LDX 2101®
Duplex Stainless Steel

Steel grade

Outokumpu	EN	ASTM
LDX 2101®	1.4162	S32101

Characteristic properties

- High strength
- Good fatigue resistance
- Very good weldability
- Good corrosion resistance
- High resistance to stress corrosion cracking
- High energy absorption

Applications

- General-purpose applications and environments
- Building and construction
- Storage tanks
- Reinforcement bars
- Water piping

General characteristics

LDX 2101 is a low-alloyed, general-purpose duplex stainless steel. Its high mechanical strength is similar to that of other duplex grades and its good corrosion resistance is on par with that of most standard stainless steel grades. Combined, these properties can be utilised to arrive at a design optimised with respect to strength, maintenance, durability and long-term cost efficiency.

Chemical composition

The chemical composition is shown in Table 1.

Microstructure

The balanced chemical composition of LDX 2101 results in a microstructure containing approximately equal amounts of ferrite and austenite after annealing at a temperature of 1050°C. Due to its relatively low alloying content, LDX 2101 is less prone to precipitaition of intermetallic phases than other duplex steels. The high nitrogen content results in rapid re-formation of austenite in weld thermal cycles.

Mechanical properties

LDX 2101 has high mechanical strength due to its duplex microstructure and high nitrogen content. In Table 2 the minimum and typical values for the grade are presented. The mechanical properties at elevated temperatures are shown in Table 3.

Chemical composition Table 1

Outokumpu steel name	International steel No		Typical composition, %					
	EN	ASTM	C	N	Cr	Ni	Mo	Others
4301	1.4301	304	0.04	0.04	18.1	8.3	–	–
4404	1.4404	316L	0.02	0.04	17.2	10.2	2.1	–
4436	1.4436	316	0.04	0.05	16.9	10.7	2.6	–
904L	1.4539	N08904	0.01	–	20	25	4.3	1.5Cu
SAF 2304®	1.4362	S32304	0.02	0.10	23	4.8	0.3	–
2205	1.4462	S32205*	0.02	0.17	22	5.7	3.1	–
LDX 2101®	**1.4162**	**S32101**	**0.03**	**0.22**	**21.5**	**1.5**	**0.3**	**5Mn**

* Also available as S31803

Mechanical properties at 20˚C

Table 2

			Minimum values P	H	C	Typical values P (15mm)	H (4mm)	C (1mm)
Proof strength	$R_{p0.2}$	MPa	450	480	530	480	570	600
Tensile strength	R_m	MPa	650	680	700	700	790	840
Elongation	A_5	%	30	30	–	38	38	40
Impact toughness	KV[1)]	J	60	60	–	100	–	–
Hardness	HB					230	230	230

P = hot rolled plate. H = hot rolled coil. C = cold rolled coil and sheet. [1)] Full size specimen

Tensile properties at elevate temperatures, all products

Table 3

Minimum value		Temperatures 50	100	150	200	300
$R_{p0.2}$	MPa	430	380	350	330	300
R_m	MPa	630	590	560	540	540

Physical properties

The physical properties of LDX 2101 are shown in Table 4.

Physical properties

Table 4

		Temperature, °C 20	100	200	300
Density	x10³ kg/m³	7.7			
Modules of elasticity	GPa	200	194	186	180
Poissons ratio		0.3			
Linear expansion at (20→) °C	x10⁻⁶/°C	–	13.5	14.0	14.5
Thermal conductivity	W/m°C	15	16	17	18
Thermal capacity	J/kg°C	500	530	560	590
Electric resistivity	nΩm	750	800	850	900

Fatigue

The high tensile strength of duplex steels also implies high fatigue strength. Table 5 shows the result of pulsating tensile fatigue tests (R=0.1) in air at room temperature. The fatigue strength has been evaluated at 2 million cycles and probability of rupture 50%. Since the test was made using round polished test bars from hot rolled plate, correction factors for surface roughness, notches, welds etc, are required in accordance with classical theory relating to fatigue failure. As shown by the table the fatigue strength of the duplex steels corresponds approximately to the proof strength of the material.

Fatigue, pulsating tensile test

Table 5

		LDX 2101	2205	1.4404
$R_{p0.2}$	MPa	478	497	280
R_m	MPa	696	767	578
Fatigue strength	MPa	500	510	360

Standard deviation of fatigue strength, for the entire population ~ 30 MPa

Corrosion resistance

The corrosion resistance of LDX 2101 is generally good, and the grade is therefore suitable for use in a wide range of general-purpose applications and environments. The corrosion resistance is in general at least as good as that of Cr-Ni grades such as 4301 and in some cases as good as Cr-Ni-Mo grades such as 4404. A brief description of the resistance to different types of corrosion is shown below.

