# Corrosion of steel: A Review

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***Abstract*: Steel is one of the largest and oldest materials used in all engineering applications. Steel is used in construction, in industries, in machineries, in plants etc. The aim of providing steel in appropriate form is to strengthen the particular member. Hence we can conclude that apart from the oldest material steel is having the characteristic which will help in enhancing the strength of the member. If provided steel is of appropriate quality as well as of quantity it will give the strength to the member till its expected life span. But before having faith on provided steel directly its necessary to take care for the health of steel we are providing, as there are lots of risk, if we won't handle them properly it will collapse all the assumed strength as well as expected service life span of the member. The most important risk to steel is from corrosion. In this review it is tried to address the different research work done so far related to corrosion. Review takes account of corrosion phenomenon - deteriorating the strength of materials, it's types and effect on weakening of the affected material. Also the method of tackling corrosion resistant such as by coatings on materials. Study of conditions leading to the kind of corrosion developed. Use of different coating materials and their performance . Review of effect of polarization resistance on corrosion rate of zinc with an increase in the degree of deformation, forming behavior of coated steel sheets. Effect of coating type, coating thickness etc. on the forming limit strains, strain distribution, interface friction coefficient variation, lubrication characteristics, surface roughening, wear behavior etc. and also the testing methods of coating is reviewed in this research paper.**

***Keywords*: Steel, corrosion, hot deep galvanizing**

## INTRODUCTION

Corrosion is a natural process. Corrosion can be defined as a chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties. Perhaps most dangerous of all is corrosion that occurs in major industrial plants, such as electrical power plants or chemical processing plants. Plant shutdowns can and do occur as a result of corrosion. This is just one of its many direct and indirect consequences. The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than the simple loss of a mass of metal. Failures of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small. Some of the major harmful effects of corrosion can be summarized as follows:

1. Reduction of metal thickness leading to loss of mechanical strength and structural failure or breakdown. When the metal is lost in localized zones so as to give a crack like structure, very considerable weakening may result from quite a small amount of metal loss.
2. Hazards or injuries to people arising from structural failure or breakdown (e.g. bridges,cars, aircraft).
3. Loss of time in availability of profile-making industrial equipment.
4. Reduced value of goods due to deterioration of appearance.
5. Contamination of fluids in vessels and pipes (e.g. beer goes cloudy when small quantities of heavy metals are released by corrosion).
6. Perforation of vessels and pipes allowing escape of their contents and possible harm to the surroundings. For example a leaky domestic radiator can cause expensive damage to carpets and decorations, while corrosive sea water may enter the boilers of a power station if the condenser tubes perforate.
7. Loss of technically important surface properties of a metallic component. These could include frictional and bearing properties, ease of fluid flow over a pipe surface, electrical conductivity of contacts, surface reflectivity or heat transfer across a surface.
8. Mechanical damage to valves, pumps, etc, or blockage of pipes by solid corrosion products.
9. Added complexity and expense of equipment which needs to be designed to with stand a certain amount of corrosion, and to allow corroded components to be conveniently replaced.

By retarding either the anodic or cathodic reactions the rate of corrosion can be reduced. This can be achieved in several ways:
1. Conditioning the Metal. It is again sub divided into two types as follows.
(a) Coating the metal, in order to interpose a corrosion resistant coating between metal and environment.
(b) Alloying the metal to produce a more corrosion resistant alloy, e.g. stainless steel, in which ordinary steel is alloyed with chromium and nickel. Stainless steel is protected by an invisibly thin, naturally formed film of chromium(III)oxide $Cr_2O_3$.
2. Conditioning the Corrosive Environment
(a) Removal of Oxygen
(b) Corrosion Inhibitors

3. Electrochemical Control

Steel is the most important material used for various applications such as in automobile industries, industrial machineries, marine applications etc. Steel is susceptible to the corrosion and hence generally used with a protective coating. Generally metallic coating like zinc, aluminum, or their alloys and non metallic coating, phosphates, chlorides, epoxy etc. are used as protection against corrosion for plain carbon steels [1].Mild steel should not be used in an acid environment, Mild steel is suitable in atmospheric environment, Mild steel to be used in salt water environment should be coated to achieve a useful service life and with minimum maintenance, Preventive measures can be used in order to slow down the rate of corrosion of mild steel in different environments [2].The control of corrosion presents a considerable challenge to engineers and in spite of our best effort, the annual costs of corrosion damage and maintenance run into many millions of Great British Pounds (GBP), estimated at about 4% of the Gross National Product(GNP) for an industrial country. This consequence is as a result of the location of these industries, structures and metals which are mostly at marine environments and have their atmosphere polluted by corrosion pollutant gases [3].

