BRAZING - A REVIEW

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INTRODUCTION

Most of the metal articles used these days are fabricated by joining two or more components by mechanical fastening or by thermal joining process. Brazing is one of the thermal joining processes extensively used to join numerous ferrous and non-ferrous metals that can withstand a wide range of service conditions. In this article, various joining processes are reviewed, brazing process is explained and proper brazing techniques are summarized, applications of brazing are also given.

VARIOUS METAL JOINING PROCESSES

Joining of metals can be broadly classified into the following two categories :

i) Non-permanent type
ii) Permanent type

Non-permanent type joints are threaded joints or riveted joints or joints made with nuts and bolts. These joints are not generally leak-tight and are made with future disassembly in mind. Example is a pump connected to a piping assembly where the pump may need to be replaced in future. These types of joints do not exhibit high strength and do not provide high resistance to shock or vibration.

Permanent type joints are classified into the following categories :

a) Soldering
b) Brazing
c) Welding

Soldering is an economical way of joining metals which are not subjected to withstand high stress or strain. Soldered joints are much weaker joints compared with brazed or welded joints and the soldering operation is not particularly suitable for joining engineering materials.

Brazing or welding of metal assemblies are considered when strong, leak-tight, heat-resistant joints are required which may need to withstand high shock or vibration. Welding and brazing both require the use of heat and a filler metal but they work differently. Welding joins metals by *melting and fusing* them together usually with the addition of a welding filler metal. In brazing, however, the metals joined together (called base metals) are heated to a suitable temperature at which the brazing filler metal melts but the base metals *do not melt* and remain intact. The molten filler metal flows into the joint usually by capillary attraction and alloys with the base metal to create a strong metallurgical bond. Mechanical properties of properly made brazed joints are equivalent to those of welded joints. Brazing provides the following advantages over welding:

- Requires low temperatures, warpage or distortion of base metals is minimal.
- Suitable for joining dissimilar metals.
- Suitable for joining thin sections because base metals never melt.
- Does not require finishing operations like grinding or polishing.
- Ease of operation, operators can be trained in a short time.

BRAZING OPERATION

The brazing process requires the following :

i) Filler metal
ii) Flux
iii) Heat source.

Each of the above is discussed below.

Filler metal

Selection of a filler metal primarily depends on the following criteria :

a) Type of base metal(s) to be joined.
b) Service temperature
c) Stress conditions
d) Corrosive conditions

The following filler metal systems are commonly used :

i) Nickel based filler metals (American Welding Society BNi series)
(Ni-B-Si, Ni-Cr-B-Si, Ni-P)

ii) Silver based (AWS BAg series)
(Ag-Cu-Cd-Zn, Ag-Cu-Zn, Ag-Cu-Zn-Sn etc.)

iii) Copper based
(AWS BCu series)
(Cu-Zn, Cu-Sn)

iv) Copper-Phosphorous based
(AWS BCu P series)
(Cu-P, Cu-Ag-P, Cu-Sn-P)

v) Aluminium based
(AWS BAlSi series)
(Al-Si)

Different uses of the above filler metals are given in Table-1

Flux

Except for Ni-based filler metals, fluxes are always required when using Ag-based, Cu-based and Al-based filler metals. Cu-P based filler metals are self-fluxing on copper but require fluxing for joining brass or bronze.

The function of a flux is :

a) To minimize oxidation of base metals during initial heating.

b) To completely remove oxide scales from base metal surfaces just prior to melting of the filler metal to promote wetting.

Selection of a proper flux, therefore, depends on base metal/filler metal combination. For example, if steels are joined using Ag-based filler metals, the flux should completely melt and be active at about 700^{0}C just prior to melting of the filler metal. However, if Cu-Zn based filler metal is used to join steels, then a flux active at higher temperature (about 900^{o}C) should be used. This is because Cu-Zn filler metal melts at a higher temperature compared with Ag based alloys. Brazing of high-chromium stainless steels, carbides or aluminium bronzes will require powerful fluxes since refractory oxides on many of these alloys are hard to remove. Similarly, joining of aluminium will also require a different flux.

Flux residues should also be easy to remove after brazing to prevent corrosion of base metals.

Heat source

The following methods of heating are commonly used:

a) Torch
b) Furnace
c) Induction

Of the above three, heating with an oxy-acetylene torch is commonly used.

