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Al- FeAl-TiAl-Al_2O_3 composite with hybrid reinforcement

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Abstract: The process of obtaining cast aluminium composite of dispersive structure and hybrid reinforcement has been presented in the article. An Aluminium alloy was modified with a powder mixture which, when in reaction with aluminium, reinforced the matrix with intermetallic phases and aluminium oxide. The reinforcing phases were using Fe-Ti-Al powder mixtures with aluminium oxide formed in a self-propagating high-temperature synthesis process (SHS). The structure and phase composition of the composite powder used for the matrix alloy modification are shown in Figure 1.

A Composite alloy Al-FeAl-TiAl-Al_2O_3 was produced by casting method (gravity casting, mechanical mixing) after which its structure was determined. It was assumed, that the final product of the applied production process will be an aluminium composite with hybrid reinforcement, consisting of Fe-Al and Ti-Al intermetallic phases and aluminium oxides. Optical microscopy, electron scanning microscopy and X-ray phase analysis were used to characterize the microstructure of the composites produced. Presence of aluminium, Al_3Ti and $Al_{13}Fe_4$ phases and dispersed Al_2O_3 was confirmed in the composite by XRD method. The dispersion structure and phase composition of the composites are presented in Figures 2 and 3.

The designed process allows for the structure modification of the applied casting aluminium alloys in different technological variants.

Keywords: Aluminium alloy, Composite powders, Intermetallic phases, Gravity casing, Structure.

1. INTRODUCTION

The methods of incorporating fine dispersed particles into a liquid metal applied up to now make use of the in situ reaction between a liquid metal (or a chemical element being a component of the alloy) and the incorporated reacting substance, most frequently gas, e.g. oxidation of Al by oxygen), run-purge with CnHm gases, as a result of which dissociation and carbides formation occur [1-4]. The exchange reactions, which proceed between Al and the incorporated oxides of high dispersion (particles of a few dozen micrometers in size),can be applied as well. An example of such a solution is the application of oxides like CuO [2].

Another solution allowing the incorporation of fine dispersed particles into Al alloys is to apply a mechanical alloying (MA) process in which Al powder is combined with ceramic powder [5,6].

This paper presents only a fragment of investigations conducted by article's authors on the use of chemically active and passive composite powders obtained in the SHS process (self-propagating high-temperature synthesis) for the production of hybrid composites reinforced with intermetallic phases and fine dispersed ceramic particles produced by casting methods (mechanical stirring and centrifugal casting) [5-7].

2. PURPOSE AND SCOPE OF THE RESEARCH

The main purpose of the research was to determine the chemical composition of metallic-ceramic powders and the process of production aluminium-based composite casts with hybrid reinforcement of high phase dispersion.

The scope of the research covered:

- development of a material and technological concept of composite material production;
- selection of chemical compositions of metallic-ceramic powder mixtures;
- carrying out the initial research with the purpose of the basic material production parameters determination in the accepted technological cycle;
- determination of structure and phase composition of the chosen composite powders and the produced composite casts;
- correction of parameters in the technological cycle of producing aluminium casts of the assumed dispersive structure and phase composition of the reinforcement.

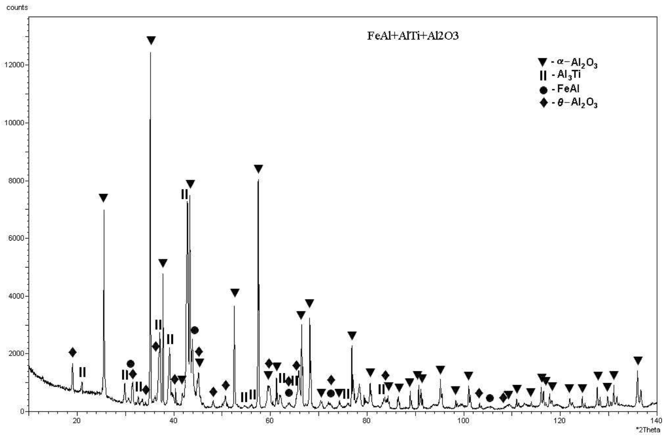
3. MATERIALS AND METHODOLOGY OF RESEARCH

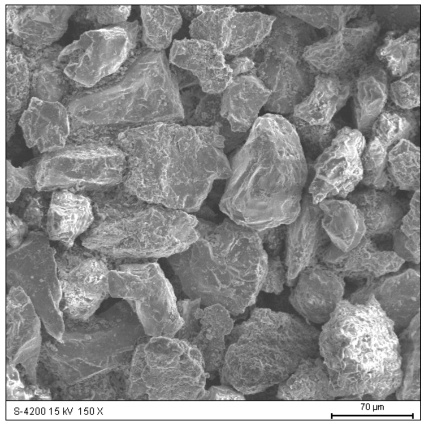
For the assumed analytic purposes, powder materials, aluminium alloys, technological devices and research methods chosen allowed the production of a composite material of an aluminium matrix composites type (AlMCs). Selection of materials and methods for the composite material production included application of powder metallurgy [8] and casting processes [9]. For the purpose of powder mixtures production, ilmenite and powders of aluminium as the substrate, of a pure sort were used. Sinters of the composite were produced in a high-temperature synthesis process (SHS) followed by crushing, milling in a rotary-vibration mill and separation into adequate fractions. The powders were introduced into liquid aluminium alloys at the temperature scope from 700^0 to 720^0. Aluminium was modified with magnesium up to 2% of its content in the bath. In the casting process of the composite material production, resistance furnaces were used. The mixture of powders was introduced into melted aluminium in a rotary motion and stirred mechanically for 30 minutes. The composites produced were cast into a graphite mould.

