DEVELOPMENT OF THE TECHNOLOGY FOR BRAZING OF TITANIUM ALLOYS USING FILLER ALLOYS BASED ON THE Al–Mg SYSTEM

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It should be noted that, despite a large number of the investigations performed on brazing of titanium using aluminium filler alloys, brazing of titanium by using the Al–Mg system based filler alloys have not received acceptance in the territory of Eastern Europe and, particularly, in Ukraine. However, the quantity of publications covering developments of new aluminium alloys for brazing of titanium alloys is growing, this being indicative of the demand of the industry for commercial medium-melting point filler alloys for brazing of titanium and its alloys. The purpose of the present study was to develop the technology for brazing of titanium alloys by using the Al–Mg system based filler alloys. Presented are the investigation results on brazing of the samples of titanium alloy VT1-0 using aluminium filler alloys by radiation heating in vacuum. Structural and chemical heterogeneity of the brazed joints was investigated. It was found that aluminium filler alloys based on the Al–Mg system are suitable for producing sound brazed joints on titanium alloys. The dense and defect-free joints were made in brazing of models of sections of lamellar-ribbed heat exchangers by using filler alloy AMg6, the strength of the joints being sufficient for this type of the items. Brazing filler alloy TiBrazeAl-665 was found to be suitable as well. 4 Ref., 3 Figures.

Keywords: *brazing, brazing filler alloys, titanium alloys, aluminium alloys, lamellar-ribbed heat exchangers, honeycomb structures, microstructure, mechanical properties*

In fabrication of heat exchangers, honeycomb structures and other complex engineering items the use of light Ti- and Al-base alloys provides the maximum decrease in their weight and increase in strength, corrosion resistance and other operational properties. Brazing is the most promising method for fabrication of such structures.

Brazing of lamellar-ribbed heat exchangers is a complex technological process related to the need to simultaneously produce the seams of a large length (the seams in heat exchangers can be hundreds or even thousands of metres long), as well as to the impossibility to correct defects formed inside a structure. Therefore, considering the above-said, as well as high reactivity of titanium at increased temperatures, the most promising method to fabricate heat exchangers of titanium alloys is vacuum brazing [1, 2].

The composition of a filler alloy plays an important role in the process of brazing of lamellar-ribbed heat exchangers. Erosion activity of a filler alloy can be minimal, as heat exchangers are made from thin-sheet elements. In addition, the temperature and time of brazing of heat exchangers should be such that they prevent undesirable changes in structure and properties of the base metal [1–3]. The choice of aluminium filler alloys is based on their relatively low cost, good wetting and spreading of these filler alloys on the titanium substrate [3, 4] at a comparatively low temperature, as well as a low level of erosion of the base metal in brazing.

Despite a large amount of the performed experimental studies on brazing of titanium by using aluminium filler alloys, brazing of titanium with this type of the filler alloys have not received acceptance in the territory of Eastern Europe and, particularly, in Ukraine. However, at present the quantity of the publications covering developments of new aluminium filler alloys for brazing of titanium alloys is growing, this being indicative of the demand of the industry for commercial medium-melting point filler alloys for brazing of titanium and titanium alloys.

The purpose of the performed experimental studies was to develop the technology for brazing of titanium alloys by using filler alloys based on the Al–Mg system. Alloy VT1-0, which is practically a non-doped Ti-base alloy with a good thermal conductivity for titanium alloys, was chosen as a material for fabrication of the lamellar-ribbed heat exchanger elements. Aluminium alloy AMg6 (Al–6Mg–0.6Mn–0.4Si–0.4Fe–0.1Ti) and modern commercial filler alloy TiBrazeAl-665 (Al–2.5Mg–0.2Si–0.4Fe–0.2Cr) were selected as filler alloys. The experiments on brazing were carried out in vacuum furnace

