

# LDX 2101<sup>®</sup> for Bar Applications



LDX 2101<sup>®</sup> has a unique combination of characteristics (good corrosion properties, high strength and good machinability), which together with its relative price stability, makes it the material of choice for bar applications.

## LDX 2101<sup>®</sup> Summary/Overview

Outokumpu	EN	ASTM
LDX 2101 <sup>®</sup>	1.4162	S32101

### Characteristic properties

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

### Applications

- General purpose applications and environments
- Building and storage construction
- Structural members
- Reinforcement bars
- Rotors, impellers, shafts
- Water treatment
- Pulp and paper equipment
- Fittings
- Fasteners

### General Characteristics

LDX 2101<sup>®</sup> 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 equivalent to 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 characteristics

The chemical composition is shown in Table 1.

### Microstructure

The balanced chemical composition of LDX 2101<sup>®</sup> results in a microstructure containing approximately equal amounts of ferrite and austenite after annealing at a temperature of about 1050°C. Due to its relatively low alloying content, LDX 2101<sup>®</sup> is less prone to precipitation 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<sup>®</sup> has high mechanical strength due to its duplex microstructure and high nitrogen content. In Table 2 the minimum values for the grade are presented.

### Fatigue

The high tensile strength of duplex steels also implies high fatigue strength. Table 3 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 the probability of rupture is 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 yield strength of the material.

Table 1

Outokumpu	International Steel No.		Typical composition, %					
	EN	ASTM	C	N	Cr	Ni	Mo	Others
4301	1.4301	304	0.04	0.04	18.1	8.1	—	—
4404	1.4404	316L	0.02	0.04	17.2	10.1	2.1	—
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 <sup>®</sup>	1.4162	S32101	0.03	0.22	21.5	1.5	0.3	5Mn

\* Also available in S31803

### Mechanical Properties (Thickness 5mm-10mm)

Table 2

Type	EN
LDX 2101*	
Proof Strength ( $R_{p0.2}$ ), MPa	530 min
Tensile Strength ( $R_m$ ), MPa	700 min
Elongation ( $A_5$ ), pct.	30 min
304L / 1.4307	
Proof Strength ( $R_{p0.2}$ ), MPa	400 min
Tensile Strength ( $R_m$ ), MPa	600 min
Elongation ( $A_5$ ), pct.	25 min
316L / 1.4404	
Proof Strength ( $R_{p0.2}$ ), MPa	400 min
Tensile Strength ( $R_m$ ), MPa	600 min
Elongation ( $A_5$ ), pct.	25 min

### Fatigue, pulsative test

Table 3

Minimum value	LDX 2101*	2205	316L / 4404
	MPa	MPa	MPa
Yield Strength 0.2%	478	497	280
Tensile Strength	696	767	578
Fatigue Strength	500	510	360

Standard deviation of fatigue strength, for the entire tested 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 304 / 4301 and in most cases as good as Cr-Ni-Mo grades such as 316L / 4404. A brief description of the resistance to different types of corrosion is described 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 (see Table 4).

LDX 2101\* has a better resistance than 304 / 4301 and in most cases performs as well as 316 / 4401. One exception is sulphuric acid as shown in Figure 1.

Temperature, °C

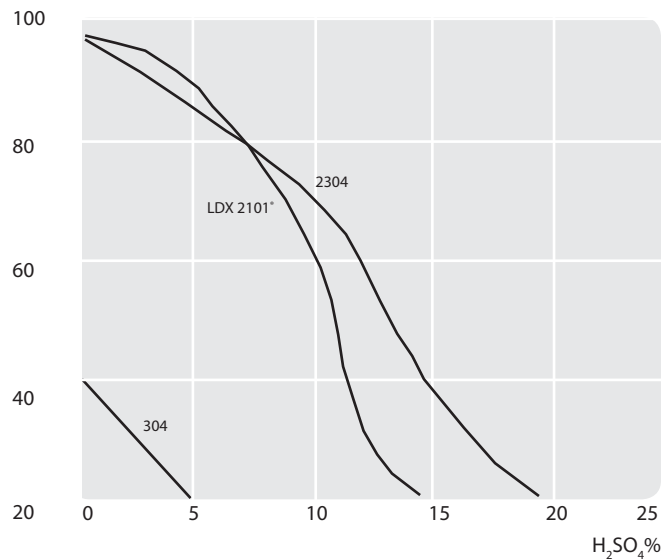


Fig. 1 Isocorrosion curves, 0.1 mm/year, in sulphuric acid

#### 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 304 / 4301 and approaching that of Cr-Ni-Mo grades such as 316L / 4404.

