

Ultra High Corrosion-resistant Aluminum for Differential Pressure and Pressure Transmitter Housings

Makoto Watanabe *1

In recent years, demand for corrosion-resistant housings has been growing for field instruments, especially those for marine and coastal applications. To satisfy this need, Yokogawa has picked ultra high corrosion-resistant aluminum for differential pressure and pressure transmitter housings, in addition to conventional stainless steel. Although aluminum is inferior to stainless steel in corrosion resistance, it is superior in weight and cost. Ultra high corrosion-resistant aluminum has high corrosion resistance properties close to stainless steel while maintaining the merits of aluminum. This paper describes the corrosion resistance property of ultra high corrosion-resistant aluminum when used for differential pressure and pressure transmitter housings.

INTRODUCTION

Global demand for energy is expected to grow in the future due to population increases and development in emerging nations. Major oil companies have established a policy to increase investment in mining areas called “upstream”. Mining sites are expected to expand to the sea far from the land in accordance with advancements in search and drilling technologies in the future.⁽¹⁾ As a result, installation of field devices in such environments is expected to increase. Because field devices installed in offshore and coastal areas are subjected to damage by seawater, further corrosion resistance is required of them.

To respond to these situations, Yokogawa has developed ultra high corrosion-resistant aluminum housings for differential pressure and pressure transmitters (hereinafter, “differential pressure and pressure transmitters” are referred to as “transmitters”), releasing them in October 2011. Applying these housings along with existing stainless steel ones, Yokogawa offers a wide range of solutions for customers.

ALUMINUM CORROSION RESISTANCE

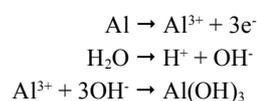
Importance of High Corrosion Resistance

Corrosion resistance is the ability to resist against corrosion. The term “durability” is similar in a broad sense. Durability is usually recognized as an ability to function to the utmost limit, and in the ISO 12944-1: 1998⁽²⁾, it is defined as “the expected life of a protective paint system prior to its first major maintenance.” This sentence can be understood in the case of the corrosion resistance of housings as “Durability is the period until maintenance or replacement of products is required due to their corrosion.” Superior resistance to corrosion of the housings is beneficial for their users.

Corroding Process

One of the causes of aluminum corrosion is galvanization. This is a phenomenon in which a metal loses electrons due to a chemical reaction, where they are emitted in the form of metal ions from the original metal, causing corrosion. The potential to ionize differs in different types of metal.

When aluminum is exposed to water, a local battery is produced between the aluminum and other metals contained within. The metal that ionizes more easily will corrode. In the case of aluminum corrosion, the following reaction takes place, thereby producing a white aluminum hydroxide:



*1 Mechanical Hardware D&E Dept., Global Development Center, IA Platform Business Headquarters

Aluminum housings of field devices are painted to protect the aluminum from corrosive atmospheres. The corrosion resistance of the housing is not affected by aluminum corrosion resistance as long as it is properly coated with paint. However, during practical use, the paint may get scratched or peeled, exposing the aluminum material to the external atmosphere. Therefore, enhancing corrosion resistance of an aluminum material is an important issue for field devices used in a corrosive atmosphere.

Applying Ultra High Corrosion-Resistant Aluminum

In this paper, ultra high corrosion-resistant aluminum refers to an aluminum material which enables a product to be used for a longer period of time in marine and coastal areas than that achieved by standard aluminum when used as a material for its housing.

Elements such as silicon, copper, iron, magnesium, zinc, manganese are added to aluminum alloys for casting to improve properties such as castability, strength, machinability and seizure prevention⁽³⁾. The added elements, however, do not always act in a favorable manner. For example, copper, which enhance strength and machinability, has a larger difference from aluminum in ionization tendency than other metals. Therefore, when an aluminum material that contains a lot of copper contacts water or the like, galvanization occurs, causing severe corrosion. It is important to select an aluminum material with low copper content for a highly corrosion resistant aluminum material.

