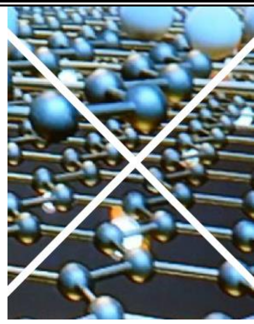
TIJMET, Vol. 003 (2020) 160-170

The International Journal of

Materials and Engineering Technology

ISSN: 2667-4033
TIJMET ID: 200302010 (11 pages)
Type of the Paper: Article
Received 30.11.2020 Revised: 25.12.2020 Accepted: 25.12.2020 Published (Online): 30.12.2020
Journal homepage: http://dergipark.gov.tr/tijmet



INVESTIGATION OF WEAR WEIGHT LOSS IN ALUMINUM MATRIX COMPOSITES

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Abstract

In this study, the wear behavior of Al2024 and composite materials produced by the stir casting method of Al 2024-0.2 (50% MgO + 50% CNT) was investigated. A mixture of 50% by weight of Magnesium oxide (MgO) with an average diameter of <40 nm and a 50% multi-walled carbon nanotube (MWCNT) 1.5 µm in length and 9.5 nm in diameter were used as reinforcement. Al was added in the melting pot as matrix material and continued until the liquid temperature rising to 750 °C. During the melting process, reinforcements were added into the melting pot and the mixing velocity was slowly increased to 500 rpm. The reinforcement material MgO and CNT were mixed in the liquid matrix. Mixing was continued at 500 rpm for about 10 minutes to have a homogeneous distribution of the reinforcements in the composite. The melting crucible was removed and left it at room temperature to cool. The hardness analysis performed, and abrasive wear behavior of composites have been investigated at different sliding distances (250m-500m-1000m) under 2N and 5N loads. The hardness of the materials has been increased with the doping of the reinforcing mixture. The hardness value of Rockwell F was improved up to 69 HRF with the addition of MGO and CNT. In the abrasion tests performed at 2 N loading and 1000 m sliding distance, wear of Al 2024 was 0.0039 gr, while the wear of hybrid composite was 0.0037 gr. Abrasion tests performed at 5 N loading and 1000 m sliding distance, the wear of

Al 2024 was 0.0072 gr, while the wear of hybrid composite was 0.0049 gr. The added reinforcing mixture significantly reduced the abrasion weight loss of the material.

Keyword: Wear, Composite, CNT, MgO, Al2024

1. Introduction

In many industrial applications, hardness and wear come to the fore, especially in materials in contact with each other. It is almost impossible to completely prevent abrasion loss in materials in contact with each other. However, it may be preferable to minimize this rate with various methods or to ensure the abrasion of the material with lower economic value. New and up-to-date materials are needed to minimize wear loss, which is one of the most important mechanisms in engineering applications. It is important to use engineering materials with high friction resistance, especially in places where there is friction. Metal Matrix Composites (MMCs) consist of minimum one metal and one reinforcement material such as fibers, compounds, intermetallic particles, oxides, carbides, or nitrides to achieve the expected properties that cannot be met with single-component materials [1–4]. The stir-casting is one of the well-known methods of producing MMCs with reinforcements. It is possibly a way of producing MMCs materials with low-cost [5,6].

In the production of MMCs, Al and its compounds are the most generally used matrix material [7–13]. The wear behavior of particle reinforced Aluminum Matrix Composite (AMC) has been extensively studied in recent years, thanks to their promising wear resistance [14]. Particularly, the no-lubricant wear resistance of AMCs doped with ceramic particles or fibers have been investigated recently [15,16]. AMCs have been found to generally exhibit superior wear resistance. Areas of application are automotive disc brake of rotors and calipers, connecting rods, cylinder liners, pistons, and turbine compressors. Besides, abrasion resistance cannot be noted as a structural material property. The parameters affecting the wear resistance also include the test conditions, the properties of the matrix, the reinforcements and their bulk content, and the matrix reinforcement including ratio [17,18].

As a result of technological developments, the composite material system is one of the important features in mechanical and tribological behavior. Particularly reinforced composite materials are preferred and tried to be developed in applications requiring high wear resistance. As reinforcement materials, SiO_2, MgO, Al_2O_3, and ZrO_2 are generally preferred because of their high strength and biocompatible properties [19–21]. In some areas, Al and its compounds doped with nanoparticles are recently used. The combination of carbon nanotubes (CNT) and Al compounds have excellent potential in the applications of weight-sensitive. The wear properties of materials are one of the important topics investigated by many researchers [22]. Recent works on the composite materials show that thermal properties, temperature, hardness, strength, sliding speed and abrasion load of the composite affect the wear behavior [23–29].

