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# Development of optimum process parameters and a study of the effects of surface roughness on brazing of copper

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ABSTRACT

Brazing experiments on commercially-pure copper plates, using brazing filler metal (MBF-2005), are conducted at temperatures in the range of 650–750 °C for time-durations in the range of 5–15 min. Shear tests for braze-joints involved use of a universal testing machine. Based on the shear-test results, a new brazing cycle has been developed that corresponds to the greatest shear strength of the braze-joint. The brazing cycle has been performed under a controlled dry-argon atmosphere in a tube furnace. Microscopic observations were made by use of both optical and electron microscopes; whereas surface roughness measurements were made by using a *TR100 Surface Roughness Tester*. It is found that successful brazing and good wetting can be achieved by the least voids by using an average surface roughness ($R_a$ value) for the base material.



## 1. Introduction

The surface roughness of the base metal plays an important role in braze joint strength and spreadability of filler metal. Extensive studies have been reported on the effects of surface roughness on the brazing and soldering of metals [1–4]. Despite of the great industrial importance of brazing processes [5], no research work has been reported on the effects of surface roughness on the brazing of copper; this gap in the engineering literature is now filled by the research reported in the present paper.

Brazing is the most suitable joining process for small copper parts and when high joint strength is required [6]. Shabtay and co-workers have reported that copper and its alloys can withstand high-temperature brazing processes without a substantial loss in strength [7]. In addition to surface roughness, an important consideration for a sound and defect-free braze joint calls for the selection of right brazing filler metal (BFM) [8]. In order to obtain high-quality brazed joints, parts must be closely fitted, and the base metals must be exceptionally clean and free of oxides. The base-metal surface roughness of 0.8–2 μm root mean square (RMS) is generally acceptable but is not considered optimal for all base metal or base/filler metal combinations. Tests must be conducted to ensure optimal conditions for a specific brazing process [9]. Kowalewski and Szczurek have reported that the best surface for brazing is the “as-received” surface roughness of the material coming into the shop. This as-received surface roughness may be 32 RMS, 64 RMS, 125 RMS or even greater [10]. Surface roughness of the part adds surface area to the joint, which provides countless extra capillary paths for BFM to follow during brazing.

A properly brazed joint should never fail in the joint; it should always fail in the base metal outside of, and far away from, the brazed joint. Recent studies on brazing have shown that the surface roughness or scratches on bond face of a braze joint have great influence on its reliability [4]. A roughly ground bond face induces many scratches resulting in reduction and large scatter in strength of the braze joint. It is, therefore, important to carefully grind the bond faces of the joint.

## 2. Experimental work

Commercially (99.99%) pure copper was selected as the base material for brazing. Rectangular samples of the base material were prepared for brazing. The surface roughness of the base metal was controlled by various grit-sized SiC papers. The copper alloy (Cu-9.7Sn-5.7Ni-7P), designated as MBF-2005, was selected as filler metal. The 20-μm thick filler metal foil (MBF-2005) was cut into rectangular (11 mm × 33 mm) area. A trial experiment using one piece (single layer) of filler metal was conducted. It was found that

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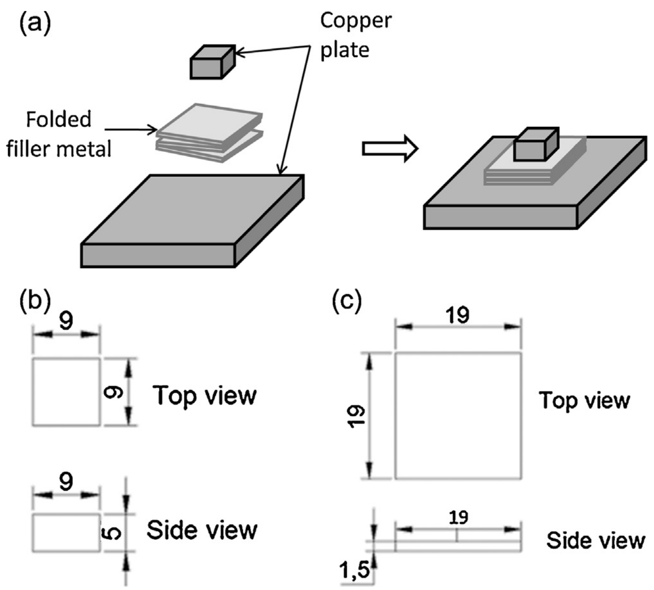


**Fig. 1.** (a) Schematic of brazing sample arrangement. (b) Dimensions (in mm) of upper base metal. (c) Dimensions (in mm) of lower base metal.

the 20-μm thickness of filler metal is not enough to completely wet the braze surface because the surface required a minimum of 50-μm thick brazing filler metal (BFM). This is why the BFM was folded into three layers; which were then finally sandwiched between copper plates, as shown in Fig. 1a–c.

