

Corrosion of Aluminum Components and Remedial Measures

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Abstract. Aluminum has versatile physical properties, mechanical strength, corrosion resistance, and is used in special applications like aerospace, automobiles and other strategic industries. The outdoor exposed structural components of aluminum have very good corrosion resistance due to the thick oxide layer (0.2 - 0.4 μ). This study involves the corrosion of aluminum based components, though aluminum is protected by an oxide layer but due to extreme weather and environmental conditions the oxide layer was damaged. The corroded product was removed, pits or cavities formed due to the material removal were filled with epoxy resins and acrylic-based compounds containing fibreglass as reinforcement. Optimum results were obtained with epoxy resins incorporated with 5% glass fibres. The inner surface of the components was provided further protection with a cellulose nitrate compound.

Keywords: corrosivity, aluminum, components, passivity

Introduction

The properties of aluminum have made this metal and its alloys the most economical and attractive for a wide variety of uses, as related with appearance, light weight, ease of fabrication, physical and mechanical properties, and corrosion resistance. It has good resistance against corrosive elements in most of the environments, such as water, marine atmosphere, oils, and a number of chemicals (Brown and Binger, 1960). Aluminum and its alloys provide high ratio of strength to weight, which can be easily fabricated and joined readily by most of the methods commonly used. Aluminum alloys have high conductance of heat, electricity, high reflectivity of heat radiant energy, visible light and electromagnetic waves. Aluminum and its alloys are also nonmagnetic, therefore, aluminum alloys are widely used in high technology industries, such as air crafts, radars, etc. Aluminum is an active metal having good resistance to corrosion due to the passivity produced by a protective oxide film. The limits of passivity being dependant on the temperature, the form of oxide present, and low dissolution of aluminum (Bohni and Uhlig, 1969). Increased corrosion resistance is secured through the use of alclad alloys and anodic coatings. The corrosion resistance is further improved by the application of special paints (Van Horn, 1967).

Aluminum may corrode because of defects in its protective oxide film. Resistance to corrosion improves considerably as purity is increased, but the oxide film even on the purest aluminum nevertheless contains a few defects where corrosion can develop. The presence of second phase corrosion becomes the more important factor. These phases are present, as the insoluble constituents of intermetallic compounds are

produced primarily from iron, silicon and other impurities, and the smaller precipitates of compounds are produced from soluble alloying elements. Most of these phases are cathodic to aluminum, but a few are anodic. In either case, they produce galvanic cells because of the potential difference between them and the aluminum matrix (Hollingsworth and Hunsicker, 1979). Pitting corrosion of aluminum is more prevalent than other forms of damage. Corrosion of this type is produced mostly by halide ions, of which chlorine is the most frequently encountered. Aluminum may develop pitting in aerated solutions of halides simply because the reactions occurring on its cathodic regions are sufficient to polarize it to its pitting potential (Metikos-Hukovics, 2000). The aluminum alloy used in the manufacture of radar parts belongs to the 5XXX series (Al-Mg). Magnesium is the most soluble element in aluminum and remains in solution even at low temperature, though dissolves at elevated temperature exceeding its solubility limit. While studying the pitting in aluminum fuel tanks during the closer inspection, Munikrishnaiah (2003) had found dark spots/patches on the bulkhead forgings. The present work involves the cleaning of aluminum alloy components used in equipments exposed to extremes of atmospheres and were relolving.

The author then flushed the tank with aviation fuel and collected the sediments. The analysis of the sediments revealed that Al_2O_3 particles were the major components of the sediments, besides containing the general corrodents like Cl, Ca and O. This pitting was attributed to the presence of active chloride ion which is the major corrodent of aluminum. The present work involves the cleaning of aluminum alloy components used in equipments exposed to extremes of atmosphere and were revolving.

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Materials and Methods

Corroded samples of aluminum alloy were subjected to the following treatment in order to remove the corroded products from their surfaces. Concentrated hydrochloric acid solution was used for pickling to remove the corroded product from the upper surface. The pickling period varied from 45-60 min, and was continued till the corroded products were removed. The cleaned aluminum alloy panels were then passivated in a 5% solution of potassium dichromate for 12 h at room temperature. Copper-based salt was added as accelerator. After 12 h treatment, the samples were removed from the passivating solution and then treated with 50% potassium hydroxide or sodium hydroxide solution for the removal of excess acidic material, and washed thoroughly with water till the surface was neutral.

The pits and cavities in the outer surface of the aluminum alloy-based component were filled with the following compounds: (a) acrylic resins incorporating 5% fibre glass material; (b) acrylic resin incorporating 10% fibre glass material; (c) epoxy resin, as such; (d) epoxy resin containing 5% fibre glass material; (e) epoxy resin containing 1% fibre glass material.

The aluminum alloy component, after filling and leveling of the depression pits and cavities, was given a dip in a brightening solution containing equal volumes of nitric acid and

sulphuric acid. The inner surface of the aluminum alloy component was given protection with the following two compositions: (a) air drying alkyd-base lacquer; and (b) nitrocellulose-base air drying lacquer.

