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Structure and properties of $Al_{67}Ti_{25}Fe_8$ alloy obtained by mechanical alloying

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ABSTRACT

Purpose: The goal of this work is to investigate structure and properties of powders$Al_{67}Ti_{25}Fe_8$ alloys obtained by mechanical alloying.

Design/methodology/approach: The powders of the $Al_{67}Ti_{25}Fe_8$ alloys were obtained by mechanical alloying method in a planetary Fritsh Pulverisette 5 mill. The changes of the constitution phases were tested by means of the X-ray diffractometer. The microscopic observation of the shape and size of the powdered material particles was carried out by the scanning electron microscope. The cross-sectional microstructure evolution and element distribution of $Al_{67}Ti_{25}Fe_8$ powder alloys were investigated using backscattering electrons of SEM. The distribution of powder particles was determined by a sieve analysis.

Findings: The laboratory test shows that, by using the mechanical alloying method, one can produce powder of $Al_{67}Ti_{25}Fe_8$ alloys with intentional chemical constitution and desirable structure. Neither impurities nor undesirable phases were observed inside the milled materials.

Research limitations/implications: Using refinement of grains and phase modification it is possible to improve properties of $Al_{67}Ti_{25}Fe_8$ alloy. All of the presented experiments in this article are made on a laboratory scale. It is intended to develop this laboratory scale technology of production materials with better properties then traditionally cast materials in order to bring it into full production in industry.

Originality/value: In addition a good microstructural homogeneity end first of all mechanical properties was achieved, also practical application will be possible. The Al-Ti-Fe alloys have been considered to be potentially important for applications at high temperature owing to their low density end expected high specific strength.

Keywords: Metallic alloys; Mechanical alloying; Powder metallurgy; Al-Ti-Fe alloy

MATERIALS

1. Introduction

The mechanical alloying (MA) technique is a simple method to obtain compound phases from elemental powders. Mechanical alloying method enable to obtain supersaturated solid solution, intermetallic phases, crystalline and amorphous phases. Mechanical alloying is a complex process that require optimizing many parameters to achieve desirable material. The following parameters have an influence on powder structure and properties: time of milling process, the mill type, atmosphere, ball to powder weight ratio, process control agent. The essence of the mechanical alloying process is the action of the grinder balls colliding with powder grains and the interaction of the powder grains. During this process the change of the chemical composition and material microstructure occurs [1-9].

The Al-Ti and Al-Fe alloys have specific properties: low density, high strength, good corrosion resistance at elevated temperature. They are very attractive materials for the aircraft and defense industry. There have been a lot of investigations on the mechanical alloying of binary Al-Ti and Al-Fe system. The mechanical alloying process of these powders has been studied by Liu et al., Bonetti et al. and Venkatasuwamy et al., separately. The addition of a third element to the binary alloys can improve their properties. For example: Al is very ductile, Ti element has a positive influence on tribological properties, increase the yield strength, raised the transition temperature and produced precipitation strengthening at elevated temperatures [10-15].

The main goal of the present investigation was to study the structural and phase transformations that take place during the mechanical alloying of the ternary $Al_{67}Ti_{25}Fe_8$ alloy in a planetary ball mill. This paper is concerned with the structural characterization of mechanically alloyed Al-Ti-Fe powders.

2. Experimental procedure

The investigation on $Al_{67}Ti_{25}Fe_8$ alloy were conducted. The test material was the mixture of aluminium, titanium and iron powders in suitable weight relation. The mechanical alloying process was conducted in a high-energy planetary ball mill Fritsch Pulverisette 5. In this process wasn't added process control agent. The ball to powder weight ratio was 8:1. In order to prevent powder oxidation, the samples were sealed in the vial under argon atmosphere. The powders were ground for 100 hours. The microscopic observation of the shape and size of the powdered material particles was carried out by means of the OPTION DS 540 scanning electron microscope, within the magnification of 500 and 2000 times. The changes of the powder structure were tested by means of the Philips PW 1140 X-ray diffractometer. Powder samples were analyzed by energy dispersion spectroscopy too. The measurements of particles size were carried out by means of the sieve analysis.

3. Results

The as-milled powders consist of a fine mixture of pure elements and amorphous phases. The phase X-ray analysis no exhibit the changes in the phase composition occurring in the 100 hrs of mechanical alloying process. The diffraction pattern recorded for the powder ground for 100 hrs shows the peaks characteristic for Al, Ti and Fe-α (Fig. 1). The extending of peaks is connected with the size reduction in the powder grain as well as with the presence of considerable stresses resulting from the intensive plastic strains occurring during the grinding.

There is broadening of the XRD patterns and increasing the background as mechanical attrition progresses, suggesting the formation of an amorphous phase, fine crystalline grains and high density of defects.

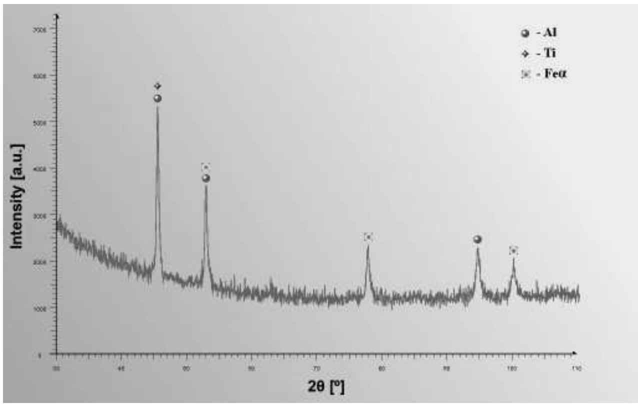

Fig. 1. The X-ray diffraction patterns of $Al_{67}Ti_{25}Fe_8$ powder alloy after 100 hrs of mechanical alloying

The morphology of initial powder particles was presented in Fig. 2, Fig. 3. The shape of particles powder is irregular.

