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Filler Metal Control in Sinter Brazing

This method is applied to control the flow and retention of the filler metal at the sinter braze joint

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Sinter brazing has become a significant tool in the manufacturing of many complex powder metal components. Although the compaction technology has advanced substantially over the years, the ability to bond two components while sintering has enabled the industry to broaden its capabilities and remain competitive in many markets.

The primary issue with the brazing of two powder metal components, in either the green or sintered states, is the competition between the capillary effect that draws the filler metal into the joint clearance and the capillary effect produced by the porosity of the compact, which results in the filler metal being pulled away from the joint clearance and into the part. If this filler metal is pulled into the part, the bond may be compromised or not formed at all.

This article reviews the fundamentals of brazing and applies them in a way that better controls the flow and retention of the filler metal at the sinter braze joint. This is achieved by reviewing key variables and their effect on the wetting of the filler metal. The sintering atmosphere, flux content of the filler metal, and the density of the components are all important to filler metal control.

Fundamentals of Brazing

The fundamental driving forces for the formation of a good braze joint are the wetting of the base metal by the filler metal and the capillary force that results and pulls the filler metal through the braze root opening,

$$\text{Capillary Force} = 2\gamma\cos\Theta/r$$

where γ is the surface tension, Θ is the contact angle, and r is the radius of the capillary.

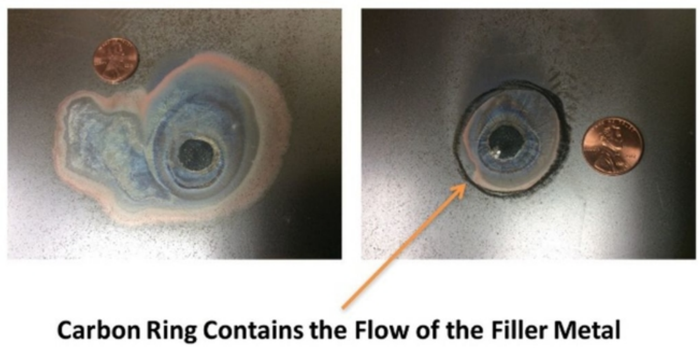

Fig. 1 — Effect of surface contamination on wetting.

There are a few key steps that must be followed to produce a good braze joint, as detailed below.

Surface Preparation

When the filler metal melts, the wetting of the filler metal is strongly affected by the cleanliness of the surface — Fig. 1.

Figure 1 shows the effect of a carbon ring on the filler metal flow (AB-72) on a carbon steel plate. If the surface is not free of dirt, oxides, and oils, the filler metal will not wet the base metal and will not be pulled into the braze joint.

Braze Joint Design

Proper braze joint design is critical to achieving the desired strength in the component. The total length of the braze joint should be three times the thickness of the thinnest cross section being joined — Fig. 2. This will ensure that a good braze will result in a joint that is stronger than the base metal.

The joint clearance, through which the filler metal is pulled via the capillary force and is a strong function of the r, must be 0.05 mm (0.002 in.) to 0.20 mm (0.008 in.) wide at the brazing temperature. This means that the

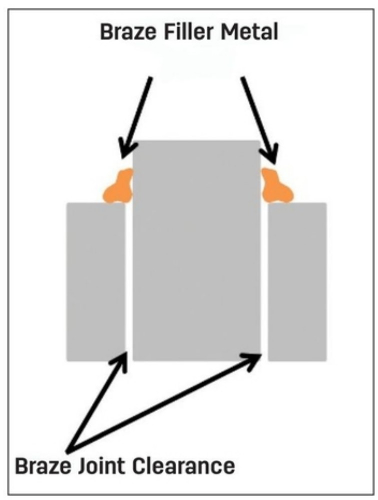

Fig. 2 — Proper braze joint design.

