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CONTENTS

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DIFFUSION BONDING OF γ-TiAl BASE ALLOY IN VACUUM BY USING NANOLAYERED INTERLAYERS

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The effect of nanolayered interlayers Ti/Al, Ni/Ti and Ni/Al on structure of the diffusion bonds made in vacuum on γ-TiAl base alloy was studied. It is shown that when using the nanolayered interlayers of a composition differing from that of the base alloy it is necessary to conduct homogenising annealing to lower the degree of chemical heterogeneity in the bonding zone.

Keywords: *diffusion bonding in vacuum, intermetallic titanium-aluminium alloy based on γ-TiAl, nanolayered interlayer, homogenising annealing, joint, heterogeneity, structure, microhardness*

Titanium aluminides and alloys on their base belong to a new class of light heat-resistant materials, which are intended for operation at a temperature of 700–1100 °C, that is much higher than the service temperature of modern titanium superalloys ($T \leq 600$ °C). The interest in titanium aluminides is caused by their high potential for application in aerospace engineering instead of titanium and nickel superalloys.

Studies [1, 2] investigated joinability of titanium aluminides (Ti–45 at.% Cr–2 at.% Nb) when using the Ti–Al system nanolayered interlayers of the Ti–(48–50) at.% Al composition, which were deposited on the mating surfaces by magnetron sputtering. Thickness of the interlayers was 2.0–2.5 μm, thickness of the individual layers being 4 nm. The TiAl nanocrystals with a higher hardness than that of the base metal form in the interlayers during deposition of a film. The authors of the above studies consider the following parameters of the process to be the optimal ones: bonding temperature $T_{bond} = 1000$ °C, pressure $P = 50$ MPa, and bonding time $t_{bond} = 1$ h.

It is shown in study [3] that the optimal parameters for diffusion bonding of γ-TiAl alloys through the nanolayered interlayer Ti/Al produced by vacuum deposition are as follows: $T_{bond} = 1200$ °C, $P = 10$ MPa, and $t_{bond} = 20$ min. With these parameters the bonding zone is free from pores and cracks.

No investigation results on the possibility of using other compositions of nanolayered interlayers are available in the literature.

The purpose of this study was to investigate peculiarities of formation of permanent bonds on the γ-TiAl base alloy by using nanolayered interlayers of the Ti/Al, Ni/Ti and Ni/Al systems in the form of foils 15–30 μm thick, produced by electron beam evaporation and vapour-phase deposition in vacuum [4, 5]. The foils consist of alternating nanolayers of the components, in which solid-phase reactions of synthesis of intermetallics take place during heating.

The following interlayers were chosen for bonding of samples of alloy Ti–48 at.% Al–2 at.% Nb–2 at.% Mn: Ti/Al (Ti–38 at.% Al), Ni/Ti (Ti–44 at.% Ni) and Ni/Al (Al–46 at.% Ni).

Diffusion bonding of the 10 × 10 × 6 mm samples of intermetallic Ti–48 at.% Al–2 at.% Nb–2 at.% Mn (below referred to as γ-TiAl) was performed by using unit U-394. The electron beam heater was employed as a heat source. The mating surfaces were preliminarily prepared by removing the cold worked layer with a diamond wheel, and then by degreasing. Bonding was carried out under the following conditions: heating temperature $T_h = 1200$ °C, heating time $t_h = 20$ min, $P = 20$ MPa, and vacuum in the working chamber at a level of $1.33 \cdot 10^{-3}$ MPa.

Microstructure and chemical composition of the base metal and bonds were analysed by using optical microscope «Neophot-32», as well as scanning microscope «CamScan» equipped with energy-dispersive system «Energy 200» for local analysis. Phase composition was evaluated by the X-ray diffraction analysis method using diffractometer DRON-3 in Cu_{K_α} radiation. Microhardness of the samples was measured with meter PMT-3 under a load of 0.1–0.5 N.

Results of X-ray diffraction phase analysis show that the γ-TiAl alloy in the initial state contains two phases — TiAl (γ-phase) and Ti_3Al (α_2-phase). The volume content of the α_2-phase in the alloy, with respect to the γ-phase, is 7 %. A fragment of the diffraction pattern of the γ-TiAl alloy is shown in Figure 1.

As revealed by metallography, the alloy in the initial state has a fully lamellar structure. The alloy consists of homogeneous, practically equiaxed grains approximately 60–120 μm in size, having the γ- and α_2-phase lamellae of a certain orientation inside them (Figure 2).

It is noted in study [6] that normally the α_2-phase is present in the lamellar structure in the form of thin