Yokogawa has chosen an aluminum material with a copper content of 0.03 wt% or less as an ultra high corrosion-resistant aluminum for transmitters. When choosing, pressure proof tests in addition to corrosion resistance evaluation tests were conducted to verify that the lower copper content does not impact on strength, which is one of the requirements for explosion proof performance.

Copper Content and Corrosion Resistance

To verify the relationship between the copper content and the corrosion resistance of aluminum materials, salt water immersion tests over a period of 1000 hours were conducted. Table 1 summarizes the test conditions, and Figure 1 shows a comparison of the corroded conditions of multiple aluminum alloys for casting after the salt water immersion tests. The salt water immersion test was selected to minimize influences from differences in shape and surface condition.

Table 1 Salt water immersion test conditions

Temperature	50 °C
Salinity concentration	5 wt%
Testing time	1000 hours
Other	<ul style="list-style-type: none"> · Original test method · Put in a container and stored in a thermostat chamber

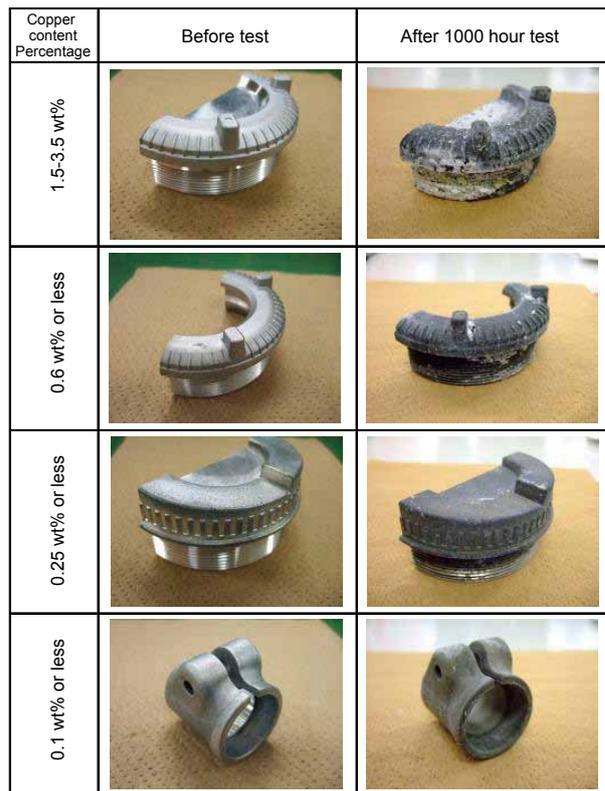


Figure 1 Results of salt water immersion tests using aluminum alloys for casting

Conditions of generated white rust (aluminum hydroxide) after the tests differ in each of the samples. It is confirmed that the lower copper content in the sample causes less white rust. Particularly in the sample with a copper content of 0.1 wt% or less, white rust is hardly seen, and this sample is considered to be highly resistant to corrosion.

The sample with the highest copper content showing severe corrosion is made of general aluminum alloys for die casting (hereinafter referred to as general aluminum), which accounts for approximately 94% of the amount of aluminum die cast production in Japan⁽⁴⁾.

Corrosion Resistance of Ultra High Corrosion-Resistant Aluminum

The results of the quantitative measurement of corrosion resistance of the ultra high corrosion-resistant aluminum are described below. The salt spray test with a test condition of 1440 hours of testing time was selected. Because these test conditions are equivalent to environment class C5-M (marine, offshore, estuaries, coastal areas with high salinity) and durability class “High” (over 15 years until the first major maintenance) defined in ISO 12944-6:1998⁽⁵⁾. Although these standards are for steel, they were applied as criteria for this form of corrosion resistance because no standards exist for aluminum materials. In addition, the test method conforms to JIS Z 2371: 2000⁽⁶⁾ defining methods for salt spray testing.

