outokumpu
high performance stainless steel

Forta DX 2304

EN 1.4362, ASTM UNS S32304

General characteristics

Duplex grade with good resistance to localized corrosion and stress corrosion cracking in combination with high mechanical strength. Used in e.g. offshore topside applications since more than 20 years.

The grade is also available as Forta EDX 2304 with enhanced corrosion resistance and strength, but still within the same EN/ASTM standards as Forta DX 2304. The EDX version has a NORSOK approval from Aker Engineering & Technolgy ASaccording to NORSOKM standard M-650 Edition 4, September 2011 "Qualification of manufacturers of special materials".

Typical applications

- Desalination plants
- Firewalls and blast walls on offshore platforms
- Bridges
- Components for structural design
- Storage tanks
- Pressure vessels
- Heat exchangers
- Water heaters
- Rotors, impellers and shafts

Products & dimensions

Cold rolled products, available dimensions (mm)

		Coil / Strip		Plate / Sheet	
Surface finish		Thickness	Width	Thickness	Width
2B	Cold rolled, heat treated, pickled, skin passed	0.50-6.00	30-2000	0.50-6.00	300-2040
2BB	Bright-pickled	0.70-3.50	30-1250	0.70-3.50	600-1250
2C	Cold rolled, heat treated	0.70-5.00	30-1250		
2D	Cold rolled, heat treated, pickled	0.70-5.00	30-1250	0.70-5.00	600-1250
2E	Cold rolled, heat treated, mech. desc. pickled	0.50-6.00	30-2040	0.50-5.00	300-2040
2G	Ground	0.70-3.00	30-1250	0.70-3.00	600-1250
2J	Brushed or dull polished	0.70-3.00	30-1250	0.70-3.00	600-1250

Continous hot rolled products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
1C	Hot rolled, heat treated, not descaled	4.00-8.00	750-1350		
1D	Hot rolled, heat treated, pickled	3.00-10.00	50-2040	3.00-10.00	300-2040
1U	Black hot rolled	4.00-8.00	750-1350		

Quarto plate products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
1D	Hot rolled, heat treated, pickled			5.00-100.00	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. The relatively low Ni and Mo content of Forta DX 2304 and Forta EDX 2304 makes these grades more price stable compared to common standard stainless steel grades.

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

The chemical composition is given as % by mass.

	C	Mn	Cr	Ni	Mo	N	Other
Typical	**0.02**		**23.0**	**4.8**	**0.3**	**0.10**	**Cu:0.30**
ASME II A SA-240	≤0.030	≤2.50	21.5-24.5	3.00-5.50	0.05-0.60	0.05-0.20	Cu:0.05-0.60
ASTM A240	≤0.030	≤2.50	21.5-24.5	3.0-5.5	0.05-0.60	0.05-0.20	Cu:0.05-0.60
EN 10028-7	≤0.030	≤2.00	22.0-24.0	3.5-5.5	0.10-0.60	0.05-0.20	Cu:0.10-0.60
EN 10088-2	≤0.030	≤2.00	22.0-24.5	3.5-5.5	0.10-0.60	0.05-0.20	Cu:0.10-0.60
EN 10088-3	≤0.030	≤2.00	22.0-24.0	3.5-5.5	0.10-0.60	0.05-0.20	Cu:0.10-0.60
EN 10088-4	≤0.030	≤2.00	22.0-24.0	3.5-5.5	0.10-0.60	0.05-0.20	Cu:0.10-0.60
IS 6911	≤0.030	≤2.50	21.5-24.5	3.0-5.5	0.05-0.60	0.05-0.20	Cu:0.05-0.60

Corrosion resistance

Uniform corrosion

The resistance to uniform corrosion increases with high chromium content and the duplex stainless steels generally have a high chromium content. Forta DX 2304/Forta EDX 2304 is no exception. In strongly oxidising acids like nitric acid non-molybdenum alloyed steels are often more resistant than the molybdenum alloyed steels. Forta DX2304/Forta EDX 2304 is an excellent alternative due to high chromium content and low molybdenum content. More information about the resistance in different acids can be found in Outokumpu Corrosion Handbook. The corrosion tables can also be found from the here: Corrosion tables.

Pitting and crevice corrosion

The resistance to pitting and crevice corrosion increases with the content of chromium, molybdenum and nitrogen.