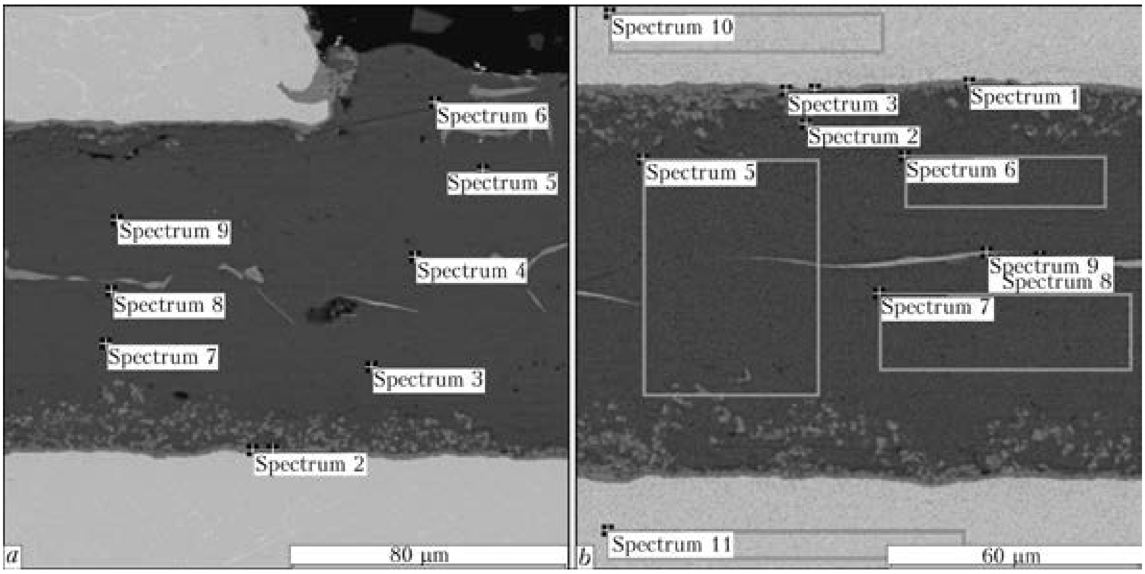

Figure 1. Microstructures of fillet region (*a*) and seam centre (*b*) of the brazed joint on titanium alloy VT1-0 made by using filler alloy AMg6 (T_{br} = 685 °C, *t* = 3 min, vacuum $5\cdot10^{-5}$ mm Hg)

SGV 2,4-2/15-I3, in vacuum of $5\cdot10^{-5}$ mm Hg. Brazing was performed in a titanium container with a getter to ensure additional cleaning of the brazing atmosphere.

Metallographic examinations of the brazed joints made by using the Mg-containing aluminium filler alloys (Figure 1) showed the presence of a continuous intermetallic interlayer at the filler alloy–base metal interface. Chemical composition (wt.%) of the interlayer varies from 49.53Al–48.81Ti–1.06Si–0.6Mn in the fillet region to 76.16Al–21.73Ti–0.79Mg–0.87Si–0.45Mn at the seam centre. In the first case it approximately corresponds to the composition of intermetallic compound $TiAl_2$, and in the second case — $TiAl_3$. The low (≈ 1.2 wt.%) manganese content of the seam can be explained by evaporation of magnesium from the seam metal during heating and melting of the filler alloy in vacuum, this causing destruction of the aluminium oxide film on the filler alloy surface.

The strength values of the brazed joints made by using Mg-containing filler alloy TiBrazeAl-665 and filler alloy AMg6 are almost identical and equal to 82–83 MPa. Resulting strength of the brazed joints is suitable for brazing of honeycomb and lamellar-ribbed structures, as well as for brazing of sheet items with a large contact area.

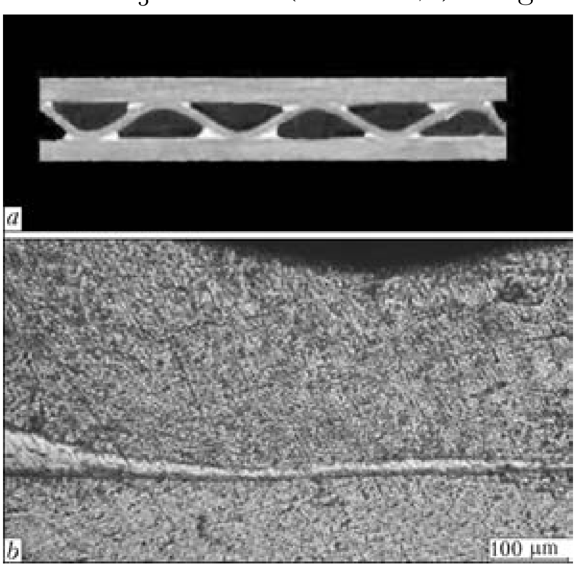

Figure 2. Fragment of a high-efficiency lamellar-ribbed heat exchanger (alloy VT1-0) made by using brazing filler alloy AMg6 (*a*), and microstructure (×100) of region of the joint (*b*) (vacuum $5\cdot10^{-5}$ mm Hg, container with getter, T_{br} = = 680 °C, *t* = 3 min)

