North American Stainless

Long Products Stainless Steel Grade Sheet

2205
UNS S2205
EN 1.4462

2304
UNS S2304
EN 1.4362

INTRODUCTION

Types 2205 and 2304 are duplex stainless steel grades with a microstructure, when heat treated properly, of nearly equal proportions of austenite and ferrite.

This microstructure ensures that these are much more resistant to stress corrosion cracking than 304 or 316. The higher chromium, molybdenum and nitrogen contents give 2205 significantly improved pitting and crevice corrosion resistance in the presence of chlorides. 2304, also called lean duplex, exhibits excellent pitting and crevice corrosion resistance. These grades exhibit better corrosion resistance than 316 SS in high pH and in presence of the chlorides, making these very suitable for use as rebar for bridge constructions in colder areas to resist road salt. These grades have much higher yield strength than 316 SS.

These grades have a very low ductile-to-brittle transition temperature of about –50°C.
2205 steel can become embrittled when exposed to temperatures between 575°F and 1025°F (475°C embrittlement) and 1025°F and 1825°F (sigma (s) and chi (c) phase formation). Thus, application temperatures are generally limited from –60°F to 575°F.
2304 however, does not have the embrittlement due to sigma and chi phases.

2205 is a highly suitable material for service in environments containing chlorides and hydrogen sulfide, such as marine environments and the oil and gas extraction and processing industries. Typical applications also include the chemical industry, the pulp and paper industry and the mining industry.

PRODUCTS AVAILABLE

Reinforcement Bars, Wire Rod and Round Bars. *See product sheet for dimensions, tolerances, finishes available and other details.*

Standard Chemical Composition

Elements			C	MN	P	S	SI	CR	NI	CU	MO	N
UNS S2205	2205	Min						22.00	4.50		3.00	0.140
		Max	0.03	2.00	0.030	0.020	1.00	23.00	6.50		3.50	0.20
UNS S2304	2304	Min						21.50	3.00	0.05	0.05	0.05
		Max	0.03	2.50	0.040	0.030	1.00	24.50	5.50	0.60	0.60	0.20

Nominal Mechanical Properties (annealed condition)

Tensile Strength ksi[MPa]	**Yield Strength** ksi[MPa]	**% Elongation** 4d	**% Reduction in Area**
110[760]	65[450]	30	40

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed 2205. These values are given as a guideline only, and should not be used for design purposes.

SHORT TIME ELEVATED TEMPERATURE TENSILE PROPERTIES

Temperature (°C)	100	200	300	400
Tensile Strength (MPa)	630	580	560	550
0.2% Proof Stress (MPa)	365	315	285	275
Young's Modulus	190	180	170	160

MAXIMUM RECOMMENDED SERVICE TEMPERATURE
(In oxidising conditions)

Operating Conditions	Temperature (°C)
Continuous	980
Intermittent	980

PHYSICAL PROPERTIES

The values given below are at 20°C, unless otherwise specified.

Density	7 860kg/m³
Modulus of Elasticity in Tension	200GPa
Specific Heat Capacity	470J/kgK
Thermal Conductivity: @ 100°C	17.0W/mK
@ 500°C	21.0W/mK
Electrical Resistivity	850η m
Mean Co-efficient of Thermal Expansion: 0 – 100°C	13.0µm/mK
0 – 300°C	14.0µm/mK
0 – 400°C	14.5µm/mK
Melting Range	1 410–1 460°C
Relative Permeability	Ferromagnetic

ANNEALING

Annealing is achieved by heating to between 1900°F and 2000°F for 60 minutes per inch thickness followed by quenching in water. Controlled atmospheres are recommended in order to avoid excessive oxidation.

HOT WORKING

These grades can be readily forged, upset and hot headed. Uniform heating of the steel in the range of 2100°F to 2300°F is required. Initial hot working should be done without large reductions or change of shape (especially if upsetting or staving up). Once the material starts to flow, progressively more deformation can be accomplished.

