DISTRIBUTION OF CHEMICAL ELEMENTS IN THE ZONE OF ALUMINIUM ALLOY AMg6 TO TITANIUM ALLOY VT6 JOINTS PRODUCED BY DIFFUSION WELDING IN VACUUM

Yu.V. FALCHENKO, E.V. POLOVETSKY and **L.M. KAPITANCHUK**
E.O. Paton Electric Welding Institute, NASU
11 Bozhenko Str., 03680, Kiev, Ukraine. E-mail: office@paton.kiev.ua

The possibility of a combined use of titanium and aluminium alloys in the form of permanent joints is of high interest to many industries. However, no investigations involving evaluation of the effect of the diffusion welding process on distribution of chemical elements and microstructure of the welded joints have been conducted so far. As revealed by the metallographic examinations carried out in this study, magnesium during the welding process diffuses from alloy AMg6 to the zone of joining with alloy VT6 and accumulates in the contact region. An interlayer of aluminium AD1 was used to eliminate the negative effect of magnesium. A gradual decrease in the concentration of magnesium from AMg6 to AD1 was observed in the joining zone when using the aluminium interlayer. A region of diffusion interaction, in which titanium and vanadium diffused from VT6 to AD1, was detected in the AD1 + VT6 joining zone. It can be concluded from the investigation results that in vacuum diffusion welding of titanium alloys to aluminium alloys containing magnesium the use of the interlayer of pure aluminium provides the sound welded joints with a gradual distribution of magnesium in the joint. The main role in formation of the titanium alloy to interlayer joint is played by the processes of diffusion of titanium and vanadium in a direction of the interlayer. 7 Ref., 3 Figures.

Keywords: *diffusion welding in vacuum, welded joint structure, distribution of chemical elements, diffusion, diffusion interaction zone*

The progress in modern machine building, aerospace, chemical and other engineering fields is related to the application of components made from aluminium and titanium alloys. Of the highest interest to designers is the possibility of the combined use of titanium and aluminium alloys in the form of permanent joints.

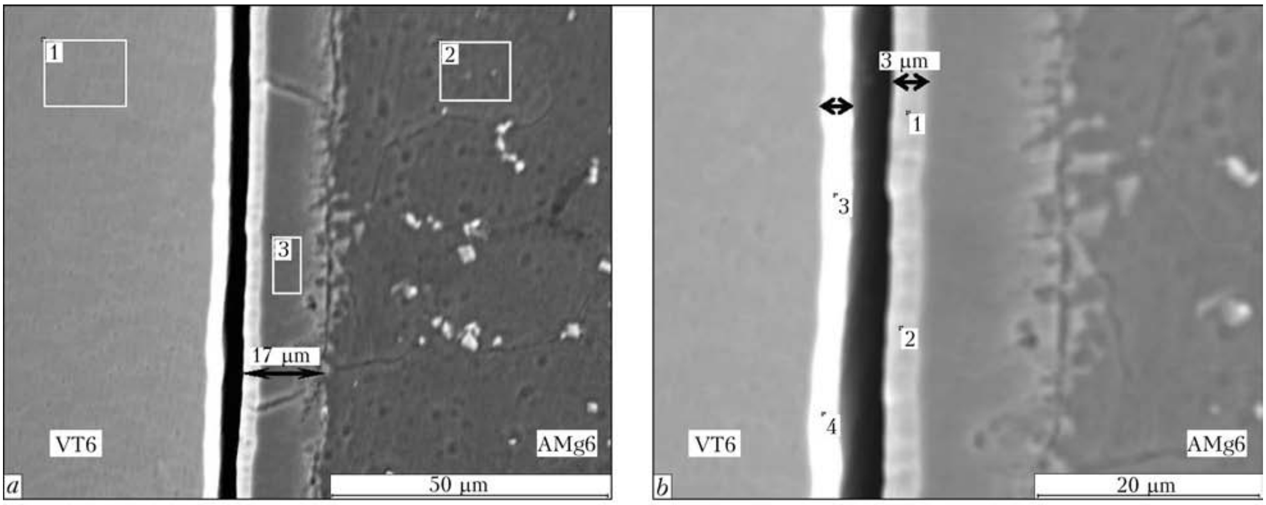
The problem of producing components from such materials can be solved by using vacuum diffusion welding (VDW) [1–3]. Analysis of literature data shows that no detailed investigations of the effect of distribution of chemical elements in the welded joint on its microstructure have been conducted up to now for this pair of alloys [4–6].

