International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 36 العدد
Part 1 المجلد

http://www.doi.org/10.62341/ghid1254

Received	2024/11/12	تم استلام الورقة العلمية في
Accepted	2024/12/15	تم قبول الورقة العلمية في
Published	2024/12/26	تم نشر الورقة العلمية في

Dry Wear Characteristics of MAO Applied on AZ31 Sheet Alloys with % Lanthanum Additions

[1*]Galal Elmansouri
Metallurgical and Materials Engineering Department
College of Engineering Technology, Zuwara, Libya
galal_mansouri@yahoo.com

[2*]Hayrettin Ahlatci
Metallurgical and Materials Engineering Department
Karabuk University, Karabuk Turkey
hahlatci@karabuk.edu.tr

[3*]Ismail Hakki Kara
Metallurgical and Materials Engineering Department
Karabuk University, Karabuk Turkey
1987ihk@gmail.com

***Corresponding author galal_mansouri@yahoo.com**

Abstract
In this research, AZ31 alloys were enhanced with 0.2% and 0.5% La (Lanthanum) using the low-pressure die casting method. These alloys underwent hot rolling at 400°C with speeds of 4.7 and 10 (m/min) meters per minute, Maintaining a deformation rate of 30% with each pass. Post-production, Micro Arc Oxidation (MAO) has been utilized. The durability against wear of the extracted material sheet samples, each having different surface morphologies due to varying La percentages, was investigated under dry conditions following The ASTM G-133 standard method assesses the sliding wear of ball-on-flat surfaces using a linear reciprocating motion. This study conducted a systematic analysis of how the MAO coating and the addition of La influence wear resistance, supported by microstructure analysis.

Keywords: AZ31, La, Wear, Hot rolling, MAO.

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ISTJ
http://www.doi.org/10.62341/ghid1254

خصائص التأكل الجاف لأكسدة القوس الصغير المطبقة على سبائك صفائح الماغنيسيوم (ZA31) مع اضافات اللانثانيم

*1جلال المنصوري، *2خيرالدين احلاتش، *3اسماعيل هاكايا

galal_mansouri@yahoo.com, hahlatci@karabuk.edu.tr, 1987ihk@gmail.com

الملخص

في هذا البحث، تم تعزيز سبائك الالومنيوم AZ31 بنسبة 0.2% و0.5% من إحدى العناصر الأرضية النادرة(Lanthanum) (La) باستخدام طريقة الصب بالقالب منخفض الضغط. خضعت هذه السبائك للدرفلة الساخنة عند درجة حرارة 400 درجة مئوية وبسرعات مختلفة (4.7 و10 أمتار في الدقيقة)، مع الحفاظ على معدل تشوه بنسبة 30% لكل تمريرة. بعد الإنتاج، تم تطبيق الأكسدة القوسية الدقيقة (MAO). تم اجرا اختبار مقاومة البلاء على الجاف لعينات الصفائح المستخرجة، والتي تتميز كل منها بأشكال سطحية مختلفة بسبب النسب المئوية المتفاوتة من La، في ظل ظروف جافة وفقًا لطريقة الاختبار القياسية ASTM G-133 للبلاء المتردد الخطي الناتج عن الانزلاق الكروي على السطح. قامت الدراسة بتحليل منهجي لتأثير طلاء الأكسدة القوسية MAO وإضافة نسب من La على مقاومة التآكل السطحي بناءً على تحليل البنية الدقيقة.

الكلمات المفتاحية: سبائك الالومينيوم، اللانثانيم، التأكل الميكانيكي، الدرفلة الساخنة، طلاء الاكسدة القوسية

1- Introduction

Magnesium alloys have gained considerable interest among manufacturers of lightweight materials, Due to their exceptional low density, impressive specific strength, and reasonable resistance to corrosion [1], these alloys offer significant advantages. Nevertheless, their tribological properties still require further exploration face challenges that restrict their potential applications [2]. To enhance the wear characteristics of Mg alloys, researchers have explored various approaches, including alloying, ion implantation, and laser direct melting. An interesting alternative is Micro-Arc Oxidation (MAO), which significantly improves The corrosion resistance and wear characteristics of magnesium alloys

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[3] show significant improvement when a ceramic coating is applied to the metal's surface. This coating enhances the surface qualities, leading to a wear loss that is considerably less than that observed in uncoated samples. [4]. Moreover, the addition of rare earth metals, such as Neodymium and lanthanum, has proven beneficial in bolstering the tribological performance of Mg alloys under both dry and corrosive environments.

