DIFFUSION BRAZING AND WELDING OF THE ACCELERATING STRUCTURE

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Abstract

This work presents technologies of copper accelerating structure diffusion joints. The formation conditions of copper diffusion joint with minimal residual plastic strain are determined experimentally.

INTRODUCTION

The quality of the normal conducting accelerating structures at the stage of the waveguides assembling is basically determined by the accuracy of cups joining technology. The main requirements to the accelerating structure joining technology are as following:

- high joint efficiency;
- vacuum hermiticity;
- accelerating structure geometry accuracy;
- minimum of the residual strains.

To meet these requirements, it is necessary to provide the corresponding conditions of the accelerating structure joining. The present paper considers the joining of the copper accelerating structure by the method of high frequency brazing and diffusion welding in vacuum.

ACCELERATING STRUCTURE BRAZING TECHNOLOGY

The accelerating structure consists of separate elements, made of copper cups, which are assembled in a package and brazed with each other by a silver solder Ag-Cu (eutectic 72/28) in vacuum agent. During the brazing process modifications in geometry may occur due to the thickness of the filling alloy [1,2]. To provide the required electric parameters and good wetting of the solder, preliminarily the silver is applied over the cups junctions by galvanic method. The usage of an intermediate element in the form of galvanic application of silver, which is softer than copper, results to localization of plastic compressive strain in it. Physically the contact is formed mainly due to active strain and silver creep, which fills in the micro-asperities of joining surfaces, and that decreases noticeably the minimum necessary level of compression pressure and residual strain of items. While joining copper through a thin layer of silver at temperature slightly high than the melting temperature of Ag-Cu eutectic (but remaining below the melting temperature of silver), a process of contact-reactive melting is developed. Here the compression pressure on the joining details, which impacts on the physicochemical processes in the contact place, plays an important role.

It is known from the diagram of copper-silver system constitution, that the silver has bounded solubility in copper of utmost 8%, that's why the galvanic coating thickness should be minimal. The study has shown that the optimal coating thickness is 8-12μm. Further increase of coating thickness results in the strength reduction of the joint and in the increase of residual strain.

The joining of copper accelerating structures has been carried out in vacuum under the 1.3 MPa pressure, 1053 K temperature and the compression pressure of 1MPa. Figure 1 schematically presents a facility for joining the accelerating structure of up to 1.2 m length [3]. The developed facility allows provide the optimum performance of joining at the junction of each two cups along the full length of the accelerating structure.

The constancy of pressure is provided by the control system of magnet, which decreases the load during the heater top-down travel. The constancy of joining time is provided by heater dimensions and the speed of its travel.

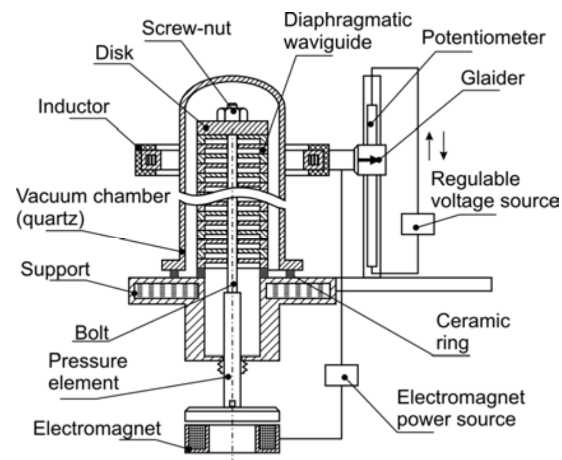

Figure 1: The schematic layout of the facility.

The constancy of heating temperature is provided by gradual decrease of the heat source power during the heater top-down travel. Figure 2 shows the example of diaphragmatic waveguide brazed with silver in vacuum.

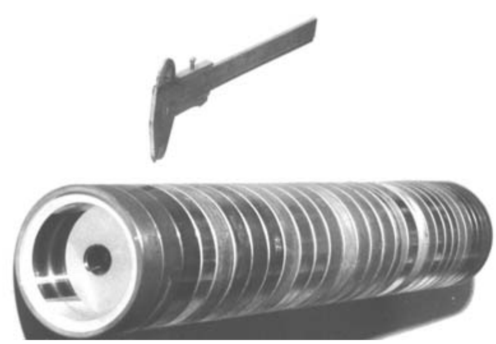

Figure 2: Diaphragmatic waveguide brazed with silver in vacuum.

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DIFFUSION JOINT WITH MINIMAL RESIDUAL PLASTIC STRAIN

Diffusion joint of copper in vacuum or in a rare gas agent doesn't present any special difficulties. It should be mentioned that there isn't consensus of opinion concerning the optimum performances of copper diffusion welding [4,5].

