HEAT RESISTANCE OF Fe40Al5Cr0.2TiB ALLOY INTERMETALLIC SURFACE REMELTED WITH TIG METHOD

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Abstract

The practical use of FeAl intermetallic alloys will be possible in a wider range after the development of not only the technology of making permanent joints, but also after determining their physicochemical properties. In the work, the surface condition of the intermetallic FeAl alloy by use TIG AC and DC(-) were remelted and in the air at 900 and 1000 °C were oxidized. Differences in the surface state of melted Fe40Al5Cr0.2TiB alloy were found depending on its area, in particular in the area of remelting and fusion line. For the tests, the Fe40Al5Cr0.2TiB intermetallic alloy was used as the basic material after casting, which was modified by TIG remelting. Next, microstructure analysis was performed using light microscopy, scanning electron microscopy and hardness measurements before and after oxidation. In addition, corrosion products were analyzed using XRD.

Keywords: TIG AC/DC method, remelting, FeAl alloys, properties

1. INTRODUCTION

The alloys based on intermetallic phases are characterized by an ordered internal structure and properties resulting from the occurrence of three types of bonds: metallic, ionic and covalent. The energy of binding of two different atoms is greater than the bonds between the same elements in the alloy, which ensures ordering the structure of the solution. A significant share of aluminum in the composition of alloys based on intermetallic phases provides these materials, owing to the intrinsically tight protective layers that form, a high heat resistance to corrosion of the aggressive environment. Aluminum and titanium also determine their low density with relatively high strength and high modulus of lateral elasticity. The FeAl intermetallic phases containing 36% to 51% of aluminum atoms have stable properties over a wide temperature range [1-5]. They are also characterized by a low density of 5.5 g/cm^3, high corrosion resistance compared to traditional construction materials, aggressive environments, seawater, carburizing, sulphur and very good tribological properties at elevated temperature. Fe-Al alloys have found wide application in many branches of industry, such as energy, air and petrochemical [6-8]. In the automotive industry, they can be used as elements of a hot turbocharger part, rings, catalyst elements [9]. Due to low material costs and satisfactory properties, these alloys can replace some steels containing chromium and nickel. The development of methods for joining these alloys would expand the range of their application, e.g. as elements of combustion engines.

2. RESEARCH MATERIAL AND METHODOLOGY

The aim of the research was to determine the weldability of the alloy by TIG welding on the Fe-Al intermetallic phase matrix, determine the structure changes occurring in the material during TIG-AC and TIG-DC(-) melting and the resistance of the resulting joint to high temperature corrosion [10]. The test material was an alloy based on the Fe40Al5Cr0.2TiB intermetallic phase after casting, the chemical composition of which is summarized in **Table 1**. The Pure melt was used to melt the alloy: Armco iron (technically pure), Aro aluminum (99.995% pure), chromium aluminotermic obtained by the Koll method and amorphous boron (chemically pure). The melts were carried out in the Balzers induction vacuum furnace VSG-2. Smelting was carried out in a vacuum (10^{-2} Pa). Fe melting of the alloy on the Fe-Al intermetallic phase was carried out using the TIG method in protective gas shielding. The process parameters are summarized in **Table 2**. The TIG method was used to remelting alloy samples on the intermetallic phase matrix due to the concentrated electric arc, the ease of selection of parameters and the high quality of the products obtained. Samples remelted with the TIG method were subjected to oxidation in an oven under air at 900 and 1000 °C for 100 h. The material was then subjected to microstructure observations using the Olympus GX51 light microscope and the Hitachi S-4200 scanning electron microscopy together with the X-ray microanalysis of the EDS chemical composition. The next step was to conduct a phase analysis of corrosion products created during oxidation in the air. The tests were carried out on an Empyrean X-ray diffractometer from PANalytical, designed for the analysis of the phase composition of polycrystalline materials.

