SANDVIK 353 MA
TUBE AND PIPE, SEAMLESS

DATASHEET

Sandvik 353 MA is an austenitic chromium-nickel steel alloyed with nitrogen and rare earth metals. The grade is characterized by:

- High creep strength
- Very good resistance to isothermal and cyclic oxidation
- Very good resistance to combustion gases
- Very good resistance to carburization
- Good resistance to nitriding gases
- Good structural stability at high temperatures
- Good weldability
- Maximum operating temperature is approx. 1175°C (2150°F)

Trademark information: 353 MA is a trademark owned by Outokumpu OY.

STANDARDS

- UNS: S35315
- EN Number: 1.4854

Product standards

- ASTM A312
- EN 10297-2

CHEMICAL COMPOSITION (NOMINAL)

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	N	Ce*
0.07	1.6	1.5	≤0.040	≤0.015	25	35	0.16	0.05

* The quantity of other rare earth metals should be added to cerium, because the addition takes the form of misch metal containing about 50 % Ce.

APPLICATIONS

The excellent oxidation and carburization resistance of Sandvik 353 MA in constantly carburizing gas, makes it particularly suitable grade for high-temperature petrochemical furnaces. The high nitriding resistance is very beneficial for service in high temperature cracked ammonia gas. Typical applications are:

- Ethylene furnace, radiant cracking tubes
- EDC furnace tubes
- Tubes in wast heat recovery systems in the metallurgical industry, e.g. recuperators

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- Tubes in heat treatment furnaces, e.g. muffle tubes, radiant tubes, thermocouple protection tubes, burner components, furnace rollers
- Recuperator tubes in chemical waste and sewage sludge incineration

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CORROSION RESISTANCE

Oxidation

Owing to the high silicon content and the addition of rare earth metals (REM), Sandvik 353 MA has very high resistance to oxidation. The REM addition also contributes to improved scale adhesion during temperature cycling. Figure 1, which shows the measured weight increase after 45 h cyclic oxidation at different temperatures, illustrates how Sandvik 353 MA compares with some other high temperature grades. Weight increase after longer exposure at 1150°C (2100°F) is shown in Figure 2. The weight increase shown in Figure 1 and Figure 2 includes the weight of any spalled oxide.

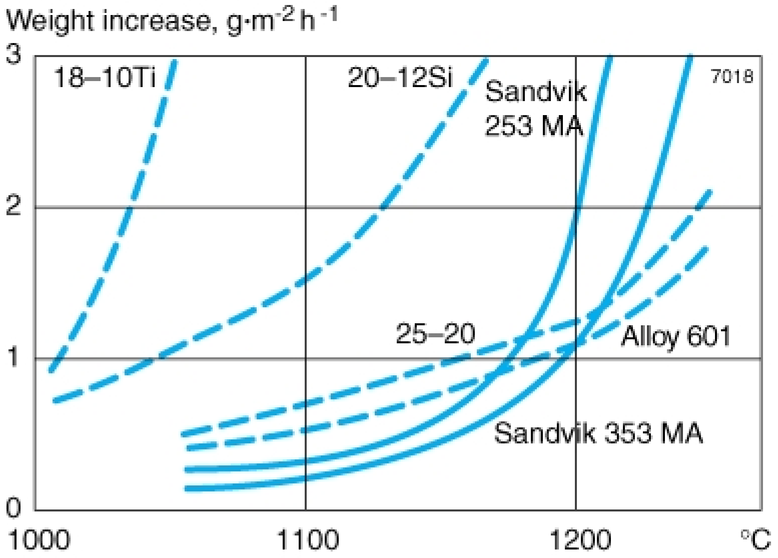

Figure 1. Weight increase for Sandvik 353 MA and other grades after 45h oxidation.

