ISSN 1225-8024(Print)
ISSN 2288-8403(Online)

<연구논문>

한국표면공학회지
J. Kor. Inst. Surf. Eng.
Vol. 48, No. 5, 2015.
http://dx.doi.org/10.5695/JKISE.2015.48.5.194

A Blade-Abrading Method for Surface Pretreatment of Mg Alloys

Sungmo Moon[a,b*]

[a]Korea Institute of Materials Science, Changwon 51508, Korea
[b]Advanced Materials Engineering, Korea University of Science and Technology, Taejon 34113, Korea

(Received October 28, 2015 ; revised October 29, 2015 ; accepted October 30, 2015)

Abstract

A blade-abrading method was newly developed for the preparation of clean Mg alloy surface and reported for the first time in detail in this paper. The blade-abrading method includes abrading of the Mg alloy surface with a sharp blade or knife to remove the surface oxide and contaminants on the skin of Mg alloys mechanically, thereby providing very clean surface of Mg alloys. The clean surface prepared by the blade-abrading method in the air was found to be covered with thin and dense air-formed oxide films. Based on the experimental results obtained in this work, it is concluded that the newly developed blade-abrading technique is a very simple and useful pretreatment method which can provide clean and well-defined surface for the following surface treatments.

Keywords : Blade-abrading method, Magnesium alloy, surface pretreatment, roughness, air-formed oxide film

1. Introduction

Mg has been great interest for automobile, aircraft, mobile phone case and cooking tools because it is the lightest metal among engineering metals. However, since Mg alloys are electrochemically too active to be used without surface treatment in corrosive environments, their practical applications have been limited. Thus, many scientists have tried to develop surface treatment methods to improve corrosion resistance of Mg alloys[1-9]. For the surface treatment of Mg alloys, one of the most important and difficult steps is a pretreatment process by which clean and well-defined surface should be obtained.

Acid etching was a conventionally used pretreatment process to remove the surface oxide and contaminants for the following surface finishing[10-16]. However, since acid etching of Mg alloys not only leaves thick oxide films on the surface but also do not etch them uniformly, acid etching hardly be used generally as a pretreatment process for the following chemical conversion coating or electrophoretic painting processes. Thus, a simple pretreatment method which can provide clean surface, is needed for surface finishing of Mg alloys.

In this work, a blade-abrading method is suggested to be a simple pretreatment method for Mg alloys, which can provide uniform and clean surfaces of Mg alloys. The roughness profile of the blade-abraded surfaces was compared with that of the SiC paper-abraded surfaces and the surface films formed on AZ31 Mg alloy after blade-abrading in the air was examined by TEM.

2. Experimental

AZ31 Mg alloy plates (wt.%, Al 2.94, Zn 0.8, Mn 0.3, Si < 0.1, Fe < 0.005, Cu < 0.05, Ni < 0.005, and Mg balance) were employed for this study. The alloy plate of 1 mm thickness was abraded using SiC papers successively from # 220 up to #2000 SiC paper with ethanol. The SiC paper-abraded specimen surface was also finally abraded by pressing and moving of a sharp blade on the Mg alloy surface and then blown by air to remove the surface residuals.

*Corresponding Author : Sungmo Moon
Korea Institute of Materials Science; Advanced Materials Engineering, Korea University of Science and Technology
E-mail : sungmo@kims.re.kr

The blade-abrading can easily remove the surface scales and contaminants.

A groove was formed by steel knife on the AZ31 Mg alloy surface, and then its surface was examined by confocal scanning laser microscope (CSLM) with the number of blade-abrading up to 60 times. The rate of surface abrading by a blade was calculated from the height changes of the groove with the number of blade-abrading. The roughness profiles of SiC paper-abraded and blade-abraded surfaces were obtained using a surface roughness tester (Surftest SJ-4400, Mitutoyo). Photographs of SiC paper-abraded and blade-abraded surfaces of the AZ31 Mg alloy specimen were taken using a digital camera. The surface films formed on AZ31 Mg alloy after blade-abrading in the air and after further immersion for 5 min in DI water at RT and in boiling DI water, were observed by TEM using samples prepared by focused ion beam (FIB) machining.

3. Results and Discussion

Figure 1 shows the surface of Mg alloy prepared by a blade-abrading method. The blade-abraded surface in left side appears to be very clean and bright but original surface in right side showed many imperfections such as dark buffing lines, contaminants and corrosion spots. These indicate that the newly developed blade-abrading method can remove the surface contaminants completely and leave very clean and bright surface of Mg alloys. Since Mg alloys are extremely soft, their skins can be removed easily by abrading using a blade. However, the blade-abrading method can not be applied to Al alloys for the preparation of clean surface because the surfaces of Al alloys are too sticky. Thus it should be stressed that the blade-abrading method is quite useful for the preparation of clean surface of Mg alloys.

