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# STUDY OF EROSION CORROSION BEHAVIOUR OF MAGNESIUM AND ITS ALLOYS

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## Abstract

Erosion Corrosion is the degradation of material by means of combined effect of mechanical flow and chemical reactions with the surrounding environment. Light weighting of automobiles has been a critical issue in the transportation industries. Magnesium alloy seems to be the best promising next generation's material and as a substitute to aluminium alloy and steel that are being used in automotive, aerospace industries. In this study ,Magnesium,AZ31 and AZ91 were used to investigate the erosion corrosion rate and corrosion rate in 3.5% wt NaCl .The experiments involved the measurement of weight loss .Experimental setup was used to carry out the erosion corrosion test. Immersion test was conducted to determine the corrosion rate. Results include erosion corrosion analysis, comparative analysis of erosion corrosion and corrosion rate. Further SEM analysis was done to study the microstructure behaviour of the samples. It was found that the corrosion rate increases as time of exposure increases. It was also inferred that the erosion corrosion rate is higher than corrosion rate due to moving fluid under the same environmental condition.

***Keywords:*** *Erosion Corrosion, Magnesium, AZ31, AZ91, Weight loss method*

## 1. INTRODUCTION

Automotive industry is highly growing and has a global impact. Need for fuel efficient, better performance and decreased greenhouse gas emissions places a new demand for the change to better material's usage. Magnesium is the most promising next generation material for its low density, high strength to weight ratio, machinability, castability and above all a unique character of good recycling potential which makes its usage wide spread in the field of automotive, aerospace, electronics, biomedical and defence. Inspite of all its advantages, magnesium has poor corrosion resistance when exposed in real time environment especially where chloride exist (Jae Ioong Kim, et al., 2008, Nicholas Lutsey, 2010). Degradation of material is wear. Wear includes oxidation process, adhesion, abrasion, corrosion, fatigue, erosion and fretting. Erosion corrosion is also one such mechanism of wear. It has dual effect of erosion due to flow and chemical reaction with the surrounding environment. The combined effect of it will naturally tend to increase the material loss of the metal in practical application environment (Nesic, 2000, Rajaram, et al., 2009, Jayabharathy, et al., 2015). From the literature survey it is clear that the most of research information were focused on corrosion behaviour of magnesium alloy (Gaungling Song, 2005, Singh, et al., 2015). Moreover, there are ample of interesting researches in the study of erosion corrosion behaviour of steels and aluminium but there is no literature available related to the erosion corrosion behaviour of magnesium alloy and comparative study of erosion corrosion rate and corrosion rate.

## 2. EXPERIMENTAL DETAILS

***2.1 Materials:*** Magnesium, AZ31 and AZ91 were used for the study owing to their highest application in automotive industries (Sameer Kumar, et al., 2014). The chemical compositions of the test samples are listed in the table1. The test specimens were cut from the rod to the dimension of 15mm in diameter and 5mm in thickness. The samples were first grounded with SiC emery sheet upto 1200 grit, polished, then cleaned with acetone and finally dried. The surface area and weight of the samples were measured before conducting the test. The prepared test samples were used for immersion test as per ASTM G31 to evaluate the corrosion rate. The corrosion rate was calculated for each sample using the data obtained from the immersion test.

Corrosion rate = 87.6W/D A t (1)

Where W-weight loss in mg, D- density of the test material in $g/cm^3$, A-surface area in $m^2$, t- time of exposure in h

Table 1 Chemical composition of Magnesium and its alloy as per ASTM data sheet

| Grade | %Al | %Zn | %Mn | %Fe | %Mg |
|---|---|---|---|---|---|
| Mg | 0.00 | 0.006 | 0.01 | 0.001 | 99.9 |
| AZ31 | 2.98 | 0.94 | 0.02 | 0.003 | Bal |
| AZ91 | 9.01 | 0.98 | 0.16 | 0.002 | Bal |

***2.2Experimental Test Rig:*** For the erosion corrosion test, experimental setup was fabricated. The design of the setup was based on that described by (Ahmed El-Shenawy et al.,2014). The samples were held in the specimen holder. The test was conducted by exposing the test samples to the flowing fluid 3.5% wt NaCl at the regular interval of time up to 6 hours. The erosion corrosion rate was determined using the equation below

Erosion Corrosion rate =W/At (2)

