Effect of Hot Pressing and Reinforcement of TiC and WC on the Mechanical Properties and Microstructure of AlCuFeCrNi HEAs Alloy

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Abstract:
In this study, a powder mixture consisting of TiC (titanium carbide) and WC (tungsten carbide) reinforced AlCuNiFeCr was produced using the hot pressing technique. The AlCuNiFeCr powder mixture, TiC and WC were added at a rate of 5 %, 10 % and 15 %, respectively. In order to produce and control to produce parameters have been produced having automation systems type of laboratory a hot pressing machine. Graphite moulds were used in production and sintering processes were carried out in a protective argon gas atmosphere. Composites were produced at a sintering temperature of 900 °C and under a pressure 35 MPa and for 4 minutes. To understand the microstructure and mechanical properties of produced specimens, their SEM and EDS analysis, XRD analysis, fracture surface SEM images, SEM mapping of elemental distribution and EDX spectrums, hardness, three-point bending, and corrosion tests were investigated. As a result, the best sample has been identified that belong to AlCuNiFeCr- 15 % WC with great features.

Keywords: High-entropy alloy (HEA); Hot pressing; TiC reinforcement; WC reinforcement; Mechanical properties.

1. Introduction

The necessity for working under high temperatures and dynamic loads has called for the development of industries and the creation of new tools and structures to allow for working under such conditions and to enhance the working capacity of materials throughout urgent tasks [1]. In 2004, Yeh et al. first identified high-entropy alloys (HEAs) [2], which can be defined as alloys with at least five or more equal quantities elements [3]. Unlike conventional alloys that have one or two elements as the main element, additional elements are added to improve the properties of HEAs [4]. These alloys are produced to be stable at high temperatures where they have a single phase with a simple crystal structure during configurational entropy [5]. Increased levels of additives reduce the formation of intermediate compounds, which have hardness and brittleness. During high entropy, they tend to form simple solid solutions such as body centre cubic (BCC), face centre cubic (FCC) and hexagonal close-packed (HCP) [6, 7], which are responsible for the characteristics of the alloy [8]: strength and hardness [9], enhanced corrosion resistance [10], exceptional fatigue and
toughness [11], anti-oxidation [12], great structural stability [13], high-temperature strength [14], good wear resistance [15] and creep resistance [16].

HEAs are widely studied due to their mechanical properties and good microscopic structure [17]. TiC particles are added to reinforce alloys, improving their mechanical properties, hardness, stability, and melting points [18]. In previous studies, the aluminium alloy reinforced with TiC had an elongation to failure of about 5.6 % and a tensile strength of 351.8 MPa [19]. WCCo is likely to be replaced by TiC in cutting tools due to its good surface finishing, high wear resistance and high hardness, and because it is highly soluble, especially with TiB2 – in which case it is thermodynamically stable up to 2600 °C [20, 21]. WC also has high wear resistance, voltage, modulus of elasticity [22], elasticity and resilience to molten metal’s [23]. TiC is added to WC to enhance durability in addition to mechanical and physical properties such as breakage resistance and plastic deformation [24].

Corrosion is a major cause of mineral failure, resulting in losses comprising 3 % of the global annual output [25]. Although some minerals constitute a negative layer that reduces corrosion, topical drilling can quickly cause application failure if the negative layer collapses [26]. For this reason, new alloys are made with high negatives [27], although there are few studies on the corrosion of highly entropic ingots and most confirm adding aluminium reduces alloy corrosion resistance, especially in sulphuric acid at 27 °C due to the formation of the oxide layer [28] on the alloy’s surface. This indicates that other studies have shown the effect of the entropy mixed with these alloys is positive and supports corrosion resistance, particularly at evaporation temperature [29, 30]. Some showed good corrosion resistance concerning the required properties [31].

The purpose of this study is to experimentally investigate the following:

1. TiC and WC reinforced AlCuNiFeCrNi HEAs produced via the hot pressing method.
2. Microstructure and phase formation properties of the produced HEAs.
3. The effect of TiC and WC reinforcement on mechanical properties of the produced HEAs.
4. The effect of TiC and WC reinforcement on transverse rupture strength of the produced HEAs.
5. The corrosion resistance of the produced HEAs.

