Applying Brazing Fundamentals to the Sinter Brazing Process

How the success of sinter brazing technology is built on a basic understanding of the process

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Sinter brazing is a process that allows producing complex components of powder metal by bonding multiple powder metal pieces during sintering of the compact to produce a single part with features that cannot be made through current molding technology.

This process is used to produce many parts with complex shapes, yet its fundamentals are not widely understood. The result is often marginal success in the sinter brazing process and increased costs. In this article, the fundamentals of brazing are used to further understand the sinter brazing process. Issues such as surface cleanliness, sinter brazing atmosphere, and the impact of good sinter brazing practices will be reviewed.

Fundamentals of Brazing

Brazing is a widely used process for bonding materials. It is commonly employed in the aircraft industry and heat exchanger production. In each case, the fundamentals of the process are the same — Fig. 1.

Surface cleanliness is key to the success of the process. Any contamination on the surface of the base metals may cause the filler metal to not wet the base metal or be pulled into the joint clearance by capillary effect — Fig. 2.

Contaminants, such as forming oils or other lubricants, dissociate during the heating process to form carbon. The carbon deposits will cause a reduction in the filler metal's ability to wet the base metal and reduce the capillary force that must pull the filler metal through the joint clearance to form the braze joint.

Prior to melting the filler metal, the oxides on the surface of the base metal and the filler metal must be reduced. If allowed to remain on these surfaces, the filler metal will not flow into the joint clearance completely, and defects may form because the filler metal is not in complete contact with the base metals to form the alloy of the braze joint. Without something present to reduce or react with the oxides, the filler metal cannot form the alloy that becomes the braze joint. This reactant can be in the form of a flux added to the surface of the base metals, contained in the filler metal itself, or it

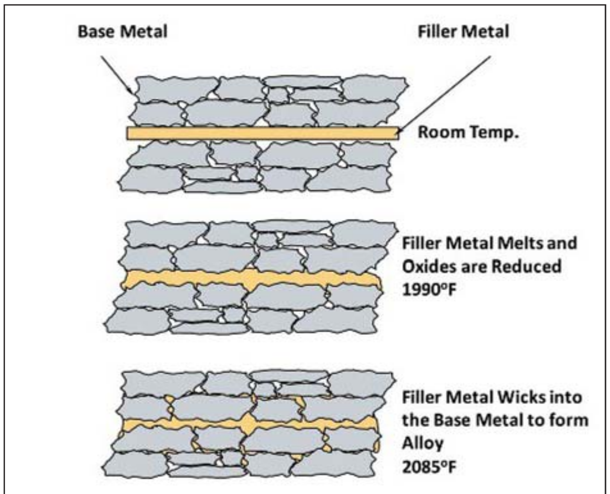

Fig. 1 — The fundamental steps in the brazing process.

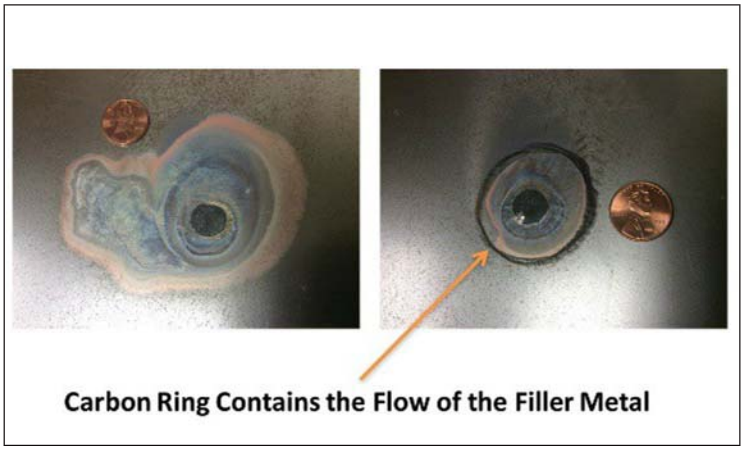

Fig. 2 — The photo on the left shows the wetting of 1.5 g of filler metal on a metal plate. The photo on the right shows the wetting of 1.5 g of filler metal with a carbon ring around it that stops the wetting.

