Global and economic effects of corrosion - An overview

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Global and Economic Effects of Corrosion – An Overview

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Abstract. Corrosion has been in existence since man began to process ores into metals. Corrosion is the deterioration of a metal due to its interaction with its environment. This paper highlights the global and economic effects of corrosion in the society and amongst various industries. Extensive research is required regarding corrosion control methods and this should be carried out by companies and countries concerned. Failure to do so would result in more damage than could be predicted. Extreme consequences of corrosion are seen in loss of lives as well as buildings, bridges, etc. High rise structures have collapsed due to deterioration of certain parts of their construction material. Some developed countries already spend millions of dollars on extensive research on the control of corrosion so as to prevent losses of property and lives.

Keywords: Corrosion, economic effect, environment, global effect

INTRODUCTION

Corrosion in various forms has impacted the world on a global scale both positively and negatively. Metals are extracted from their ores and in line with the law of nature, all materials revert to their original state [1]. This conversion can be classified as corrosion; it is the deterioration of a metal due to its interaction with its surrounding and under various conditions.

Metals have been an enormous driver of the development of nations as they are employed as structural materials, manufacturing and are used even in human bodies to strengthen weak parts [2]. Due to this reason, corrosion is therefore an important study because it can lead to disastrous occurrences, even loss of lives [3].

In recent times the corrosion problem has become a great issue to industries in various fields as well as individual issues also. The effects of corrosion are mostly negative and they have resulted to lots of damages, accidents and even as far as loss of lives have been as a result of corrosion. There have been various disappointments when it comes to corrosion and this would result to large economical loss because this would require very costly substitutions. Below are some of the dangerous effects of corrosion [4];

- Projects would be stalled and this would result to loss of time in completing projects.
- Objects and substances won't have so much value as they had before and this would result to economic losses.
- It could lead to poisoning of food and drinks if the vessels used to prepare them are not totally free from corrosion.
- Leakages in funnels and vessels which would allow the fluid to leave the contained space and cause damage to our environment due to the harmful substances contained in them. A great example is when sea water enters the boilers of a power station if the tubes of the condenser are allowed to perforate.
- Due to a form of corrosion called erosion corrosion which involves loss of the top surface that have important properties of metals. Some of these important properties could include frictional and bearing properties, surface relativity, electrical conductivity of surfaces in contact as well as heat transfer across the metal surface [5].

It is important for countries as well as companies to carry out extensive research on the control of corrosion. Failure to do so would result to more damage than they even bargained for at the very beginning. Some developed countries already spend millions of dollars on extensive research on the control of corrosion so as to prevent losses of property and lives [6].

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Global Effects of Corrosion

Metallic corrosion is one of the problems we have often encountered in our industrialized society. Iron and steel have the natural tendency to return to their initial state when combined with chemical elements in the environment. The environment represents the surrounding in which the material is in operation.
The factors that characterize the environment can be classified into;

- Physical state: it could either be a gaseous environment or liquid environment
- Chemical composition— constituents and concentrations of the environmental conditions play an important role in the corrosion of a metal
- Temperature
- Stress loads on the material
- Flow of a solution on a metal

The results of corrosion are seen in the society and even directly affect us in our various households on our various possessions and properties. It attacks our car bodies, utensils and furniture. Extreme consequences are seen in the loss of lives as buildings, bridges, high rise structures have collapsed due to deterioration of certain parts of their construction material. Overtime as these materials are exposed to varying conditions and failure may occur in a brittle manner; without warning or in a ductile manner; with visible deformation. These failures are enhanced by crack propagations. An event was the collapse of the silver bridge that crosses the Ohio river in 1967, which led to the death of 46 people and millions of dollars for repairs [7, 8].
Industrial plants are greatly affected by corrosion and the cost of remedy is voluminous as it can lead to complete shutdown of the entire plant operations. Below is a list of certain consequences of corrosion in an industrial plant;

Complete Shutdown of Corroded Equipment

Every equipment in a plant has their various functions for the processing of raw materials into final products. The breakdown of one equipment can lead to the shutdown of the entire plant leading to loss of productive hours and loss of income.

Contamination of the Product

In process plants where purity of product is of paramount importance, corrosion of one of the transfer lines can cause contamination of the entire product and the sale of substandard products will lead to a fall in the reputation of such companies and in extreme conditions can lead to close of business

Loss of Product Due to Failure of Storage Facility/Equipment.

The storage of products in a plant is of importance as proper storage is a key part of any industry. A breakage in storage tanks can lead to loss of products and a loss in production.