Therefore, the effect of hot pressing and reinforcement of TiC and WC on the mechanical properties and microstructure of AlCuFeCrNi HEAs alloy were investigated. The mechanical and microstructure properties of the produced HEAs were investigated by using Scanning Electron Microscopy (SEM), Energy Dispersive Spectrometry (EDS), Fracture surface SEM images, SEM mapping of elemental distribution and EDX spectrums and the phase formation was investigated with X-Ray Diffraction (XRD). In addition, the produced HEAs were examined with microhardness, transverse rupture strength and corrosion analysis.

2. Materials and Experimental Procedures

The elements Cu, Ni (99.95 % pure), Fe, Al (99.99 % pure), Cr (99.98 % pure), TiC, WC (99.9 % pure) were selected, preferably with 325 mesh and 44 µm, then mixed and subjected to hot pressure. The samples were subjected to mixing for 60 minutes using a Turbula mixer (Celnia Group 7T, Turkey), during which 1.5 wt% PEG 400 (Polyethylene Glycol) was added to improve mixing and reduce friction. Cold pressure was then applied as each sample was massed for every 20 g. The AlCuCrFeNi-TiC-WC was subjected to 300 MPa pressure by using a double-effect hydraulic press (Dim-Net WP-45SA, Korea) and placed in graphite moulds under an inert gas by a PLC-controlled direct hot pressing machine (Zhengzhou Golden Highway, SMVB 80, China) and sent to the sintering furnaces for the
application of hot pressure. Table I shows the parameters of the hot pressure to which the alloys were subjected. Following production, the samples were ground and polished (Metkon Forçimat, Turkey). For grinding, 200, 400, 800 and 1200 mesh sandpapers were used. For polishing, the diamond solution was used to check the SEM, an EDS device (“FEI” brand “Quanta FEG 250” Kastamonu University) was used and samples were then subjected to the XRD analysis. The samples were analysed using the SEM device to examine the fracture surfaces. The samples were subjected to a hardness test using the Brinell test under (HB10) a 2.5 mm diameter tip with 62.5 kg of load.

| Samples No | Pressure (MPa) | Temperature (°C) | Time (min.) | Chemical composition (%)          |
|------------|----------------|------------------|-------------|-----------------------------------|
| 1          |                | 35               |             | AlCuFeCrNi                        |
| 2          |                | 900              | 4           | AlCuFeCrNi – 5% TiC               |
| 3          |                |                  |             | AlCuFeCrNi – 10% TiC              |
| 4          |                |                  |             | AlCuFeCrNi – 15% TiC              |
| 5          |                |                  |             | AlCuFeCrNi – 5% WC                |
| 6          |                |                  |             | AlCuFeCrNi – 10% WC               |
| 7          |                |                  |             | AlCuFeCrNi – 15% WC               |
| 8          |                |                  |             | AlCuFeCrNi – 5% TiC+5% WC         |

After polishing, the surfaces of the samples were etched using a specialized etcher consisting of 2 ml HF, 3 ml HCl, 5 ml HNO_3 and 190 ml H_2O. The microstructure was then examined before a final three-point bending test was conducted using a 50 kN capacity universal-type tensile device in accordance with the ASTM B 528-83a standard at a test speed of 1 mm/min. Samples with dimensions of 40×10×10 mm were used for this.

Corrosion measurements were made using the Gamry brand Reference 3000 Potentiostat/Galvanostat/Zra corrosion system. In conducting the corrosion tests, samples were sanded with coarse and fine sandpaper and polished with 3- and 1-micron solutions, then cleaned with ethanol in the ultrasonic bath for 30 minutes. The samples left standing at room temperature (25 °C), 96.5 % by weight in distilled water and 3.5 % in NaCl solution, for 30 minutes for surface stabilisation before the experiments were performed. A conventional three-electrode cell was used for all electrochemical measurements. An Ag/AgCl electrode was used as the reference electrode and a carbon electrode was used as the counter electrode. A potentiodynamic sweep was performed with a sweep speed of 1 mV/s in the ± 0.25 mV potential range, according to Eocp standard. Three experiments were performed for each sample. The new solution was used in each experiment and the arithmetic mean of the results was taken. The rate of corrosion was calculated according to the Astm-G102 standard.