Table 1 Chemical composition Fe40Al5Cr0.2TiB alloy

Compound	Fe	Al	Cr	Ti	B	C
weight %	68.18	23.50	5.67	0.14	0.015	0.056

Table 2 Parameters of welding process

TIG Current-electrode	**Thickness** (mm)	**Shielding gas**	**Current** (A)	**Flow rate** (l/min)	**Position of welding**	**Welding** speed (mm/s)
DC(-) WTh 2,4	5	Argon I1	100	10	PA, Flat - Down hand	1.0-2.5
AC WTh 2,4	5	Argon I1	100 Balance 50%	10	PA, Flat - Down hand	1.0-2.5

3. EXPERIMENTAL RESULTS

The work analyzed the properties of a welded joint made of FeAl alloy by TIG (AC). Observations of the remelted microstructure before oxidation were carried out. The results of the observations are presented in **Figures 1** and **2**. It was found that in the case of a weld joint obtained with the TIG AC method, grains in the weld are arranged in a directional way to a greater extent than in the case of a weld obtained with the TIG DC (-) method. This is due to the amount of heat input to the welding site, which is confirmed by the depths of remelting the layer. For the TIG DC (-) method, the penetration depth is about 20% higher compared to the TIG AC method. In both cases, the grain size in the weld was reduced in relation to the native material.

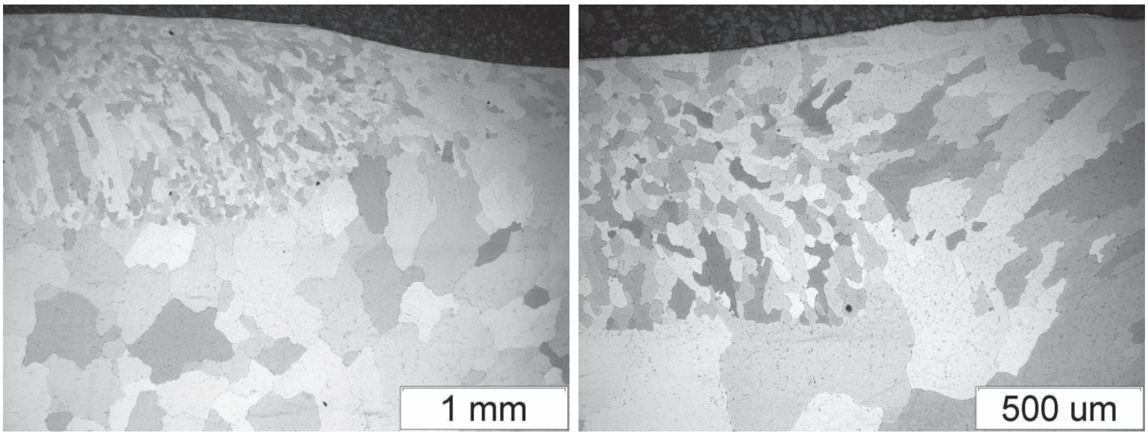


Figure 1 Microstructure of Fe40Al5Cr0.2TiB alloy melted with TIG-AC before oxidation

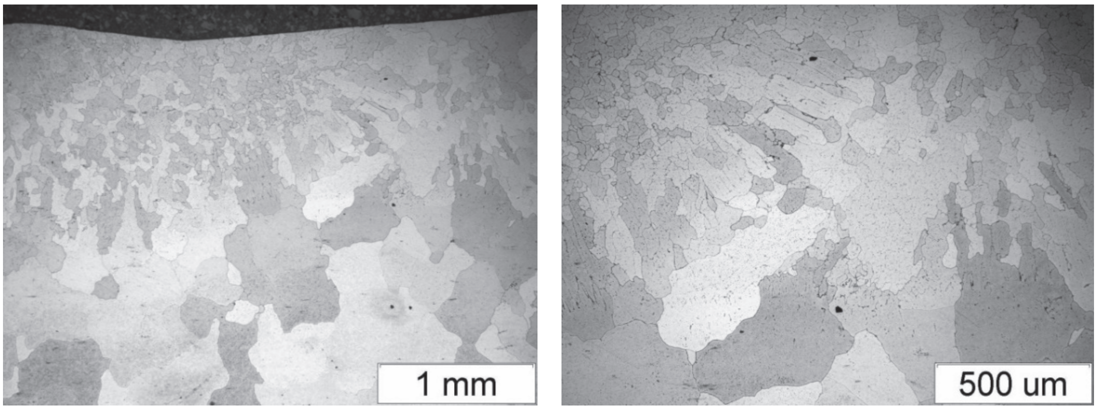


Figure 2 Microstructure of Fe40Al5Cr0.2TiB alloy melted with TIG-DC before oxidation