All the samples, after covering both inner and outer surfaces with the protective layers, were subjected to the corrosion accelerated salt spray (CASS) test for 120 h at 35 °C, 98% relative humidity, and outdoor exposure at 45° facing north. They were also dipped in acidic solution having pH 6 in order to determine the corrosion rate.

Results and Discussion

The results of the corrosion accelerated salt spray (CASS) test are given in Table 1. The corroded area was calculated as per ISO 4549-1980.

Out-door exposure. Aluminum alloy panels which had been given different treatments as shown in Table 1 and 2 were observed for their corrosion resistance as after outdoor exposure at 45° facing north. It was observed that aluminum alloy panels coated with epoxy resin incorporating 5% fibre glass had the minimal corrosion attack, showing less than 0.01% corrosion area, while other treatments showed area ranging from 0.25-0.5% under corrosion attack. Similarly the inner side of the aluminum panel, protected with nitrocellulose lacquer, had corrosion attack limited to area less than 0.001%.

Table 1. The corrosion rate after different treatments

Description of the treatment	Corroded area (%)	Corrosion rating*
Aluminum alloy treated with acrylic resin incorporating 5% fibre glass	<0.01	8/10
Aluminum alloy treated with acrylic resin incorporating 10% fibre glass	<0.01	8/10
Aluminum alloy treated with epoxy resin	<0.01	8/10
Aluminum alloy treated with epoxy resin incorporating 5% fibre glass	<0.001	9/10
Aluminum alloy treated with epoxy resin incorporating 10% fibre glass	<0.001	8/10
Inner side of aluminum component coated with alkyd-base lacquer	<0.1	8/10
Inner side of the aluminum component coated with nitrocellulose based lacquer weight loss	<0.001	9/10

* = the corrosion rates, after different treatments, are given in Table 2, whereas the corrosion rating was determined as per ISO 4540-1980

Table 2. Inner side of the aluminum alloy treated with various materials

Description of the sample	Corrosion rate
Aluminum alloy treated with acrylic resin incorporating 5% fibre glass	<0.20 cm/yr
Aluminum alloy treated with acrylic resin incorporating 10% fibre	<0.21 cm/yr
Aluminum alloy treated with epoxy resin	<0.29 cm/yr
Aluminum alloy treated with epoxy resin incorporating 5% glass fibre	<0.15 cm/yr
Aluminum alloy treated with epoxy resin incorporating 10% glass fibre	<0.16 cm/yr
Inner side of aluminum component coated with alkyd-base lacquer	<0.20 cm/yr
Inner side of the aluminum component coated with nitrocellulose based lacquer weight loss	<0.17 cm/yr

In alclad aluminum products, the difference in the solution potential between the core alloy and the cladding alloy is used to provide cathodic protection to the core. These products primarily consist of a core, coated on one or both surfaces with a metallurgic layer of a bonded alloy. The thickness of the cladding layer usually is less than 10% of the product. Cladding alloys generally are of non-heat treatable type, although for higher strength heat treatable alloy is used. Composition relationships of the core and cladding alloys are generally designed so that cladding is 80 to 100 mv more anodic than the core. Because of the cathodic protection provided by the cladding, corrosion progresses only to the core/cladding interface and then spreading laterally. Moderately high strength and resistance to corrosion combines to make the heat treatable wrought alloys. Al-Mg-Si alloy is highly suitable for equipment and other strategic applications (Reinhart, 1976). The Mg_2Si phase, which is the basis for the precipitation hardening, is unique in that it is an ionic compound and is not only anodic to aluminum but also reactive in acidic solutions. However, whether in solid solution or as submicroscopic precipitate, Mg_2Si has negligible effect on electrode potential. Because these alloys are normally used in the heat-treated conditions, no detrimental effects derive from the major or from the supplementary alloying elements. Chromium, manganese or zirconium is added for controlling grain structure. The addition of copper which augment strength in many of the alloys, is limited to small amounts to minimize effects on corrosion resistance. In general, the level of resistance decreases somewhat with increasing copper content.

Aluminum alloys, exhibit high resistant to weathering in most atmospheres, as demonstrated by their extensive use for architectural applications in commercial, industrial and residential buildings, and high technology equipment (Tian, 1999). Paints are applied in certain instances to aluminum surfaces to provide extra protection. The depth of attack during weathering of coated aluminum mostly decreases after the initial period of exposure. The loss of strength also decreases in the some manner after an initial period, but not to as low a rate. The difference is a consequence of the fact that while older sites of attack tend to become inactive, newer ones develop. The newer sites of attack decrease cross-sectional area on which strength depends and the average depth of attack but not the maximum depth.

Conclusion

Aluminum alloy that was given protection with epoxy resin incorporating 5% glass fibres showed the maximum protection against corrosion attack and damage. The aluminum alloy that was given inner surface protection with nitrocellulose showed the least corrosion damage.

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