The first phase of experimental work involved the preliminary tests that were conducted to choose the best brazing parameter. Pre-brazing surface preparation involved grinding the surface of the base metal by using grit-120 SiC paper. Brazing experiments were conducted at temperatures in the range of 650–750 °C for time-durations in the range of 5–15 min (see Table 1). Brazing tests were conducted under a controlled atmosphere using dry argon in an automatically controlled tube furnace (Model: KYK Furnace). The tube furnace was heated by induction heating method. The tube was surrounded by heating coils that were embedded in a ceramic fiber to allow an optimum heat transfer.

In order to determine the optimum brazing process parameters, it is important to assess the shear strength of the braze joint [11]. The samples A-C (see Table 1) used in the shear tests were cut in cross-section into halves having dimensions for the upper base metal and the lower base metal as 9 mm × 4.5 mm × 5 mm (approximately) and 19 mm × 9.5 mm × 5 mm (approximately), respectively. The bonding strength of the braze joint was determined by dividing load by the bonding area. The bonding area (area of the upper base metal surface at the brazing side) was measured under an optical microscope. The bonding strength of the braze joints for the samples A–C (at their cross sections) were determined by conducting shear tests by the use of a universal testing machine (INSTRON) with a low cross-head speed of 0.5 mm/min. The low cross-head speed was chosen for high sensitivity reading during the test so as to accurately determine the shear strengths of the braze joint. Based on the shear-test results (see Fig. 2), a new brazing cycle/process design was developed (see Fig. 3); which was used to braze copper.

**Table 1**
Brazing parameters for the first phase of experimentation.

| Sample id # | Temperature (°C) | Time duration (min) |
|---|---|---|
| A-1 | 650 | 5 |
| A-2 | 700 | 10 |
| A-3 | 750 | 15 |
| B-1 | 650 | 5 |
| B-2 | 700 | 10 |
| B-3 | 750 | 15 |
| C-1 | 650 | 5 |
| C-2 | 700 | 10 |
| C-3 | 750 | 15 |

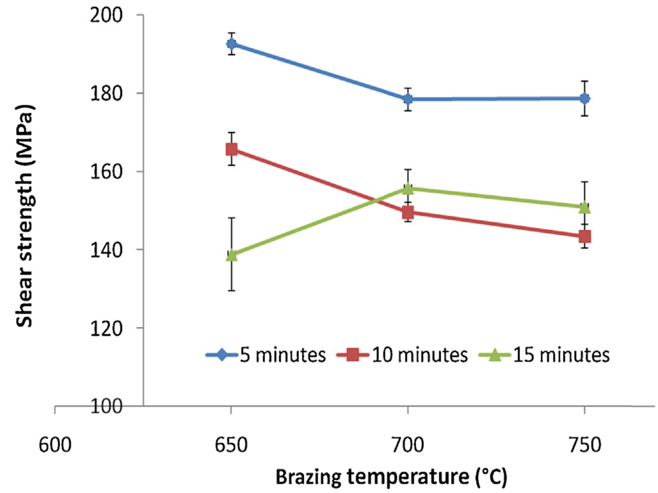


**Fig. 2.** Variation of shear strength of braze joint with brazing-process parameters resulting from the first phase of experimentation (the short vertical lines indicate error bars in easuring the shear strength values).

The second phase of the experimental work was conducted to identify the best surface roughness for brazing of the base material: copper plates. Prior to the brazing, the surfaces of the base material were ground by using four (4) different grits of emery (SiC) papers: (a) 400, (b) 600, (c) 800 and (d) 1000 grit. Then the surface roughness values, $R_a$, were measured by use of a surface roughness tester (*model: TR100*). For microstructural analysis, the brazed samples were sectioned by using a low-speed diamond cutter. Then the samples were ground with different grits of SiC and polished with high alumina powder until mirror finished. The surface-finish observations were made by use of a field emission scanning electron microscope (FESEM) (Model: JSM 5410LV) operating at a voltage of 20 kV.

The results leading to the identification of the best brazing cycle design and the surface roughness for brazing of copper are discussed in Section 3.

## 3. Results and discussion

### *3.1. Results leading to the identification of the best brazing process parameter*

We have mentioned in the preceding section that bonding strength of the braze joints of the samples A–C (see Table 1)

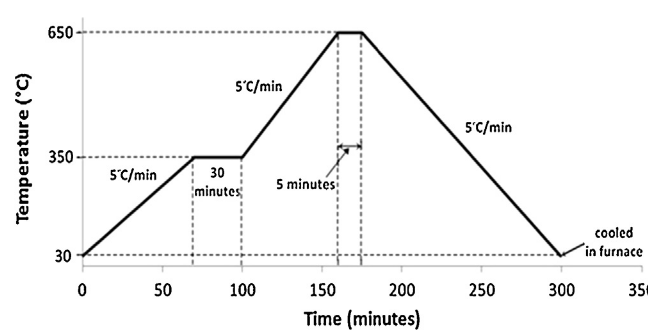


**Fig. 3.** The new brazing cycle showing the optimum parameter for brazing of copper.