



MINING AND METALLURGY INSTITUTE BOR
and
TEHNICAL FACULTY BOR, UNIVERSITY OF BELGRADE



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5rd
**International October
Conference on Mining
and Metallurgy**

PROCEEDINGS

Editors:
Ana Kostov
Milenko Ljubojev

3 – 5 October 2022. Hotel "Albo" Bor, Serbia



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REASONS FOR BRAZING WITH COPPER FILLER METAL ALLOYED WITH THE COPPER (I) AND IRON (III) OXIDES

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Abstract

Brazing history is a pretty long, might be over 5000 years. In the new era, it is accepted that the brazing filler metal must contain pure metal(s) or more frequently the pure alloys. Pureness here means the absence of various non-metallic inclusions and/or oxides in filler metal: it is explainable by the reduction of mechanical or other important servicing properties. It is wide accepted that during providing the process of brazing (also soldering), the wetting properties are also reduced if the mentioned non-metallic inclusions or oxides are present in the filler metal. Attempts should be respectable, and so one could find that in copper filler metal intentionally were added copper(I) and iron(III) oxides, but without explanations about the mechanism of such acting. It is evident that these oxides have shown a positive effect on wettability when brazing is done using such combination of copper-oxides.

Keywords: copper filler metal, Cu_2O , Fe_3O_4 , wetting properties, capillary properties

1 INTRODUCTION

Brazed components usually have no high values of mechanical properties, first of all the strength, but instead of that in many cases the brazing, also could be said for soldering, offer some advantages over the welding technology. A wide spectra of filler metals and alloys is present in the brazing technology. Many filler materials are used as a two- or multicomponent alloy, but always without the presence of oxides. One of the crucial demands from the filler metal is the wetting of materials to be brazed. The wetting property in metallurgy is well known in the casting technology [1] ordinary called the castability, as the ability to fulfill the mold cavity and obtain a sound casting. It became clear that the property of castability could not be easily explained as one component parameter, rather must be taken really the great number of influencing parameters: chemical composition of the as-casted metal/alloy, casting temperature, composition of mold mixture (when the kind of sand mold is used), thin walls, height of walls from castings, hydraulic behavior of pouring the molten metal, etc., and similarly these properties really become the crucial demands in the casting but also brazing technology. [2-5]

2 BRAZING OVERVIEW AND CAPILLARY ACTION AND CASTABILITY

Brazing is used for bonding (practically all) metals, sometimes dissimilar metals and even (metalized) ceramics. Disadvantages from welding, as the heat affected zone etc., could be avoided applying a brazing, because brazing usually preserves the metallurgical characteristics of brazed material. At all brazing operations, the working temperature are lower than melting temperature of material(s) to be brazed, so the thermal distortions are

lower than after welding. [6] Strength of brazed joints are lower than welded joints. The disadvantage of brazing is limitation for using at higher temperatures. Thin sheets or tubes with thin walls are unusual for welding while the brazing is succeeded. Brazing filler metals commonly are made of nonferrous metals, so the brazed joint show different color than the parent metal. Such aesthetic demand is rarely present in welding. At brazing processes, the using a flux is obviously, but sometime the residues may have influence on the corrosion processes. The problem during brazing is in a narrow gap between components to be brazed, and this demand reflects on ensuring the capillary action of brazing filler metal.

When the molten metal is poured into the mold cavity and filled between the thin walls and make castings, then it is usually said that the castability is well. Of course, that the castability depends from numerous factors, suppose that pouring metal is well refined, it means that the non-metallic inclusions were removed, and other numerous casting demands were satisfied. Similarly, to this action, a good fulfilling of the gap(s) between brazed components is needed to be in the brazing process, shown in Figure 1. [7]

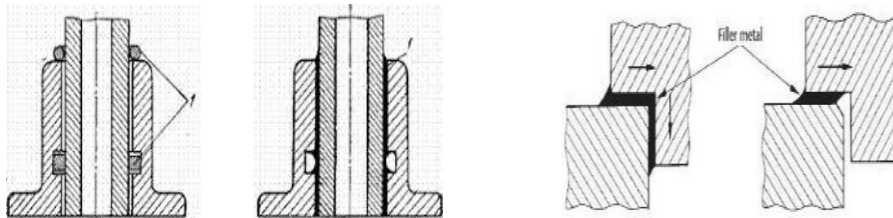


Figure 1 Few examples of design and good wettability; round and square shape of filler metal

