

# Study on arc-ultrasonic TIG welding of titanium alloy

Zhou Ronglin, Guo Delun, Li Congqing and Zhang Yingen

周荣林, 郭德伦, 李从卿, 张银根 \*

**Abstract** TCA alloy was welded by conventional TIG welding and arc-ultrasonic TIG welding respectively. The microstructure of joint was analyzed by means of optical-microscope, scanning electron microscope in order to study the relationship between the macro-properties of joint and the microstructure. The results show that the joints were all welded successfully by conventional TIG welding and arc-ultrasonic TIG welding. With the increment of ultrasonic frequency and activated voltage, the width of joint became narrow step by step. The microstructure became more and more fine and was inclined to equiaxed crystal. Moreover, the dendrite depredation was not observed obviously. The properties of welded joint were improved markedly compared with that of conventional TIG welding.

**Key words** arc-ultrasonic, TIG welding, titanium alloy

## 0 Introduction

The welded structure of Ti alloy is of extensive promising prospect in the field of aviation, aerospace, voyage and petroleum chemical engineering and so on. However, the coarse microstructure of welded joint, which leads to the poor weldability and the difficulty in obtaining high strength welded joint, severely hinder its application. Therefore, the key to solve the coarse microstructure effectively becomes more and more imminent<sup>[1,2]</sup>.

With a view to the changing resistance load characteristic of welding arc, arc will become a kind of controlled ultrasonic emission source when it is modulated with outer high frequency. Up to now, this technique has been applied in the field of steel welding to some extent<sup>[3]</sup>.

In this paper, the microstructure of joint was analyzed by means of X-ray radiographic inspection, optical-microscope and scanning electron microscope in order to study the relationship between the macro-properties of joint and the microstructure. It is significant to drive the appliance of the arc-ultrasonic welding technique and titanium alloy welding structure.

## 1 Experimental material and process

Experimental material is TC4 (Ti6Al4V) alloy, its size is 2 mm × 50 mm × 300 mm. Welding wire is TC3, its size is  $\phi 1.2$  mm. Table 1 shows the welding parameters of arc-ultrasonic TIG welding and conventional TIG welding respectively.

Table 1 Welding parameters

| Diameter of tungsten pole /mm | Welding current/A | Arc voltage/V | Welding speed/m · h <sup>-1</sup> | Wire feeding rate/m · h <sup>-1</sup> | Shielding gas /L · min <sup>-1</sup> |                |               |
|-------------------------------|-------------------|---------------|-----------------------------------|---------------------------------------|--------------------------------------|----------------|---------------|
|                               |                   |               |                                   |                                       | Welding torch                        | Dragging cover | Backing plate |
| $\phi 3.2$                    | 165               | 10            | 12.5                              | 27                                    | 10                                   | 10             | 8             |

The microstructures of joint welded by conventional TIG welding and arc-ultrasonic TIG welding with various parameters were analyzed by means of X-ray radiographic

inspection, optical-microscope and scanning electron microscope in order to study the relationship between the macro-properties of joint and the microstructure.

\* Zhou Ronglin, Guo Delun and Li Congqing, Beijing Aerospace Machinery Technology Research Institute, Beijing, 100024. E-mail: zhouronglin2000@sina100.com (Zhou Ronglin) Zhang Yingen, Da Gang Qil Manage Office, Tianjin, 300020.

## 2 Results and discussion

ultrasonic TIG welding.

### 2.1 X-ray radiographic inspection

The welded joint was inspected by X-ray radiographic inspection, and the results show that the joint were all welded successfully by conventional TIG welding and arc-

### 2.2 Microstructure of welded joint

Fig. 1 was the microstructure of welded joint with various parameters.



(a) Conventional TIG welding



(b)  $f = 30 \text{ kHz}$ ,  $U = 35 \text{ V}$



(c)  $f = 80 \text{ kHz}$ ,  $U = 70 \text{ V}$

Fig. 1 The microstructure of welded joint with various parameters  $300 \times$

It could be seen that with the increment of ultrasonic frequency and activated voltage, the width of welded joint became narrow step by step. The microstructure was more minute than that of conventional TIG welding and its configuration was inclined to equiaxed crystal. When  $f = 80 \text{ kHz}$ ,  $U = 70 \text{ V}$ , the equiaxed crystal microstructure was dispersed in welded joint by and large.

### 2.3 The tensile strength of welded joint

Table 2 shows the results of tensile strength of joint welded by conventional TIG welding and arc-ultrasonic TIG welding. It also could be seen that with the increment of ultrasonic frequency and activated voltage, the properties of welded joint were improved to some degree, which were superior to that of conventional TIG welding.

