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*Araştırma Makalesi / Research Article*

# Use Of Powder Metallurgy Method in The Production of SiC Reinforced Cu-Al-Ni Composites and Characterization of The Production Result

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## Abstract

Powder metallurgy (PM) is an important production route of alloys and is also important in terms of its properties and economy. This method is suitable for the production of complex and versatile forms and structures. In this study, it was tried to improve the microstructure and mechanical properties of CuAlNi and CuAlNi-SiC alloys sintered at constant pressing and temperature. Composite samples were manufactured by supplementing the CuAlNi powder mixture with SiC powders at different weight ratios (2.5%, 5, 7.5 and 10%) at the micron level. Scanning electron microscope (SEM) and optical microscope were used to determine the microstructures of the manufactured samples, and X-Ray Fluorescence (XRF) and X-Ray Diffraction method (XRD) analyzes were used to determine the phases formed in their internal structures. Micro hardness ($HV_5$) was taken to determine the hardness effect. According to the micro structure results, SiC particles were homogeneously dispersed in the structure. Depending on the increasing SiC reinforcement, an increase in hardness values was observed.

**Keywords:** Powder metallurgy, Composite materials, SiC.

## INTRODUCTION

Scientists working on materials science have sought materials with better properties and more economical due to reasons such as not having all the features sought from materials produced with traditional manufacturing methods and not being economical in production. The physical, chemical and mechanical properties sought from materials are determined by the composition properties of the materials. Therefore, the requirements for materials with better properties have increased. Due to the need for materials with these properties, the importance of metal-based powders has increased (Akinay, Hayat, Cakir, & Akin, 2018; Çalıgülü, Taşkın, & Kejanlı, 2008; Salur, Aslan, Kuntoglu, Gunes, & Sahin, 2019; Şap, Usca, Uzun, Kuntoğlu, & Salur, 2022).

Today, CuAlNi alloys prepared by PM draw attention. Control of the chemical composition of this alloy can be obtained with PM. PM has been improved as an alternative manufacturing method to manufacturing methods like machining, casting, cold and hot pressing (Salur, Aslan, Kuntoğlu, & Acarer, 2021; Usca et al., 2021). By using the PM method, material properties such as wear resistance and corrosion, tension and surface friction can be improved by manufacturing composites. Composites have an important place among materials in engineering applications. The reason for this is that the strength-to-weight ratio can be increased with composites and thinner and lighter materials can be developed, and production and operating costs can be reduced. With CuAlNi alloys, which are good in terms of strength and lightness, it is possible to produce composite materials with desired high level mechanical properties.

CuAlNi and its alloys are preferred mainly in biomedical, automotive and aerospace fields due to their excellent corrosion and heat resistance, strength and toughness (Kim et al., 2020; Lei et al., 2019; Wang et al., 2018). In addition, there are many areas of use in machinery equipment, construction materials, industrial applications such as medical and electronic devices and in many areas that ease daily life such as telephone antennas (Atapek, Pantelakis, Polat, Chamos, & Çelik, 2020; Wu et al., 2013). Despite its wide usage area, problems may occur in industrial applications of CuAlNi and its alloys in terms of their mechanical properties and content (Dash, Sohn, Vaßen, Guillon, & Gonzalez-Julian, 2019). For this reason, in the study, due to the insufficient mechanical properties of the CuAlNi alloy and in order to improve it, it was strengthened with SiC particles by means of PM. By improving the mechanical properties of the produced samples, the gap needed in the sector will be eliminated. Some of the studies in the literature can be summarized as follows.

Akbarpour et al. studied the hardness, friction and wear properties of Cu-SiC nano composites. They stated that increasing the SiC nanoparticle content up to 2% by volume increases the hardness of the nano composite, while the hardness decreases at higher SiC contents. They concluded that the nano composites they produced showed a higher hardness compared to micro grained Cu (Akbarpour, Najafi, Alipour, & Kim, 2019). Dileep et al. studied the corrosion and mechanical behavior of Al-Ni-SiC metal matrix composites. They added 2.4%, 6%, 8% SiC and 4% Ni as reinforcements to the pure basic matrix. The hardness of the aluminum matrix increased as the percentage of SiC increased, with a maximum increase of 87% for 8% SiC composite (Dileep, Ravikumar, & Vital, 2018). Mamundi Azaath et al. conducted a study on the mechanical properties, corrosion and micro structure effect of Cu-20Al-4Ni/SiC composites synthesized by PM. Silicon carbide (0, 2, 4, 6) in three different weight percentages is reinforced with aluminum bronze matrix (Cu-20%Al-4%Ni). Using this compact tube furnace, it was heated at two different temperatures, 650 and 750 °C. The density decreased with the increase in silicon carbide content. Aluminum bronze sintered at 750 °C showed the maximum hardness of 4% SiC composite with 32 HRC (Azaath, Natarajan, Veerappan, Ravichandran, & Marichamy, 2022). According to this study, there is a difference in material production temperature.

