Selected properties and microstructure of the titanium alloy connection made using EBW

Wybrane właściwości i mikrostruktura złącza ze stopu tytanu spawanego wiązką elektronów

SŁAWOMIR SPADŁO
WOJCIECH DEPCZYŃSKI
PIOTR MŁYNARCZYK
WOJCIECH WÓJTOWICZ
RADOSŁAW MIJAS *

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The paper presents microstructure investigations as well as properties and technical parameters of welds made using the electron beam welding method (EBW). Electron beam welding is a bonding process, especially suitable in the case of titanium and other oxidation-sensitive materials, because it must be carried out in a vacuum. Integrity of the joint was determined on the basis of mechanical properties and microstructure evaluation. The micro-hardness of the weld was measured with the Matsuzawa-Vickers MX 100 – a load of 100 G (0.98 N) was used. Nikon Eclipse MA200 microscope was used to examine the microstructure and determining the size of individual articulation zones.

KEYWORDS: electron beam welding, surface engineering, microstructure, micro-hardness

The paper discusses the welding technology, structure and properties of titanium alloy. Titanium is a unique material and its processing (regardless of type), especially welding, requires special attention.

Titanium and its high strength alloys are some of the best engineering materials for industrial applications [1–3]. Excellent combination of properties, such as high strength, long life, exceptional corrosion resistance and low density, make these materials widely used in the aviation, aerospace, military and medical industries.

Titanium alloys have a high chemical activity, therefore they are easily absorb the atmospheric gases – oxygen, hydrogen and nitrogen. This aggravates the mechanical properties of these materials and causes the appearance of unstable structures in joints [4, 5].

The TIG welding is a well known and commonly used method, while laser beam welding (LBW) and microwave welding, as well as EDM and EDS machining are considered new technologies for welding and machining of titanium alloys. They are characterized by high energy density and welding speed [6–10]. Due to the use of modern high-vacuum electron beam welding machines (EBW-HV), it is possible to carry out a welding process in conditions, which allow the weld to be protected against gaseous contamination [11–20].

* Dr hab. inż. Sławomir Spadło, prof. PŚk (sspadlo@tu.kielce.pl), dr inż. Wojciech Depczyński (wdep@tu.kielce.pl), mgr inż. Piotr Młynarczyk (piotrm@tu.kielce.pl) – Zakład Materiałoznawstwa i Technologii Amunicji, Politechnika Świętokrzyska; mgr inż. Wojciech Wójtowicz (w.wojtowicz@mesko.com.pl), mgr inż. Radosław Mijas (r.mijas@mesko.com.pl) – Mesko S.A.

Research equipment and study object

In the experimental work, TECHMETA NC device was used for electron beam welding. The vacuum level in the chamber of the device was 10^{-4} Pa, and the parameters of the beam were as follows: current 40 mA, acceleration voltage 40 kV. Welded specimens were prepared for metallographic testing (the welds were made according to standard metallographic procedures for titanium alloys). Metallographic welds were used for observations in the metallographic microscope Nikon Eclipse MA200 with the NIS 4.20 image analysis system and the SEM JEOL JSM 7100 scanning microscope with the OXFORD X-MAX electron micro-probe. Weld preparation included: joint cutting, resin embedding, polishing and etching. The weld structure was then observed under a microscope.

Micro-hardness measurement

The micro-hardness test was carried out with a Vickers indenter at a load of 100 G (0.98 N) for 15 s (exemplary imprints shown in fig. 3). Matsuzawa-Vickers MX 100 micro-hardness tester was used for tests – 100 G (0.98 N) load was applied. The studies included welded joints and heat transfer zones in the base material.

Fig. 1. Macrophotography of the EBW weld (50× magnification)

Microstructure of the connection

Scanning electron microscopy (SEM) was used to identify the particle size distribution and microstructure of the weld material and the heat transfer zone (figs. 2–4). The micro-hardness of the connection was measured with a Matsuzawa-Vickers MX 100 micro-hardness tester at 100 G (0.98 N). The hardness of the joint zone (407 HV) increased slightly as compared to the micro-hardness of the base metal (391 HV).

Thermal impacts did not result in unfavorable grain size distribution. The micro-hardness of the joint was characterized by a slight increase in hardness in the heat transfer zone. Literature analysis in the subject area indicates the convergence of the obtained results with the results of other authors [20–25].

No negative impact of heat on the microstructure of the heat transfer zone was observed in the tested connection. No microcracks have been observed in the connection.

Evaluation of the welded joint indicates that the welding process conditions have been correctly selected.

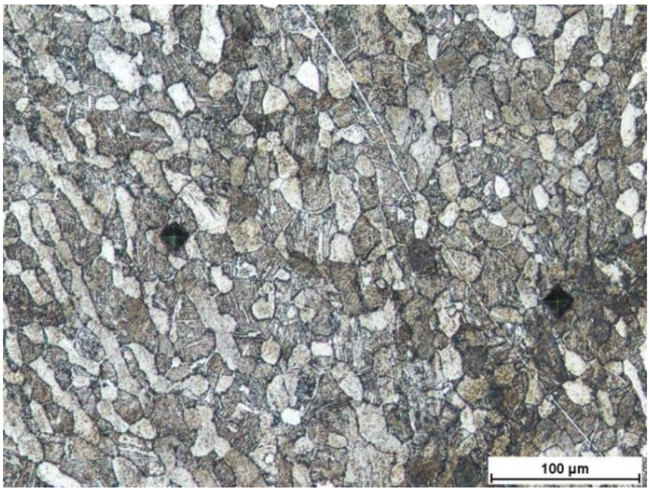

Fig. 2. Microstructure of native material Ti6Al4V weld (200× magnification, Nikon Eclipse MA200 metallographic microscope)

