TYPES OF STAINLESS STEEL

Stainless steels are steel alloys that contain more than 10.5% chromium with excellent corrosion resistance. Chromium reacts strongly with oxygen to form a very thin, invisible, stable oxide film on the surface of the stainless steel. This film is called the passive layer and forms rapidly in ordinary atmospheres. If it is damaged, the film usually heals spontaneously. It is this passive layer that gives stainless steel its corrosion resistance.

There are many different stainless steels, with different amounts of alloying elements added to give the best balance of corrosion resistance, mechanical properties and cost. Although straightforward for most applications, choosing the optimum grade of stainless steel can sometimes be complex, and Austral Wright Metals engineers and metallurgists will be pleased to provide assistance.

The stainless steels can be divided into five groups – austenitic, ferritic, duplex, martensitic and precipitation hardening. Each group has different dominant characteristics, and there are several grades within each group.

AUSTENITIC GRADES

Austenitic stainless steels are easy to work and weld, and have excellent ductility, toughness and corrosion resistance with good strength. They contain 17 to 25% chromium and 8 to 20% nickel, and may contain other elements to achieve the desired properties. The most common extra element is molybdenum, which greatly improves corrosion resistance. Austenitic stainless steels are usually used in the annealed condition, when they have a useful range of mechanical and physical properties. Strength can be increased by cold working, but not by heat treatment. Welding of this group is straightforward, although welding procedures are a little different to those used for carbon steel. Austenitic stainless steels are non-magnetic in the annealed condition, but will become slightly magnetic when cold worked.

304 Grade 304 is the most widely used stainless steel with good resistance to atmospheric corrosion and to many organic and inorganic chemicals. This grade has excellent workability, weldability and impact strength. It is sometimes known as 18/8 stainless steel, since it contains 18% chromium and 8% nickel. It is suitable for use in a variety of applications, in fact it is the most common stainless steel, and about 60% of all stainless steel used in the world is grade 304.

304L Grade 304L is a low carbon (<0.030%) variant of 304 with the same corrosion resistance, but with less susceptibility to sensitisation when welded at thicknesses of 4 mm of greater, or after heat treatment. Sensitisation can allow intergranular corrosion to occur. Grade 304L is used in parts of 4mm and thicker which will be welded but not post weld annealed. Parts made from this grade are generally limited to service at temperatures up to 425^{O}C. The physical properties and thermal treatments are similar to those of grade 304.

316 Grade 316 is known as the marine alloy. The corrosion resistance is improved by an addition of 2 to 3 % of molybdenum, as well as 18% chromium and 10% nickel. Grade 316 has better corrosion resistance than grade 304 in many chemicals as well as in marine atmospheres. Grade 316 also has applications in the chemical, textile and paper industries. It has similar strength to grade 304, and gives better performance in deep drawing.

316L Grade 316L is a low carbon (<0.030%) variant of 316 with the same corrosion resistance, but with less susceptibility to sensitisation when welded at thicknesses of 4 mm of greater, or after heat treatment. Sensitisation can allow intergranular corrosion to occur. Grade 316L is used in parts of 4mm and thicker which will be welded but not post weld annealed. Parts made from this type are generally limited to service at temperatures up to 425^{O}C. The physical properties and thermal treatments are similar to those of grade 316.

303 Grade 303 was developed to improve the machinability of grade 304. It is used where production involves extensive machining in automatic screw machines. It contains 18% chromium and 8% nickel. Sulphur or selenium is added to give excellent free machining and nonseizing properties. The addition of sulphur or selenium lowers corrosion resistance and grade 303 should not be used in water. Grade 303 is non hardenable and not recommended for welding. Austral Wright Metals standard stock of round bar in grades 304 and 316 has a controlled addition of calcium to improve machinability, and grade 303 is used less nowadays.

253 MA® Grade 253MA® is used at high temperatures. It has excellent resistance to oxidation and excellent strength at elevated temperatures. This grade has very good high temperature corrosion and erosion resistance in most environments. It also has good formability and weldability properties. Most suitable temperature range is 850-1100°C (standard grade 304 is qualified for pressure applications up to 800^{O}C). 253MA® contains about 22% chromium, 11% nickel and 0.09% carbon, with about 0.05% of the rare earth metal cerium added to improve the protective ability of the oxide.

FERRITIC GRADES

Ferritic stainless steels have similar strength, ductility and fabrication characteristics to carbon steels, with much better corrosion resistance. This group contains grades with 10.5% up to 22% chromium, which do not have the nickel addition made to austenitic grades. The amount of chromium controls the corrosion resistance, and there are some special grades where there is an extra addition of molybdenum. The limitation of the ferritic grades is that welds in some grades lack toughness, and they are rarely used in structural applications – hence they are mainly available as sheet and coil up to about 1.6 mm in thickness. Ferritic grades cannot be strengthened by heat treatment, and are not much strengthened by cold work, so they are usually used in the annealed condition. All the ferritic grades are magnetic in all conditions.

