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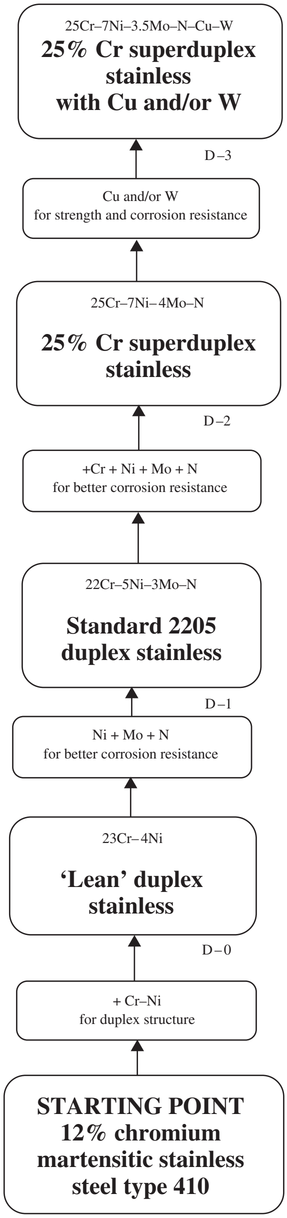
Group D

Duplex and superduplex stainless steels



Group D: Duplex and superduplex stainless steels.

Introduction

The starting point for Group D is the plain 12% chromium martensitic stainless steel. The simple addition of chromium and a modest amount of nickel changes the microstructure from martensite to a duplex ferritic-austenitic microstructure and at the same time improves corrosion resistance. The remaining alloys in the group maintain a similar microstructural duplex balance but with progressively increasing alloy content, and corresponding improvements in corrosion resistance. The superduplex types with a PREn > 40 and additional alloying in the form of copper and/or tungsten probably represent the limit of alloy development for this group. Any further alloying would make the material too sensitive to heating and would result in the very rapid development of undesirable intermetallic phases in the weld HAZ and weld metals, resulting in loss of toughness and corrosion resistance. This would effectively limit fabrication using currently available welding processes, and hence the alloys' potential usefulness.

D–0

Lean alloy duplex stainless steels

Also known generically as 2304 duplex

Description

These steels are the so-called ‘lean duplex’ grades with low carbon, 18–23% chromium, 3–7% nickel, up to 3% molybdenum, up to 1.5% copper and in some cases controlled nitrogen additions. The compositions are all balanced to give a duplex microstructure with about 50% austenite and 50% ferrite. Typical compositions are:

		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	N
Weight %	**3RE60**	0.03	1.5	1.5	<0.01	<0.02	18	4.5	2.5	-	-
	2304	0.03	2.5	0.5	<0.01	<0.02	23	4.5	-	0.3	0.15
	UR50	0.04	2	0.5	<0.01	<0.02	22	7	2.5	1.5	0.1

The steels are normally supplied as proprietary alloys in accordance with one of the following UNS specification numbers:

UNS/ASTM	EN	Proprietary alloys
S31500	1.4362	Sandvik 3RE60
S32304		Sandvik 2304
S32404		Industeel UR50

These steels are always solution treated followed by quenching to give an approximately 50% austenite, 50% ferrite duplex structure without any deleterious phases such as sigma. They have typical pitting resistance equivalents (PREn) ranging from 26 up to about 32.

Background

Lean alloy duplex stainless steels were the predecessors to the 2205 standard duplex alloys. They range in composition from 3RE60, which is essentially a 316L alloy with reduced nickel, to give a duplex microstructure, up to UR50 which has additions of copper and nitrogen and is quite close in alloy content and PREn value to the standard 2205 types (D–1). These steels were designed to give corrosion resistance comparable to standard austenitic alloys such as 316L and 317L (E–3 and F–0) but with improved strength and at reduced cost because of the lower nickel content.

Performance

Duplex stainless steels offer the following:

- High strength – about twice that of standard austenitic stainless steel grades such as 316L.
- Good general corrosion resistance, comparable to 316L and 317L grades in a wide range of environments.
- High resistance to chloride-induced SCC because of their high ferrite content.
- Moderate resistance to pitting attack in chloride environments, e.g. seawater, dependent upon molybdenum content and PREn values.

Applications

These alloys have widespread application in the chemical, offshore oil and gas and pulp and paper industries, but because of their relatively modest corrosion resistance they now have a small market share when compared with the standard 22% chromium, 2205 types (D–1).

