High Performance Austenitic Stainless Steel

Steel grades

Outokumpu	EN	ASTM
904L	1.4539	N08904
254 SMO®	1.4547	S31254
4529	1.4529	N08926/N08367
4565	1.4565	S34565
654 SMO®	1.4652	S32654

Characteristic properties

- Very good resistance to uniform corrosion
- Good to exceptionally good resistance to pitting and crevice corrosion
- Very good resistance to various types of stress corrosion cracking
- Very good ductility
- Good weldability
- Excellent formability

Applications

- Process equipment in chemical industry
- Bleaching equipment in the pulp and paper industry
- Flue gas cleaning
- Desalination
- Seawater handling
- Hydrometallurgy
- Food and beverage
- Pharmaceuticals
- Heat exchangers

General characteristics

High performance austenitic stainless steels differ substantially from more conventional grades with regard to resistance to corrosion and, in some cases, also mechanical and physical properties. This is mainly due to the high contents of chromium, nickel, molybdenum and nitrogen. High performance austentic stainless steels have good weldability and excellent formability.

Outokumpu manufactures a number of steels of this type: 904L, 254 SMO®, 4565 and 654 SMO®. Grade 4529 can also be delivered if specified. The properties of 4529 are in general terms very similar to those of 254 SMO®.

Chemical composition

The typical chemical composition of Outokumpu grades are shown in Table 1. The chemical composition of a specific steel grade may vary slightly between different national standards. The required standard will be fully met as specified on the order.

Chemical composition Table 1

	Outokumpu steel name	International steel No		Chemical composition, % typical values						National steel designations, superseded by EN			
		EN	ASTM	C	N	Cr	Ni	Mo	Others	BS	DIN	NF	SS
Austenitic	4404	1.4404	316L	0.02	–	17	10	2.1	–	316S11	1.4404	Z3 CND 17-11-07	2348
	4439	1.4439	S31726	0.02	0.14	18	13	4.1	–	–	1.4439	Z3 CND 18-14-05 Az	–
	904L	1.4539	N08904	0.01	–	20	25	4.3	1.5 Cu	904S13	1.4539	Z2 NCDU 25-20	2562
	254 SMO®	1.4547	S31254	0.01	0.20	20	18	6.1	Cu	–	–	–	2378
	4529	1.4529	N08926/N08367	0.01	0.20	20	25	6.5	Cu	–	1.4529	–	–
	4565	1.4565	S34565	0.02	0.45	24	17	4.5	5.5 Mn	–	1.4565	–	–
	654 SMO®	1.4652	S32654	0.01	0.50	24	22	7.3	3Mn, Cu	–	–	–	–
Duplex	2205	1.4462	S32205*	0.02	0.17	22	5.7	3.1	–	318S13	1.4462	Z3 CND 22-05 Az	2377
	2507	1.4410	S32750	0.02	0.27	25	7.0	4.0	–	–	–	Z3 CND 25-06 Az	2328

* Also available as S31803

Microstructure

The high performance austenitic stainless steels have a fully austenitic microstructure in the quench annealed condition. They can, however, contain traces of intermetallic phases (sigma phase) at the centre of the material. Normally, this does not affect the corrosion resistance or mechanical properties of the steel. Provided that the recommendations given for hot forming, welding and heat treatment are followed, such precipitates typically have negligible effect on usability.

Mechanical properties

The strength and elongation of 904L are similar to those for conventional austenitic stainless steels. The addition of nitrogen in 254 SMO®, 4529, 4565 and 654 SMO® gives higher proof strength and tensile strength, see tables 2 and 3.

Despite the greater strength of these steels, the possibilities for cold as well as hot forming are very good.

Mechanical properties at 20°C — Table 2

			Minimum values, according to EN 10088			Typical values		
			P	H	C	P (15mm)	H (4mm)	C (1mm)
904L								
Proof strength	$R_{p0.2}$	MPa	220	220	240	260	280	340
Proof strength	$R_{p1.0}$	MPa	260	260	270	300	330	370
Tensile strength	R_m	MPa	520	530	530	600	600	700
Elongation	A_5	%	35	35	35	50	45	54
Hardness	HB		–	–	–	155	150	163
254 SMO®								
Proof strength	$R_{p0.2}$	MPa	300	300	320	340	390	380
Proof strength	$R_{p1.0}$	MPa	340	340	350	380	440	420
Tensile strength	R_m	MPa	650	650	650	680	740	740
Elongation	A_5	%	40	35	35	50	45	59
Hardness	HB		–	–	–	160	190	178
4529								
Proof strength	$R_{p0.2}$	MPa	300	–	–	320	–	*
Proof strength	$R_{p1.0}$	MPa	340	–	–	360	–	*
Tensile strength	R_m	MPa	650	–	–	700	–	*
Elongation	A_5	%	40	–	–	50	–	*
Hardness	HB		–	–	–	180	–	*
4565								
Proof strength	$R_{p0.2}$	MPa	420	420	420	440	–	*
Proof strength	$R_{p1.0}$	MPa	460	460	460	480	–	*
Tensile strength	R_m	MPa	800	800	800	825	–	*
Elongation	A_5	%	30	30	30	55	–	*
Hardness	HB		–	–	–	200	–	*
654 SMO®								
Proof strength	$R_{p0.2}$	MPa	430	430	430	475	–	520
Proof strength	$R_{p1.0}$	MPa	470	470	470	510	–	590
Tensile strength	R_m	MPa	750	750	750	860	–	950
Elongation	A_5	%	40	40	40	60	–	59
Hardness	HB		–	–	–	200	–	226

P = hot rolled plate. H = hot rolled strip. C = cold rolled coil and strip. *new product, typical values under establishment.

