# Basics of Brazing with Induction Heating

## *Properly used, induction brazed joints offer a number of advantages*

**BY BRETT DALY**

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Brazing is a process for joining two metals with a filler material that melts, flows, and wets the metals' surfaces at a temperature that is lower than the melting temperature of the two metals. Protection from oxidation of the metal surface and filler material during the joining process is achieved using a covering gas or a flux material.

Brazing and silver soldering are terms that usually refer to the joining process where the filler materials have a melt temperature above 752°F (400°C) to create a stronger joint.

### The Benefits of Brazing

The brazing process does not melt the base metals being joined, yet it can produce strong robust joints. Brazing offers distinct advantages over other joining techniques:

- Similar and dissimilar metals can be brazed.
- Brazing uses lower temperatures, resulting in less part distortion and joint stress.
- Dimensional integrity of the finished product is easier to control.
- Brazing produces strong low-stress joints.

### Advantages of Using Induction Heating

Induction heating addresses some of the issues of other brazing methods. It removes the requirement for a skilled operator, reduces energy costs, and decreases the equipment footprint while implementing a lean manufacturing process for higher-quality parts.

Induction brazing is used in the joining of many different metals for multiple applications. Typical joints are steel to steel, steel to brass, steel to copper, brass to copper, copper to copper, aluminum to aluminum, and copper to aluminum. The six key steps include the following:

1. Design the joint correctly allowing for a 0.0015 to 0.005 in. (40 to 125 µm) clearance between the two surfaces at the braze material flow temperature to allow for capillary action and joint wetting — Fig. 1.
2. Clean the surfaces of the joint materials.
3. Apply flux to both pieces.
4. Fixture the two pieces together with a braze ring or preform then position in the coil.
5. Heat the parts until both pieces achieve the braze material flow temperature then stick feed the braze material if preforms are not being used.
6. Clean the brazed joint to remove all of flux residue.

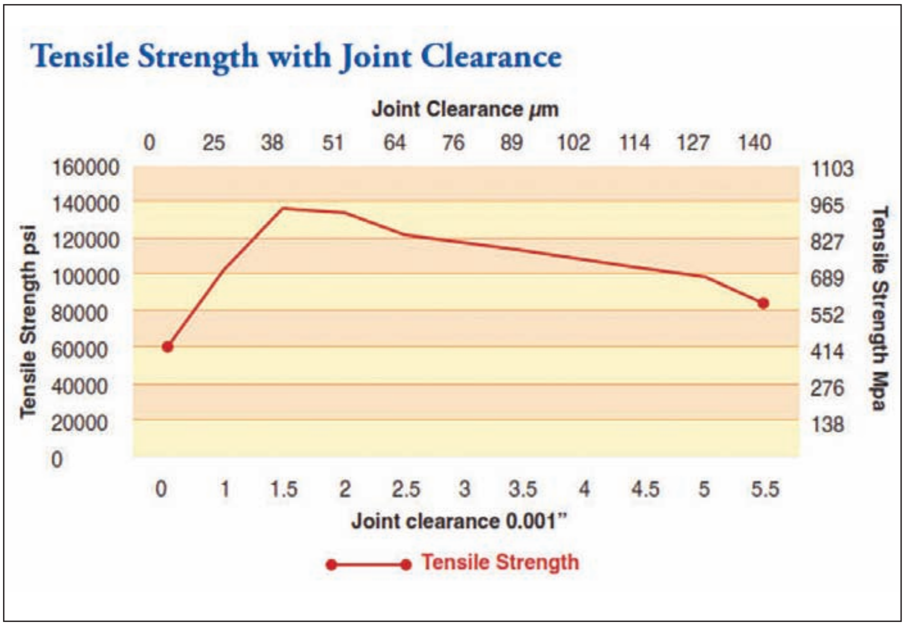


*Fig. 1 — The optimum braze joint strength occurs with a part joint clearance between 0.001 and 0.005 in. (25 and 125 µm). Data from Lucas Milhaupt.*

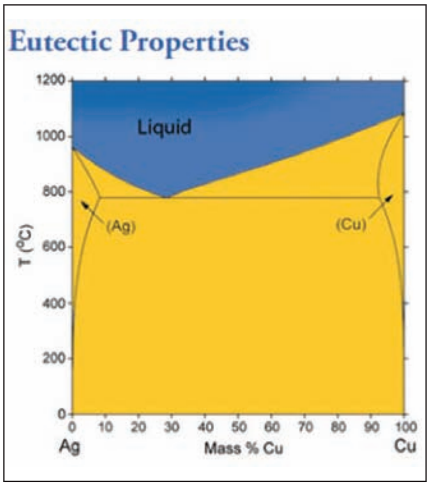


*Fig. 2 — Eutectic properties of silver (Ag) and copper (Cu). It is critical that the filler metal alloys melt and flow at a lower temperature than the melt temperatures of both base metals.*