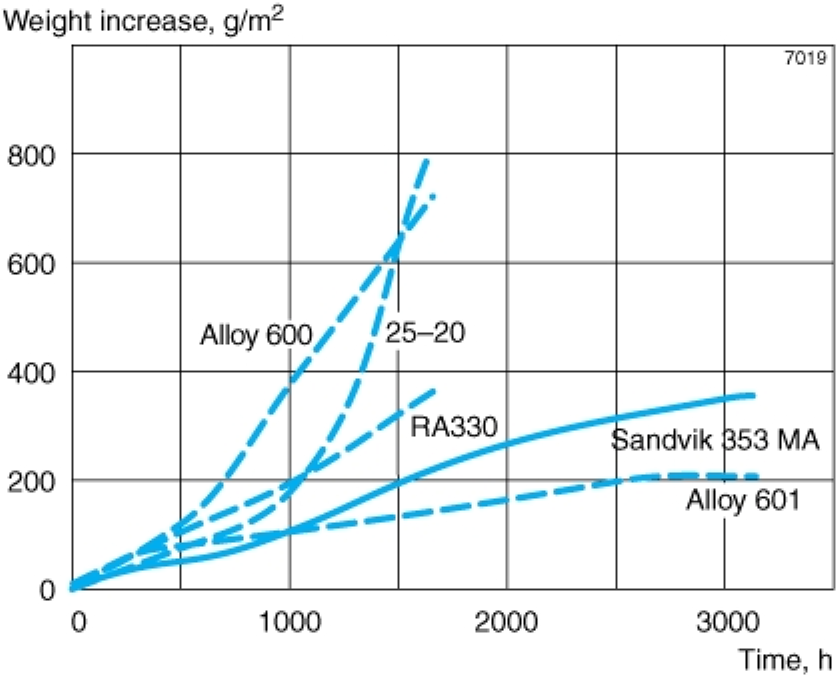

Figure 2. Weight increase versus time during oxidation at 1150°C (2000°F).

Carburizing and nitrogen pick-up

Corrosion attack by carburization or nitrogen pick-up usually follows a parabolic rate law: $x^2=k_p * t+C$, where x is the attack, expressed as penetration depth or weight increase, k_p a rate constant, t exposure time and C a constant accounting for the initial attack (which follows a different rate law).

Due to its ability to form a dense chromium oxide and its high nickel content, Sandvik 353 MA also has good resistance to carburization and nitrogen pick-up.

Figure 3 shows the measured rate constants for carburization tests of various alloys at different temperatures. Cyclically carburizing-oxidizing conditions are often more detrimental, but, as Figure 4 shows, Sandvik 353 MA is able to resist these conditions better than other alloys.

In nitrogen pick-up tests, Figure 5, Sandvik 353 MA showed similar resistance to Alloy 601.

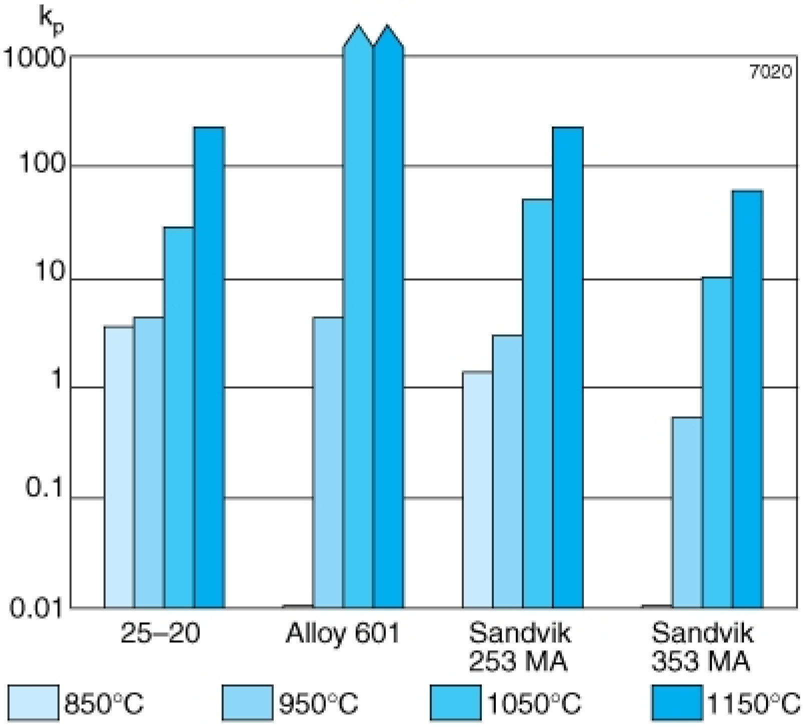

Figure 3. Rate constant for total carburization; a_c=1; PO₂~0.