Where W-weight loss in mg, A-surface area in $m^2$, t- time of exposure in h

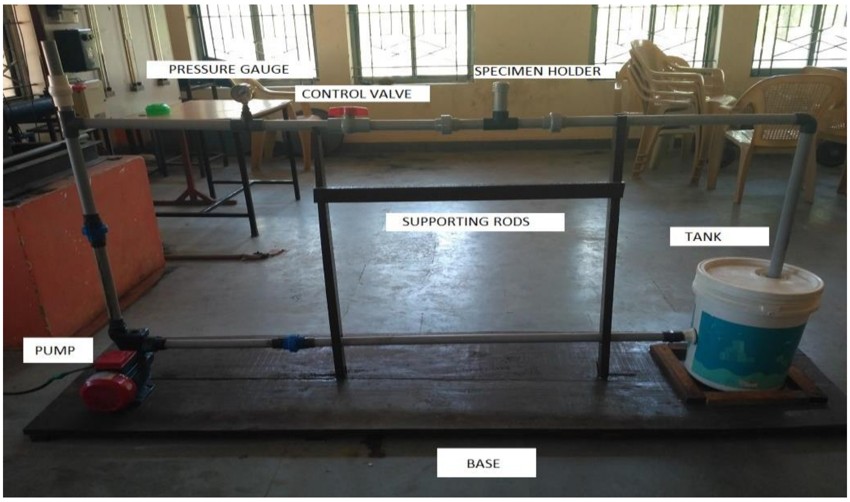
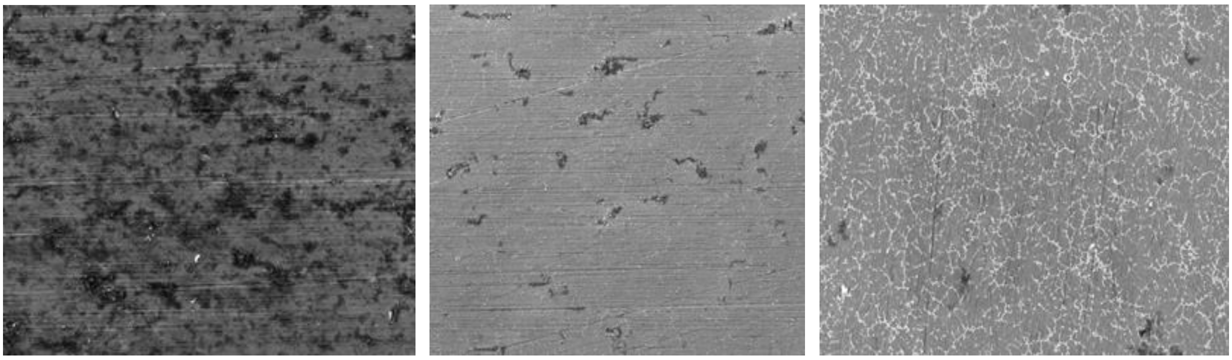



**Fig.1.** Experimental test rig for erosion corrosion

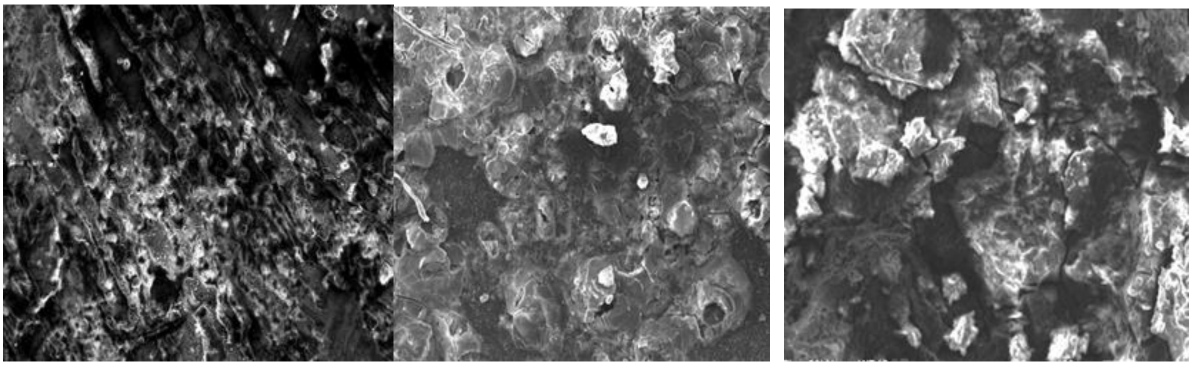
## 3. RESULTS AND DISCUSSION

***3.1 Effect of Chloride ion on corroded surface and corrosion rate:*** Fig. 2 and Fig.3 shows the microstructure of Magnesium, AZ31, and AZ91 before and after the exposure of test specimen to 3.5%wt NaCl. From the immersion test, the materials exhibited rise in corrosion rate with increase in time of exposure. In AZ3 1magnesium alloy, pit formation is more than AZ91. It is also observed that mixed oxide films of aluminium-magnesium are formed. Chloride ions are aggressive for magnesium as well as aluminium. The adsorption of chloride on the surface weakens the oxide film. In pure magnesium, corrosion rate is not so high as it has stable oxide layer of magnesium. AZ31 possesses a greater corrosion rate at the beginning of the exposure time. The sudden increase of corrosion rate is followed by the formation of oxide layer. The layer formed is of unstable because of this there would be further occurrence of corrosion rate. AZ91 tend to have gradual increase in the corrosion rate for 3.5% concentration at the begining. Then there would be steep increase in the corrosion rate with the increase in exposure time (Rajan Ambat, et al.,2000, Thirumalaikumara samy, 2014, Singh, et al., 2015).