Table 2 summarizes the test conditions and Figure 2 shows the appearance before and after the test. The general

aluminum not only generates white rust but turns to black on the whole. In contrast, the ultra high corrosion-resistant aluminum turns only to grey, and its metallic luster is observed in some places. This suggests that the ultra high corrosion-resistant aluminum has extremely higher corrosion resistance than the general aluminum.

Table 2 Salt spray test conditions

Temperature	35 °C
Salinity concentration	5 wt%
Testing time	1440 hours
Other	· Conforms to JIS Z2371:2000 · Conducted in an outside test laboratory

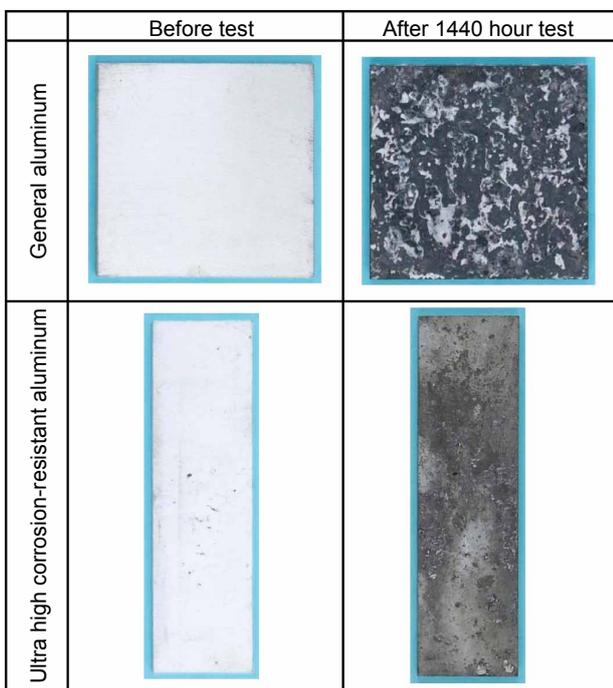


Figure 2 Comparison of appearances of the samples before and after the 1440 hour salt spray test

Figure 3 shows corrosion weight losses of each material after the salt spray tests. The corrosion weight loss is the difference of the weight before and after the environment tests. The weight decreases after the tests because elements of the aluminum are emitted from the metal by galvanization. The weight after the tests was measured after removing corrosion products using nitric acid. Average values are calculated using 3 samples for each material, and the percentage of the corrosion weight loss of the ultra high corrosion-resistant aluminum compared to that of the general aluminum is shown in the figure. In order to eliminate the effect of a difference in shapes of the samples, the corrosion weight losses are converted to the weight per unit surface area for comparison.

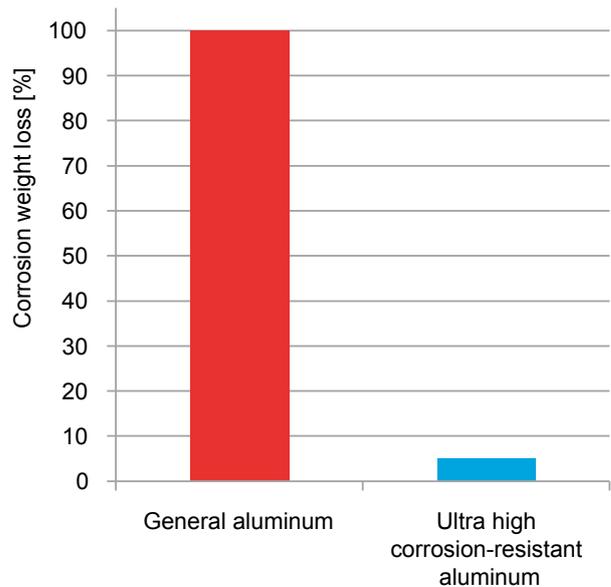


Figure 3 Comparison of the corrosion weight losses through the 1440 hour salt spray test

The corrosion weight loss of the ultra high corrosion-resistant aluminum is approximately 5% of that of the general aluminum. It was quantitatively confirmed that the ultra high corrosion-resistant aluminum is superior to the general aluminum.

