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The Effect of the Addition of Tuff on the Properties of Brass and Bronze

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Abstract. *The article presents studies aimed at identifying the effect of the addition of volcanic tuff, rocks with ceramic properties, on the properties of brass and bronze, which make up the metal matrix of the composite. The research methods included: structure study (microscopic observations using an optical microscope and a scanning microscope), EDS analysis, as well as testing of composites for abrasion and microhardness. The results of the study of samples formed by tuff with brass and bronze show the stability of the structures obtained. Microscopic observations confirm that the distribution of mineral filler particles is uniform. No significant gaps were found between the filler and the matrix. The results of mechanical abrasion tests were the best and the maximum increase in hardness values was achieved with 10% addition of tuff to brass and bronze matrices.*

Keywords: *metal matrix composites, particle-reinforced composites, volcanic tuff, brass and bronze matrix composites, abrasion, microstructure.*

Introduction

Composite materials on a metal matrix reinforced with ceramic particles, combine good strength properties and high plasticity of metals, with high strength and resistance to high temperatures characteristic of ceramics [1-3]. Composites using brass and bronze are created to improve the properties of these materials, including corrosion resistance of materials working in seawater [5, 6], improvement of tribological and mechanical properties [6, 7]. The most frequently used ceramic particles reinforcing this type of composites are: metal carbides (SiC, TaC, WC, B_4C), metal nitrides (TaN, ZrN, Si_3N_4, TiN), metal borides (TaB_2, ZrB_2, TiB_2, WB) and metal oxides (ZrO_2, Al_2O_3, ThO_2) or their mixtures [1, 4]. Currently, work is underway on the development of composites with a metal matrix and the addition of natural mineral particles [7]. These kinds of additives are also ecofriendly.

On of the possibly mineral additives is tuff. It is a type of hard sedimentary rock, belonging to a crumb rock, with high porosity and low density, which occurs naturally in areas of former volcanic activity. It includes clay minerals and zeolites, in their structure there are empty, tubular spaces, the lumen of which is several Å. This material has many possible applications. It can also be used as an additive to metals, which increases their anti-corrosion properties and increases resistance to abrasion. The article presents research on the influence of the addition of volcanic tuff, rocks having the properties of ceramics, on the properties of brass and bronze that make up the metal matrix of the composite.

Research methodology and materials

The samples, weighing 10g and 5mm in diameter, were prepared by powder metallurgy based on brass and bronze powder and tuff. The powder compositions for the samples were with the following content (wt. %): brass 100 (designation M0); brass 98, tuff 2 (M2); brass 95, tuff 5 (M5); brass 90, tuff 10 (M10); bronze 100 (B0); bronze 98, tuff 2 (B2); bronze 95, tuff 5 (B5); bronze 90, tuff 10 (B10).

The elemental composition (%) for bronze / brass were the following: Cu = 63/62; Fe = 24/-; Sn = 12,5/-; Al = 0,5/-; Zn = -/37; other elements – balance.

The tuff was pre-crushed and then ground, in an ultra-centrifugal laboratory mill, to a grain size of 10-50 μm and annealed at 850°C for 2 hours. The chemical composition of the tuff is the following (%): SiO_2 = 47.2-66.22; Fe_2O_3 = 12.31-14.49; Al_2O_3 = 10.73-13.90; CaO = 1.67-2.79; K_2O = 1.48-2.43; Na_2O = 0.59-4.87; MgO = 0.26-7.00; TiO_2 = 0.21-1.34; SO_3 = 0.09-0.17; MnO = 0.03-2.43; P_2O_5 = 0.03-2.43; H_2O = 0.43-5.22; other = 1.62-2.13.

The samples were subjected to one-side pressing followed by sintering under an inert gas – nitrogen atmosphere at 900°C for 60 minutes in a tubular silite furnace (heating rate 10 K / min). After the sintering process, the samples were cooled together with the furnace. The mean of change by weight / change by dimension (%) after sintering of the samples with respect to the original weight and size of the sample were the following: 100.13 / 80.74 for B0; 99.81 / 100.66 for B2; 99.98 / 100.96 for B5; 100.14 / 110.32 for B10; 100.48 / 90.32 for M0; 99.65 / 90.82 for M2; 99.83 / 90.24 for M5; 99.81 / 110 for M10.

Research has been carried out on the effect of the addition of volcanic tuff on the properties of brass and bronze. They included: structural tests (microscopic observations using an optical microscope and a scanning microscope), EDS analysis as well as abrasion and microhardness tests of composites.

