

## DIFFUSION WELDING OF HETEROGENOUS MATERIALS IN ACCELERATING TECHNIQUE

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### Abstract

The results of the joining of heterogeneous materials, such as titanium with stainless steel (serviceable at 4.2 K), copper with aluminum, titanium with niobium, stainless steel with aluminum, copper with stainless steel are presented.

### INTRODUCTION

The design of accelerators components often meets with the necessity to use bimetallic transitional elements, reliable joints from heterogeneous materials in a wide range of temperature and power load.

Present methods of the joining of heterogeneous materials do not always provide the obtaining of transitional elements, which meet extreme service conditions, such as ultrahigh vacuum, high pressure, temperature range of 4.2 - 623 K, vibration, radiation etc. The problems of heterogeneous materials welding or brazing arises due to formation of brittle joints and newly formed phases. In spite of that, the application of heterogeneous materials welding can significantly modify the quality of the particular design.

### DIFFUSION WELDING OF TITANIUM WITH STAINLESS STEEL

Taking into account the main alloying elements of stainless steel (iron, chromium and nickel), titanium has limited mutual solubility, forms intermediate constitutes and low-temperature eutectics [1]. Thus, the temperature of eutectic formation titanium-iron and titanium-nickel constitutes 1358 and 1228 K, respectively. Taking into consideration that titanium is a strong carbide-former (solubility of carbon in  $\alpha$  - titanium is up to 1,1% (at.), and in  $\beta$  - titanium up to 0,2 % (at.), for joining with the steel intermediate material is chosen – from the side of steel – copper, from the side of titanium – vanadium. The welded one-phase alloys of titanium 3.7035 and stainless steel 1.4435, as well as metals of intermediate layers have different physical-chemical properties. The choice of optimum performance of welding has been carried out taking into account all these properties.

Studies have been carried out on the laboratory facilities [2] shown in Fig. 1. In the welding process redistribution of carbon occurs in the side of vanadium, which becomes more intense with the increase of carbon in the steel, and regarding to copper, it squeezes and contacts with titanium, that results in low-temperature eutectic formation and embrittlement of the welded joint.

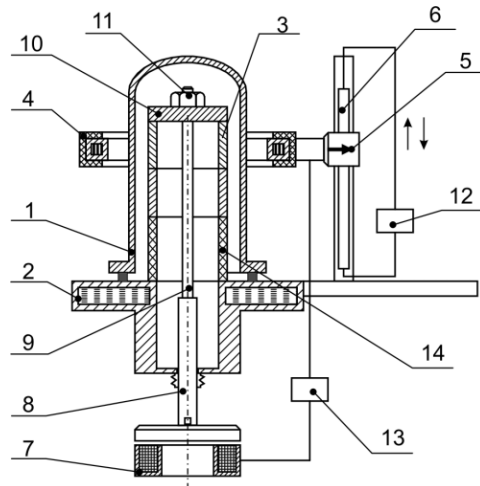


Fig. 1 Diagram of diffusion welding set-up in vacuum. 1 -vacuum chamber; 2 -bearing plate; 3 -welded piece; 4 - inductor; 5-slider; 6 -potentiometer; 7 - electromagnet; 8 - pressure; 9 -stud; 10- washer; 11 -screw; 12 -voltage supply; 13- power supply; 14 -ceramic washer.

This unfavorable phenomenon has been avoided in the following way: a method to join a detail with foil has been developed, where only the detail is heated during the welding. The detail reaches the welding temperature, then the heat is disconnected and in the process of compression of the detail with foil, a high-quality joint is obtained thanks to quick after cooling [3].

The welding technique and the technological methods providing the stability of the welding process have been developed. For instance, an experiment proved the appropriateness of the heat source location in preference from the side of steel and the necessity of preliminary heating of the welded elements. Taking into account titanium particularities, induction heating is chosen.

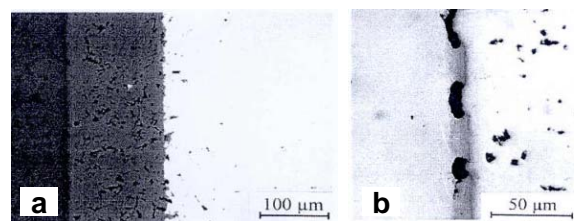


Fig.2 Diffusion welding of vanadium + copper.