RESULTS OF THE ULTRA HIGH CORROSION-RESISTANT ALUMINUM FIELD TEST

Figure 4 shows a photograph of the sample for the field test conducted before the release of the housings made of the ultra high corrosion-resistant aluminum. The test was conducted on an offshore platform 200 km off the coast of Thailand. As shown in Table 3, the temperature of the atmosphere is approximately 30 °C throughout the year; and the sample was installed for a period of about three years, from December 2009 to January 2013.

The field test was conducted using the sample combining the general aluminum and the ultra high corrosion-resistant aluminum. The cover was made of the general aluminum and the case was made of the ultra high corrosion-resistant aluminum.

The paint on the part made of general aluminum was completely separated from the basis metal and peeled off when merely touched. Severe corrosion was observed in the aluminum material. As for the ultra high corrosion-resistant aluminum, no obvious corrosion was observed, though some dirt was seen on the surface. The ultra high corrosion-resistant aluminum is supposed to have an equally good result even after the longer period test.

Table 3 Field test environment

Installation period	Approx. 3 years, 12/2009 to 1/2013
Installation location	· 200 km off the coast of Thailand · Near the center of Thailand Bay · 20 to 15 m above sea level · On an offshore platform
Other	Average temperature of approx. 30 °C throughout the year

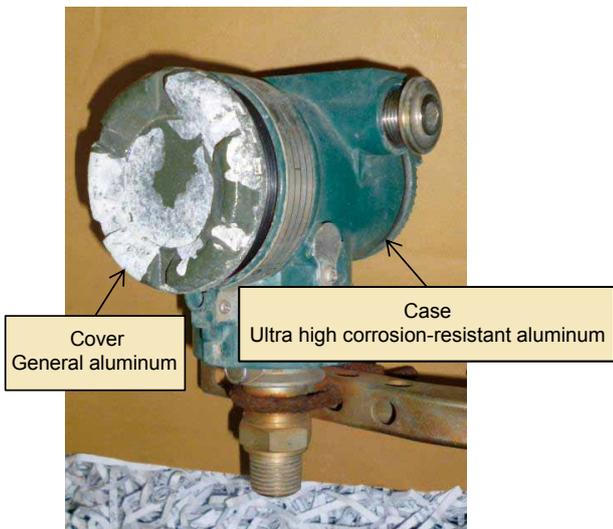


Figure 4 Field test sample

CONCLUSION

This paper has introduced the corrosion resistance of ultra high corrosion-resistant aluminum while including an explanation of the principle of corrosion, and a comparison with other aluminum materials.

Corrosion resistance of housings has a significant impact on product durability. Yokogawa believes that the newly developed housings made of ultra high corrosion-resistant aluminum will enhance durability of transmitters used in marine and coastal areas and contribute to lowering their maintenance costs.

Yokogawa will continue our product development to meet the various needs of customers in the future.

REFERENCES

- (1) Norihito Komatsu, Offshore Plant, Vessels and Marine Engineering, a separate volume of the journal, The Piping Engineering, Vol. 56, No. 3, 2014, pp. 1-5 in Japanese
- (2) ISO 12944-1: 1998, Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 6: Laboratory performance test methods, the International Organization for Standardization
- (3) R. Winston Revie, Herbert H. Uhlig, Corrosion and Corrosion Control second edition, John Wiley & Sons, Inc.
- (4) What's Die Casting?, Japan Die Casting Association, 2003 in Japanese
- (5) ISO 12944-6:1998, Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 6: Laboratory performance test methods
- (6) JIS Z 2371:2000, Methods of salt spray testing, Japanese Standards Association