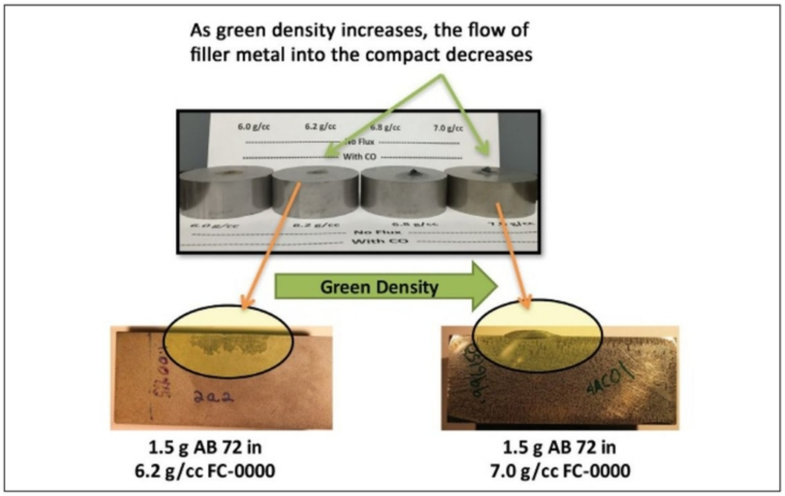

Fig. 3 — Effect of green density on the flow of filler metal into the compact.

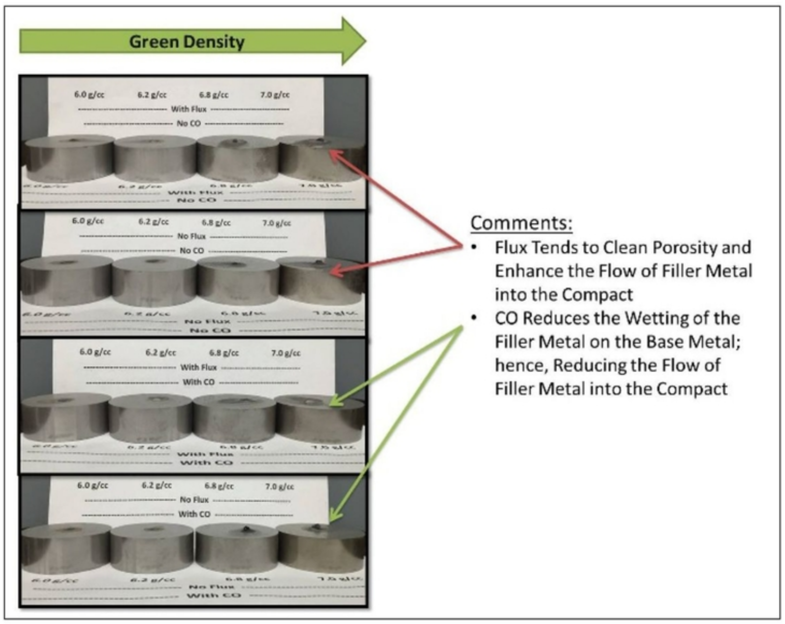

Fig. 4 — Effect of flux and CO on filler metal infiltration into the compact.

thermal expansion of the components must be considered when designing the joint.

Furnace Atmosphere

All metals contain oxides on their surface. If these are not removed, the filler metal cannot alloy with the base metal. Hence, the oxides must be removed from the surfaces of the base metal and filler metal prior to the filler metal melting. This can be accomplished by using a flux (typically an acid or other material that will remove/react with the oxide layer to produce a clean metal surface) or a reducing furnace atmosphere. Unlike a flux, the reducing furnace atmosphere will not leave a residue that must be removed post brazing. Some typical dew points of reducing atmospheres are –51°C (–60°F) for stainless steels and –35°C (–30°F) for carbon steels.

Time and Temperature

The time for a filler metal to flow into a clean, properly designed braze joint, and form a good braze, is 3 to 5 min at the brazing temperature that is above the liquidous temperature of the filler metal.

Sinter Brazing

Sinter brazing is a manufacturing technique used to produce complex shapes from powder metal that cannot be produced directly from the compaction press. Multiple shapes are produced using current pressing technology. These shapes are then assembled in the green state, or some may be presintered, and a filler metal is placed in or near the adjoining surfaces of the shapes to allow for brazing to occur simultaneously with the powder metal sintering process.

Common to sintering and brazing, the metal particles and surfaces must be free of dirt and oils. The hydrogen in the furnace atmosphere then reduces the oxides on the surface of the metals to produce clean particles and surfaces for sintering and brazing. As the components continue to travel through the sintering furnace and heat up to the sintering temperature, the filler metal melts and begins to wet the surface of the component surfaces; however, this is where the most common issue related to sinter brazing arises. Not only is the filler metal able to wet the surfaces that are to be brazed, but the pores within the compacted components also compete for the filler metal. The surface tension between the filler metal and the base metal, along with the capillary effect produced by the small pores of the compact, pull the filler metal away from the braze joint and compromise the bond. This compromise may be a reduced amount of joint filling to no bonding at all.

