outokumpu
stainless steel & high performance alloys

High Temperature Austenitic Stainless Steel

High temperature austenitic stainless steels

The high temperature austenitic stainless steels include grades Outokumpu 4948 (1.4948, 304H, S30409), 4878 (1.4878, 321H), 153 MA™ (1.4818, S30415), 4833 (1.4833, 309S, S30908), 4828 (1.4828), 253 MA® (1.4835, S30815), 4845 (1.4845, 310S, S31008) and 4841 (1.4841, 314, S31400).

Chemical composition

The chemical composition of the high temperature austenitic grades are shown in Table 1. The chemical composition of a specific steel grade may vary slightly between different national (and international) standards. The required standard will be fully met as specified on the order.

General properties

- Good resistance to oxidation
- Good resistance to high-temperature corrosion
- Good mechanical strength at elevated temperatures

Applications

Outokumpu high temperature steels can be and have been used in a number of applications where the temperature exceeds 550°C, e.g. for equipment and components within:

- Iron, steel, and non-ferrous industries
- Engineering industry
- Energy conversion plants
- Cement industry
- Automotive industry

Chemical composition **Table 1**

Outokumpu steel name	International steel designation				Typical chemical composition, % by wt.					
	EN	ASTM	UNS	ISO	C	N	Cr	Ni	Si	Others
4948	1.4948	304H	S30409	4948-304-09-I	0.05		18.1	8.3		
4878	1.4878	321H	–	–	0.05		17.3	9.1		Ti
153 MA™	1.4818	–	S30415	4818-304-15-E	0.05	0.15	18.5	9.5	1.3	Ce
4833	1.4833	309S	S30908	4833-309-08-I	0.06		22.3	12.6		
4828	1.4828	–	–	4828-305-09-I	0.04		20	12	2	
253 MA®	1.4835	–	S30815	4835-308-15-U	0.09	0.17	21	11	1.6	Ce
4845	1.4845	310S	S31008	4845-310-08-E	0.05		25	20		
4841	1.4841	314	S31400	4841-314-00-E	0.07		24.5	19.5	2	

General characteristics

A common feature of Outokumpu high temperature steels is that they are designed primarily for use at temperatures exceeding ~550 °C, i.e. in the temperature range where creep strength as a rule is the dimensioning factor and where high-temperature corrosion occurs. Optimising steels for high temperatures has meant that their resistance to aqueous corrosion has been limited. All steels are austenitic, resulting in relatively high creep strength values.

All steels except EN 1.4948 (i.e., all EN 1.48XX) are included in the European Standard EN 10095 "Heat-resisting steels and nickel alloys". EN 1.4948 is included in EN 10028-7 "Flat products made of steels for pressure purposes – Part 7: Stainless steel". The above steel grades are also included in ASTM A240 except for 1.4828, which is only included in the European Norm 10095, and 314 which is included in ASTM A314.

4948 is a creep-resistant variant of 4301, with a standardised minimum carbon content for service at temperatures up to 800°C in dry air.

4878 is a heat-resistant variant of 4541, with a slightly higher maximum carbon content. The recommended maximum service temperature for this steel in dry air is also 800°C.

153 MA™ is also a variant of 4301, with increased contents of silicon and nitrogen, and microalloyed with rare earth metals (REM). This has raised the maximum service temperature (in dry air) to 1000°C.

4833 and 4828 are standardised high-temperature steels for service at temperatures up to 1000°C in dry air. Utilisation in the temperature range 600-900°C can lead to embrittlement of the material.

253 MA® is a variant of 4828 which has an increased nitrogen content and has been microalloyed with rare earth metals (REM). The most suitable temperature range is 850-1100°C, because structural changes when used between 600 and 850°C can lead to reduced impact toughness at room temperature.

4845 is a standardised high-temperature steel for use at temperatures up to 1100°C in dry air. This steel is also prone to embrittlement after exposure between 600 and 900°C.

4841 is a variant of 4845 with an increased content of silicon, which has enhanced the steel's resistance to oxidation/corrosion but also made it more susceptible to embrittlement.

Microstructure

For most high-temperature alloys, the composition is optimised with regard to strength and/or resistance to corrosion at elevated temperatures.