The powders and casts structure was observed on metallographic specimens, using the Reichert MF2 microscope with digital camera for the photographs registration. The chosen specimens were analysed using a Hitachi scanning microscope equipped with EDX equipment, in Norton's Voyager system. The phase composition of the composite powders and casts was analysed with the use of Philips diffractometer with copper lamp and carbon beam filter. The diffraction patterns were analysed by means of ASTA cards and X-Pert Software programme.

4. THE RESEARCH RESULTS

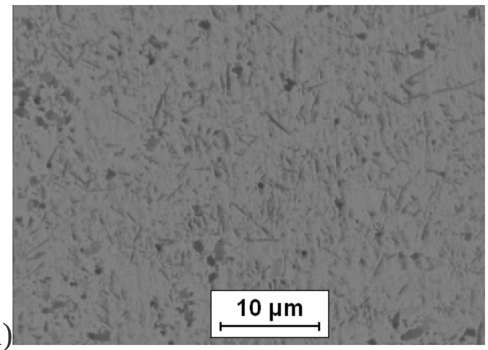
The structure and phase composition of the chosen reactive powders are shown in Figure 1. On the basis of structural investigations as well as an X-ray analysis the occurrence of the aluminium matrix reinforced with intermetallic and ceramic phases has been confirmed (Figures 2,3). The size of reinforcing particles is in correlation with granulation of the powder used.



a)


b)

Figure 1. Diffraction pattern a) and the structure b) of FeAl-TiAl-Al_2O_3 initial powder mixture used for the matrix alloy modification.

a)


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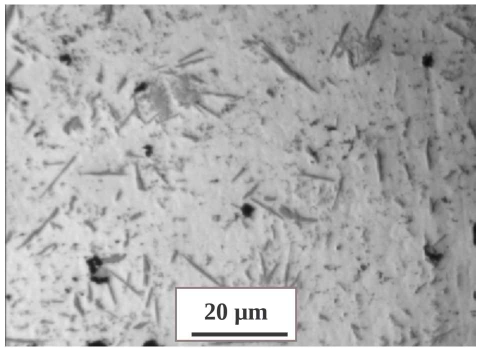
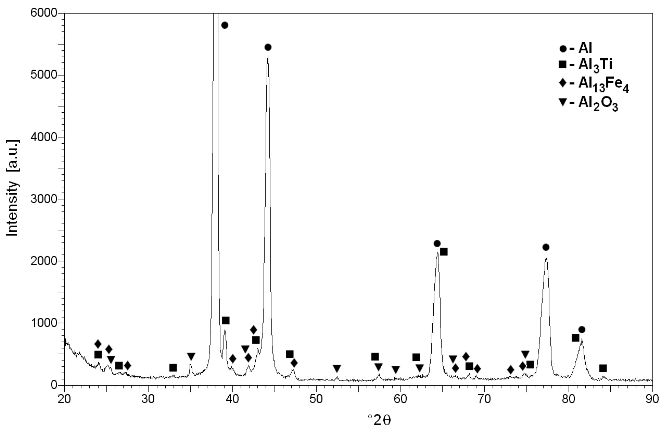
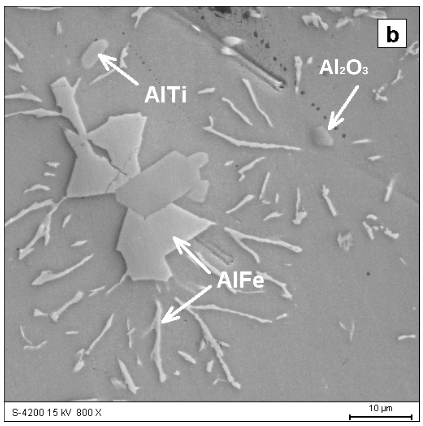


Figure 2. The dispersive structure of Al-FeAl-TiAl-Al_2O_3 composite casts.



a)


b)

Figure 3. Diffraction pattern (a) and the structure (b) of Al-FeAl-TiAl-Al_2O_3 composite casts.

That fabricated composite casts were characterized by a dispersive structure of a predefined chemical and phase composition.

According to the assumptions and on the basis of the earlier thermodynamic analysis and thermal differential analysis, the matrix reinforcement can be written down by means of the following reactions:

$$FeAl + TiAl + Al_2O_3 + (x + 4)\ Al \rightarrow FeAl_3 + TiAl_3 + Al_2O_3 + x\ Al \quad (1)$$

It needs to be emphasised that while introducing the powders mixture into liquid metal, an exothermal effect of the reactions in progress was observed.

5. SUMMARY

The production technology of aluminium matrix composite casts with hybrid reinforcement of high phases dispersion has been presented in the article. The technological process variants enable application of the semi-finished composite product for the centrifugal casting process of aluminium matrix composites alloys [10].

Owing to the editorial reasons, the chosen results of research upon the production of Al-FeAl-TiAl-Al_2O_3 cast composites have been presented.

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