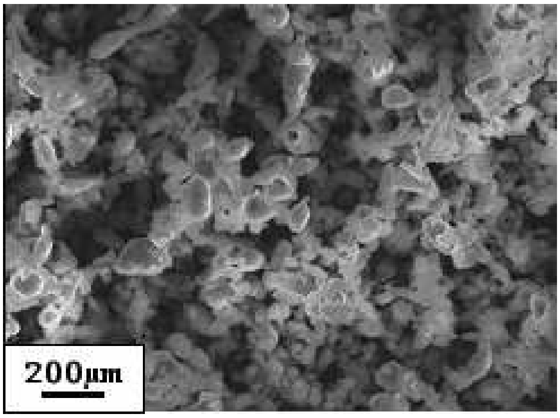

Fig. 2. Structure of initial powder mixture of Al-Ti-Fe alloy

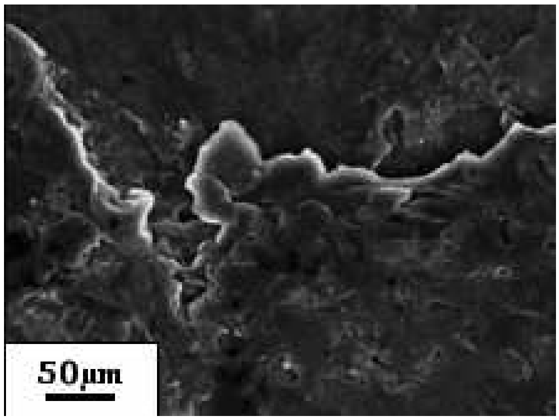

Fig. 3. Structure of powder particle surface of Al-Ti-Fe alloy after 100 hrs of mechanical alloying

The cross-sectional microstructure evolution and element distribution of $Al_{67}Ti_{25}Fe_8$ powder alloy were investigated using

SEM. Typical images of the cross section of $Al_{67}Ti_{25}Fe_{8}$ powders after 100 hrs of mechanical alloying is shown in Fig. 4. Bright, grey and dark areas in this micrographs correspond to Fe, Ti and Al, respectively. From these images, it can be seen that the elemental distribution of Fe, Ti and Al was not uniform in this stage of milling. During the process, the powders become effectively broken up while the equilibrium between the cracking and joining is fixed, which results in the laminar structure. Chemical composition of the areas' powder particles after 100 hrs of mechanical alloying are shown in table 1.

Table 1.
Chemical composition of investigated powders

Test area	Identify elements	Atomic percent [%]	Weight percent [%]
1	Al	2.90	1.42
1	Ti	0.54	0.47
1	Fe	96.56	98.11
2	Al	2.23	1.27
2	Ti	97.77	98.73
3	Al	100	100
4	Al	89.08	80.65
4	Ti	4.17	6.7
4	Fe	6.75	12.65

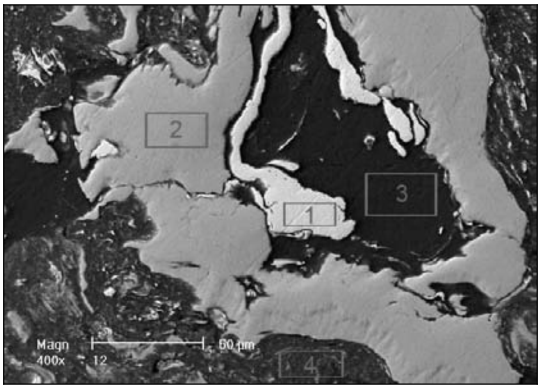

Fig. 4. Cross section SEM image of $Al_{67}Ti_{25}Fe_{8}$ powder alloy mechanically milled for 100 hrs

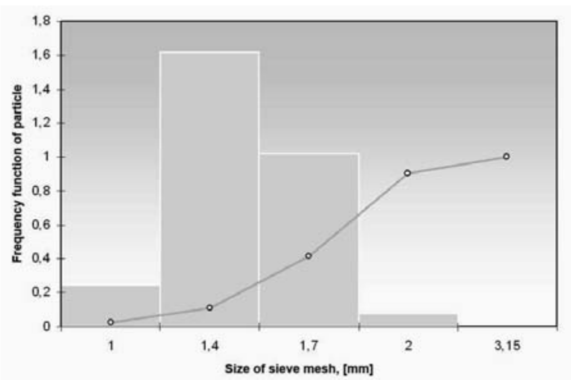

Fig. 5. Particle size distribution

The important factor determining properties of materials is the particle size. The distribution of powder particles was determined by a sieve analysis. The powder particles size and their distribution are presented in Fig. 5.

4. Conclusions

Mechanical alloying method can be used to produce satisfactory materials in Al-Ti-Fe systems.

The laminar structure generally result from repeating welding of powder particles during mechanical alloying. Probably, the laminar structure will be broken as the process will be continued, a homogeneous structure will be formed.

The process control agents have an strongly influence on the phase composition of the manufactured alloy. Aluminium is very ductile, therefore a process control agent should be used for preventing of sedimentation of Al powder to the mills' walls and balls.

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