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PECULIARITIES OF MECHANICAL PROPERTIES AND STRUCTURE OF AREA OF Ti – Tib_n ALLOY WELDING JOINT WITH TITAN ALLOYS

Analysis of structure and mechanical characteristics changes for material of Ti – TiB_n system alloy and (α + β) Ti alloy welding joint, obtained by electron-beam welding under various technological modes, is carried out. The variable parameters are the velocity of electron beam movement and initial temperature of the parts subjected to welding. Regularities of sizes and distribution character changes of boron-contained structure components depending of parameters varied are revealed. It is established that the strength of welded joints obtained is not worse than the strength of materials subjected to welding. [dx.doi.org/10.29010/085.14]

Keywords: *titanium alloys; titanium boride; metallographic structure; mechanical characteristics; welded joint; electron-beam welding; welding parameters.*

Introduction

In the course of investigation cycle, aimed at research of technical possibilities of Ti – TiB_n [1-3] alloy use, the results of analysis of structure and mechanical characteristics of Ti – TiB_n system alloy and (α + β) Ti alloy welding joints, obtained under various conditions of electron-beam welding, are presented.

Problem statement

For practical use of Ti – TiB_n system alloys in machine-building it is necessary not only to obtain the non-detachable welding joints with various metallic materials, but to reach the strength level of joint not less than the strength of materials subjected to welding. This determines the purpose of the present investigation aimed at determination of strength characteristics of welded joints of Ti – TiB_n system alloy (T1) and (α + β) titan alloy (T2), obtained under various technological parameters of electron-beam welding, as well as fulfillment of metallographic analysis of material in welding seam region.

Results of investigation

Experimental samples of 500x1,000x10 mm dimensions were connected with one another along 1,000x10 mm plane. During the welding the surfaces under connection were fixed in the end-to-end manner in plane-parallel condition. The welding was carried out in the following mode: U_{acc} = 60 kV, I_{eb} = 90 mA. Electron beam movement velocity was changed as follows: v_{eb} = 7; 10 and 13 mm·s^{-1}, and beam sweep was maintained as an elliptical and transversal (3×4 mm). At the velocity of v_{eb} = 13 mm·s^{-1} the temperature of samples subjected to welding was 600, 400 and 20 °C, in other cases the preliminary heating was not used and initial temperature T_0 was 20 °C.

The method of Ti – TiB_n alloy (hereinafter referred to as T1) obtaining is in [2-3]. Chemical composition of titan in T1 micro-composition alloy (Ti-mas. 95% and TiB_2-mas. 5%) was as follows: Al-1.3%, Fe -1.4%, 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 results of the investigation shown that the metal structure in welding seam region, as well as mechanical properties of welding joints and basic metal, depends upon welding fulfillment modes (see the Table 1). Under the tensile testing at the temperature 20 °C the rupture of welded samples from T1-T1 and T1-T2 alloys was in the basic metal which is an evidence of such fact that the strength of welding joint is not worse than the strength of the basic material.

It should be noted that without finish thermo-processing fulfillment, which optimizes the structure of alloys subjected to welding, its mechanical properties do not reach its maximum values. Under mechanical tensile testing of T1-T2 welding joints the brittle rupture were observed in most cases, but in thermal affecting area and at the minimum electron beam movement it was possible to reach some level of ductility (see the Table 1).

In result of mechanical testing of T1-T2 welding joints in all cases the rupture took place in the areas out of welding seam area in T2 alloy. In such cases the maximum strength with minimum ductility was observed at the minimum movement of electron beam.

Table 1

Structure of material in welding seam region and mechanical characteristics of Ti – TiB_n alloy welding joints with titan alloys obtained by electron-beam welding under various modes

