X-ray microanalysis of Al-austenitic steel boundary formed by explosion welding

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Abstract. *The primary purpose in surface analysis is to identity the surface elemental composition (qualitatively), to dermine the amount and nature of species adsorbed and to elucidate the properties of the surface atoms. Of the four basic particle probe beams(electrons, ions, neutrals and photons), electron probes have been used longer and more extensively than any of the others. This is because electron beams of controlled energy and density can be easily generated. The scientist today is often required to observe and correctly explain phenomena occuring on a micrometer and submicrometer scale. Electron scanning microscope (SEM) and electron microprobe (EPMA) are two power- ful instruments which permit to characterize heterogenueos materials on a such fine scale. In both instruments production of many signals such as secondary electrons, photons of various energies etc. are produced as a consequence of irradiating the sample in question by the electron probe. The presented paper deals with the study of materials such as Al and CrNi steels which have been welded by explosion. The explosion welding takes on importance worldwide as many materials can not be welded by classic welding procedures. The evaluation of the quality of the quality of joints was carried out by SEM and EPMA.*

Keywords: *Explosion welding, x-ray microanalysis, CrNi steel(1.4301)+AW-1050 A, CrNi steel(1.4541)+AW-1050A, structural stability of bimetals.*

1. Introduction

In our rapidly expanding technology, the scientist today is often required to observe and correctly explain phenomena occuring on a micrometer and submicrometer scale, i.e. nanoscale. Several years ago while looking at the various techniques of surface analysis it was quite possible to review virtually all existing methods in a reasonable period of time The last few years, however, have seen a tremendous explosion of interest in surface studies accomplished by a very large increase in the number of people working in the field. This expansion has led to a simultaneous increasing development of new methods of surface analysis. While in early 1970-ties some authors reported approx. 56 methods of surface analysis by now no one person can hope to seriously review in any detail all of the techniques of surface analysis witin a reasonable effort. One assumes the number of the methods currently used exceeds 100. Electron scanning microscope (SEM) and Electron microprobe (EPMA) are two powerful instruments which permit to characterize heterogenueos materials on a such fine scale. In both instruments the area to be examined is irradiated with a finely focused electron beam, which may be static, or swept in a raster across the surface of the sample. The types of signals produced when the focused electron beam impinges on the sample surface include various signals such as secondary electrons, backscattered eletrons, characteristic X-rays, Auger electrons and photons of various energies. If one wants to get both chemical and physical information from an unknown sample various signals must be applied so to get the required information. The signals include electric field, magnetic field, thermal heating, irradiation by neutrals, ions, electrons and photons (see Fig. 1). The most effective tools in obtaining the required information of both chemical and physical nature used by scientists are SEM and EPMA. Then primary purpose in surface analysis is to identify the surface elemental composition (qualitatively), to determine the amount and nature of species adsorbed and elucidate the properties of the surface atoms or adtoms.

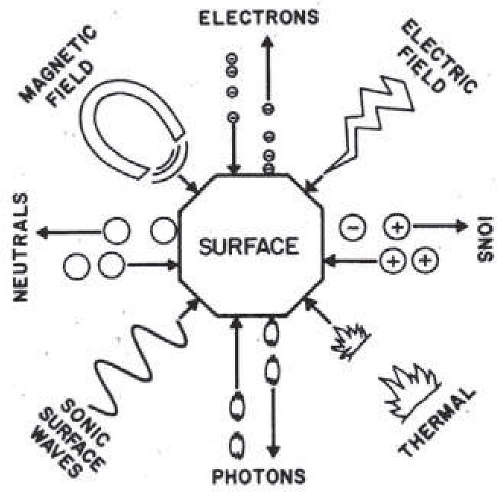

Fig. 1. Pictorial representation of surface analysis techniques

In the electron probe microanalyzer (often known as an electron microprobe) the primary signal of our interest is the characteristic X-rays which is emitted as a result of bombardment of the sample by electrons. Analysis of the characteristic X-rays which is emitted from the area where the electron probe falls upon the sample provides compositional information of both quali- and quanti-tative character. In the SEM the primary signal of our interest is the change of electron emission which takes place when the electron probe is swept over the surface as a result of surface topography. Historically, however, both instruments (SEM and EPMA) look alike they were developed independently and differ from each other in the way they are used.

