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Microstructure and mechanical properties of intermetallics on the base of Fe-Al alloy obtained by casting

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ABSTRACT

Purpose: The aim of this work is to study the results of investigations of chromium addition influence on a microstructure and tensile properties of intermetallics from the Fe-Al system based on Fe_3Al phase.

Design/methodology/approach: The alloys for investigations were prepared by induction melting and gravity casting. The microstructure was analyzed after homogenizing which was performed at 1000°C for 24 and 48 h. Mechanical properties have been analyzed by the tensile tests witch were carried out at ambient temperature. After that the fracture has been analyzed (sample after 48 h).

Findings: As a result of microstructure observations of test alloys containing Cr and without Cr addition, the presence of phases and precipitates has been found. In both alloys Fe-28Al and Fe-28Al-5Cr the phases rich in Zr can be observed. Moreover in Fe-28Al-5Cr, phases rich in Cr are present mainly on grains boundaries, whereas Zr is present both on the borders and inside the grains. Carried out tensile tests and the results obtained indicate very low plasticity of both alloy without Cr addition and the alloy with the addition of 5% of Cr.

Research limitations/implications: The investigations showed that the most important part of production of iron aluminides is casting process. One can not avoid the casting defects in the materials after casting. Therefore one should particularly pay attention to melting and casting sequence. After the casting process one should the mechanism and the cause of the formation of phases and particles to get to know. The alternative for these materials so to subject produced in the aim of more far analyses to the plastic deformed.

Practical implications: The reasons of formation of Zr, Cr and other phases in these alloys have not been exactly known until now. They can significantly affect the properties of intermetallics from the Fe-Al system.

Originality/value: There have been disclosed the phases which are formed during casting and thermal processing in iron aluminides based on Fe3Al phase. They can significantly affect the properties of intermetallics from the Fe-Al system.

Keywords: Metallic alloys; Iron aluminides; Fe-Al alloys; Phases; Tensile strength

PROPERTIES

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1. Introduction

Ordered intermetallic alloys based on Fe-Al diagram are considered as materials for high temperature applications. They constitute model potential substitutes for stainless steel or nickel superalloy. The interest in Fe-Al alloys is, among others, caused by their perfect resistance to the effect of oxidizing atmosphere, which contains sulphur compounds. The other reason for the interest in above-mentioned alloys is their high resistance to abrasive wear and their relatively low density as well as high technological properties while melting and casting together with low material costs [1,2,3,4] The matrix of potential structural alloys from Fe-Al system may constitute two intermetallic phases: Fe_3Al phase, which occurs in alloys containing 23-36 % at. of aluminium and FeAl phase, which is present in alloys including 36-48% at. of this chemical element [5,6,7]. The main obstacle in application of the aforementioned alloys as structural materials of full value is low plasticity in room temperature.

One of the most important conclusions from recent researches on iron aluminides is that low plasticity of alloys containing less than 40 at.% Al, which can be observed, for example, during the tensile test, is mainly caused by environmental effect, and particularly the moisture contained in the air [1,2,3,8]. In iron aluminides with low-aluminium content plasticity may be achieved through chromium-alloying as well as thermal treatment, without any significant effect on mechanical properties. In many works It has been proved, that proper technological plasticity may be achieved through the control of microstructure, control of hot deformation parameters and introduction of Cr in the amount of 2-6 at. [5, 9-12]. Moreover hot plastic deformation process study could be the basis to the development of this interesting alloys as a constructional materials with especial technology of plastic working design and brittle cracking susceptibility. [10,12,14-16]

2. Experimental details

Material for investigations constituted of multicomponent Fe-Al alloys (Fe-28Al, Fe-28Al-5Cr), the composition of which has been presented in table 1. The alloys have been subjected to melting in induction vacuum furnace. The melt has been made with the use of charge in the form of: ARMCO iron, aluminium of min. fineness of 99,98%, molybdenum in the form of pressed metal powder of technical fineness, powdered iodine zirconium of technical fineness, carbon in the form of anthracite, amorphous boron of chemical fineness. The obtained heat was melted twice. The next stage was casting the melt to the graphitoidal moulds in the form of bars with dimensions of Ø12mm and l=120 mm. Subsequently, the material was subjected to homogenizing annealing at the temperature of 1000^0C for 24 and 48h.

Table 1.
Chemical composition of the alloys.