3. Results and Discussion

The SEM images of the HEAs produced by the powder metallurgy method (Fig. 1) were taken and evaluations were made according to the obtained images. The presence of two different structures can be clearly seen, Fig. 1. The dark grey areas signify HEA matrix, the white and sharp-edged grains TiC and WC. It was seen that TiC and WC particles were homogeneously distributed in general, Fig. 1.
Fig. 1. SEM images of HEA: (a) HEA, (b) AlCuNiFeCr – 5% TiC, (c) AlCuNiFeCr – 10% TiC, (d) AlCuNiFeCr – 15% TiC, (e) AlCuNiFeCr – 5% WC, (f) AlCuNiFeCr – 10% WC, (g) AlCuNiFeCr – 15% WC, and (h) AlCuNiFeCr – 5% TiC-5% WC.

Mechanical properties of the HEAs negatively affected because the reinforcement particles were not homogeneously distributed [32]. It can be clearly seen from scanning
electron microscope micrograph that there was an increase in the amounts of TiC and WC in microstructure along with an increase in the rates of reinforcement particles.

The EDS analysis of the structure AlCuNiFeCr – 15% WC given in the Fig. 2. The result of EDS analysis of AlCuNiFeCr – 15% WC and supports the produced sample. In the EDS spot 1 contains 25.70% Al, 11.24% Cr, 10.31% Fe, 25.13% Ni and 27.62% Cu. In the EDS spot 2 contains 100% W. In the EDS spot 3 contains 91.31% W and 8.69% C. In the EDS spot 4 contains 94.30% W and 5.70% O. In the EDS spot 5 contains 80.02% W and 19.98% C.

HEAs have been analyzed by using SEM mapping of elemental distribution and EDS spectrums analysis to determine the distribution of TiC and WC particles (Fig. 3). The basic elements are Al, Cu, Ni, Fe and Cr. The reinforcement particles are Ti, W and C. It is clear that reinforcement particles are distributed uniformly. The homogeneous distribution of the elements has a positive effect on the physical, chemical and mechanical properties of the material [33].
Fig. 3. SEM mapping of elemental distribution and EDS spectrums of HEA: (a) HEA, (b) AlCuNiFeCr – 5% TiC, (c) AlCuNiFeCr – 10% TiC, (d) AlCuNiFeCr – 15% TiC, (e) AlCuNiFeCr – 5% WC, (f) AlCuNiFeCr – 10% WC, (g) AlCuNiFeCr – 15% WC, and (h) AlCuNiFeCr – 5% TiC-5% WC.
The XRD analysis was performed for each HEAs (Fig. 4, 5 and 6) in order to determine whether a phase formed to provide bonding in the interface of matrix to HEA and reinforced to TiC/WC particles or not.

![Fig. 4. XRD graphic of the HEA.](image1)

![Fig. 5. XRD graphics of the HEA+TiC.](image2)
It is clear that the peaks an Al\textsubscript{0.99}Fe\textsubscript{0.99}Ni\textsubscript{0.22}, AlCrCu\textsubscript{2}, Al\textsubscript{2}Cu\textsubscript{9}, AlFe\textsubscript{3}, Cu\textsubscript{3}Al, Al\textsubscript{2}Cu\textsubscript{3.4}, AlCrFe\textsubscript{3}, Cu\textsubscript{2.9}Ni\textsubscript{1.1}, Al\textsubscript{2}CuFe, Al\textsubscript{2}Fe, AlFe, Cr, C, AlFe\textsubscript{0.23}Ni\textsubscript{0.77}, Cr\textsubscript{0.7}Fe\textsubscript{0.3}, W\textsubscript{3}C, Fe\textsubscript{7}Al\textsubscript{11}, AlCrFe\textsubscript{2}, Al(Fe\textsubscript{0.5}Ni\textsubscript{0.5}), Cr\textsubscript{0.2}Fe\textsubscript{0.8}, W\textsubscript{2}C\textsubscript{0.84}, W\textsubscript{2}C phases are dominant, Fig. 4, 5 and 6. During the sintering process, Al\textsubscript{0.99}Fe\textsubscript{0.99}Ni\textsubscript{0.22}, AlFe, Cu\textsubscript{3}Al, Al\textsubscript{7}CrCuFe and W\textsubscript{2}C phases occurred between the Al, Cu, Fe, Cr, Ni, Ti, W and C elements.

