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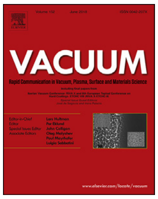

Microstructural evolution and mechanical properties of vacuum brazed Ti_2AlNb alloy and Ti60 alloy with Cu75Pt filler metal

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ABSTRACT

Cu75Pt filler metal was firstly used to vacuum braze Ti_2AlNb alloy to Ti60 alloy and the sound joints were obtained in this work. The solidus temperature of Cu75Pt filler was 1127 °C. The typical interfacial microstructure of Ti60/Cu75Pt/Ti_2AlNb joint brazed at 1180 °C for 10 min was Ti60 substrate/β-Ti + α-Ti + Ti_3Pt/Ti_3Pt/B2 + α_2/Ti_2AlNb substrate. The effects of brazing temperature on the interfacial microstructure and mechanical properties of the Ti60/Cu75Pt/Ti_2AlNb brazed joints were investigated. The increasing of brazing temperature accelerated the diffusion of liquid filler into substrate, resulted in the decrease of Ti_3Pt brittle phase and the grain growth of substrates. The shear strength of the joints brazed at 1200 °C for 10 min reached the maximum of 93 MPa. The fracture surface of the joint was characterized as Ti_3Pt brittle phase and it cracked in β-Ti when brazing temperature reached 1210 °C.

1. Introduction

As a new class of titanium intermetallic alloys, Ti_2AlNb alloy has become the focus of attention as potential materials for aircraft engine applications because of its ordered orthorhombic structure which can offer the advantages of high fracture toughness, good ductility and workability compared with TiAl alloys [1–3]. Ti60 is a kind of near-α type titanium alloy, which has low density combined with excellent mechanical properties at service temperature of 600 °C. It has been used for manufacturing critical components of aero-engines, such as the blisks or blades of high-pressure compressors. To fully enhance the performance of the components such as the high-pressure compressor disc and turbine disc, it is of great significance to investigate the appropriate welding procedures of Ti_2AlNb alloys and Ti60 alloys [4,5].

Currently, various joining techniques have been performed to obtain sound joints of Ti_2AlNb alloys and titanium alloys, such as laser welding, fusion welding, electron beam process and diffusion bonding [6–11]. As an economical and feasible joining method, brazing has been gaining attentions in joining titanium alloys. However, the active element Ti in titanium alloys easily reacts with oxygen to form titanium oxide in non-vacuum [12]. The titanium oxide can restrict the reaction at the interface of the brazing joint [13]. To guarantee a sound joint with sufficient interfacial reactions, vacuum brazing is a better choice to join titanium alloys.

To date, Ag-based and Ti-based brazing alloys were successfully applied to braze Ti_2AlNb alloys and conventional titanium alloys [14–17]. However, Ag-based brazing alloys failed to satisfy the thermal resistance of joints, and the obtained joints could not meet high-temperature applications [18]. Ti-based brazing alloy demonstrated excellent room and high temperature performance in brazing many titanium alloys [19,20]. Recently, some high-temperature fillers were researched to braze titanium. For example, Ti-Ni eutectic brazing alloy was used to vacuum braze high Nb-containing TiAl alloy to Ti60 alloy and Ti_2Ni was found in the brazing beam [21]. J. Cao et al. used Ti-27Co eutectic alloy to join TiAl alloys with Ti_2AlNb alloys. The phases of α_2-Ti_3Al, β-Ti, TiCo, Ti_2Co and B2 were formed in the interfacial microstructure of the joints [22]. These previous researches revealed that the main reason for brazing titanium alloys was the interactions between Ti element and other elements. And most of the brazed joints are composed of Ti-containing compounds. As brazing Ti-based substrates with the brazing temperature over 1100 °C, the non-Ti based filler metals can be considered to satisfy the high-temperature

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application. Cu75 Pt, as a Cu-based brazing alloy, has not been previously reported yet. It is noting that Cu is one of the few elements that can be currently doped into the brazing filler metal such as Ti-Cu based alloy and Ag-Cu based alloy when brazing titanium alloys [23,24]. In addition, Pt is a classical inert metal like Au that can be beneficial for the high temperature performance of the brazing joints and the addition of Pt can increase the oxidation and hot corrosion resistance of the joints [25,26]. Hence, it is of great significance to study on the brazing process and interface structure of Ti60/Cu75 P t/Ti$_2$AlNb joints. In this work, Cu75 P t filler metal was firstly applied to vacuum braze Ti$_2$AlNb alloy to Ti60 alloy. The interfacial microstructure and mechanical properties of the obtained brazed joints were analyzed in details, and the effect of brazing temperature on the interfacial microstructure and the evolution of the brazed joints was proposed.

2. Experimental section

Ti$_2$AlNb alloy provided by Baoji Titanium Industry Co. is Ti-22 A l-24Nb-0.5Mo (*at.* %) alloy, which consisted of matrix phase O-Ti$_2$AlNb (grey), α_2-Ti$_3$Al phase (dark) and B2 phase (white), as shown in Fig. 1 (a). Ti60 alloy (Ti-5.6Al-3.7Sn-3.0Zr-0.6Mo-0.9Ta-0.3Si-0.01C, *wt.* %) is provided by Northwest Institute for Non-Ferrous Metal Research, Xi'an, China, and the typical microstructure is shown in Fig. 1 (c), which is composed of equiaxial α-Ti (dark) and a small amount of β-Ti (white) distributing in the grain boundary. The X-ray diffraction (XRD) patterns of Ti$_2$AlNb alloy and Ti60 alloy are given in Fig. 1 (b) and (d), which are corresponding to the analyses of microstructures in Fig. 1 (a) and (c) respectively. And the X-ray source is Cu Kα.