Reduction in Overall Plant Efficiency:

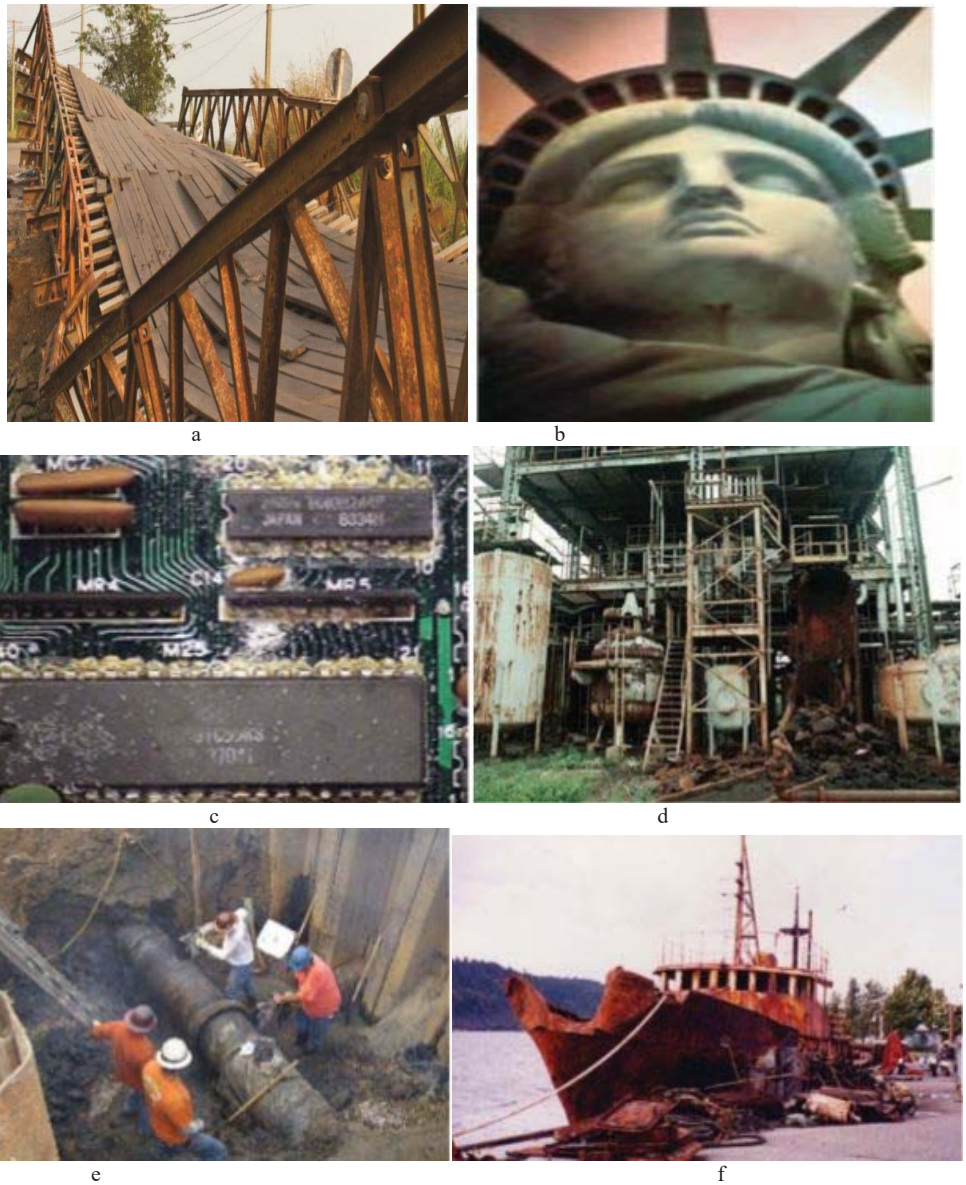
Most equipment in the plant require some sort of fuel to run and the failure of the equipment will lead to loss of those fuels and an increment in the production cost with no means for reimbursement.
Hence, corrosion can be seen as a capital-intensive problem when left unchecked through corrosion prevention techniques and proper maintenance.
It also has various social effects such as;

Adverse Effect on Health:

Pipes that deliver water to homes most times aren't maintained and which leads to the contamination of the water. Various materials are currently being developed for implants; such materials are extremely corrosive resistant because any slight deterioration will lead to contamination of the individual system causing breakdown.