In our research both instruments, i.e. SEM and EPMA, were used to characterize various bimetals and their application in industry.

An important parts of material science are technological procedures and in this way new materials can be produced that can be characterized by high technical parameters. A very important conclusion from the material science point of view is that materials such as Al and NiCr steels which are well known can not be metalurgically joined by classical nor by special melting technologies. This gave rise to pay attention to special technologies of welding in solid state. One of the possible special technology seems to be **welding by explosion** which can be described as **high speed welding**. This technology takes on importance as many international conference on this behalf have been held during last few years. Trends in material science technology are directed to replace classic steel materials by another metals including bimetals and multicomponental composites.

Nowadys, welding by explosion belongs to technologies which have been described both theoretically and also from the application point of view. Using this technology enables welding of solid joints between the same metals as well as between materials with very different physico-chemical properties (melting temperature, sound speed in metals, density, chemical composition etc.) and also with different crystallographic lattice. The most frequent welding by explosion is carried out on large scale surfaces. This technology is very useful in production of various bimetalic and multilayer metalplates.

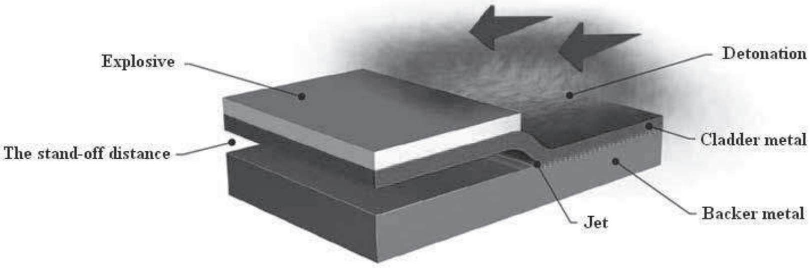

Fig. 2. Parallel way of set up of materials welded

2. Fabrication of bimetal

The accelerated material was the austenitic CrNi steel type 17 240 (STN 41 7240). The material was heat treated by solution annealing and by stress relieve heat treatment. The semi-product was a plate of rectangular shape of 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, 15 mm in thickness. This procedure used for fabrication of Al - austenitic CrNi steel bimetal can also be called as one-sided cladding of aluminium with austenitic CrNi steel. In order to maintain the 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. 3).

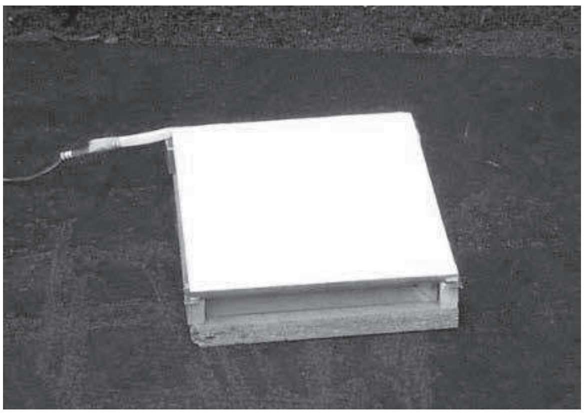

Fig. 3 Parallel welding set up

Fig. 4. Al-austenitic CrNi steel bimetal

The initiation of the explosive and point of initiation was selected in such a manner that the movement direction of detonation wave front would be identical with the detonation velocity of explosive. While the initiation explosive Semtex 10SE was used it was initiated with an electronic detonator. The fabricated bimetal austenitic CrNi steel - Al (Fig. 4) attained the final dimension of (146 x 116) mm. The distance spacing ***h*** and the charge parameters were designed according to the calculations performed by specialists from the VÚPCH Pardubice. Bimetal thickness was reduced on the fringes from 12 mm to 14 mm. The thickness in the central part was 16 mm.

