CT Innovations

TT-W012

Aluminum In Corrosive Environments:

TOUGHTray

1.0 ABSRACT

Aluminum was first discovered in 1825 by Hans Oersted. Today, aluminum alloy cable tray systems are widely used in various industries due to their lightweight, strength, and excellent corrosion resistance properties. This technical paper explores the suitability of aluminum alloys in different corrosive environments, including atmospheric, aqueous, and chemical exposures. The mechanisms of corrosion resistance, types of aluminum alloys, and methods to enhance their performance in corrosive conditions are discussed.

2.0 INTRODUCTION

Aluminum alloys are essential materials in many applications such as transportation, construction, and packaging. The inherent corrosion resistance of aluminum stems from the formation of a thin, protective oxide layer on its surface. This paper reviews the performance of aluminum in various corrosive environments, the factors affecting its corrosion resistance, and strategies to improve its durability.

3.0 CORROSION MECHANISMS IN ALUMINUM

The primary mechanism of corrosion resistance in aluminium is the formation of a stable aluminium oxide (Al_2O_3) layer when exposed to oxygen. This oxide layer acts as a barrier to corrosion. However, in certain environments, this protective layer can be compromised, leading to different forms of corrosion such as pitting and galvanic.

4.0 TYPES OF ALUMINUM ALLOYS & THEIR CORROSION RESISTANCE

Aluminum alloys are categorized based on their main alloying elements. The alloying elements influence the mechanical properties and corrosion resistance of the material.

- 1000 Series: Pure aluminium with excellent corrosion resistance, ideal for food processing equipment.
- 2000 Series: Copper is the primary alloying element, providing high strength but lower corrosion resistance.
- 3000 Series: Manganese alloying improves corrosion resistance, often used for chemical and food equipment.
- 4000 Series: Silicon is the primary alloying element, typically used for automotive components.
- 5000 Series: Magnesium alloying offers good corrosion resistance, especially in marine environments.
- 6000 Series: Silicon and Magnesium provide good strength, extrudability and excellent corrosion resistance.
- 7000 Series: Zinc is the main alloying element offering high strength but with lower corrosion resistance.
- 8000 Series: Zinc, Manganese, Silicon are primary alloying elements, offering strength and corrosion resistance.

5.0 CORROSION BEHAVIOR IN DIFFERENT ENVIRONMENTS

5.1 Atmospheric Corrosion

Aluminium performs well in most atmospheric conditions due to the protective oxide layer. However, in highly polluted or marine environments, the presence of chloride ions can lead to pitting corrosion. Protective coatings and alloy selection are crucial in these conditions. AA6063 is an excellent choice of alloy for use in highly polluted and marine environments, it is commonly referred to as a copper free marine grade aluminum alloy.

5.2 Aqueous Corrosion

In fresh and seawater, aluminium alloys exhibit varying degrees of corrosion resistance, from poor to excellent depending upon the alloy. The 5000 and 6000 series, containing magnesium, show excellent performance in seawater. Chloride ions in saltwater can initiate pitting and crevice corrosion, especially at heat effected areas in the alloy due to welding which can degrade the protective oxide layer. Selecting the correct alloy will ensure good corrosion protection.

5.3 Chemical Corrosion

Aluminium is resistant to many chemicals, but its surface can be degraded over time due to chemical reactions in the environment caused by specific chemicals such strong acids, alkalis, bases and salts. Protective coatings and surface treatment can enhance corrosion resistance in aggressive chemical environments. The chemical compatibility of the alloy should be determined prior to use. Refer to technical data sheet CTI-TDS-S65002.

5.4 Galvanic Corrosion

This type of corrosion may occur when aluminum alloy and another different type of metal comes into contact with each other in the presence of an electrolyte, such as water or moisture. When dissimilar metals are in contact, an electric current flows between them, which causes one metal to corrode more than the other. Several factors can contribute to the likelihood or prevention of galvanic corrosion, such as:

- The type of metals/materials in contact.
- The presence of moisture or other electrolytes in the cable tray environment.
- The surface area ratio of the two metals/materials in contact.
- The metals position and differential within the periodic table *(such as ZN being close to AL)*.
- The environment in which the cable tray is located *(such as marine or industrial environments)*.
- The metal/material finish *(such as galvanized zinc or painted finish which will act as an isolator)*.

Prevention methods can be:

- Minimizing the dissimilar metals contact areas *(a small SS contact area to AL is considered as no risk)*.
- Isolating the dissimilar metals *(isolation pads installed between the aluminum tray and tray supports)*.
- Coating one or both dissimilar metals *(zinc galvanized or painted finish tray supports)*.
- Cathodic protection *(the aluminum cable tray system is electrical bonded and grounded)*.

For further information, refer to technical data sheet CTI-TDS-S65002.

5.5 Enhancing Corrosion Resistance

a) Alloy Selection

Choosing the right aluminium alloy for specific environments is crucial. For example, the 5000 and 6000 series are preferred for marine applications due to their superior resistance to chloride-induced corrosion. Cable tray systems are generally manufactured from a combination of these two aluminum alloys to be suitable for service in harsh corrosive marine environments.

b) Surface Treatments

Surface treatments such as heat treatment, anodizing, and painting can significantly enhance the corrosion resistance of aluminium. Anodizing increases the thickness of the natural oxide layer, providing better protection while heat treatment (tempering) improves alloy strength, maintains ductility and protection.

6.0 CORROSION CASE STUDIES

6.1 Marine Applications

In marine environments, 5000 and 6000 series aluminium alloys are widely used due to their excellent resistance to seawater. Examples include ship hulls and superstructures, offshore structures, flooring, handrail, electrical and instrumentation equipment, lighting and cable tray systems.

6.2 Construction Industry

Aluminium is used in building facades, windows, roofing materials, electrical equipment and cable tray systems. The naturally forming oxide layer provides good protection in urban, rural and marine atmospheres, with additional coatings often applied for enhanced durability and aesthetics.

6.3 Chemical Processing

In the chemical industry, aluminium is used for storage tanks and piping. The choice of alloy and protective coatings is critical to prevent attack from aggressive chemicals. Refer to technical data sheet CTI-TDS-S65002.

6.4 Energy, Oil & Gas Industry

Aluminum alloy cable tray systems, electrical equipment and construction materials are commonly used in this industry, both onshore and offshore, in harsh and hazardous areas. The selection of the correct alloy is imperative when installed within hazardous areas. Both 5054 and 6063 are commonly used for aluminum cable tray systems in harsh hazardous service onshore and offshore.

7.0 CONCLUSIONS

Aluminium's suitability for use in corrosive environments is dependent upon the specific environmental conditions and the aluminum alloy used. By selecting the correct aluminum alloy, understanding the mechanisms of corrosion and applying appropriate protective measures, aluminium can be effectively utilized in a wide range of applications, offering excellent performance and reliability in the harshest environments.

8.0 REFERENCES

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This letter provides a comprehensive overview of the suitability of aluminum alloys in corrosive environments, addressing the different types of corrosion, alloys, and methods to enhance corrosion resistance. For marine coastal and offshore harsh and hazardous service, a 5000 and 6000 series aluminum alloy cable tray system is recommended. The recommended specific alloy grades are marine copper free AA 5052 and AA 6063.

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