CPT, [°C]

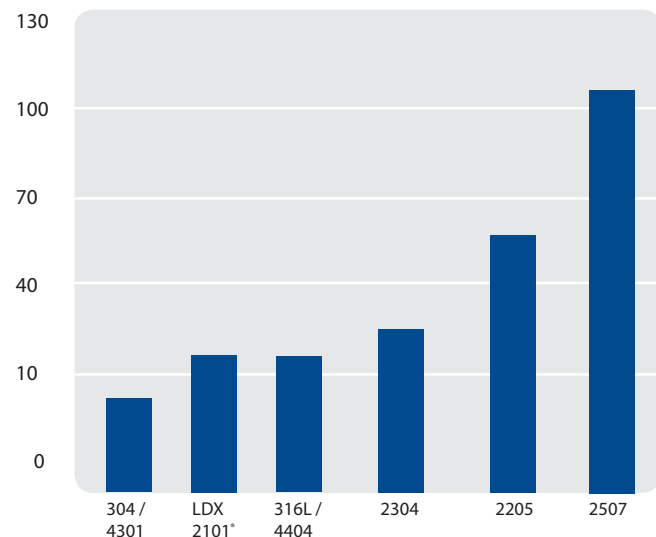


Fig. 2 Typical CPT values in 1M NaCl for tested stainless steels tested in the ground condition according to ASTM G150.

Uniform Corrosion Results

Table 4

Test solution	Conc, wt%	Critical temperature °C		
		316L / 4404	304 / 4301	LDX 2101*
<b>Hydrochloric Acid</b>				
HCl	0.2	>bp	>bp	>bp
HCl	1.0	30	30p	55
HCl+FeCl <sub>3</sub>	1.0HCl + 0.3FeCl <sub>3</sub>	25p	20p	20
<b>Sulphuric Acid</b>				
H <sub>2</sub> SO <sub>4</sub>	10	50	N.T.	75
	60	<15	N.T.	<30
	96.4	45	N.T.	30
<b>Phosphoric Acid</b>				
H <sub>3</sub> PO <sub>4</sub>	85	95	80	100
<b>Nitric Acid</b>				
HNO <sub>3</sub>	10	>bp	>bp	>bp
	65	100	100	105
<b>Organic Acids</b>				
Acetic acid CH <sub>3</sub> COOH	80	>bp	100	>bp
Acetic acid+ acetic anhydride CH <sub>3</sub> COOH+ (CH <sub>3</sub> CO) <sub>2</sub> O	50+50	120	<bp	105
Formic acid HCOOH	50	40	<10	95
<b>Sodium Hydroxide</b>				
NaOH	50	90	85	85

N.T.= Not Tested

bp.= Boiling Point

p.= Pitting Corrosion

### 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<sup>®</sup> shows good resistance to these types of corrosion, it may be assumed that the resistance to atmospheric corrosion is good. Accordingly LDX 2101<sup>®</sup> should be sufficiently resistant in most environments.

### Stress corrosion cracking

Like all duplex steels, LDX 2101<sup>®</sup> 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<sub>2</sub>) solution at 100° C for 500 hours. The U-bending was performed both longitudinal and transverse to the rolling direction. The results are shown in Table 5.

### Intergranular corrosion

Due to its duplex microstructure LDX 2101<sup>®</sup> offers very good resistance to intergranular corrosion. Duplex stainless steels are less susceptible to this kind of corrosion than austenitic stainless steels.

Results from U-bend stress corrosion testing in MgCl<sub>2</sub>

Table 5

	Longitudinal/Transverse
LDX 2101 <sup>®</sup>	No SCC (some uniform corrosion)
2304	No SCC (some uniform corrosion)
304 / 4301	SCC cracks + pitting corrosion

Summary of Test Results for the Wick Test

Table 6

Material	Number of Specimens	
	Tested	Failed due to SCC
304 / 4301	2	2
LDX 2101 <sup>®</sup>	6	0
2304	2	0
2205	2	0

Summary of Test Results for Concentrated Calcium Chloride

Table 7

Material	Exposure time [h]	Number of Specimens			
		U-bend		4-PB	
		Tested	Failed due to SCC	Tested	Failed due to SCC
304 / 4301	96	6	6	—	—
	340	—	—	4	4
LDX 2101 <sup>®</sup>	500	6	0	2	0
	2304	6	0	2	0
2205	500	6	0	2	0
2507	500	—	—	2	0

### 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<sup>®</sup>.

LDX 2101<sup>®</sup> 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.