3. Assessment of joint quality

Specimens for heat treatment carried out at 250 °C were taken out from the fabricated bimetal (Fig. 3), hereas they were used for the study of structure in boundary zone of welded joint by optical microscopy, Microhardness measurement, EDX and EBSD analysis. Fig. 5 shows the microstructure in boundary zone of welded joint. Mechanical intermixing of welded metals but also indistinct undulated boundary were observed. In the islands formed by mechanical intermixing the intermetalic phases ($FeAl_3$, Fe_2Al_5, FeAl) probably occur. The austenitic CrNi steel is generally considered to be well forming and thus it also has good explosion weldability. Due to the strain rate of grains a more significant material strengthening may be supposed, however, just in the vicinity of bimetal boundary.

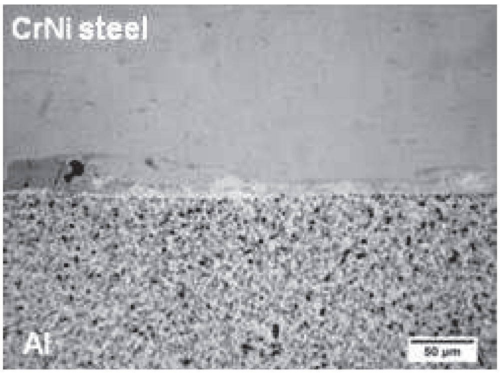

Fig. 5. Boundary zone of Al - austenitic CrNi steel bimetal after heat treatment at 250 °C / 100 hrs and mechanical polishing

4. EDX microanalysis

EDX microanalysis of bimetal boundary zone was performed on JXA-840 JEOL equipment. The line profiles of Ni, Cr, Fe, Al elements through the joint boundary in the zone (Fig. 6) are shown in Fig. 7.

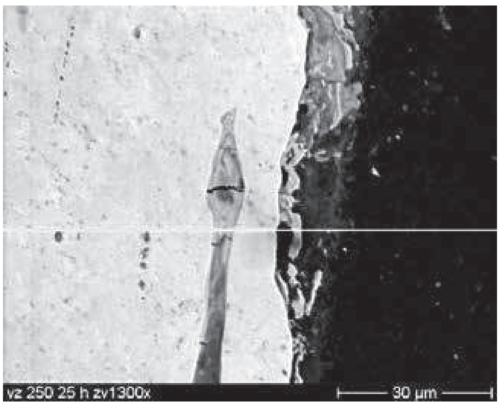

Fig. 6. Concentration line profile using EDX analysis

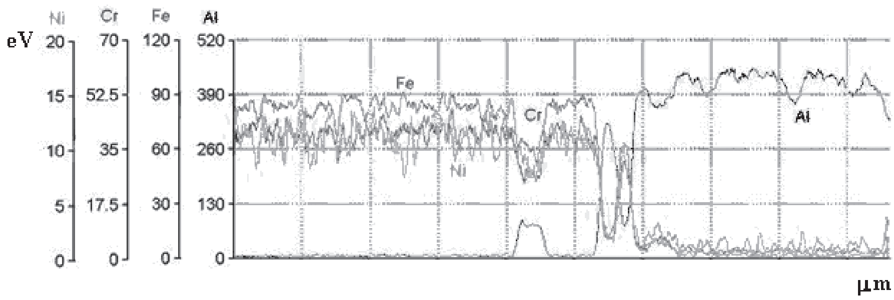

Fig. 7. Line concentration profile of Fe, Cr, Ni, Al, through the boundary of Al-austenitic CrNi steel bimetal

5. EBSD analysis

EBSD (Electron Back Scattered Diffraction) analysis was performed on JEOL JSM 7000F FEG SEM equipment. The results of measurements performed by EBSD analysis have proved that the coarse-grained zone consists of aluminium. Fig. 8 shows the microstructure in boundary zone of welded metals which are separated by the supposed amorphous phase. Fig. 9 shows the EBSP (Electron Back Scatter Pattern) of aluminium obtained from the point marked with a cross (Fig. 8). Back scatter pattern of electrons proves that the material is crystalline.

