Alleima

Nanoflex™
Strip steel
Datasheet

Nanoflex™ is a precipitation hardening, austenitic stainless steel specifically designed for applications requiring high strength and good ductility. Mechanical strength can be increased substantially by heat treatment (ageing) of the final product, after first taking advantage of a soft 'as-delivered' condition, favorable for forming.

Normally, strip steel in Nanoflex™ is delivered in the cold rolled condition, but there is also a possibility of using the grade in the annealed condition and still reach a comparably high strength, solely by heat treatment.

Nanoflex™ is characterized by:

- Very high tensile strength with comparably good ductility
- Very high ageing effect
- Hardenable by heat treatment from the annealed condition
- No softening after exposure to temperatures up to 450°C (842°F)
- Good weldability

Standards

- ASTM: A693
- UNS: S46910

Chemical composition (nominal)

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Ti	Al
≤0.02	≤0.5	≤0.5	≤0.020	≤0.005	12	9	4	2.0	0.9	0.4

Applications

Nanoflex™ is highly suitable for products requiring good corrosion resistance, high strength and good ductility in the final product, combined with high formability in the 'as delivered' condition. It is especially suitable for complicated designs that still have high requirements on the strength of the final product. It also provides an opportunity for reaching high strength levels in relatively heavy gauge components.

One suitable application is statically loaded springs, especially when a low relaxation at elevated temperatures is required. Nanoflex™ is, however, less suitable for applications exposed to high dynamic stresses, as the same high fatigue strength as in an ordinary stainless spring steel, like Alleima® 12R11 (type ASTM 301), cannot be reached.

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Corrosion resistance

Nanoflex™ has better corrosion resistance than ASTM 304L. In this respect, it is superior to hardened and tempered martensitic chromium steels.

Pitting corrosion

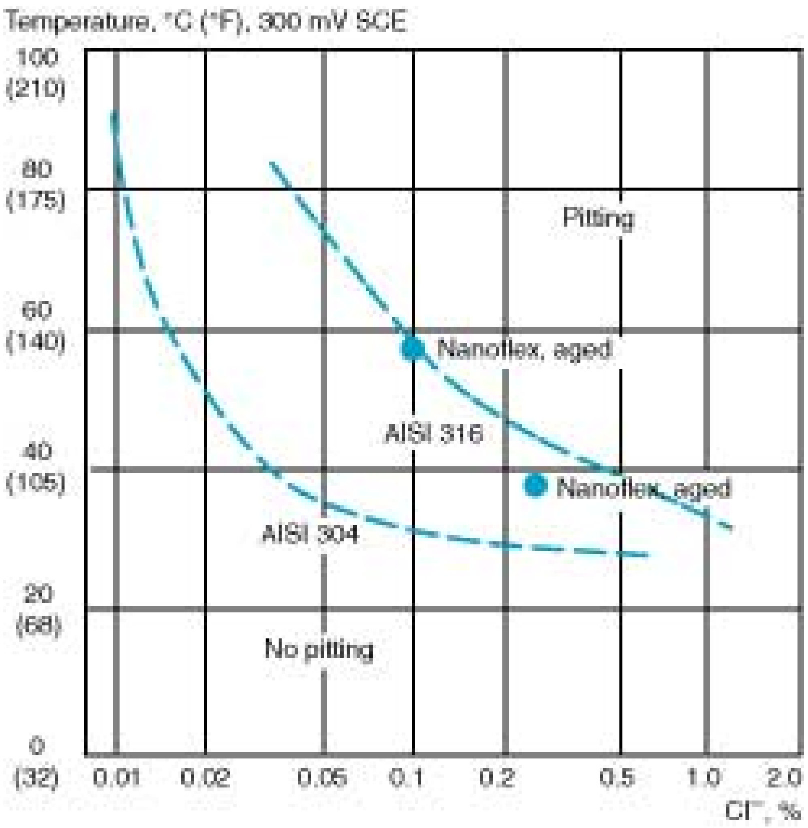

Figure 1: Critical pitting temperatures (CPT) for Nanoflex™, ASTM 304 and ASTM 316 at varying concentrations of sodium chloride. Potentiostatic determinations at +300 mV (SCE), pH = 6.0.

