Q: We braze Titanium Grade 2 parts in a vacuum using a standard BTI-5 filler metal. The brazing temperature is 900°C, according to AWS A5.8, Specification for Filler Metals for Brazing and Braze Welding. When we set up the process, we tested different dwell times and found the strength of the joints was very sensitive to the dwell time value — even when changed in 5-min increments. Our first intention was to minimize dwell time in order to minimize the growth of brittle intermetallic layers at the interface. However, even 1-min dwell time resulted in low joint shear strength. While the joint had low strength at 5 min, 10–12 min showed strength almost double that at the short dwell time. Hoping to further improve the strength, we switched to a 20–22-min dwell time. However, the strength of the brazed joints dropped again. Can you explain this brazing quality volatility? The second question we have is how to optimize timing to provide stable strength values of brazed joints.

A: Titanium brazing filler metals of the Ti-Cu-Ni and Ti-Zr-Cu-Ni families are characterized by high reaction ability and intense diffusion exchange during interaction with base metals, because A) the base metal does not contain Cu, Ni, and Zr, and B) titanium forms a number of intermetallic phases in contact with liquid filler metals. Brittle intermetallic phases (such as TiCu1.6, TiAl3, TiNi3, Ti2Cu2, (Ti, Zr),Cu, etc.) are formed in practically all titanium brazed joints. For example, brittle intermetallic phases are found in a titanium-to-steel joint shown in Fig. 1. Mostly, the fracture of brazed joints is caused by an intermetallic layer formed at the interface of the base metal, or at least intermetallic phases initiate the nucleation of microcracks in the joint metal. This may result in a significant decrease in the strength of brazed joints.

If the thickness of the joint metal is <50 microns (0.002 in.), the amount of reaction occurring in components such as copper or nickel is insufficient to form a thick intermetallic layer at the interface of the base metal. But the volume of liquid filler metal (as a source of copper and nickel) is much larger in fillet areas, where a thick, brittle layer is always formed at the titanium base interface. This layer may initiate the first crack that is further propagated into the joint. If titanium is brazed to steel, the (Ti, Zr)Fe3 intermetallic layer formed at the steel interface can also cause fracture of the brazed joint — Fig. 1.

Therefore, the first recommendation for keeping stable quality and reliability of titanium brazed joints is to avoid large fillets. If you minimize the size of chamfers, you minimize the volume of liquid filler metal in fillet areas, and subsequently limit the growth of brittle intermetallic layers.

Figure 2 presents the microstructure of a joint brazed at a 5-min dwell time. There is no intermetallic layer at the interface, but we observe many structural constituents, including an eutectic layer in the middle of the joint metal, the solid solution areas around the eutectic, recrystallized, needle-like grains of the diffusion zones, and fine crystals of intermetallic phases (as determined by EDX analysis) distributed everywhere. This unstable and irregular microstructure comprised of components with different hardness and crystal structures — in other words, many phase boundaries — causes low strength of the brazed joint. The microstructure of titanium brazed joints can be improved by adjusting the brazing thermal cycle.

Thermal cycle plays an important role in optimizing the microstructure and in decreasing the presence of intermetallic phases in the joint metal. There are two approaches to changing the thermal cycle for these purposes. The first approach is an additional diffusion and aging heat treatment of a brazed structure. This method requires separate consideration; we shall not discuss it here.

The second approach lies in the limitation of reaction time between the base and filler metal in order to pre-
metal diffusion zones become so large it can affect the strength of the brazed structure. Perhaps this is the explanation of low shear strength after 20–22-min dwell time in your case.

The bottom line: There is an optimal holding time value for brazing titanium at each selected temperature, and this process parameter should be learned experimentally when setting up the production process.

References

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Readers are requested to post their questions for use in this column on the Brazing Forum section of the BSMA website www.brazingandsoldering.com.