Deposition and Tribological Behaviour of Electrical Discharge Coated ZE41A Magnesium Alloy

U. Elaiyarasan
Dept of Mechanical Eng-
Karpaga Vinayaga College of Eng &Tech

C. Senthilkumar
Dept of Mechanical Eng-
Karpaga Vinayaga College of Eng &tech

V. Satheeshkumar
Dept of Mechanical Eng-
Karpaga Vinayaga College of Eng &Tech

S. Santhoshkumar
Dept of Mechanical Eng-
Government college of Engineering

S. Saronkumar
Dept of Mechanical Eng-
University College of Engineering

Abstract:- **The objective of this research is to study the deposition and tribolgical behaviour of ZE41A magnesium alloy coated with WC/Ni material under pin on disc method with different sliding condition has been investigated. Dry sliding experiments were conducted under condition of normal load (1.5 kg - 3.5 kg), sliding speed (100RPM - 300 RPM) and sliding time (3min - 7min). Wear maps were drawn for the various wear parameters. Wear mechanism maps was drawn against sliding condition of normal load and sliding speed which has been utilized to study the dominance of particular wear mechanism that dominates a particular wear regime. Different wear regime such as mild wear, severe wear ultra severe wear was developed by adjustment of contour line of the wear rate map. Various mechanisms such as abrasion, oxidation, delamination, plastic deformation, and melting were indentified using scanning electron microscope (SEM).**

Keywords: Wear mechanism, Pin on disc, Wear regime, Mild wear, Abrasion, SEM

1.INTRODUCTION

Magnesium and its alloys are elegant for several engineering purpose due to good mechanical properties and low density. Though, the wear resistance of magnesium alloys is very poor in the critical environments [1,2]. Furthermore, it is highly susceptible to wear when sliding contact with another metal. In practical applications, the poor corrosion and wear resistance of magnesium alloys often results in high maintenance costs or exclusion from other potential applications. A prospective way to improve the wear resistance of magnesium alloy, hard coating is possible. Combination of Tungsten carbide and copper is proposed as attractive materials for coating of magnesium due to superior wear resistance and electrical and thermal conductivity. Owing to dense protective carbide, magnesium alloy has good wear resistance in neutral environments. The following research articles have been focused on the wear behaviour of the different materials under different dry sliding condition.

Taltavull et.al [3] studied the wear behaviour of AM50B magnesium alloy using pin on disc configuration on dry sliding condition with carbon steel as counterpart. From SEM microstructure studies, Abrasion and Oxidation mechanism were dominated at the lowest normal loads and sliding velocity. Delamination and adhesion mechanism were dominated when increase the normal load and sliding velocities. The plastic deformation dominated at highest range of normal load and sliding speed. Similarly López et.al[4] investigated the wear behaviour of ZE41A magnesium alloy using pin on disc technique with steel as counterpart. The sliding parameters such as sliding velocity and applied load on the wear rate and coefficient of friction has been studied. At lower sliding speed, oxidation mechanism and small participation of abrasion and delamination mechanisms were dominated regardless of the load. At high speed, the main mechanism changed from abrasion at low loads and to delamination at intermediate loads and to plastic deformation at high loads. Rodrigo et al.[5] improved the wear resistance of ZE41A magnesim alloy coated with Al–SiC composites using pin on disc apparatus. From the microstructure results, a thin mechanical mixed layer (MML) was appeared between the contact surface of the material and abrasion was the dominating the wear mechanism during this sliding condition.

In this paper, wear mechanism of ZE41A magnesium alloy coated with WC/Cu composite materials under dry sliding conditions has been investigated. Wear tests were carried out using a pin-on-disc wear tester. Wear mechanism map drawn against sliding speeds and normal loads on the wear behaviour and performance were studied.

Worn surface of the material was analyzed using JEOL scanning electron microscope (SEM).

2. EXPERIMENTAL

2.1. WC/CU COATING ON MAGNESIUM ALLOY

In this section, coating was produced on the surface of the workpiece using electrical discharge coating (EDC) with powder metallurgy (PM) electrode. Die sinking EDM (5530 EDM E-series) machine was used to coat the magnesium alloy in the present investigation. ZE41A magnesium alloy was utilized as workpiece and presents of chemical composition is Si-0.003, Cu-0.002, Zn-3.80, Zr-0.60, Fe-0.004, TRE-1.18, Ni-0.002, Mn-0.003, Al-0.006 and balance pure magnesium. Tungsten carbide and copper powder were selected as electrode material due to high strength and wear resistance and good thermal and electrical onductivity. The electrode was prepared for coating with combination of WC70:Cu30 through powder metallurgy method. During compaction of powder different loads were applied such as 150 MPa, 175MPa, 200MPa using punch and die setup with 10 mm diameter further it was sintered about 600 degree celsius for 20 min using tubular furnace. The prepared WC/Cu cylindrical electrode was presented in fig.1. After complete process of electrode it has been utilized as EDM electrode for coating purpose using EDC with dielectric of EDM oil. In the EDM process, two different parameters such as current (2A, 3A, 4A) and pulse on time (50µs, 70 µs, 90 µs) were selected to produce the coating on the surface. finally the optimized parameter was found on the maximum WC/Cu coating of magnesium alloy. These optimized parameters such compaction load, current and pulses on time are 150MPa, 4A and 90 µs respectively. The optimized parameter was found by using Minitan-16 software.

