Crevice Corrosion Theory, Mechanisms and Prevention Methods

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Abstract

This paper reviews theory and mechanisms of crevice corrosion as well as its prevention methods. Crevice corrosion is one of the most important and harmful forms of localized corrosion that may cause sudden failure of the metal in service if not prevented properly. So far several protection methods against crevice corrosion have been developed including cathodic protection and using inhibitors and coatings. Hot wax dip method and sealing crevices with polysulfide are two popular protection methods currently used in automotive and aerospace industries respectively. However researches about this devastating type of corrosion still continue.

1.Introduction

Crevice corrosion is a type of localized corrosion that can be found within crevices or at shielded surfaces where a stagnant solution is present [1]. It is one of the most frequently encountered forms of localized corrosion and at the same time one of the most harmful ones because it happens in the alloys that normally exhibit perfect corrosion resistance such as stainless steel and it also occurs in areas that are not immediately visible. Therefore crevice corrosion may lead to sudden devastating failure of the metal in service. Crevices make a chemical environment which is different from that of freely exposed surfaces and therefore accelerate corrosion. This environment keeps moisture, traps pollutants, concentrates corrosion products and meanwhile excludes oxygen. Most cases of crevice corrosion occur in near-neutral solutions in which dissolved oxygen is the cathode reactant. The crevices in which crevice corrosion happens may be formed by:

1.The geometry of the structure, e.g. riveted plates, welded fabrications, threaded joints.

2.Contact of the metal with non-metallic solids, e.g. plastics, rubber, glass.

3.Deposits of sand, dirt or permeable corrosion products on the metal surface (a type of crevice corrosion that is referred to as deposit attack). Table1 shows types of mechanical crevices of stainless steels in which crevice corrosion may be found.

2.Theory of Crevice Corrosion

Corrosion requires energy. During corrosion the reacting components go from a higher to a lower energy state and release the energy needed for the reaction. In the dry corrosion the metal and the oxygen combine to produce the oxide on the surface because the reaction leads to a compound (the oxide) at a lower energy level. The oxide layer shields the metal from the oxygen and forms a barrier. The oxide will not react with the oxygen in the air or the metal [2]. The barrier makes it difficult for oxygen in the air to contact the metal and it eventually grows so thick that the movement of electrons and ions across it stop. Provided the oxide layer does not crack, or is not removed, the metal is protected from further corrosion.

3.Mechanism

The Fontana and Greene model describes crevice corrosion mechanism [3]. This model consists of four stages. Stage 1: Corrosion occurs as normal both inside and outside the crevice: Anodic reaction: $M \rightarrow M^{n+} + ne$,cathodic reaction: $O_2+2H_2O+4e=4OH^-$. The positively charged metallic ions are electrostatically counterbalanced by OH^-. Stage 2: at this stage, the cathodic reaction inside the crevice consumed most of the oxygen available. Stage 3: Cl^- and OH^- diffuse into the crevice to maintain a minimum potential energy. Metal chloride is formed. Hydrolysis of metal chloride lowers pH and $MCl_n + nH_2O = M(OH)_n + nHCl$. Stage 4: More M^{n+} ions attack more Cl^- leads to lower pH inside crevice, metal dissolution accelerates and more M^{n+} ions will be produced that will lower pH. Figure 1 shows mechanism of active and passive corrosion and its corresponding Anodic and Cathodic reactions in crevice corrosion.

4.Prevention Methods

The simplest method for preventing crevice corrosion is reducing crevices in the design of the structure When it is not possible to get rid of crevices, improving drainage and sealing of edges or keeping crevices as open as possible and therefore preventing entrance of moisture is the best protective action A protection method called “hot wax dip” is commonly used in automotive industry. In this method faying surfaces that will make crevices are usually painted before assembly. In aerospace industry sealing the faying surfaces with a polysulfide is known to be an effective method for preventing crevice corrosion. Cathodic protection could be an effective method against crevice corrosion, but anodic protection is often improper. Another common protection method is using alloys which are less vulnerable to crevice corrosion. Addition of inhibiting substances to bulk solution is also a protection method. Application of passivating compounds such as chromate and nitrate is well practiced to prevent crevice corrosion. Overlaying susceptible areas with an alloy which is more resistant to crevice corrosion is another protective measure.

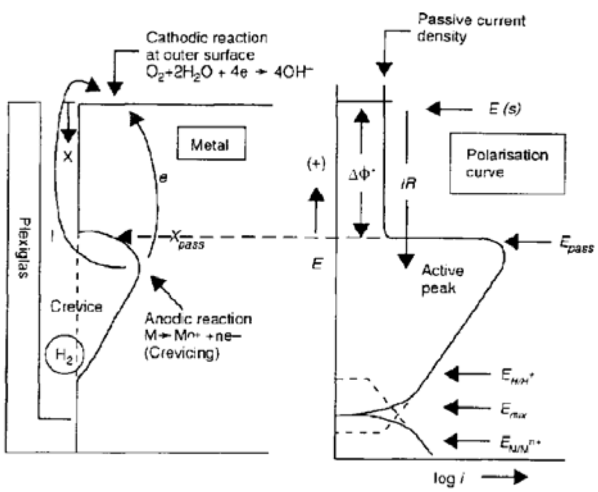

Fig1: Mechanism of active and passive corrosion and its corresponding Anodic and Cathodic reactions in crevice corrosion[3]

5.Conclusion

This paper review theory and mechanisms of crevice corrosion as well as its prevention methods. It is good to know that the mechanism for the crevice corrosion in quite similar to that of pitting and galvanic corrosion which one element is donating electrons and the other one accepting the electrons. Crevice corrosion rate can be affected by several factors such as the materials used, the gap between two metals as described in the text. So far several protection methods against crevice corrosion have been developed including cathodic protection and using inhibitors and coatings. Hot wax dip method and sealing crevices with polysulfide are two popular protection methods currently used in automotive and aerospace industries respectively. However researches about this devastating type of corrosion still continue.

Table1: Types of mechanical crevices of stainless steels in which crevice corrosion may be found [1].

Metal to Metal Crevices	
Crevice Corrosion Frequent	**Crevice Corrosion Not Frequent**
Bolt head to washer	Sleeve to pump shaft
Washer to base plate	Tube to tube sheet
Bolt thread to nut thread	
Wire rope	
Root pass of pipe welds with incomplete fusion	
Attachment pads to vessel wall	
Fillet welded rib to desk	
Metal to Non-Metal Crevices	
Crevice Corrosion Frequent	**Crevice Corrosion Not Frequent**
O-ring to polished surface	Valve stem packing
Gasket to flange face	Pump shaft packing
Teflon to metal	Dirt deposits
Polyethylene tape to metal	Robber gasket to metal plate in plate type heat exchangers
Barnacle to metal	Sand or mud deposits
Silicone to metal	
Molybdenum disulfide to metal	
Graphite lubricated gasket to metal	

[1] Sedrikes, J., “Corrosion of Stainless Steels”, Wiley- Interscience, 1996
[2] Hebert, K. and Alkire, R., “Dissolved Metal Species Mechanism for Initiation of Crevice Corrosion of Aluminum: II. Mathematical Model”, Journal of the Electrochemical Society, Vol. 130, No. 5, 1983
[3] Schweitzer, P., “Corrosion Engineering Handbook”, Dekker, 1996