Tensile properties at elevated temperatures, minimum values according to EN, MPa — Table 3

	904L			254 SMO®			4529			4565			654 SMO®		
	$R_{p0.2}$	$R_{p1.0}$	R_m	$R_{p0.2}$	$R_{p1.0}$	R_m	$R_{p0.2}$	$R_{p1.0}$	R_m	$R_{p0.2}$	$R_{p1.0}$	R_m	$R_{p0.2}$	$R_{p1.0}$	R_m
100°C	205	235	500	230	270	615	230	270	560	350	400	750	350	390	680
200°C	175	205	460	190	225	560	190	225	520	270	310	640	315	355	620
300°C	145	175	440	170	200	525	170	205	480	240	270	640	300	335	585
400°C	125	155	–	160	190	510	160	190	–	210	240	610	295	330	560

Physical Properties

In Table 4 typical values of some physical properties are given for 904L, 254 SMO®, 4565 and 654 SMO®.

Typical values according to EN 10088 — Table 4

		904L	254 SMO®	4529	4565	654 SMO®
Density	g/cm^3	8.0	8.0	8.1	8.0	8.0
Modulus of elasticity	GPa	195	195	195	190	190
Linear expansion at (20 → 100)°C	$\times 10^{-6}$/°C	15.8	16.5	15.8	14.5	15
Thermal conductivity	W/m°C	12	14	12	12	11
Thermal capacity	J/kg°C	450	500	450	450	500
Electric resistivity	μΩm	1.0	0.85	1.0	0.92	0.78

Corrosion resistance

Uniform corrosion

The high content of alloying elements gives the steels 904L, 254 SMO®, 4565 and 654 SMO® exceptionally good resistance to uniform corrosion.

904L was originally developed to withstand environments involving dilute sulphuric acid and it is one of the few stainless steels that, at temperatures of up to 35°C, provides full resistance in such environments within the entire range of concentration, from 0 to 100%, Figure 1. 904L also offers good resistance to a number of other inorganic acids, e.g., phosphoric acid, as well as most organic acids.

Acids and acid solutions containing halide ions can, however, be very aggressive and the corrosion resistance of 904L may be insufficient. Examples of such acids are hydrochloric acid, hydrofluoric acid, chloride contaminated sulphuric acid, phosphoric acid produced according to the wet process (WPA) at elevated temperatures, and also pickling acid based on nitric acid and hydrofluoric acid mixtures. In these cases 254 SMO®, 4565 and 654 SMO® are preferable and in certain cases they can be an alternative to other considerably more expensive alloys, Figures 2-5 and Tables 5 and 6.

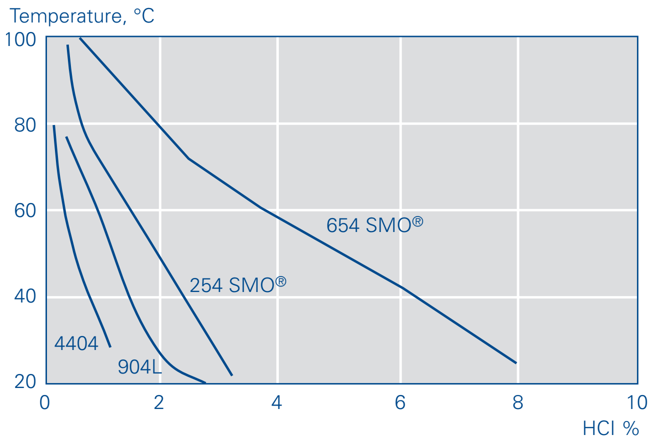

Fig. 3. Isocorrosion curves, 0.1 mm/year, in pure hydrochloric acid.

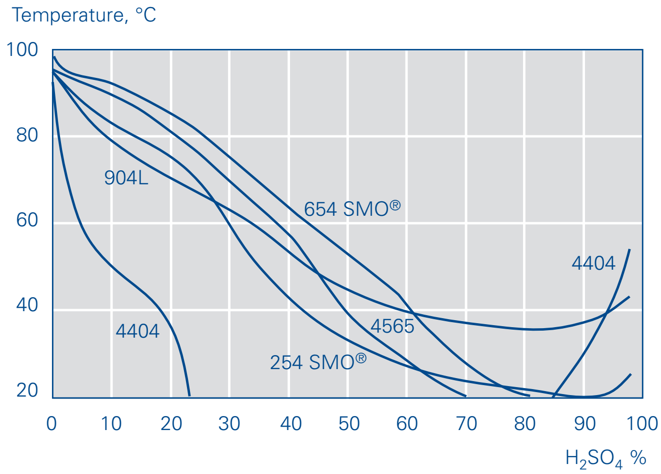

Fig. 1. Isocorrosion curves, 0.1 mm/year, in pure sulphuric acid.