FILLER METAL FORMS

i) Wire
ii) Rod
iii) Strip
iv) Powder

Wire filler metals are usually fabricated to perform shapes, such as rings to facilitate mass production brazing operations. Rods are fed by hand to joint areas.

Strips are also cut to various shapes like washers or discs or they are used as is.

Powder filler metals are generally mixed with an organic binder and a flux to make a thick, highly viscous paste. Pastes are dispensed through syringes or automatic dispensing machines. During heating, the binder first burns, then the flux begins to melt and finally the filler metal melts and flows to the joint to create a bond. Pastes are more economical than wrought products and they do not require separate fluxing. For these reasons they are increasingly used in the brazing industry.

TABLE 1 : List of brazing filler metals

FILLER METAL SYSTEM	SERVICE TEMP	METALS JOINED	CORROSION RESISTANCE	USES	APPLICATIONS
NICKEL BASED	HIGH >550°C	● Stainless Steels ● Steels ● Super alloys	Excellent	Low	Primarily Aircraft Engine Components
SILVER BASED	MEDIUM TO LOW < 55O°C	● All Ferrous & Non Ferrous Alloys, ● Carbides	Excellent	High	Air Conditioners, Refrigerators, Compressors, Heat Exchangers, Cutting tools, bicycles, Control valves, pressure sensing equipment, Furniture, Eye glass frames, surgical instruments, Auto radiators.
COPPER BASED	MEDIUM ~ 550°C	● Ferrous & Non Ferrous Alloys, ● Carbides	Good	Low	Cutting Tools, Utensils etc.
COPPER PHOSPHOROUS BASED	LOW ~ 300°C	● Copper ● Brass ● Bronze, Not for Steels	Fair	High	Washers, Air Conditioners, Refrigerators, Auto radiators, Heat Exchangers
ALUMINIUM BASED	LOW	Aluminium & its alloys	Good	Moderate	Auto radiators

SIX BASIC STEPS OF BRAZING

Step 1: Good fit and proper clearances

Since brazing uses capillary attraction to distribute the molten filler metal between the surfaces of the base metals, the clearance between base metals should not be too tight nor it should be too loose. An optimum clearance between base metals is about 0.4mm.

Step 2: Cleaning the metals

All oil, grease, rust scale or plain dirt must be thoroughly removed chemically or mechanically. Once the parts are cleaned they should be fluxed as soon as possible.

Step 3 : Fluxing the parts

Fluxes should be applied to the parts before heating. This way the parts will be protected from further oxidation during heating. Fluxes in paste forms are easiest to apply generally by using a brush. More flux should be used for joining heavier parts compared to lighter or thinner parts. This is because heavier parts take longer time to heat compared with thin sections. It is advised to flux the parts generously, since the flux is the only protection against oxidation and also it absorbs oxides like a sponge absorbs water. An insufficient amount of flux quickly becomes saturated with oxides and loses its effectiveness. Cleaning or rinsing after brazing is also easy with parts which are heavily fluxed.

Step 4 : Assembly for brazing

When the parts are cleaned and fluxed, they should be held in position for brazing. Depending on the shape and weight of parts, the simplest way to hold them is by gravity. Additional weights can also be used. Sometimes special fixtures need to be fabricated to hold complex parts together.

Step 5 : Brazing the assembly

In torch brazing operations, parts should be heated uniformly and evenly rather than concentrating the heat source to a particular area. Good fluxes also act as temperature indicators, they change their appearance uniformly from 'milky' to 'clear' like water when they are completely active. Filler metal should be applied when the flux is completely clear.

Step 6 : Cleaning the brazed joint

Since flux residues are chemically corrosive, they should be completely removed after brazing. The simplest way to remove flux residues is to quench the hot parts in hot (about 50°C) water followed by mechanical scrubbing. Chemical cleaning is also employed using a mild acid solution.

CONCLUSION

Brazing is a widely used metal joining process in Western and other developed countries of Asia. Automatic brazing equipment for dispensing pastes or placing preforms are commonly used to reduce production costs. Applications of brazing include aircraft engines, air-conditioner and refrigerator compressors, heat exchangers, faucets, automotive radiators and other components, bicycles, eye glasses, heat-exchangers, washing machines and hundreds more. With continued technological advancement and increased use of cars and other appliances, brazing soon will be also a popular metal joining process in India.

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