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Design and Manufacturing of Brazed Joint to Study the Effect of Varying Joint Clearance on Joint Quality

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Abstract – Oxygen Free Electronic (OFE) Copper is widely used for manufacturing of room temperature accelerator components due to its high electrical conductivity. Joining of different sections of accelerator parts are preferably done by brazing. Successful brazing depends upon factors like flow of brazing filler metal, capillary action, brazing atmosphere, joint design, and joint clearance. In brazing, joint should exhibit proper joint strength and leak tightness under operating conditions. In this context, a study is being conducted to estimate the effect of varying joint clearance on joint strength, leak tightness and flow of molten filler metal. To qualify the brazed joint, samples have been designed and machined for tensile testing, shear testing, leak tightness and metallographic examinations. Brazing would be carried out in vacuum and hydrogen atmosphere. Tensile and shear strength samples would assess the brazed joint strength. Further, brazed joint would be evaluated by metallographic techniques to check flow of molten filler metal. Specimens would also be tested by Helium Mass Spectrometer Leak Detection (MSLD) test for leak tightness. The results would help assess the effect of braze gap on the quality of braze joints.

Keywords — OFE Copper, Brazing, Joint Clearance, Joint Strength, Leak tightness, Metallography

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INTRODUCTION

Brazing, an advanced joining process, is widely used in aerospace, nuclear, defense industries and accelerator components to join many similar and dissimilar metals. Accelerator components are manufactured using OFE copper due to its high electrical conductivity. Although accelerator components have been joined using electron beam welding, laser welding, tungsten inert gas welding, soldering, brazing is better suited as lesser distortions are observed during uniform heating and cooling in protective atmosphere furnace. Also quality of brazed joint [2] is found to be more superior to many other joining processes.

Successful brazing depends on process parameters like joint design, brazing filler metal (BFM), brazing atmosphere, brazing temperature and time. OFE copper based accelerator components [3] have been successfully brazed earlier using proper joint designing under 10^{-5} torr vacuum atmosphere and at 810ºC temperature with silver based eutectic BVAg-8 filler in foil form. BVAg-8 BFM in wire form [4] has also been used. Reducing gases [6] like hydrogen have been purged at elevated temperature for successful brazing to remove oxide layers. Heating rate varies according to mass and geometry of parts to be brazed. Soaking is necessary before reaching to liquidus temperature of filler metal to equalise temperature of parts. Parts are therefore may be soaked at 20-30ºC below the liquidus point of BFM.

Surfaces of the joints are necessary to be cleaned prior to brazing to remove the contaminations which prevent the proper wetting and flow of the brazing filler metal. Chemical cleaning processes [5] prior to brazing is necessary to remove oxide layer formed, dust, and grease, etc.

Machining of large sections of accelerator components requires stringent geometric tolerances [1] like straightness, parallelity, flatness, circularity, cylindricity and perpendicularity. Despite tight tolerances, it is difficult for the assembly surface to touch each other at every location. This results in variation in joint clearances at different locations. Leak tightness and strength of brazed joint will be affected due varying clearance which would result from variation of capillary flow of BFM. For this varying clearance, it is necessary to find the effect of joint gap on leak tightness, flow of molten filler metal and joint strength. Tensile, shear and leak testing as well as metallographic evaluation [7] of brazed joint would be carried out for this study. Scanning Electron Microscopy (SEM) can be used to observe the eutectic phase of BVAg-8 BFM in the Cu-Cu brazed joint as well as to study grain boundary diffusion of filler alloy in base metal. A maximum gap of 50 μm may result during assembly of structures and hence our study has focused up to a gap of 50 μm. In the next section, methodology followed for conducting experiments is presented.

METHODOLOGY FOR EXPERIMENTS

Since the samples to be tested would require different joint clearances, so the design was prepared which ensures varying clearances for butt and lap joints. Methodology to carry out this study includes specimen design, machining, chemical cleaning prior to brazing, brazing trials, testing and analysis of results. These steps are further discussed below.

Specimen Design

Specimens were designed for tensile and shear testing. Butt joint is designed by considering available furnace facility, for which self fixturing is found to be essential. Pre-placement of BFM wire is also taken into consideration during designing. Butt joint is designed for zero thickness, 25μm and 50 μm which are shown in below fig. 1.

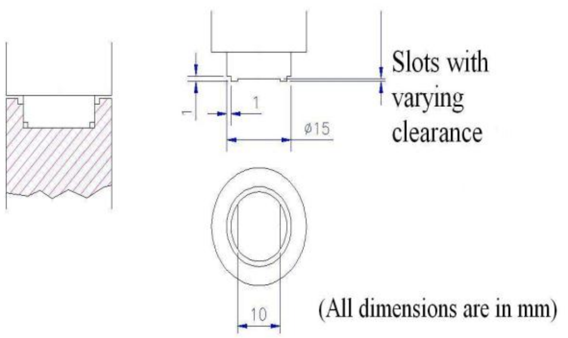

Fig. 1 Butt joint design for varying clearance

After brazing, tensile specimen is to be turned to standard test piece as shown in fig. 2 by referring AWS B4.0:2007 standard. Diameter (d), length of reduced section (L) and gripping diameter (D) would be 9 mm, 44 mm and 12.5 mm, respectively.