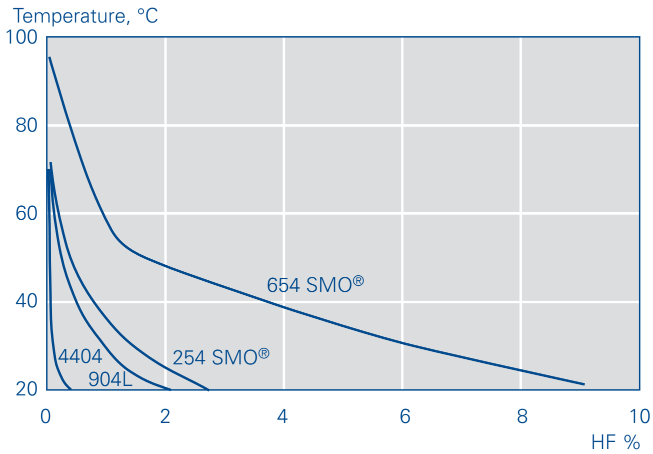

Fig. 4. Isocorrosion curves, 0.1 mm/year, in pure hydrofluoric acid.

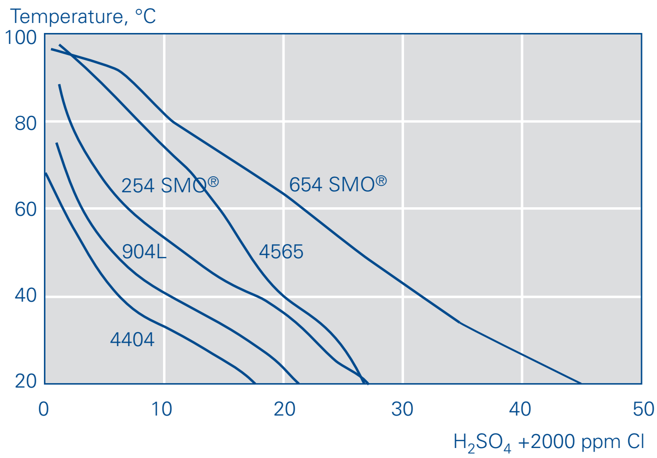

Fig. 2. Isocorrosion curves, 0.1 mm/year, in sulphuric acid containing 2000 ppm chloride.

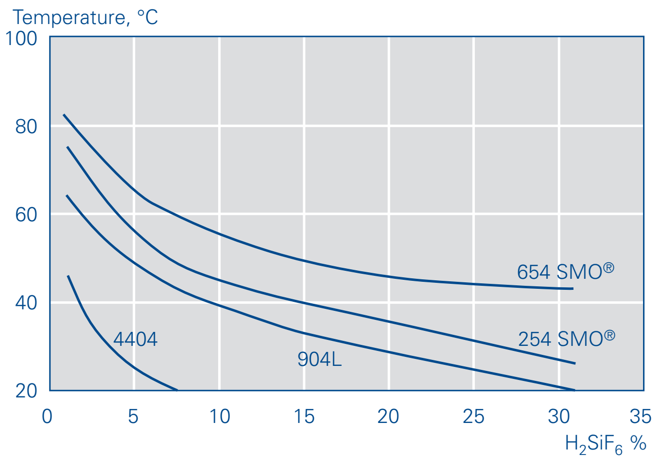

Fig. 5. Isocorrosion curves, 0.1 mm/year, in pure fluosilicic acid.

Uniform corrosion in wet process phosphoric acid at 60°C Table 5

Steel grade	Corrosion rate, mm/year
4404	>5
904L	1.2
254 SMO®	0.05

Composition: 54% P_2O_5, 0.06% HCl, 1.1% HF, 4.0% H_2SO_4, 0.27% Fe_2O_3, 0.17% Al_2O_3, 0.10% SiO_2, 0.20% CaO and 0.70% MgO

Uniform corrosion in pickling acid* at 25°C Table 6

Steel grade	Corrosion rate, mm/year
4404	>6
904L	0.47
254 SMO®	0.27
654 SMO®	0.06

*Composition: 20% HNO_3 + 4% HF.

Fractional distillation of tall oil often need better material than the 4404, or even the more frequently used 4439. Table 7 presents the results of exposing test coupons at a Swedish tall oil plant with the object of determining suitable material for woven packings of stainless steel.

In this particular case, packings produced from about 20,000 km of 0.16 mm diameter 254 SMO® wire were used.

Corrosion rates in a fatty acid column for the distillation of tall oil at 235°C Table 7

Steel grade	Corrosion rate, mm/year
4404	0.88
4439	0.29
904L	0.06
254 SMO®	0.01

In hot concentrated caustic solutions the corrosion resistance is mainly determined by the nickel content of the material, and 904L in particular can be a good alternative to more conventional stainless steels.

For more detailed information concerning the corrosion resistance of the different steels in other environments, see the Outokumpu Corrosion Handbook.

Pitting and crevice corrosion

Resistance to pitting corrosion (and also crevice corrosion) is determined mainly by the chromium, molybdenum and nitrogen content in the material. This is often illustrated using the pitting resistance equivalent (PRE) for the material, which can be calculated using the formula:
PRE = %Cr + 3.3 x %Mo + 16 x %N. PRE values are presented in Table 8.

PRE values for different stainless steels Table 8

Steel grade	PRE
4404	25
4439	33
2205	35
904L	35
2507	43
254 SMO®	43
4529	45
4565	46
654 SMO®	56

The PRE value can be used for rough comparisons of different materials. A much more reliable means is to rank the steel according to the critical pitting temperature of the material (CPT).

There are several different methods available to measure the CPT. Figure 6 shows the CPT, as measured in the Avesta Cell (ASTM G 150), in a 1M NaCl solution (35,000 ppm or mg/l chloride ions). The actual values of mill finish surface may vary between different product forms.

