

A review on brazing parameters and the experiments used to analyze the parameters.

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ABSTRACT

Brazing is a joining technique which is commonly used in many industrial applications. There are many parameters which decide the perfectly brazed joint. This paper presents a literature survey on the different parameters which affect the successful brazing of components and the different tests used to analyze the parameters. As the brazing technique has numerous applications even in the current industrial scenario, many researches are being carried out on the same. This paper gives a general view of the research work carried out on brazing and the parameters affecting it.

Keywords.

Brazing; Joining process; Brazing parameters; Induction.



1. INTRODUCTION

The American Welding Society (AWS) defines brazing as a group of joining processes that produce coalescence of materials by heating them to the brazing temperature and by using a filler metal (solder) having a liquidus above 840°F (450°C), and below the solidus of the base metals.[1,2]

Brazing doesn't melt the base metals. So the brazing temperatures are lower than the melting points of the base metals. Also, it will always be much lower than the welding temperatures for the same base metals. Brazing creates a metallurgical bond between the filler metal and the surfaces of the two metals being joined.[2]

Some of the prominent types of brazing techniques are Torch brazing, Dip brazing, Induction brazing, Furnace brazing, Resistance brazing and Laser brazing.[3,4,5]

2. BASIC STEPS IN BRAZING [2,3]

The basic steps involved in brazing can be classified as follows. Proper care has to be taken in each of the steps to avoid a faulty joint upon brazing.

- a) Ensure proper fit and clearance
- b) Clean the metal
- c) Flux prior to brazing
- d) Fixturing of parts
- e) Brazing the assembly
- f) Cleaning the new joint

3. DIFFERENT PARAMETERS & THEIR EFFECTS ON BRAZING.

There are many different parameters which affect the brazing characteristics of a joint. Some of the parameters have been selected and are classified as follows.

3.1 Failure Mechanisms.

When two aluminum alloy 3003 plates connected by a layer of aluminum alloy 4047 filler material were manufactured the mechanism of joint failure in the reaction zone was crack initiation at shrinkage cavity sites and crack propagation through the eutectic microstructure.[9]

When the vanadium alloy - stainless steel brazing in a high vacuum furnace using Au18Ni filler material was analyzed, it was found that, in the stable crack growth region a cohesive failure mechanism dominates while with the unstable crack growth a mixed mechanism of both cohesive and adhesive failures are associated.[11]

3.2 Interaction layers.

3.2.1 Interaction layers:

Interaction layers containing CuTi and Cu₂Ti were formed at the titanium/silver-brazed alloy when the lap joint of a commercially pure titanium plate (CP Ti) to a low-carbon steel plate was produced with a vacuum-brazed furnace using silver-based filler alloy. Microhardness measurements revealed that Cu₂Ti, which formed at low brazing temperature and increased at high temperature, gave the highest hardness value in all of the joints.[10]

3.2.2 Inter Metallic Compound (IMC):

When brazing of titanium to steel was done, it was found that there is a strong relation between the thickness of Inter Metallic Compound (IMC) formed at the interfacial region, the values of shear strength of the joints, the location of the

fracture or crack propagation, and the brazing temperature. The smaller the thickness of the IMC, the higher is the shear strength. An increase in the brazing temperature led to an increase in IMC thickness.[16]

3.3 Wettability.

The poor wettability of ceramic may be improved by the use of alloys containing an element capable of modifying the chemistry of the ceramic surface (active braze).[6]

It was found during laser brazing experiment that the presence of iron oxides on the bare steel surface inhibits wetting process. Also, superior brazing ability of the galvanized steel (GI) and electro-galvanized steel (EG) products relative to that of bare steel, correlates to that of the final wetting angle.[14]

3.4 Brazing Temperature.

It was found that the brazing temperature has a strong influence over the bond strength and the electrochemical behaviour, particularly over the corrosion rates (icorr) of brazed joints. This is mainly due to the different interfacial morphologies and reaction products corresponding to a particular brazing condition.[7]

When active brazing of Alumina to Copper with Ag-Cu-Zr-Sn brazing alloy was done, it was found that a low brazing temperature is required to obtain high bond strength for an Al203/Cu joint [15]. It is observed that the thickness of the total reaction layer increases with elevating brazing temperature when Si3N4/Si3N4 joints were brazed with Ag-Cu-Ti + Mo composite filler material in a vacuum furnace.[18]

3.5 Effect of different filler materials.

Many different varieties of filler materials are available for brazing. Few of the brazing filler materials and their effects are discussed below.

3.5.1 Copper & Silver brazing filler materials:

Joints brazed with copper base brazed alloy at 1000 degC achieved higher shear strength compared to joints brazed with silver base brazed alloy at 850 degC. This result could be explained by the fact that copper base alloy has higher strength compared to silver base alloy.[8]

The average fracture load of the joint in the shear tests showed a general tendency to decrease with increasing lap width and temperature in case of specimen brazed with silver alloy. The joints brazed with copper alloy showed a general tendency to decrease in average shear strength with increasing overlap width and decreasing temperature.[8]

3.5.2 Aluminum alloy 4047 filler material:

When brazed butt joints consisting of two aluminum alloy 3003 plates connected by a layer of aluminum alloy 4047 filler material were manufactured, it was found that the ultimate tensile strength of a joint decreases with increasing brazing period and decreasing joint thickness because the amount of strong eutectic microstructure formed in the joint decreases and the amount of shrinkage porosity increases.[9]

3.5.3 Al-Si-Cu-Ni-RE Filler Material:

Sound joints can be obtained for 6063 aluminum alloy using a new low melting point Al-Si-Cu-Ni-RE filler metals at lower temperatures than the traditional Al-12Si filler metal. The results showed that the hardness of the brazed joint was higher than that for the base metal.[20]