Investigations of the alloy microstructure after oxidation are shown in **Figures 3 and 4**. No change in the grain size as a result of oxidation of Fe40Al5Cr0.2TiB alloy after melting by TIG AC and DC (-) at both 900 °C and 1000 °C. This means that the material has a stable microstructure in high temperature conditions. There was no grain growth in the melting zone. The oxidation process was carried out in an oven at 900 and 1000 °C in an air atmosphere. Conducting this type of tests was aimed at determining the corrosion resistance of the melted alloy Fe40Al5Cr0.2TiB with the TIG method in an inert gas shield (Argon-100%). Due to the fact that this material is resistant to oxidation, it is appropriate to determine the corrosion resistance at elevated temperature of the welded joint because in the course of remelting changes occur in the material structure and chemical composition in relation to the starting material.

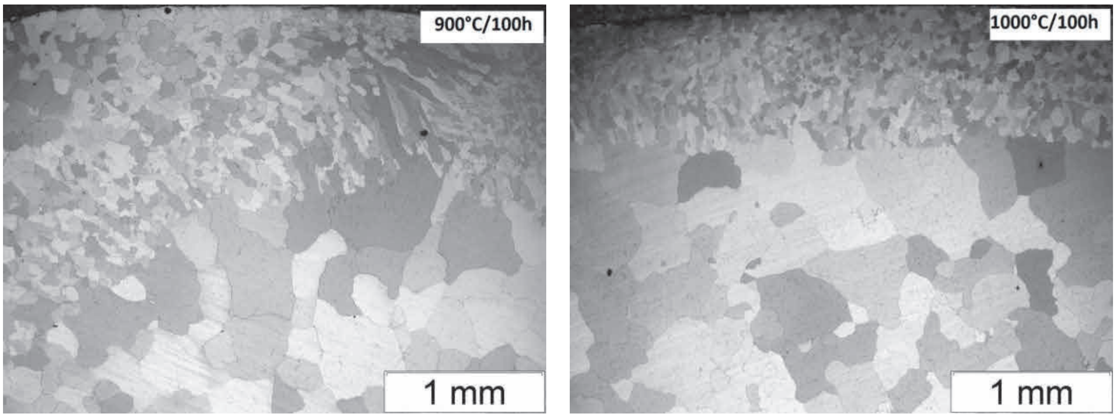


Figure 3 Microstructure of Fe40Al5Cr0.2TiB alloy melted with TIG-AC after oxidation at 900 and 1000 °C

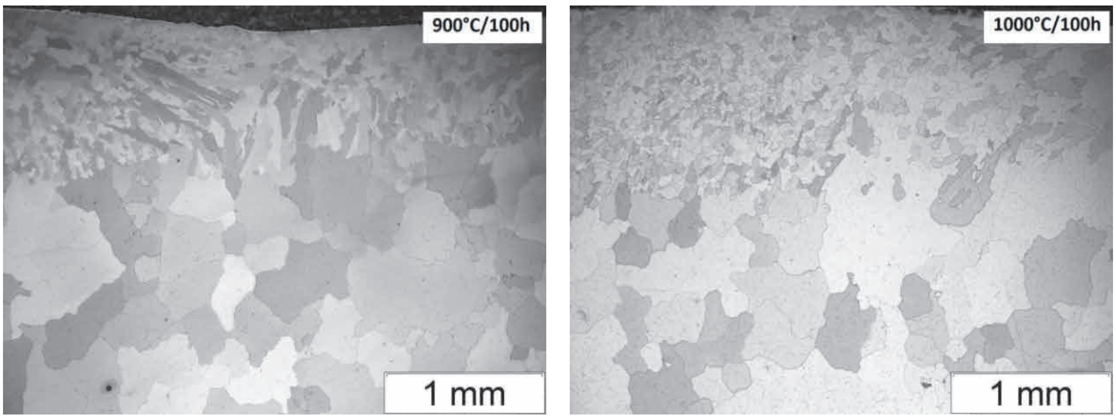


Figure 4 Microstructure of Fe40Al5Cr0.2TiB alloy melted with TIG-AC after oxidation at 900 and 1000 °C