[5,6]. Furthermore, to enhance the high-temperature mechanical properties and corrosive resistance, Lanthanum-doped titanium-zirconium-molybdenum (La-TZM) alloys boast impressive mechanical characteristics, showcasing both high strength and toughness, which can be attributed to their intricate secondary phases. The stability of material at elevated temperatures has been established [7]. However, the influence of varying amounts of La on the Dry Wear Characteristics of AZ31 Magnesium Sheet Alloys remains uncertain. The research aims to explore the dry wear characteristics of AZ31 Mg sheets with 0.2% and 0.5% (wt) La added, which have undergone deformation at two distinct rolling speeds and a deformation rate of 30%, followed by the application of the MAO process.

2- Material and Method

Protected an electric resistance furnace from atmospheric contamination. The process involved using argon gas to successfully melt pure materials. magnesium, aluminum and zinc the ingots at temperature of 775°C for one hour. To achieve the intended composition, master alloys of magnesium-aluminum (30 wt %) and magnesium-zinc (10 wt %) were added during the melting process. For the casting operation, we employed. The low-pressure die casting process was carried out in a mixed gas atmosphere of CO_2 and SF_6. The liquid metal was injected into a stainless steel mold at pressures ranging from 2 to 3 atmospheres and at a temperature of 350°C. For the analysis of the material's chemical composition, X-ray fluorescence (XRF) was performed and the results are detailed in Table 1. To prevent segregation, the materials underwent a homogenization process at 400°C for 24 hours. After homogenization, we successfully produced semi-finished metals with dimensions of 12x36x60 mm. To manufacture is 2 mm sheets from the 12 mm billets, we applied the hot rolling. The deformation rate per pass was set at 30%, with rolling speeds of 4.7 m/min and 10 m/min at 400°C. The materials were preheated

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at 400°C for 30 minutes prior to rolling and for 5 minutes between passes.

Table 1. Chemical Composition of Materials

Mg	La	Mn	Zn	Al	Alloys
Bal	0.21	0.10	1.06	2.96	AZ31 0.2 % La
Bal	0.54	0.23	1.06	3.11	AZ31 0.5 % La

The metallography processes, MAO, and surface roughness analyses were performed following the methodology detailed in our earlier research [8]. For the microstructure examination, we employed light optical microscopy (LOM - Equipment: Nikon Eclipse MA200 with Clemex software) and scanning electron microscopy (SEM - Equipment: Carl Zeiss Ultra Plus Gemini Fesem), complemented by energy dispersive spectroscopy (EDS).To investigate wear under dry friction conditions, we introduced a 6 mm diameter steel ball made from AISI 52100. The experiments were performed in accordance with The ASTM G-133 standards were followed under ambient conditions, with the load varied at three different levels: 1N, 2N, and 5N. The tests were conducted with an oscillation amplitude of 8 mm, a sliding speed of 5 mm/s, and a total sliding distance of 50 m.

3- Results and Discussion

The images of LOM alloys studied are presented in Figure 1.

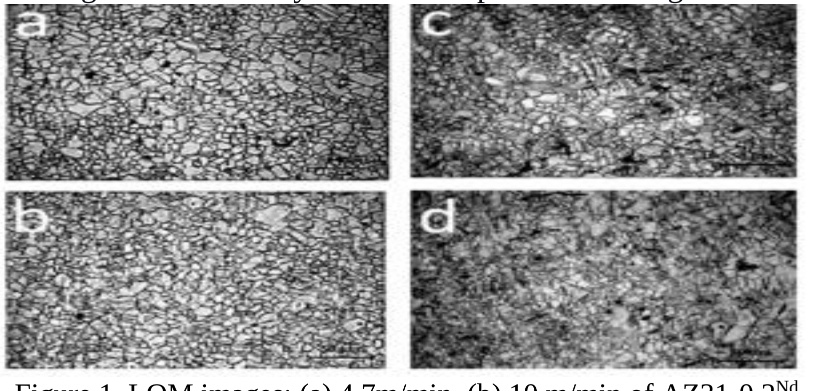

Figure 1. LOM images: (a) 4.7m/min, (b) 10 m/min of AZ31-0.2Nd (c) 4.7 m/min and (d) 10 m/min of AZ31-0.5Nd

Both alloys exhibit equiaxed grain structures; however, the grains in samples deformed at rolling speed of 4.7 m/min are generally larger than those processed at 10 m/min. Additionally, dynamic recrystallization (DRX) emerges as the predominant mechanism in

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the samples rolled at 10 m/min. It's noteworthy that continuous dynamic recrystallization (CDRX) was only observed in the 0.2% La alloy processed at this higher speed. On the other hand, the alloy with 0.5% La, which was deformed at 4.7 m/min, exhibited the formation of shear bands.

