MECHANICALLY ALLOYED COMPOSITE MATERIALS BASED ON DUMPING WASTE WITH COMPLEX COMPOSITION

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Abstract

The present study investigates the possibility of obtaining of the mechanically alloyed composite material based on mixed industrial metal waste in the form of chips. Mechanical alloying of chip's particles with average composition Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr were carried out in a planetary mill. Change of the structure and properties of the granules of this material during mechanical alloying is estimated. For an assessment of some operational characteristics the consolidated sample is obtained. The consolidated sample of this material has a high hardness at room and elevated temperature, low value of linear thermal expansion coefficient and high wear resistance.

1 Introduction

At the companies which specializing in the production of secondary aluminum alloys during preparation for re-melting of chip's waste a significant amount of the so-called dumping waste is accumulated. Dumping waste is a mixture of chips with different chemical composition which contains Fe in the form of mechanical impurities and may also contains a significant amount of solid non-metallic impurities such as abrasive grains of cutting tools. Such wastes are practically non-recyclable. The chemical composition of each batch of dumping waste is different, but in conditions of the concrete company the composition of dumping waste from defined batches of chips is similar. Due to powerful shock-abrasive effect on the material in the high-energy mill it is possible to achieve a total dispersion of all components [1-2]. This kind of waste can be inexpensive raw material for the production of dispersion strengthened composite materials by mechanical alloying [3-4].

2. Materials and Testing Methods

To investigate the possibility of obtaining of composite material based on the dumping waste the chip's material from industrial company was taken with following composition: Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr. This chip material contains Fe in the form of mechanical impurities.

Efficiency of all processes at mechanical alloying is defined by the type of apparatus providing the transfer of mechanical energy to the material. In work it has been preferred a planetary mill with massive quasi-cylindrical milling bodies (fig. 1). Process of mechanical alloying with using of this kind of milling bodies is characterized by more rare and powerful single impacts in comparison with use of traditional ball load [5]. The containers with an initial charge were vacuumized before milling and then filled with argon for exception of material oxidation. The containers were cooled by flowing water during milling. The ratio “milling body:charge” was 6:1 in weight. The milling time was 2 - 6 h.

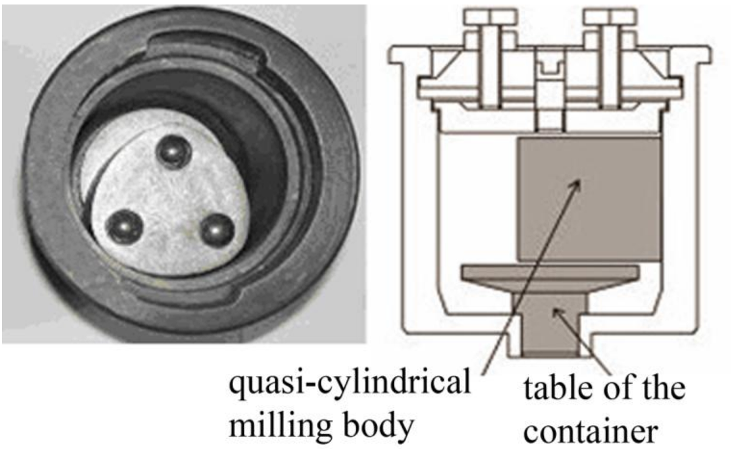
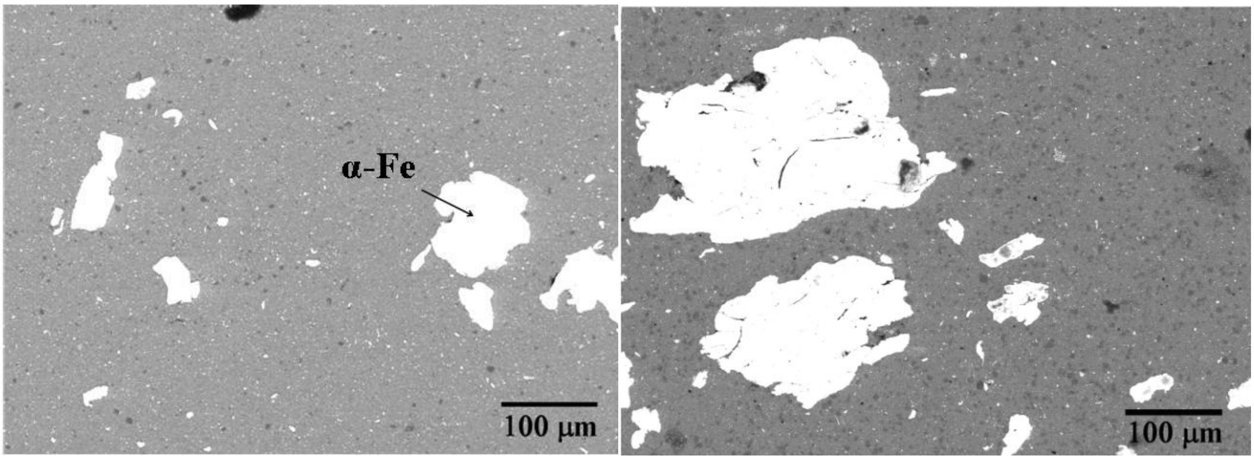


