Corrosion Basics

Understanding the basic principles and causes of corrosion

Corrosion Behavior of Cast Irons

Cast iron is a generic term that applies to high-carbon/iron alloys containing silicon. The common ones are designated as gray cast iron, white cast iron, malleable cast iron, and ductile or nodular cast iron.

Gray Cast Irons

Gray cast irons contain about 2 to 4% carbon and 1 to 3% silicon. These are the least expensive of the engineering metals. The dull or grayish fracture is due to the free graphite flakes in the microstructure. Gray cast irons can be readily cast into intricate shapes because of their excellent fluidity and relatively low melting points. They can also be alloyed for improved corrosion resistance and strength.

In most cases, gray cast iron is about twice as resistant to natural waters as steel because of the bonding of rust products by the graphite flakes. In modern engineering practice, most cast-iron piping receives an internal cementitious lining for improved water-side corrosion resistance. Soft or low pH waters may cause graphitic corrosion, also called graphitization. Graphitization of gray cast iron is the selective dissolution of iron from the iron/carbon matrix. The overlapping graphite flakes that remain provide little resistance to pressure surges or mechanical stresses; however, the graphitized pipe can often withstand normal operating pressures for many years. This characteristic is partly responsible for the remarkable service life of gray cast iron piping, sometimes well beyond 100 years.

White Cast Irons

White cast irons have practically all of their carbon in the form of iron carbide. These are extremely hard and brittle. Silicon content is low because this element promotes graphitization. Graphite formation is related to the rate of cooling from the melt, so chilling can produce a white iron from one that would normally be gray.

Malleable Cast Irons

Malleable cast irons are produced by high-temperature heat treatment of white irons of suitable composition. The graphite forms as rosettes or clusters instead of flakes, and the material shows good workability (hence the name malleable).

Ductile Cast Irons

These materials, also known as nodular cast irons, exhibit ductility in the as-cast form. The graphite is present as nodules or spheroids as a result of special ladle additions to the molten metal. The mechanical properties of ductile cast irons can be altered by heat treatment similar to that used for ordinary steels. The superior mechanical properties of ductile irons permit the manufacture of thinner-walled piping compared to gray cast iron piping with similar strength. This offers a significant saving in material costs and in handling.

High-Silicon Cast Irons

When the silicon content of gray cast iron is increased to more than 14%, it becomes extremely corrosion resistant in many environments. The notable exception is hydrofluoric acid (HF). In fact, these high-silicon irons are the most universally resistant of the commercial (non-precious) metals and alloys. Their inherent hardness makes them resistant to erosion-corrosion. A straight high-silicon iron contains about 14.5% silicon and 0.95% carbon. This composition must be closely controlled within narrow limits to provide the best combination of corrosion resistance and mechanical strength. The excellent corrosion resistance of high-silicon irons is due to the formation of an inert silicon dioxide (SiO₂) surface layer, which forms during exposure to the environment.

High-silicon cast irons are available only in cast form for drain lines, pumps, valves, and other process equipment. Because of their low consumption rates, high-silicon cast irons have also found extensive use as anodes for impressed current cathodic protection.

Other Alloy Cast Irons

In addition to silicon, molybdenum, nickel, chromium, and copper are added to cast iron for improved corrosion, abrasion, and heat resistance, and enhanced mechanical properties. In particular, copper additions impart better resistance to sulfuric acid (H₂SO₄) and atmospheric corrosion.