409 Grade 409 is a utility grade of stainless steel containing about 10.5% of chromium. It is mainly used in automotive exhaust systems, and other applications where appearance is not important. The surface soon stains, but the rate of metal loss is much lower than with carbon steel.

430 Grade 430 is the most common ferritic stainless steel, used for mild indoor environments, dishwasher liners and automotive trim. It contains 17% of chromium, and hence the corrosion resistance is a little less than that of grade 304. In architectural applications it is usually only used indoors.

DUPLEX and SUPER DUPLEX GRADES

This group of stainless steels typically consists of equal parts of austenite and ferrite. This group has 18 to 29% chromium, 3 to 8% nickel and various other elements, particularly molybdenum and nitrogen. The duplexes offer advantages over austenitic grades. They are strong, with twice or more the yield strength of the common austenitic grades, and are highly resistant to chloride stress corrosion cracking. The higher alloyed grades have excellent resistance to pitting and crevice corrosion in many environments. The duplex grades are not heat treatable and have a low response to cold work, so are used in the annealed condition. They are easy to weld and fabricate, although not as easy as the austenitic grades. The duplex grades are magnetic in all conditions.

2205 Grade 2205 is a duplex stainless steel containing 22% chromium, 5% nickel and 3% molybdenum. The high alloy content gives it superior resistance to pitting and crevice corrosion, and the duplex structure gives excellent resistance to stress corrosion cracking. The grade has high strength. The steel is well-suited for high chloride environments. Applications include heat exchangers, chemical tankers, chemical reactor vessels, flue gas filters, acetic acid distillation, oil and gas industry equipment.

S32750 Grade S32750 is a super duplex stainless steel containing 25% chromium, 7% nickel and 4% molybdenum. It has the highest resistance to pitting and crevice corrosion of the duplex grades, with high resistance to stress corrosion cracking and very high strength. Applications include oil and gas industries, offshore, petrochemical plants, desalination plants and mechanical and structural components demanding high strength combined with high corrosion resistance.

MARTENSITIC GRADES

This group contains 12% to 16% chromium and 0.08% to 2.00% carbon. The high carbon content makes the martensitic grades respond well to heat treatment to give high mechanical strength and hardness. However, the carbon is detrimental when welding and these grades are difficult to weld. The ductility of these grades is limited and they are not cold worked. In the heat treated condition, this group of stainless steels show a useful combination of corrosion resistance and mechanical properties that qualify them for a wide range of application. The martensitic grades are magnetic in all conditions.

410 Grade 410 is the general purpose corrosion and heat resisting stainless steel. It contains 12.5% chromium and can be used in mildly corrosive environments. It is the most inexpensive corrosion resistant steel for general purposes, but is not suitable under severe corrosion conditions. Frequently used for stainless steel cutlery, furnace parts, bolts, bushings, and uses requiring high strength and wear resistance such as chutes, screens and mineral processing equipment.

420C Grade 420C also has 12.5% chromium, with a higher carbon content than 410 (0.25%) to increase hardness to a maximum of approximately 500 Brinell (50 HRC). It has optimum corrosion resisting qualities when hardened and tempered. Used for springs, shafts, valves.

431 Grade 431 is a 16% chromium martensitic stainless steel with a small (2%) addition of nickel. It can be heat treated to the highest mechanical properties, and is mainly used for fasteners and shafts. Its corrosion resistance is superior to that of grades 410 and 420C.

PRECIPITATION HARDENING GRADES

This group contains 12% to 16% chromium and 3 to 9% nickel, with small additions of precipitate forming elements such as aluminium, copper, niobium and titanium. They are designed to be heat treatable to very high strength, with better ductility than the martensitic grades. They are usually machined and fabricated in the soft, solution annealed condition, then tempered up to the required combination of strength, ductility and toughness. Because the chromium content is limited, most of the precipitation hardening grades have similar corrosion resistance to 304. Most applications are in the aerospace and other high-technology industries, and in boat shafting.

TECHNICAL INFORMATION

POPULAR MYTHS ABOUT STAINLESS STEEL

Stainless Steel

"All Stainless Steel is the same"

Actually, stainless steels are a family of alloys, which can have a great range of properties, depending on what they are to be used for. Stainless steels are often used for their appearance or corrosion resistance, but they are also used for heat resistance, strength or toughness, and for their magnetic properties. The best grade of stainless is chosen to suit the application. The grades fit into branches of the family, called austenitic, ferritic, duplex, martensitic or precipitation hardening, depending on their crystal structure.

