In-Situ Observation of Molten Brazing Filler Metal with New Joint Design Specimen

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Generally, brazing is completed when the brazing filler metal penetrates the gap by uniform wetting. It is believed that the joining process is completed with the formation of joint defects "voids" in the process of uniform wetting. However, previous studies have shown that what occurs when brazing is performed is non-uniform wetting. It is suggested that this non-uniform wetting is the cause of void generation.

Wetting and spreading of brazing filler metal is tested on a metal plate, as described in JIS Z 3191[1)]. The resulting angle between the molten brazing filler metal and the base metal surface is substituted into the "Young's equation". This is used to investigate the wetting of the brazing filler metal. However, this method does not cover the wetting of the molten brazing material as it moves into the gap. Therefore, it is suggested that the JIS Z 3191[1)] experiment is insufficient to evaluate the wetting of the molten brazing filler metal that penetrates into the gap.

In this experiment, we created new specimen. It is called us “V-groove specimen”. Specimens were created with two base metals. They are pure copper and lead-free brass in which bismuth was used as an alternative element. In order to do in situ experiments, it was not possible to observe the inside of a conventional electric furnace. Therefore, we produced a furnace with a window for in-situ observation and experimented with it. Two types of brazing filler metals. They are BAg-7 and BAg-8. As a result of experiments with V-groove specimens, it was found that there are two types of wetting of brazing filler metal. they are called "primary wetting" and "secondary wetting". We evaluated these two types of wetting and investigated the wetting of the brazing filler metal. It was found that the wetting of the molten brazing filler metal was different for each base metal.

Keywords: *Wetting experiment, Brass, Elemental analysis*

1. Introduction

Conventionally, free-cutting brass with Pb added has been widely used for piping components[2)]. However, in 1996, the US Safe Drinking Water Act was revised, and the weighted average value of Pb contained in plumbing components for drinking water was required to be less than 0.25%. Therefore, Pb-free free-cutting brass that meets this requirement and has Bi or Si added as an alternative element has been put into practical use[3,4)]. When joining Pb-free brass as piping components, Sn–Ag–Cu or Sn–Sb solders, which are high-strength Pb-free solders, are used. Soldering is generally performed using a torch as the heat source when performed at the workplace. In torch soldering, a pure Cu pipe is inserted into a brass valve, which is then heated by the torch. In this process, the solder is heated only from the side of the brass valve, which generally results in non-uniform heating that differs from the soldering process in which the base metal and solder are uniformly heated, such as soldering in a furnace. Heating using an electric furnace provides uniform heating because the specimen is heated from all sides.

In previous studies[5-7)], parallel two-plate specimens were proposed, and experiments were conducted to investigate void formation. A previous study[5)] classified the voids generated in a parallel two-plate specimen and successfully reduced spherical voids in the joint area. A new evaluation method called soldering line-spread velocity was also proposed[7)] and used to successfully evaluate solderability. The results of these studies suggest that it is necessary to thoroughly understand the wetting and spreading behavior of the molten brazing filler metal to obtain effective soldered and brazed joints with fewer defects, such as voids.

The method for evaluating solderability presented in previous studies[6)] assumed that the solder penetrates into parallel gaps that have a sufficiently large area for the amount of solder. In these studies, the void formation process was investigated using this evaluation method. However, the cause of heterogeneous wetting and spreading is often the joint geometry. It has also been suggested[7,8)] that in situ observation is important to clarify the causes of heterogeneous wetting and spreading.

In this study, a new test specimen was developed, and the behavior of molten solder and molten brazing filler metal during joining was observed and analyzed through in situ observation experiments to clarify the effect of joint geometry on solder wetting and penetration into gaps.

2. In situ observation experiment with a V-groove specimen

2.1 Specimen Shape and Experimental Equipment

In situ experiments with the groove specimens indicated that the specimen shape needed to be changed. There were two conditions for the new specimen shape. The first was that the specimen must mimic a gap like the groove specimen. If the specimen is shaped like a perfect gap, it cannot be observed in situ. The second condition is that the entire specimen should resemble a plate. A V-groove specimen was created based on these two requirements, and the specimen shape is illustrated in Figure 1. This specimen had a V-shaped groove created on the plate. The bottom area of the groove resembled a gap where capillary action occurred. The other areas were shaped like plates to facilitate in situ observation.