The microstructure research provided on the optical microscope allowed us to obtain preliminary information about the structure of the material. More detailed information was obtained from scanning electron microscopy (SEM) type JOEL JSN5510LV. Before testing, the sample surface was covered with a conductive gold layer on the vacuum evaporator JOEL JEE-4X.

Abrasiveness tests were carried out for eight samples (M0-M10, B0-B10).

The samples were subjected to mechanical abrasion. The weight loss after 5 and 10 minutes was measured.

The microhardness tests were carried out on the ZHV1-A microhardness tester using the Vickers method, with a force of 490.3 mN. On each of the samples, a minimum of 20 measurements were carried out, with the first 10 including measurements made on the width of the sample every 0.5 mm, and subsequent measurements were made along the sample every 2 mm.

Results and discussion

Examples of microstructures of the examined bronze sinters with the addition of tuff are shown in Figure 1. It shows that the tuff particles are evenly distributed in volume of the matrix in both cases – brass and bronze.

The tuff particles are dark fields in a bronze and a brass structure that is distinctly bi-phase (light, dark gray areas shown in the photos).

Figure 2 a, b shows a good coherence of the tuff particles with the matrix of the metallic materials. No discontinuities were observed at the boundary between the tuff and the metal matrix.

The EDS analysis of the samples made it possible to confirm the presence of tuff particles in the matrix and determine their elemental composition, Figure 3.

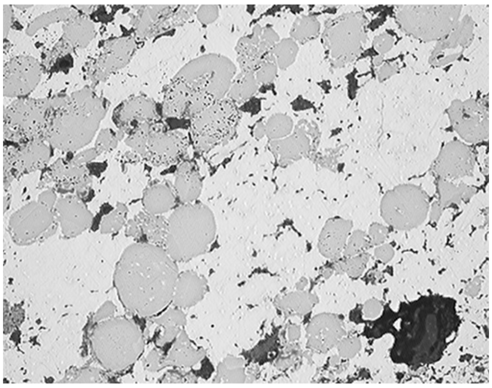
Measurements in the point 1 of Figure 3a, b shows the diverse elemental composition of the mineral filler. The important elements for tuff composition are Si, Al, and O. The EDS show in different proportions at the point of measurements. The EDS for the bronze matrix (point 3, Figure 3a) confirms their composition mainly with Cu and Sn. The similar analysis for the brass matrix (point 2, Figure 3b), confirms its composition from Cu and Zn. It is consistent with expectations.

Figure 4 shows the microstructure of the sample B5 and the EDS analysis (linear distribution of elements on the tuff – matrix boundary). The changes in chemical composition between matrix and additive are very well visible.

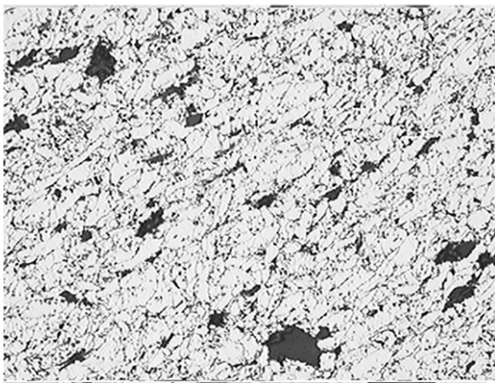
The performed measurements, which are qualitative in nature, allowed for orientation in the elemental composition of the composite and allowed to show that the structure of the composite was uniform (no major discontinuities between the filler and the matrix were shown).

The results of abrasion tests are presented on Table.

Different trends in the behavior of the samples can be seen. The results are given for the first 5 minutes, because in this time the mass changes are the fastest the abrasion process. The results for abrasion test were the best for composites containing 5% and 10% of mineral filler addition. There were worse than for