In this study, SiC particles with different ratios (2.5%, 5%, 7.5% and 10%) were reinforced into the CuAlNi alloy and produced by the PM technique. Micro structure images were obtained with post-production SEM. Energy Dispersive Spectroscopy (EDS) analyzes were performed on the samples with EDS analysis. XRF and XRD analyzes were carried out to provide information about the chemical composition of the test samples. In addition, the hardness values due to SiC powder were obtained by micro hardness measurement method.

## MATERIALS AND METHODS

The purpose of the experimental study is to produce CuAlNi alloy filled with silicon carbide particles with different ratios (2.5%, 5, 7.5 and 10%) by PM method. For this aim, CuAlNi alloy powders were prepared by weighing with respect to the percentage chemical compositions in Table 1. The SiC ratios added to the CuAlNi alloy are given in Table 2.

**Table 1.** % Chemical composition of CuAlNi.7

| Materials | % Cu | % Al | % Ni |
|---|---|---|---|
| **CuAlNi** | 84 | 12 | 4 |

**Table 2.** Production parameters.

| Sample | % CuAlNi | % SiC | Temperature (°C) | Pressure of pressing (MPa) | Pressing time (min) |
|---|---|---|---|---|---|
| **1** | 100 | - | 850 | 35 | 5 |
| **2** | 97,5 | 2,5 | | | |
| **3** | 95 | 5 | | | |
| **4** | 92,5 | 7,5 | | | |
| **5** | 90 | 10 | | | |

## Preparation of Samples

SiC was added to the CuAlNi powder mixture at the rates of 2.5-5-7.5 and 10. The mixing process of the prepared mixture powders was carried out with a 3-axis turbula for 1 hour. Hot pressing of the prepared powders was done. The size of the powders in the composite material is 325 mesh. Hot pressing was done at a pressing temperature of 850 °C, a pressure of 35 MPa and a duration of 5 minutes. Before pressing, the pressing medium was kept in a vacuum environment for 10 minutes, and then the pressing process was carried out in an argon gas environment. The mould used in pressing is in the form of a rectangular prism with a diameter of 10x10x25 mm. After sintering, micro structure examinations of the test materials were taken by means of optical microscope and SEM. Sanding, polishing and etching processes were performed on the samples in order to make micro structure studies. The sample surfaces were sanded consecutively between 200-1200 mesh. Then, polishing process was applied to the sample surfaces by means of 3 and 1 μ diamond suspensions. Finally, etching was done by immersion for 10 seconds.

## RESULTS

The images obtained by the optical microscope of the composite materials manufactured by the PM method were evaluated. As a result of the examination of the SEM and optical microscope images of the sample number 1 in Figure 1, the CuAlNi matrix structure is seen. Due to the powder metallurgy method, there is pollution and oxidation of the powders in the experimental samples produced. Therefore, there are partial pores.

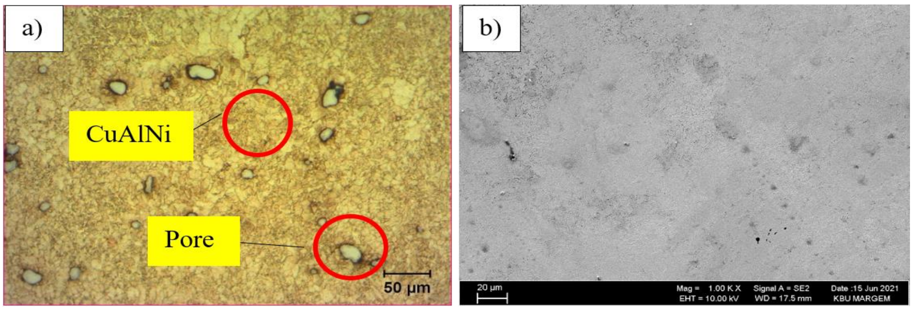



**Figure 1.** SEM and Optical images of pure sample with CuAlNi matrix structure.

In addition, as a result of the examination of the micro structure images obtained from the samples with 2.5%, 5%, 7.5%, 10% SiC reinforcement, it is seen that the SiC particles are homogeneously distributed. These images are given in Figures 2, 3, 4 and 5.

