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# THE USE OF WELDING FOR FORMING FEAL COATING ON S235

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**Abstract:** *Implementation of new materials into industrial practice allows to build more durable and reliable machine parts suitable to operate at high temperature and other special conditions. The paper analyzes implementation of welding method to make intermetallic surface Fe40Al5CrTiB on material grade S235JR. The process was made with tungsten inert gas (TIG) and with the use of reserved polarity direct current (DC-). Welded sample was made as: single bead, multi bead and as multilayer. After the welding process, samples were tested with geometric measurement, Vickers hardness (HV), light microscopy (LM) and scanning electron microscopy (SEM). This technology can by used to develop resistance surfaced in the power industry in the future.*

**Keywords: Coating, FeAl, Intermetallic, Imperfection, TIG.**

## 1. Introduction

Currently, in order to increase the lifespan of equipment used outside special working surfaces welded with electrodes or wires of specifications are applied. Surfacing is one of the modern processes of machines parts and devices regeneration. Obtaining layer material that fulfils the criteria specified for the construction will meet the market demand, thereby it can solve the problem of their durability. The innovatory method of obtaining the coating of improved properties is modifying the surface layer by welding wire made of alloy based on intermetallic phase Fe40Al5Cr0,2TiB. Changing the properties of the material depends on the dimensions (thickness) of the welded layer. The alloys based on intermetallic phase matrix FeAl are characterized by very good resistance to high-temperature corrosion, and also good corrosion resistance in both oxidizing and carburization atmosphere and in sulfur-containing compounds.

The alloys based on intermetallic phase matrix FeAl have many advantages, for example low density, relatively low price of raw materials, and good resistance to oxidation. There are also some disadvantages, like the lack of ductility at ambient temperature.

With the use of welding process intermetallic alloys FeAl properties can be changed. The Fig. 1 shows the microstructure alloy after crystallization (a) and after welding (b).

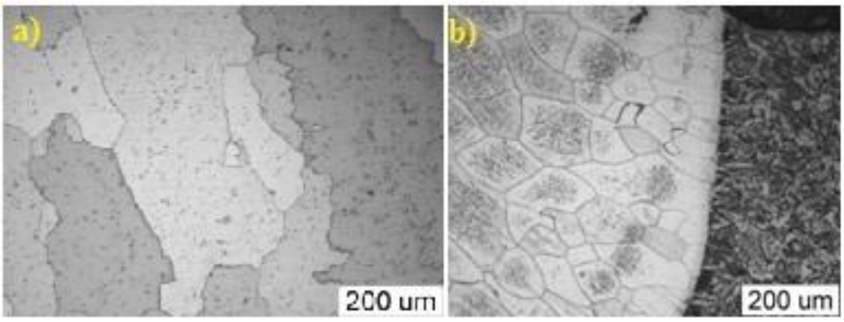


*Fig. 1: Microstructure of the Fe40Al5CrTiB alloy: a) additional material for cladding; b) after welding.*

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## 2. Methods

Material used in the research consists of Fe40Al5CrTiB alloy samples after crystallization. The chemical composition of the alloy is shown in Tab. 1

*Tab. 1: Chemical composition of the Fe40Al5Cr0.2TiB alloy.*

| Fe40Al5Cr0.2TiB | Fe | Al | Cr | Ti | B |
|---|---|---|---|---|---|
| % mass | 68.21 | 23.66 | 5.77 | 0.15 | 0.015 |

The paper analyzes implementation of welding method to make intermetallic surface Fe40Al5CrTiB on material grade S235JR. Welding process was conducted by tungsten inert gas (TIG). Parameters of welding process were described in Tab. 2 with the use of reserved polarity direct current (DC-).

*Tab. 2: Parameters of welding process.*

| TIG | 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 |

Tests were made for a single bead (SB), multi bead (MB) and multilayer (ML). Fig. 2 shows location of the bead.