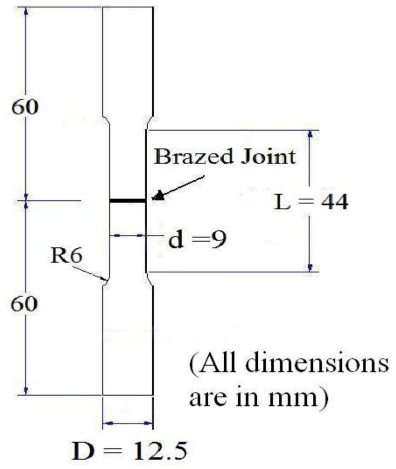

Fig. 2 Standard drawing for tensile testing specimen

Fig. 3 shows the design for shear testing. For a particular thickness of plate, length of overlap must be 3 to 6 times the thickness. Hence for 5 mm thick plate, 20 mm length of overlap was designed.

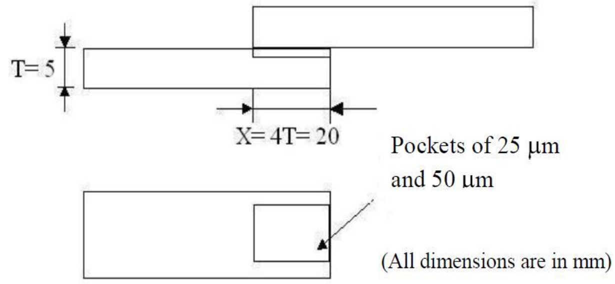

Fig. 3 Shear testing specimen

Design for the leak testing specimens, was made as shown in fig. 4.

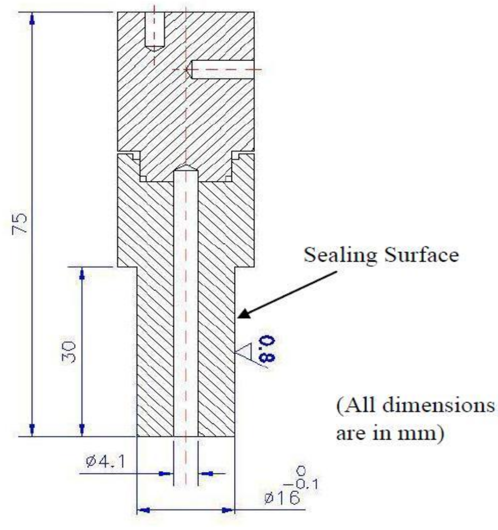

Fig. 4 Leak Testing Specimen Drawing

Machining of Specimens

Machining of specimens has been successfully completed. Samples were also inspected for dimensional accuracy and observed deviations are as follows,

1. For shear testing samples, flatness and depth of surface is observed within 5 µm tolerance limit.

2. For tensile testing samples, hole diameter is found within 20 µm above basic size while for shaft diameter is within 20 µm to 40 µm, below the basic size.

Arrangements for thermocouples have been made by drilling hole of diameter 3.2 mm and 10 mm deep in case of vacuum furnace brazing.

Chemical Cleaning

Primary chemical cleaning is to be done to remove the dirt, grease and oxides. It includes ultrasonic cleaning in trichloroethylene for 15 minutes and immersion in 50% v/v HCl (37%) for 2 minutes followed by water rinsing.

Brazing of Specimens

Specimens with varying clearances would be brazed in vacuum furnace at 10^{-5} torr vacuum pressure and hydrogen furnace separately. Silver based eutectic BVAg-8 BFM, in the form of wire of 0.8 mm diameter, would be used for tensile testing and leak testing specimens while filler metal in the form of foil of thickness 125 µm would be used for shear specimens. Brazing temperature would be 810°C.

Testing of Specimens

Following tests would be conducted to test the joint for desired quality for varying joint clearance

1. Tensile and Shear Testing: It would be carried out on universal testing machine.

2. Leak Testing: Helium Mass Spectrometer Leak Detection (MSLD) test would be carried out to obtain desired hermeticity.

3. Metallography: It would be used to study flow of filler metal in varying joint gap. It comprises of sectioning of specimen, mounting, grinding, polishing, and microscopic observation under optical microscope

EXPECTED RESULT

The effect of brazed joint clearance on the quality of the joint would be analysed using the results of tensile, shear, leak testing as well as metallographic examinations.

CONCLUSION

A proper designing of tensile, shear and leak testing samples were successfully carried out. Machining for different joint clearances has been completed.

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