Uniform corrosion

Uniform corrosion is characterised by a uniform attack on the steel surface in contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/year. The resistance to uniform corrosion in sulphuric acid is shown in Figure 1. LDX 2101 has a better resistance than 4301 and in some cases performs as well as 4436.

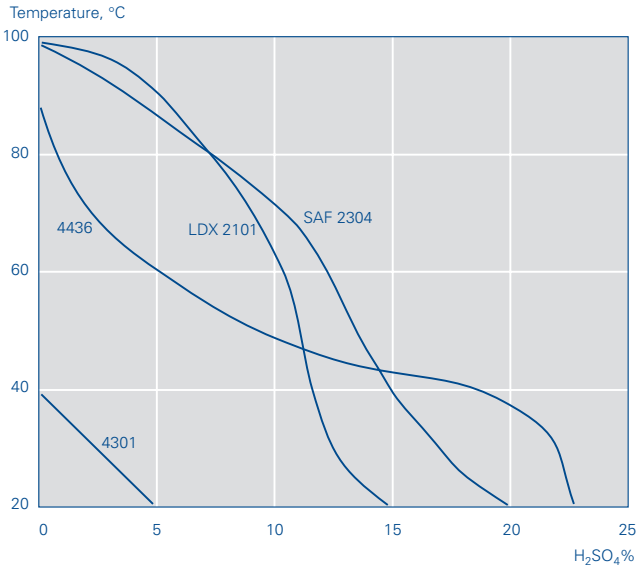

Fig. 1. Isocorrosion curves, 0.1 mm/year, in sulphuric acid.

Pitting and crevice corrosion

The resistance to pitting and crevice corrosion increases with the content of chromium, molybdenum and nitrogen in the steel. The resistance to these types of corrosion, which are mainly caused by chloride containing environments, is good due to the grade's high chromium and nitrogen content. The pitting corrosion resistance has been

evaluated using the Avesta Cell (ASTM G 150). Figure 2 shows that the resistance is higher than that normally obtained with Cr-Ni grades such as 4301 and approaching that of Cr-Ni-Mo grades such as 4404.

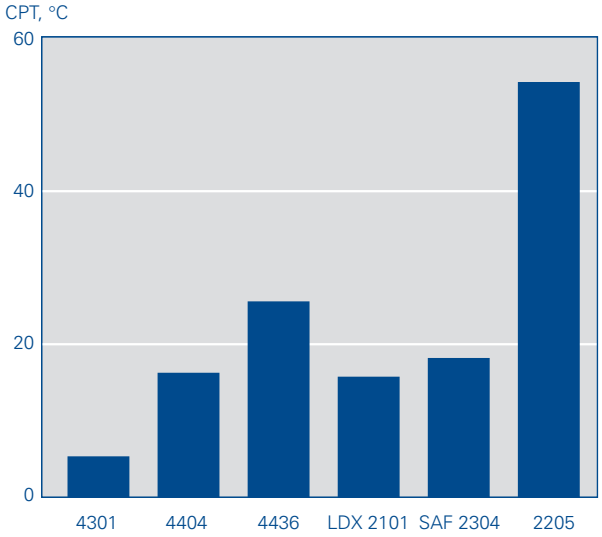

Fig. 2. Critical pitting temperatures (CPT) in 1M NaCl according to ASTM G 150 using the Avesta Cell. Typical values have been given for conventional grades.

Atmospheric corrosion

A steel's resistance to atmospheric corrosion is strongly linked to its resistance to uniform corrosion and localised corrosion such as pitting and crevice corrosion. Since LDX 2101 shows good resistance to these types of corrosion, it may be assumed that the resistance to atmospheric corrosion is good. Accordingly LDX 2101 should be sufficiently resistant in most environments.

Stress corrosion cracking

Like all duplex stainless steels, LDX 2101 shows good resistance to chloride-induced stress corrosion cracking (SCC). Many test methods are used to rank the different steel grades with respect to their resistance to SCC. One such test method is the U-bend test according to MTI Manual no. 3, in which the specimens are exposed to 3M magnesium chloride ($MgCl_2$) solution at 100°C for 500 hours. The U-bending was performed both longitudinal and transverse the rolling direction. The results are shown in Table 6.

Results from U-bend stress corrosion testing in $MgCl_2$ Table 6

	Longitudinal/Transverse
LDX 2101	No SCC (some uniform corrosion)
SAF 2304	No SCC (some uniform corrosion)
4301	SCC cracks + pitting corrosion

Intergranular corrosion

Due to its duplex microstructure LDX 2101 offers very good resistance to intergranular corrosion. LDX 2101 passes intergranular corrosion tests according to EN/ISO 3651-2 method A (Strauss) and method C (Streicher). Such results are as expected for duplex steels, which are less susceptible to this kind of corrosion than austenitic stainless steels.