With the purpose of deciding the optimal conditions providing the obtaining of joints with minimal residual plastic strain, the impact of surface preparation and performance parameters on mechanical properties of diffusion joints has been studied. The studies have been carried out on prototypes made of copper M1 (prototype diameter – 12mm, length – 30mm). The process conditions varied within the following limits:

Specific pressure P, MPa	2-8
Heating temperature T, K	973-1173
Curing time τ, min	5-20

The abutting surfaces of the prototypes have been treated with diamond cutters reaching the roughness of Ra=1.5-0.025μm. Analysis of joint temperature effect on σ (joint rupture strength) (Fig. 3) shows that the more intensive increase of residual plastic strain ε occurs at T≥ 1073K, while the joint strength at this temperature is already at the level of the base metal.

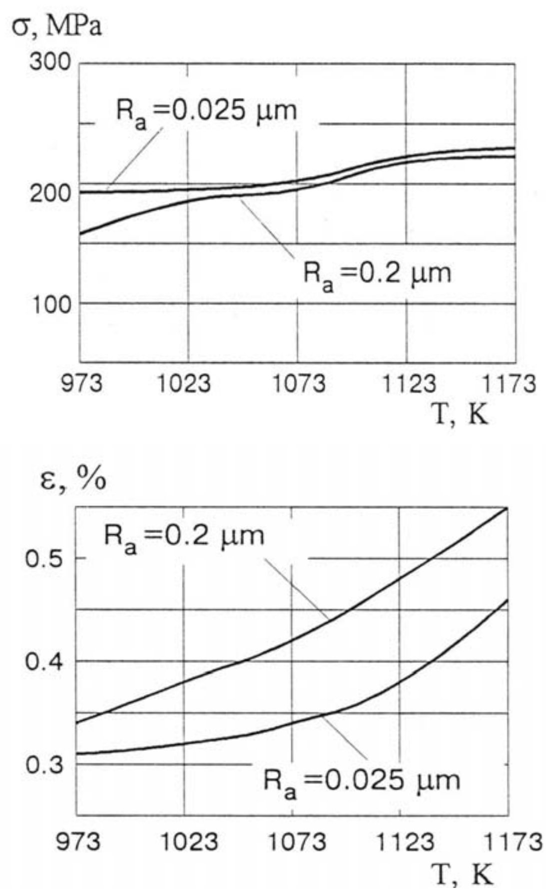

Figure 3: Dependence of welded joints σ and ε on temperature (P = 4MPa, τ = 20min).

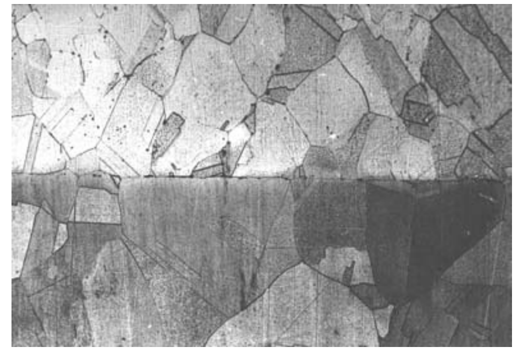

Figure 4: Effect of the diffusion temperature on the copper structure (x200).

At high-temperature creep in the contact zone, the effect of intergranular sliding increases, which contributes to the physical contact formation. Metallographic studies demonstrate that with the increase of the joint temperature, the number of defects in the joint zone decreases, moreover the maximal effect of the temperature increase appears at the surfaces treatment purity of Ra=0.025 μm, and the general formation of grains is observed (Fig. 4).

The diagram of dependence of σ and ε joints on the value of unit pressure is presented in Figure 5. As it is evident from the diagram, the increase of pressure improves the joint strength, while the residual strain rises steeply. The most intensive increase is observed starting with P=4MPa.