Diffusion controlled transformations will occur in the material at sufficiently high operating temperatures. The most common type of reaction is the precipitation of non-desirable phases, which, besides lowering the corrosion resistance by consuming beneficial alloying elements (above all chromium), leads to a reduced toughness/ductility of the material – especially at room temperature.

The precipitates are often intermetallic phases such as sigma, chi, and so-called Laves phases.

In 153 MA™ and 253 MA® the formation of sigma phase is counteracted by the relatively high contents of nitrogen in the steels (and carbon in 253 MA®). Instead, precipitation of carbides and nitrides can occur in the same temperature range, which can result in an equally low impact toughness at room temperature as for intermetallic-embrittled high temperature alloys. Experience and certain laboratory tests have, however, shown that carbide/nitride embrittled steels have a greater ductility when deformation rates are lower, e.g. in tensile and bending tests.

The best steels with regard to embrittlement are 4878, 4948 and 153 MA™.

Characteristic temperatures

Table 2

Steel grade	Solidification range, °C	Maximum service temperature in dry air, °C	Hot forming, °C	Solution annealing, °C	Stress relief annealing (min. 0.5 h), °C
4948	1450 - 1385	800	1150 - 850	1050 - 1110	840 - 900
4878	1440 - 1370	800	1150 - 850	1020 - 1120	840 - 900
153 MA™	1450 - 1370	1000	1150 - 900	1020 - 1120	900
4833	1420 - 1350	1000	1150 - 950	1050 - 1150	1010 - 1040
4828	1420 - 1350	1000	1150 - 950	1050 - 1150	1010 - 1040
253 MA®	1430 - 1350	1100	1150 - 900	1020 - 1120	900
4845	1410 - 1340	1100	1150 - 980	1050 - 1150	1040 - 1070
4841	1400 - 1330	1125	1150 - 980	1050 - 1150	1040 - 1070

Mechanical properties

Whilst Outokumpu high temperature steels are mainly optimised for oxidation and high temperature corrosion resistance, they also have good mechanical properties, partly due to their austenitic structure and partly due to certain alloying elements.

Design values are usually based on minimum proof strength values for constructions used at temperatures up to around 550°C. For higher temperatures, average creep strength values are used.

Mechanical properties at room temperature, according to EN 10095

Table 3

Steel grade	Proof strength (min.)		Tensile strength	Elongation	Hardness
	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	min. %	max. HB
4948*	210	250	510 - 710	45	-
4878	190	230	500 - 720	40	215
153 MA™	290	330	600 - 800	40	210
4833	210	250	500 - 700	35	192
4828	230	270	550 - 750	30	223
253 MA®	310	350	650 - 850	40	210
4845	210	250	500 - 700	35	192
4841	230	270	550 - 750	30	223

*values according to EN 10028-7

Elevated temperature proof strength, $R_{p0,2}$, MPa (minimum values)

Table 4a

Steel grade	Temperature °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
4948*	–	157	142	127	117	108	103	98	93	88	83	78	–
4878	–	162	152	142	137	132	127	123	118	113	108	103	–
153 MA™	245	200	178	165	156	150	145	140	135	130	125	120	110
4833	–	140	128	116	108	100	94	91	86	85	84	82	–
4828	–	140	128	116	108	100	94	91	86	85	84	82	–
253 MA®	280	230	198	185	176	170	165	160	155	150	145	140	130
4845	–	140	128	116	108	100	94	91	86	85	84	82	–

*values according to EN 10028-7

Elevated temperature proof strength, $R_{p1,0}$, MPa (minimum values)

Table 4b

Steel grade	Temperature °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
4948*	–	191	172	157	147	137	132	127	122	118	113	108	–
4878	–	201	191	181	176	172	167	162	157	152	147	142	–
153 MA™	280	235	208	195	186	180	175	170	165	160	155	150	135
4833	–	185	167	154	146	139	132	126	123	121	118	114	–
4828	–	185	167	154	146	139	132	126	123	121	118	114	–
253 MA®	315	265	230	215	206	200	195	190	185	180	175	170	155
4845	–	185	167	154	146	139	132	126	123	121	118	114	–

*values according to EN 10028-7

Elevated temperature tensile strength, R_m, MPa (minimum values)

