BY ALEXANDER E. SHAPIRO

Q: We are very interested in brazing titanium products. My question concerns brazing titanium with steel. Basically, we would like to join titanium Grade 5 plate with stainless steel 304 round bars (1 or 7/8 in. in diameter) and require a strength of 40 ksi at the joint. Please suggest a suitable filler metal and a brazing process for us to try.

A: Technically, vacuum brazing of titanium Grade 5 (Ti-6Al-4V alloy) to stainless steel is not a problem. The process of joining titanium to nickel-plated stainless steel using a silver-copper eutectic (AWS BAg-8) as a brazing filler metal has a long history of industrial application, and has been studied rather thoroughly (Ref. 1).

The brazing is carried out over a wide temperature range from 820° to 920°C depending on design of joined parts and the required joint strength.

BAg-8a — the lithium-modified BAg-8 filler metal — can also be used in the same range of brazing temperatures. The brazed parts are shown in Fig. 1. BAg-8a is not suitable for vacuum brazing, unless the heating rate is so high that it takes only 1 to 2 min. to reach the brazing temperature. So, this braze is ideal for induction brazing or brazing by energy beam (electron or laser).

Within the last two decades, new processes and material options have been studied and tested. The application of new titanium flux RL3 A16 opened the opportunity to join titanium to titanium and titanium to steel in air using torch brazing or, preferably, induction brazing. Standard silver-based filler metals such as BAg-24 or BAg-34 are successfully used for brazing in air. A key point of this process is rapid and uniform heating of the joint area, because titanium oxidizes very fast and the protection ability of flux is limited in time. Therefore, brazing in air is successful mostly for small-size parts.

Precoating the titanium part before brazing is recommended. This means that you should use a three-step process: 1) deposition of the silver braze alloy onto the titanium surface by heating and melting with the flux, 2) removing flux residues from the surface using hot water and a metal brush, and 3) assembling with the steel part and brazing them together with new additions of flux and braze filler metal.

The joint clearance between the parts to be brazed should be as small as possible due to difference of coefficients of thermal expansion. With your design, this means that you should slightly compress the parts during brazing and cooling.

Fig. 1 — Stainless steel and titanium tubes brazed to titanium plate in vacuum using BAg-8a filler metal in the form of 1/16-in. wire ring placed inside the tubes. (Photo courtesy of Dr. Yury Flom, NASA Goddard Space Flight Center.)

Brazing titanium to steel can also be done in air with the same flux and aluminum-based filler metal TiBrazeAl-635 (the Al-Cu-Mg system) or TiBrazeAl-655 (the Al-Cu system) at a temperature below 700°C — Fig. 2. The aluminum filler metals can be used, when a low brazing temperature is needed, while the strength of joints is not a critical issue.

However, vacuum brazing with BAg-8 is still the most often used process for joining titanium to stainless steel. In order to reach the maximum strength of the brazed joint, the brazing should be done in compliance with the recommendations below.

First, the stainless steel should be plated with nickel 0.0004 to 0.0006 in. (10 to 15 microns) thick. Nickel plating significantly improves the spreading of liquid filler metal along the steel surface. Sometimes, electroless nickel plating does not provide a stable quality of coating. Then, silver plating 0.0006 ± 0.0001 in. (12 to 15 microns) thick is used instead of a nickel coating. The nickel or silver layer serves as an effective barrier to prevent the formation of brittle Ti-Fe intermetallics that are replaced by NiTi, AgTi, and CuNiTi phases.

Second, the brazing temperature in the range of 830° to 850°C and dwell time from 3 to 6 min are optimal process parameters to produce 25 to 30 ksi (170 to 210 MPa) joint shear strength. Higher brazing temperature and longer holding time result in uncontrolled growth of the brittle $TiCu_2$ intermetallic layer at the interface of the joint metal with titanium, and the strength of the joints goes down to 20 ksi (140 MPa) or even lower values.

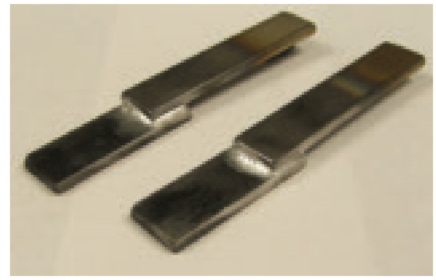

Fig. 2 — Titanium Grade 5 brazed in air to stainless steel 304 using TiBrazeAl-655 filler metal. The shear strength of these brazed joints is 17 to 19 ksi (118 to 130 MPa).

If you want to increase the strength of the joints to 40 ksi (275 MPa) and higher, you will have to change the joint design. For example, use a tube-in-tube design instead of a simple overlapping, or provide so-called mechanical securing of brazed joints, such as brazing of a threaded connection.◆

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Reference

1. Shiue, R. K., Wu, S. K., Chan, C. H., and Huang, C. S. 2006. Infrared brazing of Ti-6Al-4V and 17-4 PH stainless steel with a nickel barrier layer. *Metallurgical and Materials Transactions A*, Vol. 37, No. 7: 2207−2217.

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