Elements contents [at. %]						
Al	Mo	Cr	Zr	C	B	Fe
28,0	0,20	-	0,05	0,1	0,01	71,64
28,0	0,20	5,0	0,05	0,1	0,01	66,64

The Mo addition has been used for the purpose of improving the high temperature resistance. In order to decrease grain sizes after the crystallization process, a modifier in the form of zirconium has been used. The carbon addition has been used in order to increase resistance, and boron has been used in order to increase the resistance of grain boundaries [4]. Metallographic researches were carried out with the use of metallographic light microscope. The microanalysis of chemical properties of tested alloys after the process of homogenization were carried out with the use of HITACHI S-3400N scanning microscope. The microscope was equipped with VOYAGER SYSTEM SIX roentgen microanalysis system together with EDS spectrometer.

The mechanical properties of presented alloys were determined during the tensile test. The research was conducted at the ambient temperature with the use of cylindrical samples with the following dimensions of gauge: d=6mm and l=30 mm. The properties were determined for two samples of each of the alloys.

3. Results of the research

Microstructures of Fe28Al alloy without Cr (Fe-28Al) and Fe28Al alloy with Cr (Fe-28Al-5Cr) after the process of homogenizing annealing with assumed parameters have been presented in Fig. 1-4. The microstructure - the grains of variable dimensions with characteristic residues of dendritic structure were observed in tested materials. Both on the boundaries of dendrite grains and inside the grains, the phases of different size and form are observable. A detailed analysis of revealed phases has been carried out with the use of scanning microscope with EDS analyzer. The analysis has proven the occurrence of the phases rich in Fe and Al as well as single Zr precipitates in Fe28Al alloy without Cr. The phases rich in Cr and Zr have been identified in alloy containing Cr (Fig. 4). The presence of the phases is probably a result of the casting processes during the formation of precipitates while the annealing process. A detailed analysis of the causes for the formation of particular types of phases and precipitates will be the objective of further research.

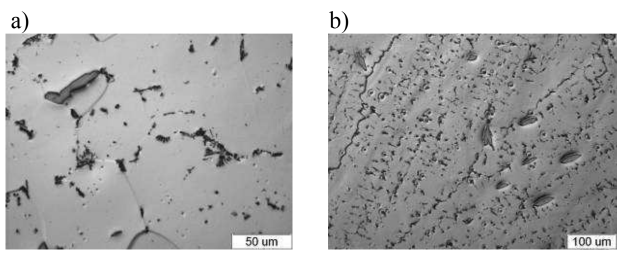

Fig. 1.Microstructure of Fe28Al alloy after 24h (a) and 48 h (b) annealing. Precipitates and phases on the boundaries of grains and inside the grains

After the process of thermal treatment, tested alloys were subjected to uniaxial tensile test at ambient temperature. As a result of conducted tensile tests, relation charts $F = f(\Delta l)$ were obtained (the charts presented in Fig. 5 and 6). Furthermore, some basic mechanical properties of tested alloys (i.e. R_m, $R_{0,2}$ i A_5) were determined (Table 2). The results obtained indicate low plasticity level of both alloy without Cr addition and alloy with the contents of 5% of Cr. As an example, the extension of A_5 for no. 1 specimen of Fe-28Al alloy accounts for 1,2% and for no.1 specimen of Fe-28Al-5Cr alloy is equal to 2,5%.

a) b)

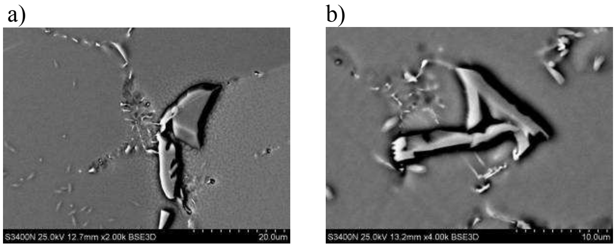

Fig. 2. Microstructure of Fe28Al alloy without Cr after 24h (a) and 48 h (b) annealing. The phases visible with the use of BSE technique.