Figure 2. presented the surface roughness for alloys with 0.2% La is greater than that of the 0.5% La alloys (refer to Fig. 3). Nevertheless, a higher rolling speed resulted in increased Rate values for both types of alloys.

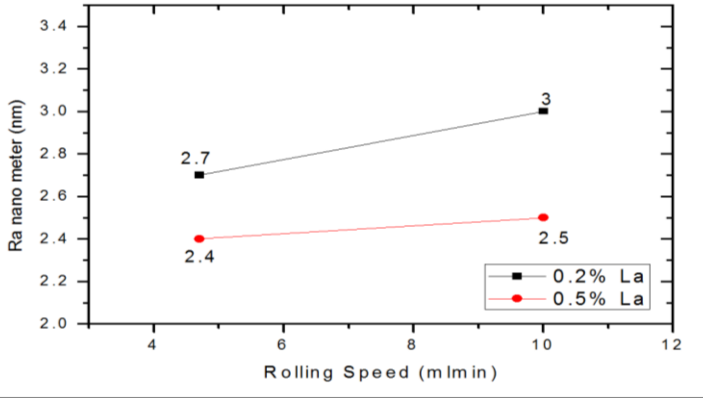

Figure 2. Surface roughness of alloys

SEM images taken from the surface of the alloys post-MAO process showcase a range of characteristics, including holes, cracks, and distinct island formations. (see Figure 3).

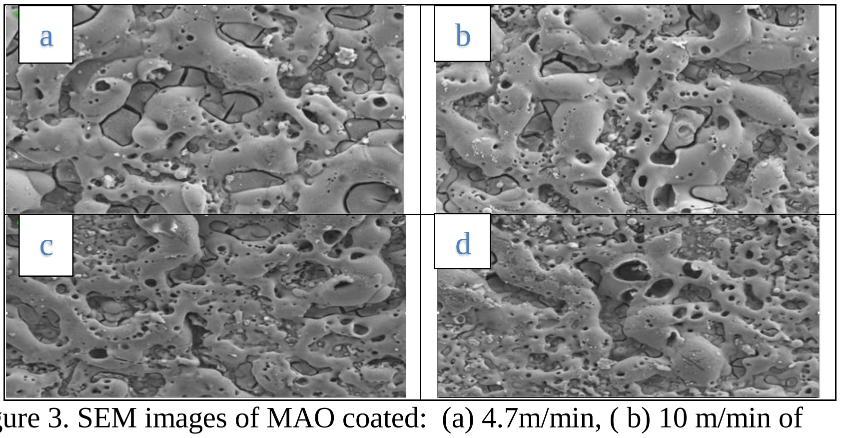

Figure 3. SEM images of MAO coated: (a) 4.7m/min, (b) 10 m/min of AZ31-0.2%La (c) 4.7 m/min and (d) 10 m/min of AZ31-0.5%La.

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Notably, the rolling speed significantly impacts the size of the holes. For instance, the samples rolled at speed of 4.7 m/min exhibit larger hole diameters, while those processed at 10 m/min display much finer holes. Additionally, the islands formed in the 10 m/min samples showcase fewer holes compared to those rolled at 4.7 m/min. Furthermore, a notable increase in the formation of cracks is prevalent in the alloys with a 0.2% addition of La.

The wear test results for alloys with 0.2% La added, deformed at various rolling speeds, are illustrated in Figure 4. It was observed that the metal loss at a rolling speed of 4.7 m/min was significantly higher compared to the loss at 10 m/min

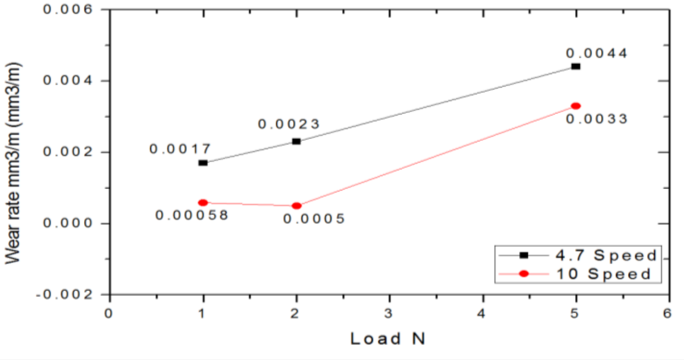

Figure 4. Wear test result of 0.2%La added alloys.

The wear test results of alloys with 0.5% La addition, deformed at different rolling speeds, are presented in Figure 5. As observed in this figure, the metal loss for the alloy rolled at 4.7 m/min was significantly higher than that of the alloy rolled at 10 m/min across all loads. Notably, at a 5N load, the metal loss for the 10 m/min speed-rolled sample exhibited a marked increase.