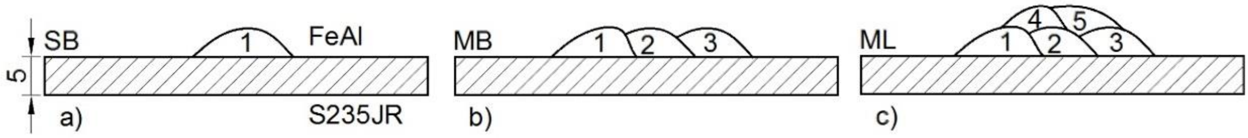


*Fig. 2: Hardness distribution of the distance from the top surface of the bead.*

Alloy microstructure based on intermetallic phase FeAl after welding process was analyzed by light microscope OLYMPUS GX51. The tests were made for three samples: single (SB), multi bead (MB) and multi layer (ML).

Processing of welding alloy matrix intermetallic FeAl removes casting defects (Fig. 3) but not completely. On the cross-section surface of intermetallic bead some imperfection of welding was seen. Fe-Al intermetallic alloy on S235JR steel is characterized by microstructure of columnar grains occurring in the zone from the melting point and by the presence of equilateral grains in the outer part of the clad.

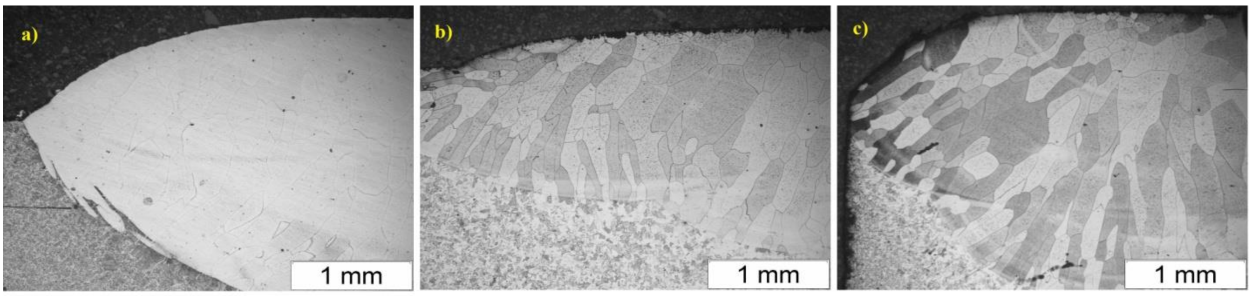


*Fig. 3: View of welding samples with imperfection.*

Hardness measurement was conducted on cross-section material. Hardness was measured with Vickers method according to a norm PN-EN ISO 6507-1 with a load 9.81 N (HV1) the device type ZWICK.

The Fig. 4 shows the results of hardness distribution HV1 measurement for specimens: SB, MB, ML.