3.5.4 AgCuTi-TiC Filler Material:

When the vacuum brazing process of cubic boron nitride (CBN) grains and AISI 1045 steel with AgCuTi-TiC mixed powder as a filler material was carried out, brazing resultants of TiB₂, TiB, and TiN were produced at the interface of the CBN grains and the AgCuTi-TiC filler layer by virtue of the inter-diffusion of B, N, and Ti atoms. The experimental results indicate that the spreading of the molten filler material on AISI 1045 steel decreased with the increase of TiC content.[21]

3.5.5 63Ag-34Cu-2Ti-1Sn Filler Material:

The addition of short, bare, carbon fibers to a silver-based active brazing alloy (63Ag-34Cu-2Ti-1Sn) resulted in up to 30% improvement in the shear/tensile joint strength of brazed joints between stainless steel and alumina.[22]

3.5.6 Gold containing Filler Material:

Brazing filler metals containing 37 to 82 percent gold are used for brazing of Nickel, Iron, and Cobalt-base alloys for the applications in which high resistance to oxidation or corrosion is required. They are ideal for joining thin sections of materials and are commonly used for this purpose, because of their low rate of interaction with the base metal.[23]

3.5.7 Gold-nickel alloy Filler Material:

To achieve the high level of integrity demanded in every brazed joint in Concorde aeroplane, the stainless steel tubes and fittings are brazed individually with the gold nickel alloy in a glass sheath purged with argon. Heating is by an induction coil with automatic control. Every brazed joint (there are several hundreds of them in each Concorde) is then submitted to pressure testing and radiographic examination.[12]

3.6 Other Aspects.

3.6.1 Processing Route:

When commercially pure Ti and Al₂O₃ brazed joints were prepared using new processing route allows for the substitution of the usual sequence of metalizing, plating and brazing by a direct brazing in which the pretreatments are replaced by the use of the TiH₂. [19]

3.6.2 In Vacuum:

Brazing in vacuum is a relatively economical method to provide an accurately controlled brazing atmosphere and is an effective means of protecting the parts to be brazed from oxidizing gases and other impurities. The vacuum pressures generally used range from 10⁻³ to 10⁻⁵ mbar. [6]

3.6.3 Ceramic – Metal joints:

Brazing is an efficient technique in joining metals but is also one of the most promising methods to join ceramic-metal joints because of its comparatively non-stringent joint tolerance requirements and because ductile brazes are able to accommodate the thermal expansion mismatch occurring in a dissimilar joining system. [6]

3.6.4 Lap Width:

It was found that the shear strength of brazed joints depends largely on the lap width. Because, the shear strength of the joints increased as the lap width decreased when the lap joint of a commercially pure titanium plate (CP Ti) to a low-carbon steel plate was produced with a vacuum-brazed furnace using silver-based filler alloy. [10]

3.6.5 Mechanical Vibration:

The effect of mechanical vibration on transient liquid phase (TLP) brazing shows that with an increase in vibration frequency, the shear strength increases. The brazing was carried out using induction chamber of the assembly in an argon atmosphere and a mechanical vibration frequency varied from 0 to 400 Hz and amplitude of 20 micrometer. [13]

3.6.6 Brazing Time:

When vacuum brazing of TiAl-based alloy to 40Cr steel using Ag-Cu-Zn filler metal was done, it was found that the change of joint strength with the brazing time is to a large extent dependent on the joint microstructure. [17]

4. TESTS USED IN DIFFERENT EXPERIMENTS.

The tests used in some of the experiments are analyzed and are classified into three sections, as follows.

4.1 Leak Tests

- a. Vacuum Leak Test. [25]
- b. Sealing tests using a He Leybold VL 200 leaking detector. [28]

4.2 Strength & Hardness Tests

- a. Tension tests at room temperature using an Instron-type test machine. [24]
- b. Tensile tests with an electromechanical testing machine (Schenck Trebel RSA 250kN). [26]
- c. Micro-Vickers hardness tester – to determine the hardness. [27]
- d. Servohydraulic testing machine (Schenk Hydroplus 5666) - to determine the fatigue behavior. [26]

4.3 Microstructural Analysis

- a. Collimated X-Ray Diffractometry (Cu K α , collimator diameter: 100 mm). [24]
- b. Optical microscopy using Reichert Jung- Polyvar microscope connected to a FC-TK – F7300U – JVC digital image acquisition system. [28]
- c. Optical Microscopy (Leitz). [25]
- d. XJG-05 Optical Microscopy (OM). [27]
- e. Scanning Electron Microscopy (SEM Cambridge Stereoscan 440). [25]
- f. Scanning Electron Microscopy (SEM). [24]
- g. JSM-6360LA Scanning Electron Microscope (SEM). [27]
- h. Electronic Microscopy using Philips XL-30 ESEM system. [28]
- i. X-ray Energy Dispersive Spectrometry- to obtain chemical information on the separated surfaces. [24]
- j. EDS (Energy Dispersive Spectrometry), MICROPIXE and SIMS - to investigate the composition of the brazed zones and reaction layers. [25]
- k. EDS (Energy Dispersive Spectrometry) (OXFORD-INCA) attached to the microscope - to identify the phases of microstructure observed in SEM. [27]
- l. Transmission Electron Microscopy (TEM, JEOL JEM-2010) - to investigate single particles for precipitated phase distribution determination. [27]

5. CONCLUSION

Brazing is a highly efficient method for joining and finds an important place in the current industrial scenario especially

in aerospace and automotive applications. More methods of brazing are expected to be invented in the near future and this paper provides an insight into the existing brazing techniques and the test methods, so that the researchers can easily understand some of the overall developments.

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