General corrosion

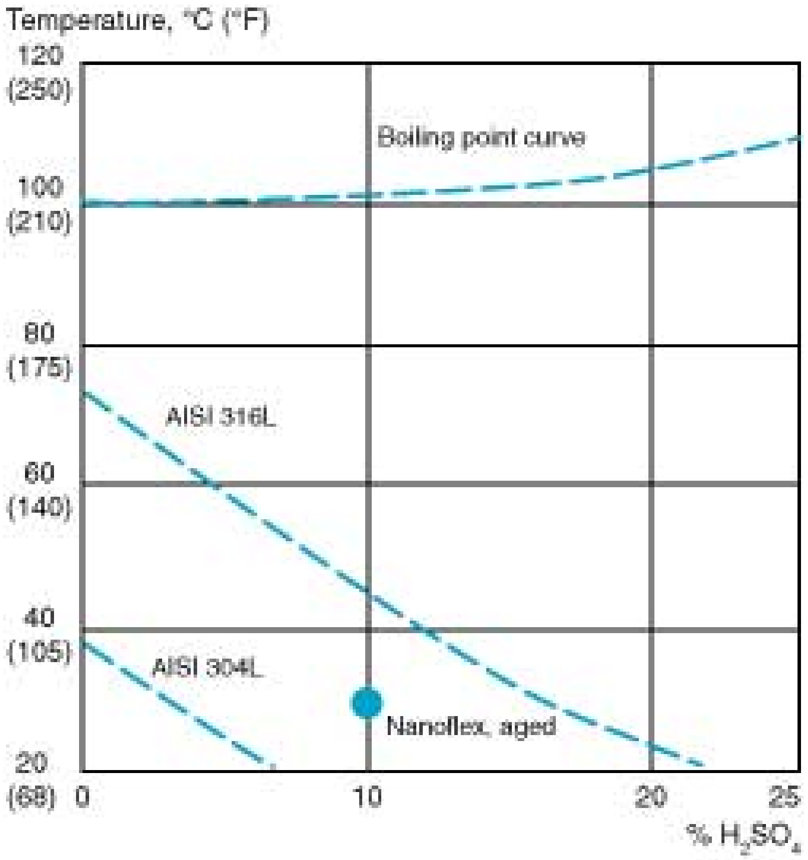

Figure 2: Isocorrosion diagram for Nanoflex™, ASTM 304L and 316L in stagnant sulfuric acid. The curves for ASTM 304L and 316L and the dot for Nanoflex™ represent a corrosion rate of 0.1 mm/year.

Bending

Nanoflex™, because of the very high ageing effect, has good opportunities for forming in a soft condition and still reaching a high tensile strength in its final condition. This is illustrated by the diagrams in fig. 3-4. In fig. 3, the tensile strengths, necessary to reach the same final tensile strength of about 1850 MPa after ageing, are indicated for Nanoflex™ and compared to some other Alleima grades. In fig. 4, a comparison of the bendability for the same materials in corresponding cold rolled tensile strengths is given.

The bending tests were carried out according to Swedish Standard SS 11 26 26 method 3, i.e. a test piece with a 35 mm width is bent in a 90° V-block with a 25 mm die opening, with the burrs from blanking, facing into in the bend. The minimum bending radius, without crack formation, for three test pieces is determined.

For very severe forming cases, the possibility of hardening Nanoflex™ from the annealed condition might be an option, see section 'Heat treatment'.

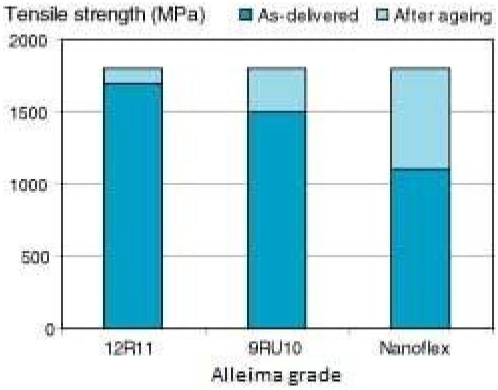

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Figure 3. 'As delivered' tensile strength needed to reach the same final tensile strength of about 1850 MPa after ageing in Nanoflex™ compared to two other spring steel grades.

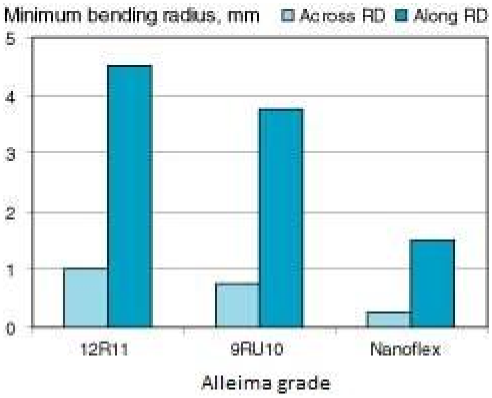


Figure 4. Minimum bending radius at 'as delivered' tensile strength according to figure 3. Testing has been made across and along the rolling direction (RD). Strip thickness 0.5 mm.