Reduction in Aesthetics and Appearance:

Several building and materials which have corroded lose their beauty and their attractiveness thereby causing a reduction in their overall value.



a b c d e f

FIGURE 1. Some global effects of corrosion (a) Collapsed bridge due to corrosion (b) Corrosion of statue of liberty(c)Corrosion of an integrated circuit (d) Corrosion of an industrial plant and (e) A pipeline affected by corrosion (f) A corroded ship

ECONOMIC EFFECTS OF CORROSION !

In civil engineering a major concern is the corrosion of reinforcing steel bars which is majorly used in the most of the structural building processes and it is a major reason for the disintegration of infrastructures around the globe. The cost of repairs of the structure that has been destroyed due to the effect of corrosion has been analysed recently to make up to three percent of the GDP of developed countries [9]. Although some countries with more terrible climate changes such as the Middle East where the temperature and humidity are on the high part of the scale and they also encounter air borne chlorides have a GDP of about 5%.

The economic effect of corrosion is underestimated and it is beyond what most people can fathom in the first place. Another report that was given in 2001 stated that the cost estimate of corrosion in the United States was around $278 billion annually and out of this amount about 50% of it was spent on trying to reduce the occurrence of corrosion through various controlling methods and thus left the remaining amount as the net loss of the economy. Recently, in 2016, the annual cost of corrosion in the United States was estimated to be over $1.1 trillion dollars. Just as how corrosion is important in the building and setting up of structures it is also highly important in the creation and maintenance of utilities such as getting clean and drinkable water, good drainage systems, clear sewer system, all of these are affected the most economically while transportation and creation of vehicles come in after that. It is widely understood that shafts, metallic wires and metal bars are used across a lot of fields [10].

Apart from Industrial and engineering effects of corrosion during the middle of the 20th Century, there was an improvement of objects as well as materials that have been used to protect our cultural heritage. In transportation, we also experience corrosion which is better known as rusting [11-16].

Parts of vehicles experience rusting and this would cause a defect in the performance of the vehicle. Even in our normal daily activities that take place we also experience corrosion in our utilities that make it difficult for us to continue using the particular object or machine. For example, when doing simple house chores such as washing clothes, cooking or ironing. When drying clothes in this part of the nation, the rods we dry the clothes on after some time would start to corrode and this would result to spoiling and staining the clothes and then the clothes cannot be worn again. In older times the pots used to cook were designed to be mainly heat resistant, while they are being washed and exposed continuously, they begin to corrode unlike pots of nowadays that are not constructed mainly from metal but also ceramic [7, 17-19].

CONCLUSION

Corrosion is the deterioration of a material due to its reaction with its environment. This has both positive and negative impact. Positive in the development of the dry cell battery and negative in its effect in the industrial sector, to mention a few. Diverse methods have been developed as prevention methods to curb the effect of corrosion and increase the life span of our equipment to ensure optimal performances.

RECOMMENDATION

The following are recommendations that can help reduce the rate of corrosion of various metals:

- ❖ Weld joints rather than rivet, because they provide opportunity for crevice corrosion
- ❖ Systems should be designed in such a way that the components are easily replaceable for components where failure can occur frequently.
- ❖ Avoid stress concentration on components and mechanical stresses due to the processing of the metals
- ❖ Avoid contact between two dissimilar metals as this leads to galvanic corrosion. The use of similar metals should be encouraged
- ❖ All designs should be done in the best possible way to exclude air. If oxygen is excluded the life span of a metal is greatly increased. Attention should be given to various air inlets.

REFERENCES

1. Hua, L., & Hou, H. N. (2017). Microelectronics Reliability Electrochemical corrosion and electrochemical migration of 64Sn-35Bi-1Ag solder doping with xGe on printed circuit boards. Microelectronics Reliability, 75, 27–36.