The analysis of Cr addition influence on mechanical properties has shown that in the samples containing Cr in the amount of 5% at., double increase of A_5 extension in comparison with samples which do not include Cr can be observed. The above-mentioned observations are related to the decrease of materials resistance properties (i.e. R_m, $R_{0,2}$).

a) b)

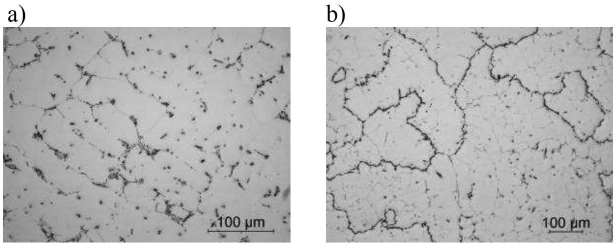

Fig. 3. Microstructure of Fe28Al-5Cr after armeling at 1000°C for: a) 24h and b) 48h. Precipitates and phases on the boundaries of grains and inside the grains.

a) b)

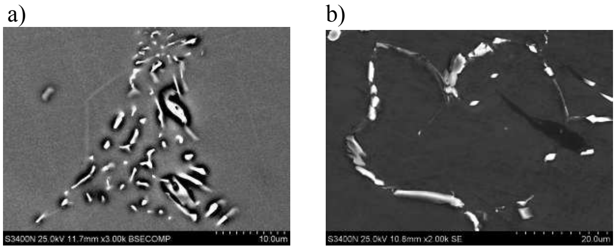

Fig 4. Microstructure of Fe28Al-5Cr after armeling at 1000°C for: a) 24h and b) 48h.. Phases and precipitates revealed with the use of SEM.

Table 2.
Mechanical properties determined during the tensile test.

Alloy	R_m[MPa]	$R_{0,2}$ [MPa]	A_5 [%]
Fe28Al	463,6	414,7	1,2
Fe28Al5Cr	285,3	271,6	2,5

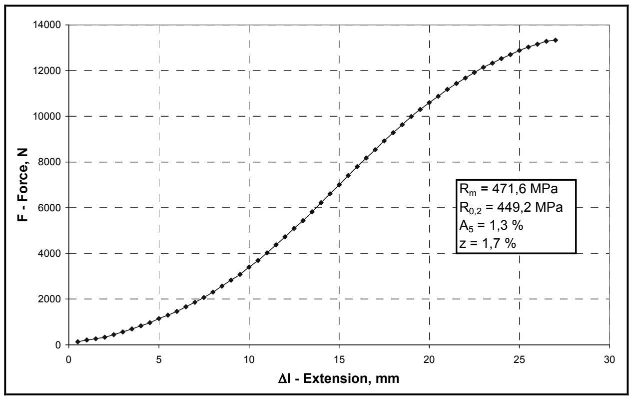

Fig.5. The chart on Fe28Al extension.

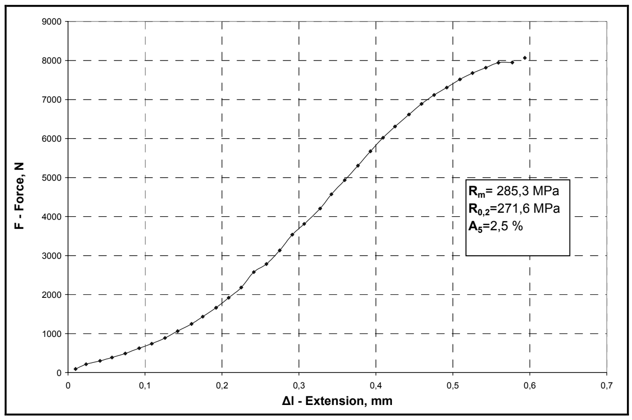

Fig.6. The chart on Fe28Al-5Cr extension.

4. Conclusions

As a result of microstructure observations of tested alloys containing Cr and without Cr addition, the presence of phases and precipitates has been shown. In case of the alloy without Cr addition, the majority of phases are the phases with chemical composition similar to the matrix. It should be noted that the phases are probably not stoichiometrically identical. It has been proven that their microhardness is significantly higher than the matrix hardness. Apart from the aforementioned, Zr precipitates are present in the structure. In Fe-28Al-5Cr alloy, the phases rich in Cr and Zr can be observed. Moreover, Cr occurs mainly on the grains boundaries, whereas Zr is present both on the borders and inside the grains.

Carried out tensile tests and the results obtained indicate low plasticity of the alloy without Cr addition and the alloy with the addition of 5% of Cr as well. However, the improvement of plastic properties of materials with Cr addition as well as the extension measured during tensile strength, which increased by 100%, has been proven. The above-mentioned facts prove the favourable impact of Cr alloying the Fe_3Al intermetallics.

However, it should be noted that performed researches were carried out with the use of alloys after casting. In case of such alloys, the occurrence of casting defects can not be eliminated. After the tensile tests, defects in the form of voids caused by casting contraction were revealed in the samples' axis. The abovementioned had a great influence on obtaining both the tensile strength value and the proof stress.

Acknowledgements

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