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Structures and phases transitions of the alloys on the bases of Fe-Al intermetallic phases

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ABSTRACT

Purpose: The paper presents study the results of investigations the influence of the chemical composition and thermal treatment on the microstructures and phases transitions of intermetallics from the Fe-Al system.

Design/methodology/approach: Investigated alloys with 28, 38 and 42% at. Al were melted in vacuum induction furnace. Next stage of the preparing was gravity casting for cylindrical graphite moulds in the form of bars. The structure was analyzed after annealing at 1000°C for 24 and 48 h. The phases transitions were carried out by using a DTA method on the Setsys made by Setaram.

Findings: The microstructure observations indicated the presence of phases and precipitates in all investigated alloys. In all of the investigated alloys, precipitation of phases present in the structure as a result of the introduction of alloying additions, such as Zr, Cr, Mo and C, is visible. transformations connected with both disorder-order transitions and the initial temperature at which a liquid phase occurred in the alloys had taken place during heating.

Research limitations/implications: The investigations showed that the very important in production of intermetallics from Fe-Al system is casting and thermal treatment process. The important is knowledge about the phases transformations in this alloys which taking the informations about the melting points, order – disorder transition and their correlations with structure and in consequence the mechanical properties.

Practical implications: The formation of phases and precipitates during the heat treatment in these alloys have not been known until now. This structures aspects are significantly affect the properties of intermetallics from the Fe-Al system. In correlation with temperatures of phases transition they could take the most important informations for technological processing.

Originality/value: We needed more details about intermetallic from Fe-Al system for their development. This paper are the valid supplement for development knowledge of the iron aluminides.

Keywords: Metallic alloys; Iron aluminides; Phases transitions

MATERIALS

1. Introduction

Alloys based on intermetallic phases have been popular for more than ten years now. Due to a mixed nature of interatomic bonds, they belong to a group of materials somewhere between metals and ceramics, in terms of their properties. One of such groups is represented by intermetallics from the Fe-Al system. These materials are characterised, inter alia, by capacity for operating at elevated temperatures, as well as good strength-related properties and resistance to oxidation and corrosion at an increased temperature. In addition, a low cost of alloy components and low density caused by aluminium content are their advantages. The above-mentioned properties are mostly a consequence of the long-range arrangement present in these materials, resulting from a reversible order-disorder transition. The long-range arrangement contributes to the creation of strong chemical bonds and dense filling of space with atoms [1-6].

Therefore, Fe-Al intermetallics can be an alternative to both nickel superalloys in the production of equipment for aircraft, aerospace and power engineering industries, and in the production of steel with specific properties [1,3-7]. In practice, however, their low plasticity at an ambient temperature is still an obstacle to their industrial application. On one hand, the orderly structure is an important factor exerting a positive impact on a number of strength properties and structural stability at an increased temperature and; on the other hand, their limited plasticity seems to necessitate a complex thermo-plastic treatment for their forming. As recent studies show, it is not only the orderly structure that positively influences FeAl intermetallics' strength properties, but also the presence of other phases in the structure, induced by the introduction of alloying additions. Strengthening is caused by both phase precipitation during alloy casting and thermal treatment [6-11].

The scope of this paper covers phase transition studies in alloys with different Al content, i.e. 28 at.%, 38 at% and 42 at.%, and analyses of these alloys' microstructures after casting and homogenization [2,6-9, 12-14].

2. Methodology of research

The research materials used are alloys with a Fe-Al intermetallic phase matrix and a chemical composition presented in table 1.

Table 1.
Chemical composition of investigated alloys (%at.)

-	Al	Mo	Cr	Zr	C	B	Fe
Fe28AlCr	28,0	0,20	5,0	0,05	0,1	0,01	66,64
Fe38Al	38,0	0,20	-	0,05	0,1	0,01	61,64
Fe42Al	42,0	0,20	-	0,05	0,1	0,01	57,64

The material was prepared using the gravity casting technique. Melts were produced in an induction vacuum furnace at a pressure of 1.0 Pa. Having melted the charge, the bath was homogenized and cast into graphite moulds. Such process was repeated three times with a mechanical cleaning between the three operations. Ingots were obtained with the following dimensions: f15mm and l=120mm.

Next, the materials were subjected to homogenization at a temperature of 1000 °C for the period of 24h and 48h so that any structural changes caused by changing soaking parameters could be observed. A Differential Thermal Analysis (DTA) was made for the as-annealed materials in order to identify the phase transitions and their temperatures. The studies were conducted using a Setaram's thermal analyzer, Setsys. The process of heating was conducted in an argon atmosphere with a heating speed of 5°C/min to the temperature of 1450°C. An EDS analysis of the microstructure and precipitates in the examined alloys was conducted by means of a Hitachi scanning microscope.