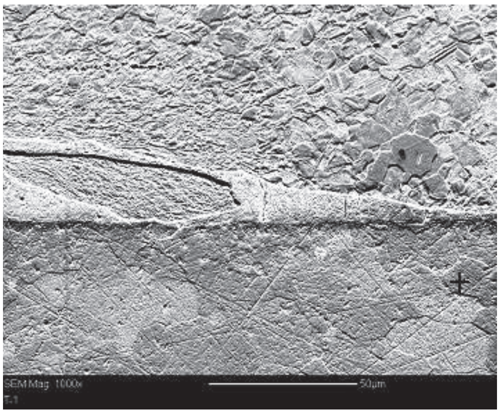

Fig. 8. Boundary of Al-CrNi steel bimetal

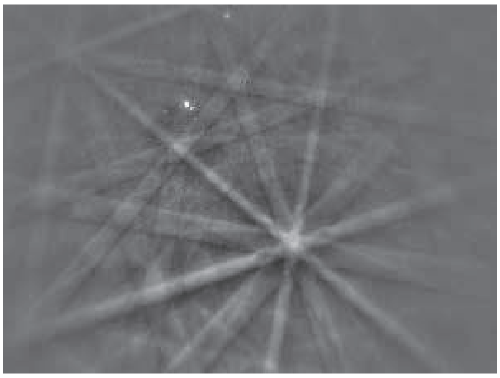

Fig. 9. EBSP attained from Al 99.5

Point of analysis of the supposed amorphous phase is marked with a cross in Fig. 10. Based on the obtained EBSP pattern one may with great probability suppose the presence of the amorphous state in the pointmarked with a cross (Fig. 11).

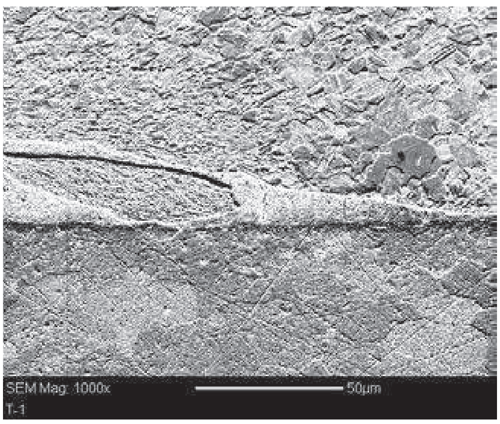

Fig. 10. Boundary of Al- CrNi steel bimetal

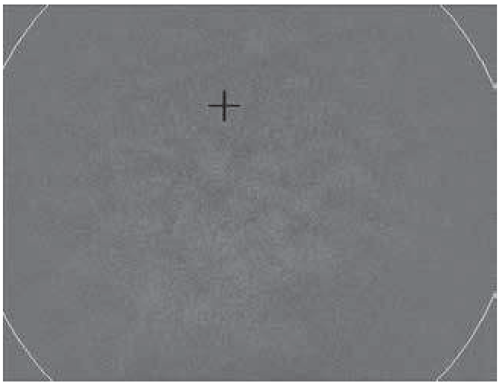

Fig. 11. EBSD patterns from the marked zone Fig. 9

6. Conclusions

The aim of the presented paper was to design and fabricate 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 the prognosis of its utility properties. The bimetals were fabricated by solid state welding by explosion. This technology always comprise a question concerning both elucidation of joint formation mechanism and the structural situation in the boundary zone in welded joints of combined metals. The work presents obtained results from optical microscopy, microhardness measurements through the bimetal boundary, EDX microanalysis of boundary zone (line analysis of individual elements of welded metals), EBSD analyses of boundary in Al – CrNi austenitic steel bimetal. The existing knowledge from explosion welding was extended by 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 may be supposed that the mentioned bimetals could play a significant role in the field of construction of vacuum equipment for special technological processes and in others industrial fields. It can be stated that the fabricated welded joints (bimetals) showed good quality from both the mechanical properties point point of view and the structural stability.

Acknowledgments

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