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Investigation of Electrical Behavior of Al6061+B4C/GNP Hybrid Composite

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Abstract – It is aimed to investigate the electrical behavior of the aluminum hybrid composite produced by the vortex method with different additive ratios in this study. For this purpose, electrical measurements were made on hybrid composite samples, and electrical resistance and conductivity values were calculated. According to the obtained data, it was observed that while the electrical resistances decreased, the electrical conductivity values increased in the hybrid structures formed with B4C and nanographene plate (GNP) doped into the Al6061 alloy. The highest electrical conductivity was obtained from 10% B4C+1.5% GNP added hybrid composite. Compared to the pure Al6061 undoped sample, a conductivity increase of approximately 273% was achieved. It has been determined that this value is also the same as the conductivity value of pure copper. Furthermore, it has been evaluated that the increase in conductivity is caused by the excellent physical properties of carbon-based graphene in the hybrid composite structure, as well as very good conductivity.

Keywords – Hybrid Composite, Al6061, B4C, GNP, Electrical Properties

I. INTRODUCTION

Features such as high strength, rigidity, lightness, high corrosion resistance, high wear resistance, and economy are desired in engineering materials used in the last century. It is challenging for existing engineering materials to meet all of these properties. For this reason, the demand for composite materials has been increasing in recent years. Composite materials are widely used in almost all industrial fields [1]. Metal matrix composites (MMC), a type of these composites, are in demand in many industrial fields, especially in the defense, automotive, and machinery industries. Aluminum and its alloys are mostly preferred as the primary material in MMCs. Composite structures are formed by adding ceramic-based particles into the main element (matrix) as a reinforcement element. Reinforcing elements reinforced into these matrix metals are generally Al2O3, SiC, B4C, TiC, MgO, TiB2 etc. ceramic-based metal oxides, carbides, and nano-sized carbon materials. Recently, hybrid composites have been produced by adding a second reinforcement element into MMC composites. Nano graphene plate (GNP) is one of these elements [2]. However, in studies investigating hybrid composites reinforced with carbon-based nanomaterials, the mechanical properties of the composite structure are generally discussed [3-6]. It is known that the electrical properties of MMC materials are important according to their usage areas. It should be taken into account that while metals, which are the matrix material of MMCs, are conductors, ceramic particles, which are reinforcement elements, are insulators. In addition to these two different physical properties, a third element, carbon-derived nanomaterials, has been added. In this case, it is essential to investigate what kind of conductive behavior will emerge.

Therefore, unlike the literature, it was aimed to investigate the electrical properties of Al 6061 matrix, B4C, and Graphene Nano Plate (GNP) reinforced composite structure in this experimental study. For this purpose, electrical measurements of Al 6061+B4C/GNP composite samples [1, 2, 7], which were previously produced and on which various studies were carried out, were interpreted by determining conductivity and resistivity values.

II. Materials and Method

As a matrix material in the production of hybrid composites, 0.70% Fe, 0.60% Si, 0.85% Cu, 0.15% Mn, 1.0% Mg, 0.25% Zn, 0.15% Ti and% 0.20 Cr was used. In addition, B4C (boron carbide) powder with an average grain size of 40-105 microns and a nano-sized graphene plate (GNP) were used as additives. The matrix and additive ratios based on the production of hybrid composite materials are given in Table 1.

Table 1. Hybrid composite production parameters [1,2,7]

Sample	Al 6061 (%)	B4C (%)	GNP (%)
S1	100	-	-
S2	95	5	-
S3	93	7	-
S4	90	10	-
S5	95	5	0.5
S6	95	5	1.0
S7	95	5	1.5
S8	93	7	0.5
S9	93	7	1.0
S10	93	7	1.5
S11	90	10	0.5
S12	90	10	1.0
S13	90	10	1.5

In the production of hybrid composite materials, vortex (mixed casting), a liquid phase method, has been applied. For this purpose, the matrix element Al 6061 alloy was first put in an electric melting furnace and melted at 750C. Then, additives B4C and GNP were added to liquid Al 6061. After mixing at 900 rpm for 5 minutes, it was poured into prepared steel molds and left to cool [8]. The vortex system in which hybrid composites are produced and the samples produced are shown in Figure 1. Digital microscope images showing the microstructures of 5%, 7%, and 10% B4C added composites are given in Figure 2.