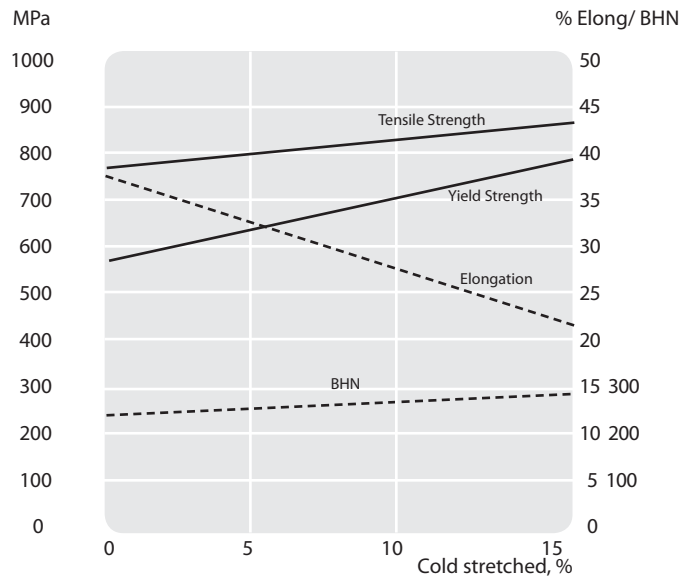


Fig. 3 Mechanical properties of LDX 2101<sup>®</sup> after cold deformation.

**Heat treatment**

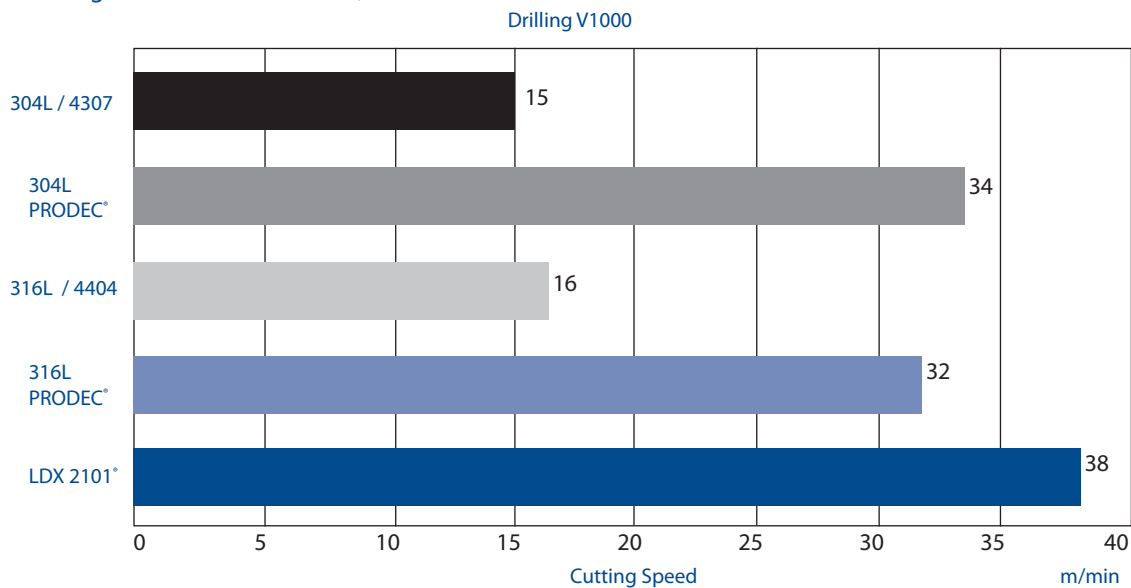
LDX 2101<sup>®</sup> is solution annealed at 1020°-1080° C. Rapid cooling is recommended after annealing.

**Machining**

LDX 2101<sup>®</sup> has shown excellent machining properties. Other duplex steels are generally more difficult to machine than conventional austenitic stainless steel such as 316L / 4404, due to the higher hardness.

Drilling with standard method, V1000 for HSS tools

Table 8



V1000 can be explained as the cutting speed that gives a tool lifetime for a drilled length of 1000mm.