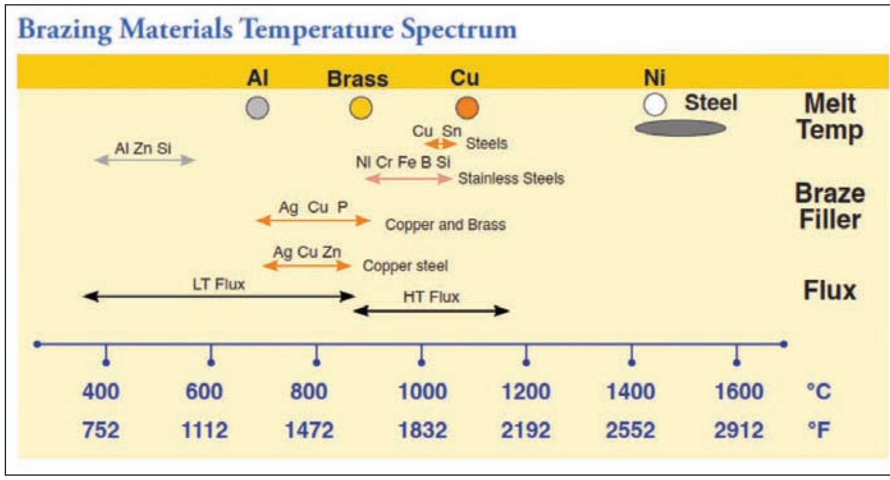


*Fig. 3 — Filler metal and flux operating temperature ranges for typical materials used in brazing steel, copper, brass, and aluminum.*

## Filler Metals and Fluxes

The function of braze filler metal is to provide a metallurgical bond to the surfaces of the materials on both sides of the joint. There are many different braze alloys that are designed to correctly melt, flow, wet, and bond materials for joining. Typical braze filler materials that are used to create the correct alloy for the joint materials are copper, silver, zinc, nickel, and aluminum.

Some filler metal alloys have eutectic properties (Fig. 2) that are very useful for the brazing process, where the alloy melts and flows at a lower temperature than the melt temperature of either of the base materials. As shown in the diagram (Fig. 3), the 30% copper/silver braze melts at 1454°F (790°C) compared to a melt temperature of 1980°F (1180°C) for copper and 1760°F (960°C) for silver.

The primary function of the flux is to protect the two metal surfaces being joined and the braze metal from oxidation during the heating process. Some flux materials also act as a cleaning agent. A typical flux material for lower-temperature brazing would be a potassium salt of boron and fluorine with a temperature range from 1050° to 1800°F (565° to 982°C). Other flux materials with less fluorine are available for higher braze temperatures between 1600° and 2200°F (870° and 1100°C).

## Brazing Different Metals

**Aluminum.** Aluminum requires a lot of energy to heat using induction and its thermal conductivity is 60% compared to copper. Coil design and time for the heat

*Examples of various assemblies heated to brazing temperature using induction heating.*

**Table 1 — Physical Characteristics of Commonly Brazed Metals**

| Material | Thermal Conductivity k cal/cm s °C | Electrical Resistivity ohm m × $10^{-8}$ | Typical Melting Temp. °C | °F |
|---|---|---|---|---|
| Aluminum | 0.60 | 2.65 | 660 | 1220 |
| Brass | 0.26 | 7.1 | 930 | 1710 |
| Copper | 0.95 | 1.7 | 1084 | 1983 |
| Carbon Steel | 0.11 | 74 | 1480 | 2700 |
| Stainless Steel | 0.05 | 74 | 1510 | 2750 |

to flow are critical in a successful induction brazing process for aluminum parts. Recent advances in lower-temperature aluminum braze materials have allowed induction to effectively replace flame and furnace heating in high-volume brazing of aluminum assemblies.

The low melting temperature of aluminum requires that the induction brazing process apply the energy to the part correctly, to raise both part surfaces to the braze flow temperature at the same time, without overheating and melting the edges of the part.

**Steels.** Induction brazing is the ideal technique for joining steel parts where welding is not suitable. A well-designed induction brazed steel joint provides many benefits, including part geometry integrity and lower part stress.

Carbon and stainless steels have high resistivity. They couple well to induction energy and heat easily. However, they have poor thermal conductivity so the induction brazing of steel parts should not be rushed. With steel, it is important to allow the heat to soak through to the joint surface for proper flow and wetting of the braze material.

Copper-based alloys are often used as a low-cost braze material on carbon steels, while nickel-based alloys are used for stainless steels.

## Some Brazing Facts

- Steel heats well, but is a poor thermal conductor.
- Copper takes more induction energy to heat, but is an excellent thermal conductor.
- Brass heats better than copper, but has lower thermal conductivity.
- Silver copper alloys are popular braze materials for brass and copper parts.

Induction brazing is an excellent method for joining parts made of dissimilar metals. Applications with mixed metal joining include steel to copper, steel to brass, and brass to copper. With these metals, it's all about timing. For a successful brazed joint between different metals, it is critical that both metal surfaces reach the braze flow temperature at the same time as the joint. The induction heating solution must take into account the different thermal conductivities of the materials, and the time each material takes to get to temperature (Table 1).

As you can see, there are many advantages to using induction heating for brazing. Induction heating is, in fact, a very versatile method that can be leveraged for joining a wide range of materials.♦