Atlas Tech Note No. 13
3CR12 & 3CR12Ti–The 12% Chromium Ferritic Stainless Steels

Background

The first 12% Chromium utility ferritic stainless steel was developed more than thirty years ago by Southern Cross Steel in the Republic of South Africa. This company produced their "3CR12" as a "utility steel" because of a perceived market in the gold mines of South Africa. Subsequently other applications were found, and the grade is still produced by the same company under their current name of Columbus Stainless. The 3CR12 grade has been effectively marketed and well accepted, particularly in mineral processing, mineral transport, sugar processing and other resource applications.

Over the years there have been a number of other steel producers that have begun manufacturing 12% Chromium utility steels (often with "…CR12" designations), and there have also been changes to the original grade's composition. Today there are two broad grades, one stabilised and the other not, and also a closely related alternative for a special application.

Applications

The CR12 steels are stainless steels. With a chromium content of 10.5% minimum they are at the very lowest end of the stainless steel family in terms of corrosion resistance. They have good resistance to destructive corrosion in mild atmospheric and industrial environments but are likely to undergo light surface corrosion under almost any exposure. They are sometimes painted to prevent unsightly rusting. Strength and hardness are a little higher than the usual austenitic grades, and being ferritic they resist galling better. They often perform well in mildly corrosive applications with some abrasion or wear resisting requirement. The applications are almost exclusively industrial, not aesthetic.

Good For

☺ - Economical stainless steel due to low alloy content. Low nickel and no molybdenum.

☺ - Good resistance to mildly corrosive environments – especially useful in wet abrasion or wear applications.

☺ - Readily fabricated by bending, plasma cutting and conventional electric welding processes.

☺ - Low thermal expansion coefficient results in reduced distortion in welding and in high temperature applications.

☺ - Good scaling resistance to over 600oC, and useful strength at these elevated temperatures – can be a good choice for furnace bodies or flues.

☺ - Immune to chloride stress corrosion cracking.

Not Good For

☹ - Low resistance to corrosive media – PREN about 11. Unsuitable for marine exposure. Not usually acceptable for aesthetic or decorative applications.

☹ - Cannot be strengthened by heat treatment or cold work.

☹ - Generally, not available with a bright decorative finish.

☹ - Offer no advantages in dry abrasion or wear applications ... use Q&T carbon steel plate, austenitic manganese steel, weld overlays, rubber lining etc.

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Weldable Ferritic Stainless Steels

The Good News

The CR12 steels are ferritic stainless steels. Some clever metallurgy makes them all resistant to the main problem of all other ferritic stainless steels – they resist the excessive grain growth that results in reduced toughness in the weld heat affected zone (HAZ) of all other ferritic grades. The CR12 family therefore are able to be welded in heavy sections – well over the limit of about 3mm that applies to other ferritic grades.

Some Cautions

Like all other ferritic stainless steels, they are potentially susceptible to sensitisation – precipitation of carbides in the HAZ when heated to welding temperatures. If it occurs this condition results in susceptibility to intergranular corrosion.

For austenitic grades such as 304 or 316 it is possible to eliminate this problem by reducing the carbon content to below about 0.03%, hence the existence of “L” grades such as 304L and 316L. Ferritic grades are much more susceptible to sensitisation, and reducing the carbon content well below 0.03% reduces but does not entirely solve the problem.

For many applications however, and particularly in heavy sections which will be welded in multiple passes, the low carbon but un-stabilised grade 3CR12 has been proven entirely adequate.

3CR12Ti stabilised by Titanium and/or Niobium achieves higher resistance to sensitisation. The titanium (and/or niobium) content required to achieve stabilisation is usually specified as a multiplier of the amount of carbon plus nitrogen present, usually 4 times. In practice this means a level of about 0.1% to 0.2% Ti. Niobium is less effective than Ti and is used in conjunction with some Ti.

For extremely demanding applications, particularly involving high stress levels and fatigue conditions in significantly corrosive environments there are further refinements to the composition that ensure absolute immunity from sensitisation – this is the domain of the proprietary 410RW “Rail Spec” version of 3CR12Ti.

Welding Recommendations

All versions of the grade can be readily welded by all the usual electric processes. Welding to carbon steel or to other grades of stainless steels is also routinely carried out. The recommended electrode grade is 309L. Heat input should be controlled to within the range 0.5 – 1.5kJ/mm per pass; both minimum and maximum limits are important. All weld discolouration should be removed by pickling if full corrosion resistance is to be achieved but some users choose to not pickle as weld scale will be abraded off in early service.

Three Versions of CR12

3CR12

The standard, 1.4003 grade most commonly stocked. This is un-stabilised and consequently has the best surface finish.

3CR12Ti

A proprietary titanium stabilised grade, with improved resistance to sensitisation in weld heat affected zones.