FIG.1. WC/CU CYLINDRICAL ELECTRODE FOR EDC

2.2. WEAR TEST

The wear experiments were carried out in coating produced samples at optimized parameter setting. The wear test was conducted using pin on disc technique (TR-20-PHM-M1, Ducom, India). The wear samples were prepared with dimension of 10mm diameter and 20mm length as presented in fig.2a The counterpart disc was made by EN31 steel with hardness of 65HR$_C$ and it was polished with emery sheet grade of 1000 as given in fig.2b. Three different sliding parameters such as normal load, sliding speed and sliding distance were selected to study wear arte and coefficient friction. As design of experiment, Taguchi L9 orthogonal array was adopted with setting of three factors three level. Dry sliding parameter of the experiment was given in table 1.

FIG.2. A) WEAR TEST SPECIMEN B) COUNTERPART DISC (EN31 STEEL

TABLE.2. EXPERIMENTAL PARAMETER AND LEVELS.

Control factors	Unit	Level		
		I	II	III
Normal load	Kg	1.5	2.5	3.5
Sliding speed	RPM	100	200	300
Sliding time	min	3	5	7

3. RESULT AND DISCUSSION

3.1. CONSTRUCTION OF WEAR MECHANISM MAP

A wear map is a graphical illustration of wear rate values used for study the influence of normal applied load and sliding speed. Wear map has been drawn in the form of contours line. The contour lines represent the end of wear mode from mild wear to severe wear or from severe wear to ultra-severe wear. Wear map was developed from MINITAB programs by plotting the normal load on the X-axis, the sliding speed on the Y-axis, and the values of wear rate on the Z-axis. From the wear map, wear mode map has been constructed easily which is known as a wear regime map, a wear transition map, or a wear mechanism map. The explore for margins of regions of predominant wear and their transitions is main trouble to construct the wear mechanism map where the competing processes may change the wear rate values [6]. Boundaries of regions such mild wear, severe wear, and ultra-severe wear are mechanics of sliding wear.

In view of engineering side, mild wear regime has been consider good enough or satisfactory but the severe wear and ultra-severe wear regimes are considered unacceptable. In order to recognize the different mechanisms during wear of the ZE41A alloy, the worn pins surface and the wear debris were observed. Wear mechanisms such as abrasion, oxidation, and delamination, plastic deformation and melting were observed test conducted in different parameter conditions as shown in fig.3.

At low normal load and sliding speed, many fine grooves were formed, which are the proof of abrasion. The ploughing was formed in the sliding direction. The movement of the particles on the surface cause the removal of material along its path on the surface of the Mg alloy. This wear mechanism predominates in the low normal load and sliding speed [7]. The formation of oxidation was occurred in the mild wear regime when test conducted in the sliding conditions of low load (1.5 kg) and sliding speed (200RPM). The origin of oxidative wear lies in the own oxidation sensitivity of Mg alloys that is enhanced by means of frictional heating caused by sliding. Coated Magnesium alloys strongly tend to oxidation even in the absence of aggressive conditions. Hence, it is possible that the oxidation wear may play an important role in this behaviour of material [8]. The occurrence of this oxidation layer prevented from metallic contact and resulted in small wear rates.

At low load and intermediate sliding speed, delamination mechanism was formed which occurred in mild wear regime. This owing to during the wear process subsurface cracks grow and in combination with cracks perpendicular to the sliding direction cause the detachment of sheet-like fragments of the worn material. These volumes are equivalent to voids observed in the pin surface, confirming that delamination was the predominant wear mechanism [9]. This mechanism was formed samples processed at high normal load and sliding speed which is occurred in severe wear regime. In this case, it was observed that the grooves caused by abrasion cannot be observed and that the surface of the samples was clearly deformed [10]. At lower sliding speed and normal loads this mechanism was not dominant.

