Q: Our company is producing steel and titanium parts using the additive manufacturing process. Sometimes we find open pores in the metal after machining contact surfaces of flanges. Sometimes we also have to remove one or two printed components due to local defects in them. We would normally weld a quality component instead of removing one, but 3D printed metal is not weldable. We want to find a way to recover these parts to save production costs. The idea is to braze additive manufactured steel or titanium. We did not find any information about brazing or soldering additive manufactured metals. Any advice?

A: The number of machine parts made by additive manufacturing technology is drastically growing every year. The first additive manufactured metal parts were brazed in the United States a couple of years ago. Many individual parts have been joined since that time, but a serial brazing process has not been set up yet. Below, I describe some examples of the brazing and soldering application used for recovering defected surfaces or joining 3D printed metal parts by brazing.

A defect-containing surface of additive manufactured (AM) 304 stainless steel is shown in Fig. 1. The solder Zn-2Al was deposited on this surface to fill porosity and recover the surface. Soldering was performed by heating.

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Fig. 1 — Defects on the surface of AM stainless steel.

Fig. 2 — Solder Zn-2Al deposited on the AM stainless steel to fill defects such as open porosity.
with a propane torch and applying a flux. The soldered surface of 3D printed stainless steel is shown in Fig. 2. After machining and polishing, this surface has no porosity and can be used in a sealing structure. The AI-22Zn solder can also be used for the same purpose, as well as the standard tin-zinc eutectic solder Sn-9Zn. All mentioned soldering operations are carried out at 400°C.

Recovery of AM titanium surface can be done by heating in vacuum furnace using standard BTI-3 or BTI-5 filler metal pre-placed on top of the deformed metal in the form of powder, paste, or foil. Brazing temperature is 880°–890°C for BTI-3 and 890°–920°C for BTI-5.

Brazing of commercially pure titanium (Grade 2) or Ti-6Al-4V alloy (Grade 5) can be done by the same BTI-3 or BTI-5 filler metals, as well as BNI-2 amorphous foil 50–60 μm thick. The AM titanium Grade 2 coupons brazed by BTI-5 amorphous foil 75 μm thick are presented in Fig. 3. Shear strength of joints brazed at 1080°C by BNI-2 foil 50 μm thick is in the range of 43–48 ksi (297–331 MPa). Shear strength of joints brazed by BTI-5 foil is in the range of 34–38 ksi (234–262 MPa). That is lower by 15–20% than that of brazed joints of wrought metal. However, the strength of the AM titanium brazed joints is sufficiently high for most practical applications. Lower strength of AM titanium brazed joints can be explained by a specific microstructure of a joint metal and an interface zone of the base metal. Liquid metal penetration along the grain boundaries is significantly more active when AM titanium is brazed when compared with brazing of the wrought titanium. Therefore, we can expect that the strength of the brazed joint will be higher if the brazing temperature and/or holding time during brazing operation in a vacuum furnace is lower. This means filler metals such as Incusi®ABA, TiBraze800, or TiBraze590 may result in higher joint strength for AM titanium brazed joints.

Heat-resistant joints of AM titanium also can be made by vacuum brazing using standard filler metals BTI-1 or BTI-5 alloyed with niobium or molybdenum. Additive manufactured Ti-6Al-4V alloy brazed by TiBraze200Nb (Ti-17Zr-17Cu-17Ni-17Nb wt-% or Ti₂ZrNbCu₃Ni₅ at-%) is shown in Fig. 4. In this case, brazing temperature is 1020°–1040°C, which is significantly higher than that for brazing with standard BTI-5 filler metal. Shear strength of these joints is 19.6–25.2 ksi (133–160 MPa) at room temperature. Higher temperature is needed to provide a full and uniform dissolution of niobium or molybdenum in the joint metal. The same filler metal was used for brazing AM Ti-6Al-4V alloy with alumina ceramic — Fig. 5. These brazed joints are suitable for applications at 500°–800°C.