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3CR12Ti/410RW "Rail Spec" Version

"410RW" is the grade name used by the manufacturer of this steel, JFE Steel Corporation of Japan. It is also stabilised with titanium, but additionally has some other tweaks to the composition as demanded by builders of rail wagons for coal and iron ore. It is a higher cost, and specifically indented for very specific customers. It is not normally held as stock.

Columbus Grade Names

Columbus Stainless originally made 3CR12 as a stabilised grade, i.e. with Ti. In about 1990 they changed 3CR12 (still the same name) to the non-stabilised 1.4003 composition. Then in about 2002 they changed 3CR12 to being stabilised again (3CR12Ti). Columbus now also market another grade they call "3CR12L" which is the non-stabilised 1.4003 (3CR12).

Because Columbus were the originators and very effective marketers of the utility stainless steels the grades are very commonly generically referred to by end users as 3CR12 and 3CR12Ti, irrespective of the steel's source.

Specifications

The original grade began life as a purely proprietary grade, without any national specification endorsement. This is common for innovative products. By the mid-1990s the un-stabilised grade 3CR12 had been endorsed by both European (Euronorm) standards and ASTM standards in America. This grade is referred to by its Euronorm number of 1.4003 or the ASTM UNS numbers S41003 or S40977. In some standard specifications (such as AS/NZS 1554.6 covering welding of stainless steels) the grade is generically referred to as "4003".

Neither the regular stabilised grade 3CR12Ti nor the 410RW rail spec version are standardised in any national specifications.

Chemical Compositions

Grade		C	Mn	Si	P	S	Cr	Ni	N	Ti & Nb
1.4003 S40977	min.	-	-	-	-	-	10.50	0.030	-	
	max.	0.030	1.50	1.00	0.040	0.015	12.50	1.00	0.030	
S41003	min.	-	-	-	-	-	10.5	-	-	
	max.	0.030	1.50	1.00	0.040	0.030	12.5	1.50	0.030	
3CR12Ti	min.	-	-	-	-	-	10.50	-		4(C+N)
	max.	0.030	2.00	1.00	0.040	0.030	12.50	1.50		0.6
3CR12TI 410RW	min.	-	1.0	-	-	-	10.9	-		4(C+N)
	max.	0.025	2.0	1.0	0.040	0.030	12.5	1.0	0.02	0.03

Composition limits for 1.4003 as in EN 10088-2, for S40977 and S41003 as in ASTM A240.
3CR12Ti and 3CR12Ti/410RW limits are proprietary.
3CR12Ti/410RW composition is also verified by laboratory sensitization testing.

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Mechanical Properties

Grade	Tensile Strength (MPa)	Yield Strength 0.2% Proof Stress (MPa) min.	Elongation (% in 50mm) min.	Hardness	
				Rockwell (HR) max.	Brinell (HB) max.
1.4003 (1)	450 - 650	280 (long), 320 (trans)	20	-	-
S40977	450 min.	280	18	HR B88	180
S41003	455 min.	275	18	HR C20	223
(1) Properties specified for cold rolled coil and hot rolled coil plate. Quarto plate has different values. Mechanical property limits for 1.4003 as in EN 10088-2, for S40977 & S41003 as in ASTM A240.					

Grade	Thickness (mm)	Tensile Strength (MPa)	Yield Strength 0.2% Proof Stress (MPa) min.	Elongation (% in 50mm) min.	Hardness Brinell (HB) max.
3CR12Ti	<3	460 min	280 min	18	220
	3 – 4.5	460 min	300 min	18	220
	>4.5	460 min	300 min	20	220
These properties are specified for the proprietary grade 3CR12Ti. There are no national or international specifications covering this grade.					

Grade	Tensile Strength (MPa)	Yield Strength 0.2% Proof Stress (MPa) min.	Elongation (% in 50mm) min.	Hardness	
				Rockwell (HR) max.	Brinell (HB) max.
3CR12Ti 410RW	460 min	340 min	20 min	HR B96	
Special mechanical properties are available for this Rail Specification, subject to specific project enquiry.					

Physical Properties

Grade	Density (kg/m³)	Elastic Modules (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity	Specific Heat	Electrical Resistivity (nΩ.m)
			20-100°C (µm/m/°C)	20-300°C (µm/m/°C)	20-500°C (µm/m/°C)	at 100°C (W/m.K)	0-100°C (J/kg.K)	
1.4003	7700	220	10.4	11.2	11.9	25	430	600
Source: EN 10088-1. All versions of CR12 have similar physical properties.								

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References & Further Information

- Atlas Grade Data Sheets for 3CR12 and 3CR12Ti, available for download from the Atlas Steels website.
- Columbus Stainless website www.columbusstainless.co.za
- JFE Steel Corporation website www.jfe-steel.co.jp
- ASTM A240M “Standard specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels and for General Applications”
- EN 10088-1:2005 “Stainless steels – Part 1: List of stainless steels”
- EN 10088-2:2005 “Stainless steels – Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes”