# Effect of the Brazing Technique on Microstructure of TC4 Alloy Joint

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**Keywords:** Brazing Technique, Microstructure, TC4 alloy joint.

**Abstract.** The TC4 alloy was connected by brazing using the active brazing filler metal ($(Ti_{0.46}Cu_{0.14}Zr_{0.27}Ni_{0.13})_{99.5\%}Si_{0.5\%}$) in this experiment, and the microstructures of brazing sample joint interfaces were analyzed. It was found by research that the joint microstructures from the outside to the center of welding were made up of TC4/mesh basket (α + β) Ti + trace $CuTi_2$/darkgray island + light-gray island + white bar. The welding temperature and holding time had a great impact on the joint microstructure, and the great importance should be attached to the impact.

## 1. Introduction

Titanium alloy has been widely used in such high-tech fields as aerospace, and its main features are low density, high strength and sound tenacity [1, 2]. Titanium plays a very important role in metal material, and it is even known as a "universal metal", and also regarded as the third metal following iron and aluminum [3, 4]. Thus, titanium alloy was widely used[5, 6], and a great many studies had been done since it was discovered. Of course, the titanium alloy [7, 8] was further used in more fields with the in-depth study. It needed to be used after brazing in many application fields. The brazing was done generally in vacuum or argon protection due to strong high-temperature activity [9]. As the titanium was easily alloyed with the brazing filler metal [10], so the titanium alloy was brazed more easily. However, in this case, the joint became crisp with the metal compound produced. So proper temperature and brazing time should be determined in the brazing of titanium alloy to avoid the crisp metal compound occurring. By this way, the requirement for brazing quality can be satisfied.

In the vacuum condition in this paper, TC4 alloy was connected by brazing using active amorphous brazing filler metal $(Ti_{0.46}Cu_{0.14}Zr_{0.27}Ni_{0.13})_{99.5\%}Si_{0.5\%}$, and the impacts of different parameters such brazing temperature and holding time on welding joints were studied in this experiment.

## 2. Experimental method

The brazing filler metal $(Ti_{0.46}Cu_{0.14}Zr_{0.27}Ni_{0.13})_{99.5\%}Si_{0.5\%}$ was used in this experiment. The brazing process: (1) Sample cleaning: TC4 samples were polished first, and then they were cleaned ultrasonically with acetone; after that, the samples were dried ten minutes; (2) Assembling: The brazed samples were assembled and then put in the special sintering boat at an applied pressure of 800 N; (3) Brazing: The assembled brazing samples were put into the vacuum brazing furnace at a certain brazing temperature. The brazing temperature control curve is shown in FIGURE 1. (4) Sampling and recording: The samples were taken out of the furnace when the furnace temperature cooled down below 25 °C. The vacuum degree was always controlled below $5\times10^{-3}$ Pa in the whole brazing process. The effect of brazing temperature (T) and holding time (t) on joint microstructure was studied. The analysis on the microstructure was done using US FEI/Quanta TM 250 scanning electron micrograph.



DOI: 10.25236/icceme.2019.022

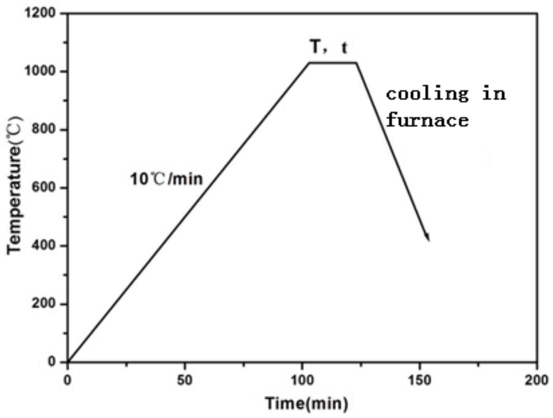


**Figure 1.** Brazing heating curve.

## 3. Results and analysis

This complex alloy brazing filler metal was used for the brazing to connect titanium alloy, and the complex chemical reaction happened to form different microstructures in the high temperature. Through observing the SEM pictures of brazing samples in different parameters, it was found they had basically similar morphology which was divided into five areas. There were significantly different microstructures in the five areas, and they were defined as Areas A, B, C, B and A. Area A was TC4 alloy area, Area B showed the deep gray matrix + light-gray strip at the alloy side, and Area C was the mosaic texture area showing the deep-gray island + light-gray island + white strip at the middle layer. The effect of brazing temperature (T) and holding time (t) on joint microstructures were discussed. Five groups of parameters were selected for analysis, and they were: (1030 ℃, 10 min), (1030 ℃, 30 min), (1000 ℃, 20 min), (1030 ℃, 20 min) and (1060 ℃, 20 min).

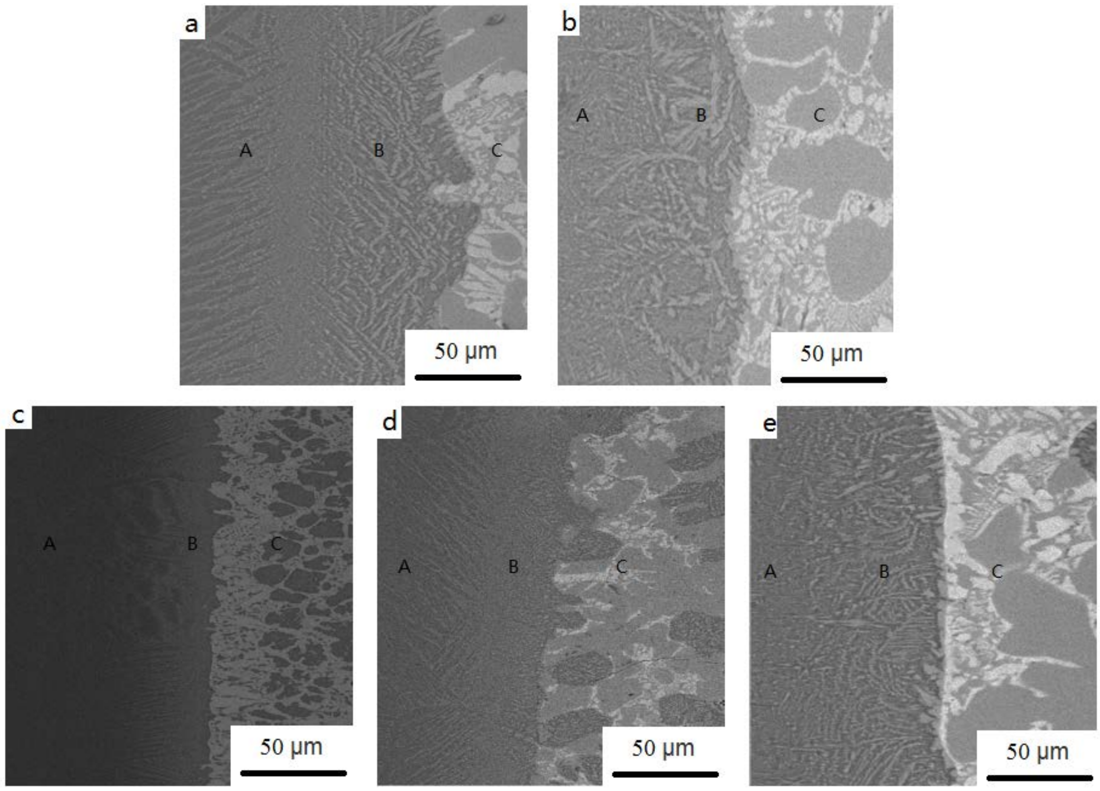


**Figure 2.** Brazing joint microstructure pictures.

It is seen from the welding microstructure pictures that the morphology in Area A has not a typical TC4 alloy microstructure but a typical Widmannstatten structure. FIGURE 2. (a), (b), (c), (d) and (e) are the welding microstructure pictures of brazing samples respectively with brazing parameters (1030 ℃, 10 min), (1030 ℃, 30 min), (1000 ℃, 20 min), (1030 ℃, 20 min) and (1060 ℃, 20 min). It is known from FIGURE 2 that the welding microstructure morphology of samples is the same at Area A in five welding parameters. The Widmannstatten structure of TC4 titanium alloy is characterized by the continuous α phase distributed in the crystal boundary of original thick β grain. By comparing the welding line areas of brazing samples in different parameters, it is known Area A is made up of Widmannstatten structure, but the structure size changes with temperature and holding time. For example, the Widmannstatten structure was less at 1000 ℃ for 20 minutes (holding time) than the structure at other temperature.

The elements at Area B were Ti, Zr and Cu, and they had very similar percentage of atom quantity. From constituent analysis, the component content of deep-gray and light-gray microstructures was the same at Area B; so the microstructure at Area B could be determined as the basket-weave microstructure of TC4. The basket-weave microstructure of TC4 was the one made up of the cross-banding lamellas with the α-phase lamellas shortened as the crystal boundary was broken when the original β phase deformed. The furnace cooling way applied in this experiment could result in a less descent rate of temperature. So plenty of α-phase microstructures were separated out from the β-phase ones, so that the β-phase boundary was broken. As a result, the microstructure of TC4 presented a basket-weave state with the staggering of α and β phases. This agreed with the microstructure at Area B of welding in brazing samples in this experiment. Area B contained a certain quantity of Cu elements for the Cu in brazing filler metal diffused into Area B. So $CuTi_2$ was possibly produced in terms of Cu-Ti binary phase diagram. Based on above comprehensive analysis, it was concluded the final product at Area B was the basket-weave (α + β)Ti + trace $CuTi_2$.

Area C of the welding was made up of the microstructures presenting the "dark-gray island + light-gray island + white bar", and its microstructures were most complicated. It is known from FIGURE 2. (a) and (c) that there is no the dark-gray island microstructure at Area C of the joint when the welding parameters were (1030 ℃, 10 min) and (1000 ℃, 20 min) respectively. However, it is known from Fig (b), (d) and (e) that the microstructures with three morphologies--"dark-gray island + ligh-gray island + white bar" occur when the welding parameters are (1030 ℃, 30 min), (1030 ℃, 20 min) and (1060 ℃, 20 min). It is known by observing that there was no dark-gray island microstructure in the joint in lower temperature or shorter holding time. This was because of insufficient element diffusion reaction with lower welding temperature or shorter holding time.

## 4. Conclusions

The TC4 alloy was connected by brazing using active brazing filler metal $(Ti_{0.46}Cu_{0.14}Zr_{0.27}Ni_{0.13})_{99.5\%}Si_{0.5\%}$ in this experiment, and the microstructures of brazing sample joint interfaces were analyzed. It was found by research that the joint microstructures from the outside to the center of welding line were made up of TC4/mesh basket (α + β) Ti + trace $CuTi_2$/darkgray island + light-gray island + white bar. There are great differences in the phase composition and microstructures of joints in different welding temperature and holding time.

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