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Application of the EBSD method on explosively welded joins of Al – austenitic CrNi steel bimetal
Zastosowanie metody EBSD na bimetalicznych połączeniach spawanych wybuchowo Al - austenitycznej stali CrNi

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Abstract: *Electron Backscatter Diffraction (EBSD) is a scanning electron microscope (SEM) based technique, which enables a sample's microstructure to be analysed, visualised and quantified. The EBSD method together with associated techniques provides useful information how to interpret the obtained results. Microstructure is the internal structure of a material investigated on the microscopic scale. It is of interest because a material's internal features (i.e. structure) influences its properties and behaviour. The EBSD method has become the primary tool for characterising microstructures in most metals, alloys, composites and ceramics. The range of applications is numerous, from rapid measurement of grain size and texture in metal sheets, welded joints etc. Many of these materials are relatively simple to analyse using EBSD, but advanced tools such as high-resolution pattern correlation approaches can be applied to improve our understanding of these materials [1]. This method has been applied to investigace the structure of Al – austenitic CrNi steel. Only partial results as for the EBSD method will be given here.*

Streszczenie: *Detektor EBSD (dyfrakcja elektronów wstecznie rozproszonych) zainstalowany w skaningowym mikroskopie elektronowym (SEM) umożliwia analizę, wizualizację i ocenę ilościową mikrostruktury próbki. Metoda EBSD wraz z powiązanymi technikami dostarcza przydatnych informacji, umożliwiających interpretację wyników. Mikrostruktura to wewnętrzna struktura materiału badana w skali mikroskopowej. Jest ona interesująca, ponieważ wewnętrzne cechy materiału (tj. struktura) determinują jego właściwości. Metoda EBSD stała się podstawowym* *narzędziem do charakteryzowania mikrostruktur w większości metali, stopów, kompozytów i ceramiki. Zakres zastosowań jest szeroki, obejmujący m.in. szybki pomiaru wielkości ziarna i tekstury w blachach, złączach spawanych itp. Wiele z tych materiałów można stosunkowołatwo poddać analizie EBSD, ale zaawansowane narzędzia, takie jak metody operate o analizę obrazu, można zastosować w celu lepszego poznania struktury tych materiałów [1]. Metodę tę zastosowano do badania struktury bimetalu typu aluminium-stal austenityczna CrNi. W tym miejscu omówione jedynie częściowe wyniki analizy EBSD.*

Keywords: *EBFS method, explosive welding, aluminium, austenitic steel*
Słowa kluczowe: *metoda EBDS, zgrzewanie wybuchowe, aluminium, stal austenityczna*

1. Introduction

1.1. Electron Backscatter Diffraction (EBSD) integration with EDS

Microstructure is the internal structure of a material investigated on the microscopic scale. It is of interest because a material's internal features (i.e. structure) influences its properties and behaviour. The term „microstructure“ includes the identification and characterisation of grain populations, the investigation of the different phases or compounds in the material, the characterisation of the spatial distribution of elements and the analysis of the nature of interfaces between and within grains.Therefore, understanding the microstructure of a material is very important in metal research and advanced manufacturing techniques. The EBSD pattern results from diffraction of a divergent source of electrons generated within the sample just beneath the point where the primary electron strikes the specimen. The electrons that contribute to the pattern are only those:

- That have lost no more than a few electron volts of energy.
- Emerge from a depth in the specimen of no more than 30 to 40 nm, which is a considerably smaller depth than that reached by the primary beam.

In most cases EBSD can effectively differentiate between phases based on their crystallographic differences. However, the combination of chemical data from energy dispersive X-ray spectrometry (EDS) and crystallographic data from EBSD can be very powerful, both for identifying unknown phases in a sample (phase ID), correlating chemical and crystallographic variations in a microstructure or for more effective differentiation between phases that have similar crystallography. In many ways EBSD and EDS are perfect partners in the scanning electron microscope (SEM). On most SEMs the 2 detectors can be mounted on the same side of the chamber, so that simultaneous X-ray measurement and EBSD pattern collection is possible. The ideal geometry, with the EDS detector mounted above the EBSD detector, is shown in the Fig. 1.