Table 4c

Steel grade	Temperature °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
4948*	–	440	410	390	385	375	375	375	370	360	330	300	–
4878	–	410	390	370	360	350	345	340	335	330	320	300	–
153 MA™	570	525	500	485	478	475	473	470	455	435	410	385	300
4833	–	470	450	430	420	410	405	400	385	370	350	320	–
4828	–	470	450	430	420	410	405	400	385	370	350	320	–
253 MA®	630	585	560	545	538	535	533	530	515	495	472	445	360
4845	–	470	450	430	420	410	405	400	385	370	350	320	–

*values according to EN 10028-7

Creep strength

Figure 1 shows the relative creep strength for rupture after 100 000 hours as a function of temperature. Reference steel: 253 MA®.

Diagrams of this type provide a quick and clear presentation of the relative strength of different steel grades, e.g. 4828, 4833, and 4845 are only half as strong as 253 MA® at 800°C, i.e. twice the material thickness is required for "normal" dimensioning.

The creep rupture strenght, R_{km}, and 1% creep deformation strenght, R_{A1}, values given for each alloy and temperature in Tables 5a-5d are the mean values from tests of several heats.

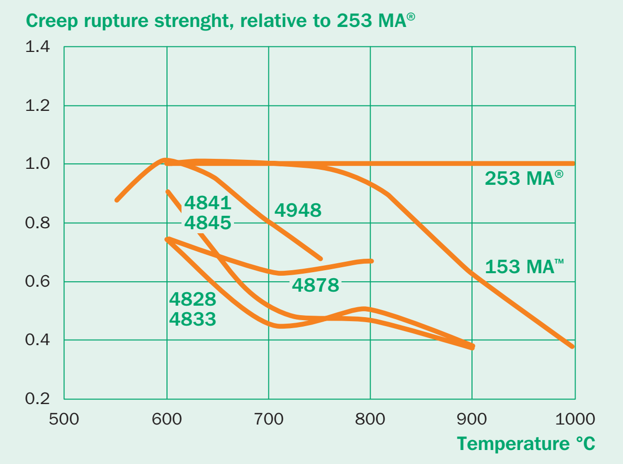

Fig. 1. Relative creep rupture strength.

Fatigue

Service conditions at elevated temperatures are rarely constant. In most cases, a component will be subjected to both varying loads and temperatures, which eventually can lead to fatigue failure. Isothermal fatigue can be subdivided into two groups: High Cycle Fatigue, HCF, which is stress controlled with low amplitudes, and Low Cycle Fatigue, LCF, strain controlled with great amplitudes and a correspondingly shorter life. HCF is mainly occurring in rotating and/or vibrating components, while LCF is primarily due to great transients during start-ups, shut-downs, and major changes in service conditions.

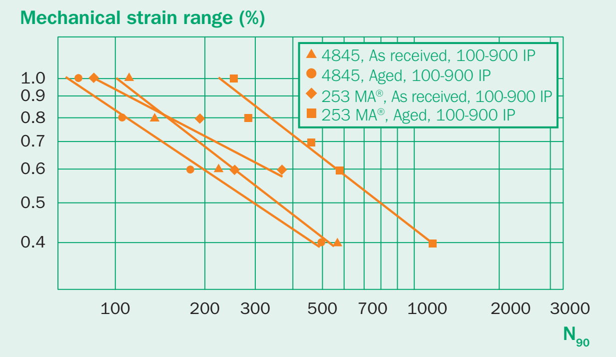

Fig. 2. Thermomechanical fatigue tests shows that ageing of Outokumpu 253 MA® is beneficial, but for 4845 it is detrimental.

Pure thermal fatigue in a component is caused by thermal gradients and the corresponding differences in (internally constrained) thermal expansion.

The most complex situation is when temperature and load vary simultaneously, ThermoMechanical Fatigue, TMF. A simplified test method for these conditions consists of letting the temperature and stress/strain vary in phase or 180° out of phase. In Figure 2, results from in phase (IP) TMF test series are presented, showing that ageing has a beneficial effect on the fatigue life of (nitride forming) Outokumpu 253 MA®, while the effect is detrimental for 4845 due to sigma phase precipitation.