Figure 1. Appearance and drawing of container for mechanical alloying with use quasi-cylindrical milling body

Preparation of consolidated samples was carried out in two stages. First stage performs double-sided pressing of granules of the composite material at room temperature for obtaining a pre-form with a density no less than 80% of the theoretical value. The next stage was carried out by double-sided hot-pressing of the pre-form at a temperature of 480 ^{0}C. The samples had the following dimensions: diameter of 15-25 mm and a height of 10 mm.
Microstructure researches were spent on scanning electron and optical microscopes. Hardness and microhardness of a material was assessed in the Vickers hardness test. Long-term hardness tests of compact samples was carried on Brinell hardness tester with the electroresistance furnace. The test temperature was 350±2 ^{0}C. The tested sample held under loading for 1 h. Researches of wear resistance of compact samples under the scheme "pin-on-disk" were spent on Tribometer (CSM Instruments) without greasing. Wear test conditions are: counter body is steel (100Cr6) ball with 3 mm in diameter; normal load - 1 N; linear velocity - 10 mm/s. Linear thermal expansion coefficient (CTE) was estimated on dilatometer LINSEIS 76/1000. CTE measurements spent in an air atmosphere in 20-500 ^{0}C, with heating rate 10 K/min. By results of measurements the coefficient of thermal expansion was counted as average in temperatures range.

3. Results and Discussion

The chip's particles of dumping waste were milled in a planetary mill for 2 - 6 h with the addition of 10 vol. % SiC, and without the introduction of strengthening particles. The large inclusions of iron up to 200 μm of the consolidated samples of the material milled for 2 h are visible in the microstructure (Fig. 2). Refinement of these inclusions is observed with increasing of milling time and after 6 h of milling the microstructure is much more homogeneous (Fig. 3).
The microhardness of granules, hardness, and long-term hardness of consolidated samples versus milling time are shown in Fig. 4 and 5. The increase of these parameters with increasing of milling time is due to the refinement of all structural components of the matrix and SiC particles.



a b

Figure 2. The microstructure of the consolidated samples of material based on Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr after 2 h of milling in a planetary mill: a) – without SiC particles; b) – with 10 vol. % of SiC particles

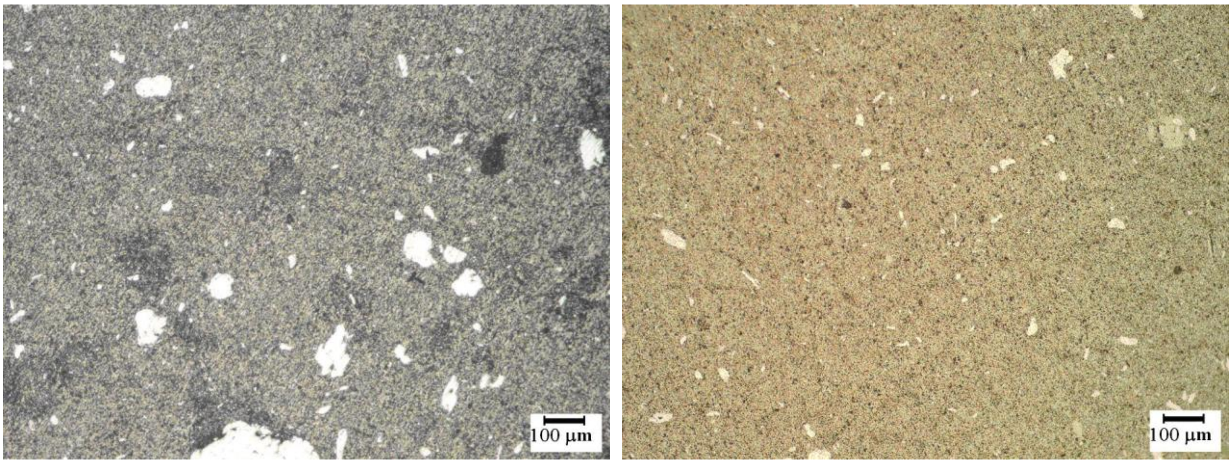


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Figure 3. The microstructure of the consolidated samples of material (Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr) – 10 vol.% SiC: a) - after 4 h of milling; b) - after 6 h of milling.

The introduction of SiC particles is especially strong effect on the level of long-term hardness of the material based on Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr (Fig. 5). However, in the material without strengthening particles this characteristic is also high and reaches 37 HB. For comparison, traditional heat-resistant piston alloy (Al – 12% Si – 2% Cu – 1% Mg – 1% Ni – 0.4% Mn – 0.1% Ti) have this characteristic at the level about 12 HB at the same conditions. Both materials have low values of the average CTE in the temperature range from room temperature to 500 ^{0}C and high wear resistance (Table 1).