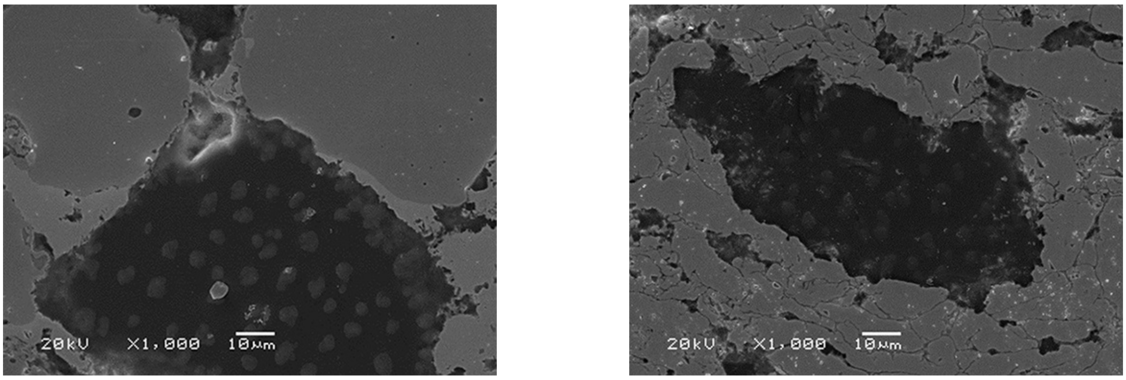
a



b

a – sample B5 (x50); b – sample M5 (x50)

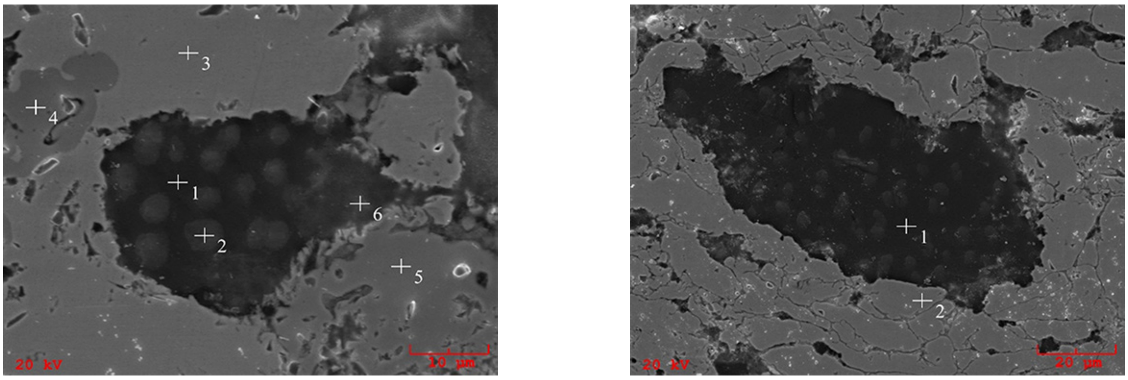
Figure 1 – Microstructure of bronze and brass with 5% addition of tuff



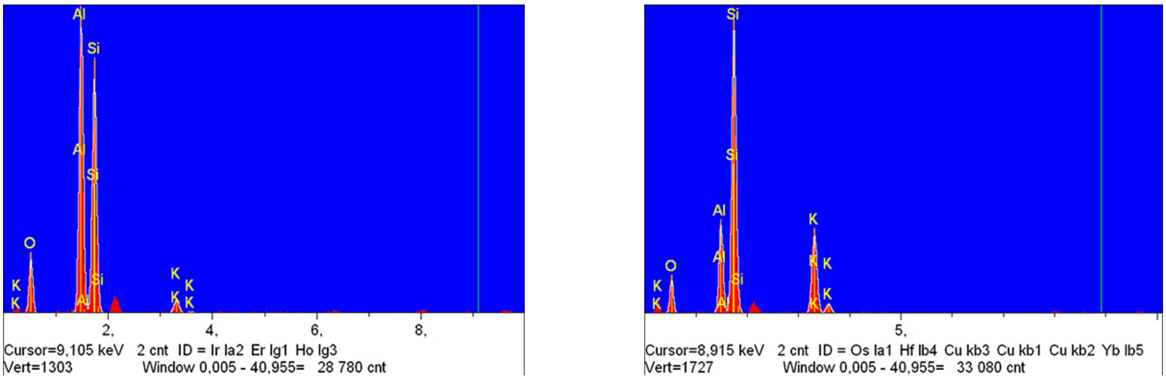
a b

a – B5 (x 1000), b – M5 (x 1000)