(a) (b) (c)

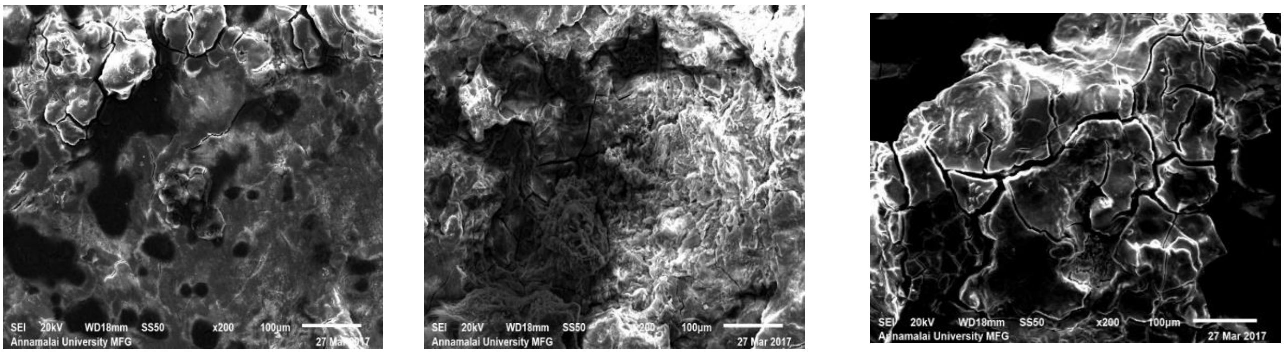
**Fig. 2:** SEM micrographs of corroded surface of (a) Pure Mg,(b) AZ31 and (c) AZ91 before in 3.5% NaCl concentration



(a) (b) (c)

***Fig. 3:*** *SEM micrographs of corroded surface of (a) Pure Mg, (b) AZ31 and (c) AZ91 after exposure in 3.5% NaCl concentration in immersion test*

***3.2 Erosion corrosion behavior:*** From the experimental test result Fig.5 and Fig.6, it was inferred that the erosion corrosion rate of magnesium, AZ31 and AZ91 is higher than the corrosion rate. This is due to the effect of flowing fluid. The passive films formed are destroyed by moving fluid. The aggressive chloride ions adhere to the surface of the metal, making the surface porous. These porous surfaces have accumulation of chloride ions which leads to irregular surface roughness and local turbulence enhancing the erosion corrosion mechanism. It is observed from Fig. 4 that the micro cracks on the surface are the result of the flowing fluid destroying the passivating film. This has caused in cleavage of the film easily resulting in exposure parent metal surface to the working environment. Moreover, the rate of film formation is lower than the rate of dissolution and transfer of metal into the moving fluid. Thus, electrochemical corrosion plays a vital role in the removal of material by attacking the weakened layer of eroded surface. Erosion corrosion resistance is comparatively better in AZ91 than AZ31. The mixed oxide layer formed on the surface are more stable in AZ91 as aluminium content is higher (Lei Wang et al., 2010).




(a) (b) (c)

**Fig. 4:** SEM micrographs of corroded surface of (a) Pure Mg, (b) AZ31 and (c) AZ91after exposure in 3.5% NaCl concentration under erosion corrosion process