Some authors have examined the aging effect on the wear of these composites and stated that different aging conditions can lead to various wear behaviors. For example; Sozhamannan et al. prepared hybrid composites by stir casting technique.

The wear tests were performed by a pin on disc technique at the no-lubricant conditions with different load of 40 N to 80 N and sliding speed of 1.5 m/s to 4.5 m/s. They emphasized that both unreinforced Al 6061 matrix and hybrid composites weight losses increased with the increase of load and sliding speed. However, the weight loss of hybrid composite was 23.33 percent less than the 6061 Al matrix [30]. Zakaulla et al. investigated the friction and wear behavior of Al2024 alloy doped with 10 wt.% B_4C particles and MWCNTs varied in 1 wt.% and 2 wt.%. They fabricated the hybrid composite of Al2024 using the stir casting method. They performed experiments using a pin-on-disk machine under a load of 10 N, 20 N, and 30 N with a sliding speed of 0.84 m/sec. They found that Al2024-10wt.% B_4C + 2 wt.% MWCNTs showed a low friction coefficient and abrasion rate compared to Al2024-10 wt.% B_4C + 1 wt.% MWCNTs, Al2024-10 wt.% B_4C composite and Al2024 alloy [31]. Kumar et al. prepared composites containing different size ranges of garnet reinforced by liquid metallurgy route in LM13 alloy. They performed abrasive tests at a sliding speed of 1.6 m/s for a wear distance of 3000 m at different loads varying from 9.8 to 49 N. When compared to the cast iron they found that the wear rate of 15 wt.% , even a higher load of 49 N, fine size garnet mineral reinforced composite is minimum [32]. Kumar et al. examined mechanical properties of the Ni rein-forced with 7075 aluminum alloy. They developed the samples with varıous weight rates (0, 2, 4, 6, and 8 wt.%) of Ni in the Al matrix using the high vacuum casting engine. They studied the sliding wear performance of the some specimens. They found that mechanical properties have increased with the addition of Ni [33]. Wear is a way of representing the rate of wear at various loads and speeds, and the rate of wear or the wear mechanism provides a clear understanding of the various levels of wear susceptibility and the associated wear mechanism. Studies corresponding to the aluminum alloys, composites and various coatings examined show similar trends in speed and load changes in wear rates. Therefore, the influence of different wear coefficient on the wear weight loss of the produced composites was investigated in this study.

2. Materials and Methods

In this study, aluminum-copper-magnesium (Al 2024) as the matrix, 50% magnesium oxide (MgO), and 50% multi-walled carbon nanotube (MWCNT) 0.2 wt.% as reinforcement materials were used in the composites. Aluminum matrix composite was produced by stir casting method. The chemical compositions of the (Al 2024) matrix were given in Table 1, MgO in Table 2, and MWCNT in Table 3 and were embedded into the melting pot. The melting was started after putting the Al in the melting pot as matrix material and continued until the liquid temperature rising to 750 °C. To mix liquid metal a mechanism was used. In this process, reinforcements were added into the melting pot and the mixing velocity was slowly increased to 500 rpm. After the reinforcement materials, MgO and MWCNT were mixed in the liquid matrix, mixing was continued at 500 rpm for about 10 minutes to have a homogeneous dispersion of the reinforcements in the composite. After mixing process, the melting crucible was removed from the heater and the semi-solid compound was poured into steel molds and left samples at room temperature to cool.

Table 1. Chemical compositions of matrix material Al2024 (wt.%).

Al	Cu	Mg	Mn	Fe	Si	Zn	Ti	Cr
92.2	4.5	1.5	0.5	0.4	0.41	0.2	0.12	0.17

Table 2. Chemical compositions and some properties of MgO.

MgO	Na	K	Ca	Diameter	Density	Surface area	Melting degree
99.95	0.023	0.0089	0.016	45 nm	3.58 g/cm^3	> 45 m^2/gr	2852 °C

Table 3. Some properties of MWCNT.