3. Results of researches

The primary structures of studied alloys' samples, Fe28AlCr, Fe38Al and Fe42Al, are presented in fig. 1, 2 and 3. The alloy with 28 at.-% Al content showed a dendritic structure with a certain amount of precipitates. A similar microstructure is observed in the alloy with a 38 at.-% Al content. The microstructure of the alloy with a 42 at.-% Al content presents a little better shaped grain and dendrite boundaries. In all of the investigated alloys, precipitation of phases present in the structure as a result of the introduction of alloying additions, such as Zr, Cr, Mo and C, is visible.

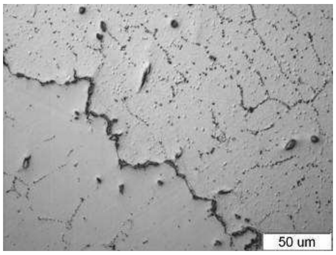

Fig. 1. Microstructure of the Fe28AlCr after casting

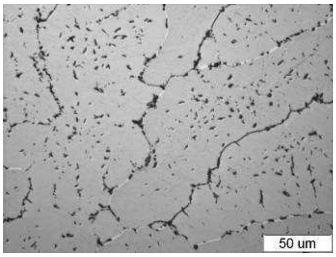

Fig. 2. Microstructure of the Fe38Al after casting

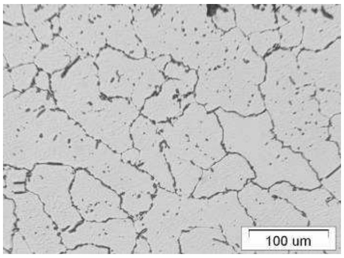

Fig. 3. Microstructure of the Fe42Al after casting

Afterwards, the investigated materials were annealed to homogenize their structure. In the case of alloys with a dendritic primary structure, the main purpose was to homogenize the composition and distribution of the precipitates, since the primary structure should not be modified. Examination of the microstructure after homogenizing treatment showed insignificant changes in the distribution of the detected phases. The materials' microstructures after homogenization are presented in fig. 4, 5 and 6.

a) b)

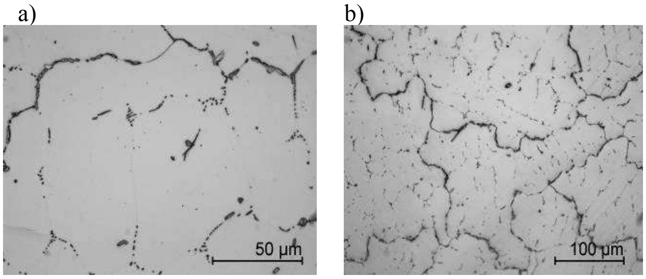

Fig. 4. Microstructure of the Fe28AlCr after homogenizing a) 24h, b) 48h – cooling with furnace

a) b)

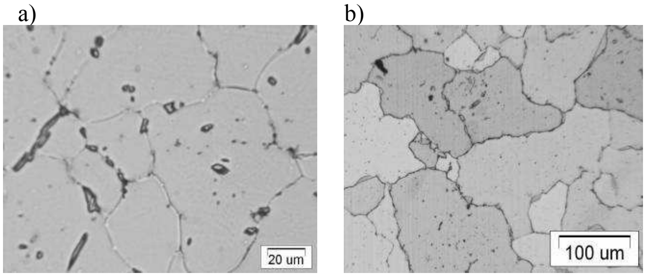

Fig. 5. Microstructure of the Fe38Al after homogenizing a) 24h, b) 48h – cooling with furnace

a) b)

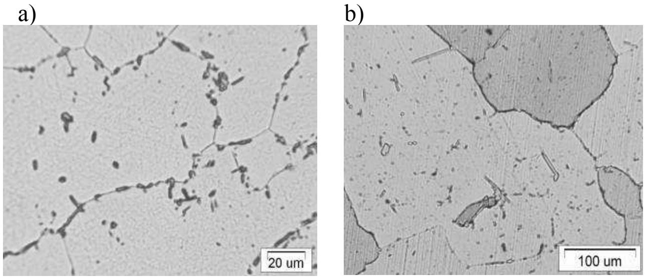

Fig. 6. Microstructure of the Fe42Al after homogenizing a) 24h, b) 48h – cooling with furnace

The studied alloys were subjected to a phase transition analysis via the DTA method (figs.7-9).