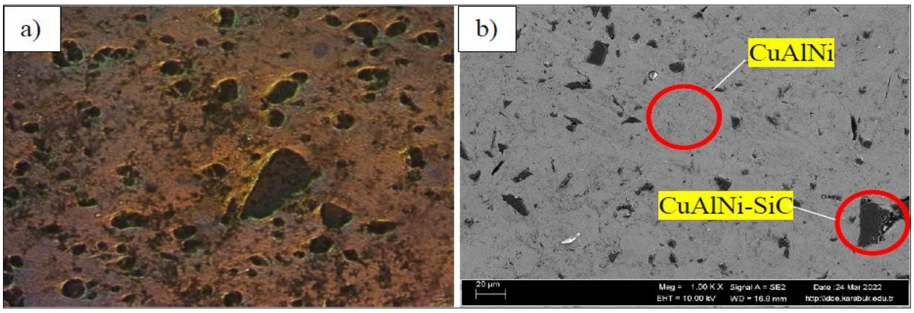



**Figure 2.** SEM and Optical images of material containing 2.5% SiC.

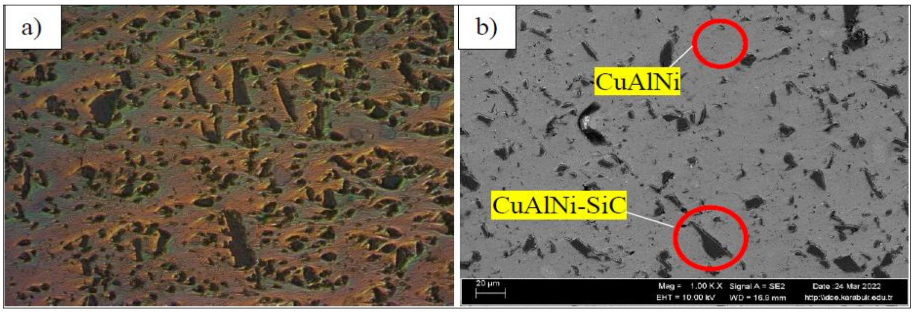



**Figure 3.** SEM and Optical images of material containing 5% SiC.

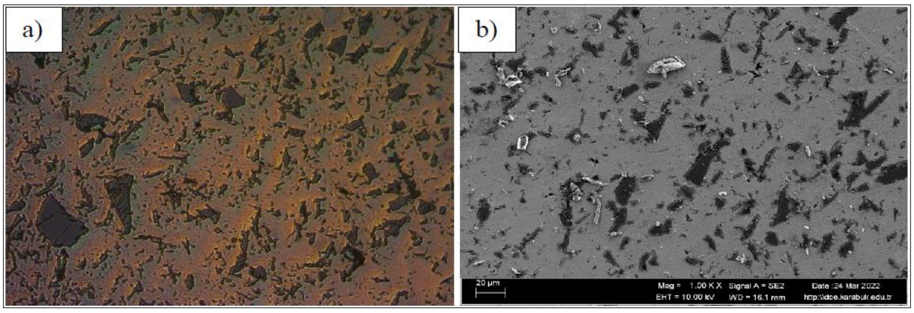



**Figure 4.** SEM and Optical images of material containing 7.5% SiC.

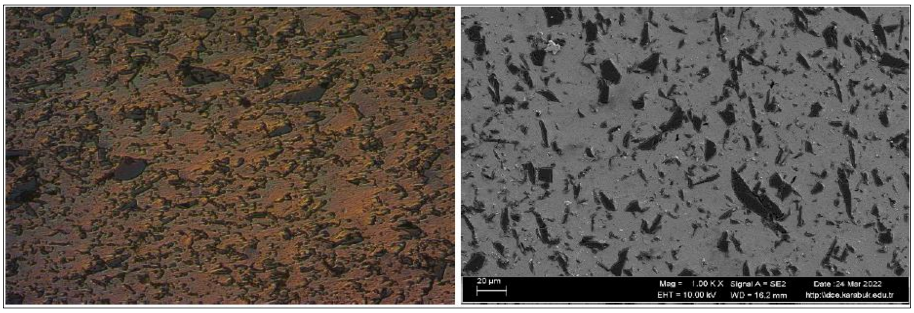



**Figure 5.** SEM and Optical images of material containing 10% SiC.

As a result of the three-dimensional mixing and pressing processes, it is clearly seen that SiC exhibits a homogeneous distribution in the micro structure. SiC has an irregular geometry in terms of structure. It is thought that SiC, which distributes homogeneously in the structure, improves the mechanical properties of the obtained composite.