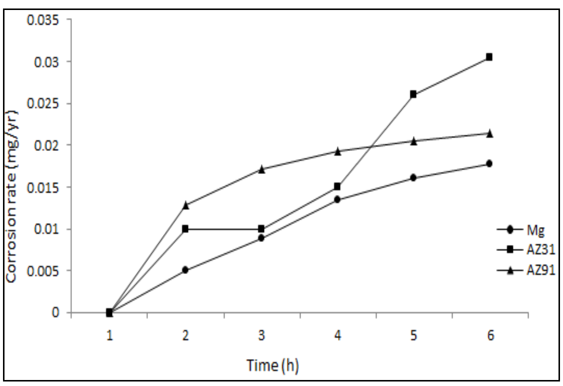



Fig. 5 Corrosion rate vs time

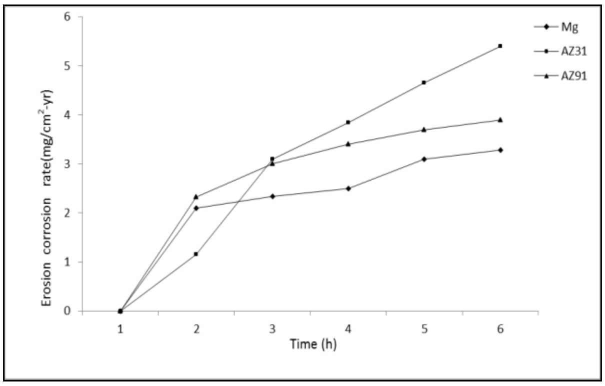



Fig.6 Erosion Corrosion rate vs time

**4. Conclusion**

Based on the results obtained from the experimental test and microstructure analysis in the present investigation, the following conclusion were drawn

1. Comparative study disclosed that the material loss is more in erosion corrosion process. Erosion corrosion rate is found to be higher than corrosion rate for magnesium, AZ31 and AZ91 in 3.5% NaCl. The erosion corrosion resistance is comparatively lower due to its instability of passive layer by the flowing fluid.
2. The result showed that chloride ions are the primary agent for corrosion attack. Initially corrosion rate increased but after 3hours linear relationship is found between corrosion rate and time of exposure for both corrosion process and erosion corrosion process.
3. It was found from microstructure analysis that the corroded surface of both the tests has different pattern. Corroded surface of erosion corrosion process has more micro cracks than corrosion process. Therefore, the material loss is more for erosion corrosion process than corrosion process.

**REFERENCES**

Altun H. and S. Sen, Materials Des.25: 637-641 (2005)

Ahmed El-Shenawy et al., Predicting the Iron Losses from Steel pipes Due to Erosive Environment Using New Algorithm. WIT Transaction, Vol 156: (2014)

Gaungling S., Recent progress in corrosion and protection of Magnesium alloy. Advanced Engineering Materials 7(7): (2005) DOI:10.1002/adem.200500013.

Jae Ioong Kim and Do Suck Han, Recent Trends and Application of magnesium alloy in the Hyundai and Kia Motors Corporation. Materials Transactions 49 (5): 984-897 (2008)

Jayabharathy, S., R. Serarajan and P. Mathiazhagan,Experimental Investigation of Erosion Corrosion Behaviour of Pipe-line Materials with Different Environ-ments. CORCON, Paper No. 152, Nace International (2015)

LeBozec, N., M. Johnson and D. Thierry, Atmospheric Corrosion of Magnesium alloy: Influence of Temperature, Relative humidity and Chloride deposition. Corro-sion 6(4): 356-361 (2004).

Lei Wang,Tadashi Shinohara and Bo-ping Zhang, Corrosion behaviour of Mg, AZ31 and AZ91 in dilute solution. Journal of Solid state Electro. Chem. 14: 1897-1907 (2010).

Makar. G.L. and J. Kruger, Corrosion of Magnesium. International material review 38 (3): 139 (1993).

Nesic. S., J. BienKowski, K. Bremhorst and K.S. Yang, Testing for Erosion corrosion under distributed flow conditions using Rotating Cylinder with a Stepped Surface. Corrosion 56(10): Nace International (2000).

Nicholas Lutsey, Review of Technical litera-ture and trends related to automobile mass reduction technology. UCD-ITS-RR-10-10, Working paper series, Institute of Transportation studies, University of California, Davis (2010).

Rajan Ambat, Naing Naing Aung and W. Zhou, Evaluation of microstructural effect on corrosion behaviour of AZ91 magne-sium alloy. Corrosion Science 42: 1433-1455 (2000).

Rajaram. S.S., T.J. Harvey and R.J.K. Wood, Erosion corrosion resistance of engineering materials in Various test condition. Wear 267: 244 -254 (2009).

Sameer K.D. and K.N.S. Suman, Selection of Magnesium alloy by MADM methods for automobile. I. J. Engineering and Manufacturing 2: 31-41 (2014).

Singh. I.B., M. Singh and S. Das, A compa-rative corrosion behaviour of Mg, AZ31 and AZ91 alloy in 3.5% NaCl solution. Journal of Magnesium and alloy 3: 142 -148 (2015).

Thirumalaikumarasamy. D, K. Shanmuga and V. Balasubramanian, Influence of Chlor-ide ion concentration on immersion corro-sion behaviour of plasma sprayed alum-ina coating on AZ31 magnesium alloy. Journal of Magnesium alloy 2: 325-334 (2014).

Thirumalaikumarasamy. D, K. Shanmuga and V. Balasubramanian, Comparison of the corrosion behaviour of AZ31 magnesium alloy under immersion test and potentio-meter polarization test in NaCl. Journal of Magnesium alloy 2: 36-49 (2014).