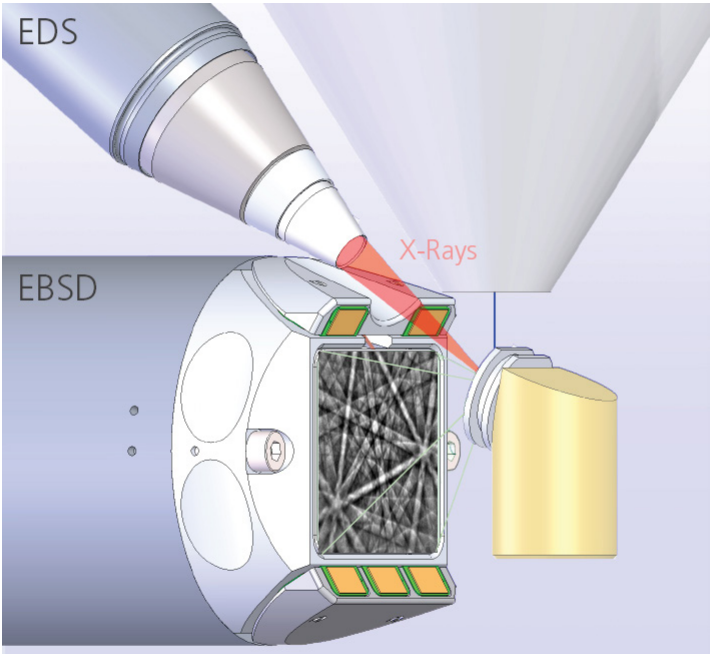

Figure 1. Geometry of both EBSD and EDS detectors [1, 2]

1.2. Fabrication of the bimetal Al - austenitic CrNi steel

Accelerated material was the austenitic CrNi steel type 17 240 (STN 41 7240). This material was heat-treated and afterwards by stress relieve heat treatment. The semi-product was a plate of rectangular shape 1mm in thickness. In fabrication of Al - CrNi austenitic steel bimetal a parallel arrangement of welded materials was selected. The stable material was Al 99.5%, (STN 42 4005) in a soft state and 15 mm in thickness. This procedure used for fabrication of Al - austenitic CrNi steel bimetal can be called also as one-sided cladding of aluminium with austenitic CrNi steel. In order to maintain stability of welding process it was necessary to set the accelerated metal - austenitic CrNi steel and the stable Al plate on a suitable rigid substrate (Fig. 2).

Figure 2. Parallel welding set up [3, 4]

Figure 3. Al - austenitic CrNi steel bimetal

The initiation explosive and the point of initiation were selected in such a manner that the movement direction of the detonation wave front would be identical with the explosive detonation velocity. Semtex 10SE was used as the explosive substance and it was initiated with an electronic detonator. The fabricated bimetal austenitic CrNi steel - Al (Fig. 3) attained the final dimension 146×116 mm. The distance spacing (*h*) and the charge parameters were designed on the basis of specific calculations as proposed from VÚPCH Explosia Pardubice [5]. Bimetal thickness on the fringes was reduced from 12 to 14 mm. The thickness in the central part was 16 mm.

2. Assessment of joint quality

Specimens for heat treatment done at 250 °C were selected from the fabricated bimetal (Fig. 3), as they were used for the study of structure in boundary zone of welded joint by optical microscopy, microhardness measurement, EDX and EBSD analysis. Fig. 4 shows the microstructure in boundary zone of welded joint. Mechanical intermixing of welded metals with indistinct undulated boundary were observed. In the islands formed by mechanical intermixing, the intermetallic phases ($FeAl_3$, Fe_2Al_5, FeAl) have been identified by both XRD and EDX analysis. The austenitic CrNi steel is generally considered for well forming, and thus with good explosion weldability. Due to strain rate of grains a more significant material strengthening may be supposed, however just in the vicinity of bimetal boundary.