Creep rupture strength, $R_{km,10\,000}$ MPa (mean values), according to EN 10095

Table 5a

Steel grade	Temperature. °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948*	250	191	132	87	55	34							
4878			142	82	48	27	15						
153 MA™		250	157	98	63	41	25	16	10	6.5	4		
4833			120	70	36	24	18	13	8.5				
4828			120	70	36	24	18	13	8.5				
253 MA®		250	157	98	63	41	27	18	13	9.5	7	5.5	4
4845			130	65	40	26	18	13	8.5				
4841			130	65	40	28	20	14	10				

*values according to EN 10028-7

Creep rupture strength, $R_{km,100\,000}$ MPa (mean values), according to EN 10095

Table 5b

Steel grade	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948*	192	140	89	52	28	15							
4878			65	36	22	14	10						
153 MA™		160	88	55	35	22	14	8	5	3	1.7		
4833			65	35	16	10	7.5	5	3				
4828			65	35	16	10	7.5	5	3				
253 MA®		160	88	55	35	22	15	11	8	5.5	4	3	2.3
4845			80	33	18	11	7	4.5	3				
4841			80	33	18	11	7	4.5	3				

*values according to EN 10028-7

Creep deformation strength, $R_{A1,10\,000}$ MPa (mean values), according to EN 10095

Table 5c

Steel grade	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948*	147	121	94	61	35	24							
4878			85	50	30	17.5	10						
153 MA™		200	126	74	42	25	15	8.5	5	3	1.7		
4833			70	47	25	15.5	10	6.5	5				
4828			80	50	25	15.5	10	6	4				
253 MA®		230	126	74	45	28	19	14	10	7	5	3.5	2.5
4845			90	52	30	17.5	10	6	4				
4841			95	60	35	20	10	6	4				

*values according to EN 10028-7

Creep deformation strength, $R_{A1,10\,000}$ MPa (mean values), according to EN 10095

Table 5d

Steel grade	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948*	114	96	74	43	22	11							
4878													
153 MA™		135	80	45	26	15	9	5	3	1.8	1		
4833													
4828													
253 MA®		150	80	45	26	16	11	8	6	4.5	3	2	1.2
4845													
4841													

*values according to EN 10028-7

Physical properties

The physical property values given in the European standard EN 10095 (EN 10028-7 for 4948) are inconsistent and poorly documented. The values below have therefore been extracted from STAHL-EISEN-Werkstoffblatt 310 or from own investigations (153 MA™ and 253 MA®).

Values for these properties at other temperatures can be supplied by Outokumpu, Avesta Research Centre, on request.

Physical properties

Table 6

Steel grade	Density (kg/dm^3)	Young's Modulus (GPa)			Thermal expansion coefficient (10^{-6}/°C) between 20°C and			Thermal conductivity (W/m°C)		Heat capacity (J/kg°C)	Electrical resistivity (µΩm)
	20°C	20°C	600°C	1000°C	600°C	800°C	1000°C	20°C	800°C	20°C	20°C
4948	7.93	196	150	120	18.8	19.4	20.0	14.3	26.0	472	0.71
4878	7.92	196	150	–	18.8	19.4	–	13.9	25.8	472	0.74
153 MA™	7.80	200	155	120	18.5	19.0	19.5	15.0	25.5	500	0.84
4833	7.77	196	150	120	18.8	19.4	20.0	12.6	24.7	472	0.87
4828	7.77	196	150	120	18.8	19.4	20.0	12.6	24.7	472	0.87
253 MA®	7.80	200	155	120	18.5	19.0	19.5	15.0	25.5	500	0.84
4845	7.76	196	150	120	18.8	19.4	20.0	11.9	24.3	472	0.96
4841	7.76	196	150	120	18.8	19.4	20.0	11.9	24.8	472	0.96

All these austenitic steels have a greater thermal expansion and a lower thermal conductivity than ferritic stainless steels. This will result in greater thermal stresses when the temperature changes rapidly – thermo-shock – which must be taken into account during design and operation.

Corrosion resistance

Aqueous corrosion

Since most high-temperature materials are optimised with regard to strength and corrosion resistance at elevated temperatures, their resistance to low-temperature wet corrosion may be less satisfactory. Components made of high-temperature material should therefore be designed and operated so that acid condensates are not formed, or at least so that any such condensates are drained away.

As 4878 is a titanium-stabilised grade, it will probably show the best resistance to aqueous intergranular corrosion.

