arc.
These results suggested that MIG torch angle changes not only appearance of arc shape but the shape of bead and penetration even in same TIG/MIG current condition. There was not seen the remarkable difference which can decides the right or wrong of weld bead. However, in other words, it can be considered that there is the rich tolerance about torch configuration for welding results.

As relative optimum configurations, TIG0° /MIG+45° was selected from the following reasons:

1. MIG torch angle needs to be more than +45° to keep forehead angle under the large repulsion condition.
2. The deviation for center of penetration is expected to be improved effectively by fixing due to the balance between the repulsion from TIG arc and stiffness of MIG arc.
3. The most flat bead shape evaluated from H/W was obtained.

Based on these considerations, we produced the original torch. Appearance of the torch is shown in fig.8. For example, Fig.9 shows the result of application for the fillet joint by using original torch. Good welded joint without oxidation was obtained on multi-layer welding even in welding position having inclined angle by unified structure of torch and nozzle.

### 4. Conclusions

In this report, the following conclusions were obtained.

1. We considered about MIG torch angle to keep forehead angle of MIG arc under the influence of repulsion from TIG arc, and it was decided on TIG0° /MIG+45° based on the results of observation for the arc shape.
2. The bead shape characteristics such as penetration, bead width, and reinforcement height were considered on each torch angle. There was not remarkable deference thus it can be expected that this process has rich tolerance for torch angle condition. It was confirmed that selected angle(TIG0° /MIG+45°) was relatively good condition for penetration depth, shape, and flatness of bead shape evaluated by cross section.
3. The original torch for TIG-MIG hybrid welding process which has fixed and unified structure on optimized configuration was produced, and it was confirmed the good weldability on practical joint welding.

### References