It can be determine that the intensity of TiC phases keeps increase with increasing TiC content (Fig. 5). According to the XRD results of HEA-TiC, it demonstrates that these samples with TiC addition are constituted solid solution associated TiC phases [35]. When all the peaks of the HEA-WC were studied, it was found that, as the amount of WC in the increased, the intensity of the WC peaks increased (Fig. 6). Yurkova et al. [1] found similar peaks in their study on “structure formation and mechanical properties of the high-entropy AlCuNiFeCr alloy prepared by mechanical alloying and spark plasma sintering”. The release of W and C from decarburization of the WC phase resulted in the generation of the W\textsubscript{3}C and W\textsubscript{2}C phases.

Fig. 6 shows SEM images of the fracture surfaces of the samples after three-point bending tests.

As noted in Fig. 7b, the 5% 5 TiC contains cracks and holes. Increasing the ratio from 10% TiC to 15% shows a recession of the cracks while holes remain present, as shown in Figs 7c and 7d. The increase in WC reduces the deformation of cracks, which may be due to plastic deformation [34]. For 5% WC, Fig. 7e shows the presence of fissures within the casting, and there are no holes by which the slip through it is very little. Fig. 7g and 7h show that upon increasing the level of WC an increase in the cracks and holes can be observed as a result of the plastic deformation of the material and the movement of slips.
Fig. 7. Fracture surface SEM images of HEA: (a) HEA, (b) AlCuNiFeCr – 5% TiC, (c) AlCuNiFeCr – 10% TiC, and (d) AlCuNiFeCr – 15% TiC, (e) AlCuNiFeCr – 5% WC, (f) AlCuNiFeCr – 10% WC, (g) AlCuNiFeCr – 15% WC, and (h) AlCuNiFeCr – 5% TiC-5% WC.

Fig. 8 and 9 shows SEM-EDS analysis of the fracture surfaces of the samples after three-point bending tests. The amount of aluminium distribution or sliding during the alloys, as is evident in the peaks, where the ease of aluminium distribution increases when the added ratios increase, but the best ratio was at 15% TiC. This means that an increase in added TiC
results in better Al distribution, as shown by Zhezen Fu et al. [35], when compared to other additives. However, the addition of WC also had a positive effect on the distribution of aluminium, as the ratio decreased from 25.76 to 18.67 upon the addition of 15% WC. As for 5\% TiC + 5\% WC, a decrease to 17.12 was observed, which is also considered good, although the best ratio was observed at 15\% TiC.

Fig. 8. Fracture surface SEM-EDS analysis of HEA: (a) HEA, (b) AlCuNiFeCr – 5\% TiC, (c) AlCuNiFeCr – 10\% TiC, and (d) AlCuNiFeCr – 15\% TiC.
**Fig. 9.** Fracture surface SEM-EDS analysis of HEA: (a) AlCuNiFeCr – 5% WC, (b) AlCuNiFeCr – 10% WC, (c) AlCuNiFeCr – 15% WC, and (d) AlCuNiFeCr – 5% TiC-5% WC.
To determine the transverse rupture strengths of high-entropy alloys, three-point bending tests were conducted using a 50 kN capacity universal-type tensile device in accordance with the ASTM B 528-83a standard at a test speed of 1 mm/min. Samples with dimensions of 40×10×10 mm were used for the three-point bending test, and the test for each sample was repeated three times. The effect of the reinforcement particles (TiC and WC) was determined by calculating the average of the values. Fig. 9 shows the effects of TiC and WC addition on the transverse rupture strengths of the HEAs.

![Fig. 9.](image)

Fig. 10. Transverse rupture strengths of HEA: (1) HEA, (2) HEA+TiC (5 wt%), (3) HEA+TiC (10 wt%), (4) HEA+TiC (15 wt%), (5) HEA+WC (5 wt%), (6) HEA+WC (10 wt%), (7) HEA+WC (15 wt%) and (8) HEA+TiC (5 wt%)+WC (5 wt%).

The transverse rupture strengths (TRS) of HEA, HEA+TiC (5 wt%), HEA+TiC (10 wt%), HEA+TiC (15 wt%), HEA+WC (5 wt%), HEA+WC (10 wt%), HEA+WC (15 wt%) and HEA+TiC (5 wt%)+WC (5 wt%) high-entropy alloys were 128, 152, 179, 157, 194, 175, 165 and 134 MPa, respectively. The TRS of reinforced high-entropy alloys were much higher than that of the unreinforced one. This is because the reinforcement particles blocked the dislocation movement, as was explained for the case of increased hardness. The TRS of WC- and TiC-containing samples were higher compared to the other samples. This is because the hardness of carbides is high and the carbides used in this study had a very small grain size compared to the matrix grain size [36].