Alloy 3RE60 is used for heat exchanger tubing, in combination with carbon steel shells, where there is a need for some stress corrosion resistance.

Alloy 2304 is used by the offshore oil and gas industries particularly for piping systems, mechanical tensioning systems, and umbilical sheathing where its mechanical properties, particularly strength, are more important than corrosion resistance.

Alloy UR50, with a higher PREn value and copper additions, was developed for the chemical industry and for digester preheaters, evaporators, and bleaching and pulp storage tanks for the paper industry. As operating conditions have become more aggressive, superduplex and superaustenitic alloys have largely superseded its use.

D–1

22% chromium, standard duplex stainless steels

Also known generically as 2205 duplex

Description

These steels are the standard duplex grade with low carbon, 22% chromium, 5% nickel, 3% molybdenum and controlled nitrogen additions. They have a reduced nickel content compared with standard austenitic stainless steels to give a duplex microstructure, and molybdenum and nitrogen for corrosion resistance. A typical composition is:

	C	Mn	Si	S	P	Cr	Ni	Mo	N
Weight %	0.03	1	0.3	<0.01	<0.02	22	5	3	0.17

The steels are normally supplied in accordance within one of the following specifications:

ASTM	UNS	EN	Proprietary alloys include
A182 Gr F51 (wrought)	S31803	1.4462	AvestaPolarit 2205
A890 Gr 4A (cast)	S32205		Sandvik SAF2205
	J92205		Sumitomo SM22Cr
	(cast)		Industeel UR45N/UR45N+

These steels are always solution treated followed by quenching to give an approximately 50% austenite, 50% ferrite duplex microstructure without any deleterious phases such as sigma. They have typical PREn of 35 or more.

Background

Duplex stainless steels were first developed in the 1930s for their combination of strength and corrosion resistance. However, it was only during the 1950s and 1960s that they started to be more widely used as castings, and only during the 1970s that they become widely available as wrought material, particularly pipe, tube, plate and forgings. During this latter period the importance of nitrogen as an austenite stabiliser and its role in improving weld HAZ microstructure and properties became more fully appreciated. As production technology for their manufacture has evolved, they have rapidly become a cost-effective alternative to many other grades of stainless steel. By the year 2000 they had become the third most widely used grade of stainless steel in Europe, after types 316L and 304L (E–3 and E–1).

Performance

These steels offer the following:

- High strength – about twice that of standard austenitic stainless steel grades such as 316L.
- Good general corrosion resistance in a wide range of environments.
- High resistance to chloride-induced SCC because of their high ferrite content.
- High resistance to pitting attack in chloride environments, e.g. seawater.

Applications

The offshore oil and gas industry has been a major driver behind the development and use of duplex stainless steels. They have been widely used for process pipework, flow lines, risers, manifolds and firewater systems.

Their benefits are now more widely appreciated, and they are used in land-based chemical and petrochemical plants. Large quantities have been used in the construction of chemical-carrying seagoing vessels and river barges.

In recent years, architectural and general engineering uses have been developed, including the construction of bridges where the combination of high strength and lack of need for maintenance can be exploited economically.

D–2

25% chromium, superduplex stainless steels

Also known generically as 2507 superduplex

Description

These steels are the superduplex grade with low carbon, 25% chromium, 7% nickel, 4% molybdenum and further controlled nitrogen additions when compared with the 2205 types. They still give a duplex microstructure and the higher molybdenum and nitrogen contribute to an improvement in corrosion resistance. A typical composition is:

	C	Mn	Si	S	P	Cr	Ni	Mo	N
Weight %	0.03	1	0.3	<0.01	<0.02	25	7	4	0.25

The steels are normally supplied in accordance within one of the following specifications:

ASTM	UNS	EN	Proprietary alloys include	
A182 Gr F53 (wrought)	S32750	1.4410	Industeel	UR47N
	J93404 (cast)		Sandvik	SAF2507

These steels are always solution treated followed by quenching to give an approximately 50% austenite, 50% ferrite duplex microstructure without any deleterious phases such as sigma. They have a typical PREn of >40.