Ti–6Al–4V alloys exhibit excellent corrosion resistance and high strength to weight loads which make them ideal candidates for use in primarily two areas of application: corrosion resistant service and specific strength efficient structures [4].Access of oxygen to all surface is important, otherwise under limited supply of oxygen, the attack may be in the form of pits; in differential aeration areas, the places with lower oxygen content act as anode, whereas larger places with higher oxygen content act as cathodes. Of all the anions, chloride is most corrosive to zinc in water, especially if it is present in amount exceeding 50 mg/l [5].
few research groups have studied the forming behavior of coated steel sheets. But, their main attention is predominantly to understand the effect of coating type, coating thickness etc. on the forming limit strains, strain distribution, interface friction coefficient variation, lubrication characteristics, surface roughening, wear behavior etc. during forming and not on the corrosion behavior of that coated steel sheets [1].

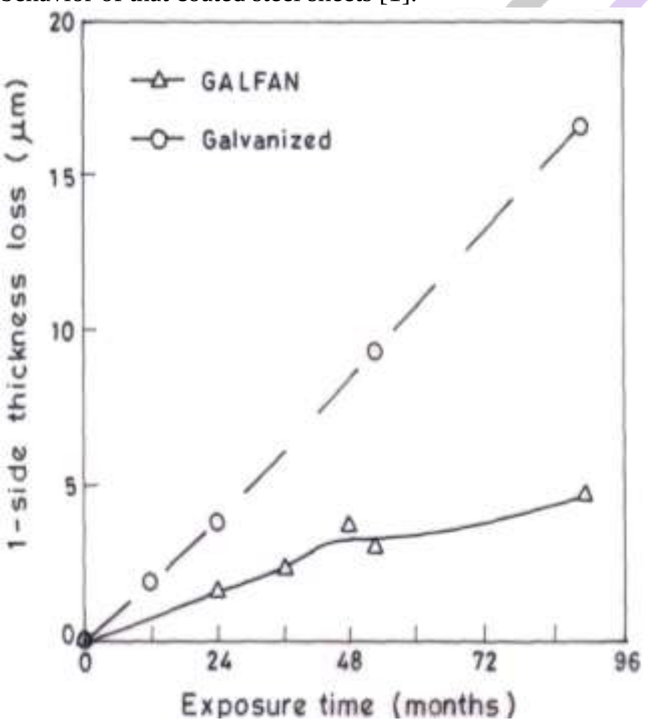


Figure 1.Seven year exposures of galfan and galvanized steel in a marine atmosphere [6].