The surface condition of the material after oxidation was analyzed. The test results are shown in **Figures 5 and 6**. It was found that the surface is covered with an oxide layer. The structure and growth mechanism of the protective scale on heat-resistant alloys depends of the type of metal in the matrix. Alloys on the FeAl intermetallic phase throughout the entire temperature range remain single phase. For this reason, the layer develops over the whole of their surface at the time of contact of the hot metallic phase with oxygen, regardless of the temperature. Under of the scale surface, during the oxidation of the intermetallic Fe40Al5Cr0.2TiB alloy, concentration gradients and cavities are formed. It can be seen on the bare (empty) FeAl surface in the Al_2O_3 oxide crushing areas (**Figures 5, 6**).

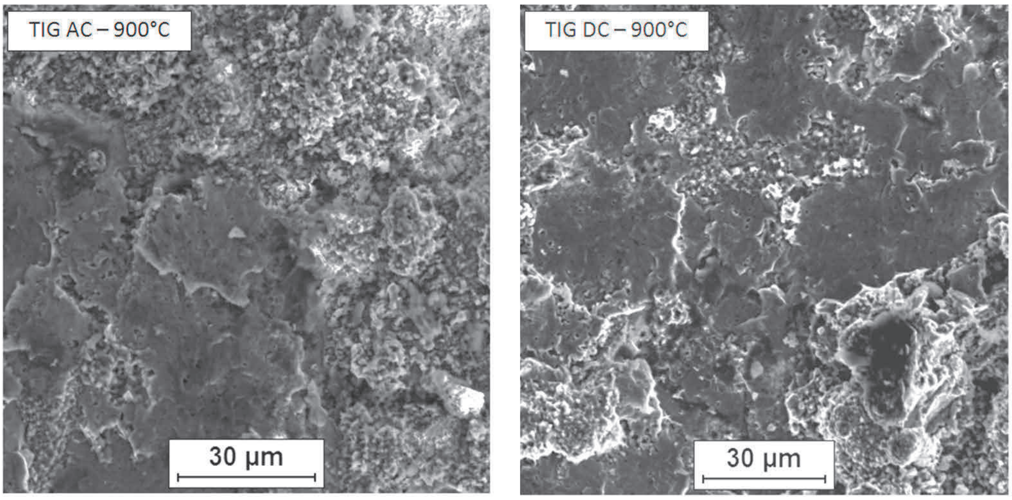


Figure 5 Condition of the surface of the remelted TIG alloy Fe40Al5Cr0.2TiB after oxidation at 900 °C

