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PECULIARITIES OF FRACTURE OF WELDED JOINTS OF TI-TiB TITAN ALLOYS WITH TITAN ALLOYS

Analysis of fracture surfaces morphology of material of welded joints of Ti-TiB system alloys and ($\alpha + \beta$) Ti alloy, obtained by electron-beam welding under various technological modes, is carried out. Parameters alterable were the electron beam displacement velocity and initial temperature of the parts welded. Prevalent effect of boron phase on fracture character of Ti-TiB system alloys and possibility of ductility increase both Ti-TiB system and ($\alpha + \beta$) Ti alloy due to thermal effect action is shown. [dx.doi.org/10.29010/087.6]

Keywords: titan alloys; titan boride; fractographic investigations; mechanical properties; welded joint; electron-beam welding.

Introduction

In continuation of investigation cycle aimed on researching of technical possibilities of Ti-TiB alloy utilization [1-3], the results of fractographic investigation of surface morphology of welded joints of Ti-TiB system alloys and ($\alpha + \beta$) titan alloy, obtained by electron-beam welding under various technological modes, are presented in this article.

Problem statement

In the result of investigation of structure and mechanic characteristics of material of welded joints of Ti-TiB system alloys and ($\alpha + \beta$) Ti alloy the regularity of material structure changes in the welded seam proximity and mechanical characteristics of welded joints of Ti-TiB system alloys with titan alloys depending of electron-beam welding parameters were established [4].

At the same time the analysis of fracture behavior of the above-mentioned joints was not been carried out. This is determined the object of the present investigation aimed at addition of strength and metallographic characteristics of welded joints of Ti1 alloy of Ti-TiB system alloys and T2 alloy of $(\alpha + \beta)$ Ti alloy, obtained under various technological modes of electron-beam welding, as well as fractographic analysis of fracture of welded joint material surface under mechanical testing.

Results of investigation

Description of experimental samples, electron-beam welding parameters and method of mechanical testing realization are in [4]. Chemical composition of titan in T1 micro-composite alloy (Ti-mas. 95% and TiB_2 -mas. 5%) was as follows Al - 1.3%, Fe - 1.4%, C - 1.8%, Si - 0.6%, Cr - 0.1%, Ti – the rest. As the T2 alloy the alloy of the following composition was used: Al - 3.5%, Nb - 3.0%, Fe - 2.5%, V - 1.9%, Mo - 1.4%, Zr - 1.3%, Si - 0.1%, Ti – the rest.

The welded joints was investigated with the JSM-840 scanning electron microscope of JEOL company, Japan, and Auger-microprobe with the JAMP-9500F field emission cathode, equipped with the INCA 450 (Oxford Instruments company) micro-analysis systems, under the following parameters: $U = 20$ kV, $I = 10-10 \dots 10^{-7}$ A. Images were obtained in regimes of secondary and back-scattering electrons. Image registration system was realized with the MicroCapture image capture computer program. Digital image was processed by the ImagePro Plus program.

The results of previous investigations [4] showed that the material structure in the welded seam proximity, as well as mechanical properties of welded joints and main metal, depends of the EBW mode realization. In all mechanical investigations on tensile testing, carried at temperature 20°C , the fracture of welded samples of T1-T1 and T1-T2 alloys took place in basic material, which is evidence that the strength of welded joint is not less than that of the main material.

The fractographic investigations carried out for welded joints of (T1) series with (T1) confirmed that all samples were fractured in main metal. This is evidence of the welded joint strength. The fracture surface is presented weakly (see Fig. 1).

During the mechanical tensile testing of given series of T1-T1 welded samples for welding temperature changes from 20°C till 400°C the maximum strength and ductility take place at minimum electron beam displacement velocity. It should be noted, that fracture character is mixed. Elements of ductile fracture and light corrugate combs are noticeable on the fracture surface (see Fig. 2a). At that, the fracture is of

