The Influence of Germanium and Silicon on the Mechanical Properties of Al-Cu Alloys

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Abstract: The article describes the process of microalloying an aluminum-copper alloy with germanium and silicon oxides. Germanium oxide is part of an alloy enclosed in a special aluminum coating. 5% silicon is added to the alloy compared to the same amount of charge. germanium oxide, on the other hand, is introduced in various amounts from 0.1% to 0.3% compared to the charge. The samples were cast in an electric resistance furnace at a temperature of 750 °C. The hardness and wear resistance of the obtained samples in terms of mechanical properties were tested by experiments. The microstructures of the samples were analyzed using a metallographic microscope. Changes in the microstructure and mechanical properties of the samples were studied by comparison with samples without the addition of germanium oxide and silicon. The article also develops a graph of the dependence of mechanical properties on alloying elements. Based on the experiments conducted, the article presents the authors' conclusions on the last of them.

1 INTRODUCTION

The growing demand for non-ferrous alloys has led to an increase in experience and research aimed at further improving their properties. Changing their composition by including various elements in the composition of non-ferrous alloys also leads to an improvement in the properties of alloys (Dai et al., 2022, Zakharov and Fisenko, 2017, Rooy, 1990, Shaw et al., 2003, Tang et al., 2013). Currently, advanced research centers are conducting various studies in this direction. A number of scientific studies, including on aluminum alloys, are aimed at obtaining high-quality foundry products with an increase in their casting and mechanical properties (Efzan et al., 2014, Zebarjad and Sajjadi, 2014, Azarniya et al., 2019). The world's leading countries in this field are Canada, the USA, Japan, China, Sweden, Germany, Russia, Ukraine and others. In the above-mentioned countries, as well as in Uzbekistan in subsequent years, due to the increase in the number of non-ferrous alloys in the production of foundry products in the foundry sector of the industry, great attention is paid to creating a technology for producing high-quality, durable foundry products based on an effective method that ensures resource conservation. (Novák et al., 2023, Tursunbaev et al., 2023a,b, Nosir and Bokhodir, 2023, Turakhujaeva et al., 2023). The article analyzes the change in the properties of D16 grade aluminum alloy from aluminum-copper alloys by including germanium oxide and silicon in its composition.

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2 MATERIALS AND METHODS

The D16 grade aluminium alloy contains 94.7% aluminium. On the other hand, copper, the main alloying element, is 4.9%. A resistance furnace was used to melt the samples. The furnace used is mainly designed for the manufacture of small parts, up to 3 kg of metal can be liquefied in the crucible. The furnace crucible is made of graphite material, which helps to cast liquid metal without sticking to the base of the crucible (Kholmirzaev et al., 2023, Ma et al., 2023, Nodir et al., 2022).

The hardness of the samples obtained in the experiments was measured by the Brinell method. At the same time, there should be no oil, rust, scratches on its surface, it should be smooth and smooth. For this, the surface is ground on a fine-toothed egg or grindstone. The smallest thickness of the sample (s) must be at least ten times greater than the depth of the submerged trace of the submerged ball (H): in this case, the value of S 10 H is determined by the formula:

$$h = \frac{0.102P}{\pi DHB}$$

where R is the load on the sample, N or kg.k; D is the diameter of the sphere, mm; HB is the Brinell hardness of the material " kg / mm2. The hardness of the test sample according to Brinell (HB).

Figure 1: Hardness tester model 187.5 F HBRV.

Experiments used the HBRV -187.5 F model hardness tester (Fig.1). The sample size was prepared in a 35x5mm circle shape and a Brinell Press was used.

Abrasive wear is the destruction of a material as a result of mechanical influences, when a cutting and scratching action occurs in the presence of a relative velocity of movement of solid particles or particles. Abrasive wear occurs when two pairs of parts come into contact with each other under mutual friction, and the hardness of one material is higher than that of the other.

The wear resistance of the samples was determined in experiments on a diamond disk device (Fig.2). Wear resistance was determined by weight loss. At certain intervals, the samples were held on a rotating disk under the same force.

Figure 2: A device with a diamond disc that determines wear resistance.

