KARA Ferritic Stainless Steel

K44X

19% Chromium with Molybdenum, Niobium stabilized

KARA key for value

"X" marks the spot for exhaust applications. K44X guarantees:

- Just in time deliveries
- Reliable quality
- The continuous improvement that the automotive market demands

Key Features

- Elevated hot mechanical properties without the risk of σ phase formation at intermediate temperatures
- Resistance to high temperature oxidation and creep (up to 1,050°C)
- Good durability against thermal fatigue
- Good corrosion resistance in an exhaust gas environment
- Greater thermal conductivity and lower thermal expansion coefficient than austenitics
- Good weldability
- Easy to form

Chemical Composition

Elements (%)	C	N	Si	Mn	Cr	Nb	Mo
K44X	0.015	0.015	0.40	0.30	19	0.6	1.9

Typical values

European designation	American designation	IMDS
X2CrMoTi18-2/1.4521 [1]	Type 444 UNS S444001 [2]	336853368

[1] According to NF EN 10088-2 [2] According to ASTM A 240

This grade complies with:

- Aperam Stainless Europe - Safety Information Sheet for Stainless Steel
- European Directive 2000/53/EC on end-of-life vehicles and later modifications

Applications

- A range of parts used in vehicle exhaust lines and engines (manifolds, tubes, particulate filter, catalysor shells and EGR systems)

Product Range

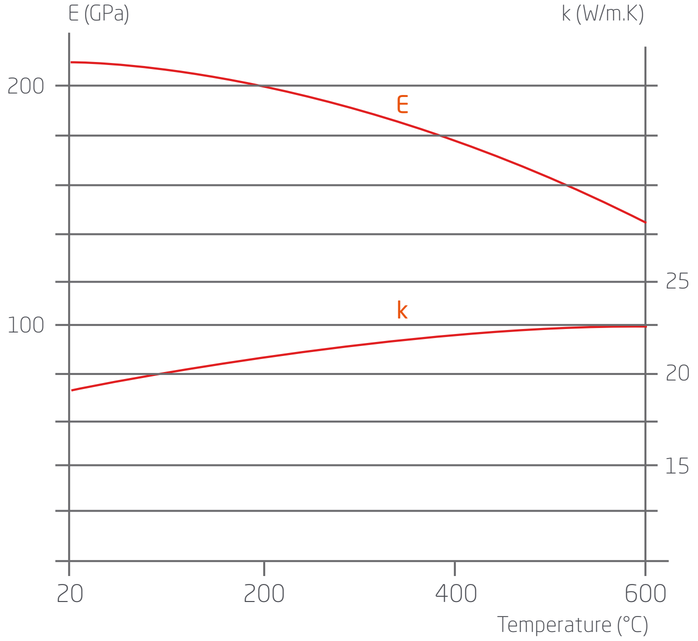
	Coils	Precision Strip	Precision Sheet	Tubes
Thickness (mm)	1.50 up to 2	0.06 up to 2.5	0.20 up to 2.5	0.80 up to 2
Width (mm)	up to 1,250	3 up to 700	40 up to 670	Ø 8 up to 168
Finish	2D	2R / 2B / 2D / 2H / 2F	2R / 2B / 2D / 2H / 2F	2D

Please contact us regarding all other dimensions, forms and finishes.

Physical Properties

Cold rolled and annealed sheet

Density	d	kg/dm³	20°C	7.7
Melting temperature		°C	Liquidus	1,447
Specific heat	c	J/kg.K	20°C	452
Thermal conductivity	k	W/m.K	20°C 600°C	19.7 22.8
Mean thermal expansion coefficient	α	10^{-6}/K	20-200°C 20-400°C 20-600°C 20-800°C	10.6 11 11.4 11.9
Electric resistivity	ρ	Ω mm²/m	20°C	0.66
Magnetic resistivity	μ	at 0.8 kA/m DC or AC	20°C	751
Young's modulus	E	GPa	Rolling direction 20°C	215



Mechanical Properties

Test piece

Length = 80 mm (thickness < 3 mm)
Length = 5.65 √ S_o (thickness ≥ 3 mm)

