outokumpu
high performance stainless steel

Forta SDX 100

EN 1.4501, ASTM UNS S32760

General characteristics

Austenitic-ferritic stainless steel also referred to as duplex stainless steels, combine many of the beneficial properties of ferritic and austenitic steels. Due to the high content of chromium and nitrogen, and often also molybdenum, these steels offer good resistance to localised and uniform corrosion. The duplex microstructure contributes to the high strength and high resistance to stress corrosion racking. Duplex steels have good weldability. All duplex grades have the maximum service temperature restricted to 250 or 325°C according to EN10028-7 or ASME II-D 2007 respectively. Outokumpu produces a range of duplex grades, LDX 2101®, 2304, LDX 2404®, 2205, 4501 and 2507. The properties of 4501 is in general terms very similar to those of 2507. Grade 4501 is delivered if specified.

Typical applications

- Pulp and paper industry
- Desalination plants
- Flue-gas cleaning
- Cargo tanks and pipe systems in chemical tankers
- Seawater systems
- Firewalls and blast walls on offshore platforms
- Components for structural design
- Storage tanks
- Pressure vessels
- Heat exchangers
- Water heaters
- Rotors, impellers and shafts

Products & dimensions

Cold rolled products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
2B	Cold rolled, heat treated, pickled, skin passed	0.80-4.50	30-1250	0.80-4.50	600-1250
2BB	Bright-pickled	0.80-3.50	30-1250	0.80-3.50	600-1250
2C	Cold rolled, heat treated	0.80-4.50	30-1250		
2D	Cold rolled, heat treated, pickled	0.80-4.50	30-1250	0.80-4.50	600-1250
2E	Cold rolled, heat treated, mech. desc. pickled	0.80-4.50	30-1250	0.80-4.50	600-1250
2G	Ground	0.80-3.00	30-1250	0.80-3.00	600-1250
2J	Brushed or dull polished	0.80-3.00	30-1250	0.80-3.00	600-1250
2R	Cold rolled, bright annealed	0.05-3.50	3-1250	0.80-3.50	600-1250

Continous hot rolled products, available dimensions (mm)

	Coil / Strip	Plate / Sheet

Surface finish		Thickness	Width	Thickness	Width
1C	Hot rolled, heat treated, not descaled	5.00-7.00	750-1280	5.00-7.00	750-1280
1D	Hot rolled, heat treated, pickled	5.00-7.00	750-1280	5.00-7.00	750-1280
1U	Black hot rolled	5.00-7.00	750-1280	5.00-7.00	750-1280

Quarto plate products, available dimensions (mm)

		Coil / Strip		Plate / Sheet	
Surface finish		Thickness	Width	Thickness	Width
1D	Hot rolled, heat treated, pickled			6.00-50.00	400-3200

Chemical composition

The typical chemical composition for this grade is given in the table below, together with composition limits given for this grade according to different standards. The required standard will be fully met as specified on the order.

	C	Mn	Cr	Ni	Mo	N	Other
Typical	**0.02**		**25.4**	**6.9**	**3.8**	**0.27**	**Cu:0.70 W:0.70**
ASME II A SA-240	≤0.030	≤1.00	24.0-26.0	6.0-8.0	3.0-4.0	0.20-0.30	Cu:0.50-1.00 W:0.50-1.00
ASTM A240	≤0.030	≤1.00	24.0-26.0	6.0-8.0	3.0-4.0	0.20-0.30	Cu:0.50-1.00 W:0.50-1.00
EN 10028-7	≤0.030	≤1.00	24.00-26.00	6.00-8.00	3.00-4.00	0.20-0.30	Cu:0.50-1.00 W:0.50-1.00
EN 10088-2	≤0.030	≤1.00	24.0-26.0	6.0-8.0	3.0-4.0	0.20-0.30	Cu:0.50-1.00 W:0.50-1.00
EN 10088-3	≤0.030	≤1.0	24.0-26.0	6.0-8.0	3.0-4.0	0.20-0.30	Cu:0.5-1.0 W:0.5-1.0
IS 6911	≤0.030	≤1.00	24.0-26.0	6.0-8.0	3.0-4.0	0.20-0.30	Cu:0.50-1.00 W:0.50-1.00