High-temperature corrosion

The resistance of a material to high-temperature corrosion is in many cases dependent on its ability to form a protective oxide layer. In a reducing atmosphere, when such a layer cannot be created (or maintained), the corrosion resistance of the material will be determined by the alloy content of the material. Below, a number of high-temperature corrosion types are treated. However, industrial environments often contain a mixture of several aggressive compounds, so the choice of material will, as a rule, have to be a compromise.

Oxidation

When a material is exposed to an oxidising environment at elevated temperatures, a more or less protective oxide layer will be formed on its surface. Even if oxidation is seldom the primary cause of high-temperature corrosion failures, the oxidation behaviour is important, because the properties of the oxide layer will determine the resistance to attack by other aggressive elements in the environment. The oxide growth rate increases with increasing temperature until the rate of oxidation becomes unacceptably high or until the oxide layer begins to crack and spall off, i.e. the scaling temperature is reached.

The scaling temperatures for our steels are not given in Table 2. Instead, a recommended maximum temperature is given for use in dry air, based on Outokumpu laboratory tests and service experience. Table 2 shows that 4841 has the best oxidation resistance, followed closely by 253 MA® and 4845.

The alloying elements that are most beneficial for oxidation resistance are chromium, silicon and aluminium. A positive effect has also been achieved with small additions of so-called (re)active elements, e.g. yttrium, hafnium and rare earth metals (REM, e.g. Ce and La). These affect the oxide growth so that the formed layer will be thinner, tougher, and more adherent and thus more protective.

The reactive element effect is especially favourable under conditions with varying temperatures, where the differences between the thermal expansion/contraction of the metal and the oxide induce stresses in the boundary layer, thereby increasing the risk of scaling. This explains the relatively high oxidation resistance of the MA grades.

The existence of water vapour in the atmosphere will reduce the resistance to oxidation and thus the maximum service temperature by up to 100°C. Other, more aggressive components in the environment will lead to even greater reductions of the maximum service temperature.

Molybdenum has a positive effect on corrosion properties at room temperature and moderately elevated temperatures, but can lead to so-called catastrophic oxidation at temperatures exceeding ~750°C.

Sulphur attacks

Various sulphur compounds are often present in flue gases and other process gases. As a rule, they have a very detrimental effect on the useful life of the exposed components.

Sulphides can nucleate and grow due to kinetic effects even under conditions where only oxides would form from a thermodynamic point of view. In existing oxide layers, attacks can occur in pores and cracks. It is therefore essential that the material is able to form a thin, tough and adherent oxide layer. This requires a high chromium content and preferably also additions of silicon, aluminium and/or reactive elements.

Under so-called reducing conditions, the oxygen activity of the gas can still be sufficiently high to enable the formation of a protective oxide layer, provided that the chromium content of the material is sufficiently high (>25%). If this is not the case, low-melting-point nickel sulphides can be formed instead. Under such circumstances, a nickel-free (or low nickel) material should be selected.

Carbon and nitrogen pick-up

In small amounts, the pick-up of carbon and/or nitrogen can improve certain properties of a material and is therefore used technically to enhance properties such as surface hardness, resistance to wear, and/or fatigue resistance.

However, excessive pick-up of either element has an adverse effect on the material. In addition to the fact that the carbides/nitrides formed have an embrittling effect, they generally have higher chromium contents than the steel itself. The corresponding chromium depletion in the adjoining metal will reduce the oxidation resistance.

The best protection against this type of corrosion is a dense oxide layer, and consequently strong oxide formers, such as chromium and silicon, are beneficial alloying elements.

Aluminium is favourable with regard to carbon pick-up, but the high nitrogen affinity of aluminium causes a significant reduction in the protective effect of the aluminium oxide under strongly nitriding conditions. In certain applications, however, a high carbon and/or nitrogen activity is combined with a low oxygen content, whereby protective oxide layers cannot be formed. Under such conditions, the bulk composition of the material will determine the pick-up resistance. The most advantageous alloying element in this case is nickel, but silicon also has a positive effect.

In certain applications with high carbon activity, low oxygen activity and moderately high temperatures, a type of catastrophic carburisation, referred to as metal dusting, can occur, manifesting itself as a disintegration of the material into particles of graphite, metal and oxide.