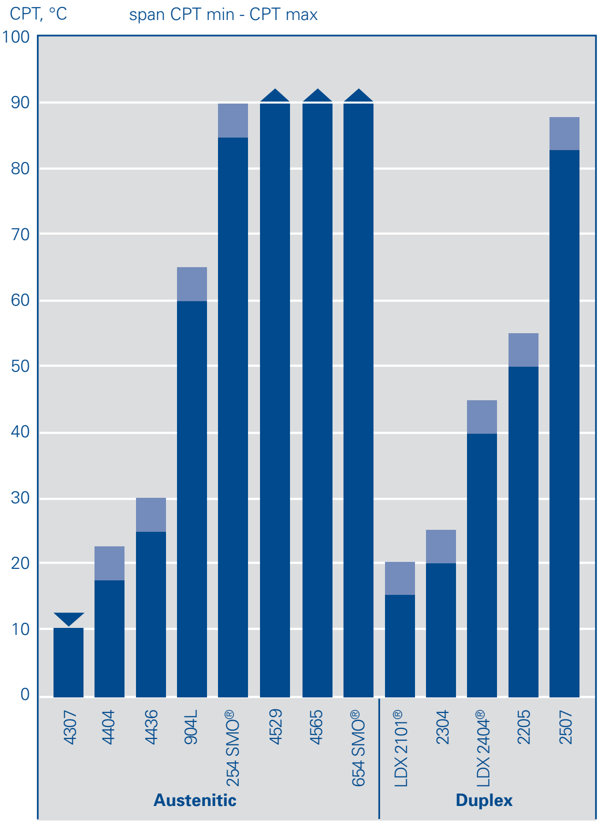

Fig. 6. Typical critical pitting corrosion temperatures (CPT) in 1M NaCl measured according to ASTM G150 using the Avesta Cell. Test surfaces were wet ground to 320 mesh. CPT varies with product form and surface finish.

Grade 4565, and especially 654 SMO®, have such a good resistance to pitting that common test methods are not sufficiently aggressive to initiate any corrosion. A better measure of resistance is given by evaluating the results of various crevice corrosion tests.

In narrow crevices the passive film may more easily be attacked and in unfavourable circumstances stainless steel can be subjected to crevice corrosion. Examples of such narrow crevices may be under gaskets in flange fittings, under seals in certain types of plate heat exchangers, or under hard adherent deposits.

Crevice corrosion occurs in the same environments as pitting, i.e. in chloride (halogenide) containing environments. Higher contents of chromium, molybdenum or nitrogen enhance the corrosion resistance of the steel, see Figure 7.

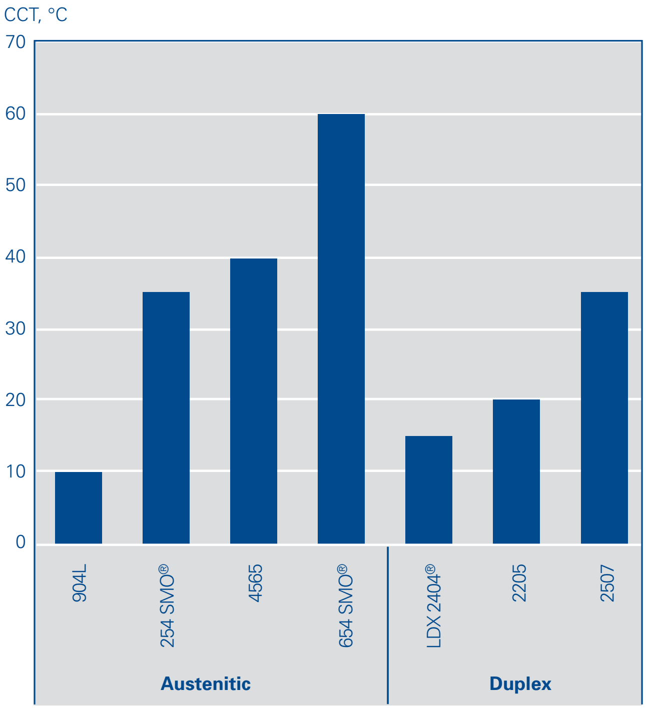

Fig. 7. Typical critical crevice corrosion temperature (CCT) according to ASTM G48 Method F. Test surfaces were dry ground to 120 mesh. CCT varies with product form and surface finish.

Guide to material selection

Figure 8 illustrates to which approximate temperatures stainless steel can be used in aerated waters of varying chloride content. It should be underlined that the resistance of a material is also influenced by factors other than temperature and chloride content. Examples of such factors are weld defects, presence of oxide from welding, contamination of the steel surface by particles of non-alloyed or low-alloyed steel, microbial activity, pH and chlorination of water.

For very severe crevices, such as under the seals of plate heat exchangers or inside threaded connections, the lines for crevice corrosion will move to the left, i.e. lower chloride content/temperature can be accepted.

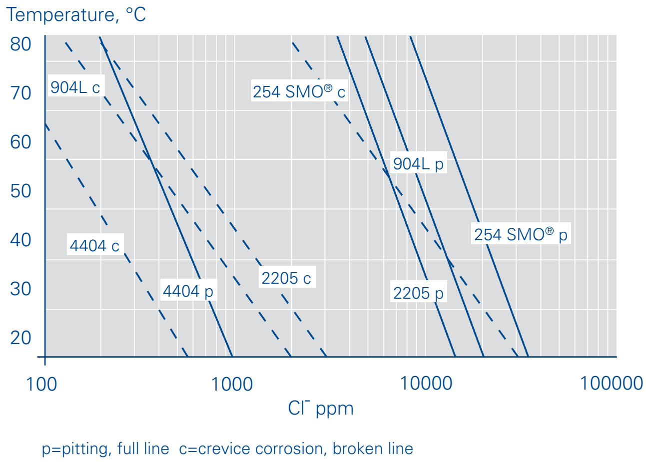

Fig. 8. Engineering diagram illustrating the risk of pitting and crevice corrosion on high performance stainless steel in water of different chloride content or temperature.