Character of diffusion zones at the edge of contacted joint materials is studied by metallographic method. In spite of high-temperature heat short-term, the width of diffusion zones reaches significant values (Fig. 2a).

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However, due to surface imperfections, various blisters can be formed in the joint zone (Fig. 2b). Insignificant increase of microhardness in the contact zone of vanadium with copper is explained by the formation of  $\beta$  - solid solution, rich in copper with cubic lattice.

Fig.3 shows the hardness distribution in the zone of titanium-steel joint. Mechanical breakdown test showed that breaking occurs on the copper. This means that the strength of the welded joint constitutes the strength of copper.

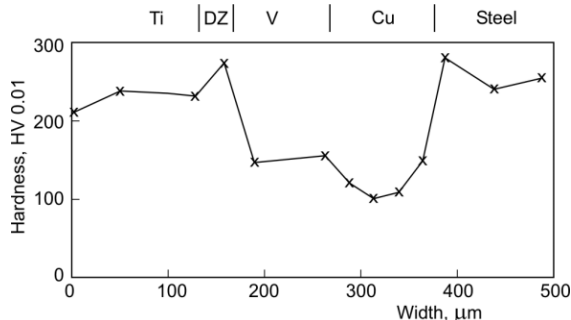


Fig.3. Hardness distribution of titanium-steel joint.

Tests on vacuum tightness of welded joints of titanium with stainless steel in the range of temperature from 300 K to 4,2 K have been carried out. The temperature of 4,2 K has been obtained by means of immersion of the welded joint in fluid helium.

After pouring of the liquid helium, leak tester sensitivity was equal to  $7 \cdot 10^{-13} \cdot \text{m}^3 \cdot \text{Pa} \cdot \text{s}^{-1}$ . No any features of helium leakage have been detected.

Table 1. Technical information of the set-up:

Pressing force of joint details, kN	4
Maximal heat temperature, K	1673
Operating vacuum in the chamber, Pa	$1.3 \cdot 10^{-5}$
Diameter of the joint piece, m	0.12
Length of the joint piece, m	1.2
Heat source power, kW	60

### WELDING OF HETEROGENOUS MATERIALS BY PRESSURE

To join aluminum with steel and titanium it is forward-looking to use cold welding, as low temperature and transience of the process exclude the possibility of brittle phases formation in the joint zone [4]. The welding method (Fig.4) consists of two welded details 1,2 and application of axial pressure to the ferrule 3. Physical contact is formed due to strong strain of the more plastic metal in the process of its impression in ring lugs made of less plastic metal. Forces of contact friction cause the plastic strain in thin near-surface layers. The welding is carried out at room temperature and the stage of volumetric interaction is limited only to seizure of contact surfaces without any development of diffusion processes.

Thanks to experimental investigations, carried out on a wide assortment of bimetallic transition elements, it is determined that the quality of the welded joint depends on

the following: velocity of the ferrule travel, which is a technological parameter of welding; angle  $\beta$  at the top of flutes and lugs and the number of lugs on the detail from less plastic metal, as well as  $\alpha$  cone angle of the ferrule - geometric parameters of the joint zone.

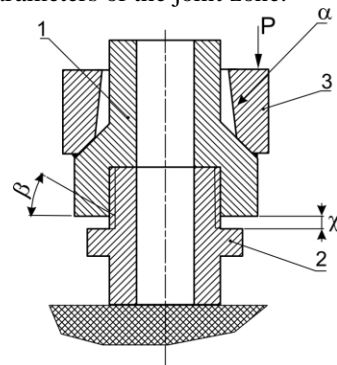


Fig.4. Diagram of bimetallic adapter manufacturing by cold welding. 1 ferrule; 2 detail from less plastic material; 3 detail from more plastic material.

Full-scale tests of aluminum - steel, titanium - aluminum and copper - aluminum transition elements have shown their high working-capacity. Their vacuum tightness is kept within the limits of leak tester sensitivity  $10^{-7} \text{ Pa} \cdot \text{s}$ . Fig. 5 illustrates some details manufactured by pressure welding.



Fig.5

### CONCLUSIONS

At present the question of welding of heterogeneous materials, used in accelerating technique, are generally solved. The quality of joints is obtained by the decrease of welding time and the increase of plastic strain in the contact zone.

### REFERENCES

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