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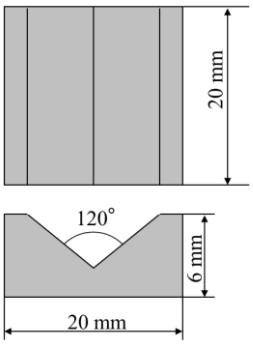
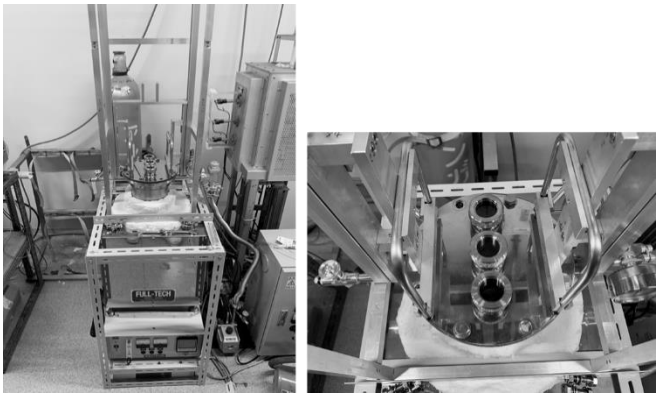


Figure 1 V-groove specimen



(a) (b)

Figure 2 Furnace. (a) Overall. (b) Top view.

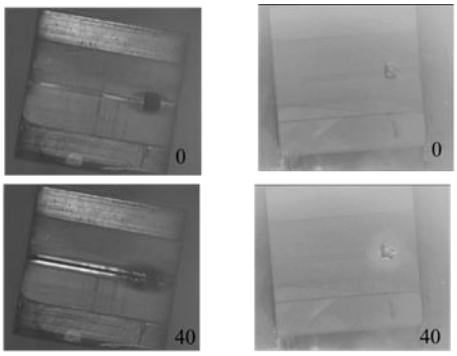
The experiment needed to be conducted in a vacuum atmosphere for in situ observation. For this reason, a special electric furnace was prepared, a photograph of which is presented in Figure 2. This electric furnace was a vertical vacuum furnace with three windows at the top. One window in the middle was used to take video using a camera, while the other two windows were used to allow light into the furnace.

2.2 Experimental Methods

The inside of the grooves of the V-groove specimens were polished with #800 waterproof paper to prepare the surface condition. BAg-7 was used as the brazing filler metal at an amount of 0.01 g. The brazing filler metal was placed on one side of the V-groove specimen, and the flow of the brazing filler metal was observed. The temperature inside the furnace was set to approximately 790 °C. C6803 brass and C1100 pure Cu were used as the base metals for the specimens in the experiments.

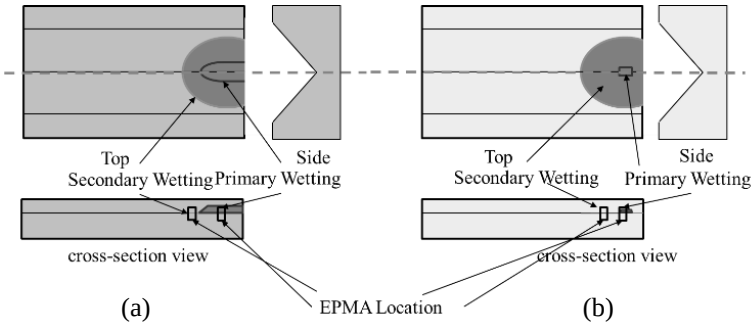
2.3 Results and Discussions

Figure 3 presents images at 0 s, at the time when the brazing material began to melt, and 40 s after the brazing material moved to the end of the specimen. The in-situ observations revealed that there were two types of wetting: primary wetting and secondary wetting. Secondary wetting is generally referred to as a halo. This region is an interfacial reaction layer or intermetallic compound layer consisting of the base metal and brazing material components[8]. In this experiment, it was possible to observe both primary and secondary wetting in the pure Cu specimen. However, primary wetting could not be observed in the brass specimen. Primary wetting was found to spread



(a) (b)

Figure 3 Results of in situ observation using V-groove specimen. (a) Cu. (b) Brass.