Welding of alloy AMg6 to alloy VT6 was performed both without interlayers and with an interlayer of aluminium AD1. Welding parameters were as follows: pressure P = 20 MPa, time t = 20 min, and welding temperature T = 540 °C. Investigations were conducted on the sections made from the investigated welded joints with their subsequent ion etching using the JEOL unit JFC-1100 (Japan) under the conditions specially selected and optimised for the investigated bimetal pairs. Investigations of distribution of chemical elements were carried out by using the JEOL Auger microanalyser JAMP 9500F equipped with the «Oxford Instruments» energy-dispersive X-ray spectrometer of the INCA system (Great Britain).

During welding the alloys are subjected to the thermal-deformation effect. This causes occurrence of the recrystallisation and diffusion processes in the joints, thus influencing the metal structure and properties.

As shown by the investigations, it is impossible to produce the welded joints between titanium alloy VT6 and aluminium alloy AMg6 by the VDW method using no technological approaches. Fracture of the resulting joints occurs directly in the joint.

According to the Mg–Ti equilibrium constitutional diagram [7], magnesium is insoluble in titanium. In the course of the welding process magnesium diffuses from AMg6 to the zone of joining with VT6, and accumulates there to form the 15–17 μm wide region with a content of up to 11 wt.% (Figure 1, *a*). Titanium at a content of up to 15 wt.% and vanadium of up to 1 wt.% were also detected in this region. The 3–4 μm deep zones with an increased content of oxygen (up to 9 wt.%) were revealed on the contact



Spectrum	O	Mg	Al	Ti	V	Mn
1	0	0	6.63	89.58	3.80	0
2	2.21	5.23	91.70	0.18	0	0.66
3	0	10.63	73.19	14.81	0.94	0.43

Spectrum	O	Mg	Al	Ti	V
1	8.49	7.32	43.12	34.07	1.99
2	4.81	8.77	58.10	23.95	1.62
3	3.03	1.91	12.78	77.76	3.72
4	4.54	2.42	14.30	74.18	3.97

Figure 1. Microstructure and distribution of chemical elements in the AMg6 + VT6 welded joint produced by the VDW method without interlayers at t_w = 20 min, T_w = 540 °C, P_w = 20 MPa: *a* — in an area of the layer with increased content of magnesium, and in the base metals; *b* — in layers at the near-contact surfaces

surfaces of both alloys. The zone on AMg6 contained also (wt.%) up to 30 Ti, up to 2 V and up to 9 Mg, while the zone on VT6 contained up to 4.5 Mg (Figure 1, *b*).

It is the formation of all these zones that prevents production of the welded joint. Therefore, the 150 μm thick interlayer of commercially pure aluminium AD1 was used to avoid the negative

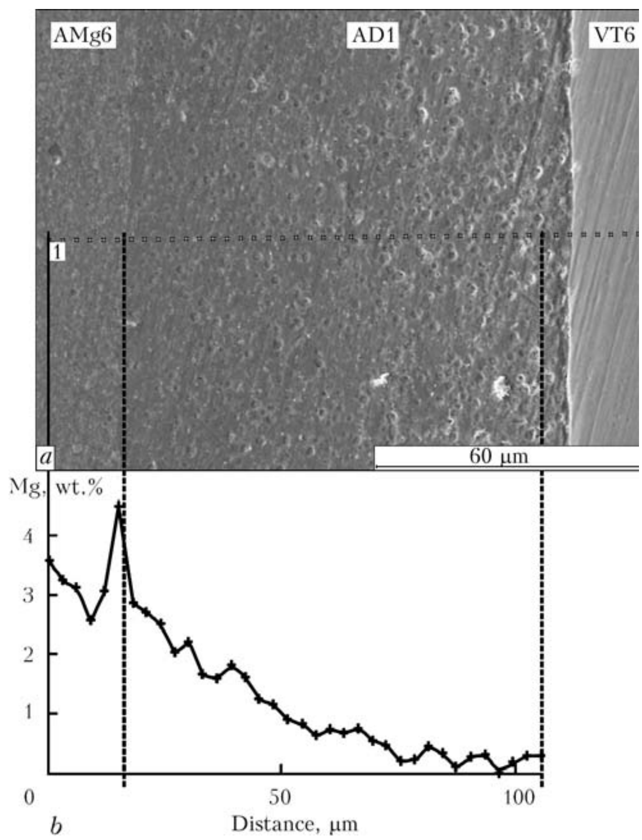


Figure 2. Microstructure of the AMg6 + AD1 + VT6 joint (*a*), and distribution of magnesium in the AMg6 + AD1 joining zone (*b*)