In general, acid etching methods have been used for the preparation of clean surface. However, since pretreatments of Mg alloys in acids not only leave thick and non-uniform oxide films on the surface but also dissolves Mg alloys too much, the acid etching method needs to be replaced by another surface pretreatment. In this work, the blade-abrading method is suggested to be one of very good surface pretreatment methods for Mg alloys.

Figure 2 is CSLM images of the AZ31 Mg alloy surface with a groove. It is clear that the sizes of width and depth of the groove decrease with increasing number of blade-abrading which indicates removal of the surface skin of Mg alloy by the blade-abrading process. Figure 3 depicts the decrease of depth of groove with the number of blade-

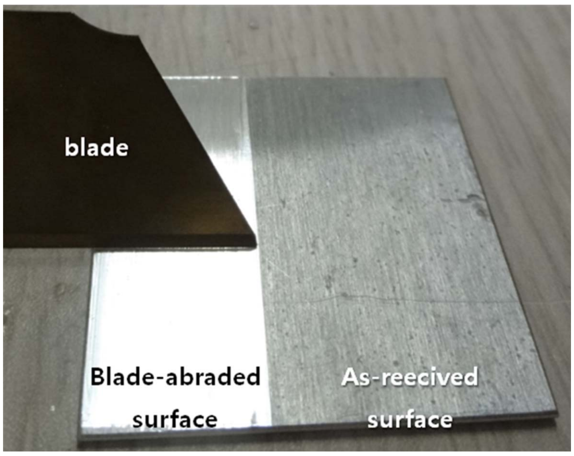

Fig. 1. Photograph of the AZ31 Mg alloy specimen surface showing blade-abraded and as-received surfaces.

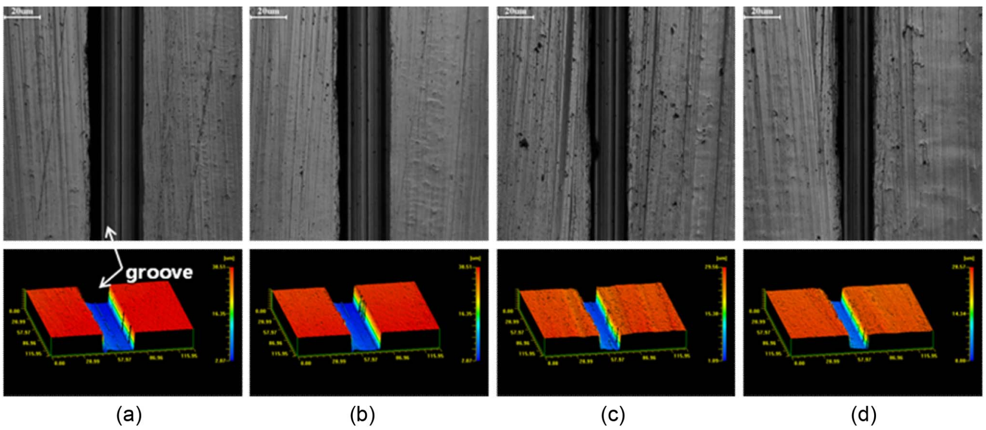

Fig. 2. CSLM contrast and 3D height images of the AZ31 Mg alloy specimen surface with a groove with the number of blade-abrading: (a), 0; (b), 20; (c), 40; (d), 60 times.

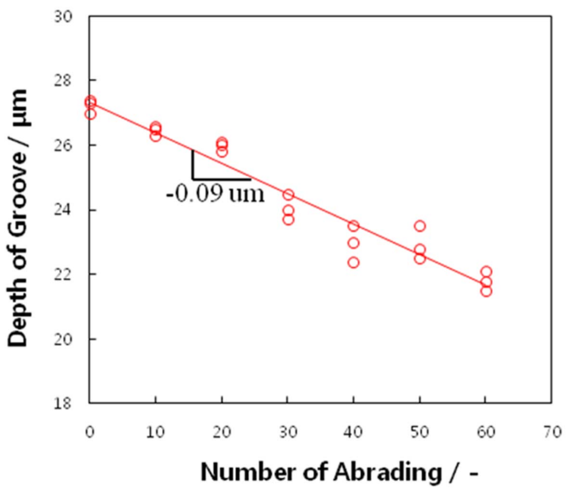

Fig. 3. Changes in depth of a groove in Fig. 3 with the number of blade-abrading in the air.