The risk of carbon pick-up increases when the material is subjected to alternating carburisation and oxidising atmospheres. This can occur in carburising furnaces or heat treatment furnaces if there are oil residues on the material being heat treated, or during decoking in the petrochemical industry.

The risk of nitrogen pick-up is particularly high in furnaces working at high temperatures with oxygen-free gases, consisting of cracked ammonia or other N_2/H_2-mixtures.

Halogens

Gases containing halogens or hydrogen halides are very aggressive to most metallic materials at higher temperatures.

Aluminium, and in particular nickel, appears to increase the resistance to corrosion in most gases containing halogens. Chromium and molybdenum, on the other hand, can have either a positive or a negative effect depending on the composition of the gas.

Molten salts

In certain industrial processes, molten salts are used “deliberately”. These salts easily dissolve existing protective oxide layers and can therefore be very aggressive. However, since the conditions are well known and relatively constant, it is possible to keep the effects of corrosion at an acceptable level by accurate process control and optimum materials selection (a high nickel content is often favourable).

However, the detrimental effects of undesirable molten salts can be much worse. The most important example of these effects is caused by deposits on the fireside of various heat transfer surfaces. This type of problem is difficult to reduce or solve by material selection. Instead, modifications should be made in operational conditions and maintenance procedures.

Erosion

Erosion is a very complex phenomenon, in which not only the properties of the construction material but also those of the eroding particles are significant, e.g. hardness, temperature, velocity and angle of impact.

Generally, an adherent, tough, and ductile oxide layer is required for good erosion resistance. Experience has shown that REM additions improves these properties and thus improve the erosion resistance at high temperatures.

Fabrication

Hot and cold forming

Hot working should be carried out within the temperature ranges given in Table 2.

Like other austenitic stainless steels, heat-resisting steels can also be formed in cold condition. However, as a result of their relatively high nitrogen content, the mechanical strength of certain grades is higher and consequently greater deformation forces will be required.

Machining

The relatively high hardness of austenitic stainless steels and their ability to strain harden must be taken into consideration in connection with machining. For more detailed data on machining, please see the Outokumpu machining guidelines available for grades 4845, 153 MA™ and 253 MA®, or contact Outokumpu, Avesta Research Centre.

Welding consumables

Table 7

Product form	ISO designation	Typical composition, %							Ferrite FN
		C	Mn	Cr	Ni	Si	N	Others	
Welding of 4948									
Covered electrode	19 9 or 308/308H[1]	0.06	1.1	20	10	0.7			5
Solid wire	19 9	0.05	1.8	20	9	0.4			10
Flux cored wire	19 9	0.06	1.5	19	9.5	0.4			5
Welding of 4878									
Covered electrode	19 9Nb	0.02	0.8	19.5	10	0.8		Nb	8
Solid wire	19 9Nb	0.05	1.2	19.5	10	0.8		Nb	10
Flux cored wire	19 9Nb	0.03	1.4	19	10	0.7		Nb	7
Welding of 153 MA™									
Covered electrode	253 MA[1]	0.08	0.7	22	10.5	1.5	0.18	Ce	9
Covered electrode	253 MA-NF[1]	0.08	1.0	19	10	0.7	0.16		0
Solid wire	253 MA[1]	0.07	0.6	21	10	1.6	0.15	Ce	9
Welding of 4833									
Covered electrode	23 12	0.05	1.0	24	13.5	0.8			15
Covered electrode	253 MA[1]	0.08	0.7	22	10.5	1.5	0.18	Ce	9
Solid wire	23 12	0.02	1.8	23.5	13.5	0.8			13
Flux cored wire	23 12	0.03	1.5	23	12.5	0.7			18
Welding of 4828									
Covered electrode	23 12	0.05	1.0	24	13.5	0.8			15
Covered electrode	253 MA[1]	0.08	0.7	22	10.5	1.5	0.18	Ce	9
Covered electrode	253 MA-NF[1]	0.08	1.0	19	10	0.7	0.16		0
Solid wire	23 12	0.02	1.8	23.5	13.5	0.8			13
Flux cored wire	23 12	0.03	1.5	23	12.5	0.7			18
Welding of 253 MA®									
Covered electrode	253 MA[1]	0.08	0.7	22	10.5	1.5	0.18	Ce	9
Covered electrode	253 MA-NF[1]	0.08	1.0	19	10	0.7	0.16		0
Solid wire	253 MA[1]	0.07	0.6	21	10	1.6	0.15	Ce	9
Welding of 4845									
Covered electrode	25 20	0.10	2.1	26	21	0.5			0
Solid wire	25 20	0.12	1.6	25.5	21	0.35			0
Welding of 4841									
Covered electrode	25 20	0.10	2.1	26	21	0.5			0
Solid wire	25 20	0.12	1.6	25.5	21	0.35			0