The finishing temperature should not be below 1700°F. If the temperature after forging is still above 1825°F, water quenching is required. Otherwise, all hot-working operations should be followed by annealing, pickling and passivation to restore the mechanical properties and corrosion resistance.

COLD WORKING

These grades have good formability, but due to the higher proof strength, more power is required for most cold-forming operations compared to austenitic stainless steels.

ATMOSPHERIC CORROSION

The atmospheric corrosion resistance of duplex stainless steels is unequalled by virtually all other uncoated engineering materials.

INTERGRANULAR CORROSION

Sensitization (and sigma precipitation in 2205) may occur in the heat-affected zones of welds. If a sensitized material is then subjected to a corrosive environment, intergranular attack may be experienced.

STRESS CORROSION CRACKING

Stress corrosion cracking (SCC) can occur in austenitic stainless steels when they are stressed in tension in chloride environments at temperatures in excess of about 140°F. If there is a likelihood of stress corrosion cracking occurring, a beneficial increase in life can be easily obtained by a reduction in operating stress and/or temperature.

Duplex grades are far less prone to this type of corrosion than the conventional austenitic stainless steels.

MACHINING

The high strength that makes these grades useful in many applications also reduces their machinability. Cutting speeds are approximately 20% slower than those for 304 SS. Machine tools should be ground to close tolerances to avoid the risk of excessive work hardening in the outer layer of the stock.

WELDING

These grades have good weldability in most applications, provided the recommended procedures are adopted. If 2205 is autogenously welded, it must be solution annealed to restore the desirable duplex microstructure and hence the toughness. Only welding consumables specified for these grades should be used to ensure that the deposited metal has correct balanced duplex microstructure. Nitrogen, added to the shielding gas, will also assist in ensuring adequate austenite in the microstructure.

The lower coefficient of thermal expansion, compared to austenitic stainless steels, reduces distortion and the associated stresses.

FATIGUE CONSIDERATIONS

The high strength of these grades also results in a high fatigue strength compared to 316L.

CORROSION RESISTANCE

These grades have excellent general corrosion resistance and, generally speaking, this is better than 316 or 317 in most environments.

PITTING CORROSION

Pitting resistance is important, mainly in applications involving contact with chloride solutions, particularly in the presence of oxidizing media. These conditions may be conducive to localized penetration of the passive surface film on the steel and a single deep pit may well be more damaging than a much greater number of relatively shallow pits.

Pitting (and crevice corrosion) resistance of stainless steels is primarily determined by the chromium, molybdenum and nitrogen contents.

OXIDATION

These grades have good oxidation resistance, both in intermittent and continuous service, up to 1800°F. However, continuous use of 2205 between 575°F and 1750°F may cause embrittlement, and lower the corrosion resistance. At the lower temperature range, the embrittlement is due to the precipitation of a' (475°C embrittlement) and nitrides or carbides. In the high temperature range, chi and sigma phases precipitate. However, during normal production and fabrication procedures, the times at these critical temperatures are such that the risk of embrittlement and/or a decrease in corrosion resistance are small. In addition, this effect does not necessarily affect the behavior of the material at the operating temperature and is less pronounced in thinner gauges.
A full anneal and rapid cooling treatment will restore corrosion resistance and toughness.

EROSION CORROSION

Conventional austenitic stainless steels are attacked by erosion corrosion if exposed to flowing media containing highly abrasive solid particles, e.g. sand, or to media with very high flow velocities.
Due to the combination of high initial hardness, work hardenability and corrosion resistance, these grades display very good resistance under such erosion corrosion conditions.

CORROSION FATIGUE

These grades possess higher strength and better corrosion resistance than ordinary austenitic stainless steels; therefore, these also possess better fatigue strength under corrosive conditions compared to austenitic stainless steels.

DISCLAIMER

indirect, particularly consequential damages, including but not limited to damages for loss of profits.