abrading. It is noted that the removal rate of the Mg alloy skin is not uniform but generally its slope is about -0.09 mm. This represents that the Mg alloy surface can be removed by about 0.09 mm by one abrading step using a blade. It should be also important to note that ten times of blade-abrading can only remove the Mg alloy skin between 0.5 and 1.2 mm. These mean that Mg alloy skin can be removed in different thicknesses between 0.05 ~ 0.12 mm by one blade-abrading step, depending on the force applied. The removed skin thickness of Mg alloy surface can be controlled by how strongly the bladed is pressed against the Mg alloy surface during the blade-abrading process.

Figure 4 presents the surface roughness profiles of AZ31 Mg alloys prepared by the blade-abrading or by SiC paper-abrading methods. The roughness of abraded surface decreases with increasing number of SiC paper and the blade-abraded surface showed a little lower surface roughness values between 0.034 and 0.049 µm than those of #2000 SiC paper-abraded surface between 0.048 and 0.065 µm. The values of the surface roughness values measured are shown in Table 1. It is clear that the blade-abraded surface is smoother than #2000 SiC paper-abraded surface. It can be also noticed that surface roughness is 10 ~ 20% higher when it is measured vertically to the abrading direction than that measured along the abrading direction.

The brightness of blade-abraded surface is compared with that of #2000 SiC paper-abraded surface, and its result is shown in Fig. 5. The blade-abraded surface showed much clear reflectance image of ruler than

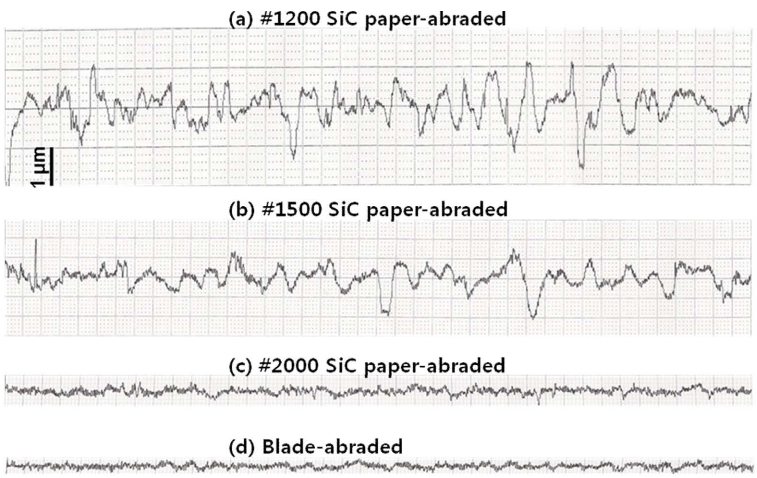

Fig. 4. Surface roughness profile of (a, b, c) SiC paper-abraded and (d) blade-abraded surfaces of the AZ31 Mg alloy specimen.

Table 1. Surface roughness of AZ31 Mg alloy specimen surface obtained from different surface finishing methods.

Surface finishing method	Surface roughness (R_a), µm	
	Parallel direction to the abrading	Vertical direction to the abrading
#1200 SiC paper-abraded	0.336 ± 0.021	0.369 ± 0.013
#1500 SiC paper-abraded	0.201 ± 0.021	0.251 ± 0.011
#2000 SiC paper-abraded	0.056 ± 0.008	0.061 ± 0.004
Blade-abraded	0.040 ± 0.006	0.044 ± 0.005

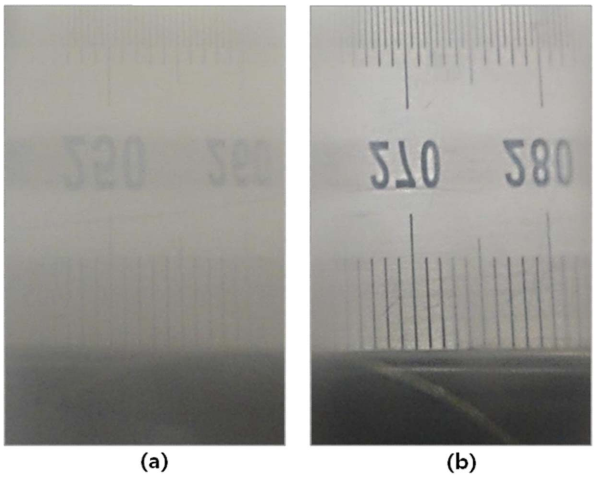

Fig. 5. Photographs of (a) #2000 SiC paper-abraded and (b) blade-abraded surfaces of the AZ31 Mg alloy specimen.

the #2000 SiC paper-abraded surface, as can be seen in Fig. 5. This manifests that the blade-abraded method can provide much smoother surface than the #2000 SiC paper-abraded surface.