Purity	Outer diameter	Inner diameter	Length	Density	Surface area
92	8-10 nm	5-8 nm	1-3 µm	2.4 g/cm3	240 m^2/g

The hardness test was performed as HRF and the wear tests were applied on a ball-on-disk engine on a CSM Instruments brand device, without a lubricant at room temperature. In the wear test, 2 and 5 N loads, 0.1 m/s sliding speed, and 250-500-1000 meters sliding distance were used. The weight loss of the produced materials in the abrasion tests was evaluated.

3. Results and Discussion

The hardness of a material is an important wear parameter. Different hardness values were obtained by adding different materials such as MgO and CNT to explore the effects of hardness and particles on friction and wear. Due to the material doping, the Rockwell F hardness value of composite increases as shown in Figure 1. The hardness of the Al 2024 matrix was measured as 62 HRF and the hardness value of the Al 2024-0.2 (50% MgO + 50% CNT) composite was determined as 69. The hardness value of the composite material has increased with the addition of reinforcement and this increase is approximately 11.3%. Similar increases have been reported in the literature [34,35,5].

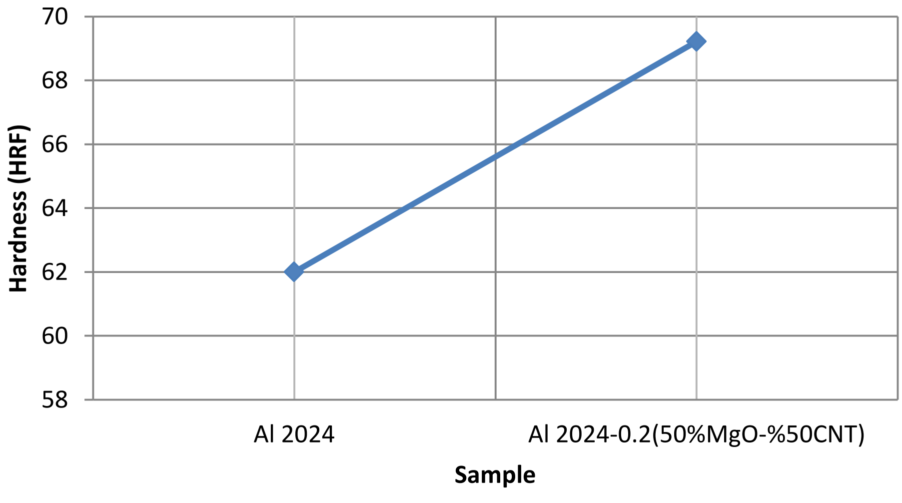

Figure 1. HRF hardness value of matrix and composite

After examining the hardness of the MMCs specimens, they were tested on ball-on-disc abrasive test apparatus.

The wear rates of the Al2024 alloy and the Al 2024-0.2% (50% MgO + 50% CNT) interpenetrating composites after 250 m, 500 m, and 1000 m sliding, under 2 N are shown in Figure 2, under 5 N are shown in Figure 3. It can be seen that although the wear amount of the Al 2024-0.2% (50% MgO + 50% CNT) is higher than that of composites, it decreases significantly with the sliding distance.

