Brazing: An Important Joining Option

Brazing provides engineers with a versatile form of joining similar and dissimilar base materials that is adaptable to varying production volumes

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To meet the constantly changing product design and economic requirements of today’s industries, engineers need to be able to modify or change many of the materials and processes used to manufacture a product. Metal joining is one of those processes that is commonly used in industry and is often affected by material changeover. Among the many joining techniques that are available, engineers most commonly will choose one of four methods (Fig 1): mechanical fastening, adhesives, welding, or brazing. Brazing provides design and manufacturing engineers with a versatile and cost-effective method of joining similar and dissimilar metals and nonmetallic materials. This article discusses many of the criteria that engineers have to consider when choosing a joining method and how brazing compares to the other primary methods.

What to Consider when Choosing a Joining Method

One of the primary characteristics that engineers consider when designing a component is the strength and durability of that component when in use. Products need to stand up to normal wear and tear and to any excessive force that may occur. Joints that hold components together can be exposed to various forces depending on the application and environment.

Aesthetics can also be an important consideration when designing consumer products. Joints between two components can affect the overall appearance and uniformity of an assembly. Engineers and designers look for joining methods that can provide a smooth, clean joint that makes the consumer product appear like one component vs. an assembly of parts. A clean, uniform joint also provides a surface that is readily plated or painted during postjoining processes.

In many of today’s industries, engineers design assemblies that are used to transfer, contain, or transport various types of media. Some of these applications include heat exchangers, fuel lines, refrigeration lines, etc. The joints that are used to connect these components must be leak tight to ensure that none of the media escapes from the assembly.

In the aerospace and automotive industries, among others, temperature and corrosion resistance are critical aspects of products that engineers consider. If a component fails due to high-temperature exposure or corrosion, severe damage of an entire product can occur. The corrosion resistance and temperature resistance of the material used to make the joint needs to be appropriate for each application.

Manufacturing and design engineers are constantly looking for ways to simplify production, reduce cycle time, and lower process costs. Joining methods can vary in cost due to the many different types and the consumables that are used for each method. Automating a process that is currently manual can reduce a lot of time and
Mechanical Joining

Primary Joining Methods

Taking the criteria discussed previously into consideration, the following section discusses the four primary methods of joining that engineers can choose from and how each method meets those particular requirements.

Mechanical Joining

Mechanical joining is commonly used to join structural components by fixing similar and dissimilar base materials together by the use of fasteners. The fasteners that are commonly used in today’s industries include tension fasteners, compression fasteners, and shear fasteners. Examples of fasteners used in industry are shown in Fig. 1A. Joining by mechanical means can provide very strong and rigid joints that are suitable for applications ranging from car frames to building trusses. Fasteners can withstand high temperatures and if chosen properly can withstand various types of corrosive media. Although joints made with this method can withstand very high forces, mechanical fasteners do not distribute stress well and can create stress concentration sites. In most cases, mechanical joining does not provide a leaktight component unless used in conjunction with an adhesive. Automation of mechanical fastening may be applied in some cases. Fasteners can be expensive and add significant mass and bulk to an assembly, which reduces the aesthetic appeal of the assembly.

Adhesives

Adhesives offer a versatile and economical means of joining various base materials. Adhesives hold the base materials together by surface attachment. Common types of adhesives include reactive, nonreactive, and hot melt adhesives. These adhesives are used to provide leaktight joints across a wide application base. Aesthetically pleasing joints are often produced with adhesives without adding significant weight to an assembly. Figure 1B shows a common application of adhesives. If strength is of concern, adhesives are usually not the best option. Most adhesives will not withstand tensile forces much greater than 5000 lb/in.² and cannot be exposed to operating temperatures above 500°F. Adhesive joining can be automated but may require extensive curing times.

Brazing

Brazing is one of the more flexible methods of joining similar and dissimilar materials. Brazing produces a metallic bond between the base materials by using a molten filler material that melts above 840°F but does not melt the base materials. The molten filler material is dispersed between the base material interfaces by capillary attraction. Figure 1D shows an example of a brazed joint. Like welding, there are many different types of brazing methods used in today’s industries. Torch, induction, resistance, and furnace brazing are some of the most frequently used methods.

If designed properly, brazed joints can meet the majority of the joint design criteria discussed in this article. Brazing produces high-strength, leaktight joints that are often as strong as the base materials in the assembly. Joint tensile strengths of up to 140,000 lb/in.² can be achieved with braze joints depending on the application, base materials, and filler materials used.