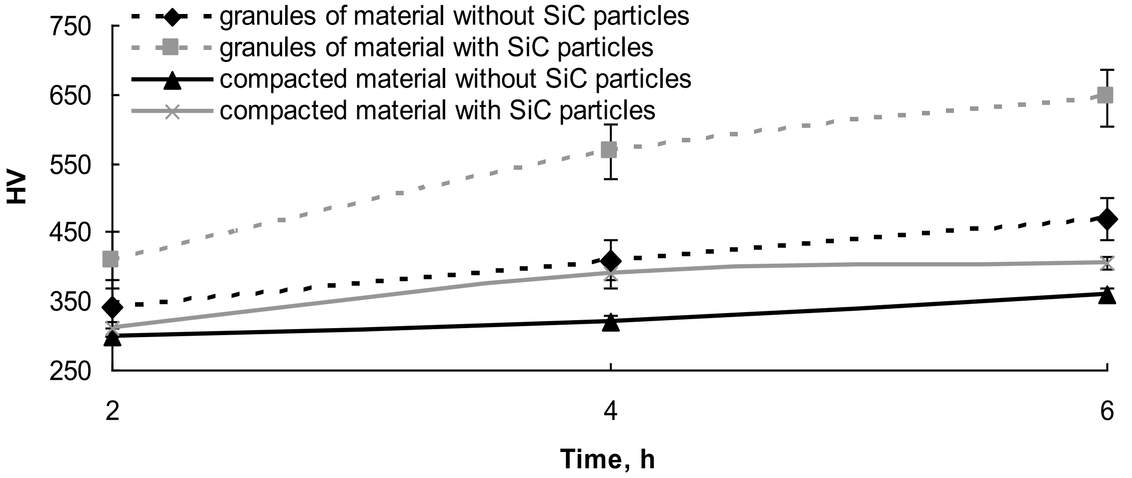

Figure 4. The microhardness of granules and hardness of consolidated samples of material based on Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr versus milling time.

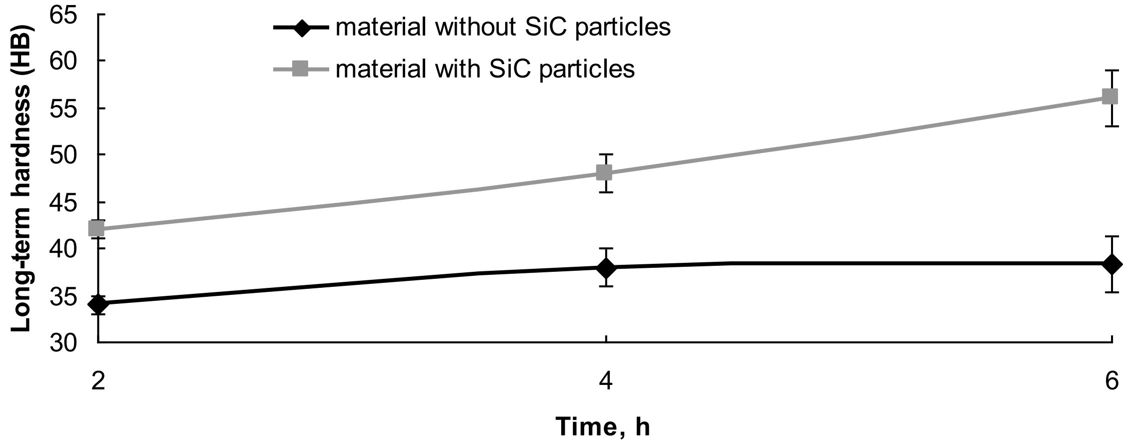

Figure 5. The long-term hardness of consolidated samples of material based on Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr versus milling time.

Material	Microhardness of granules (HV)	Hardness of consolidated samples (HV)	Long-term hardness of consolidated samples (HB_1^{350})	CTE·10^6, 1/K (20-500 ^{0}C)	Wear, mm^3/N·m
Al–20 % Si–3,3 % Fe–3,1 %Cu–2,5 % Ni–0,3 % Cr	470±30	360±10	38±3	14,4	1,8·10^{-4}
(Al–20 % Si–3,3 % Fe–3,1 % Cu–2,5 % Ni–0,3 % Cr)-10 об. % SiC	645±40	405±10	56±3	13,6	-

Table 1. The properties of the granules and consolidated samples of material based on Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr after 6 h of milling in a planetary mill

Thus, the possibility of obtaining of dispersion strengthened composite material based on mixed dumping waste with complex composition Al - 20% Si - 3,3% Fe - 3,1% Cu - 2,5% Ni - 0,3% Cr by mechanical milling in a planetary mill is shown. After 6 h of milling the microstructure of this material becomes homogeneous. Such composite materials have a high level of long-term hardness and wear resistance at low values of the average coefficient of thermal expansion in the range from room temperature to 500 ^{0}C.

References

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