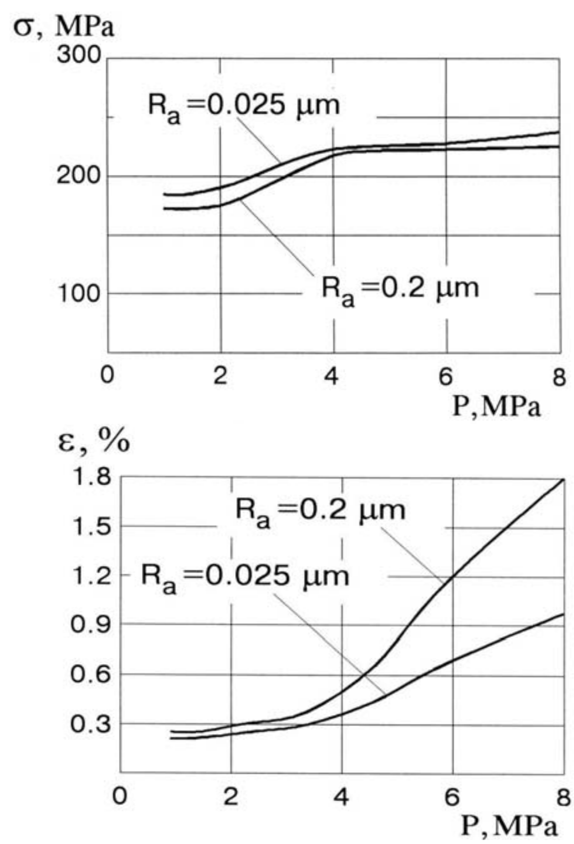

Figure 5: Dependence of welded joints σ and ε on welding pressure (T = 1123 K, τ = 20min)

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The dependence of σ and ε joints (Fig. 6) on time demonstrates that from 15 up to 20 minutes time can be recommended for joint adjustment in a real item.

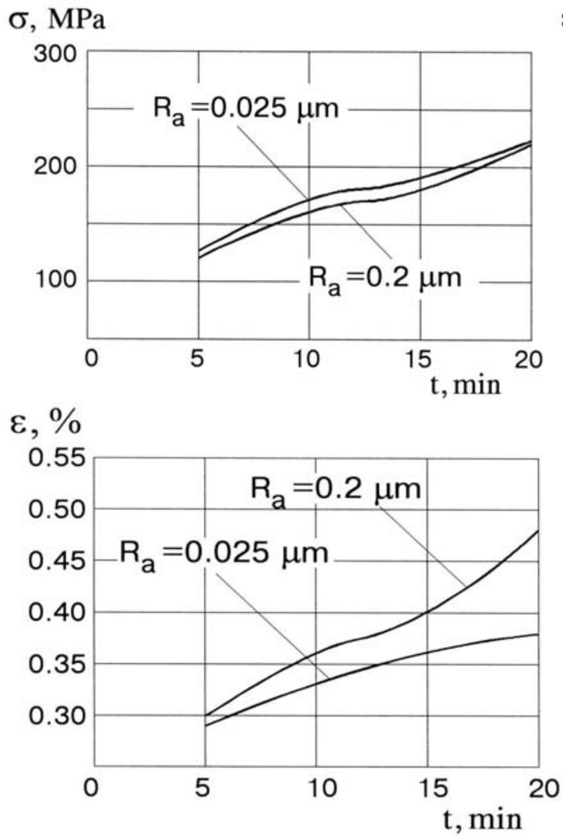

Figure 6: Dependence of welded joints σ and ε on welding time (T = 1123 K, P= 4 MPa).

According to the idea of the mechanism and the kinetics of the diffusion joint process, the following procedures to decrease the residual plastic strain of the joint can be distinguished:

- enhancement of the surface treatment purity,
- purification of the surface from oxides.

The study of diffusion junction on two oxygen-free copper cups (diameter – 105mm) has shown that the optimum performance for the surface treatment purity Ra=0.025 µm is the following: T=1073K, P=1MPa, τ = 15 min. The relative strain is then ε=0.01%. Figure 7 presents the metallo-graphic study of the joint zone. The interface remains unchanged, but its width is of the same order as ordinary inter-grain boundary, and the joint strength σ ≥ 180 MPa.

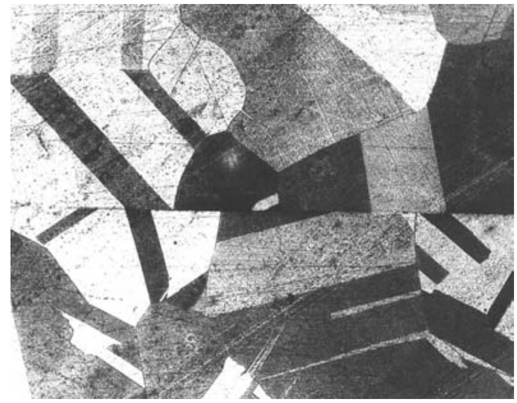

Figure 7: Microstructure of the joint zone copper-copper (x200).

CONCLUSIONS

Special-purpose hardware of diffusion joints in vacuum is developed, allowing to withstand constancy of welding pressure due to interconnection of heater travel and compression system along the full length of the waveguide for each joint of the cups.

Conditions to obtain a joint with minimal residual plastic strain depending on the process parameters are determined.

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