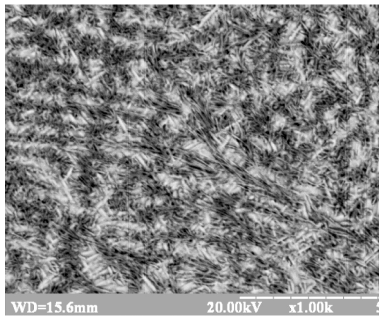
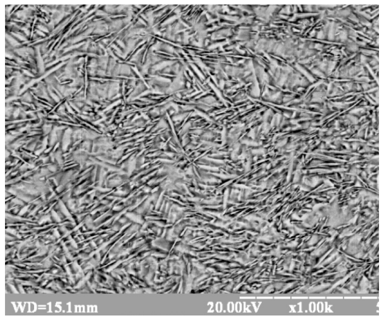
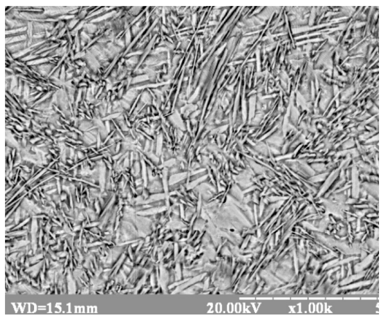
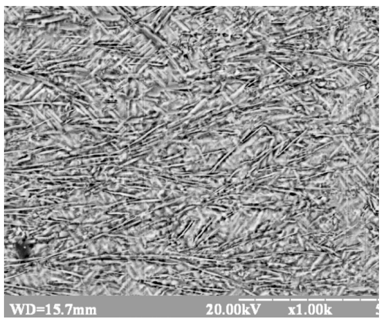
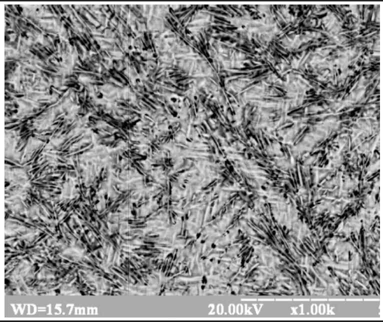
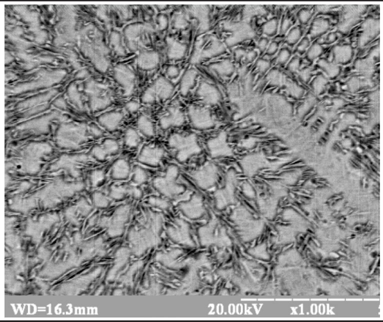
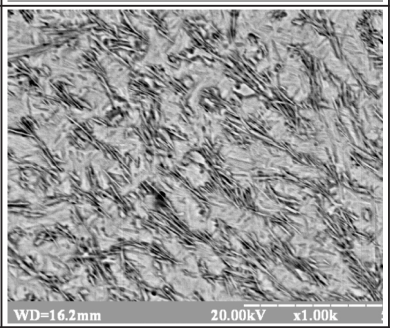
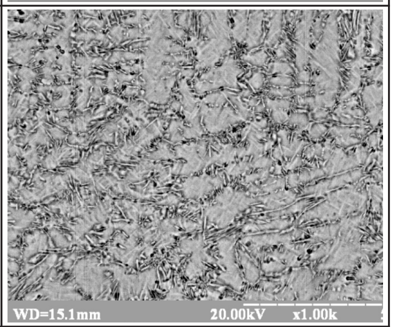
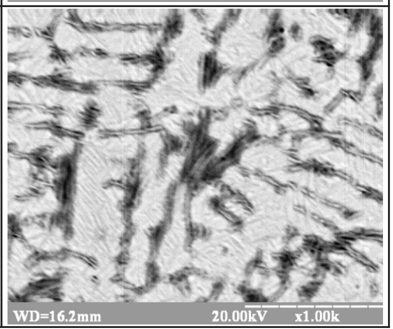
Nos. of samples	Materials of welding joint	Electron-beam welding parameters				Mechanical characteristics				Metallographic structure of material in welding seam area
		Materials temperature before welding, T, °C	Electron beam movement velocity, v_{eb} mm·s^{-1}	U_{acc}, V	I_{eb}, mA	$\sigma_{0.2}$, MPa	$\sigma_{в}$, MPa	δ, %	Ψ, %	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1-1	T1-T1	20	7	60	90	957,2	1040	2,0	6,6	
2-1		20	10			-	1023,1	-	-	
3-1		400	13			-	950,2	-	-	
4-1		20	13			-	950	-	-	

Table 1

1	2	3	4	5	6	7	8	9	10	11
1-2	T1-T2	20	7			918,9	991,5	1,2	2,3	
2-2		20	10			734,2	848,0	3,65	6,25	
3-2		400	13			740,1	844,9	5,0	5,9	
4-2		20	13			741	840	4,9	13,2	
5-2		600	13			738,4	848,0	6,5	15,6	

Maximum level of ductility was observed at the maximum electron beam movement and welding of materials preliminary heated up to 400 °C.