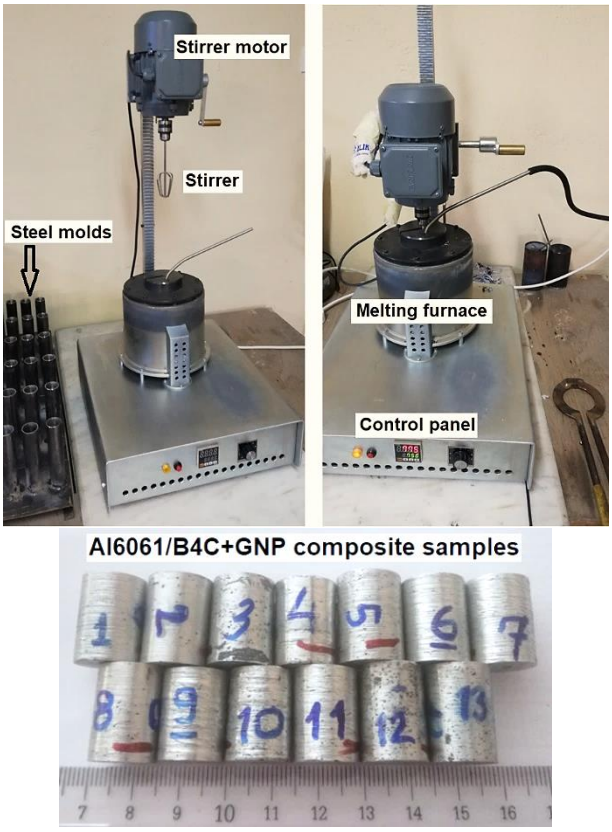

Figure 1. Vortex test setup and hybrid composite samples

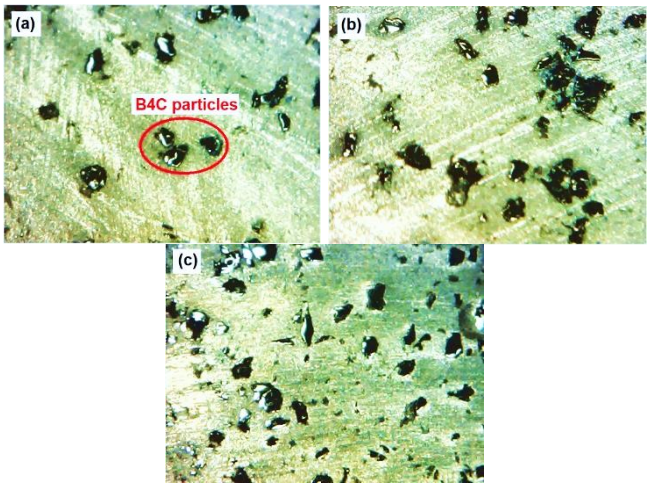

Figure 2. Microstructure images of (a) %5 B4C, (b) %7 B4C (c) %10 B4C added Al6061 composites [1,2,7]

The two-point measurement method was used for electrical conductivity measurement [9]. This method is based on Ohm's law. Direct current power supply and digital multimeter were used for the measurement method. A voltage was applied to the produced material by connecting a power source. Considering Ohm's law, the resistance value of the material was measured according to the applied voltage value. While calculating these resistance values, measurements were taken from at least five different parts of the material. Considering the

possibility of the material not being homogeneously dispersed, the average of the measured values was calculated. Electrical resistivity and conductivity coefficients were found from the obtained resistance values [10-13].

III. Results & Discussion

The values obtained from electrical measurements of B4C+GNP reinforced Al6061 hybrid composites are given in Figure 3.