EDS results of obtained pure and SiC added composites are given in Figures 6,7,8,9 and 10. The analysis results support the chemical composition of the composite. Cu, Al, Ni, Si and C elements were determined in the structure. It is also expressly seen that the homogeneous distribution of SiC precipitates in the main matrix increases in direct proportion with increasing SiC addition.

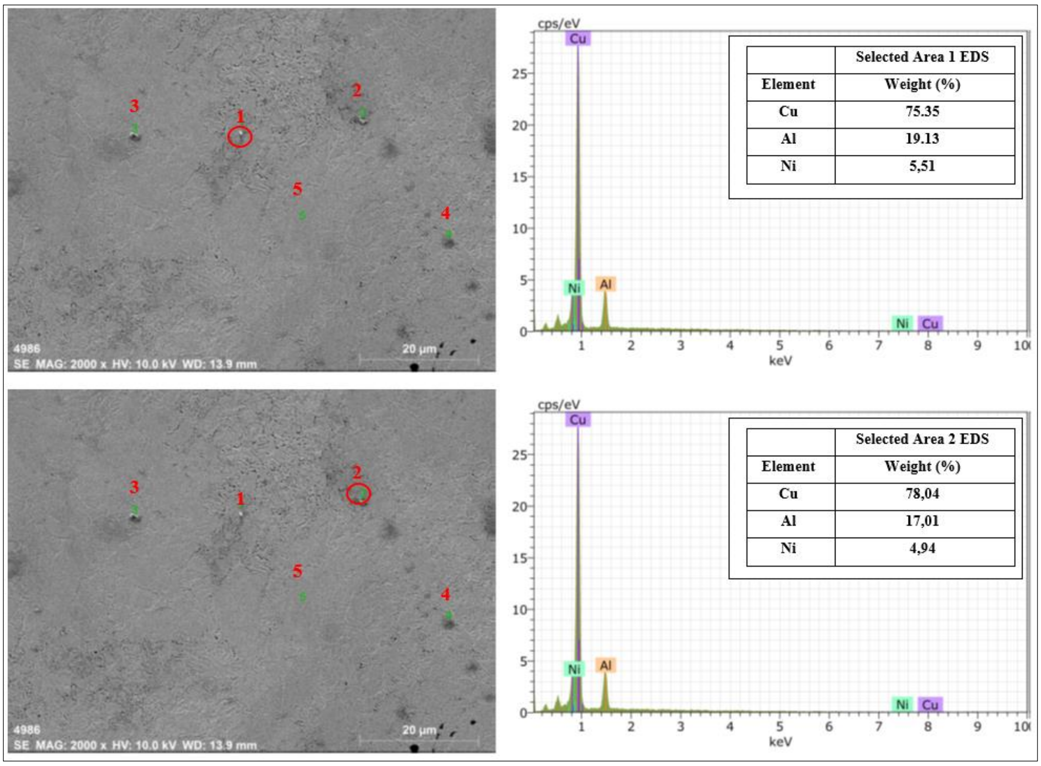
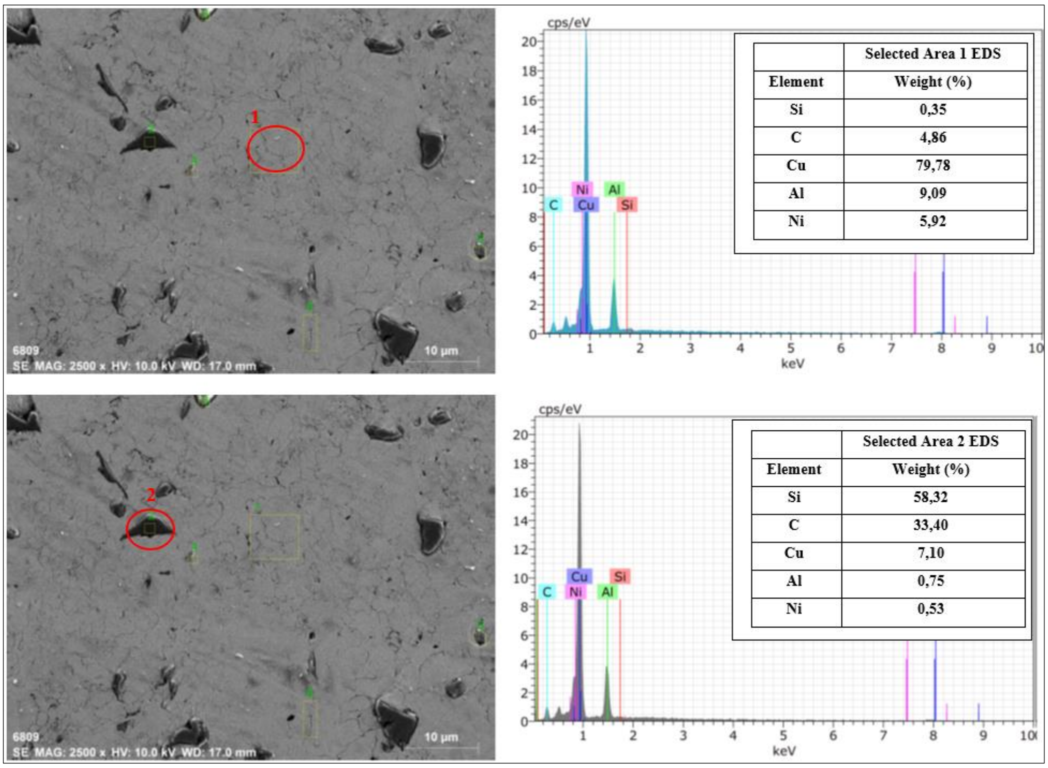