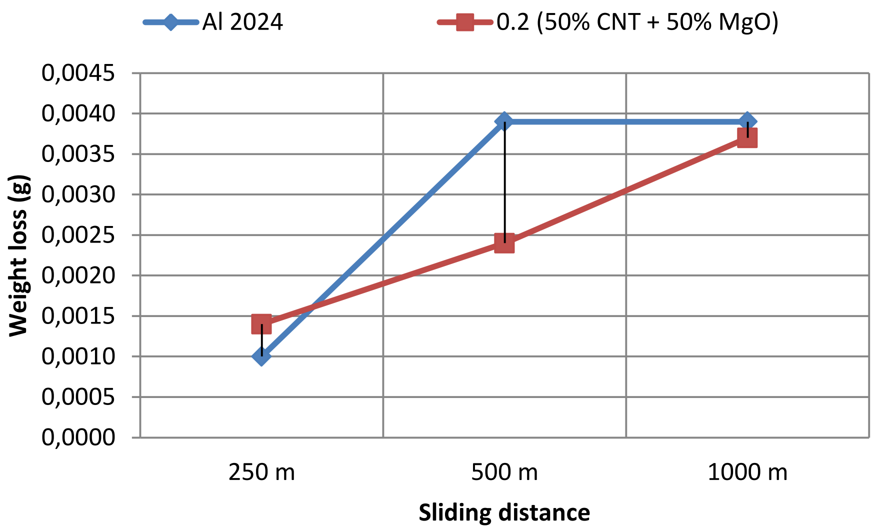

Figure 2. The effect of sliding distance on weight loss under 2 N load

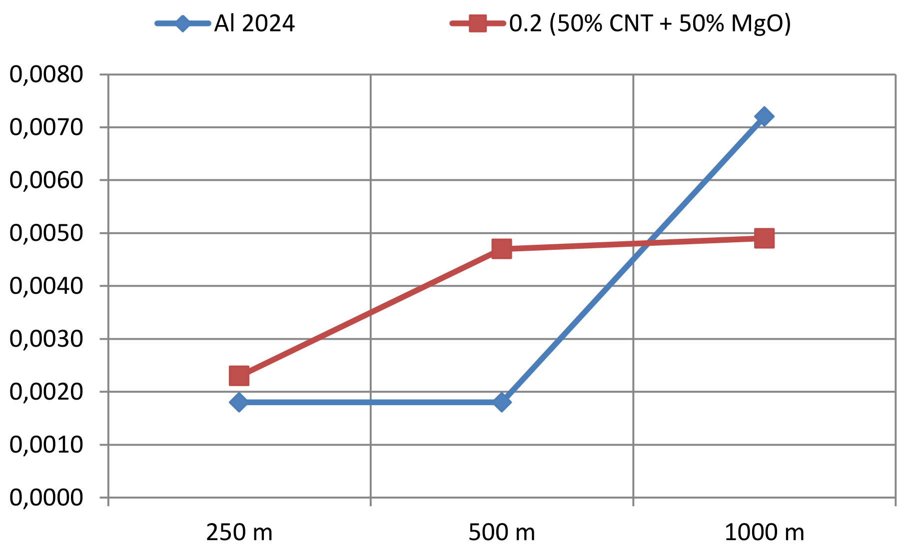

Figure 3. Effect of sliding distance on weight loss under 5 N load

The influence of sliding distance on weight loss under 2 N load is shown in Figure 2. In the wear test performed under 2 N load, the wear weight loss increased with the increase in the sliding distance of both matrix material and composite. In the abrasion tests performed at 2 N loading and 1000 m sliding distance, wear of Al 2024 was 0.0039 gr, while the wear of hybrid composite was 0.0037 gr. The effect of sliding distance on weight loss under 5 N load is shown in Figure 3. In the wear test performed under 5 N load, the wear weight loss increased with the increase in the sliding distance of both matrix material and composite. In the abrasion tests performed at 5 N loading and 1000 m sliding distance, the wear of Al 2024 was 0.0072 gr, while the wear of hybrid composite was 0.0049 gr. The added reinforcements reduced the wear weight loss in the materials [32,5].

The effect of the applied load is given in Figures 4 and 5. The increase in the applied load caused more abrasion weight loss in the matrix material. This increase occurred at a maximum loss distance of 1000 meters. Similar results are seen in aluminum matrix hybrid composites. The maximum wear weight loss was observed under 5N load and 1000 meters sliding distance.