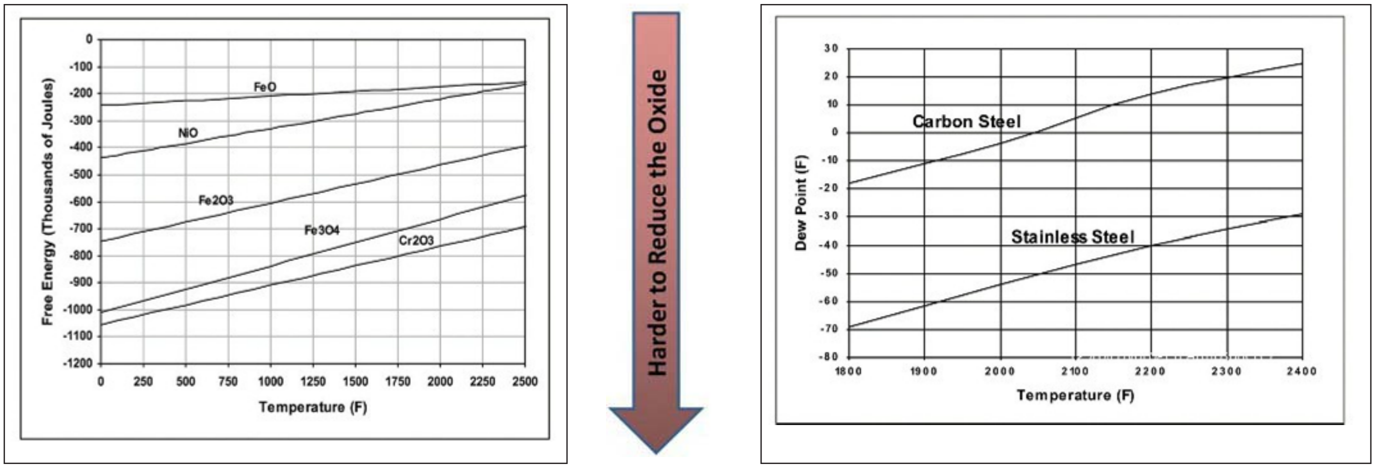

Fig. 3 — More stable oxides require a lower dew point to allow the reduction of the oxides with hydrogen. The graph on the right shows the equilibrium dew point as a function of base material and temperature.

can be the atmosphere around the system, such as hydrogen. In most sinter brazing processes, there is hydrogen present in the sintering atmosphere that reacts with the oxides on the surface to prepare the surfaces for bonding.

The chemistry of the base metal and the filler metal play an important role in the atmosphere that is required to reduce the oxides in the system. As shown in Fig. 6, lower free energies of formation of an oxide require a much lower equilibrium dew point for the oxide reduction to take place in hydrogen. It is important to note that oxides must be completed prior to the melting of the filler metal. For this reason, the dew points of the system must be much lower than those calculated at the brazing temperature. For example, in the case of copper and stainless steel, the equilibrium dew point at the brazing temperature of 1120°C (2050°F) is –46°C (–50°F); however, prior to the melting point of the copper at 1086°C (1986°F), the equilibrium dew point is less than –50°C (–60°F) — Fig. 3.

When the filler metal melts, the force due to capillary action causes the liquid filler metal to be pulled through the joint clearance. The proper design of the joint clearance is critical to the successful formation of the braze joint. If the joint clearance between the base metals to be bonded is too small or large, the capillary force will be too small to overcome the resistance to flow. The result will be a joint that is weak due to the insufficient formation of the alloy bond — Fig. 4.

The joint clearance also determines the amount of filler metal that is required to form the joint. Calculated in the hot state, the joint clearance size and volume will allow for the determination of the capillary force and the volume of filler metal needed. As indicated in Fig. 4, for a system such as stainless steel base metals and a copper filler metal, the optimal joint clearance is approximately 0.05 mm (0.002 in.) to 0.07 mm (0.003 in.). It is important to note that this optimal condition is a function of the metal sys-

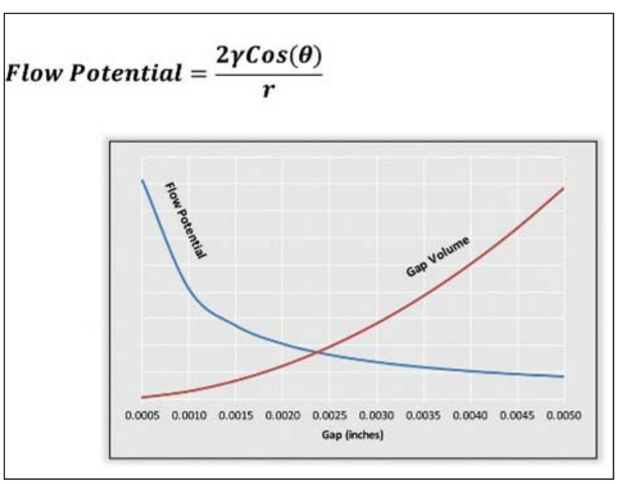

Fig. 4 — The relative relationship between the flow potential vs. the joint clearance volume.

