PDHonline Course C206 (1 PDH)

Metal Corrosion - Causes and Types

Instructor: John Huang, Ph.D., PE and John Poullain, PE

2020

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

An Approved Continuing Education Provider

Chapter 2
Causes of Structural Deterioration

2-1. Corrosion

a. Effects of corrosion. Corrosion can seriously weaken a structure or impair its operation, so the effect of corrosion on the strength, stability, and serviceability of hydraulic steel structures must be evaluated. The major degrading effects of corrosion on structural members are a loss of cross section, buildup of corrosion products at connection details, and a notching effect that creates stress concentrations.

(1) A loss of cross section in a member causes a reduction in strength and stiffness that leads to increased stress levels and deformation without any change in the imposed loading. Flexure, shear, and buckling strength may all be affected. Depending on the location of corrosion, the percentage reduction in strength considering these different modes of failure is not generally not the same.

(2) A buildup of corrosion products can be particularly damaging at connection details. For example, corrosion buildup in a tainter gate trunnion or lift gate roller guides can lead to extremely high hoist loads. At connections between adjacent plates or angles, a buildup of rust can cause prying action. This is referred to as corrosion packout and results from expansion during the corrosion process.

(3) Localized pitting corrosion can form notches that may serve as fracture initiation sites. Notching significantly reduces the member fatigue life.

b. Common types of corrosion. Corrosion is degradation of a material due to reaction with its environment. All corrosion processes include electrochemical reactions. Galvanic corrosion, pitting corrosion, crevice corrosion, and general corrosion are purely electrochemical. Erosion corrosion and stress corrosion, however, result from the combined action of chemical plus mechanical factors. In general, hydraulic steel structures are susceptible to three types of corrosion: general atmospheric corrosion, localized corrosion, and mechanically assisted corrosion (Slater 1987). For any case, the type of corrosion and cause should be identified to assure that a meaningful evaluation is performed.

(1) General atmospheric corrosion is defined as corrosive attack that results in uniform thinning spread over a wide area. It is expected to occur in the ambient environment of hydraulic steel structures but is not likely to cause significant structural degradation.

(2) Localized corrosion is the type of corrosion most likely to affect hydraulic steel structures. Five types of localized corrosion are possible:

(a) Crevice corrosion occurs in narrow openings between two contact surfaces, such as between adjoining plates or angles in a connection. It can also occur between a steel component and a nonmetal one (under the seals, a paint layer, debris, sand or silt, or organisms caught on the gate members). It can lead to blistering and failure of the paint system, which further promotes corrosion.

(b) Pitting corrosion occurs on bare metal surfaces as well as under paint films. It is characterized by small cavities penetrating into the surface over a very localized area (at a point). If pitting occurs under paint, it can result in the formation of a blister and failure of the paint system.

(c) Galvanic corrosion can occur in gate structures where steels with different electrochemical potential (dissimilar metals) are in contact. The corrosion typically causes blistering or discoloration of the paint and

failure of the paint system adjacent to the contact area of the two steels and decreases as the distance from the metal junction increases.

(d) Stray current corrosion may occur when sources of direct current (i.e., welding generators) are attached to the gate structures, or unintended fields from cathodic protection systems are generated.

(e) Filiform corrosion occurs under thin paint films and has the appearance of fine filaments emanating from one or more sources in random directions.

(3) Three types of mechanically assisted corrosion are also possible in hydraulic steel structures.

(a) Erosion corrosion is caused by removal of surface material by action of numerous individual impacts of solid or liquid particles and usually has a direction associated with the metal removal. The precursor of erosion corrosion is directional removal of the paint film by the impacting particles.

(b) Cavitation corrosion is caused by cavitation associated with turbulent flow. It can remove surface films such as oxides or paint and expose bare metal, producing rounded microcraters.

(c) Fretting corrosion is a combination of wear and corrosion in which material is removed between contacting surfaces when very small amplitude motions occur between the surfaces. Red rust is formed and appears to come from between the contacting surfaces.

c. Factors influencing corrosion. The type and amount of corrosion that may occur on a hydraulic steel structure are dependent on many factors that include design details, material properties, maintenance and operation, environment, and coating system. In general, the primary factors are the local environment and the protective coating system.

(1) The pH and ion concentration of the river water and rain are significant environmental factors. Corrosion usually occurs at low pH (highly acidic conditions) or at high pH (highly alkaline conditions). At intermediate pH, a protective oxide or hydroxide often forms. Deposits of film-forming materials such as oil and grease and sand and silt can also contribute to corrosion by creating crevices and ion concentration cells.

(2) Corrosion of steel increases significantly when the relative humidity is greater than 40 percent. Corrosion is also aggravated by alternately wet and dry cycles with longer periods of wetness tending to increase the effect. Organisms in contact with steel also promote corrosion.

(3) Paint and other protective coatings are the primary preventive measures against corrosion on hydraulic steel structures. The effectiveness of a protective coating system is highly dependent on proper pretreatment of the steel surface and coating application. Sharp corners, edges, crevices, weld terminations, rivets, and bolts are often more susceptible to corrosion since they are more difficult to coat adequately. Any variation in the paint system can cause local coating failure, which may result in corrosion under the paint.

(4) The paint system and cathodic protection systems should be inspected to assure that protection is being provided against corrosion. If corrosion has occurred, ultrasonic equipment and gap gauges are available to measure loss of material.