3 EXPERIMENTS AND RESULTS

Samples were cast according to the chemical composition shown in Table 1. The samples were melted in a resistance furnace at a temperature of 750° C. The samples were poured into sand-clay molds (Fig. 3). In experiments, 0.1% to 0.3% germanium oxide was introduced into the aluminum alloy. After germanium oxide was introduced into later samples in the same composition, silicon was added as an alloying element in an amount of 5% compared to the charge.

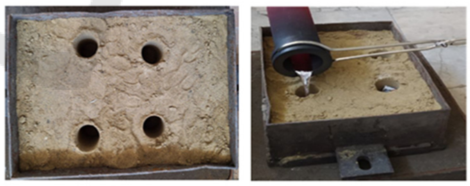

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Figure 3: Mold for samples (1) and casting process (2).

To determine the hardness of the cast samples, first cutting was performed on a lathe, and then grinding of the samples (Fig.4).

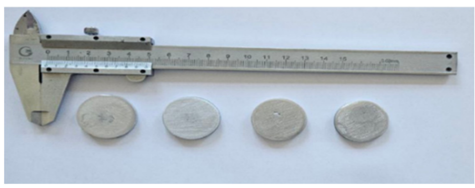

Figure 4: Polished samples.

The hardness of the samples from three points was checked and the average was calculated. The measurement results are given in Figure 5 below.

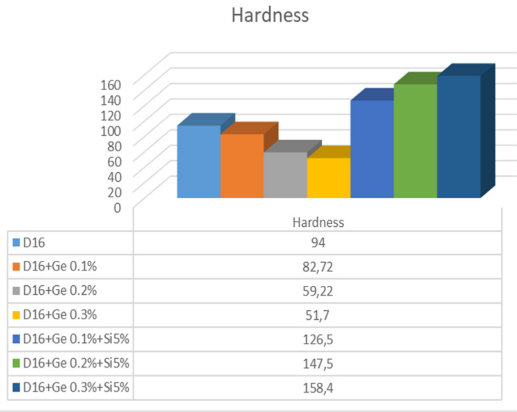

Figure 5: Hardness measurement results.

The wear resistance of the cast samples was tested using a device for measuring wear resistance using 6 minutes of the same force, i.e. using a device with a force of 3 Newton. The wear resistance was determined by differences in the weight of the samples before and after the tests. Wear resistance was carried over as a percentage of weight loss, and link graph were developed (Fig.6.).

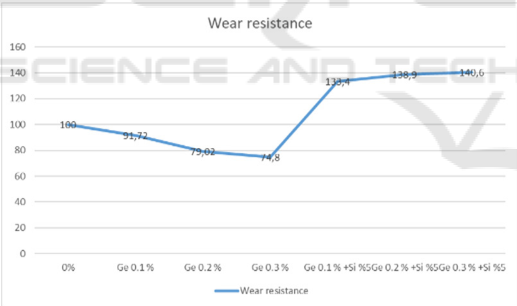

Figure 6: Link graph.

Table 1: Chemical composition of samples.

Percentage of elements in mass accounting, %								
Al	Si	Fe	Cu	Mn	Mg	Ti	Zn	Ge
91-94,7	0,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	-
91-94,7	0,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	0,1
91-94,7	0,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	0,2
91-94,7	0,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	0,3
91-94,7	5,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	0,1
91-94,7	5,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	0,2
91-94,7	5,5	0,5	3,8-4,9	0,3-0,9	1,2-1,8	0,1	0,3	0,3

4 CONCLUSIONS

Experiments have shown that the introduction of germanium oxide into the alloy led to a decrease in its mechanical properties. Including the hardness of Germanium oxide, as the content increased, the hardness decreased to 38-40%. The wear resistance has also decreased, respectively, as well as the hardness. In subsequent studies, the addition of silicon to the aluminium alloy led to an increase in mechanical properties. The introduction of more than 5% silica into the sample compared to the charge increased the hardness of the samples to 40-58%, and the wear resistance to 33-40%. According to the research results, it was found that germanium in germanium oxide, remaining in the process of liquefaction of the alloy in the aluminium-copper system, improved the microstructure of the alloy, which led to an increase in the mechanical properties of samples with a silicon element.

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