The stress-strain curves for each of the samples to which the three-point bending test was applied are given in Fig. 10.

When the stress-strain graphs was examined, brittle fracture has formed in HEA-TiC samples whilst more ductile fracture has formed as a result of a plastic deformation in HEA-WC samples compared to HEA-TiC samples. Especially strength values of HEA-WC samples are higher than strength values of HEA-TiC samples. This is because of more amount of grain growth in HEA-WC samples compared to HEA-TiC samples. Hardness measurements support this situation too. Furthermore, it was concluded that the WC has caused lower strength values by creating a notch effect as a result of increased WC amount.
Fig. 11 shows the stress-strain curves of three-point bending test samples.

The hardness variation of HEA is demonstrated in Fig. 11. The unreinforced HEA showed the lowest hardness of about 87.46 HBN. The hardness of the HEA increased depending on adding reinforcement (TiC and WC). HEA+TiC (5 wt%) and HEA+WC (5 wt%) showed the highest hardness of approximately 93 HBN due to the presence of hard TiC and WC particles, which were obstacles to dislocation motion. Even though 10, 15 % TiC and 10, 15 % WC addition increased the hardness, it was lower compared with 5 % TiC and 5 % WC addition. The increase in hardness can be explained by the mixture rule. The mixture rule for materials with high relative densities is described by:

\[ H_c = H_m f_m + H_r f_r \]

where \( H_c \) is the hardness of the alloy, \( H_m \) is the hardness of the matrix, \( H_r \) is the hardness of the reinforcement element, and \( f_m, f_r \) are the volumetric ratios of the matrix and the reinforcement element, respectively. Hard particles prevent the dislocation movement and increase the strength of the HEAs [37, 38].

When the Fig. 11 was examined, the hardness of HEAs was demonstrated with different TiC and WC content. It can be seen that, compared with the original HEA sample, the hardness of the HEA+TiC and HEA+WC increased obviously. The increase of hardness was mainly caused by dispersion strengthening effect of TiC and WC [32]. As a result the hardness should be increased with the TiC and WC content. But the content of TiC and WC reached 10, 15 wt.%, the hardness was lower than the HEAs with 5 wt.% TiC and WC. This is because the relative density of the HEAs also had important influence on the hardness. The decrease of relative density would no doubt reduce the hardness [37].
The corrosion test procedure for an alloy has been used in dimensions of 1 x 1.2. The alloy was placed in a round epoxy mould, subjected to grinding and polishing, and then washed with inert alcohol. The alloys were sequentially placed in a container containing distilled water and 3.5% NaCl with an initial potential of -0.25. Tafel curves were used to determine $E_{\text{corr}}$ (the corrosion potential), $I_{\text{corr}}$ (the corrosion current), $\beta_a$ (the anodic tafel curve), $\beta_c$ (the cathodic tafel curve) and the corrosion rate. The value of $R_p$ (the corrosion resistance) was calculated using the Stern–Geary equation (Equation 1) [39].

$$I_{\text{corr}} = \frac{\beta_a \times \beta_c}{2.303 \times R_p (\beta_a + \beta_c)} \quad (1)$$

The electrochemical results for the coatings are given in Table II. It was found that the alloy without additives had the highest corrosion resistance, followed by unreinforced HEA. The lowest was observed for 5% TiC, which exhibited a corrosion resistance of 12.42 kΩ.cm$^2$. The full results are displayed in Table II.

**Tab. II** Electrochemical results of composites.

| Alloys | $E_{\text{corr}}$ (mV) | $I_{\text{corr}}$ (µAcm$^{-2}$) | $\beta_a$ (mV) | $\beta_c$ (mV) | Corrosion rate (mpy) | Corrosion resistance (kΩ.cm$^2$) |
|--------|------------------------|---------------------------------|----------------|----------------|---------------------|-------------------------------|
| HEAs   | -542                   | 26.70                           | 123.8          | 326.9          | 12.37               | 146.03                        |
| HEAs+5%TiC | -430                 | 600                             | 229.7          | 679.3          | 331.3               | 12.42                         |
| HEAs+10%TiC | -332                | 394                             | 200.4          | 734.5          | 305                 | 17.35                         |
| HEAs+15%TiC | -403                 | 187                             | 177.4          | 513.8          | 130.5               | 30.62                         |
| HEAs+5%WC  | -393                  | 64.80                           | 151.9          | 568.7          | 45.36               | 80.33                         |
| HEA+10%WC  | -377                  | 49.20                           | 141.6          | 527.1          | 30.07               | 98.50                         |
| HEAs+15%WC | -420                  | 32.50                           | 141.1          | 753.4          | 21.58               | 121.95                        |
| HEAs+(5%TiC+5%WC) | -338               | 323                             | 100.2          | 255.6          | 67.28               |                               |