Ti$_2$AlNb alloy plate and Ti60 alloy plate were cut into specimens of cuboids 5 mm × 5 mm × 2.5 mm and 10 mm × 20 mm × 2 mm. Both the substrates were polished by silicon carbide papers, and subsequently cleaned using an ultrasonic bath with acetone as solvent prior to vacuum brazing. The Cu75 P t filler metal foils with the thickness of 40 μm were sandwiched between the substrates, as shown in Fig. 2 (a). The assembly was heated to 1000 °C from ambient temperature at a heating rate of 10 °C/min, and held for 10 min, and then the heating process continued to the brazing temperature with the holding time fixed at 10 min. Finally, the vacuum furnace was cooled down to the room temperature with the rate of 10 °C/min. Brazing experiments were conducted in a vacuum of 5×10^{-3} Pa throughout the process. Five brazing temperatures of 1170 °C, 1180 °C, 1190 °C, 1200 °C and 1210 °C were chosen.

After the brazing process, the room temperature shear tests (Fig. 2 (b)) were performed by a universal testing machine (Instron 5967) at a constant speed of 0.5 mm/min compressed the brazed specimens. In order to evaluate the bonding strength of selected

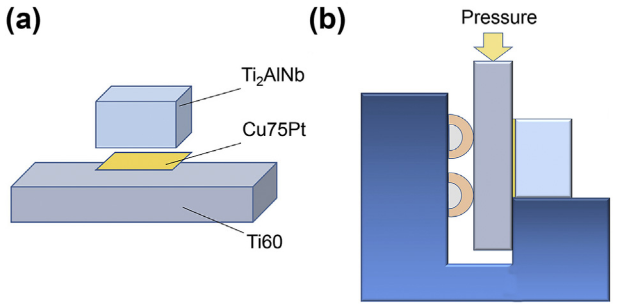

Fig. 2. Schematic diagrams of assembling brazing parts (a) and shear test experiment (b).

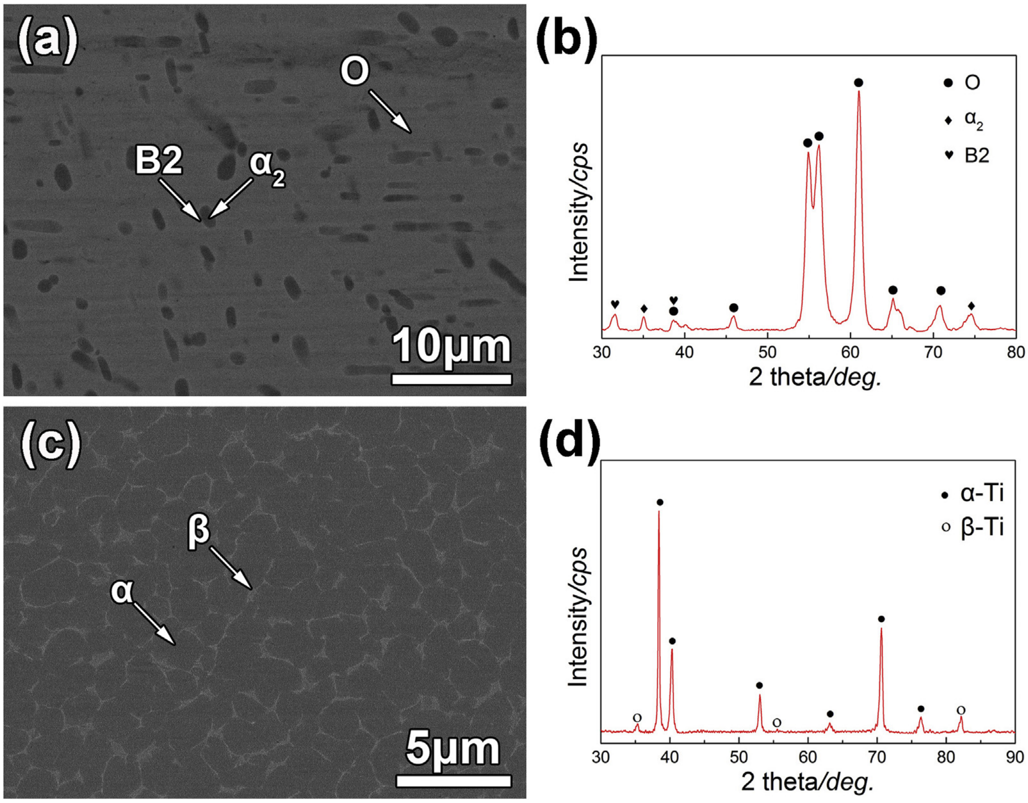

Fig. 1. Microstructures and XRD patterns of the base alloys. (a, b) Ti$_2$AlNb alloy; (c, d) Ti60 alloy.