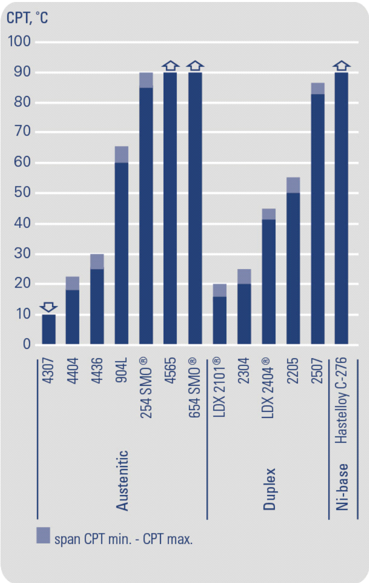
Corrosion resistance

Uniform corrosion

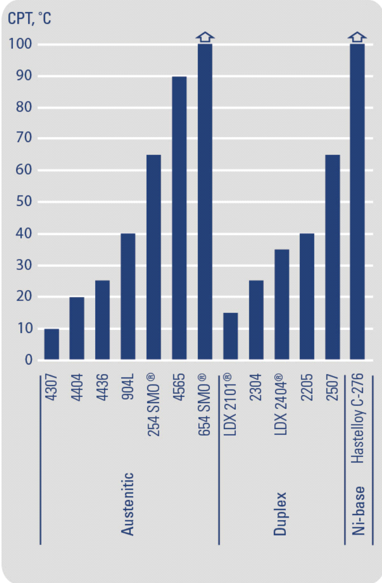
Uniform corrosion occurs when all, or at least a large section, of the passive layer is destroyed. This typically occurs in acids or in hot alkaline solutions. The influence of the alloy composition on the resistance to uniform corrosion may vary significantly between different environments; chromium is essential for ensuring the passivity of stainless steels, nickel helps reduce the corrosion rate of depassivated steel, molybdenum enhances passivity (except for strongly oxidising environments, such as warm concentrated nitric acid) and copper has a positive effect in the presence of reducing acids such as dilute sulphuric acid. In an environment with constant temperature and chemical composition, uniform corrosion occurs at a steady rate. This rate is often expressed as a loss of thickness per unit time, e.g. mm/y. Stainless steels are normally considered to be resistant to uniform corrosion in environments in which the corrosion rate does not exceed 0.1 mm/y. Impurities may drastically affect the corrosivity of acid solutions. For guidance on materials selection in a large number of environments capable of causing uniform corrosion, the tables and iso-corrosion diagrams in Outokumpu Corrosion Handbook may be consulted.

Pitting and Crevice corrosion

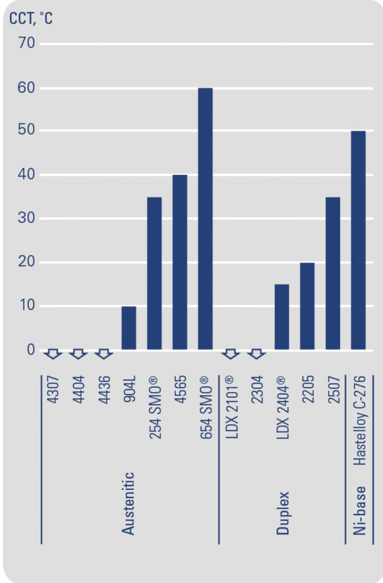
Chloride ions in a neutral or acidic environment facilitate local breakdown of the passive layer. As a result, pitting and crevice corrosion can propagate at a high rate, causing corrosion failure in a short time. Since the attack is small and may be covered by corrosion products or hidden in a crevice, it often remains undiscovered until perforation or leakage occurs. Resistance to pitting corrosion is determined mainly by the content of chromium, molybdenum and nitrogen in the stainless steel. This is often illustrated using the pitting resistance equivalent (PRE) for the material, which can be calculated using the formula: PRE = %Cr + 3.3 x %Mo + 16 x %N. The PRE value can be used for rough comparisons of different materials. A more reliable means, however, is to rank the steel according to the critical pitting temperature (CPT) of the material. There are several different methods available, for example ASTM G 150 that uses the Avesta Cell with a 1M NaCl solution (35 000 ppm or mg/l chloride ions). The CPT-values are shown in the table below. Higher contents of chromium, molybdenum and nitrogen also enhance the crevice corrosion resistance of the stainless steel. Typical values of the critical crevice corrosion temperature (CCT) in 6% FeCl3 + 1% HCl according to ASTM G48 Method F are included in the table below. The CPT and CCT values vary with product form and surface finish, the values given are for ground surfaces. Both ASTM G150 and G48 are methods for ranking the relative pitting or crevice corrosion resistance for the different stainless steels but they do not give the maximum temperature for using these alloys in real service environments.



CPT according to ASTM G150 Wet ground to 320 grit



CPT according to ASTM G48 E Dry ground to 120 grit



CCT according to ASTM G48 F Dry ground to 120 grit

Pitting corrosion resistance		Crevice corrosion resistance
PRE	**CPT**	**CCT**
42	84±2	

PRE Pitting Resistant Equivalent calculated using the formula: PRE = %Cr + 3.3 x %Mo + 16 x %N

CPT Corrosion Pitting Temperature as measured in the Avesta Cell (ASTM G 150), in a 1M NaCl solution (35,000 ppm or mg/l chloride ions).