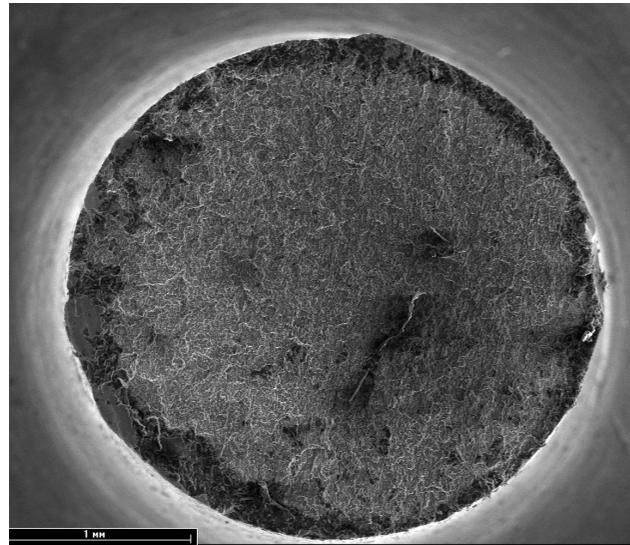


Fig. 1. General view of fracture surface of welded joints of Ti-TiBn (T1) series samples with Ti-TiBn (T1)

trans-crystalline nature by brittle cleavage mechanism (see Fig. 2b).

In Fig. 2a part of fracture is presented in which is noticeably that large rod-shaped borides are cracked, because high stresses arise around it which result in brittle fracture. More short borides (less than $5\ \mu\text{m}$) are not result in high localization of stresses and, thus, do not effect essentially on fracture toughness of matrix, which is deformed by ductile way. In Fig. 2c the fragment of brittle fracture part is presented. Besides of that, the secondary fractures are revealed on the fracture surface, which are often localized in the parts near boride inclusions.

Because in case of mechanical testing of welded joints of T1 and T2 alloys the fracture took place in parts of T2 alloy, then, from the one hand, it is the evidence of reaching of more high mechanical characteristic of material of formed welded seam, but, from the another hand, it shows the necessity to fulfill the thermal treatment of the joint obtained in order to ensure the mechanical properties of the materials welded. Optimization of such thermal processing parameters for T2 alloy may be carried out on the base of analysis of determined influence of electron beam displacement velocity on mechanical properties of welded seam proximity zone.

Investigation of fracture surface of given series of heterogeneous welded joints shows that the fracture is of mixed nature (see Fig. 3 a, b). Fracture surface, as in previous series of the samples investigated, is well-developed. On fracture surface the ductile fraction elements are observed – light corrugate combs, and brittle parts probably correspond to parts with honeycomb structure, which is in accordance with results of metallographic investigations [4].