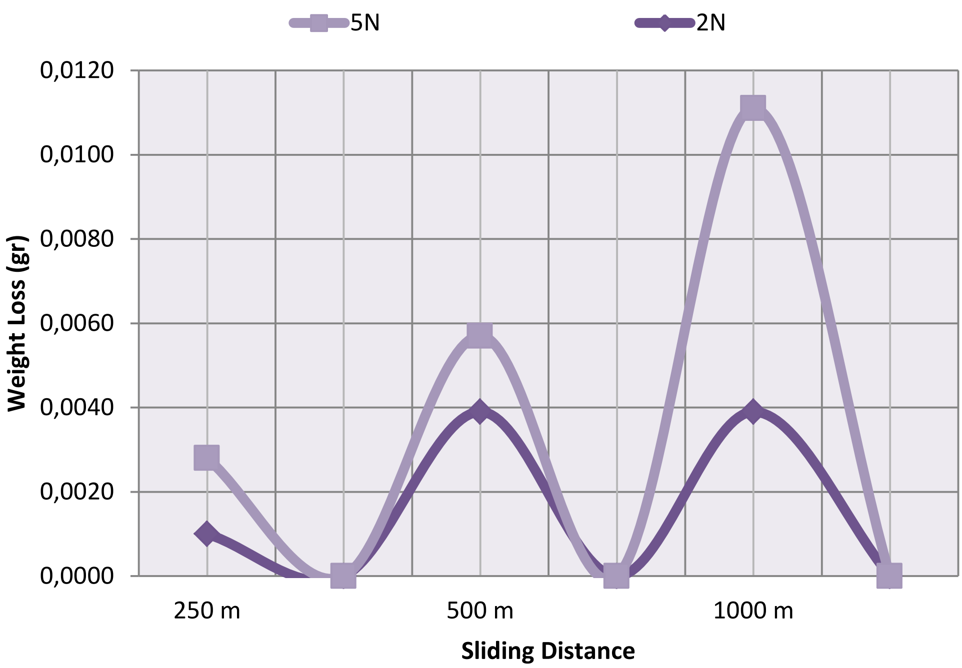

Figure 4. Effect of load on Al2024 alloy weight loss

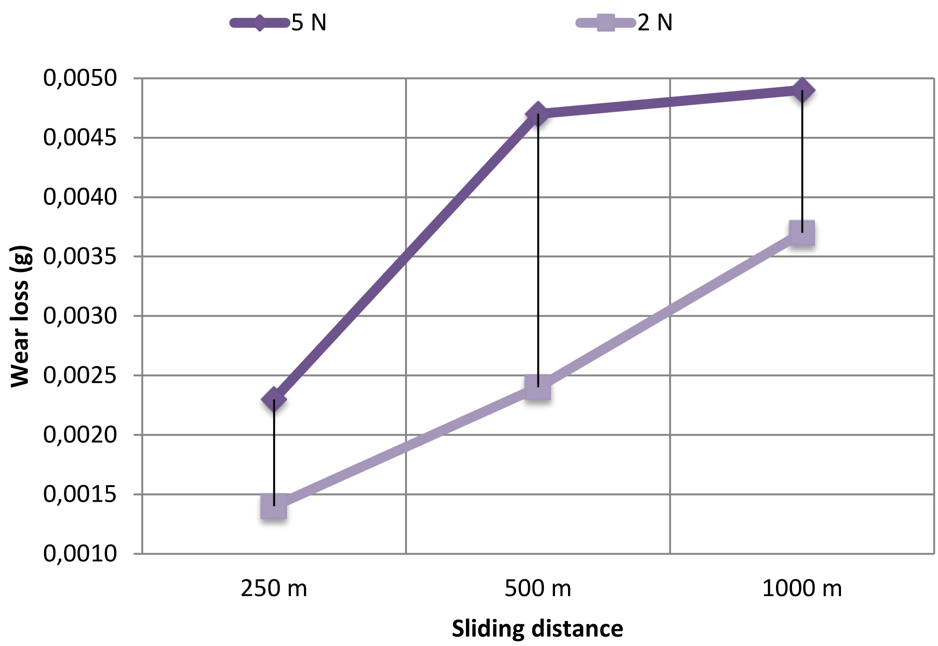

Figure 5. The effect of the load on the weight loss of the composite Al2024 0.2 (%50 CNT + %50 MgO)

The change in weight loss occurring in materials from 250 m to 500 m and 1000 m under 2 N load is shown in Figure 6. In the Al 2024 matrix, the weight loss was increased 3.9 times at the sliding distance from 250 m to 500 m and the weight loss did not change at the 1000 m sliding distance. In the same direction, the change of the weight loss in the composite occurred 1.7 and 2.6 times. In this respect, the increase in weight loss occurring in the composite material is less than the increase in the matrix material. The change in the sliding distances under 5 N load is given in Figure 7.