CCT Critical Crevice Corrosion Temperature is the critical crevice corrosion temperature which is obtained by laboratory tests according to ASTM G 48 Method F

Mechanical properties

The duplex stainless steels have much higher mechanical strength compared to standard stainless steels. If the high strength of the duplex grades can be utilised, down gauging can be done in many applications leading to cost efficient solutions. The allowable design values may vary between product forms. The appropriate values are given in the relevant specifications.

The product types P= hot rolled plate, H=hot rolled strip and C=cold rolled coil and strip.

Cold rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
ASME II A SA-240	≥ 550		≥ 750				≤ 270	
ASTM A240	≥ 550		≥ 750			≤ 32HRC	≤ 310	
IS 6911	≥ 550		≥ 750			≤ 32HRC	≤ 310	

Hot rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
ASME II A SA-240	≥ 550		≥ 750				≤ 270	
ASTM A240	≥ 550		≥ 750				≤ 310	
IS 6911	≥ 550		≥ 750			≤ 32HRC	≤ 310	

Hot rolled quarto plate	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 15 mm)	**580**		**830**	**35**			**260**	

ASME II A SA-240	≥ 550		≥ 750				≤ 270	
ASTM A240	≥ 550		≥ 750				≤ 310	
EN 10028-7	≥ 530		730 - 930	≥ 25				
EN 10088-2	≥ 530		730 - 930	≥ 25				
IS 6911	≥ 550		≥ 750			≤ 32HRC	≤ 310	

[1]Elongation according to EN standard:
A_{80} for thickness below 3 mm.
A for thickness = 3 mm.
Elongation according to ASTM standard $A_{2''}$ or A_{50}.

Physical properties

The physical properties at room temperature are shown in the table below. Data according to EN10088 or EN10095.

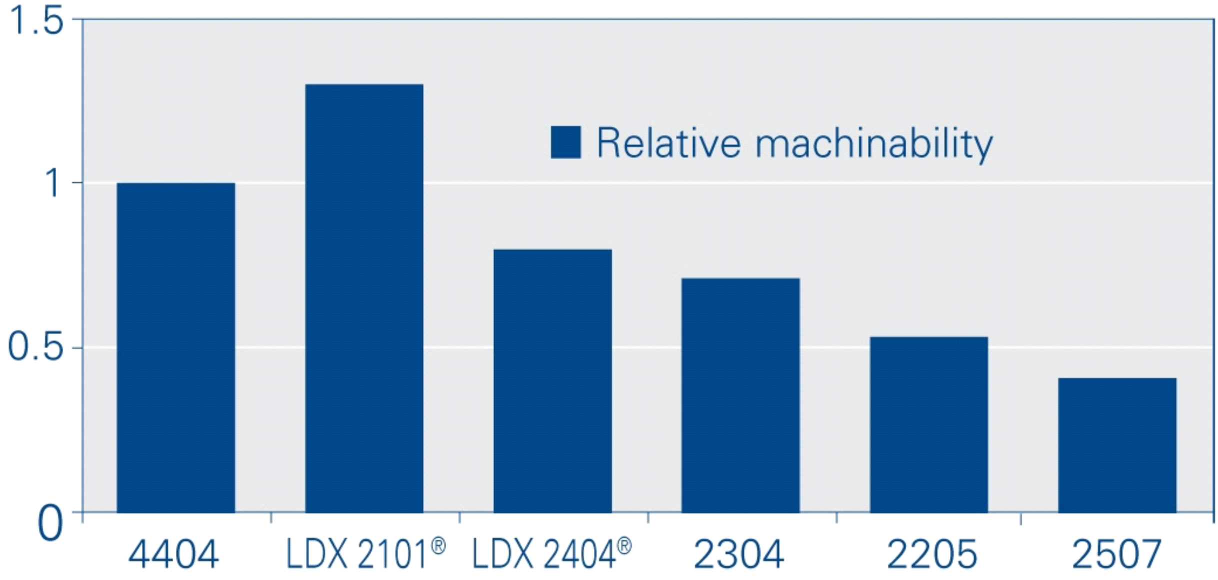
Density kg/dm³	Modulus of elasticity GPa	Thermal exp. at 100 °C 10^{-6}/°C	Thermal conductivity W/m°C	Thermal capacity J/kg°C	Electrical resistance µΩm	Magnetizable
7.8	200	13	15	500	0.8	Yes

Fabrication

Duplex stainless steel is suitable for all forming processes available for stainless steel. The high proof strength compared to austenitic and ferritics stainless steel can impose some differences in forming behaviour depending on chosen forming technique, such as an increased tendency to springback. This point is particularly relevant to forming of any high strength steel. If the forming process is not already decided, it is certainly possible to choose the most suitable one for duplex grades. Moreover, an excellent interplay between high proof strength, work hardening rate and elongation promote the duplex grades for light weight and cost-efficient applications with complex shapes. The impact of the high strength varies for different forming techniques. Common for all is that the estimated forming forces will be higher than for the corresponding austenitic and ferritic stainless steel grades. This effect will usually be lower than expected from just the increase in strength since the choice of duplex stainless steel is often associated with down gauging. It is important to consider that duplex stainless steel may also be more demanding for the tool materials and the lubricant. Also in this case attention should be given to the down gauging.