The surface oxide films formed on AZ31 Mg alloy were examined by TEM observation using FIB machined samples, and the results are depicted in Fig. 6. It is interesting to note that the blade-abraded surface of Mg alloy is covered with relatively dense air-formed oxide films with about 35 nm thick outer dense layer and about 10 nm inner less dense layer. When the blade-abraded sample is immersed for 5 min in deionized water at room temperature, outer dense layer did not show any changes in thickness and porosity but inner less dense layer of the air-formed oxide film was converted into more porous structure and thickened to be about 15 nm thickness. These suggest that the surface oxide film can grow at open-circuit potential and more porous oxide is newly formed near or at the oxide film/alloy interface by the reaction between Mg alloy and water. Thus, using water during the preparation of clean Mg alloy surface to cool down the specimen should be avoided. The changes in thickness of surface oxide films during immersion of AZ31 Mg alloy in aqueous solutions in Fig. 6 are in good accordance with the finding of surface film growth around a Fe-containing second-phase particle during the immersion in alkaline solutions[17)].

The immersion of the blade-abraded AZ31 Mg alloy sample in boiling water for 5 min can change not only inner less dense layer but also outer denser layer into very porous structure, as shown in Fig. 6(c). Such changes in morphology of surface oxide films by immersion treatment of air-formed oxide film can influence the corrosion behavior and following surface treatments. Based on the results of Figs. 6(b) and 6(c), it can be readily inferred that pretreatments of Mg alloy surface in aqueous solutions could result in the formation of thicker and more porous surface oxide films. Besides, chemical etchings of Mg alloys can induce non-uniform formation of surface films on second-phase particles and Mg matrix. Thus, it can be concluded that a blade-abrading technique is one of very simple and useful pretreatment methods which can provide clean and thin air-formed oxide film-covered surface.

4. Conclusions

A blade-abrading method was newly developed to prepare clean Mg alloys without using chemical solutions. The blade-abrading method includes only abrading process with a sharp blade or knife against

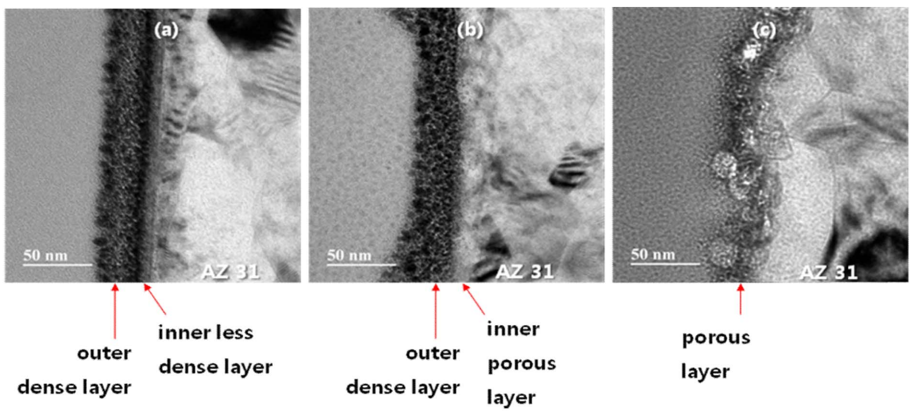

Fig. 6. TEM micrographs of the surface films formed on AZ31 Mg alloy after blade-abrading in the air (a) and after further immersion for 5 min in DI water (b) at RT and in boiling DI water (c).

the specimen surface in the air to remove the surface contaminants completely and leave very clean and bright surface of Mg alloys. The blade-abrading leaved very bright and smooth surface of Mg alloys, and lower surface roughness values than that of #2000 SiC paper-abraded surface. It was also observed that surface roughness is 10 ~ 20% higher when it is measured vertically to the abrading direction than those measured along the abrading direction. The blade-abraded surface of Mg alloy in the air appeared to be covered with relatively dense air-formed oxide films with about 35 nm thick outer denser layer and about 10 nm inner less dense layer. When the blade-abraded sample is immersed in deionized water at room temperature or in boiling water, the air-formed oxide films were converted into more porous structure and thickened, suggesting that thicker and more porous films are formed on Mg alloys if any aqueous solutions are used for the surface pretreatment. Based on the experimental results obtained in this work, it is concluded that the newly developed blade-abrading technique is a very simple and useful pretreatment method which can provide clean and well-defined thin air-formed oxide film-covered surface.