"Stainless steel doesn't rust"

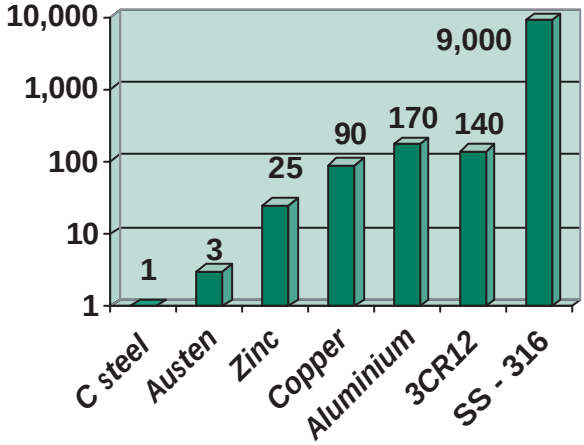
Strictly speaking, stainless doesn't rust. Some industry publications even say it can't. But like all materials, there are some environments which are just too corrosive and it will be attacked – after all, even gold will dissolve in aqua regia, a potent mixture of nitric and hydrochloric acids. And sometimes, when stainless is attacked, the corrosion product looks just like the rust you get on carbon steel.

Stainless steel resists corrosion better than most other metals because of a very thin, colourless passive layer that forms spontaneously on the surface. When the passive layer is breached, it usually forms again spontaneously. In aggressive environments, such as very close to the beach, where there is a lot of salt in the air, the passive layer may not be able to form, and some corrosion may take place. Although the stainless steel may look 'rusty', it will corrode so much more slowly than most other metals that it will still be serviceable long after any other common engineering metal.

The graph at right shows the results of a 20 year corrosion study from a very corrosive environment near a beach in South Africa: an even more severe environment than the most aggressive in Australia, such as Newcastle Beach.

Stainless steel grade 316 gave about 9,000 times the life of carbon steel. Grade 304 would be similar, although not quite as much. And this in an environment where each millimetre of carbon steel would corrode away completely in about four years.

Life, compared to carbon steel



TECHNICAL INFORMATION

POPULAR MYTHS ABOUT STAINLESS STEEL

Of course, the passive layer that stainless steel relies on for protection has to be allowed to form. Blue and black visible oxides formed during heat treating, welding and heavy grinding interfere with the formation of the passive layer. They must be removed to get the full corrosion resistance of each grade of stainless steel.

Often, when stainless steel appears to be rusting, it has actually been contaminated with carbon steel – which rusts, of course! And the stainless steel gets the blame. The secret is to fabricate the stainless steel in a dedicated area and make sure there is no contamination with carbon steel from tools, equipment and storage fixtures. And if there is carbon steel contamination, treat the stainless with a passivating acid to remove it.

"Stainless steel is not magnetic"

Some types of stainless steel, including the most common ones, the austenitics, aren't magnetic. But most types – the ferritics, martensitics, duplexes and most of the precipitation hardening grades – are magnetic. The corrosion resistance is not affected in any way by whether the grade of stainless is magnetic or not – corrosion resistance depends on how much of the key alloying elements you have, especially chromium and molybdenum.

Even the austenitics can become somewhat magnetic when they are deformed. Try putting a magnet in the corner of a stainless steel sink – some magnetism can usually be detected. The amazing ability of austenitic stainless steel to deform without breaking is used to deep draw sinks in one piece – without heating!

"Stainless steel is expensive"

Stainless steels do cost more than carbon steels, in dollars per tonne. With the extra alloys, they are bound to. But the extra performance of stainless steels more than pays for the difference, and stainless often works out as the cheapest way to do the job. Carbon steel usually needs to be painted for corrosion protection, and even if the first installed cost is lowest, the advantage disappears on the day it has to be repainted. The cost of stainless in dollars per day for the life of the job will be much lower.

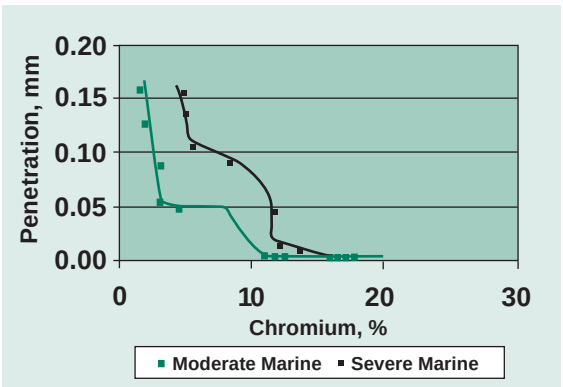
"18/10 Stainless steel is better than 18/8 stainless steel"

Actually they are both the same. The common austenitic grades contain about 18 to 20% of chromium, and 8 to 10% of nickel. Europeans often refer to them as 18/10 stainless, while the English speaking world – Australia, USA, UK – call them 18/8 stainless. There are minor differences between the standard stainless steel compositions in different parts of the world, but the performance of the grades are effectively the same wherever in the world they are made.

"All stainless steels have the same corrosion resistance"

The corrosion resistance of stainless steels mostly depends on their content of the alloying elements chromium and molybdenum, plus a few other factors, depending on the specific application. The surface finish and fabrication practice can have a major effect.

Eight years exposure to atmosphere



Resistance to pitting & crevice corrosion