made for life

KARA ferritic stainless steel offer grade K44X

Chemical composition

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

Typical values

European designation [1]	American designation [2]
X2CrMoTi18-2	type 444 UNS S44400
1. 4521	IMDS n° 336853368

[1] In accordance with EN 10088-2

[2] In accordance with ASTM A 240

This grade complies with:

- Stainless Europe Materials Safety Data Sheet No. 1: stainless steels (European Directive 2001/58/EC).
- European Directive 2000/53/EC relating to end-of-life vehicles and Annex II dated 27 June 2002.

General characteristics

The principal features of our **K44X** grade are:

- Elevated hot mechanical properties without risk of σ phase formation at intermediate temperatures
- Resistance to high temperature oxidation and creep up to 1050°C.
- Good durability in thermal fatigue
- Good corrosion resistance in exhaust gas environment
- Greater thermal conductivity than austenitics and a lower thermal expansion coefficient
- Good weldability
- Ease of forming

"X" for exhaust means the key for

- Just in time deliveries
- Reliable quality
- Continuous improvement as required by the automotive market

Applications

- Different parts from exhaust line of vehicles and engine environment (manifolds, tubes, particulate filter, catalysor shells and EGR systems).

Product range

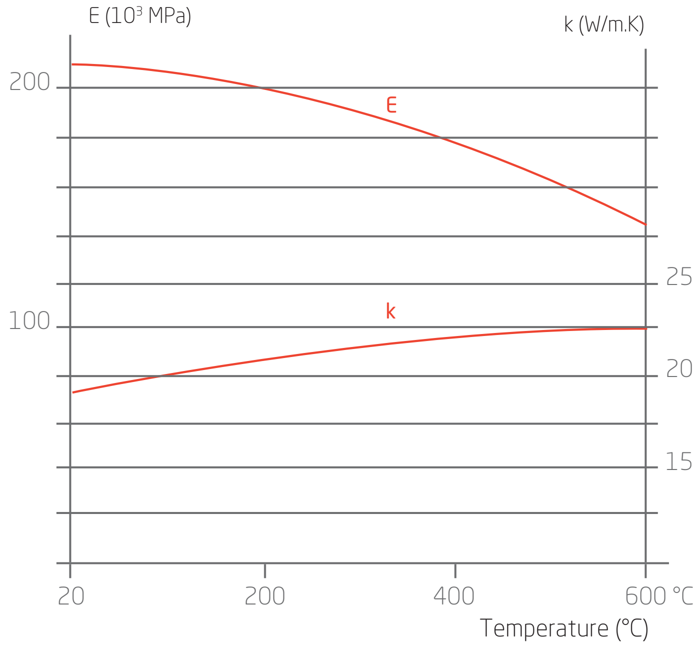
Forms: sheets, blanks, coils, strips, tubes
Thicknesses: from 0.2 to 2.0 mm
Width: according to thicknesses, consult us.
Finishes: cold-rolled

KARA
key for value

Physical properties

On cold-rolled sheet. In the annealed condition
(Typical values)

Density	d	kg/dm³	20 °C	7.7
Melting temperature		°C	Liquidus	1447
Specific heat	c	J/kg.K	20 °C	452
Thermal conductivity	k	W/m.K	20 °C 600 °C	19.7 22.8
Mean coefficient of thermal expansion	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 permeability	μ	at 0.8 kA/m DC or AC	20 °C	751
Modulus of elasticity	E	MPa.10³	Rolling direction 20 °C	215



Mechanical properties

In the annealed condition
In accordance with ISO 6892-1, test specimen perpendicular to the rolling direction