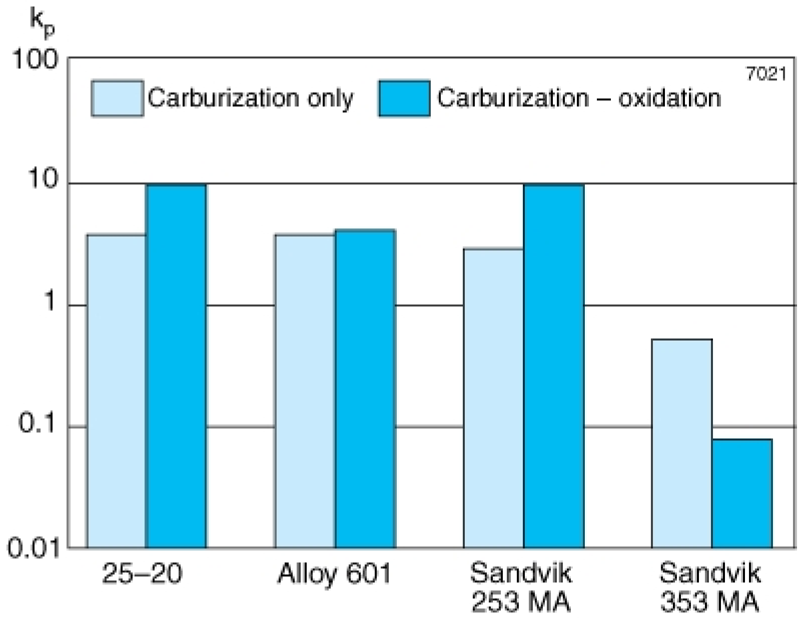

Figure 4. Rate constant for total carburization and carburization-oxidation. Carburization: 950°C(1740°F); a_c=1; PO₂~0. Oxidation: 1050°C(1920°F); a_c~0; PO₂=0.21atm.

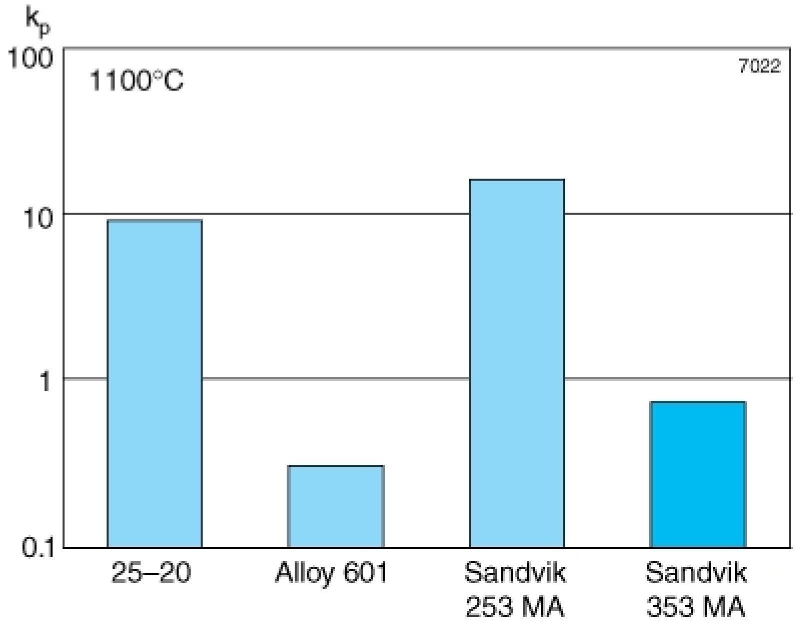

Figure 5. Rate constant for nitrogen pick-up in cracked ammonia.

Sulphur attack

Alloys with high nickel content are generally sensitive to attack by sulphur at higher temperatures. However, under oxidizing conditions a protective oxide will be able to form, contributing to an improved resistance to sulphur attack. This is illustrated in Figure 6, which shows the rate constant for different alloys in different sulphidizing-oxidizing conditions. Again, the dense oxide formed on Sandvik 353 MA is shown to be advantageous.