Background

Some duplex stainless steels with PREn values between 35 and 40 and improved corrosion properties have existed as casting alloys since the 1970s. However, developments in steel manufacturing and processing technology, coupled with demands from the offshore oil and gas industry for further improvements in corrosion resistance for more aggressive environments, led to the development of the wrought superduplex stainless steels. Superduplex stainless steels are usually defined as alloys with a PREn value of at least 40. They have become readily available in the last 20 years but command a much smaller market share than the standard 2205 types. Apart from their higher cost they are, because of their higher chromium and molybdenum contents, more sensitive to sigma formation during welding and heat treatment. Sigma and other deleterious intermetallic phases can form rapidly in the critical temperature range of ~400–800 °C and have an adverse effect on corrosion resistance, ductility and toughness. For these reasons, superduplex alloys tend to be chosen only when the increased performance can justify the additional costs and complexities of fabrication.

Performance

These steels offer the following:

- High strength – more than twice that of standard austenitic grades such as 316L (E–3), and about 10% higher than standard 2205 grades.
- Very good general corrosion resistance in a wide range of environments.
- High resistance to chloride-induced SCC because of their high ferrite content and moderate resistance to hydrogen sulphide-induced SCC.
- High resistance to pitting attack in more aggressive chloride environments, e.g. seawater at higher temperatures.

Applications

The offshore oil and gas industry is the major user of these alloys. Applications are much the same as for the standard 2205 types namely, process pipe work, flow lines, risers, manifolds and seawater systems, etc. They are generally used where corrosion conditions are somewhat more aggressive or where operating temperatures are higher. The use of these alloys in the general chemical and petrochemical industries is still rather limited.

D–3

25% chromium, superduplex stainless steels with copper and/or tungsten

Also known generically as Zeron 100, Sumitomo DP3W, Ferralium SD40, etc.

Description

These are superduplex grades with low carbon, 25% chromium, 7% nickel, 3.5% molybdenum, controlled nitrogen and additions of copper and/or tungsten. They still give a duplex microstructure and the copper and tungsten contribute to an improvement in corrosion resistance in a wider range of environments and also to providing some further increases in strength. Typical compositions are:

		C	Mn	Si	S	P	Cr	Ni	Mo	W	Cu	N
Weight %	**Zeron 100**	0.03	0.7	0.3	<0.01	<0.02	25	7	3.5	0.7	0.7	0.25
	DP3W	0.03	0.6	0.3	<0.01	<0.02	25	7	3	2	-	0.26
	SD40	0.03	1	0.7	<0.01	<0.02	26	6.5	3.3	-	1.6	0.26
	UR52N+	<0.03	1	0.3	<0.01	<0.02	25	7	3.5	-	1.5	0.25

The steels are normally supplied as proprietary alloys in accordance with UNS specifications:

	UNS		EN
Zeron 100 (Weir Materials)	S32760 (wrought)	J93380 (cast)	1.4507
DP3W (Sumitomo)	S32740	J93370	
SD40 (Meighs)	S32520		1.4501
UR52N+ (Industeel)	S32550		

These steels are always solution treated followed by quenching to give an approximately 50% austenite, 50% ferrite duplex structure without any deleterious phases such as sigma. They have a typical PREn value of >40. Tungsten is believed to improve pitting resistance and, if included, the PREw value will often exceed 40.

Background

Superduplex steels were developed in the 1970s to not only meet the demands of the offshore oil and gas industry for improved performance in more aggressive environments, but also provide much improved corrosion resistance in a number of acid environments. The role of copper in austenitic stainless steels such as 904L types (F–2) was already well established, and similar benefits can be gained with superduplex stainless steels. Tungsten is an addition in some of the grades, which increases strength and further improves corrosion resistance.

Performance

These steels offer the following:

- Very high strength – much more than twice that of standard austenitic grades such as 316L, and about 10% higher than copper and tungsten-free 2507 superduplex grades (D–2).
- Very good general corrosion resistance in a wide range of aggressive acid environments.
- High resistance to chloride-induced SCC because of their high ferrite content, plus moderate resistance to hydrogen sulphide-induced SCC.
- High resistance to pitting attack in more aggressive chloride environments, e.g. seawater at higher temperatures.

Applications

The offshore oil and gas industry is a major user of these alloys. Applications are much the same as for the standard 2205 types namely, process pipework, flow lines, risers, manifolds and seawater systems, etc. They are generally used where corrosion conditions are somewhat more aggressive or where operating temperatures are higher. However, because of their resistance to sulphuric, hydrochloric and phosphoric acids and to caustic alkalis at temperatures up to about 300 °C, they are increasingly used in the chemical and process industries. Typical applications are desalination plants, flue gas desulphurisation (FGD) components and hot acid leaching and processing of metal ores.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