Fabrication

Hot forming

Hot forming is performed in the temperature range 1100 – 900°C and should be followed by solution annealing. It should, however, be observed that the strength is low at high temperatures.

Cold forming

Due to the high proof strength of duplex material, greater working forces than those required for austenitic steel are usually needed for cold forming. Figure 3 shows the effect of work hardening on LDX 2101.
LDX 2101 is suitable for most forming operations used in stainless steel fabrication. However, due to the grade's higher mechanical strength and lower toughness, operations such as deep drawing, stretch forming and spinning are more difficult to perform than with austenitic steel. The grade's high strength, may give rise to a relatively high spring back.

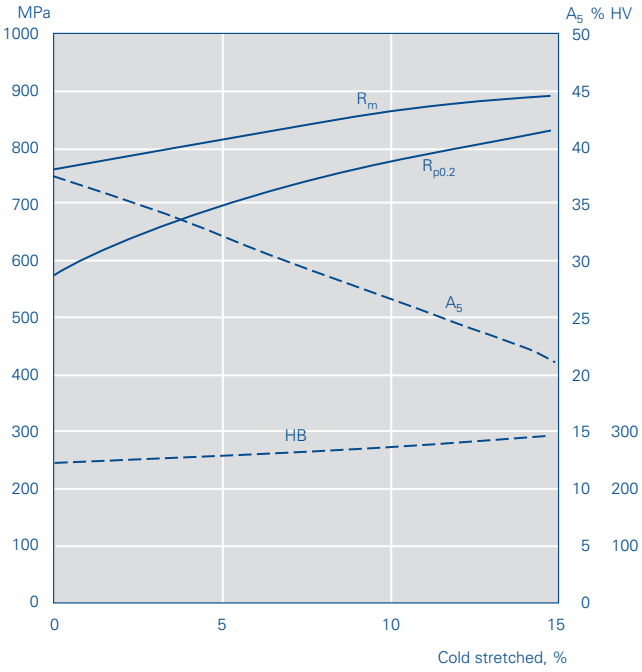

Fig. 3. Mechanical properties of LDX 2101 after cold deformation.

Heat treatment

LDX 2101 is solution annealed at 1020 – 1080°C. Rapid cooling is recommended after annealing.

Welding

LDX 2101 has a good weldability and can be welded using the same processes used for other duplex steels.
In general the recommendations for welding duplex steels also apply for LDX 2101. However, the restrictions in arc energy are less tight than for conventional duplex steels due to the grade's low alloy content and high nitrogen level. Normally, a filler of type 2209 should be used for optimum properties. Welding without filler is possible, and reasonably good properties can be obtained in the 'as-welded' condition.

Product specification and approvals

LDX 2101 is standardised by ASTM/ASME. It has an EN number and work is in progress to obtain EN standardisation for flat, bar and tubular products. Outokumpu Stainless has recieved a patent for LDX 2101.

1104EN-GB. Centrum Tryck AB, Avesta, Sweden. February 2004.

Products

Table 7

Hot rolled plate, sheet and strip	Dimensions according to Outokumpu Stainless product program.
Cold rolled sheet and strip	Dimensions according to Outokumpu Stainless product program.
Billet, wire rod and bar	Dimensions according to Outokumpu Stainless product program.
Tube and pipe	Welded tubes and pipes are supplied by AvestaPolarit Stainless Tube AB.
Welding consumables	Filler material in the form of covered electrodes of AC/DC type, MIG, TIG, FCW and SAW wire and also welding flux are supplied by AvestaPolarit Welding AB, Avesta.

Material Standards

Table 8

ASTM A240 / ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purposes
ASTM A276	Stainless and heat-resisting steel bars/shapes
ASTM A479 / ASME SA-479	Stainless steel bars for boilers and other pressure vessels
ASME Boiler and Pressure Vessel Code Case 2418	21Cr-5Mn-1.5Ni-Cu-N (UNS S32101), Austenitic-Ferritic Duplex Stainless Steel Section VIII, Division 1

SAF 2304 is a registered trade mark owned by Sandvik AB.

Outokumpu Stainless (former AvestaPolarit) is a core business within Outokumpu, a dynamic metals and technology group operating worldwide and marketing its metals, metal products, technology and services to customers in a wide range of industries. By focusing on the Group's core competence, that is, extensive knowledge of metals processing. Outokumpu's aim is to be leader in all of its core businesses: stainless steel, copper and technology.

Outokumpu Stainless AB, Avesta Research Centre
Box 74, SE-774 22 Avesta, Sweden
Tel. +46 (0)226 810 00, Fax +46 (0)226 810 77