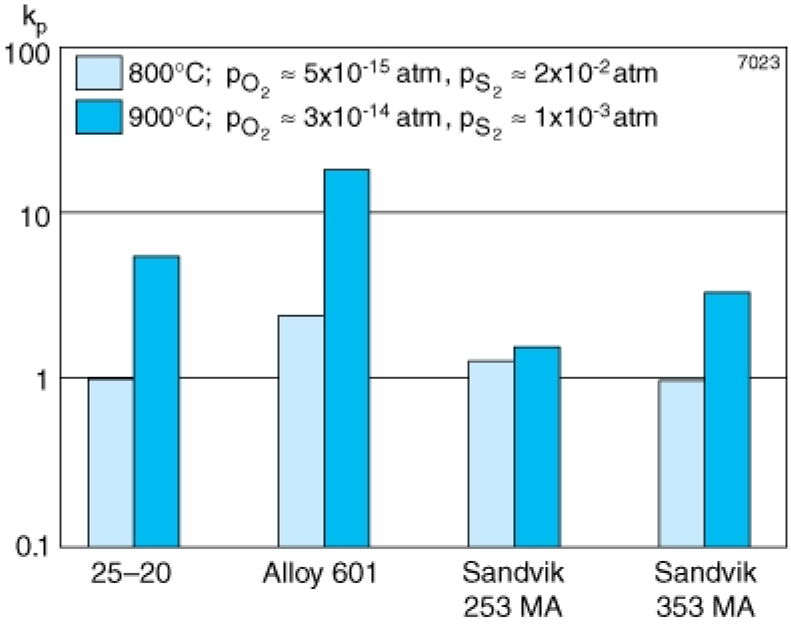

Figure 6. Rate constant for sulphidation-oxidation.

BENDING

Due to its higher strength compared with conventional stainless steels, higher deformation forces are required for cold bending of Sandvik 353 MA.

Annealing after cold bending is not normally necessary, but this decision should be made taking account of the degree of bending and the service conditions.

FORMS OF SUPPLY

Seamless tube and pipe in Sandvik 353 MA is supplied in dimensions up to 200 mm (7.9 in.) outside diameter in the solution-annealed and white pickled condition, or solution annealed by a bright-annealing process.

Other forms of supply

- Bar steel

HEAT TREATMENT

Tubes are delivered in the heat treated condition. If another heat treatment is needed after further processing, the following is recommended:

Stress relieving

1000–1100°C (1830–2010°F), 10–15 minutes, cooling in air.

Solution annealing

1100–1200°C (2010–2190°F), 5–20 minutes, rapid cooling in air or water.

MECHANICAL PROPERTIES

Metric units, at 20°C

Proof strength		Tensile strength	Elongation		Hardness
$R_{p0.2}$	$R_{p1.0}$	R_m	$A^{a)}$	$A_{2"}$	Vickers
MPa	MPa	MPa	%	%	
≥300	≥340	≥650	≥40	≥35	≈160

1 MPa = 1 N/mm^2

a) A is based on an original gauge length of 5.65 $\sqrt{S_0}$.

Imperial units, at 68°F

Proof strength		Tensile strength	Elongation		Hardness
Rp0.2	Rp1.0	Rm	Aa)	A2"	Vickers
ksi	ksi	ksi	%	%	
≥44	≥49	≥94	≥40	≥35	≈160

a) A is based on an original gauge length of 5.65 √S0.

At high temperatures

Metric units

Temperature	Proof strength		Tensile strength
	$R_{p0.2}$	$R_{p1.0}$	R_m
°C	MPa	MPa	MPa
100	≥228	≥261	≥536
200	≥195	≥223	≥498
300	≥166	≥190	≥470
400	≥152	≥173	≥444
500	≥143	≥163	≥437
600	≥138	≥159	≥422

Imperial units

Temperature	Proof strength		Tensile strength
	$R_{p0.2}$	$R_{p1.0}$	R_m
°F	ksi	ksi	ksi
200	≥33	≥38	≥78
400	≥28	≥32	≥71
600	≥23	≥27	≥68
800	≥21	≥24	≥63
1000	≥20	≥23	≥62
1100	≥20	≥23	≥61

$R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2 % offset and 1.0% offset yield strength, respectively.