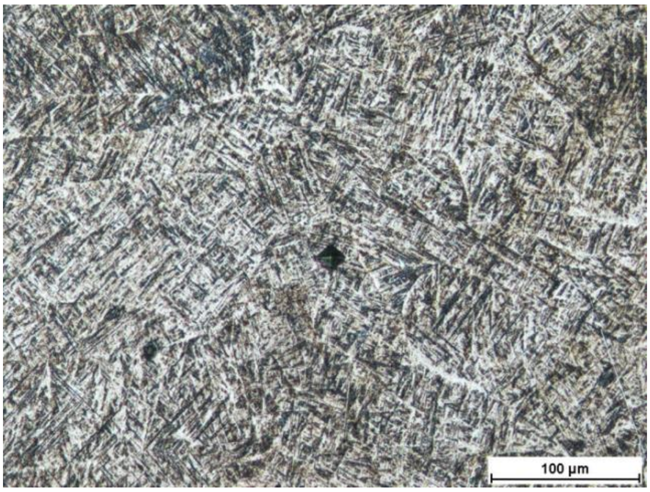

Fig. 3. Microstructure of titanium alloy Ti6Al4V weld (200× magnification, Nikon Eclipse MA200 metallographic microscope)

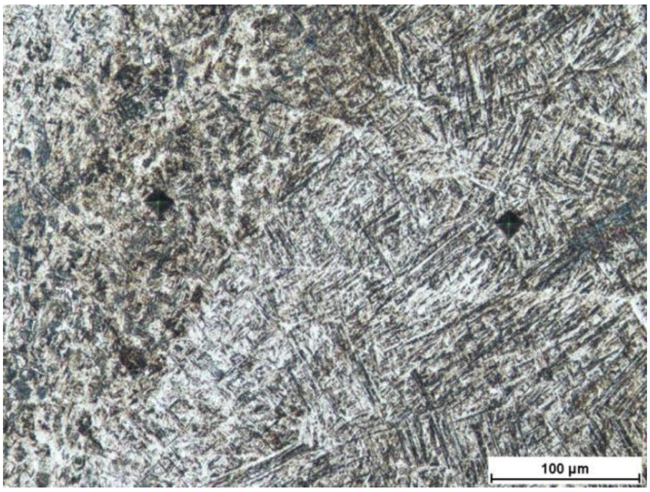

Fig. 4. Weld microstructure and heat transfer zones (200× magnification, Nikon Eclipse MA200 metallographic microscope)

Analysis of weld chemical composition

Results of metallographic examination of the weld metal are shown in fig. 5a. The microstructural analysis was supplemented with point identification of the chemical composition (both welds and zones of heat transfer), taking into account the elements Ti, V, Al and Fe. The OXFORD X-MAX electron microscope was used. Exemplary test results are shown in the diagram (fig. 5*b*). The elements Ti, Al and V, Fe, which are the alleged components of the heat transfer zone and the weld, have been identified.

a)

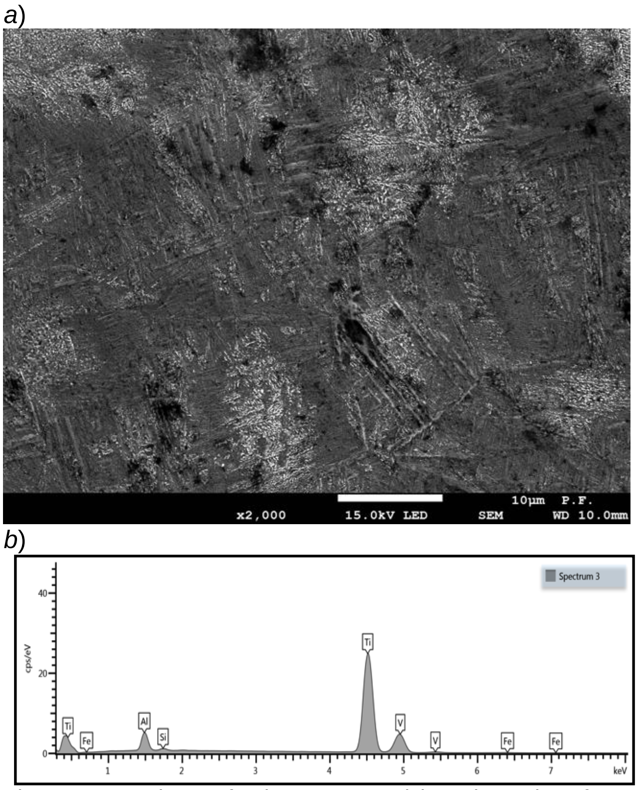

Fig. 5. SEM photo of microstructure (*a*) and results of EDS analysis of chemical composition (*b*) of welded joint

Conclusions

Based on microscopic observations and analysis of chemical composition, it can be concluded that the weld microstructure is a martensitic phase *α'*. The heat transfer zone consists of fine-grained and coarse-grained zones. Microstructure of the fine zone was the primary phase *α* + phase *β*, equilibrating with the *α* phase, and the microstructure of the native material zone was originally the *α* + *α'* phase. The microstructure of the base metal zone consists mainly of the primary *α* phase and a small amount of phase *β* residue.

The obtained micro-hardness distributions in the cross-section of the weld and the zone of thermal influences are optimal. The weld morphology is correct. Neither in the heat transfer zone, nor in the weld did a change in the chemical composition of the joined material was observed.

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