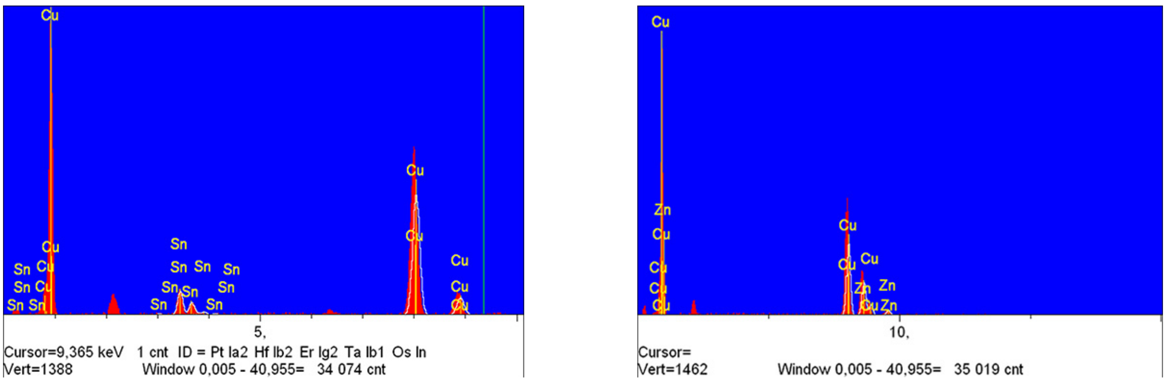
Figure 2 – Microstructure of bronze and brass with 5% addition of tuff (SEM)



a b



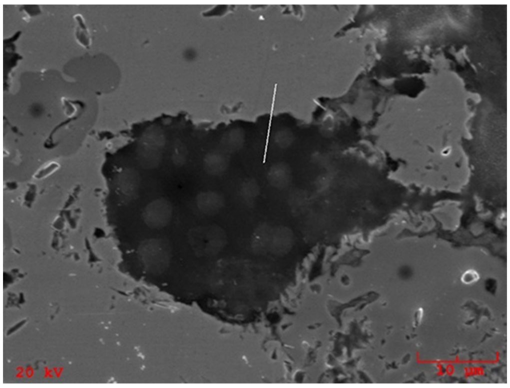
c d



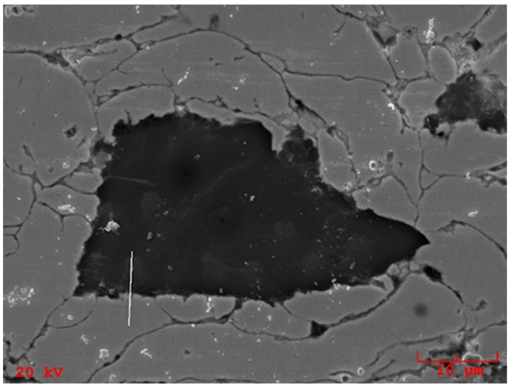
e f

a – the sample B2, visible point of measurements for EDS; b – M2, visible point of measurements for EDS; c – EDS analysis for point 1 in Figure 3a – tuff particle; d – EDS analysis for point 1 in Figure 3b – tuff particle; e – EDS analysis for point 2 in Figure 3a – bronze matrix; f – EDS analysis for point 2 in Figure 3b – brass

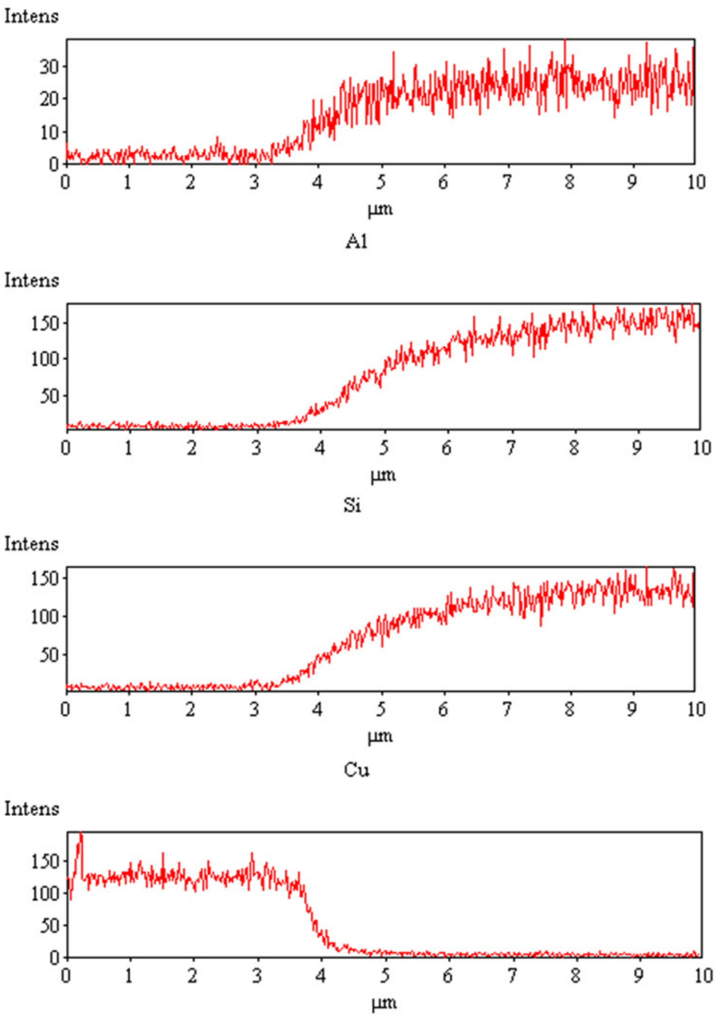
Figure 3 – Scanning electron microscope with EDS analysis