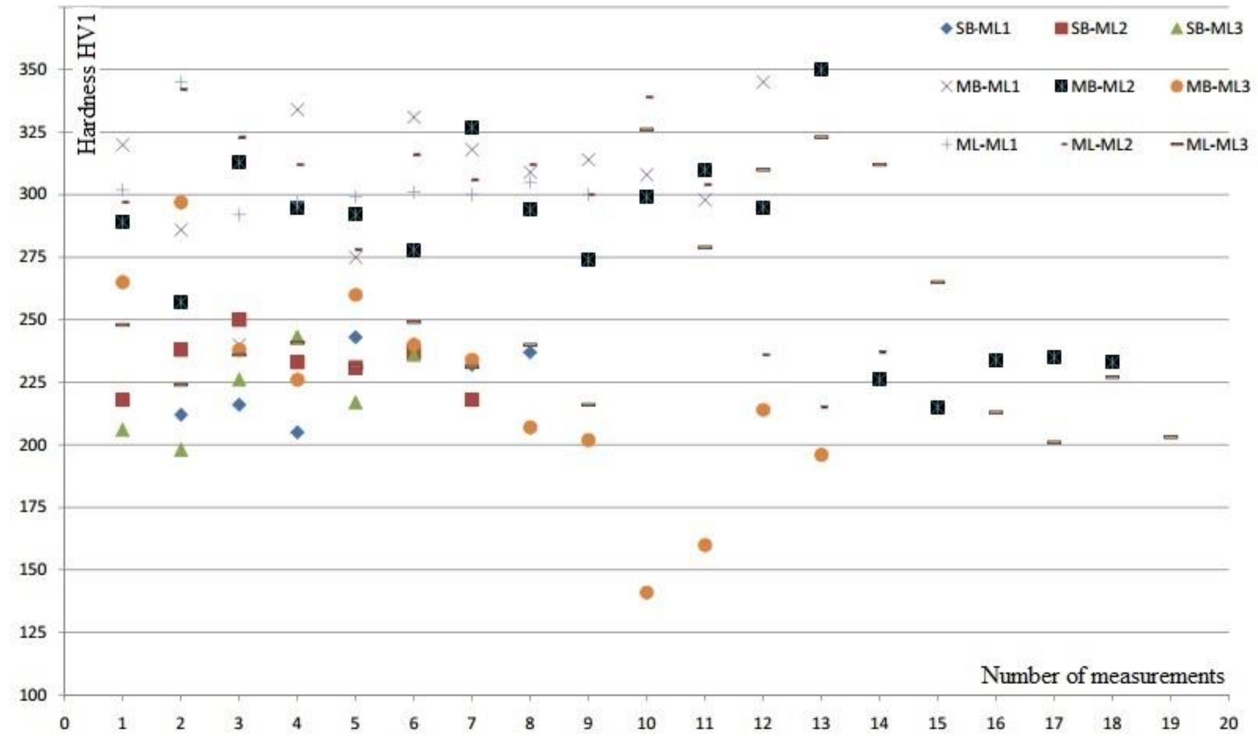


*Fig. 4: View of hardness distribution from the parent material to the top of the bead.*

Metallographic tests were conducted on polished micro-sections etched in ferric chloride. Microstructure observations were conducted with the use of metallographic microscope Olympus GX51.

Fig. 5 shows the coating structure for single bead (SB) (Fig. 5a), multi bead (MB) (Fig. 5b) and multi layer (ML) (fig.5c).