Seawater

Natural seawater contains living organisms, which very quickly form a biofilm on stainless steel. This film increases the corrosion potential of the steel and thus, also the risk of pitting and crevice corrosion.

The activity of the biofilm is temperature related. The different organisms are adapted to the natural water temperature of their habitat. Their activity varies between the different seas around the world. This means that in cold seas the natural water is most aggressive at 25-30°C while the corresponding value in tropical seas is just above 30°C. The biological activity ceases at higher temperatures.

In many seawater systems the water is chlorinated with either chlorine or hypochlorite solutions to reduce the risk of fouling. Both chlorine and hypochlorite are strongly oxidising agents and they cause the corrosion potential of the steel surface to exceed what is normal in non-chlorinated seawater, which in turn means increased risk of corrosion. In chlorinated seawater the aggressiveness increases as the temperature rises.

In crevice-free, welded constructions, 254 SMO® may normally be used in chlorinated seawater with a chlorine content of up to 1 ppm at temperatures up to about 45°C. 654 SMO® should be used for flange joints, or the sealing surfaces should be overlay welded, e.g., using an ISO Ni Cr 25 Mo16 type filler, if the temperature exceeds 30°C. Higher chlorine content can be permitted if chlorination is intermittent.
Tests have indicated that 654 SMO® can be used in plate heat exchangers with chlorinated seawater as a cooling medium at temperatures up to at least 60°C.

The risk of crevice corrosion in non-chlorinated seawater is considerably lower. 254 SMO® has sucessfully been used in some fifty installations for desalination of seawater according to the reverse osmosis process. 654 SMO® is resistant to pitting in natural boiling seawater.

Stress corrosion cracking

Conventional stainless steels such as 4307 and 4404 are sensitive to stress corrosion cracking (SCC) under certain conditions, i.e. a special environment in combination with tensile stress in the material and often also an elevated temperature.

Resistance to SCC increases with the increased content of above all nickel and molybdenum. This implies that the high performance austenitic steels 904L, 254 SMO®, 4565 and 654 SMO® have very good resistance to SCC.

Different methods are used to rank stainless steel grades with regard to their resistance to SCC. The results can vary depending on the method and testing environment. The resistance to stress corrosion cracking in a chloride solution under evaporative conditions can be determined according to the drop evaporation method. Here a salt solution is allowed to slowly drip onto a heated specimen, being subjected to tensile stress.

By this method the threshold value is determined for the maximum relative stress resulting in rupture after 500 hours testing. The threshold value is usually expressed as a percentage of the proof strength of the steel at 200°C.
Figure 9 shows the results of such a test, where high performance austenitic steels and duplex steels offer considerably better resistance to SCC than grade 4404, Figure 9.

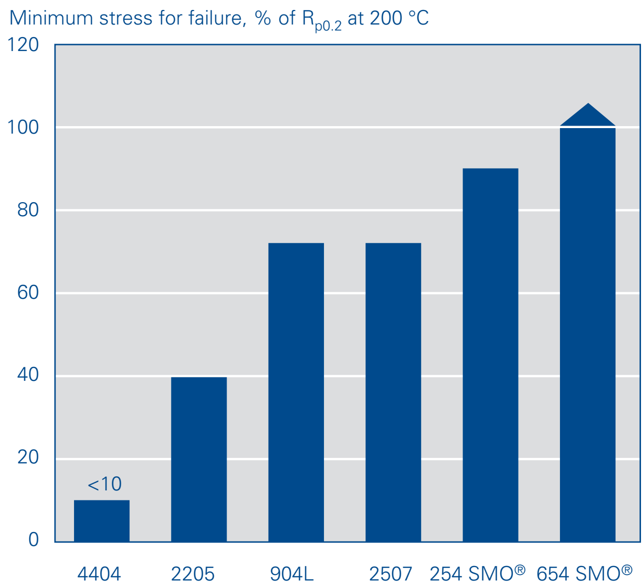

Fig. 9. Typical threshold stresses determined using the drop evaporation test.

The resistance to alkaline SCC is more dependent on the nickel content of the material and also in this respect high performance austenitic steels are superior to conventional stainless steels. Nickel-based alloys are, however, to be preferred in the most demanding conditions.

Sulphide-induced stress corrosion cracking

Hydrogen sulphide can sometimes cause embrittlement of ferritic steel and even of cold-worked duplex and austenitic steels. The sensitivity to cracking increases when the environment contains both hydrogen sulphide and chlorides. Such "sour" environments occur for example in the oil and gas industry.

NACE MR0175/ISO 15156-3 provides requirements and recommendations for selection of corrosion resistant alloys for use in oil and natural gas production in H_2S environments. It identifies materials that are resistant to cracking in a defined H_2S containing environment, but does not guarantee that the material selected using the standard will be immune from cracking under all service conditions.