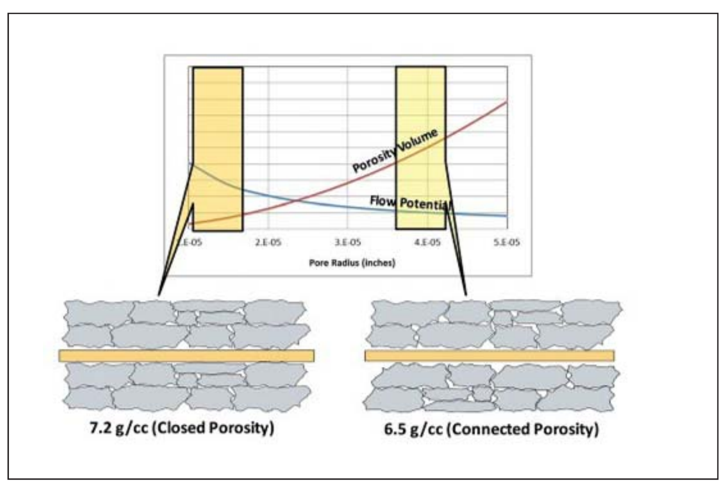

Fig. 5 — Effect of density on the capillary effect and pulling away of the filler metal from the joint clearance.

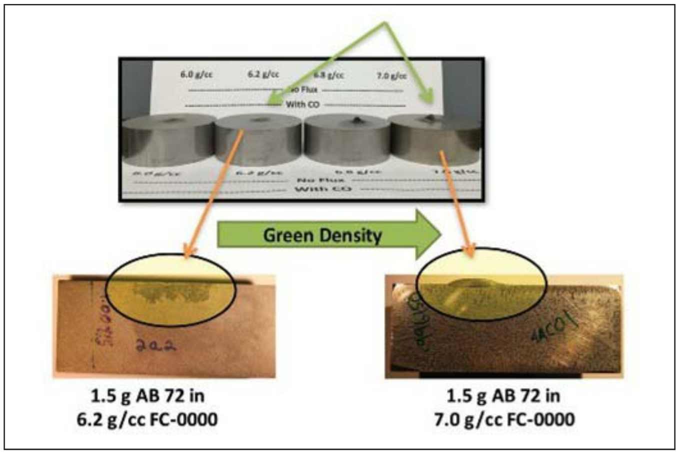

Fig. 6 — Lower density powder metal compacts pull more filler metal from the joint clearance than the higher density compact of the same material. This is shown by the deposits on the tops of the sintered compacts, as well as the volume of filler metal shown in the sectioned and etched samples.

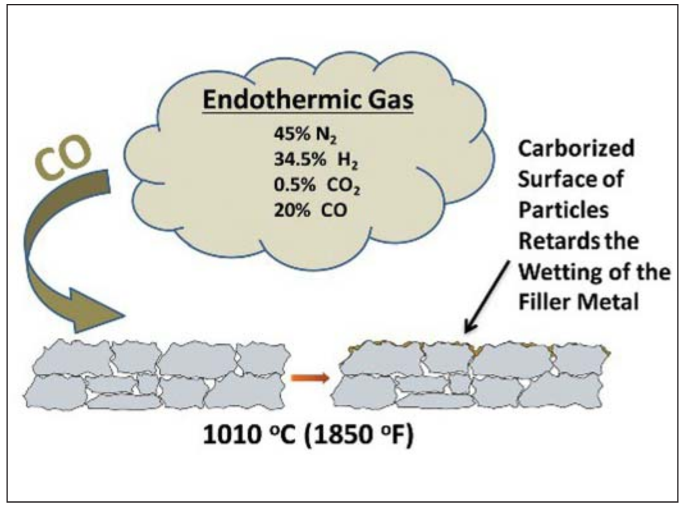

Fig. 7 — Endothermic gas carborizes the pore surfaces of the powder metal compact to slow the flow of the filler metal away from the joint clearance.

tem. In sinter brazing, this optimal joint clearance is between 0.10 mm (0.004 in.) and 0.25 mm (0.010 in.).

Sinter Brazing

Sinter brazing follows all of the fundamentals of conventional brazing, but the sintering process is concurrently taking place as well. Hence, having a very good sintering process is crucial for achieving a good sinter brazing process. Although surface contaminants from oils are not as much of a concern in the powder metal forming process, the removal of the lubricant from the powder metal compact is even more important in the sinter brazing process. If lubricant is allowed to overheat and form soot, the filler metal will not flow and joint quality will be compromised.

In sinter brazing, there is a competing process to the capillary force pulling the filler metal into the joint clearance. This is the capillary effect that pulls the filler metal into the porosity of the part and away from the joint. This is one of the most common failure mechanisms in the sinter brazing process — Fig. 5.

It is important to note that the pore size in the compact decreases as the density increases in the green compact. From Fig. 6, it can be seen that as the pore radius decreases, the capillary force to pull the filler metal away also increases; however, the total volume of the filler metal that fills those pores is less. The result is that higher density compacts tend to pull less filler metal away from the joint clearance — Fig. 6.