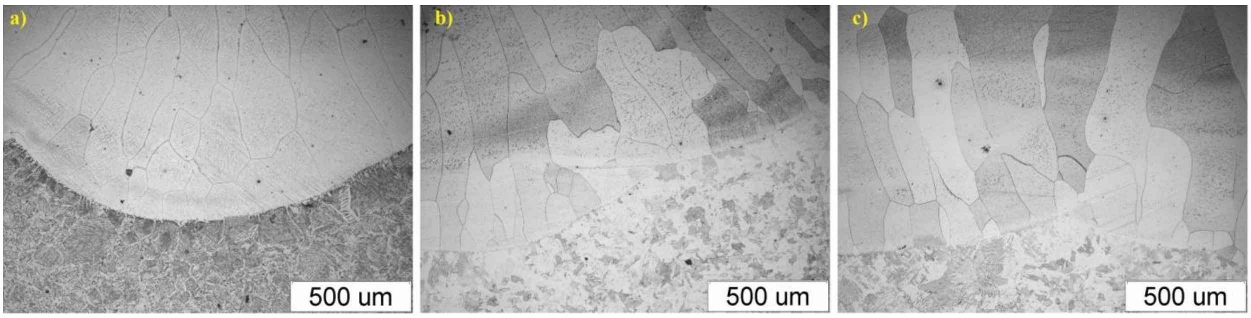


*Fig. 5: Microscopic view fusion line of clad.*

The chemical composition was determined by X-ray microanalysis EDS using a scanning electron microscope equipped with a Hitachi S4200 ray EDS detector. Fig. 6 shows the SEM surface analysis coating layers, in which, based on studies the presence of Al, Si, Cr, Fe is shown. Tab. 1 shows chemical analysis of intermetallic layers FeAl. Observations made using a scanning electron microscope of the deposit FeAl intermetallic alloy showed a coarse-grained structure of the weld layer and a clear line of separation of the base material and weld material (FeAl). The study of the chemical composition made with X-ray microanalysis EDS method showed reduced content of aluminium in the weld pad and unchanged chemical composition of the steel in the heat affected zone. The content of aluminium in the weld pad is 12 - 20 at %, indicating a substantial aluminium evaporation when melting during welding. The reduction in aluminium content of less than 37 at % results in formation of $Fe_3Al$ intermetallic alloy. Conducting the welding with reserved polarity direct current (100 A), intermetallic alloy Fe40Al obtained welding layer $Fe_3Al$ has different properties from the alloy used for welding. Despite the good corrosion resistance in high temperature compared to heat resisting steels, the corrosion resistance of FeAl intermetallic alloy is much higher.

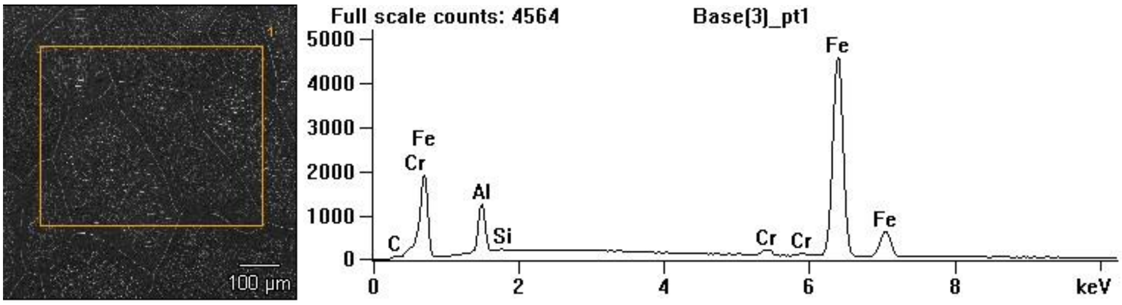


*Fig. 6: SEM analysis of the microscope together with an indication of the chemical composition.*

*Tab. 1: Number of Weight % (a) Number of Atom % (b).*

| *(a)* | ***Al*** | ***Si*** | ***Cr*** | ***Fe*** | *(b)* | ***Al*** | ***Si*** | ***Cr*** | ***Fe*** |
|---|---|---|---|---|---|---|---|---|---|
| | 6.1 | 0.2 | 1.3 | 92.3 | | 11.8 | 0.4 | 1.3 | 86.4 |

## 3. Conclusions

Microstructure of the Fe40Al5CrTiB alloy was changed after welding process. The microscopic grains grew and formed a coarse-grained structure of the material. Gas tungsten arc welding process is possible to make intermetallic surface FeAl. The test results show, that DC current can be used to burn this kind of material, but in cross section of pad several kinds of welding imperfection can be seen, such as pores, lack of fusion. This kind of imperfection is located on or near to fusion line. While making multi bead or multi layer this kind of imperfection is reduced. The imperfection occurs only in the first layer. Next bead or layer was without this kind of defects. Hardness distribution is checked in several line and results of these test show that; if it is the first or the last bead, the hardness is about 200 to 250 HV1; if there is more than one bead the hardness increases from 275 to 350 HV1. Observing by light microscopy (Fig. 4), it can be concluded that the microstructure of the weld layer of an alloy based on intermetallic phase FeAl has a heterogeneous grain size. In the boundary fused, where the speed of heat dissipation is larger, columnar crystals crystallize, whereas above they form more equated grains. This phenomenon is related to the conditions of crystallization of the weld layer. Grain between successive bead was melted and combined.

The welding layer made of an intermetallic alloy FeAl is characterized by coarseness and reduced aluminium content comparing to the content of this element in the material used for welding. The welding layer is homogeneous without the presence of welding defects such as emptiness, or discontinuity on the border of fusion.

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