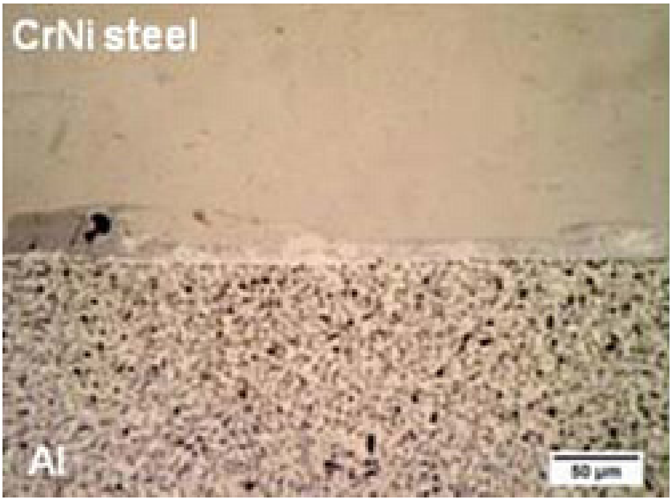

Figure 4. Boundary zone of Al - austenitic CrNi steel bimetal after heat treatment at 250 °C/100 hrs and mechanical polishing

3. EDX microanalysis

EDX microanalysis of bimetal boundary zone was performed on Hitachi SU 3600 equipment. The line profiles of Ni, Cr, Fe, Al elements through the joint boundary in the zone (Fig. 5) are shown in Fig. 6

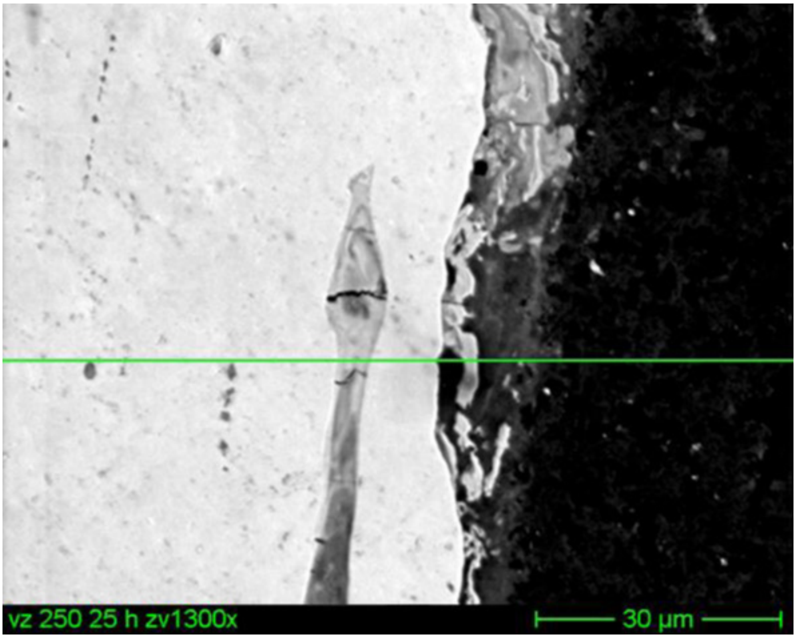

Figure 5. Concentration line profile using EDX analysis

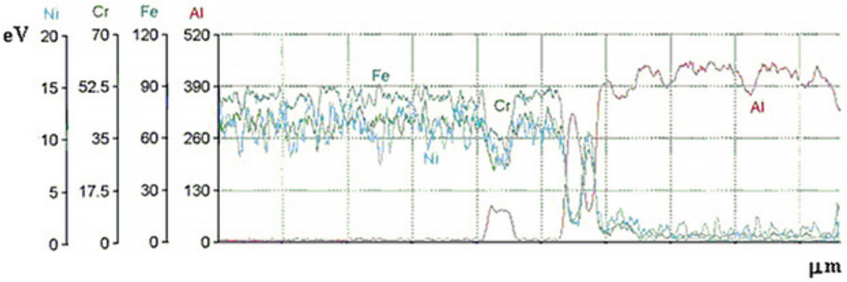

Figure 6. Course of concentration changes of Fe, Cr, Ni, Al through the boundary of Al - austenitic CrNi steel bimetal

