



MANUFACTURE OF STAINLESS STEEL–ALUMINUM TRANSITION PIECES BY VACUUM PRESSURE WELDING METHOD

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Technology of vacuum pressure welding of bimetal tubular transition pieces from 10Kh18N10T stainless steel with AD1 aluminum was developed. It is established that modifying the steel blank surface using holes promoted localizing of plastic deformation in the butt joint and producing welded joints with the strength not lower than that of aluminum.

Keywords: *vacuum pressure welding, bimetal joint, aluminum AD1, steel 10Kh18N10T, transition piece, microstructure*

Possibility of formation of the safe tube joints from dissimilar metals is a key issue in series of current structures, for example, energy devices.

Joining of the tubes from aluminum alloys with tubes from steel using transition pieces is widely used in the assembly structures where they have the high requirements on working capacity. The tubes from stainless steel and aluminum alloys being joined with the help of inserts and transition pieces are used in the vessels for storage and transportation of cryogenic products.

Significant difference in the values of melting temperature of steel (around 1539 °C) and aluminum (660 °C), differences in the coefficients of linear expansion, i.e. $23.5 \cdot 10^{-6}$ for aluminum and $11.9 \cdot 10^{-6}$ for iron at room temperature, $31.1 \cdot 10^{-6}$ and $14.3 \cdot 10^{-6}$ 1/°C, respectively, at 500 °C, and presence of a refractory oxide film Al₂O₃ on the surface of aluminum promote a complexity of obtaining of aluminum to steel welded joints.

The aim of the present paper lied in development of a technological process of vacuum pressure welding of bimetal steel–aluminum tubular transition pieces with the strength on the level of that of aluminum.

The cylinder samples and flat samples from steel 10Kh18N10T (50 × 20 × 2 mm) and aluminum AD1 (50 × 20 × 4 mm) were used for studying the influence of surface treatment on formation of the welded joints. Surface of the stainless steel samples was grinded or grinded and polished before welding and samples from aluminum were scraped. Welding of the samples was carried out in a free state in vacuum at 500 °C temperature, 8 MPa pressure and rate of heating around 5 °C/min. Deformation of the joint made, approximately, 25 %. Temperature and pressure of the process of welding were selected based on operation recommendations [1, 2].

Formation of the brittle intermetallic compounds in a butt joint promotes the main difficulties in diffusion vacuum welding of stainless steel with aluminum. There is virtually no influence of the intermetallics on mechanical characteristics of the joint on elementary stage of development, when they do not form a solid layer in a contact. Presence of a solid intermetallic layer in the contact reduces ductility and strength of the joint. This is a result of high brittleness of new phase as well as internal stresses appearing due to volumetric changes [3]. Welding of the metals forming intermetallics requires minimization of the third stage of the process of diffusion welding, i.e. stage of volumetric interaction determined by diffusion processes, in accordance with the recommendations of work [3]. Therefore, welding time made 1 min.

The joints after welding were cut on strips of 50 × 9 mm size by erosive cutting machine. Bend testing of the joints was carried out. Analysis of the obtained results indicates that the samples, steel surface of which was grinded, have bigger bending angle. Bending angle of such joints makes 120°. However, cracking along edges of the joint should be noted in both cases.

Application of the soft perforated inserts allows plastic deformation being localized on an interface of welded parts [4, 5]. 1.3–1.5 times increase of cracking resistance of the parts can be achieved in welding of cermet joints with modifying ceramic coating [6] by making of «reinforcing holes» in it. Therefore, «blind» holes were drilled in the surface of steel plate for eliminating cracking of the joints.

The holes in the surface of steel plate were 2.5 mm in diameter, approximately 1.2 mm of depth and made with 10 × 10 mm pitch. Obtained joints were also bend tested. Bending angle made 180°, and no cracking of the joint was observed at that.

The metallographic investigations of bimetallic joints (Figure 1) were carried out. Separate areas with intermetallic layer (Figure 1, *a*) were found in a joining zone of samples with holes. The intermetallics took

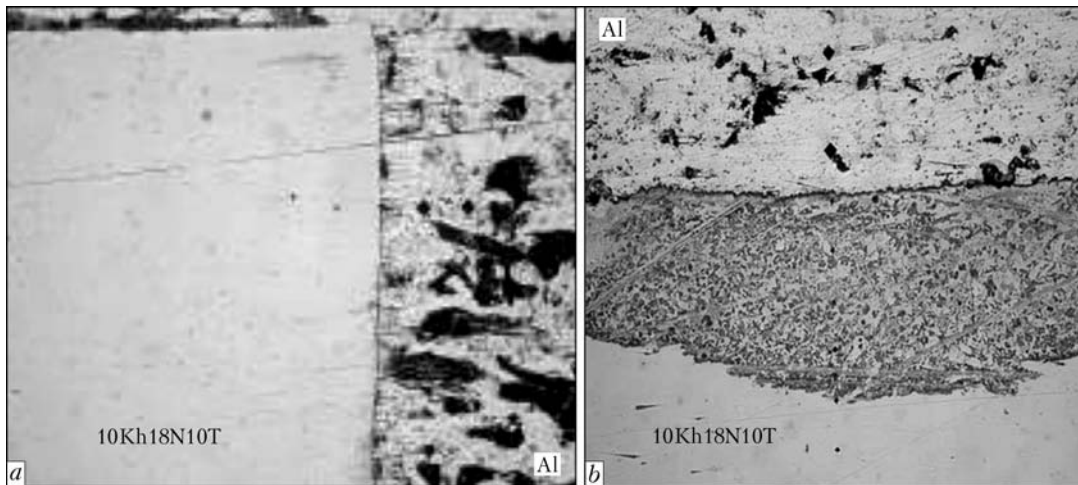


Figure 1. Microstructure ($\times 100$) of joining zone of the samples from 10Kh18N10T steel and aluminum AD1 with (a) and without (b) holes on the surface of steel blank

50–70 % of area of joining zone (Figure 1, b) in the sample without holes. It should be noted that both samples were simultaneously welded.