In order to calculate the strength of T2 alloy, in which the rupture of welding joints samples took place, the following formula proposed in [4] was used:

$$\sigma_в = 235 + 60\alpha + 50\beta,$$

were

α = %Al + 1/2 %Sn + 1/3 %Zr + 3,8

β = %Mo + 0,56 %V + 1,25 %Cr + 1,43 %Fe + + 0,3 %Nb.

Calculation value for T2 alloy is 1,051 MPa. It permits to suppose that reduced strength level of this welding joint element namely is evidence of necessity to fulfill the after-welding thermal processing.

To the peculiarities of material structure changes in welding joint area should be attributed the presence of martensite-similar structure during T1-T1 welding. At that, the regularity of boride inclusions increases with the electron beam movement velocity rise from 4 μm at v_{eb} =7 mm·s^{-1} to 12-15 μm at v_{eb} =7 mm·s^{-1} is observed. It is typical, that upon rise of initial temperature of samples subjected to welding from 20 °C to 400 °C the thickness of such martensite-similar boron-containing grains increases by 2-2.5 times.

During the welding connection of T1 and T2 alloys in case of the electron beam minimum velocity of v_{eb} =7 mm·s^{-1} the type of structure, typical for T1-T1 joints, is remain. As the electron beam velocity increase, the boride inclusions forms the cellular structure with observed tendency of the cell dimensions increase during rising of initial temperature of materials subjected to welding from 20 °C to 400 °C. If the retention of martensite-similar structure at lesser movement velocity of electron beam may be connected in such conditions with rising of boron re-distribution from T1 alloy, then the changes, connected with formation of boron-contained cellular structure and its enlargement during increase of initial temperature of materials subjected to welding from 20 °C to 600 °C, is apparently the evidence of thermodynamic instability of boron-containing phase.

Conclusions

1. The electron-beam welding at U_{acc} = 60 kV, I_{eb} = 90 mA and with elliptical transversal beam sweep (3×4 mm) for all values of veb in interval from 7 mm·s^{-1} to 13 mm·s^{-1} and initial temperatures from 20 °C to 600 °C provides the obtaining of non-detachable welding joint of T1-T1 and T1-T2 alloys samples with welding seam strength characteristics not worse than strength characteristics of materials subjected to welding.

2. Increase of initial temperature of T1 alloy samples subjected to welding from 20 °C to 400 °C results in increase of martensite-similar boron-contained grains thickness by 2-2.5 times. Upon increase of electron beam movement velocity from v_{eb} = 7 to v_{eb} = 13 mm·s^{-1} the regularity of boride inclusions from 4 μm to 12-15 μm is observed.

3. Upon increase of electron beam velocity during T1 and T2 alloys electron-beam welding from v_{eb} = 7 mm·s^{-1} to v_{eb} = 13 mm·s^{-1}, the boride inclusions change the form from martensite-similar at minimum velocity v_{eb} up to cellular structure at v_{eb} = 13 mm·s^{-1} with tendency of cells dimensions increase during increase of initial temperature of materials subjected to welding from 20 °C to 600 °C.

Nomenclature

I - electric current, A
T - temperature, deg C
U - accelerating electrical voltage, V
v - velocity, mm·s^{-1}, m·s^{-1}

Greek Symbols

$\sigma_в$ - tensile strength, MPa
$\sigma_{0.2}$ - yield strength, MPa
δ - specific elongation, %
ψ - specific contraction, %

Subscripts and Superscripts

acc - accelerating
eb - electron beam

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ОСОБЕННОСТИ МЕХАНИЧЕСКИХ СВОЙСТВ И СТРУКТУРЫ ОБЛАСТИ СВАРНОГО СОЕДИНЕНИЯ СПЛАВА Ti – TiB_n С ТИТАНОВЫМИ СПЛАВАМИ

Проведен анализ изменений структуры и механических характеристик материала сварных соединений сплава системы Ti – TiB_n 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. Обнаружены закономерности изменения размера и характера распределения борсодержащих структурных составляющих в зависимости от варьируемых параметров. Установлено, что прочность полученных сварных соединений не ниже прочности свариваемых материалов. [dx.doi.org/10.29010/085.14]

Ключевые слова: *титановые сплавы; борид титана, металлографическая структура; механические свойства; сварное соединение; электронно-лучевая сварка; параметры сварки.*

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