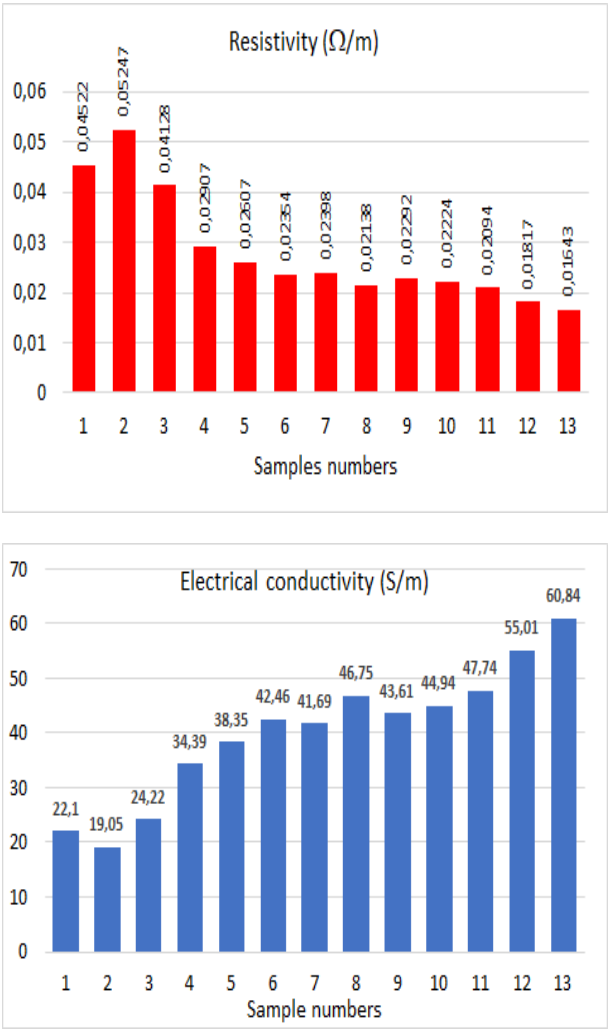

Figure. 3. Resistivity and conductivity obtained from Al6061/B4C+GNP hybrid composites produced by the vortex method

The variation of both resistivity and electrical conductivity values depending on the amount of B4C and GNP reinforcement materials in the test samples is seen in figure 3. The effect of the GNP reinforcement element, which started to take place in the structure, especially from sample number 5, is seen. It is understood that the amount of conductivity increases with the increase in the ratio of GNP and B4C in the hybrid structure. Nano graphene plates (GNP), an allotrope of carbon, lead to the improvement of conductivity. Graphene, which is a very good electrical conductor, shows this feature. Although it is included in the structure at low rates, it dramatically increases conductivity between 0.5% and 1.5%. While the 22.10 S/m conductivity value was measured in the pure Al6061 sample, this value increased to 60.84 S/m in the 10% B4C+1.5% GNP added sample. A conductivity increases of approximately 273% occurred. Since B4C is a ceramic-based structure, it is normally expected to show insulating properties. However, the highest conductivity values were obtained in samples 11, 12, and 13, although 10% of B4C was present. Here, the carbon in B4C is considered to be effective. It is thought that some carbon dissolves in liquid aluminium and contributes to the conductivity property in the production of samples. In order to interpret this situation in more detail, it may be useful to examine the phase structure of the hybrid composite by performing the XRD analysis.

The theoretical conductivity value of Al6061 alloy is given as 22.65 S/m at 300K. For the pure Al6061 alloy numbered 1, the conductivity value of 22,10 S/m was measured. Therefore, it has been observed that the measurements made are consistent. In parallel with this, when the results obtained with the measurements of the GNP-doped Al6061 composites are evaluated, the conductivity values of the GNP-doped samples show a parabolic increase compared to the pure Al6061 alloy. Considering the conductivity values that increased by more than 250% despite the additive material up to 10%, it was evaluated that the samples produced had a homogeneous structure. [13].

IV. Conclusion

It can be stated that the amount of conductivity increase obtained from this study is significant. Because the electrical resistance was decreased and the conductivity increased significantly with the average 1% GNP added into the Al6061 alloy. The conductivity value of pure copper, 59.7 S/m, was obtained from aluminium hybrid composites. In order to evaluate the effect of B4C in the hybrid composite structure on the conductivity more efficiently, it would be beneficial to produce the test samples at the same GNP ratios without the

contribution of B4C and repeat the same electrical measurements.

ACKNOWLEDGMENT

The heading of the Acknowledgment section and the References section must not be numbered.

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