A differential thermal analysis of the alloys disclosed that transformations connected with both disorder-order transitions and the initial temperature at which a liquid phase occurred in the alloys had taken place during heating.

Further details will be provided after repeating the studies using the DTA method.

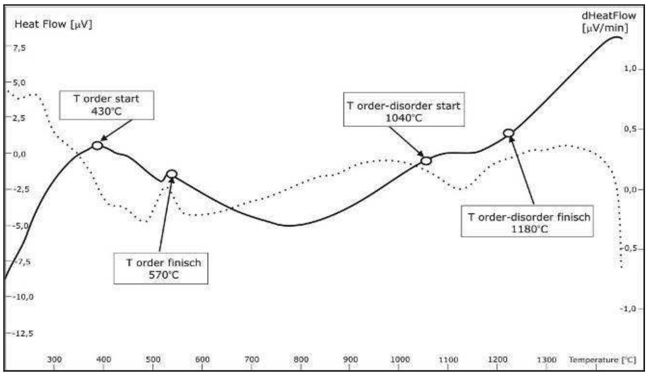

Fig. 7. DTA i dDTA curves for Fe28AlCr alloy

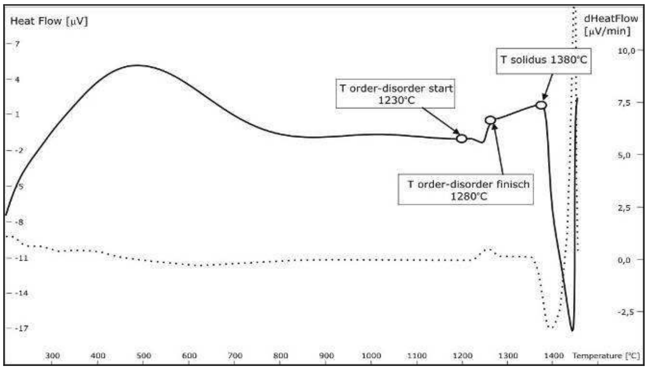

Fig. 8. DTA i dDTA curves for Fe38Al alloy

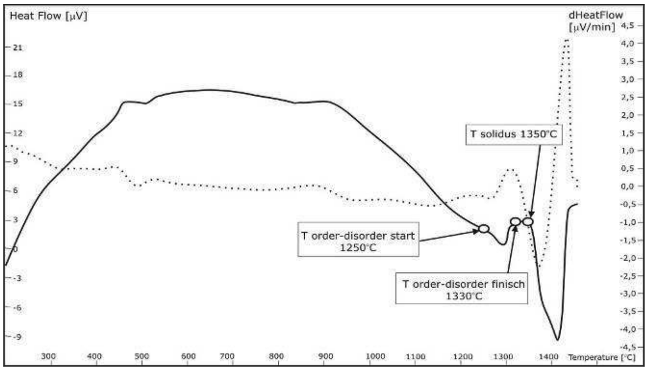

Fig. 9. DTA i dDTA curves for Fe42Al alloy

4. Conclusions

The paper deals with an evaluation of the microstructure of Fe-Al intermetallic phase based alloys with a variable aluminium content. The primary structure was disclosed, which, in the case of the Fe28AlCr alloy, was a dendritic structure with the presence of phases probably originating from the introduced alloying additions, i.e. Cr , Zr and Mo. Their presence was detected in the chemical composition microanalysis. Thermal treatment does not cause any significant changes in the structure. Studies conducted using the DTA method demonstrated the existence of two transformations during heating, which were connected with the order-disorder transition, with the first transformation in a temperature ranging from 430°C to 570°C probably accompanied by reconstruction of the internal structure. The temperature at the final stage of heating, i.e. 1450°C, is too low to detect a transformation connected with the transition from a solid to liquid state. In the case of the Fe38Al alloy, similarly to the alloy with 28 at.-% Al content, a dendritic structure is visible after casting. Analysis of the detected phases showed the presence of mostly Zr and Mo, which were also alloying additions. The DTA analysis showed the occurrence of one phase transition during heating, i.e. an order-disorder transformation. The transformation is initiated at a temperature of 1230°C, while its end is observed at 1280°C. The beginning of alloy melting took place at a temperature of 1380°C.

After casting, the Fe42Al alloy has a structure presenting a combination of a primary dendritic structure with hardly visible grains. Similarly to the other two alloys, Zr and Mo phase precipitations occur. During the analysis, an order-disorder transformation was detected, beginning at 1250°C and finishing at 1330°C. The beginning of alloy melting was determined to take place at a temperature of 1350°C.

Acknowledgements

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