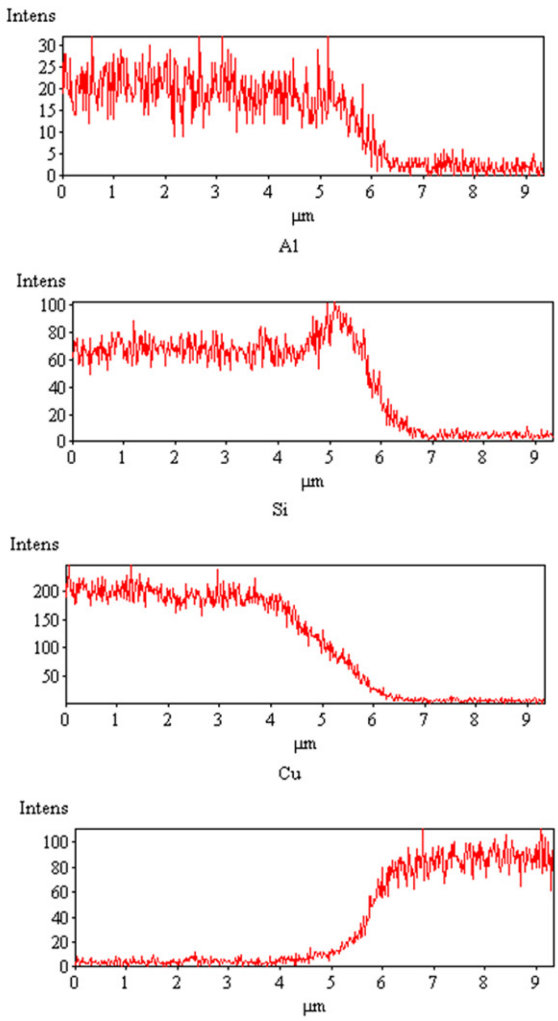
a



b



c



d

a – the sample B5, visible line of measurements for EDS; b – M5, visible line of measurements for EDS; c – EDS analysis for line in Figure 3a for selected elements at the boundary between tuff and bronze matrix; d – EDS analysis for line in Figure 3b for selected elements on the boundary between the tuff and brass matrix

Figure 4 – Scanning electron microscope with EDS

pure bronze and brass. It could be explained through the removal form matrix tuff particle during the first 5 minutes. It is expected that this tendency will be changed according the time and the results will be better for the composites.

The microhardness measurement showed the difference between the hardness of the matrix (usually less than 100 HV) and the hardness of the filler – tuff (hardness from 300 to 1070 HV).

The overall tendency show that the harness of the composites increases together with the amount of the tuff. The some abbreviations from this tendency are caused by the methodology of research – the amount of the measurements done on the tuff particle. The

The results of the abrasion test			
Sample	**Initial weight**	**Weight after 5 minutes**	**% Change by weight**
B	10.533	10.031	95.23
B2	10.816	9.764	90.27
B5	10.521	10.017	95.20
B10	10.915	10.239	93.80
M	9.689	9.670	99.79
M2	9.563	9.089	95.04
M5	9.633	9.269	96.22
M10	10.375	10.195	98.26