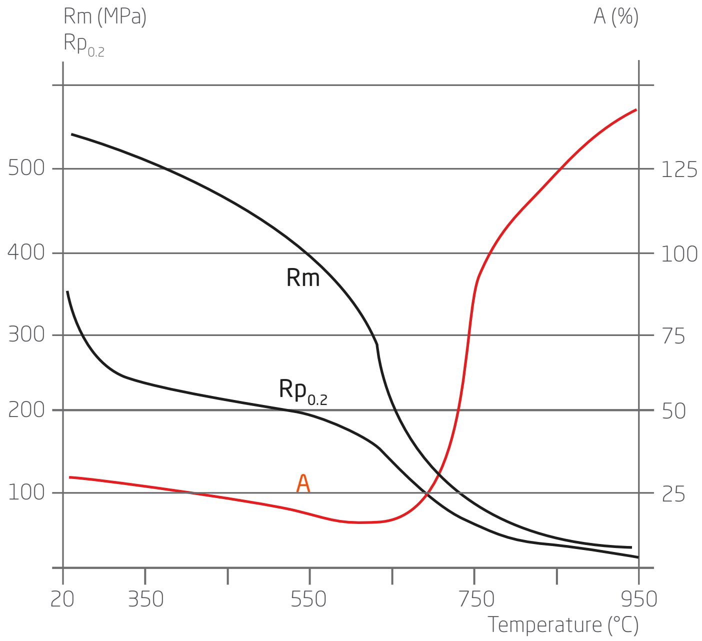
In the annealed condition

In accordance with ISO 6892-1, part 1
Test piece perpendicular to rolling direction

Grade	Condition	Rm[1] (MPa)	$Rp_{0.2}$[2] (MPa)	A[3] %	HRB
K44X	Cold- rolled	540	370	29	86

1 MPa = 1 N/mm² - Typical values
[1] Ultimate Tensile Strength (UTS) - [2] Yield Strength (YS) - [3] Elongation (A)

At high temperatures (Typical values)



High Temperature Properties

Creep sag test

K44X's high level of niobium allows for good mechanical resistance at high temperatures and optimized creep resistance as described in the table below (with test conducted at 1,000°C).

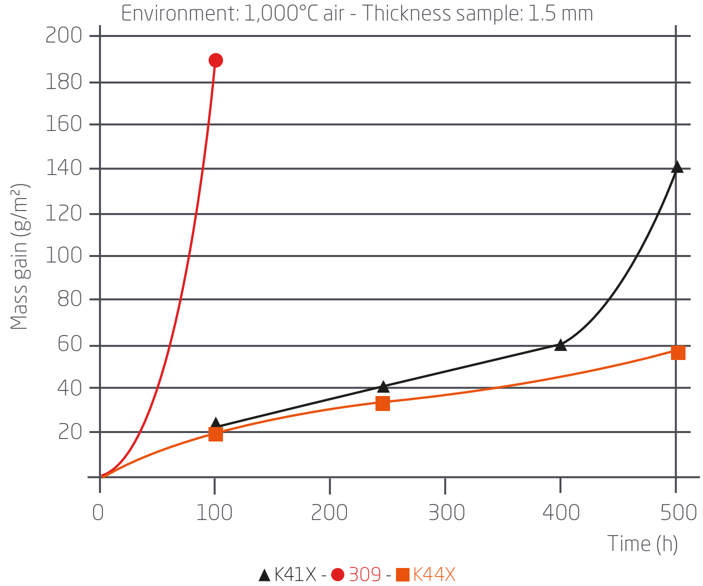
Thickness 2 mm - 1,000°C - duration: 100 h

	K44X	K41X	309
Deflection (mm)	6	21	30

K44X's chemical composition has been optimized to meet the needs of a range of exhaust line parts, including the manifold, catalysator and particulate filter.

As many of these parts undergo regular stop and start cycles, K44X takes into account resistance to thermal fatigue and the need to develop an oxidant protective layer.

Oxidation resistance



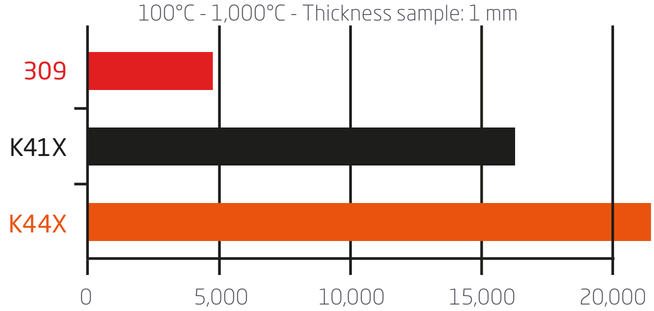
The chromium diffusion in K44X's matrix ferritic is easier than in an austenitic matrix. This prevents a decrease in chromium and favours the formation of an oxidant protective layer rich in chromium.

K44X's expansion coefficient is closer to those from oxide layer which is developed, compared to austenitic grades.

The thermal stresses are also much lower. Practically no scaling of the layer is observed. This results in a low material loss.

At high temperatures, K44X exhibits a high oxidation resistance, particularly in cyclic oxidation, which allows it to be used up to 1,050°C.

Thermal fatigue



During testing, which were carried out on V shape samples for 100-1,000°C, K44X exhibited very good behaviour compared to both the austenitic 309 and K41X grades.