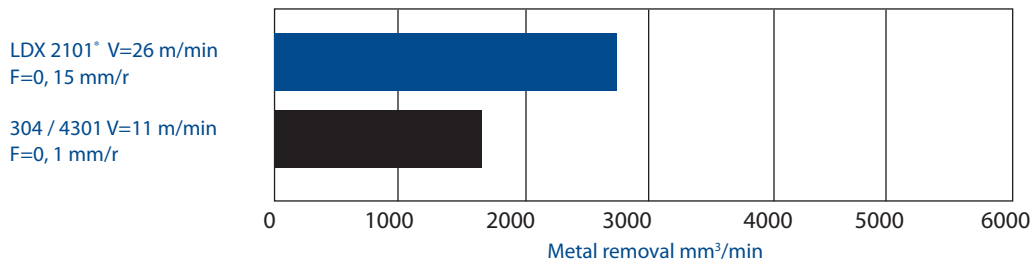
Tool Wedevag Double X

Prodec is a registered Outokumpu trademark for steel grades with improved machinability.

Metal removal, drilling LDX 2101<sup>®</sup>

Table 9

Metal removal in LDX 2101<sup>®</sup> vs 304 / 4301, drilling HSS, diameter 5,1mm



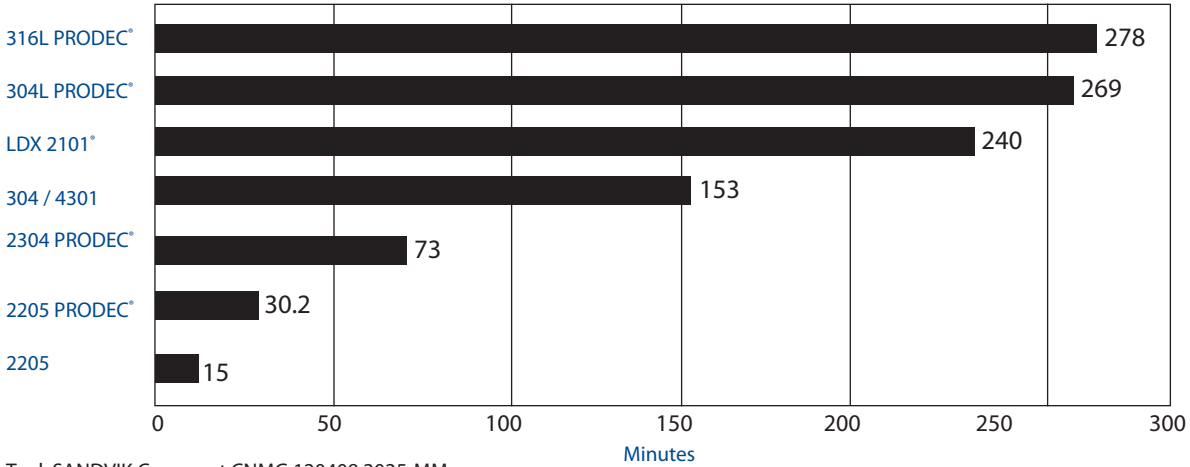
Relevant cutting speed in respective steel grade for the same tool lifetime.

Tool Wedevag Double X

Tool lifetime at 126m/min, turning

Table 10

Tool lifetime at the same cutting speed, turning with cemented carbide

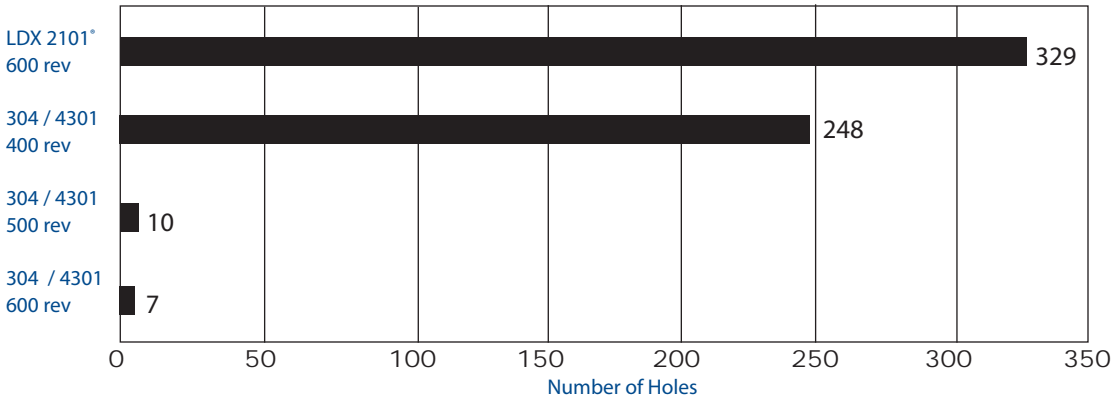


Tool: SANDVIK Coromant CNMG 120408 2025-MM  
 Prodec is a registered Outokumpu trademark for steel grades with improved machinability.