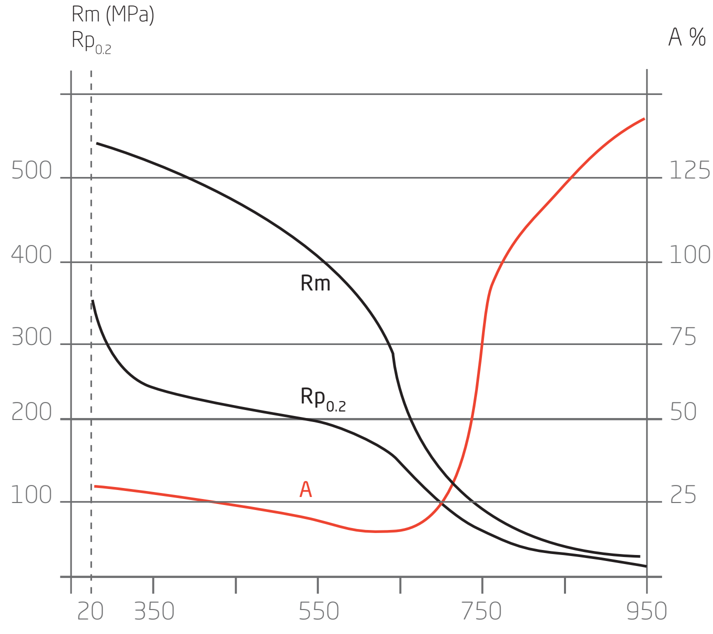
Test specimen
L = 80 mm (thickness < 3 mm)
L = 5.65 √So (thickness ≥ 3 mm)

Présentation	Rm(1) (MPa)	$Rp_{0.2}$ (2) (MPa)	A(3) (%)	HRB
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

The chemical composition of the **K44X** has been optimized to fulfill the characteristics required by the different parts from exhaust line as the manifold, the catalysator, or the particulate filter. Indeed a lot of starting up and stop cycles are applied to these parts. The first criteria taken into account were the resistance to thermal fatigue and the capacity to develop an oxidant protective layer.

Creep Sag-Test at 1000°C
Thickness = 2mm

The high level of niobium in the **K44X** permits a good mechanical resistance at high temperature and an optimized creep resistance as described in the table with a test at 1000°C.

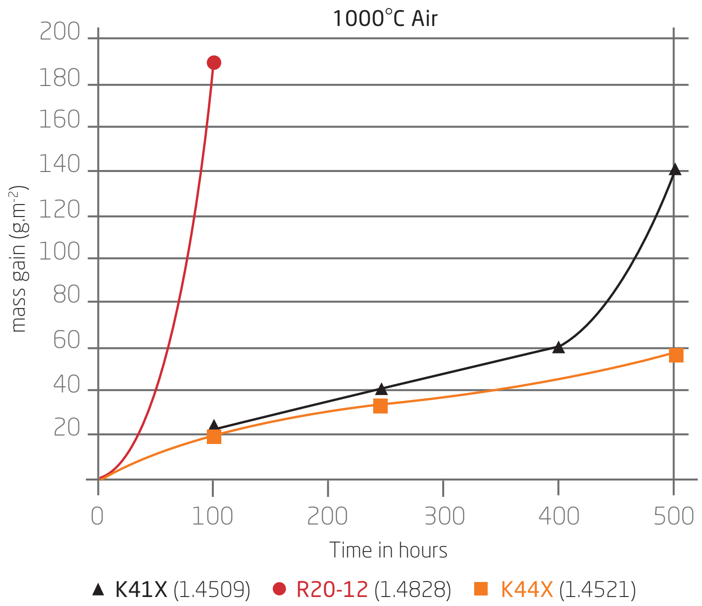
Creep sag test 1000°C- duration: 100 h	K44X	1.4509 K41X	1.4828 R20-12
Deflection (mm)	6	21	>30

Oxidation resistance

Environment: air
Thickness sample: 1.5mm

The chromium diffusion in the matrix ferritic of the **K44X** is made easier compared to an austenitic matrix.This permits to avoid the impoverishment in chromium and favours the formation of an oxidant protective layer rich in chromium.
The expansion coefficient of the **K44X** is closer to those from oxide layer which is developed, compared to austenitic grades.