Forms of supply

Cold rolled strip can be supplied in coils, bundles, on spools or in cut lengths. Contact us for more informations.

The following range of thicknesses and widths can be supplied as standard. Contact us if other dimensions are required.

Thickness	Width	Thickness	Width
mm	mm	in.	in.
0.015 - 4.00*	2 - 300	0.0006 - 0.158	0.079 - 11.8

* Depending on requested tensile strength.

Tolerances

The thickness and width tolerances are +/- tolerances to the nominal size. The normal tolerance classes for most of our strip products are T2 and B1. Tighter tolerances as well as other tolerance limits can be offered upon request.

Mechanical properties

Static strength

The possible ranges for the mechanical properties, in both the cold rolled and aged conditions are indicated below. The strength level after ageing depends on the degree of cold deformation and, therefore, also on the dimension. For more information regarding ageing, see section 'Heat treatment'.

At 20°C (68°F), nominal values

Condition	Proof strength		Tensile strength	
	$R_{p0.2}$ [a)]		R_m	
	MPa	ksi	MPa	ksi
Annealed	max. 350	max. 51	max. 750	max. 109

Cold rolled	600-1800	87-261	950-1850	138-268
Cold rolled + Aged	1200-2500	174-363	1400-2600	203-377

1 MPa = 1 N/mm^2
a) $R_{p0.2}$ corresponds to 0.2% offset yield strength.

At high temperatures, nominal values

The values represent testing on material cold worked to 1650 MPa and subsequently aged at 475°C (887°F) for 4 hours.

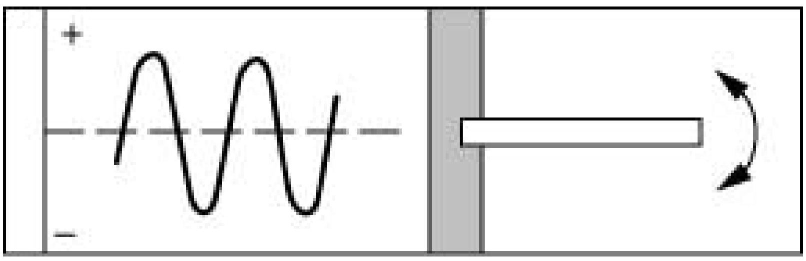
Temperature	Tensile strength, R_m	Temperature	Tensile strength, R_m
°C	**MPa**	**°F**	**ksi**
20	2450	68	356
100	2400	200	348
200	2200	400	319
300	2125	600	308
400	1975	700	287

Fatigue strength

Nanoflex™ has a comparably good fatigue strength at low tensile strengths. The tables show nominal results of testing at 20°C (68°F) after ageing at 475°C (887°F) for 4 hours. The fatigue strength represents a 50% probability of failure after 2 million cycles, with specimens parallel to the rolling direction.

Reversed bending stress

Average stress = 0
Bending transversal to rolling direction.

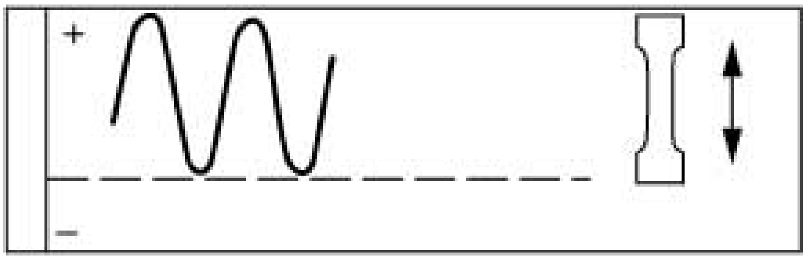


Tensile strength, R_m		Thickness	Fatigue strength, σ_u	σ_u/ R_m
MPa		**mm**	**MPa**	
Cold rolled	**Aged**			
1025	1600	0.30	± 490	0.31
1230	2000	0.50	± 450	0.23
1450	2200	0.50	± 500	0.23

1500	2350	0.50	± 450	0.19

Fluctuating tensile stress

Minimum stress = 0
Specimens parallel to rolling direction.



Tensile strength, R_m		Thickness	Fatigue strength, σ_u	σ_u/ R_m
MPa		**mm**	**MPa**	
Cold rolled	**Aged**			
1000	1470	0.30	370 ± 370	0.25

Physical properties

The physical properties of a steel relate to a number of factors, including alloying elements, heat treatment and manufacturing process, but the following data can generally be used for rough calculations. The values refer to testing at 20°C (68°F), unless otherwise stated.

Density: 7.9 g/cm^3, 0.29 lb/in^3
Resistivity: 0.9 µΩm, 35 µΩin.