Threading in LDX 2101\*

Table 11

Threading M6

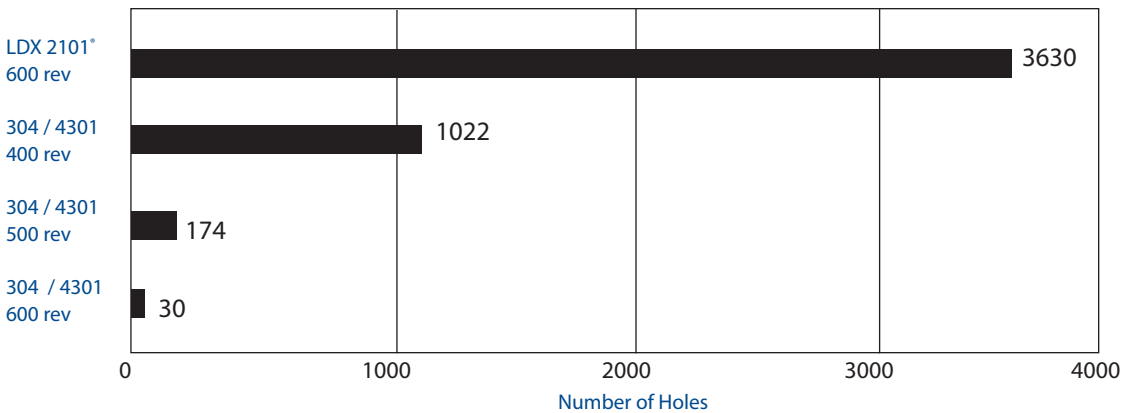


Tool: Vaporised HSS-Co tap, NORIS-SALO-REX-VA HSSE C

Tool lifetime at 26m/min, turning with HSS tool

Table 12

Tool lifetime at the same cutting speed, turning HSS



Tool: Alesa 1541 1501-01 SEGW 120404 FN HSS-ES

LDX 2101<sup>®</sup> Machining Guide

Table 13

Operation	Depth of cut or width (mm)	HSS Tooling			Carbide Tooling		
		Cutting Speed (m/min)	Feed (mm/rev)	Tool Grade	Cutting Speed (m/min)	Feed (mm/rev)	Tool Grade
Turning	1-4	14-36	0.025-0.15	T15	24-210	0.06-0.3	P15-M25
Forming	5	14-36	0.01-0.15	T15	24-250	0.01-0.25	P15-M25
Cut-off or Grooving	1-4	Up to 36	0.025-0.13	T15	24-110	0.025-0.2	M25
Drilling	All	12-36	0.08-0.23	M35	24-250	0.06-0.3	P15-M25
Reaming	All	12-36	0.08-0.6	M35	24-250	0.06-0.3	P15-M25
Taping	All	Up to 36	N/A	M35	—	—	—
Single Point Threading	—	—	—	—	35-150	Thread Size: 20-250mm Passes: 9-11	M20

- Small differences in cutting speed will affect tool lifetime
- Higher feed rate tends to give better surface and chip formation
- TiAlN coated high speed steel tools provide much longer tool lifetime than un-coated
- Results can vary depending upon tooling and machine set-up
- These are actual results obtained from production tests

**Welding**

LDX 2101<sup>®</sup> 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<sup>®</sup>. 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, the special LDX 2101<sup>®</sup> filler or 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<sup>®</sup> 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 has received a patent for LDX 2101<sup>®</sup>.

**General Standards**

Table 14

- All products are supplied in compliance with the requirements of the customer order
- Product testing is in accordance with standard procedures
- Quality Systems are assessed to ISO 9001
- Environmental Management Systems are assessed to ISO 14001
- Our products are free from any known mercury or radiation contamination
- Products are corrosion tested in accordance with EN ISO 3651-2

**LDX 2101<sup>®</sup>**

Table 15

- 1.4162
- S32101 ASTM A276 (2008a)
- ASTM A479 (2008a)
- S32101

LDX 2101® is a trademark of Outokumpu Stainless.  
254 SMO® is a trademark of Outokumpu Stainless.  
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Outokumpu is a global leader in stainless steel. Our vision is to be the undisputed number one in stainless, with success based on operational excellence. Customers in a wide range of industries use our stainless steel and services worldwide. Being fully recyclable, maintenance-free, as well as very strong and durable material, stainless steel is one of the key building blocks for sustainable future. What makes Outokumpu special is total customer focus – all the way, from R&D to delivery. You have the idea. We offer world-class stainless steel, technical know-how and support. We activate your ideas.



Outokumpu Long Products