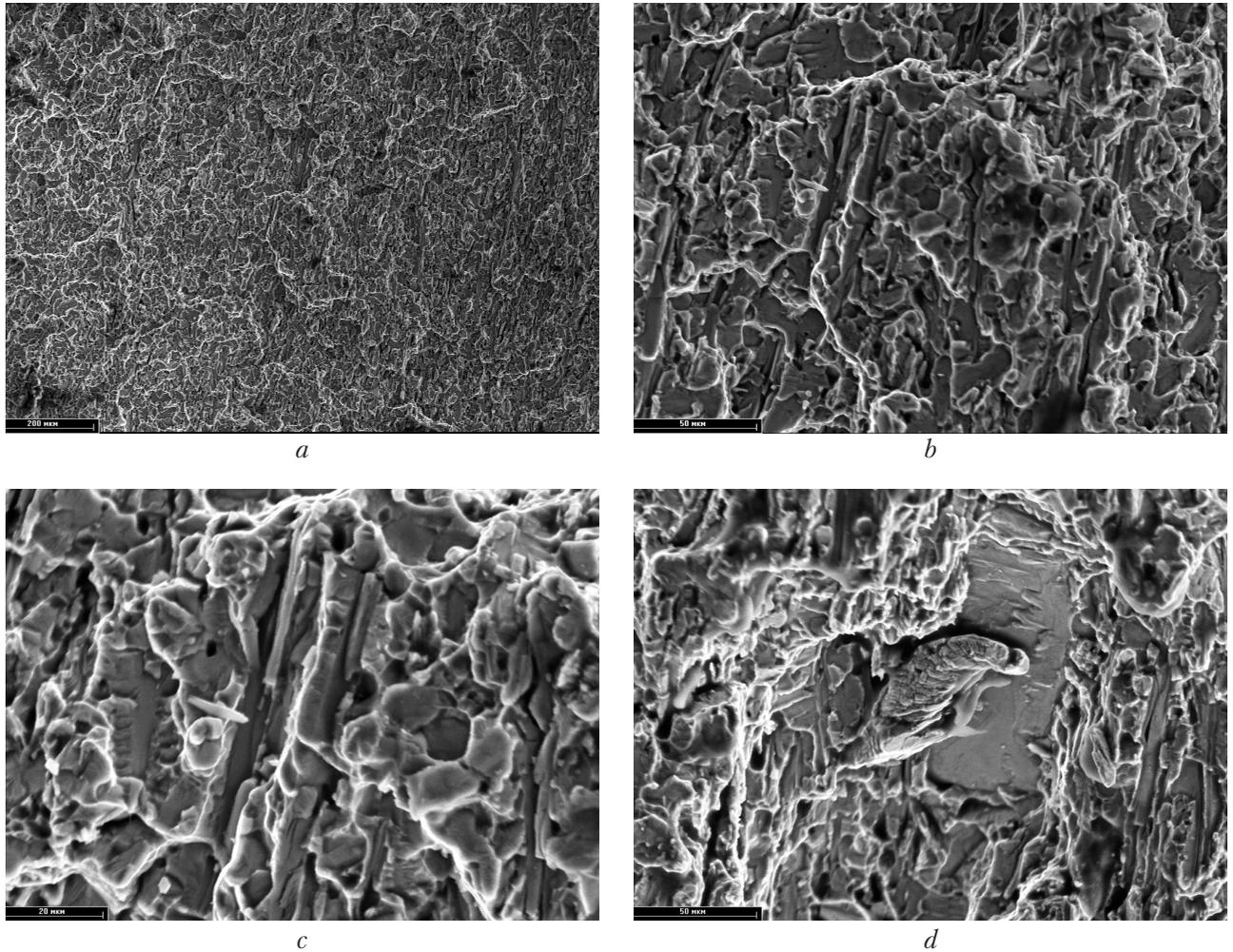


Fig. 2. Factographic investigations of (T1)-(T1) titan alloy welded joint carried out by EBW: *a* – $\times 100$; *b* – $\times 500$; *c, d* – $\times 1000$

Borides fragmentation without tearing them out the matrix (see Fig. 4) indicates high adhesion strength of interface between titan matrix and TiB particles. Boride phase, which has not ductile property during brittle cleavage mechanism realization, may be

the initiator of development and opening of crack which is able to propagate all over T1 material.

In Fig. 5 *a, b* the general view of fracture plain is presented for T1-T2 series of samples for which some ductility level is observed at all welding parameters. In

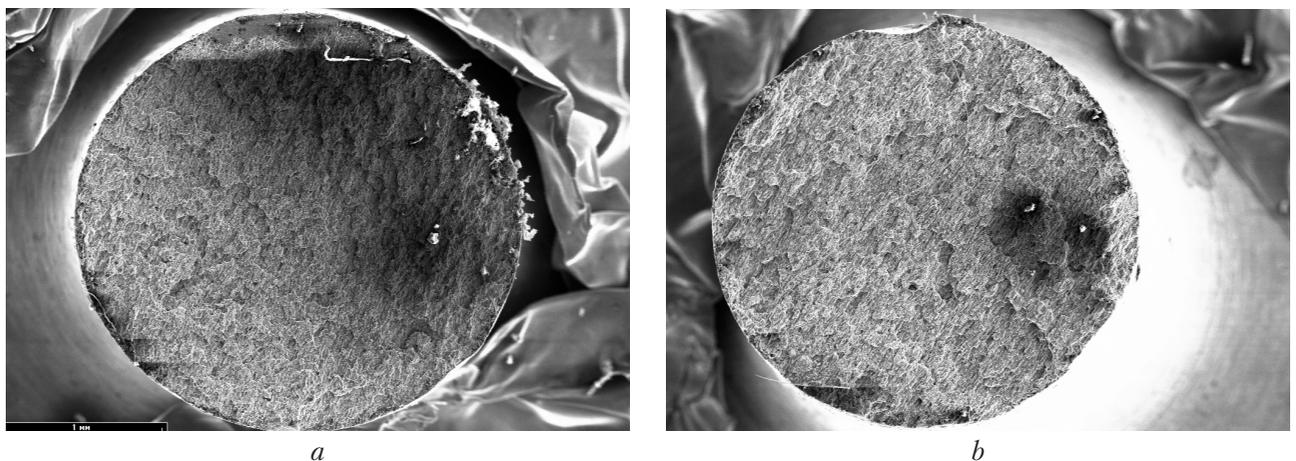


Fig. 3. General view of fracture surface of heterogeneous welded joints of T1-T2 series samples at the temperature 20 °C, $\times 30$: *a* – ductility 1.2%; *b* – ductility 3.65 %