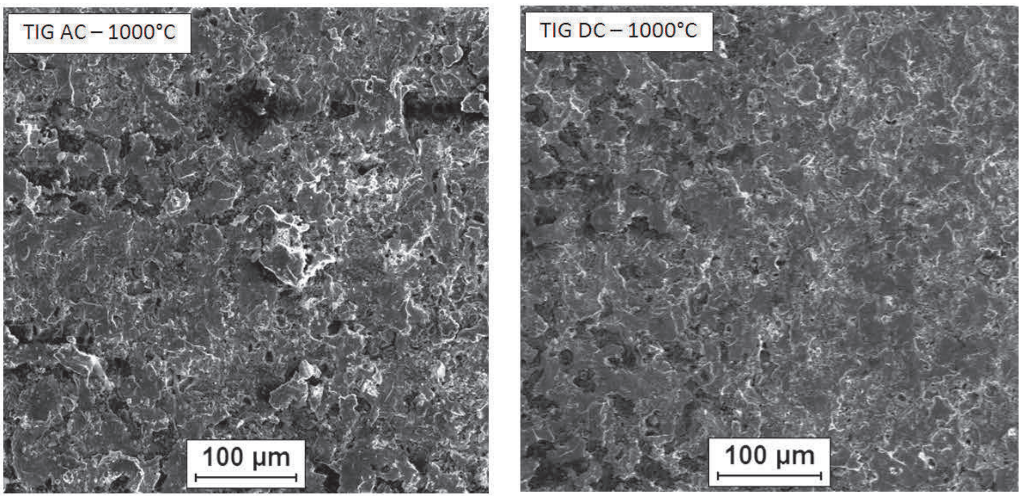
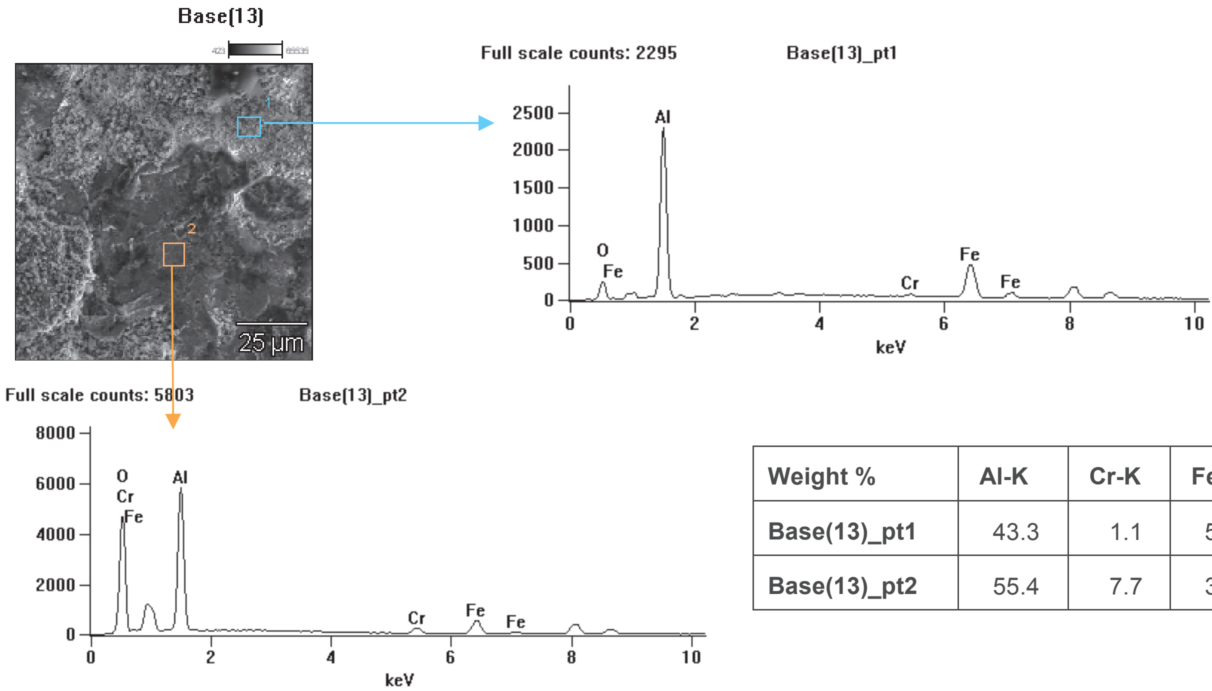


Figure 6 Condition of the surface of the remelted TIG alloy Fe40Al5Cr0.2TiB after oxidation at 1000 °C

X-ray phase analysis of corrosion products showed that on the surface of the oxidized material there are elements contained in the alloy and clear areas with a high content of Al, Fe and O, so elements constituting the oxides formed on the surface. **Figure 7** shows the results for a sample melted down by TIG AC and oxidised at 900 °C. The results for the other samples are similar. Due to the research methodology adopted, the presence of oxygen should only be considered as an estimate. To determine the type of oxidation products formed, a phase analysis was performed. The results of the observations are presented in **Figure 8** and **9**. During melting, intensive mixing of the components takes place which determines the formation of Al_2FeO_4 (spinel) because it does not create a passive layer of Al_2O_3, which hinders spinal oxygen transport. The results for TIG DC (-) remelted samples are comparable.