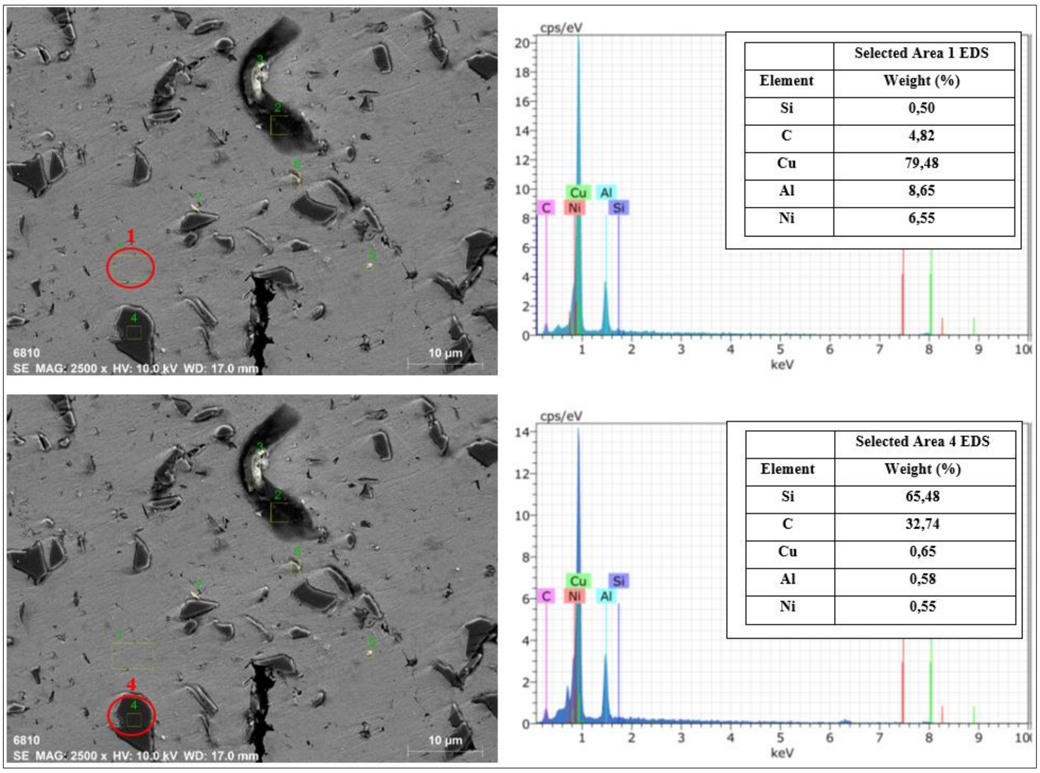

**Figure 6.** SEM and EDS analysis result of the sample with the chemical composition of CuAlNi.




| | Selected Area 1 EDS |
|---|---|
| Element | Weight (%) |
| Si | 0,35 |
| C | 4,86 |
| Cu | 79,78 |
| Al | 9,09 |
| Ni | 5,92 |

| | Selected Area 2 EDS |
|---|---|
| Element | Weight (%) |
| Si | 58,32 |
| C | 33,40 |
| Cu | 7,10 |
| Al | 0,75 |
| Ni | 0,53 |