**Fig. 12.** Corrosion curve for HEAs.
This performance can be seen in the data of Fig. 12. Because the exponentially consistent action of corrosion rate can determine with extra reinforced of TiC and WC. For this reason, increase of TiC and WC these HEAs will not increase of all performance of corrosion. The larger reinforced of TiC and WC is obligatory for enhancing mechanical properties and this knowledge will contribute a lot to the literature. As a consequence, there is a reaction among AlCuFeCrNi, TiC and WC. TiC and WC particles functions as an efficient anode to expedite of corrosion. Thus, corrosion rate is decreased for HEA-TiC and HEA-WC.

4. Conclusion

In this study, the hot pressing process in the AlCuFeCrNi-TiC/WC HEAs alloy were successfully performed. Scanning electron microscopy (SEM), X-ray diffractogram (XRD), hardness, fracture surface SEM images, SEM mapping of elemental distribution and EDX spectrums, hardness, three-point bending, and corrosion tests were successfully applied to the samples. The report of the experimental results can be summarized as below:

1. It was determined that TiC and WC particles were homogeneously distributed in general as a result of SEM analysis.
2. In EDS analysis Al, Cr, Fe, Ni, Cu, W and C peaks that were present in the HEAs were clearly seen.
3. In SEM mapping of elemental distribution and EDS spectrums analysis to determine the distribution of TiC and WC particles. The basic elements are Al, Cu, Ni, Fe and Cr. The reinforcement particles are Ti, W and C.
4. In XRD graphs; Al_{0.99}Fe_{0.99}Ni_{0.22}, AlCrCu_{2}, Al_{5}Cu_{9}, AlFe_{3}, Cu_{8.5}Al_{1.5}Ni_{6}Al_{3}Al, Al_{2}Cu_{2}, AlCrFe_{3}, Cu_{2.9}Ni_{0.1}, AlCrCuFe, Al_{3}Fe_{4}, AlFe, Cr, C, AlFe_{2.2}Ni_{0.7}, Cr_{0.7}Fe_{0.3}, W_{2}C, Fe_{7}Al_{11}, AlCrFe_{2}, AlFe_{5}Ni_{0.5}), Cr_{0.7}Fe_{0.8}, W_{2}C, W_{2}C peaks were determined.
5. In the fracture surface SEM images contains cracks and holes.
6. In the stress-strain graphs, brittle fracture has formed in HEA-TiC samples whilst more ductile fracture has formed as a result of a plastic deformation in HEA-WC samples compared to HEA-TiC samples.
7. Due to the presence of hard TiC and WC particles, the highest hardness of about 93 HBN was a HEA+TiC (5 wt%) and HEA+WC (5 wt%).
8. It has been determined that increasing the TiC and WC reinforcements in the HEAs does not increase the corrosion performance of the samples.

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У овом раду, синтетисан је побољшани AlCuNiFeCr прахом који је садржавао TiC (титанијум карбид) и WC (волфрам карбид) топлим пресовањем.
Прахови TiC и WC су додати AlCuNiFeCr, у односу 5%, 10% и 15%, истим редом. Са циљем да се направе и контролишу параметри, синтеровање је изведено у аутоматској лабораторијској топлој преси. Коришћени су графитни калупи и атмосфера аргона. Композити су добијени на температури синтеровања од 900 °C под притиском од 35 MPa током 4 минута. Да би се разумела микроструктурна и механичка својства добијеног материјала, урађене су следеће анализе: SEM, EDS, XRD, тврдоћа, савијање и три тачке и тест на корозију. Узорак са најбољим својствима је AlCuNiFeCr- 15% WC.

Кључне речи: легура високе ентропије; топло пресовање; побољшана TiC; побољшана WC; механичка својства.

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