Austenitic steels 904L, 254 SMO®, 4565 and 654 SMO® are included in NACE MR0175/ISO 15156-3. In accordance with NACE MR0175/ISO 15156-3 solution annealed 904L, 254 SMO®, 4565 and 654 SMO® are acceptable for use for any component or equipment up to 60°C in sour environments, if the partial pressure of hydrogen sulphide (pH_2S) does not exceed 1 bar (15psi), or without restriction on temperature and pH_2S if the chloride concentration does not exceed 50 ppm. Further, solution annealed 254 SMO®, 4565 and 654 SMO® are acceptable for use up to 171°C or pH_2S up to 7 bar (100 psi) if the chloride concentration does not exceed 5000 ppm.

Intergranular corrosion

High performance austenitic steels have such a low carbon content that the risk of conventional intergranular corrosion caused by chromium carbide precipitates in connection with welding is negligible.

This means that welding can be performed without risk of intergranular corrosion.

Erosion corrosion

Unlike copper alloys, stainless steel generally offers very good resistance to impingement attack and there are no motives for limiting the velocity of water, e.g. in piping systems that convey seawater. Further, stainless steel is not sensitive to seawater that has been contaminated by sulphur compounds or ammonia.

In systems subjected to particles causing hard wear, e.g., sand or salt crystals, the higher surface hardness of duplex steels can in some cases be an advantage.

Galvanic corrosion

The high performance austenitic steels 254 SMO®, 4565 and 654 SMO® are not affected by galvanic corrosion if they are connected to titanium in systems used for conveying seawater. However, the rate of corrosion for copper alloys is increased if they come into contact with most stainless steels (or with titanium). The intensity of corrosion is closely related to the surface area ratio between the stainless steel and the copper alloy, Figure 10. The tests presented have been carried out with 254 SMO® but the relation is the same for other high performance steels.

The galvanic effect is reduced somewhat if the seawater is chlorinated.

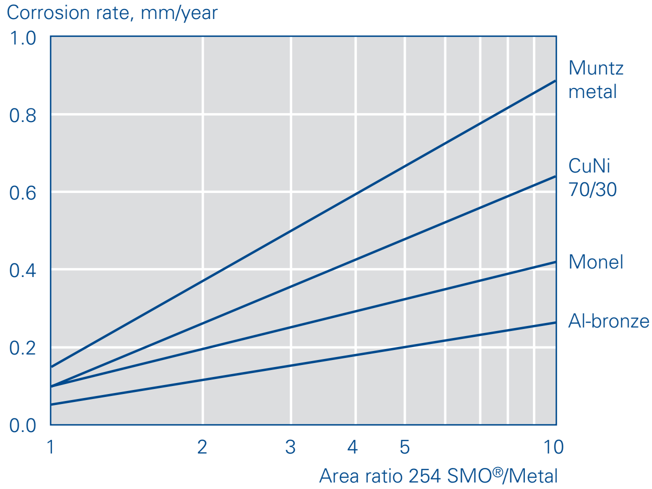

Fig. 10. Galvanic corrosion of copper alloys in slow moving seawater at ambient temperature.

Fabrication

Forming

All Outokumpu high performance austenitic grades have very good formability properties and are suitable for all forming processes available for stainless steel. The somewhat higher proof strength and in some cases lower fracture elongation compared to the most common standard austenitic steel grades can impose small differences in forming behaviour, depending on chosen forming technique, such as an increased springback. This can be compensated for, especially if the forming process can be designed for the specific steel grade. Moreover, an excellent interplay between the high proof strength, work hardening rate and elongation, make the high nitrogen containing grades 4565 and 654 SMO® excellently suited for light weight and cost effective applications with complex shapes.

The impact of a high strength varies for different forming techniques. Common for all high performance austenitic grades are that the estimated forming forces will be higher than for the standard austenitic stainless steel grades. This effect will be reduced if down gauging is possible. A common issue for the high strength steels is the high proof strength which may result in higher demands on the tool materials and the lubricant. Also in this respect attention should be given to the possibility of down gauging.

For more information on forming properties, please contact Outokumpu.

Cold forming

The high strength of the high nitrogen containing grades 4565 and 654 SMO® is clearly demonstrated when the stress-strain curves of high performance austenitic stainless steel grades are compared with the standard austenitic grade 4404, Figure 11. The deformation hardening rate is almost similar for all the austenitic grades presented in Figure 11.

The formability of Outokumpu's high performance austenitic stainless steel grades can be characterized in several ways. A sheet materials ability to withstand thinning during forming is demonstrated by the r-value in different tensile directions and the higher the r-value the better, 654 SMO® shows excellent r-values as illustrated in Figure 12.

Figure 13 gives a relative comparison of the formability in plain strain condition between Outokumpu high performance austenitic grades and the standard grade 4404. The ranking represents the most critical failure mode in sheet forming, especially in forming operations dominated by thinning (stretching). In pure drawing, all austenitic grades are comparable in that about the same limiting drawing ratio can be drawn.