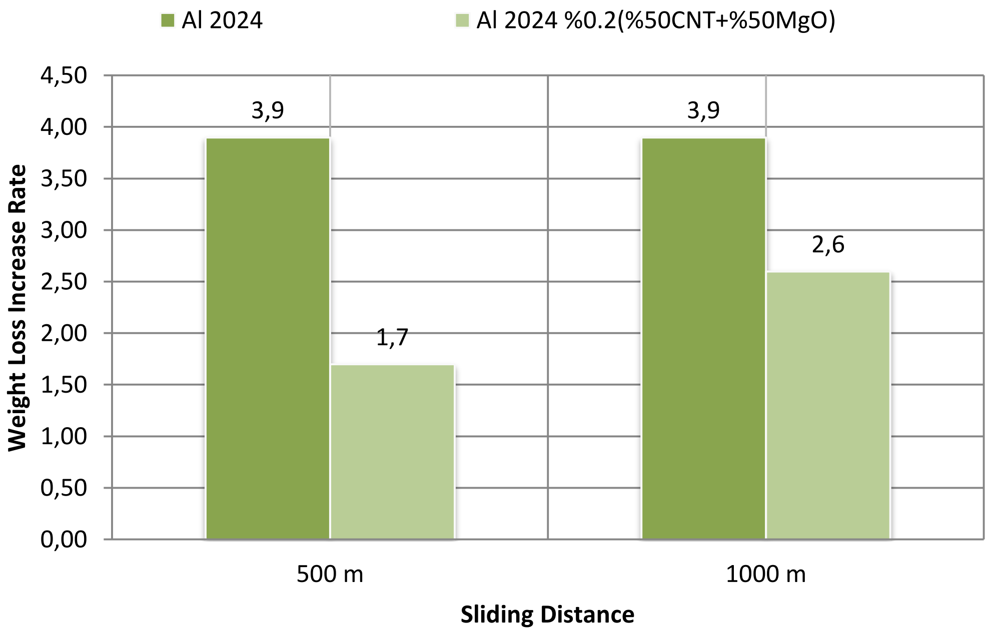

Figure 6. Weight loss change of sliding distance under 2 N load

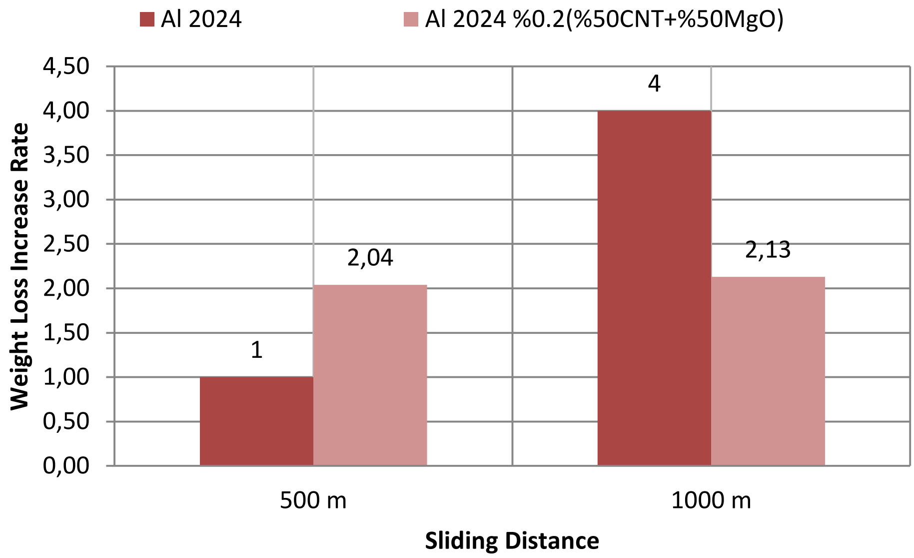

Figure 7. Weight loss change of sliding distance under 5 N load

When it comes to the sliding distance from 250 m to 500 m, the weight loss increase of the Al 2024 matrix did not change, while the weight loss increase was 4 times when the 1000 m sliding distance was reached. Composite material, on the other hand, was realized as 2.04 times and 2.13 times. It has been examined that the increase in weight loss occurring in the composite material is less than the increase in the matrix material. It is seen that the wear weight loss occurring with increasing load and increasing sliding distance is directly proportional [17,30].

4. Conclusions:

In this study, the effect of the load and sliding distance applied on the hardness and wear weight loss of hybrid composites with aluminum matrix produced by stir casting method and reinforced with magnesium oxide and multi-walled carbon nanotube was investigated. The hardness of the materials has been increased with the addition of the reinforcing mixture. With increasing load and sliding distance, the weight loss in materials increases in direct proportion. The hardness value of Rockwell F was 69 HRF with the addition of MGO and CNT. Under 2 N loading and 1000 m sliding distance, wear of Al 2024 was 0.0039 gr, while the wear of hybrid composite was 0.0037 gr. Abrasion tests performed at 5 N loading and 1000 m sliding distance, the wear of Al 2024 was 0.0072 gr, while the wear of hybrid composite was 0.0049 gr. The added reinforcement mixture significantly reduced the weight loss of the material.

Acknowledgments: I would like to express my deepest appreciation to organizing committee of HEZARFEN (International Science, Mathematics and Engineering Congress) in the selection of my study which was presented in the conference organized on 8-10 November 2019 in Ege University.

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