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Author(s)	Wang, Ting; Zhang, Binggang; Chen, Guoqing et al.
Citation	Transactions of JWRI. 2010, 39(2), p. 133-135
Version Type	VoR
URL	https://doi.org/10.18910/7555
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Effect of welding sequences on the microstructure of electron beam welded TA15 titanium alloy and 304 stainless steel joints with copper filller metal†

WANG Ting*, ZHANG Binggang*, CHEN Guoqing*, and FENG Jicai*

KEY WORDS: (TA15 titanium alloy) (304 stainless steel) (Dual-pass electron beam welding) (Welding sequence) (Microstructure) (Intermetallic layer) (Cluster)

1. Introduction

Composite components of titanium alloy and steel can fully exert the advantages of these two materials simultaneously[1-2]. Fusion welding of titanium alloy and steel was difficult to implement because of the production of brittle phases in the weld[3-4]. So far, no literature about successful fusion welding of these two alloys has been reported. Conversely, pressure welding and brazing can eliminate the problems in fusion welding because the base metals remain in the solid state during joining. Furthermore, many successful examples have been reported[5-7]. However, the service conditions may make particular processes unsuitable [8, 9].

In this paper, a copper interlayer sheet was adopted to join TA15 titanium alloy and 304 stainless steel by dual-pass electron beam welding. The effect of welding sequences on the microstructure and tensile strength of the joints were analyzed.

2. Experimental

The chemical compositions of the materials applied in this experiment were given in **Tables 1, 2**. 1 mm thick copper sheet was adopted as filler metal and embedded in the contact face before welding, then fixed by spot welding using a TIG method.

Dual-pass electron beam welding was used and two welding sequences were carried out. In one sequence, the first pass was located on the contact face between stainless steel and the copper sheet, and the second pass on the contact face between titanium alloy and the copper sheet. In another sequence, the location of the two passes is contrary. For both of the two passes in the two sequences, the parameters are 55 kV accelerating voltage, 2450 mA focus current, 300 mm/min welding speed, and 9 mA beam current.

Microstructure observation was with an optical microscope and scanning electron microscope. Tensile strength was tested under a strain rate of 0.5mm/min.

3. Results and Discussion

Macrostructures of the cross sections of the joints under different sequences are shown in **Fig. 1**. It can be seen that copper element caused clusters of yellow color located in the weld near 304SS in the joint under the first sequence. And another structure in dark gray is also located in the weld near TA15 in clusters. The joint cracked after welding. For the joint under the second sequence, the yellow and dark gray structures are distributed in the weld and dispersed uniformly. Obviously, this kind of distribution state of the different structures in the welds is dependent on the welding sequence. For the first sequence, Fe and Cu elements mixed in the weld in the first pass. Fe and Cu are immiscible to each other. So the segregation of Cu is very serious. But for the second sequence, Ti element has been melted into the weld in the first pass, so high melting temperature phase Fe-Ti can be considered as nucleating particles and Cu solidified dispersedly in the second pass.

In order to analyze the reason for the fracture of the joint under the first sequence, microstructures of the interface between TA15 and the weld and the zones I and II of each joint are examined as shown in **Fig. 2** and **Fig. 3**. There are Cu-Ti intermetallic layers in the interfaces, with thicknesses of about 75±5μm and 90±5μm, respectively. This is because the Cu-Ti intermetallic layer is formed in

Table 1 Chemical composition of TA15 titanium alloy

Al	Zr	Mo	V	Ti
5.5-7.0	1.5-2.5	0.5-2.0	0.8-2.5	bal

Table 2 Chemical composition of 304 stainless steel

C	Ni	Cr	Mn	Si	Fe
≤0.07	8-11	17-19	≤2.0	≤1.0	bal

† Received on 30 September 2010
* SKLP, Harbin Institute of Technology, Harbin, China

Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

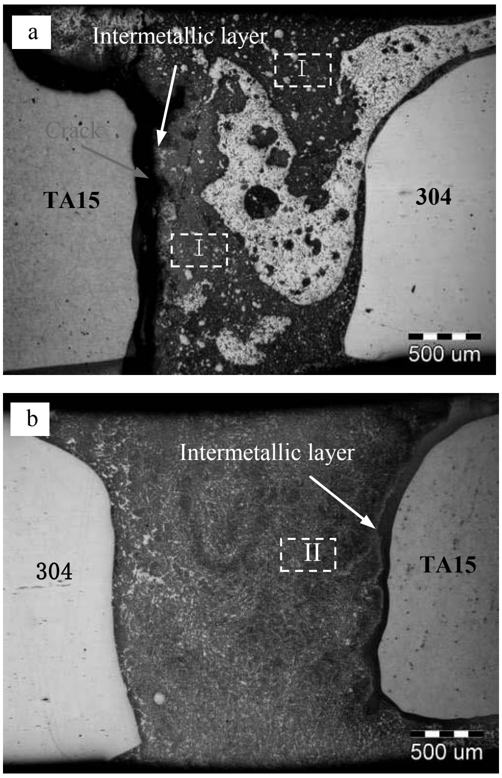

Fig. 1 Macrostructures of the cross sections of the joints under the two welding sequences. (a- The fisrt sequence, b- The second sequence)