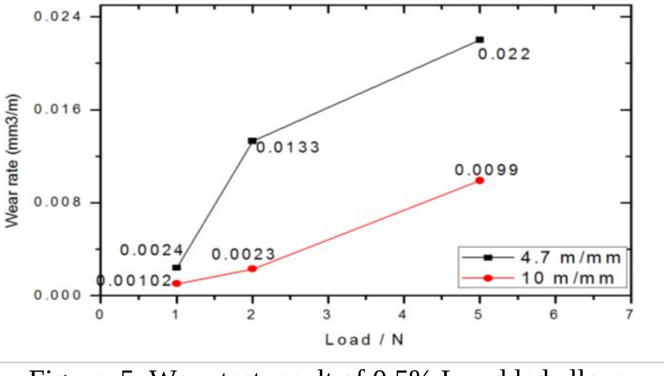

Figure. 5. Wear test result of 0.5% La added alloys

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The results of the wear test alloys with 0.2% and 0.5% La additions, deformed at a rolling speed 4.7 m/min, are presented in Figure 6. As observed, the trend of metal loss is reduced at lower loads for the sample containing 0.2% La. However, at a load of 5N, the metal loss for this sample is significantly higher.

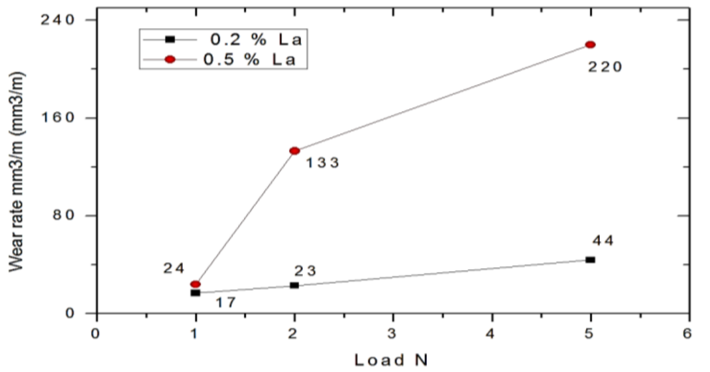

Figure 6. Wear test result of alloys deformed at 4.7m/min rolling speed.

The wear test results for alloys with 0.2% and 0.5% La showed distinct behaviors when subjected to a rolling speed of 10 m/min. As illustrated in Figure 7, the sample with 0.2% La exhibited a lower trend in metal loss. This reduction in wear can largely be attributed to the presence of pores and cracks that influence surface roughness. When a load of 1 N was applied, both the 0.2% and 0.5% La samples demonstrated increased wear resistance, as their surfaces exhibited fewer cracks and pores. However, at loads of 2 N and 5 N, the coating produced through the MAO process began to wear off, altering the surface roughness and subsequently affecting the wear rate of the specimens (9).

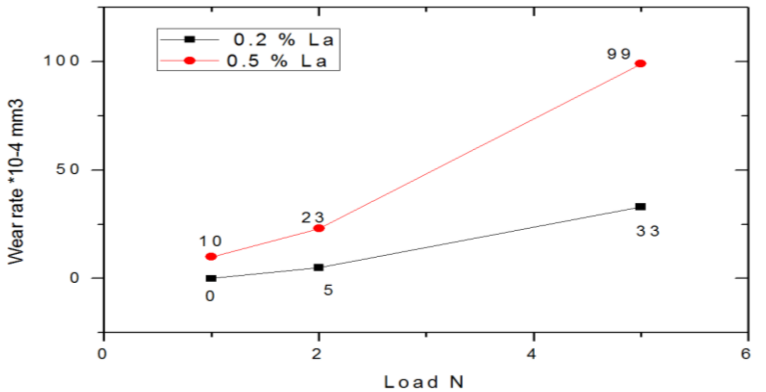

Figure 7. Wear test result of alloys deformed at 10m/min rolling speed.

http://www.doi.org/10.62341/ghid1254

4. Conclusion

In this study, the results are summarized as follows:

1. The grain size at rolling speed of 4.7 m/min is larger than at rolling speed of 10 m/min.
2. Rolling speeds significantly affect the properties surface of MAO-applied Mg alloys, particularly in terms of surface roughness, which increases at increased speeds, the quantity also increases of La alloying influences surface roughness, with higher amounts of La resulting in increased roughness.
3. The variation in rolling speed. Cause to change the size of holes, the diameter size at rolling speed of 4.7 m/min is larger than at 10 m/min.
4. The rate of wear increases in relation to the roughness of the surface. The 0.2% La alloy, with greater metal loss occurring when the Ra values are higher. However, this relationship is slightly increasing.

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