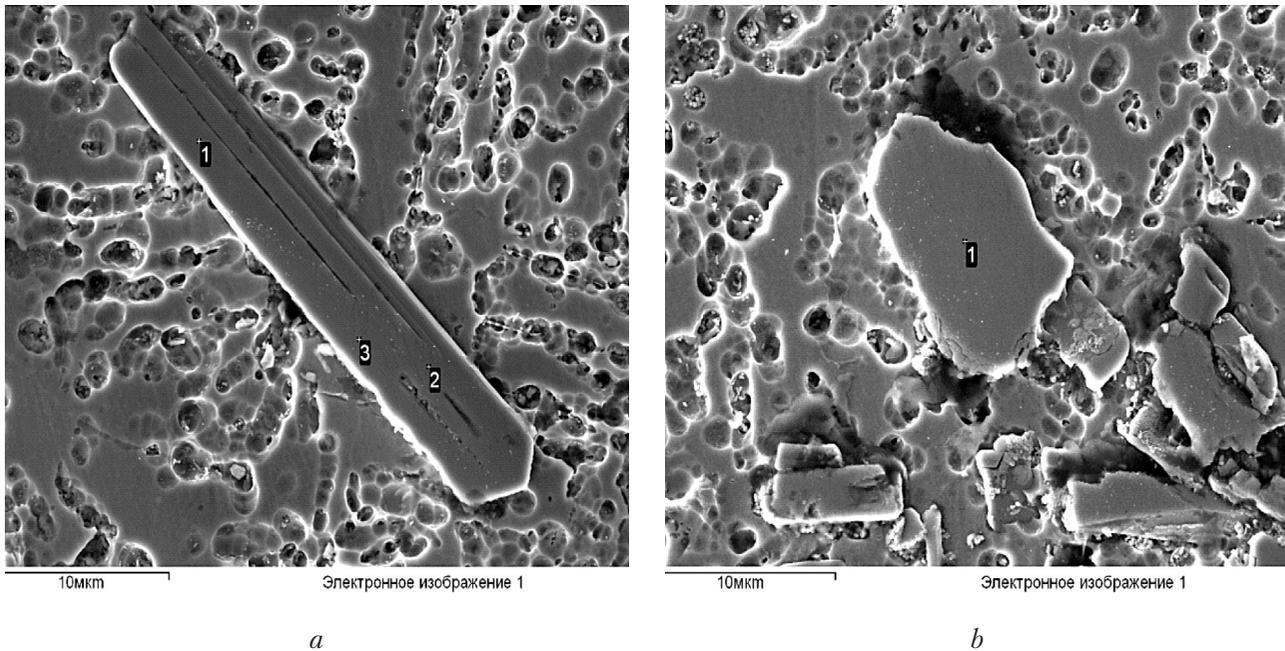


Fig. 4. Fragment of ductile fraction of welded joints fracture surface for T1-T2 series samples: at testing temperature 600 °C: a – $\times 100$; b – $\times 1000$

this case, the fracture surface is well-developed. On fracture surface the ductile fraction elements are observed – light corrugate combs, which indicate to the character of the main crack (see Fig. 3b). As it was mentioned in [4], in all cases of mechanical investigations of T1-T2 series samples the fracture took place in T2 alloy out of welded seam zone.

During tensile testing of heterogeneous welding joints of T1 and T2 alloys, obtained at lower levels of electron beam displacement velocity, the mechanical properties with some ductility level were observed: at minimum electron beam displacement velocity $7 \text{ mm}\cdot\text{s}^{-1}$ it was 1.2 %, and at electron beam displacement velocity $10 \text{ mm}\cdot\text{s}^{-1}$ it was 3.65 %.

It should be mentioned that the fractographic investigations carried out show that the fracture surface of welded joints of T1-T1 and T1-T2 series samples are of mixed nature with prevalent mechanism of brittle fracture (see Fig. 6). Upon increasing of beam velocity and temperature of T1-T2 alloys joint, the portion of ductile component on fracture surface increases. Upon reaching the stresses critical level in T1 alloy (T1-T1 series samples) large rod-shaped borides are cracked, because high stresses arise around it, which leads to brittle structure. As a rule, more short borides (less than $5 \mu\text{m}$) are not result in high localization of stresses and, thus, do not effect significantly on fracture toughness of matrix which deforms in ductile manner.