Welding

Welding is the most common method of joining metals in industry today. Welding is the joining of metal substrates by applying heat to the base metal surfaces and fusing the base materials together. Figure 1C illustrates a weld bead that is produced between two base materials during welding. While there are a vast variety of welding methods available, which allow for wide application use, the most common methods include gas tungsten arc, gas metal arc, shielded metal arc, flux cored arc, resistance, laser beam, and electron beam welding. A welded joint is a very high strength joint that can often reach tensile strengths in excess of 100,000 lb/in.². Weld joints can withstand high-temperature and corrosive environments. Welding can also produce a leaktight joint that will withstand high pressures. Welding is suitable for joining similar metals but typically cannot join dissimilar metals as easily. In order to join dissimilar base metals more specialized and costly welding methods may be required. The high amount of heat that is applied to the base materials during welding can cause distortion of the welded assembly. While being widely used, welding does require highly trained operators and some methods are not easily automated. When aesthetics are a concern, welded joints may require grinding and polishing to smooth out the weld bead that is formed on the base materials.
Brazing is commonly used for joining heat exchanger assemblies, fuel lines, and many other transfer assemblies requiring hermetic seals. Many products such as metal furniture, musical instruments, and jewelry require smooth, strong, and uniform joints that only brazing can provide. A properly brazed joint provides a surface that is aesthetically pleasing and easily painted or plated if needed. Many brazing alloys exhibit high temperature resistance and resist corrosion, lending themselves toward many aerospace and automotive applications. The variety and flexibility of brazing lends itself to automation and can reduce costs in many ways. Methods like torch, induction, and resistance brazing can be automated at several different levels in order to produce high production quantities. Many furnace brazing options can also produce high volumes.

One concern of engineers when choosing brazing as a joining method is the cost of the filler metals that are used due to the fact that many of the filler metals are precious metal based alloys. However, if the joint and the brazing process are designed properly, brazing can be an economical means of joining. Brazing typically does not require as highly skilled operator as welding demands. Using preform rings and shapes will control the amount of alloy applied in the joint area guaranteeing that an excessive amount of alloy is not used. Choosing the appropriate filler material for the application will also ensure that the most economical alloy is used. Joining of nonmetallics like ceramics, diamonds, and glasses is also possible with active metal brazing while welding does not present any readily available options.

**Brazing Tips**

In order to achieve optimum braze joint quality as discussed in the preceding section, several important steps and design factors are important to keep in mind. All braze joint designs should follow what is known as the “six fundamentals of brazing.” If the six fundamentals are properly followed, brazing will provide a suitable joint for many assemblies. The fundamentals are as follows:

1. Proper fit and clearance
2. Clean metals
3. Proper flux/atmosphere
4. Fixturing
5. Heating
6. Final cleaning.

Engineers also need to choose the appropriate brazing filler material for the application that they are designing around. There are several filler metal families that can be chosen as shown in Fig. 2. Each filler family has different characteristics and properties that lend themselves to particular applications. The Ag-based, Au-based, Ni-based alloys have wide application bases that are suitable for many industries ranging the aerospace to mining and cutting tools. Other alloys are used for brazing specific base materials like Ag-Cu-P alloys for copper-based materials and Al-Si or Zn-Al alloys for aluminum-based materials. Filler metals are available in various forms depending on the family of alloy that is used. Typical forms available include wire, strip, preforms, powder, and paste. To ensure that the proper brazing alloy and form is used for the specific application, engineers should consult their filler metal supplier for the appropriate alloy choice.

Another factor that is important to consider is the type of heating method to use for brazing. Choosing the appropriate heating method can affect braze quality, filler metal choice, production output, costs, and base metal distortion. Examples of the four main heating methods are shown in Fig. 3. Torch heating is the most flexible form of heating and is suitable for a wide variety of applications and base materials. Fast, localized heating methods like induction and resistance heating minimize base metal distortion and heat effects. Furnace brazing provides a broad uniform heat that is suitable for small and large assemblies. All of these methods can accommodate both low and high production quantity volumes.

**Conclusion**

Designers and engineers face many options when choosing a proper joining method for their particular application. Brazing can provide engineers with a versatile method for joining similar and dissimilar base materials that is adaptable to varying production volumes. When designed correctly, brazing can provide similar joint characteristics to welding while being a more flexible production process. With the increasing demand for streamlined products and processes, brazing is an important option to consider when joining of components is required.