Creep strength (average values)

Metric units

Temperature, °C	Creep strength 1%		Creep rupture strength	
	10 000 h	100 000 h	10 000 h	100 000 h
	MPa	MPa	MPa	MPa
550	149	86	206	129
600	88	52	127	80
650	54	33	82	52
700	35	21	56	36

Metric units

Temperature, °C	Creep strength 1%		Creep rupture strength	
	10 000 h	100 000 h	10 000 h	100 000 h
	MPa	MPa	MPa	MPa
750	22	14	39	25
800	15	9.7	28	18
850	10.5	6.9	20	14
900	8	5.1	15	10
950	6	3.9	11	6.7
1000	4.5	3.0	8	4.8
1050	3.5	2.3	6	3.5
1100	2.7	1.8	4.5	2.9

Imperial units

Temperature, °F	Creep strength 1%		Creep rupture strength	
	10 000 h	100 000 h	10 000 h	100 000 h
	ksi	ksi	ksi	ksi
1100	16.5	9.5	23.2	14.7
1200	8.0	4.9	12.0	7.5
1300	4.8	3.0	7.8	5.1
1400	3.0	1.9	5.4	3.4
1500	1.9	1.3	3.6	2.5
1600	1.4	0.9	2.6	1.7
1700	1.0	0.6	1.9	1.2
1800	0.7	0.5	1.3	0.8
1900	0.5	0.4	0.9	0.5
2000	0.4	0.3	0.7	0.4

Proof strength				Tensile strength		Elongation		Hardness Vickers
Rp0.2		Rp1.0		Rm		Aa)	A2"	
MPa	ksi	MPa	ksi	MPa	ksi	%	%	
min.	min.	min.	min.	min.	min.	min.	min.	approx.
300	44	340	49	650	94	40	35	160

1 MPa = 1 N/mm2
a) A is based on an original gauge length of 5.65 √S0.

PHYSICAL PROPERTIES

Density: 7.9 g/cm^3, 0.28 lb/in^3

Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h °F
20	11	68	6.5
100	13	200	7.5

Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h °F
200	15	400	8.5
300	17	600	10
400	18	800	11
500	20	1000	12
600	22	1200	13
700	23	1400	14
800	25	1600	15
900	26	1800	15.5
1000	27	2000	16
1100	29		

Specific heat capacity

Temperature, °C	J/kg °C	Temperature, °F	Btu/ft h °F
20	480	68	0.11
100	500	200	0.12
200	530	400	0.13
300	555	600	0.13
400	575	800	0.14
500	590	1000	0.14
600	610	1200	0.15
700	625	1400	0.15
800	640	1600	0.16
900	655	1800	0.16
1000	665	2000	0.16
1100	680		

Thermal expansion[1)]

Temperature, °C	Per °C	Temperature, °F	Per °F
20-100	15.5	68-200	8.5
20-200	15.5	68-400	8.5
20-400	16.5	68-800	9
20-600	17	68-1000	9.5
20-700	17	68-1200	9.5
20-800	17.5	68-1400	9.5
20-900	18	68-1600	10
20-1000	18	68-1800	10
20-1100	18.5	68-2000	10.5

1) (x10^{-6})

Modulus of elasticity[1)]

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Temperature, °C	MPa	Temperature, °F	ksi
20	190	68	27.5
200	180	400	26
400	165	800	23.5
600	155	1000	23
700	150	1200	22
800	140	1400	20.5
900	135	1600	20
1000	130	1800	19
1100	125	2000	18

1) (x10^3)

Resistivity

Temperature, °C	μΩm	Temperature, °F	μΩin.
20	1.00	68	39
200	1.07	400	42
400	1.14	800	45
600	1.20	1000	47
700	1.22	1200	48
800	1.25	1400	49
900	1.28	1600	50
1000	1.30	1800	51
1100	1.32	2000	52

WELDING

The weldability of Sandvik 353 MA is good. Suitable methods of fusion welding are manual metal-arc welding (MMA/SMAW) and gas-shielded arc welding, with the TIG/GTAW method as first choice.

In common with all fully austenitic stainless steels, Sandvik 353 MA has low thermal conductivity and high thermal expansion. Welding plans should therefore be carefully selected in advance, so that distortions of the welded joint are minimized. If residual stresses are a concern, solution annealing can be performed after welding.

For Sandvik 353 MA, heat-input of <1.0 kJ/mm and interpass temperature of <100°C (210°F) are recommended.

Recommended filler metals

TIG/GTAW or MIG/GMAW welding

ISO 18274 S Ni 6082/AWS A5.14 ERNiCr-3 (e.g. Exaton Ni72HP)

MMA/SMAW welding

ISO 14172 E Ni 6182/AWS A5.11 ENiCrFe-3 (e.g. Exaton Ni71)

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