Pitting corrosion resistance		Crevice corrosion resistance
PRE	CPT	CCT
26	25±3	<0

Pitting Resistance Equivalent (PRE) is calculated using the following formula: PRE = %Cr + 3.3 x %Mo + 16 x %N
Corrosion Pitting Temperature (CPT) as measured in the Avesta Cell (ASTM G 150), in a 1M NaCl solution (35,000 ppm or mg/l chloride ions).
Critical Crevice Corrosion Temperature (CCT) 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
Typical (thickness 1 mm)	**620**	**660**	**790**	**42**				
ASME II A SA-240	≥ 400		≥ 600				≤ 290	
ASTM A240	≥ 400		≥ 600			≤ 32HRC	≤ 290	
EN 10028-7	≥ 420		600 - 850	≥ 20				
EN 10088-2	≥ 450		650 - 850	≥ 20				
EN 10088-4	≥ 450		650 - 850	≥ 20				
IS 6911	≥ 400		≥ 600			≤ 32HRC	≤ 290	

Hot rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 4 mm)	**600**	**670**	**765**	**30**			**235**	
ASME II A SA-240	≥ 400		≥ 600				≤ 290	
ASTM A240	≥ 400		≥ 600				≤ 290	
EN 10028-7	≥ 420		600 - 850	≥ 20				
EN 10088-2	≥ 420		650 - 850	≥ 20				
EN 10088-4	≥ 420		650 - 850	≥ 20				
IS 6911	≥ 400		≥ 600			≤ 32HRC	≤ 290	

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)	**450**		**670**	**40**			**210**	
ASME II A SA-240	≥ 400		≥ 600			≤ 32HRC	≤ 290	
ASTM A240	≥ 400		≥ 600			≤ 32HRC	≤ 290	
EN 10028-7	≥ 400		630 - 800	≥ 25				
EN 10088-2	≥ 400		630 - 800	≥ 25				
EN 10088-4	≥ 400		630 - 800	≥ 25				
IS 6911	≥ 400		≥ 600			≤ 32HRC	≤ 290	

Wire rod	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical	**500**		**700**	**35**				

[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/dm^3	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

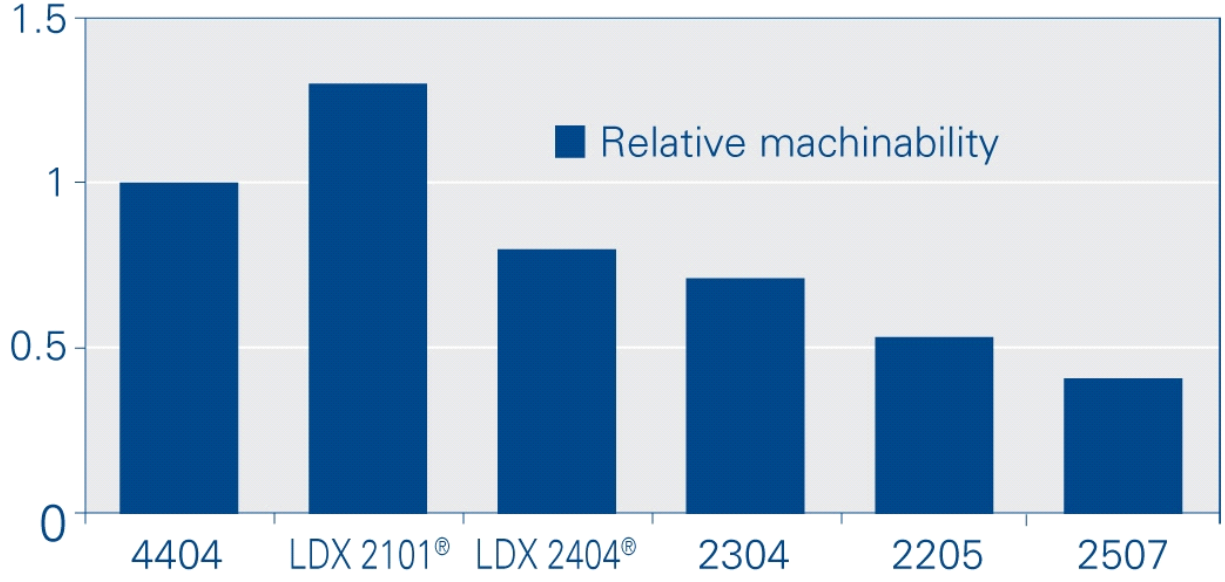
Fabrication

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.

Forta DX 2304 can be welded with high productivity methods (kg/h). For heavy gauge thickness, the use of heat input up to 3 KJ/mm can often be used without impairing weld metal properties. Suitable filler for welding Forta DX 2304 is ISO 23 7 NL or 22 9 3 NL.

More detailed information concerning welding procedures can be obtained from the Outokumpu Welding Handbook, available from our sales offices.

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 S32304
ASTM A240/A240M	UNS S32304
EN 10028-7, PED 2014/68/EU	1.4362
EN 10088-2	1.4362
EN 10088-3	1.4362
EN 10088-4	1.4362
IS 6911, AMENDMENT NO. 2	ISS 2304

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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