**Figure 7.** SEM and EDS analysis result of CuAlNi sample with 2.5% SiC added.




| | Selected Area 1 EDS |
|---|---|
| Element | Weight (%) |
| Si | 0,50 |
| C | 4,82 |
| Cu | 79,48 |
| Al | 8,65 |
| Ni | 6,55 |

| | Selected Area 4 EDS |
|---|---|
| Element | Weight (%) |
| Si | 65,48 |
| C | 32,74 |
| Cu | 0,65 |
| Al | 0,58 |
| Ni | 0,55 |

**Figure 8.** SEM and EDS analysis result of CuAlNi sample with 5% SiC added.

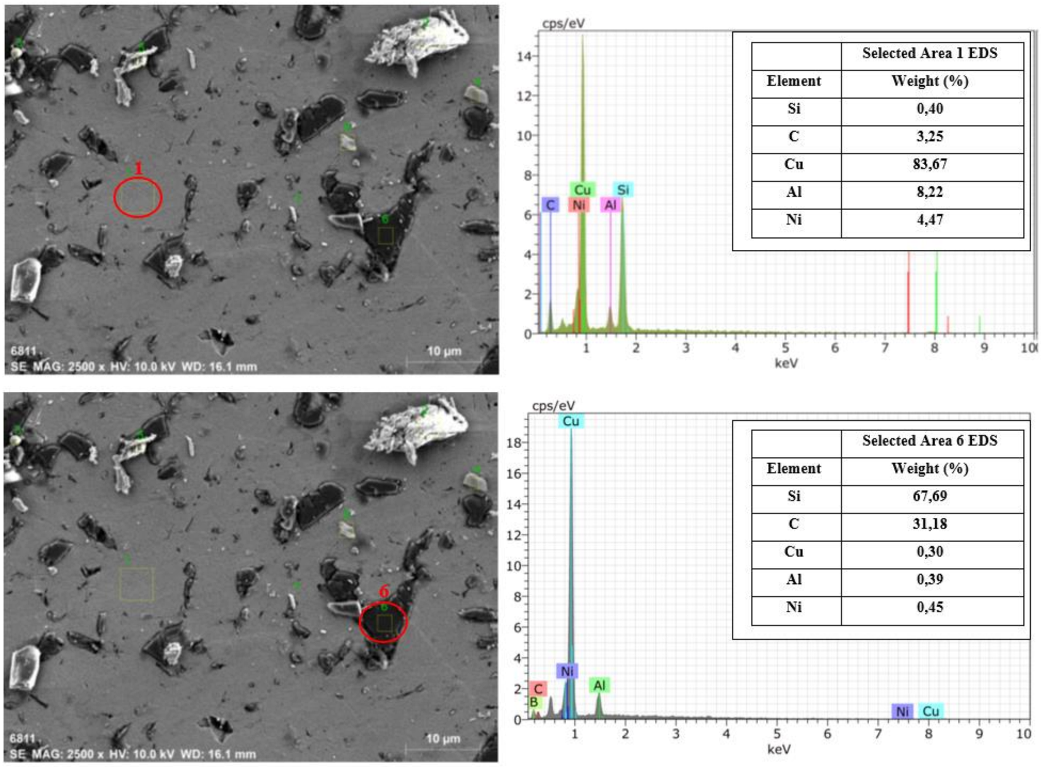



**Figure 9.** SEM and EDS analysis result of CuAlNi sample with 7.5% SiC added.

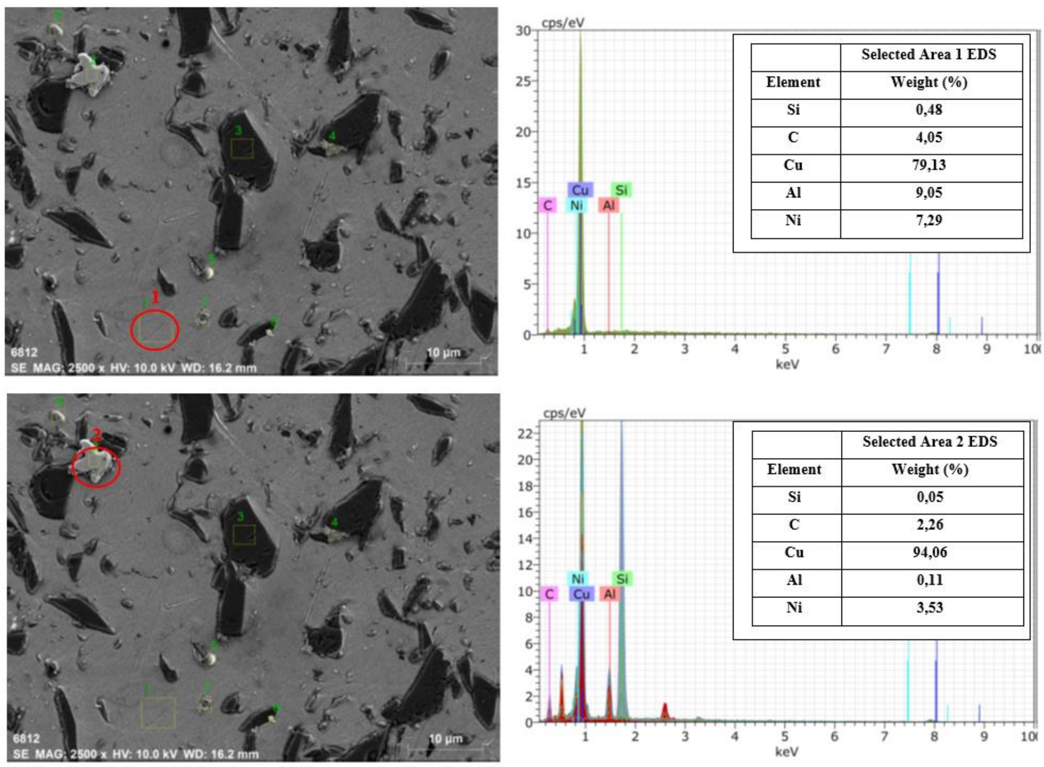



**Figure 10.** SEM and EDS analysis result of CuAlNi sample with 10% SiC added.

The XRF analysis results of the samples of the produced CuAlNi and-CuAlNi-SiC composite are given in Table 3. In XRF analysis, the presence of Cu, Al, Ni and Si elements in the structure was observed. Since element C