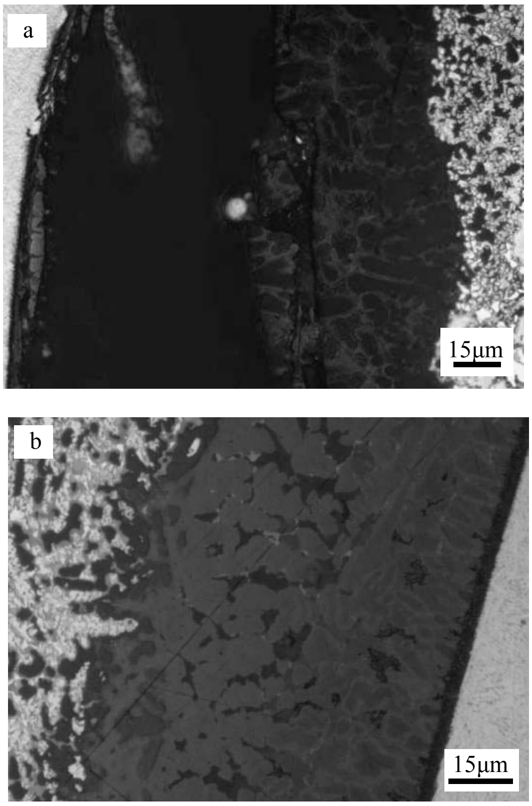

Fig. 2 Intermetallic layers between TA15 and the welds in the joints under the two welding sequences. (a- The fisrt sequence, b- The second sequence)

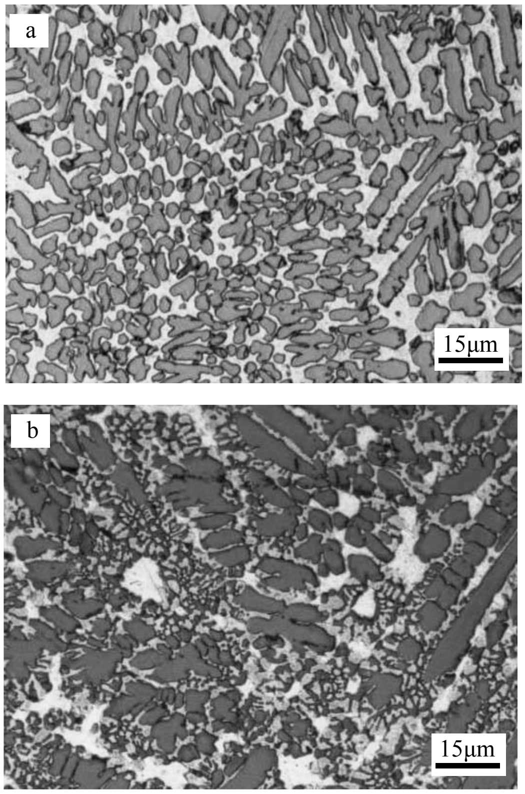

Fig. 3 Microstructure in zone I and II in the joints under the two welding sequences. (a- Zone I in the fisrt sequence, b- Zone II in the second sequence)

the last pass for the first sequence. But for the second sequence, it is formed in the first pass, so it was reheated by the second pass. Zone I is characterized by three phases, i.e, dark gray TiCu, light gray $TiFe_2$ and solid solution of copper with yellow color. But zone II only contains light gray $TiFe_2$ and solid solution of copper with a yellow color. Comparing the two joints, there is only little solid solution of copper in zone I near the intermetallic layer, but more in zone II. Copper is a soft metal, which can accommodate the deformation, as a result, the heat stress in the region was reduced. The more solid solution of copper there is, the more prominent the reduction effect is. Consequently, a crack free joint is obtained under the second sequence. The tensile strength is 234MPa and the joint fractured in the intermetallic layer when it was stretched.

4. Conclusions

(1) A crack free electron beam welding joint of TA15 and 304 stainless steel is obtained by using a copper sheet as filler metal. One important function of copper is to reduces heat stress in the weld.

(2) The microstructre and property of the joint is affected by the welding sequence. High quality joints can be obtained under the welding sequence in which the copper distributed uniformly in the weld.

References

[1]. R. R. Boyer: Mater Sci and Eng, A., 213 (1996), pp.103-114.

[2]. X. J. Yuan, G. M. Sheng, B. Qin: Mater Character, 59 (2008), pp.930-936.
[3]. A. Elrefaey, W. Tillmann: J. Mater Processing Technol, 209 (2008), pp.2746-2752.
[4]. X. Yue, P. He, J. C. Feng: Mater Character, 59 (2008), pp.1721-1727.
[5]. A. Fuji, K. Ameyama, T. H. North: J. Mater Sci, 31 (1996), pp.819-827.
[6]. B. Qin, G. M. Sheng, J. W. Huang, B. Zhou: Mater Character, 51 (2006), pp.32-38.
[7]. P. He, X. Yue, J. H. Zhang: Mater Sci and Eng. A., 486 (2008), pp.171 -176.
[8]. Z. Sun, R. Karppi: J. Mater Processing Technol, 59 (1996), pp.257-267.
[9]. M. Ghosh, S. Chatterjee: Mater Sci and Technol, 48 (2002), pp.393-399.