If the wetting characteristics of the filler metal can be controlled, the retention of the filler metal at the brazing joint can be maintained and an improvement in the bonding and overall strength of the assembly may be maximized. For many years, manufacturers have added sulfur to the compact mix and manganese to the filler metal to retard the wicking of the filler metal into the pores of the compact. Unfortunately, sulfur is not always a desired additive. For this reason, current techniques use the addition of carbon monoxide containing atmospheres as a sintering atmosphere or as an addition to the sintering atmosphere. The impact of, and mechanisms associated with the carbon monoxide addition, were not clear; however, many believe in this approach. In this article, along with the influence of flux and density, the impact of, and the mechanism associated with the addition of the carbon monoxide as it relates to controlling the wetting of the filler metal and its retention at the braze joint, is investigated.

Experimental Procedure

Discs of F-0000 were compacted to densities of 6.0, 6.2, 6.8, and 7.0 g/cc. The discs had a dimension of approximately 7.62 cm (3 in.) in diameter by 2.54 cm (1 in.) thick.

Two filler metal chemistries were pressed into 1.5-g pellets. One of the chemistries was a standard AB-72 material. The other filler metal chemistry did not contain a fluxing agent.

The pellets were then placed on top of the discs and sintered in two different furnace atmospheres. One atmosphere contained hydrogen, nitrogen, and carbon monoxide, and the other contained only hydrogen and nitrogen.

The discs were then sectioned, polished, and etched with 2% Nital etchant to reveal the infiltration of the filler metal into the compact. ImageJ software was used to measure the infiltration area.

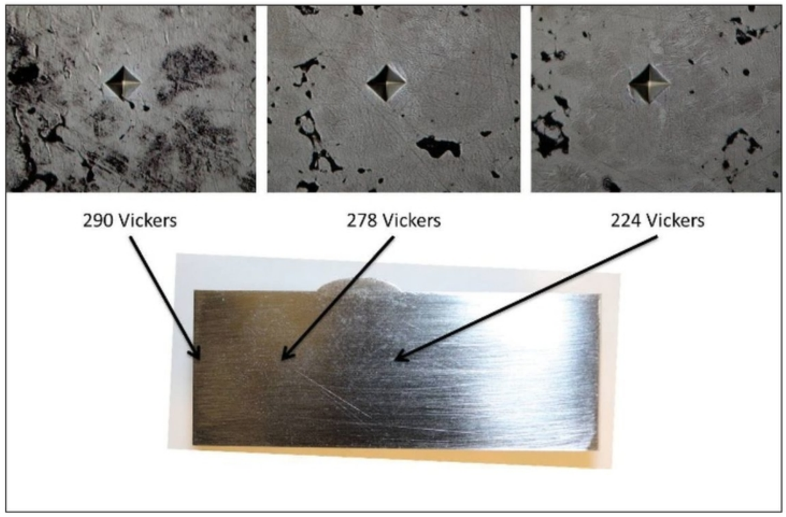

Fig. 5 — Edge-to-center hardness and carburization variation due to the presence of carbon monoxide.

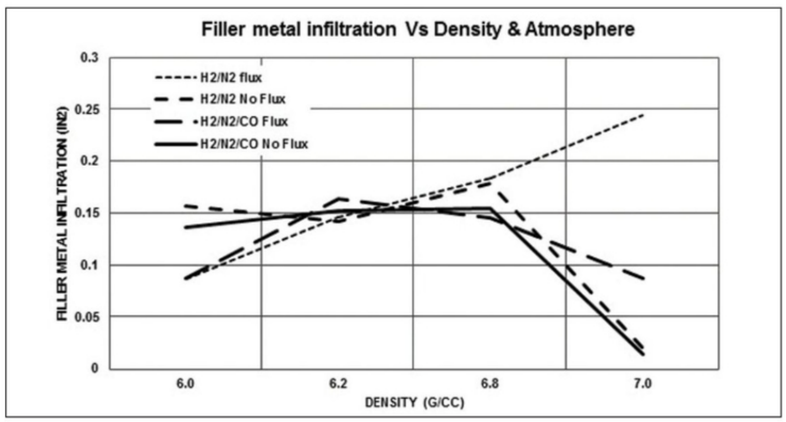

Fig. 6 — Influence of density, flux, and carbon monoxide on the infiltration of the filler metal into the compact.