(a) (b)

Figure 4 Electron probe microanalysis (EPMA) location. (a) Cu. (b) Brass.

along the groove, whereas secondary wetting was found to spread in a circular pattern.

Electron probe microanalysis (EPMA) analysis of these two types of wetting was performed for further investigation. The EPMA analysis locations are presented in Figure 4. For the brass specimens, the area where the brazing material was placed was analyzed as the primary wetting area. Elemental analysis results for the pure Cu and brass specimens are presented in Figures 5 and 6, respectively. In primary wetting on the pure Cu base metal, a reaction layer was observed, which was located between the red lines displayed in Figure 5 and indicates that the brazing filler metal was wetted on the base metal. In Figure 5, BEI is a Backscattered Electron Image. However, in the secondary wetting, the reaction layer and brazing layer were much thinner than those in the primary wetting. The results were similar for both primary and secondary wetting in Figure 6 when brass was used.

The results of the in-situ observation demonstrated that primary wetting was not observed in the experiment with brass. Therefore, the area where the brazing material was set was designated as the primary wetting area, and elemental analysis was performed. On the brass side, Zn near the base metal surface was removed by dezincification, and the brazing element Ag penetrated into the area. In the case of the combination of brass and BAg-7, the brazing filler metal penetrated into the area where Zn was removed, which is illustrated in Figure 6. This phenomenon occurred not only on the surface but in all areas where Zn was removed. This was considered to be the cause of the observed distribution of Ag.

In the pure Cu sample, Ag was detected only on the ingot surface. In the brass sample, Ag was detected in areas

where Zn had been removed.

3. Conclusions

Brazing filler metal wetting can be divided into primary wetting and secondary wetting. Primary wetting leads to a spreading area where the liquid brazing filler metal exists on top of the base metal and spreads, forming a reaction layer. Secondary wetting leads to a soaking area where the brazing filler metal is wetted and spread into the gaps in the base metal.

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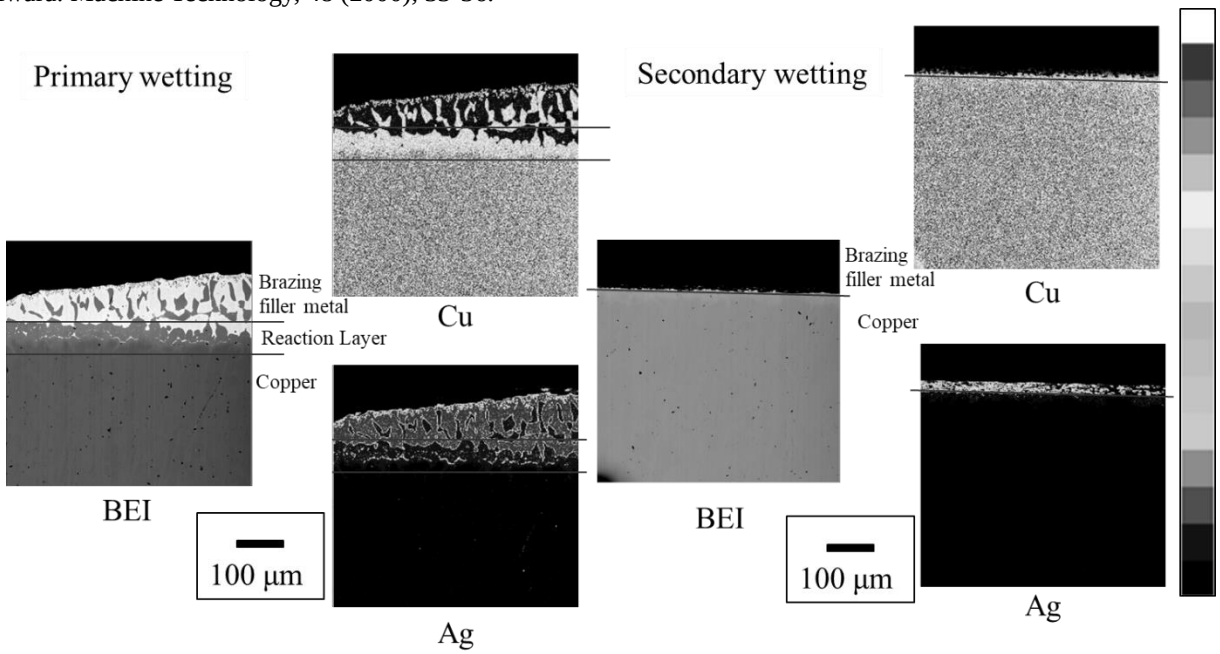