[1] Avesta Welding Designation

Welding

Outokumpu high temperature steels have good or very good weldability and can be welded using the following methods:

- Shielded metal arc (SMA) welding with covered electrodes. When welding grade 253 MA®, Avesta welding 253 MA-NF electrodes is suggested for applications at 650°C to 950°C. The absence of ferrite provides a stable, ductile microstructure in the weld metal. The 253 MA electrode can be used for applications involving temperatures over 950°C.

- Gas shielded welding, e.g., GTA (TIG), plasma arc and GMA (MIG). Pure argon is normally used as the shielding gas for TIG, while Ar + 0.03% NO or Ar + 30% He +2-2.5% CO2 is recommended for MIG welding. TIG/MIG weld joints have been found to give the best creep resistance compared to other weld processes.

- Submerged arc (SA) welding. The risk of hot cracking is less when welding 253 MA® compared to 4845 (310S). Basic fluxes are preferred.

Some general recommendations for the welding of the high temperature steels are:

1. Oxide layer on a component already exposed to high temperature must be removed by brushing/grinding before welding.

2. The penetration into base material is less for the high temperature steels compared to standard grades such as 4301/4404. Fluidity of the molten filler materials is also less. This necessitates somewhat greater bevel angles (60 -70°) and slightly increased root gap (2-3 mm) compared to standard austenitic grades.

More detailed information concerning welding procedures can be obtained from the Outokumpu Welding Handbook, available from our sales offices. Specialist support is available on requests.

Heat treatment

Heat treatment after hot or cold forming, or welding will often not be necessary because the material will be exposed to high temperatures during service. However, if that is not sufficient, the best option would be a proper solution annealing, with the second best choice being a stress relief annealing. Suitable temperature ranges for both treatments are given in Table 2.

Components, in which the material has become embrittled during service, will benefit from a rejuvenating solution anneal before any maintenance work, e.g. straightening or repair welding, is carried out.

Products

Table 8

Product	4948	4878	153 MA™	4833	4828	253 MA®	4845	4841
Hot rolled plate Quarto	✓	✓	✓	✓	✓	✓	✓	✓
Hot rolled coil and sheet	✓	✓		✓	✓	✓	✓	✓
Cold rolled coil and sheet	✓	✓	✓	✓	✓	✓	✓	✓
Rod coil	✓	✓	✓	✓		✓	✓	✓
Bars	✓	✓		✓	✓	✓	✓	✓
Semifinished (bloom, billet, ingot, slab)	✓	✓	✓	✓	✓	✓	✓	✓
Pipe	✓	✓	✓	✓		✓	✓	
Castings						✓[1]		

[1] Manufactured under license by Scana Stavanger AS, Norway, Fondinox SpA, Italy

Material standards

Table 9

EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10095	Heat resisting steels and nickel alloys
EN 10302	Creep resisting steels and nickel alloys
ASTM A167	Stainless and heat-resisting Cr-Ni steel plate/sheet/strip
ASTM A240 / ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purpose
ASTM A276	Stainless and heat-resisting steel bars/shapes
ASTM A312 / ASME SA-312	Seamless and welded austenitic stainless steel pipe
ASTM A314	Standard specification for stainless steel billets and bars for forging
ASTM A358 / ASME SA-358	Electric fusion-welded austenitic Cr-Ni alloy steel pipe for high temperature
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 and heat-resisting steel bars and shapes for use in boilers and other pressure vessels

Own notes

Working towards forever.

We work with our customers and partners
to create long lasting solutions for the tools
of modern life and the world's most critical problems:
clean energy, clean water and efficient infrastructure.
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1011EN-GB:6. Centrumtryck AB, Avesta, Sweden. November 2013.

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stainless steel & high performance alloys

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