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WEAR AND CORROSION BEHAVIOR OF VARIOUS SURAFCE TREATMENTS MgAZ91D ALLOY- A REVIEW

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ABSTRACT

Magnesium alloys (AZ91D) have excellent physical and mechanical properties. Unfortunately, MgAZ91D has a number of undesirable properties including poor wear and corrosion resistance that has obstructed its use in many applications. Therefore, it is necessary to improve the wear and corrosion performance of MgAZ91D for their future applications. Over the years, various methods of surface treatments for MgAZ91D have been studied and most frequently used are electrochemical plating technique, conversion coating, ion beam and etc. For each of the surface treatments discussed, several types of corrosion behavior and wear property have been studied with the conclusion is compared to each other.

Keywords: Mg AZ91D, surface treatment, duplex coating, wear and corrosion.

INTRODUCTION

Magnesium alloy, Mg AZ91D is used for a range of application due to excellent physical and mechanical properties. In particular its high strength to weight ratio makes it an ideal metal for automotive application where weight reduction is of significant concern. The use of Mg alloys can significantly decrease the weight of automobiles without sacrificing structural strength. However, Mg and its alloys have its undesirable properties including poor wear and corrosion resistance [1]. This drawback has obstructed its extensive use in many applications, particularly for outdoor application.

Therefore, it is necessary to improve the wear and corrosion performance of Mg alloys for their future applications. One of the most effective ways is to coat the base material. There are numbers of possible coating technologies available for Mg and its alloys. Among these technologies, electrochemical plating is the most cost effective and simple technique, but it is not suitable for the complex part which results in non-uniform plating. Besides, conversion coating on Mg is also used to provide the corrosion protection. However, the main disadvantage is the toxicity of the treatment solutions being used. The purposes of this review are to provide a clear picture of various method of surface treatment done to improve the wear and corrosion resistance behavior that currently available.

Mg AZ91D ALLOY AND ITS APPLICATIONS

Magnesium (Mg) and its alloys, especially AZ91D are receiving more consideration because of their light weight and superior specific strength. It has a high strength to weight ratio with a density is only 2/3 that of aluminum and 1/4 that of iron [1]. Mg also has high thermal conductivity, high dimensional stability, good machinability and is easily recycled to make it suitable for automotive industry [2]. However, their further application has been greatly limited due to they have a poor surface hardness referring to wear resistance and especially resistance to corrosion [1]. Mg and its alloys are extremely susceptible to galvanic corrosion, which can cause severe pitting in the metal resulting in decreased mechanical stability and unattractive appearance. Most effective ways to avoid corrosion is to coat the base material. Coating process able to protect a substrate by providing a barrier between the metal and its environment or through the presence of corrosion inhibiting chemicals in them [2]. In order for a coating to provide adequate corrosion protection, the coating must be uniform, well adhered and pore free [2]. There a number of possible coating techniques on Mg and its alloy discovered, for example electrochemical plating, conversion coating, hydride coating, anodizing and etc. that have attracted attention of many investigators, each with its own advantages and disadvantages respectively.

WEAR AND CORROSION BEHAVIOUR STUDY ON THE Mg AZ91D TREATED SURFACE

Electrochemical plating process, is one of the most cost effective process [1]. Plating on Mg surface has been shown to be useful in a number of applications for example Cu-Ni-Cr plating have a good corrosion resistance in interior and exterior environment. However, plating method is not being developed to produce a coating that can withstand a salt splash and its limited to non complex surface. Thereby it limits the use of Mg in automotive and aerospace industries. Besides, Mg is classified as a difficult for plating process due to its high reactivity, means that in the presence of air, Mg very quickly forms a passive oxide layer that must be removed prior to the plating process [1].

Next, Conversion coating also capable to protect the substrate from corrosion [1]. The coating acts as an insulating barrier of low solubility between the metal surface and environment by containing corrosion inhibiting compounds and goods adhesion property, even under humidity and thermal cycling tests [1]. There a number of different types of conversion coating available such as chromate, phosphate and fluorozirconate treatments. As with all the surface treatments, cleaning and pre treatment process for the samples are vital in order to obtain an excellent quality of conversion coating. However, the main disadvantages of conversion coating is the toxicity of the treatment solution shown to be highly toxic carcinogens [1].

Others coating methods such as ion beam implantation and plasma ion implantation also have received much interest due to high efficiency and simple instrumentation. Nitrogen ion implanted is found to improve the corrosion resistance and mechanical properties of Mg alloys. The hardness property increases after the nitrogen implantation due to formation of Mg_3N_2 phases [3],[4]. However, in the case of corrosion protection some effect occurs due to impurities and surface properties that have a large scatter in corrosion rate. Besides, it is also observed that, a lower implantation energy does not lead to the improvement and even has an adverse effect on corrosion resistance which acquire the higher cost for this method [3],[4].

Another protective coating for magnesium alloy is conventional anodization treatments that have successfully been utilized. However, these methods require harmful chemical agents such as chromium oxide and fluoride. Thus Anomag an electrolyte that consists of phosphate and ammonium salt is used due to environment load is quite lighter compared to others electrolyte [5]. The excellent corrosion protectivity obtained in Anomag is considered due to the formation of a new type protection film as well as the sacrificial function of the original amorphous anodized layer [5].

Besides, Microarc oxidation (MAO), is another new developed surface treatment technology under anodic oxidation technique [6]. Through MAO, in situ grown ceramic coating is directly formed on the surface of magnesium by which its corrosion resistance and wear resistance are greatly improved in industrial environment. Through the MAO surface treatment also reported that the corrosion current is reduced significantly and the lubricate sliding wear test results show the mass loss is 1.5 times less than the untreated [6].