Thermal conductivity for material in the aged condition

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h°F
20	14	68	8
100	16	200	9
200	18	400	10.5
300	20	600	11.5
400	21	700	12

Specific heat capacity for material in the aged condition

Temperature, °C	J/kg °C	Temperature, °F	Btu/ft h°F
20	455	68	0.11
100	490	200	0.12
200	525	400	0.13

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300	560	600	0.14
400	600	700	0.14

Thermal expansion, average values in temperature ranges

Nanoflex™ has a coefficient of thermal expansion close to that of carbon steel. This gives it definite design advantages over other austenitic stainless steels.

Metric units, ($x10^{-6}$/°C)

Grade	Temperature range, °C			
	30-100	**30-200**	**30-300**	**30-400**
Nanoflex (cold rolled)	11.5	11.5	11.5	11.5
Nanoflex (aged)	11.5	12	12	12.5
Carbon steel (0.2%C)	12.5	13	13.5	14
ASTM 304L	16.5	17.5	18	18

Imperial units, ($x10^{-6}$/°F)

Grade	Temperature range, °F			
	86-200	**86-400**	**86-600**	**86-700**
Nanoflex (cold rolled)	6.5	6.5	6.5	6.5
Nanoflex (aged)	6.5	6.5	7	7
Carbon steel (0.2%C)	7	7	7.5	7.5
ASTM 304L	9.5	9.5	10	10

Modulus of elasticity

The E-modulus is dependent on dimension, condition, direction and amount of cold reduction of the material.

The data below has been achieved by tensile testing cold rolled strip at 20°C (68°F) along the rolling direction. They are typical values only. After ageing, an increase of the E-modulus by 15-20x10^3 MPa can be expected.

Tensile strength	E ($x10^3$)	Tensile strength	E ($x10^3$)
MPa	**MPa**	**ksi**	**ksi**
1000	185	145	26.8
1200	180	174	26.1
1450	185	210	26.8

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1850	190	268	27.6

Heat treatment

In the annealed condition, Nanoflex™ has an austenitic microstructure. To be able to precipitation harden the material and take advantage of the remarkably high ageing (tempering) effect, the matrix has first to be hardened and, thereby, partly transformed to martensite. There are two ways of obtaining the necessary martensitic matrix in Nanoflex™.

Cold rolled condition:

The most common way, as in other metastable austenitic stainless steels, is to cold roll the material, whereby deformation martensite is formed. The difference is that the ageing effect is much higher in Nanoflex™ than in most other stainless steels. For optimum strength, the ageing should be made at 525°C (977°F) for 1 hour. Some examples of the ageing effect are given in the table.

Nominal values at 20°C (68°F)

Tensile strength		Tensile strength,	
MPa		**ksi**	
Cold rolled	**Aged**	**Cold rolled**	**Aged**
950	1300	138	189
1000	1600	145	232
1200	2000	174	290
1500	2300	218	334
1800	2500	261	363

Annealed condition:

With Nanoflex™ there is another way to obtain a martensitic matrix - by an isothermal treatment at a subzero temperature. This gives an opportunity to use the grade in the soft annealed condition for severe cases of forming and then utilize its ability to still reach a comparably high level of hardness after heat treatment. The required heat treatment cycle and the resulting properties are:

Austenitizing: 1200°C (2190°F) for 5 minutes in a protective atmosphere like argon, hydrogen or vacuum.
Isothermal treatment: -40°C (-40°F) for 24 hours
Ageing: 525°C (997°F) for 1 hour

Nominal values at 20°C (68°F)

Tensile strength		Tensile strength	
MPa		**ksi**	
Annealed	**Heat treated**	**Annealed**	**Heat treated**
700	1600	102	232

Welding

The weldability of Nanoflex™ is good. Appropriate welding methods are TIG and laser welding. It can be welded without filler metal (autogenously) using the TIG process or laser process, but filler metal is preferable. Suitable fillers are according to standard ISO 14343: 19 12 3 L Si; AWS A5.9/ASME SFA-5.9: ER316LSi; W.Nr.: 1.4430 and ISO 14343: 19 12 3 L; AWS A5.9/ASME SFA-5.9: ER316L; W.Nr.: 1.4430 or ISO 14343: 22 9 3 N L; AWS A5.9/ASME SFA-5.9: ER2209; W.Nr.: 1.4462.

The martensite content in the heat-affected zone (HAZ) of the material decreases after welding, resulting in a typical, annealed microstructure with an austenitic matrix and a small amount of ferrite. This means that the tensile strength will be lower for the weld compared with the high strength base material, in the same way as other cold rolled austenitic stainless steels. Therefore, welds in Nanoflex™ are not suitable for active parts of a construction, where a high stress level has to be managed.