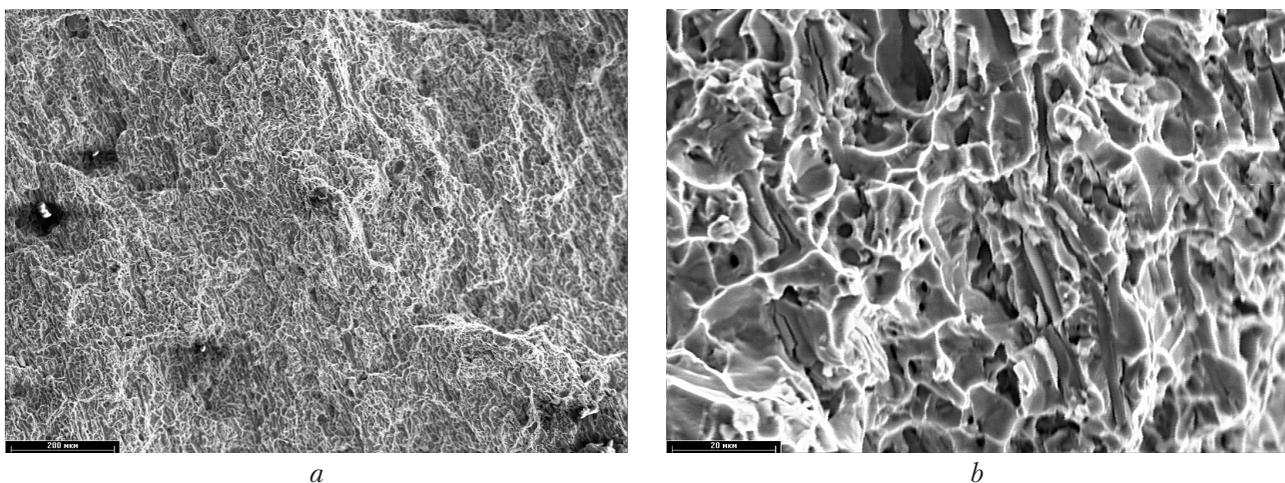


Fig. 5. Fragment of ductile fraction of welded joints fracture surface for T1-T2 series samples: at testing temperature 600 °C: a – $\times 100$; b – $\times 1000$