2. Jinlong, L., Jin, H., & Tongxiang, L. (2019). The effect of electrochemical nitridation on the corrosion resistance of the passive films formed on the 2205 duplex stainless steel. Materials Letters, 256, 126640.
3. Liu, G., Khorsand, S., & Ji, S. (2019). Journal of Materials Science & Technology Electrochemical corrosion behaviour of Sn-Zn- xBi alloys used for miniature detonating cords. Journal of Materials Science & Technology, 35(8), 1618–1628.
4. Kannan, P., Varghese, A., Palanisamy, K., & Abousalem, A. S. (2020). Evaluating prolonged corrosion inhibition performance of benzyltributylammonium tetrachloroaluminate ionic liquid using electrochemical analysis and Monte Carlo simulation. Journal of Molecular Liquids, 297, 111855.
5. Xu, Y., Li, Z., Zhang, G., Wang, G., Zeng, Z., Wang, C., … Ren, T. (2019). Electrochemical corrosion and anisotropic tribological properties of bioinspired hierarchical morphologies on Ti-6Al-4V fabricated by laser texturing. Tribology International, 134, 352–364.
6. Ichchou, I., Larabi L., Rouabhi, H., Harek, Y., Fellah, A. (2019). Electrochemical evaluation and DFT calculations of aromatic sulfonohydrazides as corrosion inhibitors for XC38 carbon steel in acidic media. Journal of Molecular Structure, 1198, 126898.
7. Fintová, S., Drábiková, J., Pastorek, F., Tkacz, J., Kubena, I., Trsko, L., … Ptácek, P. (2019). Improvement of electrochemical corrosion characteristics of AZ61 magnesium alloy with unconventional fl uoride conversion coatings. Surface & Coatings Technology, 357, 638–650.
8. Hermoso-diaz, I. A., Foroozan, A. E., Rios, J. P. F. L., & Landeros-martinez, L. L. (2019). Electrochemical and quantum chemical assessment of linoleic acid as a corrosion inhibitor for carbon steel in sulfuric acid solution. Journal of Molecular Structure, 1197, 535–546.
9. Koch, G. H., Brongers, M., Thompson, N. G., Virmani, Y. P., Payer, J. H. (2002). Corrosion cost and prevent strategies in the United States. Accessed online at https://trid.trb.org/view/707382
10. Ma, H., Wu, L., Liu, C., Liu, M., Wang, C., Li, D., … Ke, W. (2020). First-principles modeling of the hydrogen evolution reaction and its application in electrochemical corrosion of Mg. Acta Materialia 183, 377–389.
11. Afzal, N., Ra, M., Javaid, W., Ahmad, R., Farooq, A., Saleem, M., & Khaliq, Z. (2018). Influence of carbon ion implantation energy on aluminum carbide precipitation and electrochemical corrosion resistance of aluminum. Nuclear Instruments and Methods in Physics Research B: Beam Interactions with Materials and Atoms, 436, 84–91.
12. Chen, H., & Kong, D. (2019). Effects of laser remelting speeds on microstructure , immersion corrosion , and electrochemical corrosion of arc - sprayed amorphous Al - Ti - Ni coatings. Journal of Alloys and Compounds, 771, 584–594.
13. Chen, S., Li, J., Hu, G., Chen, K., & Huang, L. (2018). Effect of Zn / Mg ratios on SCC , electrochemical corrosion properties and microstructure of Al-Zn-Mg alloy. Journal of Alloys and Compounds, 757, 259–264.
14. Kim, Y., & Kim, J. (2019). Electrochemical corrosion behavior of a non-vascular , bi-stent combination, surgical esophageal nitinol stent in phosphate-buffered saline solution. Materials Science & Engineering C, 94, 821–830.
15. Loto, C. A., Joseph, O. O., & Loto, R. T. (2014). Adsorption and inhibitive properties of Camellia Sinensis for aluminium alloy in HCl. International Journal of Electrochemical Science, 9, 3637-3649.
16. Joseph, O. O., Omotosho, O. A., Ojewumi, M. E., & Loto, R.T. (2019). An assessment on the effects of *Lecaniodiscus Cupaniodes* extract and normalizing temperature in corrosion behaviour of mild steel in 0.5 M HCl. Contributed Papers from Materials Science and Technology 2019 (MS&T19) September 29–October 3, 2019, Oregon Convention Center, Portland, Oregon, USA
17. Luo, K. Y., Wang, C. Y., Cui, C. Y., Lu, J. Z., & Lu, Y. F. (2019). Effects of coverage layer on the electrochemical corrosion behaviour of Mg-Al-Mn alloy subjected to massive laser shock peening treatment. Journal of Alloys and Compounds, 782, 1058-1075
18. Ma, H., Wu, L., Liu, C., Liu, M., Wang, C., Li, D., … Ke, W. (2020). First-principles modeling of the hydrogen evolution reaction and its application in electrochemical corrosion of Mg. Acta Materialia 183, 377–389.
19. Ramezanzadeh, M., Bahlakeh, G., & Ramezanzadeh, B. (2019). Study of the synergistic effect of Mangifera indica leaves extract and zinc ions on the mild steel corrosion inhibition in simulated seawater : Computational and electrochemical studies. Journal of Molecular Liquids, 292, 111387.