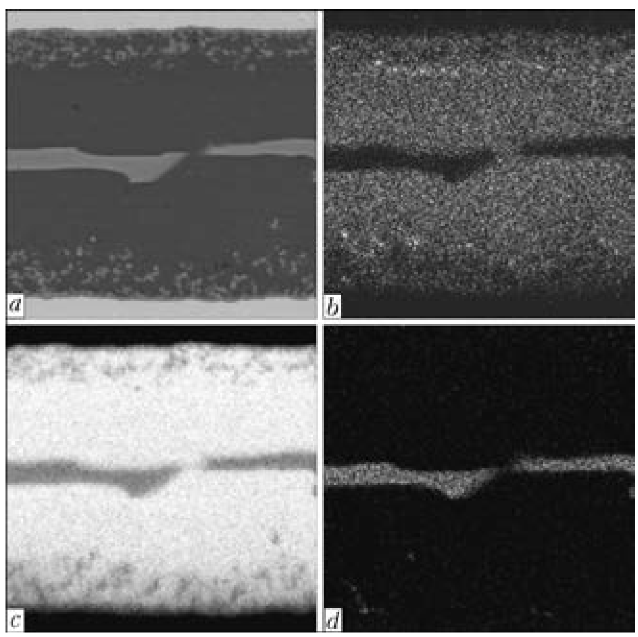

Figure 3. Microstructure of region of the joint (*a*), and distribution of magnesium (*b*), aluminium (*c*) and iron (*d*) in the brazed joint on titanium alloy VT1-0 made by using filler alloy AMg6 (T_{br} = 685 °C, *t* = 3 min, vacuum $5\cdot10^{-5}$ mm Hg)

The experiments on brazing of sections of lamellar-ribbed heat exchangers by using aluminium alloy AMg6 showed that the brazed seams are dense and defect-free (Figure 2, *a*). Analysis of microstructure of the brazed joints revealed that thickness of the intermetallic interlayer is maximal in a region of fillets of the joint and does not exceed 20 μm, and that there is almost no erosion in the base metal (Figures 2, *b* and 3, *a*, *c*).

The central part of the seam is a solid solution of magnesium in aluminium (the magnesium content is up to 1.2 wt.%). The light interlayer along the seam axis is formed by the phase enriched with iron (up to 8.66 wt.%).

Conclusions

1. Analysis of the investigation results shows that aluminium filler alloys based on the Al–Mg system (AMg6, TiBrazeAl-665) are suitable for ensuring sound brazed joints on titanium alloys.

2. In brazing of models of sections of titanium lamellar-ribbed heat exchangers by using filler alloy AMg6 at T_{br} = 680 °C for 3 min the dense and defect-free joints were produced, having a strength value sufficient for this type of the items.

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NEWS

Technology and Equipment for Manufacture of Spirally-Welded Pipes of 75–460 mm Diameter

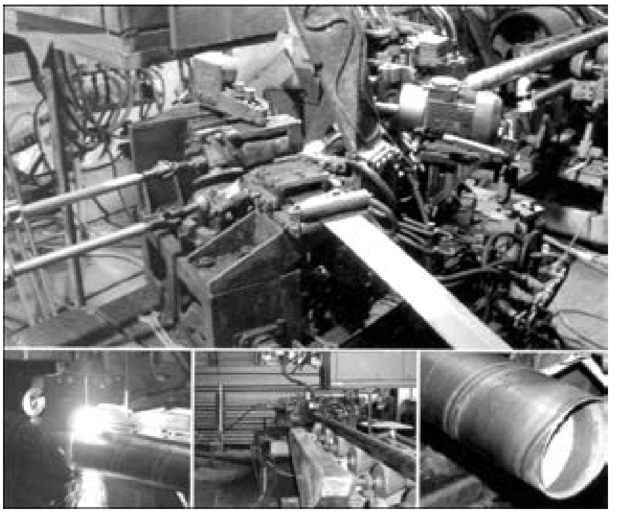
In manufacture of pipes the coiled strips of 100 or 200 mm width are used. The process of pipe manufacture is continuous, consisting in forming of a metallic strip in special devices with a simultaneous welding of edges being joined and next automatic cutting of pipes for measured length without interruption of the welding process. The metals being joined: black low-carbon steel, zinc-plated or aluminized steel (almost without losses of anticorrosion properties), stainless steel, aluminium. To join edges, the arc welding is used if the process efficiency of 3–4 m/min is required, or high-frequency welding if the higher efficiency of 30–40 m/min is required. Using this type of welding no auxiliary consumables (gas, flux, wire) are required.

Technical characteristics of equipment

Pipe wall thickness, mm	0.5±3.5
Speed of pipe outlet, m/min	1±12
Efficiency, km of pipes per shift	0.1±1.5
Capacity of power sources, kW	20±250
Capacity of electric drive, kW	up to 8
Length of pipes, m	2±6 and more
Mains voltage, V	380

Field of application. Machine building, construction, agriculture.

Efficiency:



• in case of application of electric arc welding — 100–200 m of pipe per shift;

• in case of application of high-frequency welding — up to 1500 m of pipes per shift.

Payback. The term of payback of equipment depends on annual program of pipes output and is 1 ± 2 years.