Machining

Duplex steels are generally more demanding to machine than conventional austenitic stainless steel such as 4404, due to the higher hardness. The machinability can be illustrated by a machinability index, as illustrated in below figure. This index, which increases with improved machinability, is based on a combination of test data from several different machining operations. It provides a good description of machinability in relation to 4404. More information can be found in the machining guidelines which are available for each duplex grade.



Welding

Duplex steels generally have good weldability and can be welded using most of the welding methods used for austenitic stainless steel:

- Shielded metal arc welding (SMAW)
- Gas tungsten arc welding TIG(GTAW)
- Gas metal arc welding MIG (GMAW)
- Flux-cored arc welding (FCW)
- Plasma arc welding (PAW)
- Submerged arc welding (SAW)
- Laser welding
- Resistance welding
- High frequence welding

Due to the balanced composition, the heat-affected zone obtains a sufficiently high content of austenite to maintain a good resistance to localised corrosion. The individual duplex steels have slightly different welding characteristics. For more detailed information regarding the welding of individual grades, see the Outokumpu Welding Handbook or contact Outokumpu. The following general instructions should be followed:

- The material should be welded without preheating

- The material should be allowed to cool between passes, preferably to below 150°C.
- To obtain good weld metal properties in as welded condition, filler material shall be used.
- The recommended arc energy should be kept within certain limits to achieve a good balance between ferrite and austenite in the weld. The heat input should be adapted to the steel grade and be adjusted in proportion to the thickness of the material to be welded.
- Post-weld annealing after welding with filler is not necessary.
- To ensure optimum pitting resistance when using GTAW and PAW methods, an addition of nitrogen in the shielding/purging gas is recommended.

Outokumpu 2507 is more prone to inter-metallic precipitation in the weld metal. For this reason the heat input should be below 1-1.5 KJ/mm and the interpass temperature should not exceed +100°C. If welding is done from only one side and the root side will be exposed to corrosive media, it is important to make the root thick and following beads thin with low heat input. This minimises the amount of detrimental sigma phase in the root. For SAW, the wire should not exceed Ø2.4 mm to facilitate low heat input welding.

Suitable filler for welding Outokumpu 2507 is ISO 25 9 4 NL.

Suitable filler for welding Outokumpu 4501 is ISO 25 9 4 NL.

More information

For more data regarding corrosion resistance of the Outokumpu stainless steels, please see the Outokumpu Corrosion Handbook. Contact your local Outokumpu sales office.

For more data regarding welding of the Outokumpu stainless steels, please see the Outokumpu Welding Handbook. Contact your local Outokumpu sales office.

A number of publications regarding this steel grade are available for downloading from www.outokumpu.com. The downloads can be found under Products/Useful Tools Online/Publications. Below are a few publications that might be of interest.

The duplex brochure "Material for Winning Ideas", gives a general introduction to the Outokumpu duplex grades and their advantages.

The data sheet "Duplex Stainless Steel" gives a general overview over the properties of the duplex grades LDX 2101®, 2304, LDX 2404®, 2205, 4501 and 2507.

Acom 2005 Ed: 1 Why Clad when there is Duplex?

Acom 2010 Ed:4 Acom chronicle 1980-2010. Superaustenitic stainless steels in demanding environments. Lean duplex - the first decade of service experience. 80 years with duplex steels - a historic review and prospects for the future. 30 years with acom (index) - in order. 30 years with acom (index) - by subject.

Duplex Stainless Steel - LDX 2101®, 2304, LDX 2404®, 2205, 2507

Duplex Brochure - Material for Winning Ideas

Standards & approvals

Outokumpu produce and certify materials to most international and national standards. Work is continuously on-going to get the different grades approved for relevant standards.

Standard	Designation
ASME SA-240M Code Sect. II. Part A	UNS S32760
ASTM A240/A240M	UNS S32760
EN 10028-7, PED 2014/68/EU	1.4501
EN 10088-2	1.4501
EN 10088-3	1.4501
IS 6911, AMENDMENT NO. 2	ISS 2760

Contacts & Enquiries

Contact your nearest sales office

www.outokumpu.com/contacts

Working towards forever.

We work with our customers and partners to create long lasting solutions for the tools of modern life and the world's most critical problems: Clean energy, clean water and efficient infrastructure. Because we believe in a world that lasts forever.

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