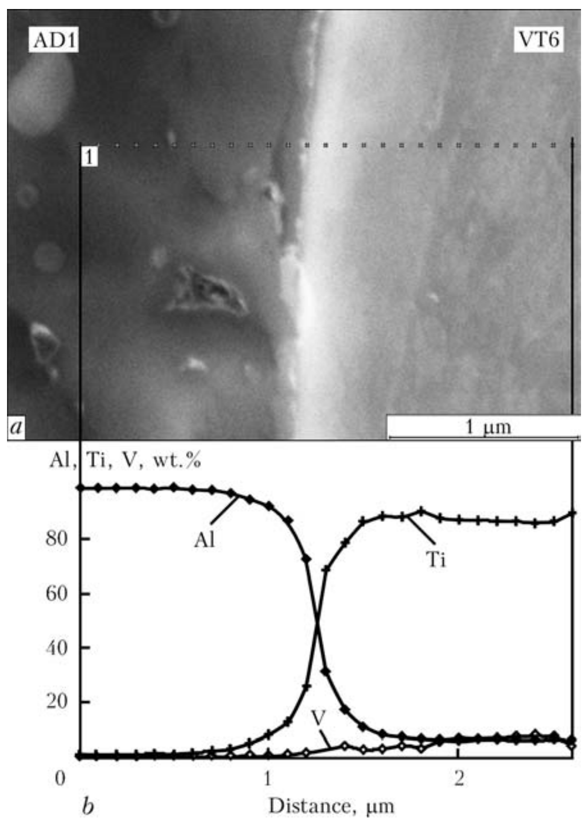


Figure 3. Microstructure of the region of contact of titanium alloy with the interlayer (*a*), and distribution of the concentration of titanium, vanadium and aluminium along the normal to the AD1 + VT6 joining line (*b*)

effect of alloying elements of alloy AMg6. The main goal of the interlayer is to block diffusion of magnesium as the most active chemical element. The thickness of the interlayer, i.e. 150 μm, was chosen in accordance with the literature data and our earlier experimental studies.

Analysis of the welded joints produced by the VDW method using the AD1 interlayer showed that during the welding process magnesium diffused from AMg6 to AD1 to a depth of 60–65 μm. In this case no accumulation of magnesium near the AD1 + VT6 joining zone was fixed (Figure 2). A region with the decreased magnesium content, down to 150 μm deep, formed in the near-contact zone of AMg6. The 1.5–2.0 μm wide region of diffusion interaction was detected in the AD1 + VT6 joining zone (Figure 3). Titanium and vanadium in this zone diffused from VT6 to AD1 to a depth of 0.5–0.8 μm, and aluminium — to VT6. In our opinion, formation of the detected region of diffusion interaction is the main condition for producing the sound welded joint.

Conclusions

1. It was established that diffusion welding of AMg6 to VT6 alloys using no aluminium interlayer fails to provide the welded joints due to the negative effect of magnesium.

2. Application of the aluminium interlayer leads to formation of two diffusion zones in the joint: AMg6 + AD1 and AD1 + VT6.

3. In the joining zone adjoining alloy AMg6, magnesium during the welding process diffuses in a direction to the AD1 interlayer. The zone with a decreased magnesium content forms in this case in aluminium alloy AMg6.

4. Diffusion of vanadium and titanium in a direction of the AD1 interlayer is observed in the joining zone adjoining alloy VT6.

1. Karakozov, E.S. (1976) *Joining of metals in solid phase*. Moscow: Metallurgiya.
2. Kazakov, N.F. (1976) *Diffusion welding of metals*. Moscow: Mashinostroenie.
3. Rabkin, D.M., Ryabov, V.R., Gurevich, S.M. (1976) *Welding of dissimilar metals*. Kiev: Tekhnika.
4. (1996) *Constitutional diagrams of binary metal systems*: Refer. Book. Vol. 1. Ed. by P. Lyakishev. Moscow: Mashinostroenie.
5. Grigorievsky, V.I. (1991) Diffusion welding of aluminium alloy AMg6 to titanium alloy OT4 through a composite titanium–aluminium interlayer. *Svarochn. Proizvodstvo*, **8**, 2–4.
6. Toshio, E., Kenji, I., Toshiharu, M. (1978) Influence of intermediate inserts on properties of diffusion welded Al–Ti joints. *J. JILM*, 16(**3**), 107–114, 127.
7. Akiomi, K., Akihika, Y., Tashihiro, Y. et al. (1985) Diffusion welding of Ti–6Al–4V alloy with intermediate aluminium insert. *J. JWS*, 3(**1**), 145–151.

Received 07.05.2013