Increase of plastic deformation rate results in 2–3 times reduction of thickness of the intermetallic layer [7]. Strains acting in the contact at the initial time of welding significantly exceed the yield strength and, as a result, elasto-plastic deformation of the microflanges is actively developed. The rate of deformation reduces 2–3 times in several seconds after loading application, and the process transfers in a transitional creep stage [8].

It can be assumed that difference in the thicknesses of formed intermetallic layer of the samples with holes and without them is caused by different rates of plastic deformation in the near-contact layers of aluminum relative to the surface of stainless steel. The rate of plastic deformation of aluminum in the first case was higher than in the second one.

The authors obtained no positive results after experiments on welding of tubular blanks on air. Obtained joints destroyed in cutting.

Tubular blanks from stainless steel 10Kh18N10T and aluminum AD1 were welded in P-115 unit vacuum chamber. Outer diameter of steel tube made 25 mm, internal one was 20 mm, height made 30 mm, and that of aluminum tube was 41.5 and 23.6 mm, correspondingly, at 30 mm height.

A demountable unit designed for alignment and fixing of the tubular blanks before welding was manufactured for the experiment performance. Figure 2 shows scheme of the unit and its general appearance. Support washer 1 was inserted inside the unit and aluminum blank 2 was position on it. Steel blank 3 was in tight contact with the aluminum one and was centered from above by guide washer 4. Fixing of tubular blanks and alignment bushes was carried out using two steel rims 5, to which ears 6 with holes were welded. The holes (Figure 3) were drilled in the

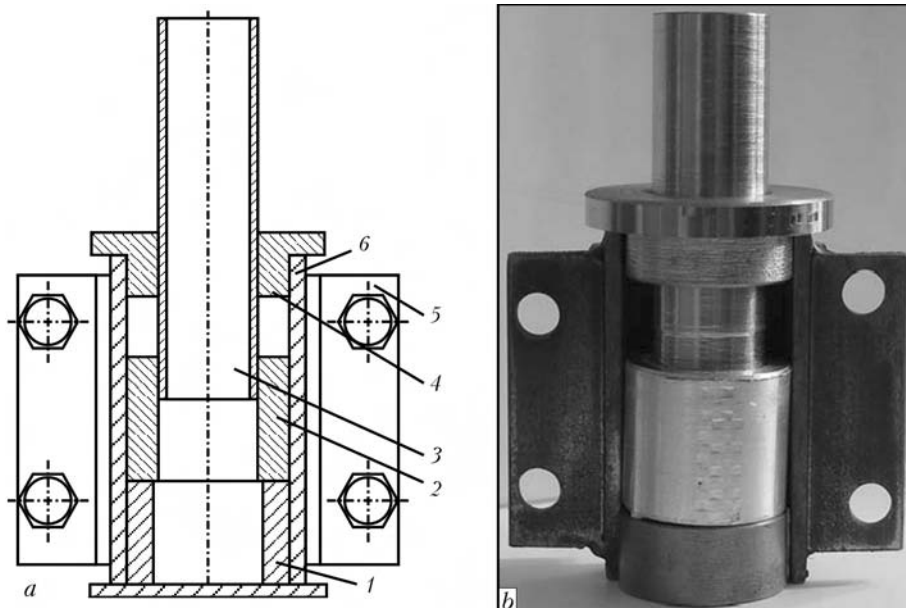


Figure 2. Scheme of unit for obtaining of bimetal tubes (a), and ready-assembled appearance (for designations see the text)



Figure 3. Appearance of steel blank

surface of steel tube in accordance with the procedure elaborated on the samples. A conicity was developed at the end of steel tube for alignment with aluminum one. The surfaces to be welded were degreased with acetone immediately before welding.

Obtained bimetal joint after welding was cut on cylinder blanks of 5 mm thickness using erosive cutting machine. Figure 4 shows macrosections of 10Kh18N10T-AD1 welded joint. As can be seen from the Figure, complete filling of the holes with aluminum extruded as a result of plastic deformation of the near-contact volumes of metal takes place in the process of welding. Mechanical tests showed that the failure of welded joints takes place along aluminum.

CONCLUSIONS

1. Technology for vacuum pressure welding of bimetal 10Kh18N10T-AD1 tubular joints was developed.
2. Modifying the surface of more strength steel blank using holes allows increasing the rate of plastic



Figure 4. Macrosection of welded joint: A — places of the holes filled with aluminum

deformation of near-contact layers of aluminum that provides obtaining of the welded joints with minimum thickness of intermetallic layer.

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