Low $E_{corr}$ of magnesium containing galvanized coating and their high anodic dissolution kinetics can make them good sacrificial coating. Generally, hot-dip galvanizes coating exhibit reasonable adherence to steel substrate because of metallurgical bond formed between steel and coating layer at high temperature. For identical hot-dip galvanized conditions, magnesium addition has enhanced the coating bond strength. Due to tact that magnesium enhances the wettability in Mg and Al alloy [6].Earlier study showed that galvanized panels with more than 15 µm thickness offers cathodic protection. Scratches up to 5 mm width can be effectively protected by the surrounding zinc layer. Pure zinc is more anodic than iron-zinc alloys. Hence, bare steel can more readily protect by zinc than by the zinc alloy [7].Alloying elements are found to increase the life of hot-dip galvanized coating hence it is importance to pay attention on modifying the metallurgical properties of the coating includes corrosion behavior, phases formed on the coating, surface morphology of coating, polarization resistance etc. As the solidified structure of the hot-dip galvanized coatings consist heterogeneous dendritic microstructure and as cast solidified alloy structures are chemically inhomogeneous due to the presence of coring and dendrite [8]. The composition of the steel substrate can significantly influence the process and performance of the hot-dip galvanized coating. Generally the presence of carbon and phosphorus tend to delay the formation of intermetallic phases, since they segregate easily toward the grain boundaries during cooling time. In contrast the presence of silicon promotes the formation of Fe–Zn alloys and produces thicker coatings [9].Surface hardness of the Zn-Mg coating is higher than the hot-dip galvanizing (HDG) coating. For these purpose the microstructure of the surface and cross section of the coating were studied. Dendrites crystals were observed in the surface of the Zn-Mg coating and the crystal grain size tend to be smaller as Mg content in the coating layer increases [11].Hot-dip zinc coating is generally used for corrosion protection of plain carbon steels but susceptible to local corrosion at grain boundaries. Literature published shows that lead, antimony and bismuth promote spangle formation (snowflake-like or six-fold star pattern) in zinc coatings. The problem has been arisen that, lead in the alloy segregates to the zinc grain boundaries causing intergranular corrosion, which weakens adhesive strength of the coating [13]. The corrosion behavior of the coring has been found to be influenced by interdendritic spacing, surface morphology formation and phases formed on the coating surface, solute distribution. Mg in the Zn-Mg coating is distributed mainly near the dendroid portion of the dendritic crystal. This is caused by precipitation of Mg near the Zn crystal grain during solidification according to Zn-Mg binary phase diagram. [12,15]. Several researchers have reported that the corrosion resistance of zinc coatings could be improved by addition of Mg. Addition of small amount of Mg in Zinc leads to dramatic increase in resistance to corrosion by using cyclic corrosion test(CCT).(CCT has evolved in recent years, largely within the automotive industry, as a way of accelerating real-world corrosion failures, under laboratory controlled conditions) [10,13].Due to increasing demand and cost of the steel it very important to enhance or increase corrosion resistance and the life of the hot dip galvanized coating and its resources. It is observed that alloying element addition has been providing better corrosion protection than pure HDG coating. The alloying elements like Al, Mg, Ni, Sr, Bi etc. is play an important role in improving galvanic performance i.e. corrosion resistance, its life etc. of hot dip galvanized coating [14].Galvanized coating is generally ductile in nature. As zinc is soft metal that flows with the steel sheet during forming. Because it posses compressive stresses easily without any peeling off. This may be due to zinc coating acting as a solid lubricant at the interface [15].

Lead and antimony are usually incorporated into zinc bath which not only increase the bath fluidity but also decrease its surface tension. Also lead in small amount about 0.004-0.2% which improves zinc coating uniformity and its adhesion to the steel substrate. Silicon is added in zinc bath to produce very thin coating. Zinc coating containing Ni and Al excepted to be more protective than that without Ni and Al. Arsenic is harmful as it increases brittleness of coating. [11].Earlier, investigators have conducted salt spray, cyclic corrosion and electrochemical tests on the hot-dip Zn-6%Al-3%Mg, Zn-0.2%Al and Zn-4.5%Al-0.1% Mg coated steel sheets produced without a chromate post-treatment were used in this study. Its observed that cross sectional structure of specimen at 5 years of exposure in the costal and rural environment. In the costal environment the Zn-0.2%Al coating layer is almost corroded and the steel substrate is covered with corrosion products. Zn-4.5%Al-0.1% Mg there are many portions where the coating is corroded to the interface between coating layer and the steel substrate. In contrast Zn-6%Al-3%Mg coating layer and its average corrosion depth is 5 microns or less [13,17]. Lead and antimony are toxic and hence needs to be substituted. Earlier researchers reported that magnesium addition in zinc alloys and aluminum alloys increase the coating hardness, reduce degree of porosity, improves mechanical properties, corrosion resistance and thermal properties [10,17,18].Polarization curve of Zn-Mg shows that Zn-Mg had lower limited diffusion current of cathodic reaction (oxygen reduction reaction) than the zinc coating due to densely packed corrosion product of Zn-Mg coating hindering the diffusion of the oxygen which is one of the reasons for higher corrosion resistance of the Zn-Mg coating [19].

**Comments on Literature Review**

A review of the literature indicates the following points related to corrosion further research are required for the prevention of structure materials from corrosion for safety and economy of the structure/members.

1. Corrosion is very dangerous for the plant or structure or the material where steel is used, because of this the working plant can also get shut down.
2. By retarding either the anodic or cathodic reactions the rate of corrosion can be reduced.
3. Preventive measures can be used in order to slow down the rate of corrosion of mild steel in different environments.
4. Magnesium addition has enhanced the coating bond strength.
5. Hot-dip zinc coating is generally used for corrosion protection of plain carbon steels but susceptible to local corrosion at grain boundaries.
6. There are many different coating agents by using them we can prevent the corrosion. Among this hot-dip galvanized coating is also the way through which corrosion can be resisted.

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