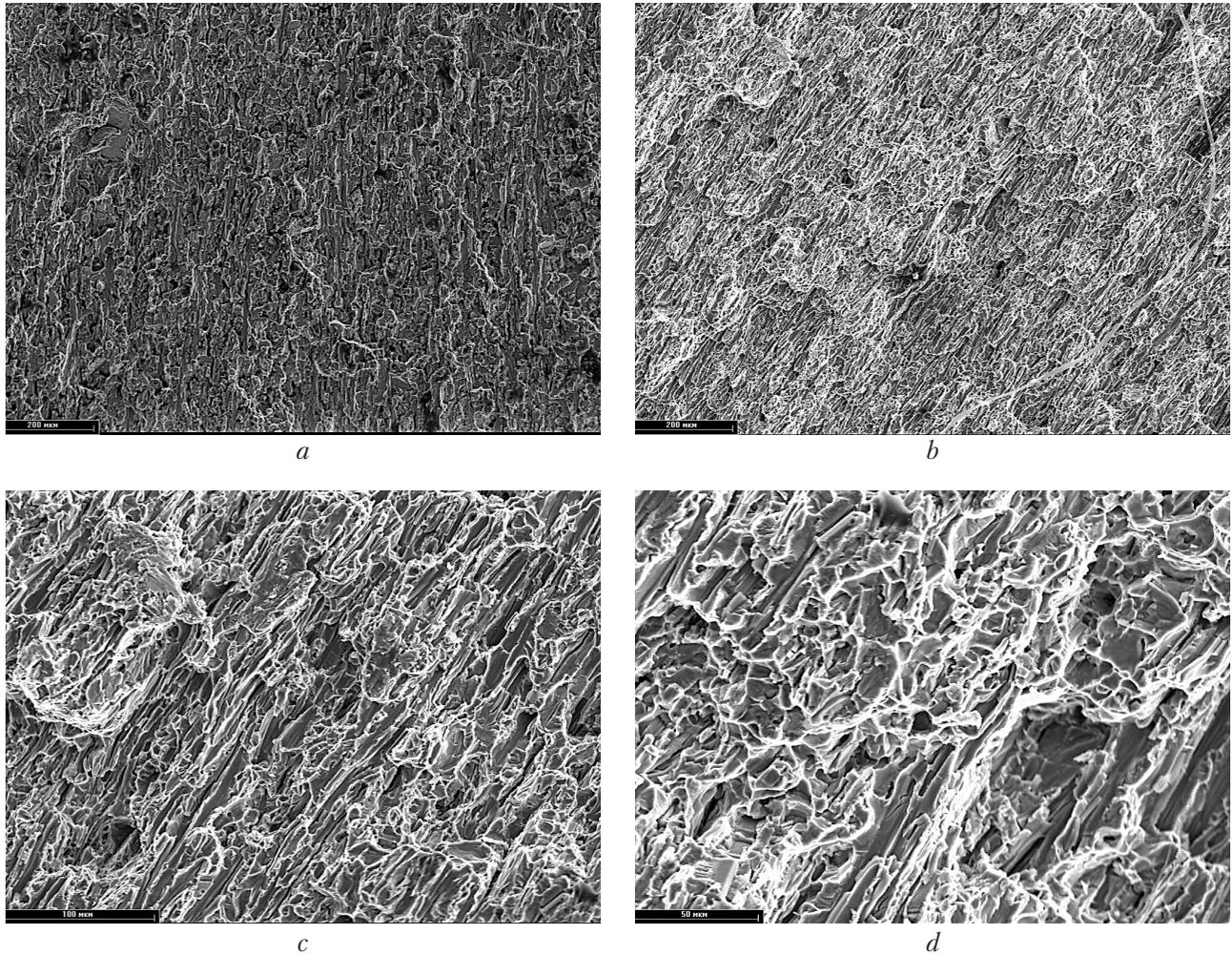


Fig. 6. Fragment of ductile fraction of welded joints fracture surface for T1-T2 series samples:
a, c – electron beam displacement velocity in 2-1 sample: *a* – $\times 100$; *b* – $\times 100$; *d* – electron beam displacement velocity in 2-2 sample:
c – $\times 300$; *d* – $\times 1000$

Conclusions

1. Welded joints of T1-T1 and T1-T2 alloys samples obtained by electron-beam welding under $U_{acc} = 60$ kV, $I_{eb} = 90$ mA, beam scanning – elliptical, transversal (3x4 mm), at all values of veb in interval from 7 to 13 $\text{mm}\cdot\text{s}^{-1}$ and initial temperatures from 20 °C to 600 °C upon reaching the critical level of tensile stresses are fractured in area which are out of welded seam zone with forming of fracture surfaces with characteristics of prevalent brittle fracture.

2. Increasing of preliminary heating temperature of subjected to welding samples of T1 alloy from 20 °C till 400 °C results in strength and ductility reduction for these alloys, which may be compensated at the expense of boride phase distribution optimization in initial material.

3. Increasing of preliminary heating temperature of subjected to welding samples of T1-T2 series from 20 °C till 400 °C and electron beam displacement from 7 $\text{mm}\cdot\text{s}^{-1}$ till 13 $\text{mm}\cdot\text{s}^{-1}$ permits to increase the strength

and ductility levels of T2 material in fraction area during mechanical testing.

Nomenclature

I – electric current, A
U – accelerating electrical voltage, V
 $0.1 = 1\cdot 10^{-1}$; $1,000 = 1\cdot 10^3$

Subscripts and Superscripts

acc – accelerating
 eb – electron beam

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ОСОБЕННОСТИ РАЗРУШЕНИЯ СВАРНЫХ СОЕДИНЕНИЙ ТИТАНОВОГО СПЛАВА Ti-TiB С ТИТАНОВЫМИ СПЛАВАМИ

Проведен анализ морфологии поверхностей разрушения материала сварных соединений сплавов системы Ti–TiB и (α+β) Ti сплава, полученных способом электронно-лучевой сварки при различных технологических режимах. Изменяемыми параметрами были скорость перемещения электронного луча и исходная температура свариваемых деталей. Показано преобладающее влияние борсодержащей фазы на характер разрушения сплавов системы Ti–TiB и возможность увеличения пластичности как сплава системы Ti–TiB, так и (α+β) Ti сплава за счет термического влияния. [dx.doi.org/10.29010/087.6]

Ключевые слова: титановые сплавы; борид титана; фрактографические исследования; механические свойства; сварное соединение; электронно-лучевая сварка.

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