4. EBSD analysis

EBSD analysis was performed on JEOL JSM 7000F FEG SEM equipment. The results of measurements performed by EBSD analysis have proved the fact that the coarse-grainedzone consists of aluminium. Fig. 7 shows the microstructure in boundary zone of welded metals which are separated by the supposed amorphous phase. Fig. 7 shows the EBSP of aluminium obtained from the point marked with a cross (Fig. 8). The EBSP proves that the material is crystalline [6, 7].

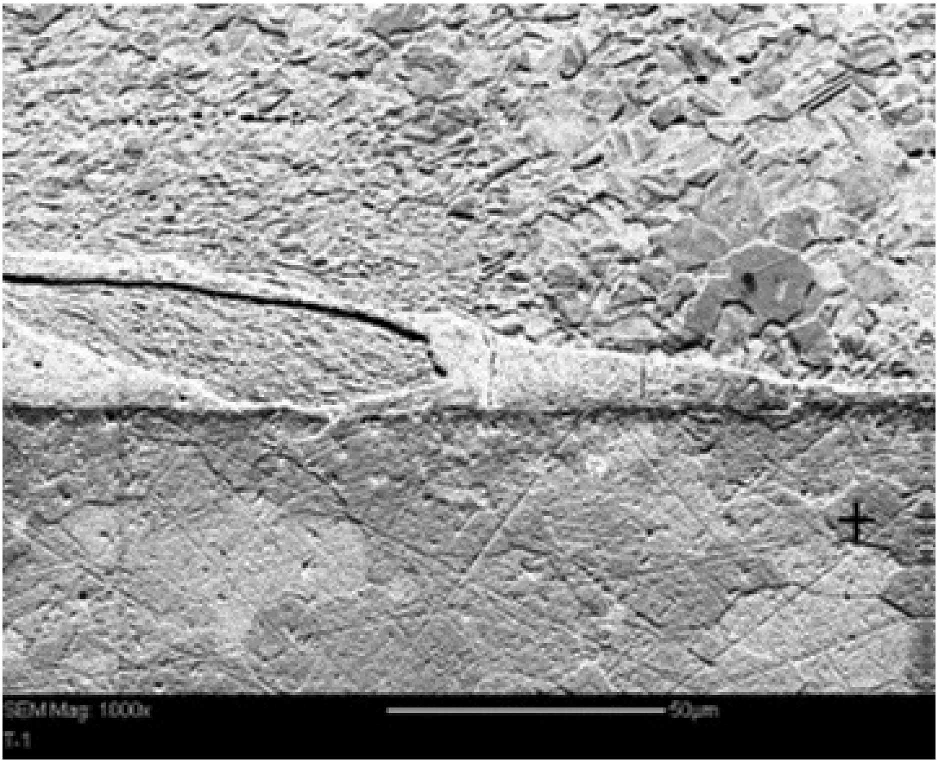

Figure 7. Boundary of Al-CrNi steel bimetal

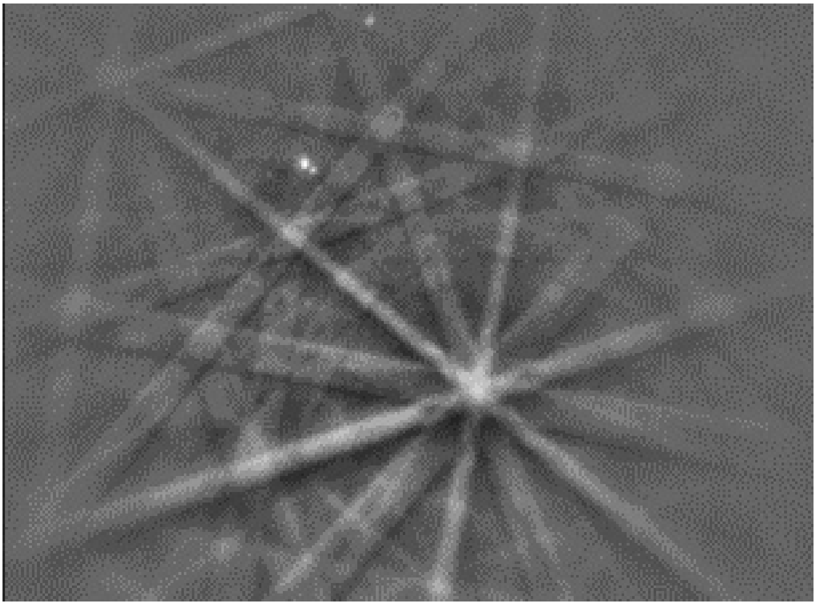

Figure 8. EBSP pattern attained from Al 99.5

5. Conclusions

- ♦ The aim of presented contribution was to introduce and possible application of the EBSD method on design and welded joints (Al - austenitic CrNi steel bimetals), and also to assess their quality, both in as-welded condition and after heat treatment as well, including data gathering for prognosis of utility properties. The bimetals were fabricated by solid state explosion welding. This technology always posseses the question concerning both, elucidation of joint formation mechanism and the structural situation in the boundary zone in welded joints of combined metals.
- ♦ The microhardness measurements through the bimetal boundary, EDX microanalyses of boundary zone (line analyses of individual elements of welded metals) and EBSD analyses of boundary in Al – CrNi austenitic steel bimetal were carried out.
