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A question of ferrite

Ferrite is an important aspect of stainless steels which can affect the corrosion resistance, mechanical strength and magnetic signature of the alloy. In the annealed condition, basic 300 series stainless steels such as 304/L and 316/L are essentially free of ferrite. However, cast products typically have some ferrite present. These alloys also form some ferrite when they are cold worked or work hardened. Stainless Steel World spoke to our resident foundry expert, Michael Porfilio, to learn more about ferrite in corrosion resistant alloys.

By Joanne Mcintyre

Mike, what are the advantages and disadvantages of having ferrite in stainless alloys?

The advantages of the presence of ferrite in stainless steel alloys are that it offers strength and general weldability. Controlled ferrite levels > 3% are occasionally added for requirements to reduce the potential of solidification cracking due to stresses introduced during welding.
Some disadvantages are that due to its magnetic signature (magnetic permeability), higher levels of ferrite will add electrical interference in some applications. Higher levels of ferrite also offer lower corrosion resistance for many applications. It should be stated that the presence or specified levels of ferrite in a stainless steel alloy should be considered during the design phase.

Which factors determine the amount of ferrite content?

The concentration of ferrite in a stainless steel, whether it be a cast or wrought product, is determined with the chemical makeup of the alloy. Specific levels of Chromium, Nickel, Molybdenum, Manganese as well as Nitrogen are strong ferrite promotors for the balance of the percentage of ferrite that will be present in our final material form.
Some commonly used industry standards for ferrite prediction are the Delong and Schaeffler diagrams. Heat treatment temperatures - including the hold time at temperature - also affect the ferrite percentages.

Stainless steel alloys in which strength or a magnetic signature is required while maintaining corrosion resistance benefit from elevated levels of ferrite. Cast and wrought duplex stainless steels benefit from the elevated ferrite concentrations for seawater and sour gas (H2S) found commonly in natural gas refinement with its high strength corrosion resistance while allowing weldability as required.

What are common percentage levels of ferrite in cast & wrought stainless products?

Cast stainless steels that are austenitic – ferritic in nature (1.4408 / CF8M) typically have ferrite levels of 5% to 20% whereas their wrought counterparts (316) may be from 0% to 5%.

"Ferrite in stainless steel alloys offers strength and general weldability"

How are ferrite levels measured & are they accurate?

Ferrite measurement can be accomplished in numerous ways. Eddy current testing with a Fischer Ferritscope will offer ferrite percentages or ferrite numbers. A cantilever device like a Severn Engineering device (ASTM A342, method 3) will measure ferrite concentrations up to roughly 30%. Mathematical calculations such as ASTM A800, which employs a Chromium vs Nickel diagram, offers a rough ferrite predictor up to roughly 30% for austenitic stainless steels. Ferrite levels higher than 30% currently do not have a reliable ferrite predictor.
The most accurate technique in many people's opinions is to perform a measurement of numerous fields of the materials microstructure with an etched sample either manually over many fields or employing image analysis. Both of these metallographic methods are viewed using a metallurgical microscope or metallograph employing ASTM E562 or ASTM E1245 respectively. All of the previously mentioned techniques are quite accurate and reliable.

What is the most effective method to minimize ferrite being present in finished cast stainless products?

Products are designed with specific alloys and material microstructure in mind for a given application. Through a chemical analysis control the ferrite using the Schaeffler diagram employing a mathematical computation of the Chromium vs Nickel ratio within ASTM A800. The low level of desired ferrite can be controlled in this manner reliably.

What are the effects on ferrite after welding cast 300 series material ferrite after post weld heat treatment?

The presence of ferrite in welds after post weld heat treatment in 300 series stainless steels is minimal. Most percentages of initial present ferrite diffuse in the base materials metal matrix solution. It can be expected that up to 15% of ferrite can or will be lost once the heat treatment goes above the materials critical temperature (1925°F).

Where is demand for ferrite enhanced stainless steels growing?

All three families of ferrite enhanced stainless steels (300 series, 400 series and duplex alloys) have growing demands. Each offer vastly different properties allowing engineering options.

- 300 series stainless steels (304 / GX5CrNi19-10, 316L / GX2CrNiMo19-11-2, 347 / GX5CrNiNb19-11) have been used heavily in the food industry. It is also a general purpose material selected for pumps and valves where medium duty corrosion resistance is required.
- For 400 series stainless steel alloys (409 / X2CrTi12, 430 / X6Cr17, 441 / X2CrTiNb18) their applications include exhaust systems and other underbody components of automobiles, electronics housings and industrial piping.
- Duplex alloys (Zeron 100 (4A) / EN14501, 2205 (4A) / X2CrNiMon22-5-3, 2507 (5A) / X2CrNiMoN 25-7-4) are used in marine, high strength pressure vessels, desalinization of seawater, oil and gas exploration to name a few. Shapes such as pipes, fittings, valve bodies are common to this alloy.

What kind of corrosion resistance can you expect from alloys that contain ferrite?

For alloys that contain ferrite, it is not an indicator of lower corrosion. All corrosion rates are determined by the environment. This is not to say that specific materials may not perform with low levels of attack with regards to pitting or crevice corrosion.
It is safe to say that 300 series stainless steel has resistance to general corrosion with acid and other mild oxidizing solutions and environments. 400 series have less general ferrite and corrosion rates compared to 300 series and duplex stainless steel alloys. General resistance to salt environments and other outdoor corrosion factors allow 400 series materials to fare well.
Duplex stainless steels can have ferrite levels that approach 50% to have tremendous corrosion properties to be able to handle sea water, sour gasses as well as many acidic solutions.

What is the future of cast stainless steels and where are they going?

The cast stainless steel industry continues to develop new cast grades from their wrought counterparts. New applications for alloys that include space and deep-sea exploration keep Metallurgists digging deep for new grades. The duplex stainless steel arena keeps evolving to continue to create the needed economic preforms that service the growing oil exploration and the production of desalinized water.

About Michael Porfilio

Michael has been in and servicing the foundry industry since 1985. His background is in the fields of Metallurgy, Quality Management, Sales and Marketing as well as Operations Management. He currently is a Certified Nuclear Quality Systems Auditor and NDT Level III. He is employed at Stainless Foundry & Engineering, Inc. as the Director of Quality.