Hot forming

Suitable temperatures for hot forming are shown in Table 9. Higher temperatures cause a deterioration in ductility and an increase in the formation of oxides (scaling). Normally hot working should be followed by solution annealing and quenching but, for 904L, if the hot forming is discontinued at a temperature above 1100°C and the material is quenched directly thereafter the material may be used without subsequent heat treatment. It is important that the entire workpiece has been quenched from temperatures above 1100°C. In the case of partial heating or partial cooling below 1100°C

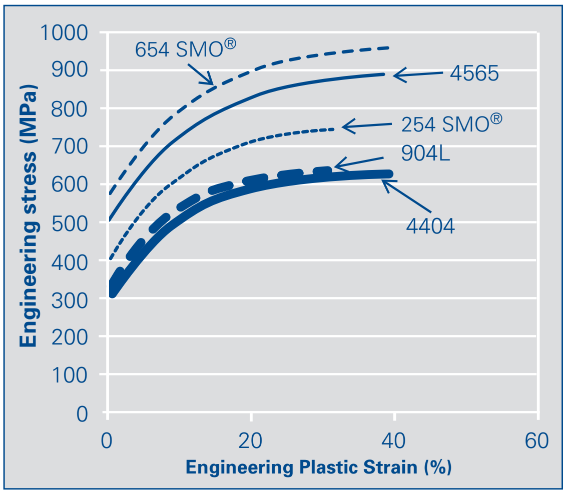

Fig. 11. Enginering stress-strain curves for high performance austenitic grades and standard austenitic grade 4404 (1.0 mm thick cold rolled).

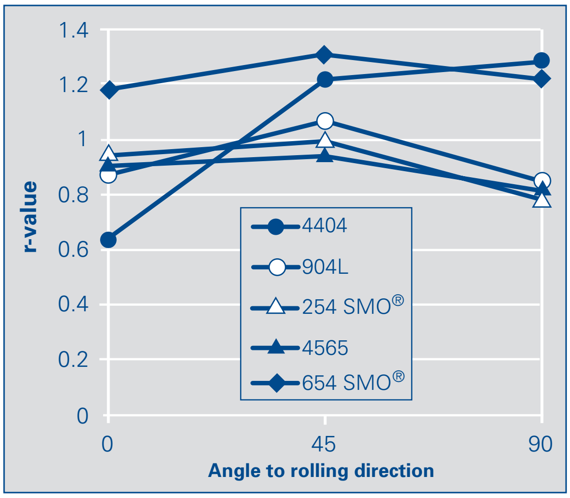

Fig. 12. r-values for high performance austenitic grades and standard austenitic grade 4404.

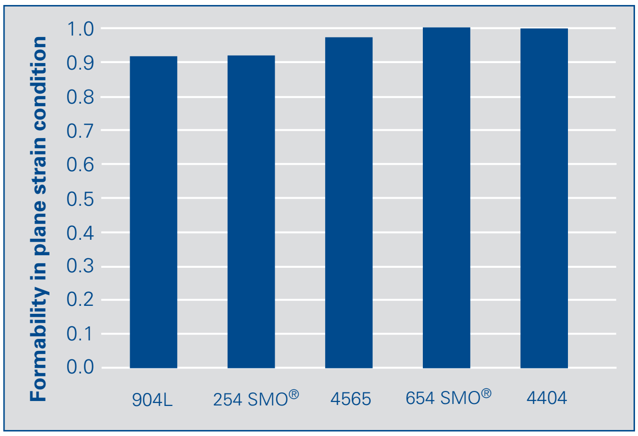

Fig. 13. Formability ranking of high performance austenitic grades in relation to standard austenitic grade 4404.

or if the cooling has been too slow, hot working should always be followed by solution annealing and quenching.

254 SMO® 4565 and 654 SMO® should be quenched at a temperature of at least 1150°C after hot working to avoid residual intermetallic phases. These phases can also rebuild if the subsequent cooling process is too slow, resulting in impaired corrosion resistance.

Characteristic temperatures, °C Table 9

	904L	254 SMO®	4529	4565	654 SMO®
Hot forming**	1150 - 850	1200 - 1000	1150 - 850	1200 - 950	1200 - 1000
Solution annealing**	1060 - 1140	1150 - 1200*	1120 - 1180	1120 - 1170	1150 - 1200
Pressure vessel approval	-196 - +400	-196 - +400	-196 - +400	-196 - +400	RT - +427***

* Quenching with water at a thickness above 2 mm, below 2 mm an annealing temperature of 1120-1150°C and cooling with air/water can be used.

** According to EN 10088-2

*** ASME Code Case 2195-1

Machining

Austenitic stainless steels work harden quickly and this, together with their high toughness, means that they are often perceived as problematic from a machining perspective, e.g. in operations such as turning, milling and drilling. This applies to an even greater extent to most highly alloyed steels and especially those that have a high nitrogen content, i.e. 254 SMO®, 4565 and 654 SMO®.

However, with the right choice of tools, tool settings and cutting speeds, these materials can be sucessfully machined. For further information see the Outokumpu Machining Guidelines for these grades.

Welding

All these steels are well suited for welding and the methods used for welding conventional austenitic steels can also be used on 904L, 254 SMO®, 4565 and 654 SMO®. However, due to their stable austenitic structure, they are somewhat more sensitive to hot cracking in connection with welding and generally welding should be performed using a low heat input.

On delivery, sheet, plate and other processed products have a homogeneous austenitic structure with an even distribution of alloying elements in the material. Solidification after partial remelting, e.g. by welding, causes redistribution of certain elements such as molybdenum, chromium and nickel. These variations, segregation, remain in the cast structure of the weld and can impair the corrosion resistance in certain environments.

Segregation tendency is less evident in 904L and this steel is normally welded using a filler of the same composition as the base material and it can even be welded without filler. For 254 SMO®, 4565 and 654 SMO®, the variation for molybdenum in particular is so great that it must be compensated for by using fillers, which have a higher content of molybdenum. EN ISO Ni Cr 21 Mo Fe Nb type of filler is normally used for welding 254 SMO® and 4529 and ISO Ni Cr 25 Mo 16 type filler is recommended for the welding of 4565 and 654 SMO®.