- ♦ The existing knowledge from explosion welding was extended using EBSD analysis. It was proved that the structural situation in the boundary zone of bimetals tends to converge to amorphous states of metals participating in the welding process. It is supposed that the mentioned bimetals can play a significant role in the field of construction of vacuum equipment for special technological processes and for other industrial fields.
- ♦ It can be stated that the fabricated welded joints (bimetals) exert good quality, both the mechanical properties and the structural stability point of view.

Acknowledgments

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References

[1] *Electron Backscatter Diffraction – EBSD.* Oxford Instruments NanoAnalysis, https://nano.oxinst.com/products/ebsd/ [retrevied 20.04.**2023**].

[2] *Practical Scanning Electron Microscopy*. Eds.: Goldstein J.I., Yakowitz H.; New York: Plenum Press, **1975**; ISBN-13 978-1461344247.

[3] Turňa M. *Special Welding Methods*. (in Slovak) Bratislava: Alfa, **1989**; ISBN 80-05-00097-9.

[4] Marônek M. *Explosion Welding of Metallic Materials.* (in Slovak) Bratislava: STU, **2009**; ISBN 978-80-227-3128-7.

[5] Nesvadba P. *Explosion Welding of Thin Metal Layers and Interlayers, Preparation of Suitable Explosives.* (in Czech) Pardubice: Univerzita Pardubice, **2006**, p. 32.

[6] Lippold J.C., Kotecki D.J. *Welding Metallurgy and Weldability of Stainless Steels.* Hoboken, NJ: Willey Interscience. **2005**; ISBN 0-471-47379-0.

[7] Mingard K.P., Roebuck B., Bennett E.G., Gee M.G., H. Nordenstrom H., Sweetman G., Chan P. Comparison of EBSD and Conventional Methods of Grain Size Measurement of Hardmetals. *Int. J. Refract. Hard Met.* **2009**, *27*: 213-225; https://doi.org/10.1016/j. ijrmhm.2008.06.009.

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