Other recent coating techniques have been carried out by the researcher is a hybrid method. Tacikowski and co-workers, performed the hybrid method by applying simultaneously the deposition of composite titanium nitride (TiN) with final tightening sub-layer an aluminum [7]. The results of the examination showed an outstanding improvement of corrosion resistance of Mg AZ91D but the tightening of the composite TiN layer plays the crucial role in achieving significant improvement in corrosion.

While also others researcher, Hongxi and co-workers, was conducted the hybrid method with a solution aging treatment, then followed by nitrogen/aluminum ion implantation process [8]. The result showed the existence of hard phase of Mg_3N_2 and AlN is the main reason to enhance the mechanical properties and corrosion resistance of Mg alloy surfaces. However, it is also observed that, the solubility of Nitrogen in magnesium alloy using this technique is very low and only a small amount of Mg_3N_2 and AlN phases was found. A promising solution seems to be covering Mg alloys with nitride surface layers, which would increase the mechanical properties in terms of wear and corrosion resistance. Table-1 shows the summary of the outcomes and findings of several studies has been discussed before.

Table-1. Wear and corrosion behavior on various surface treatments of Mg AZ91D alloy.

References	Types of surface treatment on Mg AZ91D	Results and Observations
[1]	Electrochemical plating	Cu-Ni-Cr plating have a good corrosion resistance in interior and exterior environment. However, it's limited to non complex surface.
[1]	Conversion coating	Protect by acting as an insulating barrier between the metal surface and the environment and good adhesion property.
[3],[4]	Ion beam implantation Plasma ion implantation	Nitrogen ion implanted is found to improve the corrosion resistance and mechanical properties of Mg alloys. The hardness property increases due to formation of Mg_3N_2 phases. But, a lower implantation energy does not lead to the improvement and even has an adverse effect on corrosion resistance which acquire the higher cost for this method.
[5]	Protective coating (Anodization)	Anodization process utilizing Anomag as electrolyte shows excellent corrosion protectivity due to the formation of a new type protection film as well as the sacrificial function of the original amorphous anodized layer.

[6]	Microarc Oxidation, MAO	The corrosion current is reduced significantly and the lubricate sliding wear test results show the mass loss is 1.5 times less than the untreated.
[7]	Hybrid technique	Outstanding improvement of corrosion resistance of Mg AZ91D but the tightening of the composite TiN layer plays the crucial role in achieving significant improvement in corrosion.
[8]	Hybrid technique	Existence of hard phase of Mg_3N_2 and AlN is the main reason to enhance the mechanical properties and corrosion resistance. But, the solubility of Nitrogen in magnesium alloy is very low and only a small amount of Mg_3N_2 and AlN phases was found.

CONCLUSIONS

This paper aims at highlighting the benefits of various surface treatments on Mg AZ91D for wear and corrosion resistance improvement. The review summarized as follows:

- Various methods of surface treatments of MgAZ91D alloy e.g electrochemical plating, ion and plasma implantation and hybrid technique show a significant improvement of corrosion resistance properties compare to untreated sample.
- The formation of Mg_3N_2 phases through nitrogen implanted technique lead to the improvement of corrosion resistance and mechanical properties in terms of surface hardness property.
- Most of the studies show that the available surface treatment technologies have their own drawback such as not environmentally friendly, limited to non complex surface, costly and etc.

Thus, further study needs to perform to suggest another new technique which able to overcome any weaknesses in existing methods.

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REFERENCES

[1] Gray J.E. and Luan, B. 2002. Protective coatings on magnesium and its alloys- a critical review, Journal of Alloys and Compounds, 336. pp. 88-113.

[2] Friedrich H., Schumann, S. 2001. Research for a "new age of magnesium in the automotive industry, Journal of Materials Processing Technology, 117. pp. 276-281.

[3] Hoche, D., Blawert, C., Cavellier, M., Busardo, D., Gloriant, T. 2011. Magnesium nitride phase formation by means of ion beam implantation technique, Applied Surface Science, 257. pp.5626-5633.

[4] Tian, X.B., Wei, C.B., Yang, S.Q., Ricky Fu, K.Y., Paul Chu, K. 2005). Corrosion resistance improvement of magnesium alloy using nitrogen plasma ion implantation, Surface & Coating Technology, 198. pp.454-458.

[5] Murakami, K., Hina, M., Hiramatsu, M., Nakai, K., Kobayashi, S., Saija, A., Kanadani, T. 2007. Corrosion Protection of AZ91D Magnesium Alloy by Anodization Using Phosphate Electrolyte, Materials Transactions, 48. pp. 3101-3108.

[6] Zhang, X.P.,Zhao, Z.P., Wu, F.M., Wang, Y.L. 2007. Corrosion wear resistance of AZ91D magnesium alloy with and without microarc oxidation coating in Hank's solution, J Mater Sci, 42. pp. 8523-8528.

[7] Tacikowski, M., Banaszek, M., Smolik, J. 2014. Corrosion – resistant composite titanium nitride layers produced on the AZ91D magnesium alloy by a hybrid method, Vacuum, 99. pp. 298-302.

[8] Hongxi, L., Qian, X., Damin, X., Bo, L., Chunlei, M. 2013. Microstructure and corrosion resistance of AZ91D magnesium alloy treated by hybrid ion implantation and heat treatment, Vacuum, 89. pp.233-237.