Corrosion Resistance

Pitting corrosion

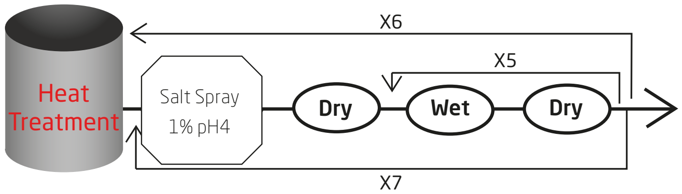
Thanks to its Chromium and Molybdenum levels and stabilization with Niobium, K44X offers very good resistance to all types of corrosion. Its PREN value is 26, which translates into a very good pitting corrosion resistance, superior to those of such austenitic grades as 304D.

Pitting corrosion values (MV/ECS) for four conditions

Grade designation	NaCl 0.02M, 23°C	NaCl 0.02M, 50°C	NaCl 0.5M, 23°C	NaCl 0.5M, 50°C
304D	540	385	305	175
K44X	775	550	555	310

Salt corrosion resistance

In addition to the ongoing need for durability, car manufacturers have increasingly demanded an aesthetically appealing exhaust line.
To answer this need, we developed a specific test that simulates the corrosive attacks on the exhaust line with sequences of dry, salt spray and heat treatments up to 300°C.
The samples are classified according to the oxidation and corrosion behaviour.
Our K44X exhibits a higher corrosion resistance than the 304D austenitic grade.



Trials carried out in climatic chamber to simulate the external corrosion phenomenon.
(Cycle duration: 24 hours, Test total duration: 500 hours, Heat treatment: 300°C, Salt spray Na Cl: 10 000 ppm)

Grade classifications in regards to cosmetic corrosion

Grade	K09X	K39M	K33X	K41X	304D	K44X [1]
Cosmetic corrosion	--	0	+	+	+	++

[1] EN 1.4521, Type 444

-- : Insufficient / - : Acceptable / 0 : Medium / + : Good / ++ : Excellent

Forming

K44X meets all forming requirements at low temperatures especially for manifolds where the designs are more complicated. This can be used through our tests, which simulate the stretching and deep drawing phenomenons that occur during stamping.

The stretching capacities are quantified by the measurement of the deflection Erichsen. The deep drawing capacity is measured by the Limiting Drawing Ratio index. K44X exhibits similar forming characteristics as K41X.
With exhaust lines becoming increasingly complex, tubes need to have as small a bending radius as possible. The bending capacity is measured by the Limiting Bending Ratio, which is the ratio between the mean radius of bending and the diameter of the tube.

Erichsen trial (stretching trial) & LDR (Deep drawing trial)

Grades	European designation	Erichsen deflection*(mm)	LDR (mm)
K44X	1.4521	10	2.05
K41X	1.4509	9.9	2.08

*Typical values – 1.5 mm thick sheet with lubricant Mobilux EP00

Bending of welded tubes

Bending (laboratory results)	Ra = R/D mini
Tube Ø 35 mm x 1.5 mm	1.1

Ra = bending ratio - D = tube diameter - R = bend radius
Angle 90°

Welding

Our K44X grade can be resistance welded using both spot and seam techniques. Good results are obtained without post treatment so long as the weld is sufficiently forged.

Welding process	No filler material	With filler metal			Shielding gas*
	Typical thicknesses	Thicknesses	Filler material		* Hydrogen and nitrogen forbidden in all cases
			Rod	Wire	
Resistance: spot, seam	≤ 2 mm				
TIG	< 1.5 mm	> 0.5 mm	G 19 12 3L Or G 18 LNb		Ar Ar + He
PLASMA	< 1.5 mm	> 0.5 mm		G 19 12 3L or G 18 LNb	Ar Ar + He
MIG		> 0.8 mm		G 19 12 3L (Si) or G 18 LNb	Ar + 2% CO_2 Ar + 2% O_2 Ar + 2% CO_2 + He
Electrode		Repairs	E 19 12 3L		
Laser	< 5 mm				He Under conditions: Ar

G 18LNb according to EN ISO 14343 A or 430LNb according to EN ISO 14343 B, 1.4511 according to EN 1600: for high thermal fatigue requirement. G 19 12 3L (Si) according to EN ISO 14343 A or ER 316L (Si) according to ISO 14343B, 1.4430 according to ISO 1600: for optimized corrosion resistance requirement

The addition of hydrogen or nitrogen to the argon must be avoided as this reduces weld ductility. For similar reasons, the use of nitrogen is forbidden and the use of CO_2 must be restricted to 3%. In order to restrict grain growth in the HAZ, the use of excessive welding power must be avoided. For example, in automatic TIG welding, the power should not exceed 2.5 kJ/cm for a sheet thickness of 1.5 mm. As a further example, pulsed MIG/MAG welding has a lower power input than conventional MIG welding and enables better control of both bead geometry and grain size.

The K44X also exhibits excellent high- and medium-frequency induction weldability.
Post-weld heat treatment is generally not necessary. Welds must be mechanically or chemically descaled and then passivated and decontaminated.
Oxyacetylene torch welding must be avoided.

www.aperam.com
stainless@aperam.com