Results

As can be seen in Fig. 3, increasing compact green density results in a decrease in the amount of filler metal that flows into the powder metal compact. This is to be expected since there is a 16.7% difference in the relative pore fraction when comparing a 7.2 and a 6.0 g/cc compact.

Flux is often added to the filler metal to help clean the surface of the base metal and enhance wetting; however, in this application, the flux not only cleans the braze joint surface but also the particle surfaces inside of the pores of the compact. The result is an enhance wetting of the pore surfaces and more filler metal being pulled from the braze joint — Fig. 4.

As the powder metal compact exits the preheat section of the furnace and enters the high-heat section of the furnace, the compact temperature is in the range of 900°C (1650°F) and 1035°C (1900°F); carbon monoxide results in the carburization of iron and steel at these temperature. Since the amount of time that the product is in this condition is small, the carburization will be a small layer on the surface of the exposed particles on the surface of the material and inside of the pores. This surface contamination reduces the wetting of the pores by the filler metal and results in less filler metal being pulled from the braze joint — Fig. 4. Figure 5 shows that although this material is a F-0000 and contains no carbon, the surface of the particles along the very edge of the compact were carburized.

The particle hardness on the surface is higher and the microstructure shows the presence of carbon on the surface of the particles.

In comparing the overall impact of the variables (Fig. 6), an interesting phenomenon was observed. In the high-density region of the graph (purple), the effects of the flux, carbon monoxide, and density were consistent with what was expected. In the lower-density sec-

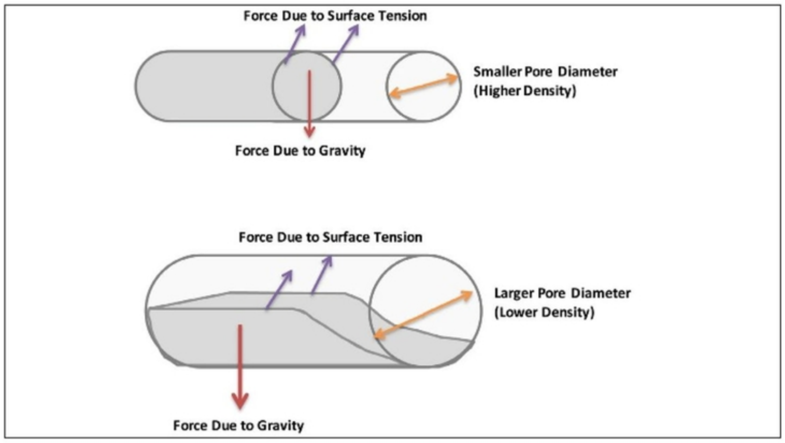

Fig. 7 — Surface tension vs. gravitational force as a function of pore size.

tion of the graph (green), the control of the filler metal wetting was not influenced by the wettability of the filler metal on the base metal.

To better understand what is shown here, one must consider the relationship between the force due to surface tension, which would want to pull the filler metal into the pores of the compact, and the force due to gravity, resisting the movement of the filler metal flow. Figure 7 illustrates that as the pore size becomes larger, lower density of compact, there reaches a point where the force due to gravity will cause the filler metal to fall and not completely fill the pore. The result is the influence of the altered surface tension is reduced and limits the ability of the producer to influence the wetting and flow of the filler metal with flux or carbon monoxide. For this reason, many producers find they have more consistent results and better quality of sinter brazed products that are 6.9 g/cc and above.

Conclusion

The control of the filler metal at the braze joint of a sinter brazed product has significant impact on the quality and yield of complex shapes that cannot be produced by current conventional compaction technology. Maintaining the presence of the filler metal at the sinter braze joint is necessary, or the components will not be bonded. However, the porosity of the powder metal compact results in capillary forces that tend to wick the filler metal away. By pressing the compacts to a density greater than 6.9 g/cc, removing the flux from the filler metal, and adding carbon monoxide to the sintering furnace atmosphere, the capillary action of the pore can be reduced and the flow of the filler metal at the joint can be controlled to produce a better bond. WJ

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