The addition of sulphur to the powder mix has been an approach to control flow of the filler metal within the compact. The sulphur joins with manganese in the filler metal to form manganese sulphide and raise the liquidous temperature of the filler metal and retard the flow of the filler metal into the compact; this approach requires sulphur, which is not always wanted in

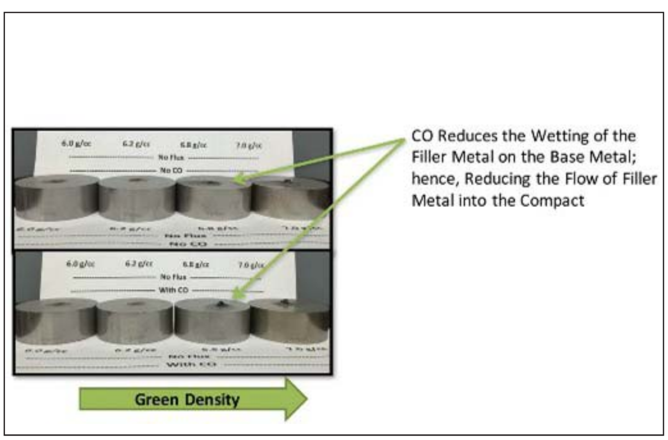

Fig. 8 — Effect of the carbon monoxide on the wicking of the filler metal away from the surface as a function of density.

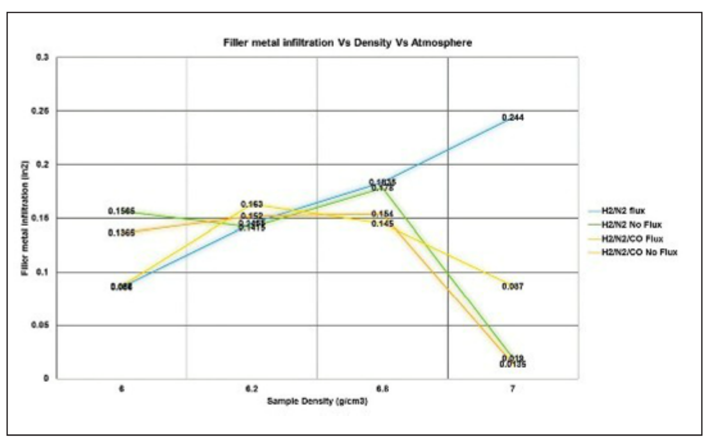

Fig. 9 — Volume of filler metal flow into the powder compact as a function of density.

the base material. A more common solution is to process the powder metal parts in a carbon monoxide-containing atmosphere. The result is a "controlled contamination" of the pore surface inside of the compact, increasing the carbon in solution at the pore surface that retards the wetting of the filler metal into the pores. Similar to the carbon ring in Fig. 2 that stopped the flow of the filler metal, the increased carbon in solution on the pore surfaces reduces the surface energy between the filler metal and the pore surface, which results in a lower capillary force and is seen as a slowing of the filler metal flow into the compact. This is achieved by the carbon monoxide in the furnace atmosphere carborizing the material at approximately 1010°C (1850°F) — Fig. 7.

The hydrogen in the atmosphere still cleans the surfaces of oxides, yet the presence of the increased carbon in solution at the surface is just enough to slow the wicking of the filler metal into the compact and away from the joint — Fig. 8.

To aid in cleaning the base metal material, a flux is often added to the filler metal to help reduce oxides. It is common in the brazing industry to only use the hydrogen in the furnace atmosphere as the oxygen-getting species for cleaning the surface. For this reason, two types of filler material were also evaluated, one with flux and one without — Fig. 9.

The results at the higher densities in Fig. 9 illustrate the impact of the flux and carbon monoxide. The cleaner the surface is, filler metal with the addition of a flux as well as having hydrogen in the atmosphere, the more metal that is pulled into the compact; however, the presence of the carbon in solution retards this flow. The results at the lower density are scattered because the overall pore size at these lower densities has a greater influence on the ability of the filler metal viscosity to fill the pore and experience the fullest capillary force possible.

Conclusion

Sinter brazing technology is becoming increasingly necessary for the growth of the powder metal industry to compete with machining and casting. The ability to sinter and bond multiple components in a single pass through a furnace is key to remaining competitive. The success of this technology is based on the need for a fundamental understanding of the brazing process. The fundamentals of brazing are directly applicable to the sinter brazing process. These principles can work hand in hand with good sintering practices. Unfortunately, the sinter brazing process is extremely sensitive to poor sintering practices. Complete lubricant removal, clean atmospheres with low dew points, sufficient atmosphere flows to flush lubricant vapors to the front door, attention to belt speeds, and part loading all play a key role in the future of expanding the powder metal market. WJ

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