Acknowledgment

This research was financially supported by the research grant of general research program (PNK4122, PNK4342) from Korea Institute of Materials Science (KIMS).

References

1. F. Zucchi, A. Frignani, V. Grassi, G. Trabanelli, C. Monticelli, Stannate and permanganate conversion coatings on AZ31 magnesium alloy, Corrosion Science 49 (2007) 4542.
2. D. K. Lee, Y. H. Kim, H. Park, U. C. Junc, W. S. Chung, Characteristic Evaluation of Anodic Film Depending on the Concentration of Sodium Silicate in the Electrolyte Anodized AZ31B Magnesium Alloy, J. Kor. Inst. Surf. Eng. 42 (2009) 109.
3. U. C. Nwaogu, C. Blawert, N. Scharnagl, W. Dietzel, K. U. Kainer, Effects of organic acid pickling on the corrosion resistance of magnesium alloy AZ31 sheet, Corrosion Science 52 (2010) 2143.
4. M. H. Kim, S. T. Kwag, M. J. Moon, Characteristics Evaluation of Conversion Coating of Acid Pickling AZ31 Magnesium Alloy by a Chromium-Free Phosphate-Permanganate Solution, J. Kor. Inst. Surf. Eng. 43 (2010) 73.
5. K. S. Choi, S. D. Choi, B. K. Min, S. H. Lee, H. J. Sin, Study of Plating Layer Formation of Lightweight Magnesium Alloy (AZ31B), J. Kor. Inst. Surf. Eng. 44 (2011) 239.
6. M. H. Kim, M. S. Lee, S. T. Kwag, M. J. Moon, Characteristics of Environmentally-Friendly Conversion Coating of AZ31 Magnesium Alloy by a Alkaline Phosphate-Permanganate Solution, J. Kor. Inst. Surf. Eng. 44 (2011) 82.
7. M. J. Kim, H. C. Kim, S. Y. Yoon, U. C. Jung, Characteristics of Films Formed on AZ31B Magnesium Alloy by Chemical Oxidation Process in Potassium Permanganate Solution, Kor. Inst. Surf. Eng. 44 (2011) 44.
8. S. Moon, Y. Nam, Anodic oxidation of Mg-Sn alloys in alkaline solutions, Corrosion Science 65 (2012) 494.
9. N. V. Phuong, K. Lee, D. Chang, M. Kim, Sangyeoul Lee1, Sungmo Moon, Zinc Phosphate Conversion Coatings on Magnesium Alloys: A Review, Met. Mater. Int. 19 (2013) 273.
10. S. Moon, C. Yang, Sangjo Na, Effects of Hydroxide and Silicate ions on the Plasma Electrolytic Oxidation of AZ31 Mg Alloy, J. Kor. Inst. Surf. Eng. 47 (2014) 147.
11. S. Moon, Corrosion behavior of PEO-treated AZ31 Mg alloy in chloride solution, Journal of Solid State Electrochemistry 18 (2014) 341.
12. S. Pommiers, J. Frayret, A. Castetbon, Martine Potin-Gautier, Alternative conversion coatings to chromate for the protection of magnesium alloys, Corrosion Science 84 (2014) 135.
13. N. V. Phuong, S. Moon, Comparative corrosion study of zinc phosphate and magnesium phosphate conversion coatings on AZ31 Mg alloy, Materials Letters 122 (2014) 341.
14. C. E. Castano, M. J. O'Keefe, William G. Fahrenholtz, Microstructural evolution of cerium-based coatings on AZ31 magnesium alloys, Surface and Coatings Technology 246 (2014) 77.
15. K. Li, J. Liu, T. Lei, T. Xiao, ptimization of process factors for self-healing vanadium-based conversion coating on AZ31 magnesium alloy, Applied Surface Science 353 (2015) 811.
16. S. Y. Jian, Y. R. Chu, C. S. Lin, Permanganate conversion coating on AZ31 magnesium alloys with enhanced corrosion resistance, Corrosion Science 93 (2015) 301
17. S. Moon, C. Yang, S. I. Pyun, A novel method to detect cathodic second-phase particles in Mg alloys, J Solid State Electrochemistry, in press.