Weight %	Al-K	Cr-K	Fe-K
Base(13)_pt1	43.3	1.1	55.6
Base(13)_pt2	55.4	7.7	36.9

Figure 7 X-ray microanalysis of EDS chemical composition after smelting with TIG AC and oxidation at 900 °C

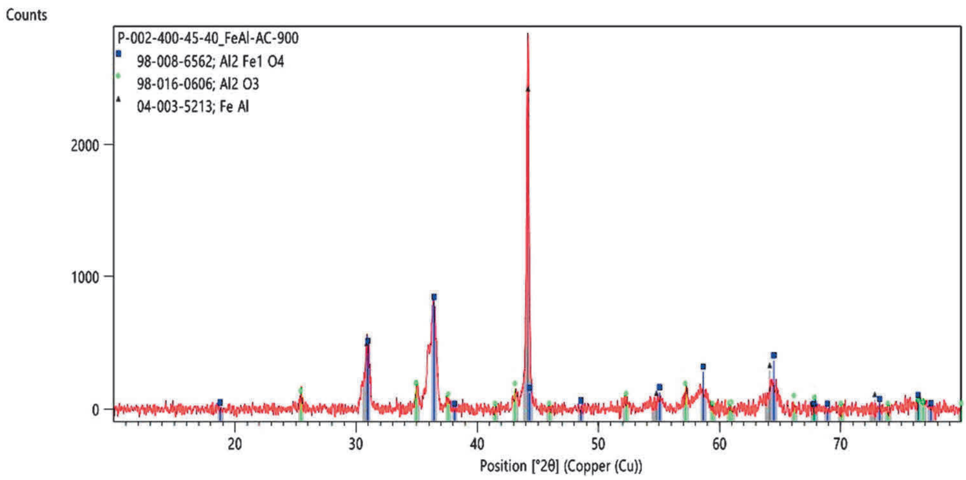


Figure 8 X-ray phase analysis of Fe40Al5Cr0.2TiB melted with TIG AC after oxidation at 900 °C

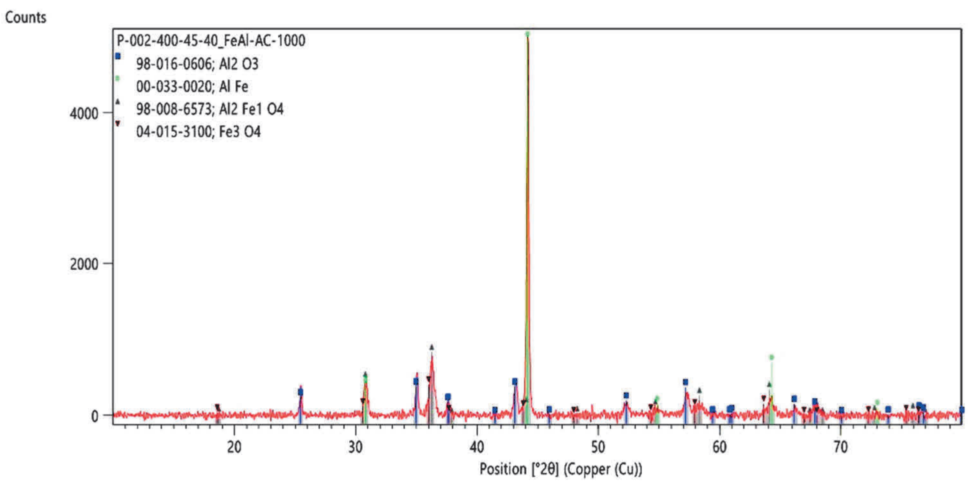


Figure 9 X-ray phase analysis of Fe40Al5Cr0.2TiB melted with TIG AC after oxidation at 1000 °C

4. CONCLUSION

The use of the TIG method for melting the Fe40Al5Cr0.2TiB intermetallic alloy makes it possible to create a weld combined with the parent material in a way that allows to conclude that both the weld and the boundary of the penetration are free from structural defects visible in the microstructure tests carried out with LM. The joint is characterized by a significant grain refinement in relation to the grain size obtained after crystallization. Untreated material subjected to corrosion tests does not show any compounds other than Al_2O_3 using the EDS method in the area of corrosion products. The passive Al_2O_3 layer prevents spinal diffusion of oxygen and the chemical affinity of Al and O causes the formation of a tight insulating layer on the surface. Probably mixing of ingredients and high temperature during the melting process cause the formation of corrosion products in the form of oxides from other material components outside of aluminum.

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