The effect of segregation after welding can also be reduced by subsequent heat treatment and quench annealing, but such action is normally limited to uncomplicated geometries, e.g., pipes, pipe fittings and end pieces.

In the case of multi-run welding, the workpiece should be allowed to cool to 100°C before welding the next run. This is the case for all four steels.

For further information regarding joint selection and preparation, welding techniques, heat input and post-weld cleaning, see the Outokumpu Welding Handbook.

Post fabrication treatment

In order to restore the stainless steel surface and achieve good corrosion resistance after fabrication, it is often necessary to perform a post fabrication treatment.
There are different methods available, both mechanical methods such as brushing, blasting and grinding and chemical methods, e.g. pickling. Which method to apply depend on what consequences the fabrication caused, i.e. what type of imperfections to be removed, but also on requirements with regard to corrosion resistance, hygiene and aesthetic appearance.

For more information, see the Outokumpu Welding Handbook.

Welding consumables Table 10

Steel grade	Welding consumables	
	Covered electrodes ISO 3581 ISO 14172	Wires ISO 14343 ISO 18274
904L	20 25 CuL	20 25 CuL
254 SMO®	Ni Cr 21 Mo Fe Nb or Ni Cr 25 Mo 16 or P54*	Ni Cr 22 Mo 9 Nb
4529	Ni Cr 21 Mo Fe Nb or Ni Cr 25 Mo 16 or P54*	Ni Cr 22 Mo 9 Nb
4565	Ni Cr 21 Mo Fe Nb or Ni Cr 25 Mo 16 or P54*	Ni Cr 22 Mo 9 Nb
654 SMO®	Ni Cr 25 Mo 16	Ni Cr 25 Mo 16

* Avesta Welding designation. For use in certain oxidising environments, e.g. chlorine dioxide stage in pulp bleaching plants, when welding 254 SMO® or 4565.

Products

Outokumpu products Table 11

Product	904L	254 SMO®	4529	4565	654 SMO®
Hot rolled plate,	✓	✓	✓	✓	✓
Hot rolled sheet and strip	✓	✓			
Cold rolled sheet and strip	✓	✓	✓	✓	✓
Bars	✓	✓			
Tube and Pipe	✓	✓			✓
Pipe fittings	✓	✓			
Wire rod and drawn wire	✓	✓			

see also www.outokumpu.com

Material standards

Table 12

EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10088-2	Stainless steels – Corrosion resisting sheet/plate/strip for general and construction purposes
EN 10088-3	Stainless steels – Corrosion resisting semi-finished products/bars/rods/wire/sections for general and construction purposes
EN 10088-4	Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes
EN 10088-5	Technical delivery conditiions for bars, rods, wire, sections and bright products of corrosion resistant steels for construction purposes
EN 10272	Stainless steel bars for pressure purposes
EN 10283	Corrosion resistant steel castings
ASTM A182 / ASME SA-182	Forged or rolled alloy-steel pipe flanges, forged fittings etc for high temperature service
ASTM A193 / ASME SA-193	Alloy and stainless steel bolts and nuts for high pressure and high temperature service
ASTM A240 / ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purposes
ASTM A249 / ASME SA-249	Welded austenitic steel boiler, superheater, heat exchanger and condenser tubes
ASTM A269	Seamless and welded austenitic stainless steel tubing for general service
ASTM A276	Stainless and heat-resisting steel bars/shapes
ASTM A312 / ASME SA-312	Seamless and welded austenitic stainless steel pipe
ASTM A351 / ASME SA-351	Steel castings, austenitic, duplex for pressure containing parts
ASTM A358 / ASME SA-358	Electric fusion-welded austenitic Cr-Ni alloy steel pipe for high temperature
ASME SA-403	Wrought austenitic stainless steel piping fitting
ASTM A409 / ASME SA-409	Welded large diameter austenitic pipe for corrosive or high-temperature service
ASTM A473	Stainless steel forgings for general use
ASTM A479 / ASME SA-479	Stainless steel bars for boilers and other pressure vessels
ASTM A743	Castings, Fe-Cr-Ni, corrosion resistant for general application
ASTM A744	Castings, Fe-Cr-Ni, corrosion resistant for severe service
NACE MR0175	Sulphide stress cracking resistant material for oil field equipment
ASTM B649 / ASME SB-649	Bar and wire
Norsok M-CR-630	Material data sheets for 6Mo stainless steel
VdTÜV WB 473	Austenitischer Walz- und Schmiedestahl. Blech, Band, Schmiedestück, Stabstahl für Druckbehälter
VdTÜV WB 537	Stickstofflegiertes austenitischen Stahl X2CrNiMnMoN 25-18-6-5 Werkstoff-Nr 1.4565

1044EN-GB:6. Centrum Tryck AB, Avesta, Sweden. March 2011.

Outokumpu is a global leader in stainless steel. Our vision is to be the undisputed number one in stainless, with success based on operational excellence. Customers in a wide range of industries use our stainless steel and services worldwide. Being fully recyclable, maintenance-free, as well as very strong and durable material, stainless steel is one of the key building blocks for sustainable future. What makes Outokumpu special is total customer focus - all the way, from R&D to delivery. You have the idea. We offer world-class stainless steel, technical know-how and support. We activate your ideas. (www.outokumpu.com)

Outokumpu Stainless AB, Avesta Research Centre
Box 74, SE-774 22 Avesta, Sweden
Tel. +46 (0)226 810 00, Fax +46 (0)226 810 77
research.stainless@outokumpu.com