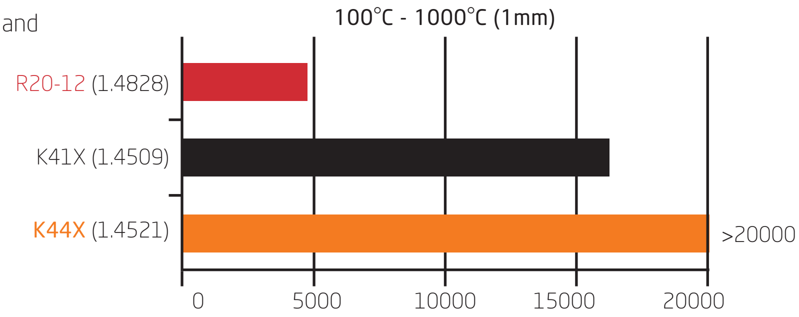
The thermal stresses are also much lower. Practically no scaling of the layer is observed. This results to a low material loss.
At high temperature, our **K44X** exhibits a high oxidation resistance, particularly in cyclic oxidation, which allows his use up to 1050°C.



Thermal fatigue

Thickness sample: 1 mm

Our tests, carried out on V shape samples for 100-1000°C, exhibit a very good behaviour of the **K44X** compared to austenitic 1.4828 and to the 1.4509.



Corrosion resistance

Pitting Corrosion Resistance

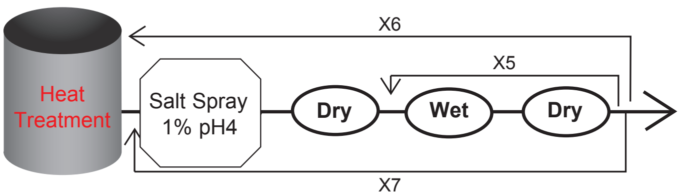
The **K44X** presents a very good resistance to all types of corrosion thanks to its Cr level, its Mo level and its stabilization with Nb. Its PREN value is 26 translating into a very good pitting corrosion resistance, superior to those of austenitic grades like 304D (18-9ED).

Pitting corrosion values (MV/ECS) for 4 conditions

Grade designation	NaCl 0.02M, 23°C	NaCl 0.02M, 50°C	NaCl 0.5M, 23°C	NaCl 0.5M, 50°C
304D (18-9ED)	540	385	305	175
K44X	775	550	555	310

Salt corrosion Resistance

Except for the durability criterion, the car manufacturers have more and more requirements regarding the cosmetic of the exhaust line.
Therefore, we have developed a specific test simulating the corrosion 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 austenitic 1.4301.



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 designation	Insufficient	acceptable	medium	good	very good
K09X	■				
K39M	■	■	■		
K33X	■	■	■	■	
K41X	■	■	■	■	
18-9ED	■	■	■	■	
K44X	■	■	■	■	■

Grades ranking regarding cosmetic corrosion.

Forming

Our **K44X** fulfils completely the forming requirements at low temperature especially for manifolds where the designs are more complicated. It can be verified through our tests which simulate the stretching and deep drawing phenomenons occurring 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.
The **K44X** exhibits similar forming characteristics as the K41X.
The design of exhaust line becoming more complicated, the tubes must have bending radius as small 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.

Deep drawing (LDR) / Stretching (Erichsen test)

Grade designation	EN	LDR*	Deflection Erichsen (mm)*
K44X	1.4521	2.05	**10**
K41X	1.4509	2.08	9.9

* on samples thickness 1.5mm with lubricant mobilux EP00

Bending of welded tubes

Bending	Ra=R/Dmini
Tube Ø 35 x 1.5	1.1

results laboratory

Ra: Bending ratio
D: Tube diameter
R: Bending radius

Welding

Our **K44X** grade can be resistance welded by spot or seam techniques. Good results are obtained without post treatment provided if the weld is sufficiently forged.
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 use of CO_2 is 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.

Welding process	Without filler metal	With filler metal			Shielding gas*
	Typical thicknesses	Thicknesses:	Filler metal		* 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		Argon Argon + Helium
PLASMA	< 1.5 mm	> 0.5 mm		G 19 12 3L or G 18 LNb	Argon Argon + Helium
MIG		> 0.8 mm		G 19 12 3L (Si) or G 18 LNb	Argon + 2% CO_2 Argon + 2% O_2 Argon + 2% CO_2 + Helium
Electrode		Repair	E 19 12 3L		
Laser	< 5 mm				Helium Under conditions: Argon

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

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