Figure 5 Results of elemental analysis using electron probe microanalysis for Cu.

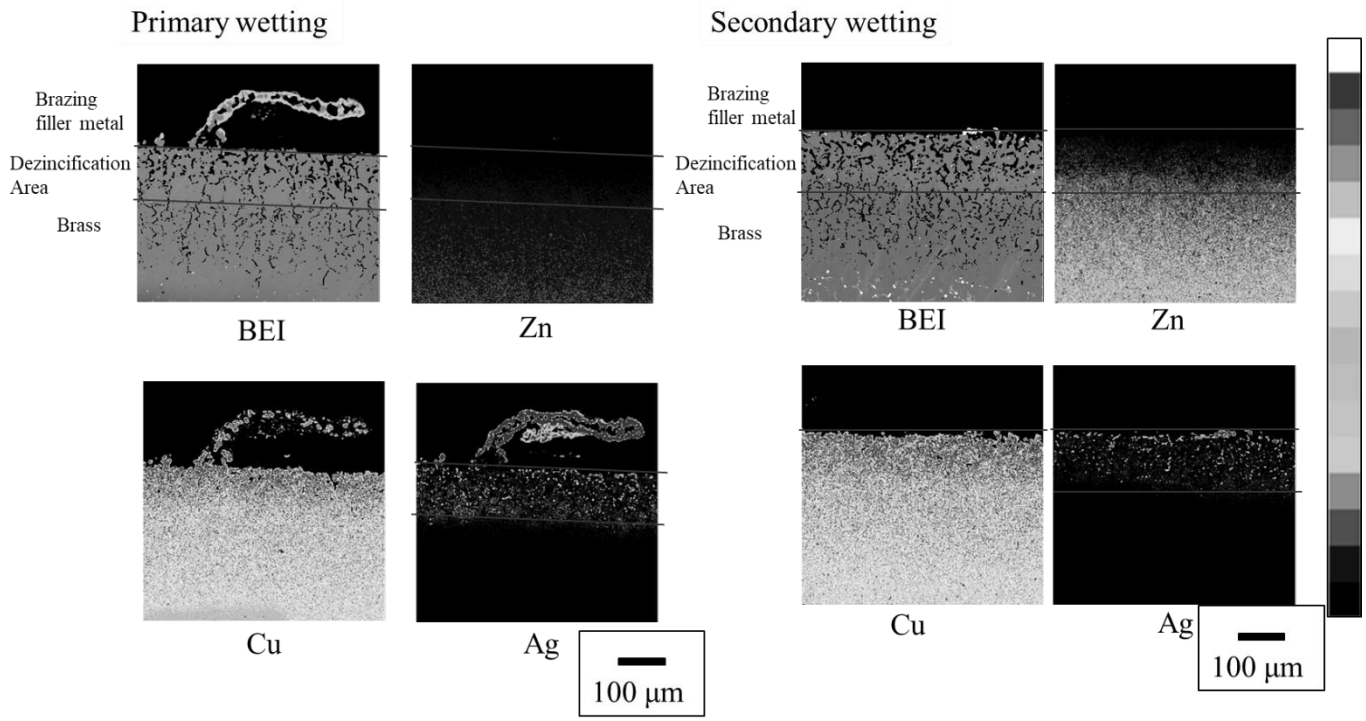

Figure 6 Results of elemental analysis using electron probe microanalysis for brass.