Table 2 The properties of joint welded by conventional TIG welding and arc-ultrasonic TIG welding with various parameters

|                                                             | Tensile strength/MPa | Yield strength/MPa | Elongation ( % ) |
|-------------------------------------------------------------|----------------------|--------------------|------------------|
| Conventional TIG welding                                    | 956.6                | 921.1              | 3.33             |
| Arc-ultrasonic( $f = 30 \text{ kHz}$ , $U = 30 \text{ V}$ ) | 966.6                | 947.1              | 3.50             |
| Arc-ultrasonic( $f = 80 \text{ kHz}$ , $U = 70 \text{ V}$ ) | 985.7                | 969.3              | 3.67             |

### 2.4 Fractographs of welded joint

Fig. 2, Fig. 3 was the fractographs of joint welded by conventional TIG welding and arc-ultrasonic TIG welding ( $f = 80 \text{ kHz}$ ,  $U = 70 \text{ V}$ ) respectively.

It could be seen that in the joint welded by conven-

tional TIG welding, the macro-fracture undulated more obviously and unevenly. In the different microscopic area, there existed dendrite depredation. It illuminated that the coarse dendrite crystal was formed in the welded joint and made the properties of welded joint reduced. However, in

the joint welded by arc-ultrasonic TIG welding, the macrofracture undulated evenly. In its corresponding different microscopic area, it was difficult to observe the dendrite deprecation. As a result, the properties of welded joint were superior to that of conventional TIG welding.

Due to the effect of ultrasonic, the oscillation and stirring of the molten pool were aggravated, the crystal nuclei forming was promoted at the same time. As a result, the texture grew up was refrained effectively and the microstructure of welded joint was dispersed uniformly.

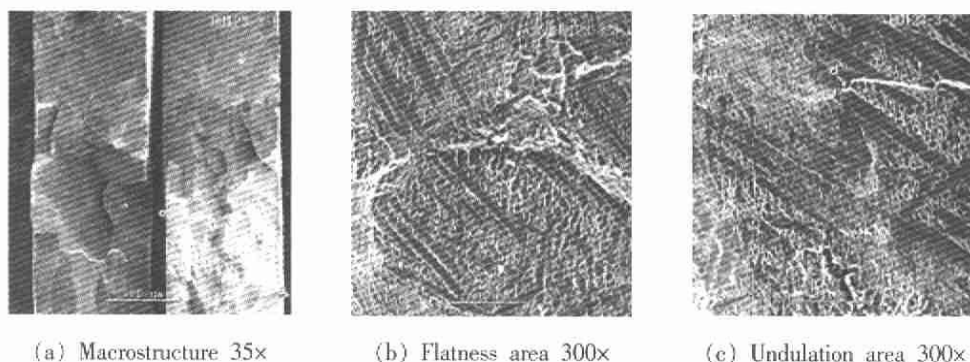


Fig. 2 Fractographs of joint welded by conventional TIG welding

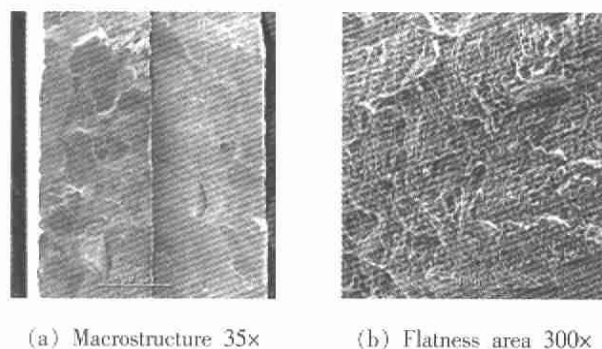


Fig. 3 Fractographs of joint welded by arc-ultrasonic TIG welding ( $f=80\text{ kHz}$ ,  $U=70\text{ V}$ )

### 3 Conclusions

(1) The microstructure of joint welded by conventional TIG welding was coarse and uneven. The fracture was inter-coarse dendrite crystal fracture.

(2) With the increment of arc-ultrasonic frequency and activated voltage, the microstructure became more mi-

nute and equiaxed crystal dispersed more uniformly. The width of welded joint reduced and the tensile strength was improved to some extent.

(3) At  $f=80\text{ kHz}$ ,  $U=70\text{ V}$ , the microstructure of joint welded by arc-ultrasonic TIG welding was minute equiaxed crystal by and large, it is difficult to observe the dendrite deprecation.

(4) The TC4 was welded successfully by conventional TIG welding and arc-ultrasonic TIG welding.

### References

- [1] Greer A L. Application to grain of aluminum by Al-Ti-B. *Acta Materials*, 2000, 48(11): 2823 - 2835
- [2] Dvornak M J. Influence of solidification kinetics on aluminum weld grain refinement. *Welding Journal*, 1991(10): 271 - 276
- [3] Stoeckinger G R. Pulsed DC high frequency GTA welding of aluminum plate. *Welding Journal*, 1973(12): 558 - 567