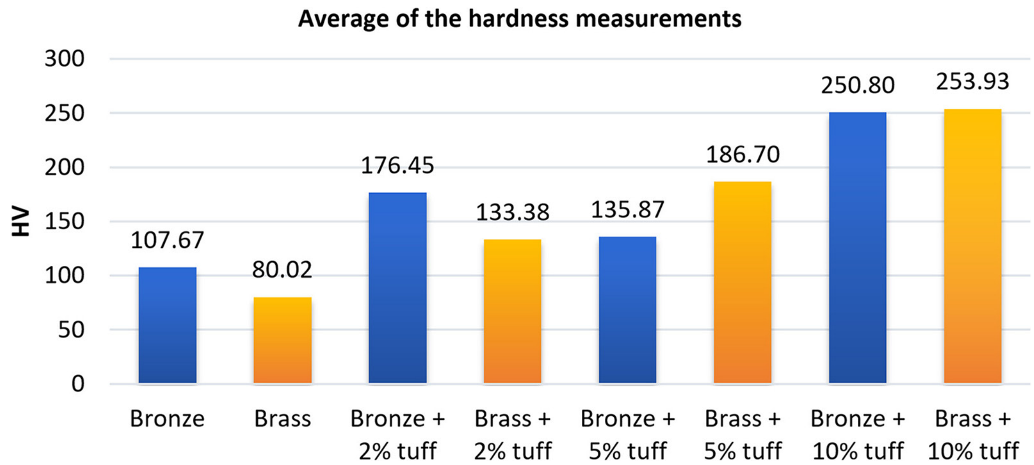


Figure 5 – Average of the hardness measurements

best results were obtained for 10% addition of tuff addition. The results obtained are coherent with other research, that shows that the addition of tuff have a positive effect on the hardness of the composite.

Conclusions

Structural research allowed us to observe the homogeneous structure formed by tuff with brass and bronze. Microscopic observations showed that the distribution of the mineral filler particles is uniform throughout the volume of the material. No discontinuities or problems in the form of decohesion of the filler with the matrix were observed in the structure. The addition of tuff to brass and bronze matrix composites improved the functional properties, i.e. abrasion and microhardness.

The predicted application for the composite elements is machine industry, however for the practical implementation investigated materials further research are needed. Limitation of wear of the machine parts can brings economic benefits. Furthermore, the advantage of tuff are: its low price, widespread availability and the natural origin of the material, which contributes to reducing the costs of manufacturing elements from the relatively expensive raw material, which are brass and bronze, while maintaining the properties of this material.

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Материалды қосудың жез бен қоланың қасиеттеріне әсері

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Аңдатпа. *Мақалада вулкандық туфты, керамикалық қасиеттері бар тау жыныстарын қосудың композицияның металл матрицасын құрайтын жез бен қоланың қасиеттеріне әсерін анықтауға бағытталған зерттеулер келтірілген. Зерттеу әдістеріне мыналар кірді: құрылымды зерттеу (оптикалық микроскоп пен сканерлеу микроскопын қолданатын микроскопиялық бақылаулар), EDS талдауы және композиттерді абразия мен микроқаттылыққа сынау. Жезден және қоладан жасалған туфтан алынған үлгілерді зерттеу нәтижелері алынған құрылымдардың тұрақтылығын көрсетеді. Микроскопиялық бақылаулар минералды толтырғыш бөлшектерінің таралуы біркелкі екенін растайды. Толтырғыш пен матрица арасында айтарлықтай алшақтық табылған жоқ. Механикалық абразивті сынақтардың нәтижелері ең жақсы болды және қаттылық мәндерінің максималды жоғарылауына жезден және қоладан жасалған матрицаларға туфтың 10% қосылуымен қол жеткізілді.*

Кілт сөздер: *металл матрицалық композиттер, бөлшектермен күшейтілген композиттер, жанартау туфы, жез және қола матрицалық композиттер, абразия, микроқұрылым.*

Влияние добавления вулканического туфа на свойства латуни и бронзы

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Аннотация. *В статье представлены исследования, целью которых являлось выявить влияние добавления вулканического туфа, горных пород, обладающих свойствами керамики, на свойства латуни и бронзы, составляющих металлическую матрицу композита. Методы исследования включали: исследование структуры (микроскопические наблюдения с использованием оптического микроскопа и сканирующего микроскопа), анализ EDS, а также испытания композитов на истирание и микротвердость. Результаты исследования образцов, образованных туфом с латунью и бронзой, показывают стабильность полученных структур. Микроскопические наблюдения подтверждают, что распределение частиц минерального наполнителя является однородным. Существенных разрывов между наполнителем и матрицей обнаружено не было. Результаты испытаний на механическое истирание были наилучшими и максимальное повышение значений твердости было достигнуто при 10%-ом добавлении туфа в латунные и бронзовые матрицы.*

Ключевые слова: *композиты с металлической матрицей, композиты, армированные частицами, вулканический туф, композиты с бронзовой и латунной матрицей, истирание, микроструктура.*

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