is the element that is difficult to detect in XRF analysis, it is not seen in the analysis results. However, the presence of element C is observed in the EDS and XRD analyses. The XRD examination results of the obtained composite materials are shown in Figure 11.

**Table 3.** XRF examination results.

| | % Cu | % Al | % Ni | % Si |
|---|---|---|---|---|
| **CuAlNi** | 67.628 | 29.123 | 3.247 | - |
| **CuAlNi-2.5% SiC** | 77.282 | 11.555 | 3.673 | 7.372 |

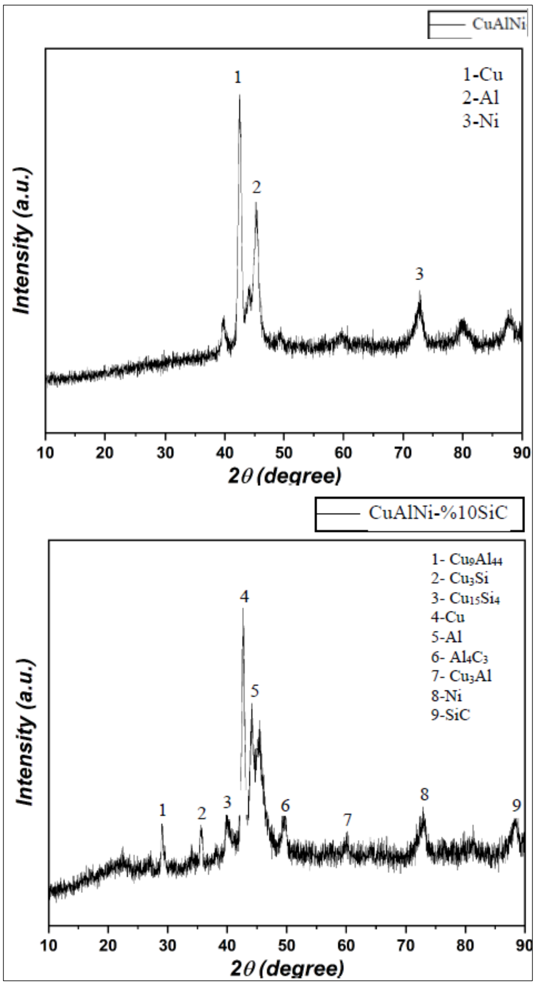



**Figure 11.** XRD analysis results.

As seen in Figure 11 is examined, the presence of Cu, Al, Ni elements in the structure of the pure composite, and the presence of $Cu_9Al_{44}$, $Cu_{15}Si_4$, $Cu_3Si$, $Al_4C_3$, $Cu_3Al$ and SiC phases in the 10% SiC added composite were determined. Also, it is clearly seen that the peaks of Cu, Al, Ni and SiC phases are dominant in the XRD graph.