So, the wettability (or capillary action) became one of the most important factors during brazing in making the tight joints. Capillarity is frequently describing through the wettability and fluidity of liquid, but if both cases (wettability and fluidity) of molten brazed metal are in agreement with the laboratory experiments, but not always. This dependance is rather complex, as shown according to a gap clearance for one of the most used filler metals on a silver base, shown in Figure 2. [8]

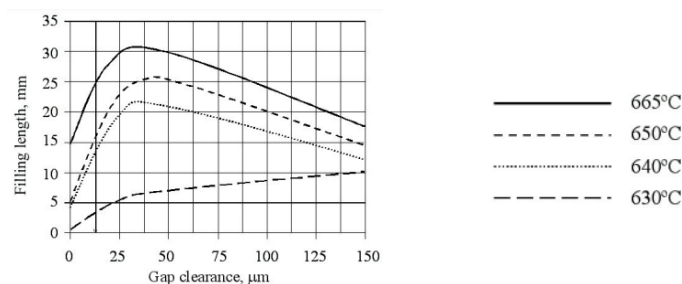


Figure 2 Dependence of filling length vs a gap clearance at common operation temperatures for silver filler metal [8]

3 HYDRAULIC DESCRIPTIONS OF FLUIDITY

It is clear from previous brief explanations that the capillary activity is a pretty complex in its nature, so many attempts have made to explain such behavior, one

approach is based on hydraulics. For liquid flow calculation serves the attempts as it is shown in some steps in Figure 3. [9-10]

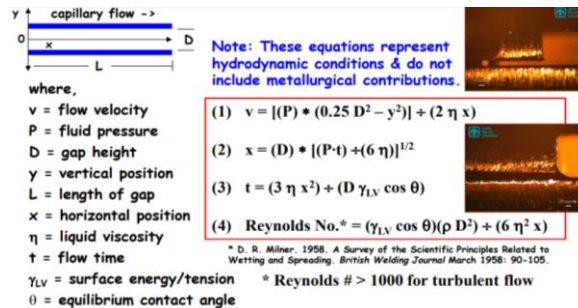


Figure 3 Some parameters in the hydrodynamics calculations of fluidity without accepting the metallurgical reactions for making an alloyed layer

4 STRUCTURE OF USED OXIDES

One of the important strengthening mechanisms in metallurgy or in science of materials is based on effecting by oxide (or other) particles into metal. It was established [11] that adding of some oxides in copper braze material in the copper has led to the increasing of capillarity of such dispersion composite material, but the three explanations for such behavior was not given.

It is established opinion that oxides in the metal usually are considered as non-metallic inclusion, it means that they are harmful either for mechanical or other properties. The experiments were approved this statement. But, one experiment is quite intrigant, it refers on the brazing ability. It is expected that introducing of oxide material into the brazing filler metal will produce just a bad property of brazed joint, but when a few oxides (on copper and iron base) were added into the copper filler metal, such brazed joint became better than a joint without those oxides. This constatation merits a particular attention, because oxides commonly prevent fusion and decrease castability, so the question is: what for serve these oxides?

4.1 Crystal structure of Cu₂O and Fe₃O₄

The crystal structure of these oxides were shown in Figure 4 [12]. Frequently, it is neglected that in those compounds oxygen atom has greater radius than metals as copper and iron, and no matter what kind of oxide is made. These oxides posses a lower density than copper $\rho_{Cu}=8.9 \text{ g/cm}^3$. When such oxides are present in metal, they decreasing the density of molten metal, and float on the top. In fact, floating of molten copper with oxides is able to produce the better fullfilling the narrow gap(s) during a brazing. It seems as a real explanation for improving the capillarity of such combination of braze materials.



Figure 4 Unit cells and densities of:
a) Cu₂O; $\rho=6.0\text{g/cm}^3$; and b) Fe₃O₄ –magnetite; $\rho=5.17\text{g/cm}^3$ [12]

In the structure of magnetite frequently are present vacant places, dark blue circles at Figure 4.b). These oxides may be added into copper filler metal up to about 15wt%.

5 CONCLUSION

Although the brazing is an old technique, it is still challenging for joining the (non)metals. The primary goal for adding the copper (I) and iron (III) oxides into copper braze filler metal is not a strengthening, although may happened, but the increasing the capillarity, i.e., braze ability of the filler metal alloy by improvement the flow properties. Capillarity is improved if the oxides Cu_2O and Fe_3O_4 are added, when the density of molten copper as the filler metal is reduced.

It could be expected that the braze filler metal, copper with oxides Cu_2O and Fe_3O_4 , will show a lower strength than a pure copper, but those oxides are acting for improving the capillarity. Better capillarity and wettability will positively influence on the total strength of brazed components.

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