Melting is a mechanism of ultra severe regime which has been occurred samples processed at high speed and normal load which is mostly dominates the wear mechanism. During sliding high temperature produces which resulted the formation of melting material. When continuous sliding on melted material which spread out of the contact surface in the sliding direction. Further increase in normal load and sliding speed causes high contact temperatures between pin and disc and also increase in frictional heat which results surface melting [11]. The transition from severe wear to ultra severe wear is also controlled by normal load and sliding speed. Higher wear rates are occurred than other mechanisms.

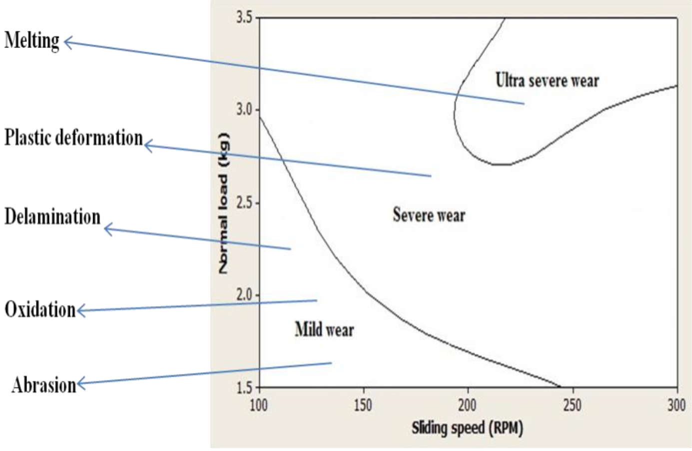

FIG. 3. WEAR MECHANISM MAP OF ZE41A MAGNESIUM ALLOY COATED WITH WC/CU COMPOSITE OF DIFFERENT MECHANISM

4. CONCLUSION

Pin-on-disc dry sliding wear tests with pins of WC/Cu coated ZE41A magnesium alloy were investigated against EN31 steel counterface in the different sliding condition. The wear rate increases with increase in normal load and sliding speed. From the observation of worn surfaces it was revealed that the sliding wear behavior WC/Cu coated ZE41A magnesium alloy can be classified in to three wear regimes, namely mild wear, severe wear and ultra severe wear. The dominant wear mechanisms in each regime were identified and summarized in the wear mechanism map namely abrasion, oxidation, delamination, plastic deformation, and melting. From the study, occurring of abrasion at 1.5 kg and 100RPM, oxidation at 1.5 kg and 200RPM, delamination at 1.5kg and 300 RPM, plastic deformation at 2.5kg and 200RPM and melting mechanism at 3.5kg and 300RPM.

REFERENCE

[1] B.A. Shaw and R.C. Wolfe, Corrosion Resistance of Magnesium Alloys, ASM Handbook, Vol 13B, Corrosion: Materials, ASM International, Materials Park, OH, 2005, p 205-227
[2] I.J. Polmear, Introduction to Magnesium in ASM Specialty Handbook: Magnesium and Magnesium Alloys, ASM International, Materials Park, OH, 1999, p 3-15
[3] C. Taltavull , P. Rodrigo, B. Torres, A.J. Lopez, J. Rams, Dry sliding wear behavior of AM50B magnesium alloy, Materials and Design 56 (2014) 549–556
[4] López, A.J., Rodrigo, P., Torres, B. and Rams, J., 2011. Dry sliding wear behaviour of ZE41A magnesium alloy. Wear, 271(11-12), pp.2836-2844
[5] Rodrigo, P., Campo, M., Torres, B., Escalera, M.D., Otero, E. and Rams, J., 2009. Microstructure and wear resistance of Al–SiC composites coatings on ZE41 magnesium alloy. Applied Surface Science, 255(22), pp.9174-9181
[6] Williams, J.A.A., 1999. Wear modelling: analytical, computational and mapping: a continuum mechanics approach. Wear, 225, pp.1-17.
[7] Mondal, A.K., Rao, B.C. and Kumar, S., 2007. Wear behaviour of AE42+ 20% saffil Mg-MMC. Tribology International, 40(2), pp.290-296.
[8] Lim, C.Y.H., Lim, S.C. and Gupta, M., 2003. Wear behaviour of SiCp-reinforced magnesium matrix composites. Wear, 255(1-6), pp.629-637.

[9] Chen, H. and Alpas, A.T., 2000. Sliding wear map for the magnesium alloy Mg-9Al-0.9 Zn (AZ91). Wear, 246(1-2), pp.106-116.
[10] El-Morsy, A.W., 2008. Dry sliding wear behavior of hot deformed magnesium AZ61 alloy as influenced by the sliding conditions. Materials Science and Engineering: A, 473(1-2), pp.330-335.
[11] Liu, Y., Asthana, R. and Rohatgi, P., 1991. A map for wear mechanisms in aluminium alloys. Journal of materials science, 26(1), pp.99-102.