The graph of the micro hardness results of CuAlNi samples produced by the PM method and CuAlNi samples with 2.5%, 5%, 7.5%, 10% SiC reinforcement is given in Figure 12. Micro hardness measurements of the manufactured composite materials were taken along a line from the sample surface at 100 μm intervals. It was determined that the hardness of the purely expressed CuAlNi sample was 214 HV5 on average. The average value of the sample hardness reinforced with 2.5% SiC was determined as 274.25 $HV_5$. The mean value of the sample hardness reinforced with 5% SiC was determined as 368 $HV_5$. The mean value of the sample hardness reinforced with 7.5% SiC was determined as 377 $HV_5$. The average value of 10% SiC reinforced sample hardness was determined as 451.5 $HV_5$. Looking at the results, it was determined that the hardness of the SiC reinforced samples was higher than the unreinforced sample. The reason for this increase is related to the presence of hard phases formed as a result of increasing silicon carbide.

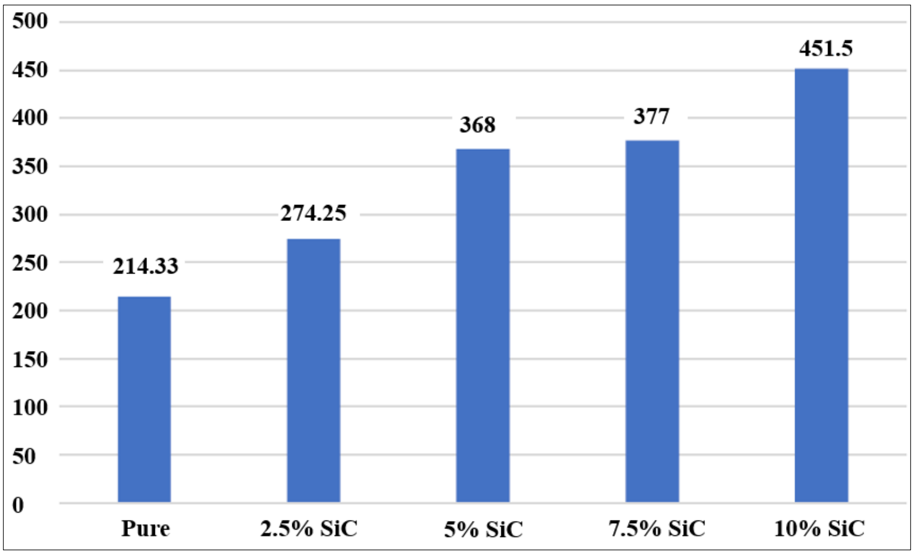



**Figure 12.** Microhardness results of samples with CuAlNi and SiC reinforcement.

## Conclusion

Despite its wide usage area, there are problems in industrial applications of CuAlNi and its alloys in terms of their mechanical properties and content. It is reinforced with SiC particles in order to improve the mechanical properties of the CuAlNi alloy. In our study, CuAlNi-SiC and CuAlNi composites were manufactured by PM method. SEM, optical microscope, XRD, XRF and micro hardness tests were successfully applied to the manufactured samples. A summary of the results is given below.

- CuAlNi and different ratios of CuAlNi-SiC were produced by PM method. SEM, optical microscope, XRD, XRF and micro hardness analyses were performed on these samples.
- In the obtained SEM and optical microscope images, it is clearly seen that SiC exhibits a homogeneous distribution in CuAlNi.
- According to the result of EDS analysis applied to the produced samples, the presence of Cu, Ni, Al, Si and C elements in the material was determined.
- According to XRD results, peaks belonging to different intermetallic phases such as Cu, Al, Ni, SiC and $Cu_9Al_{44}$, $Cu_3Si$, $Cu_{15}Si_4$, $Al_4C_3$, $Cu_3Al$ were detected.

- As a result of the hardness tests, it was determined that the hardness of SiC reinforced samples had higher values than CuAlNi samples. With the increase in the amount of SiC in the composite, there was a direct proportional increase in the hardness values. The micro hardness value of the sample obtained by adding 10% SiC was measured as 451.5 HV5.

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