outokumpu

Duplex and high-strength stainless steels

Outokumpu Forta range datasheet

General characteristics

The Forta range contains duplex and other high strength stainless steels that enable thinner structures and weight reduction (measured in $R_{p0.2}$ > 400 MPa. PRE 18 to 43).

- **Duplex** products for high strength, corrosion resistance, and enhanced resistance to stress corrosion cracking
- **H-series** austenitic products for high strength and high ductility
- **Temper rolled** products for high strength and high hardness

Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking

Outokumpu name	Typical applications	Product forms
Forta DX 2205 The most popular duplex product on the market. Offers very good resistance to uniform and localized corrosion and stress corrosion cracking in combination with high mechanical strength.	• Cargo tanks in chemical tankers • Pulp and paper industry applications such as digesters and process tanks • Oil and gas industry applications such as flanges, tubes, and pipes • Structural components in bridges • Flanges and valves	C, H, P, B, R, S, T
Forta LDX 2101 A lean-alloyed duplex product with good resistance to localized and uniform corrosion, as well as stress corrosion cracking, making it a good substitute for coated carbon steel. Also offers high mechanical strength and good machinability.	• Storage tanks • Household heaters • Structural components for floodgates and bridges, or rebar for concrete structures • Pulp and paper industry applications such as digesters and components for paper machines • Flanges and valves	C, H, P, B, R, S, T
Forta DX 2304 A duplex product with a leaner alloying composition than Forta DX 2205. It has good resistance to localized and uniform corrosion, as well as stress corrosion cracking, combined with high mechanical strength.	• Automotive exhaust systems • Sugar industry equipment • Household appliances • Flanges and valves	C, H, P, B, R, S, T

Outokumpu name	Typical applications	Product forms
Forta EDX 2304 An enhanced version of Forta DX 2304 with better corrosion resistance and higher mechanical strength.	• Offshore topside structural components • Tank applications • Flanges and valves	C, H, P, B, R, S
Forta LDX 2404 A low-nickel, high-nitrogen duplex product with higher mechanical strength than Forta DX 2205. Offers very good resistance to localized and uniform corrosion, as well as stress corrosion cracking.	• Storage tanks • Structural components for flood and sluice gates • Mining industry applications such as dewatering equipment • Flanges and valves	C, H, P, B, R, S, T
Forta SDX 100 A super duplex product with higher corrosion resistance and mechanical strength than Forta DX 2205. Often used in extremely corrosive environments such as desalination, chemical, or offshore subsea applications.	• Industrial piping • Scrubbers • Tubes for oil and gas applications • Deep-sea pipelines • Flanges and valves	P, B, R, S
Forta SDX 2507 A super duplex product with higher corrosion resistance and mechanical strength than Forta DX 2205. Often used in extremely corrosive environments.	• Desalination plants • Industrial piping • Scrubbers • Tubes for oil and gas applications • Deep-sea pipelines • Flanges and valves	C, H, P, B, R, S, T
Forta FDX 25 A duplex stainless steel with improved formability and good resistance to uniform and localized corrosion, as well as stress corrosion cracking. It has high mechanical strength and excellent forming properties, and is used in applications where the use of standard duplex is restricted due to its formability limitations.	• Plate heat exchangers • Deep drawing applications for thin materials such as beer kegs • Pump components • Flanges and valves	C, H
Forta FDX 27 A duplex product with improved formability and better corrosion resistance than Forta FDX 25. It has high strength and excellent forming properties, and is used in applications where the use of standard duplex is restricted due to its formability limitations.	• Plate heat exchangers • Deep drawing applications for corrosive environments • Pump components • Flanges and valves	C, H

H-series products with high strength and ductility

Outokumpu name	Typical applications	Product forms
Forta H400 Forta H400 has higher strength than standard 304/4301 and a lower nickel content, making it a cost-effective and lightweight austenitic product for the automotive industry. It has been used in automotive applications for over 10 years.	• Cross members • Strut domes • Bumpers	C, H
Forta H500 Forta H500 has a higher yield strength than Forta H400, making it a cost-effective and lightweight austenitic stainless steel for the automotive industry and other transport or construction applications.	• Structural components for transport applications • Tube and profile applications	C, H

Outokumpu name	Typical applications	Product forms
Forta H800/Forta H1000 Forta H800 and Forta H1000 are strain-hardened-materials with a higher yield strength than Forta H500, which creates further possibilities for lightweighting in the automotive industry and other transport or construction applications.	• Structural components for transport applications • Tube and profile applications	C, H

Temper rolled products with high strength and high hardness

Outokumpu Forta range temper rolled products

Temper rolling means a controlled additional cold rolling process, which is applied in the mill to traditional stainless steel products like Moda 430/4016, Core 301/4310, Core 301LN/4318, Core 304/4301, Core 304L/4307, Supra 316/4401, Supra 316L/4404, and Supra 316plus. Temper rolling increases the strength and surface hardness of the steel, making the material comparatively lightweight, workable, and corrosion resistant. The strength classification includes yield strength classes from CP500 up to CP1700 MPa and tensile strength classes from C700 up to C1900 MPa. The same stainless steel grade in various strength classes can be used in different places of one application, for instance in the frame of a railroad car.

Outokumpu name	Typical applications	Product forms
Forta 430/4016 A classic 16% chromium ferritic stainless steel for mildly corrosive environments. Not recommended for welding due to its decreased intergranular corrosion resistance	• Tanks • Cutlery • Household appliances	C, H, B, R, S
Forta 301LN/4318 A low-carbon, nitrogen-alloyed alternative to Forta 301/4310 with elevated strength, making it particularly suitable for lightweight construction applications.	• Vehicle chassis	C, H, S
Forta 301/4310 A lower chromium and nickel variant of Core 304/4301 with high work hardening capacity. Used for items subject to high mechanical loading.	• Springs • Press plates • Conveyor chains • Mixer blades • Automotive cylinders and head gaskets	C, H, B, R, S
Forta 304/4301 A classic 18% chromium, 8% nickel austenitic stainless steel. Forta 304/4301 is an all-purpose product with good resistance to atmospheric corrosion and to many organic and inorganic chemicals.	• Vehicle chassis • Containers • Constructions	C, H, P, B, R, S, T
Forta 304L/4307 A low-carbon alternative to Core 304/4301. Forta 304L/4307 is an all-purpose product with good resistance to atmospheric and intergranular corrosion.	• Steel constructions • Containers • Vehicle chassis	C, H, P, B, R, S, T
Forta 316/4401 A normal-carbon, molybdenum-alloyed stainless steel that is widely used for various applications with higher than average corrosion resistance requirements. Forta 316/4401 is strengthened with temper rolling for applications that require specific strength.	• Chemical tanks	C, H, P, B, R, S, T
Forta 316L/4404 A low-carbon, molybdenum-alloyed alternative to Supra 316/4401 that is widely used for various applications with higher than average corrosion resistance requirements. Forta 316L/4404 is strengthened with temper rolling for applications that require specific strength as well as improved weldability and intergranular corrosion resistance.	• Chemical tanks and tubing • Pulp and paper process equipment	C, H, P, B, R, S, T

Outokumpu name	Typical applications	Product forms
Forta 316plus A temper rolled alternative to Supra 316plus for applications that require excellent corrosion resistance, improved strength, and weight savings.	• Heat exchangers • Tanks	C, H, P
Forta 316Ti/4571 A titanium-stabilized, molybdenum-alloyed austenitic steel for highly corrosive environments, including applications in elevated temperatures.	• Chimney constructions • Flue gas applications	C, H, P, B, R, S, T

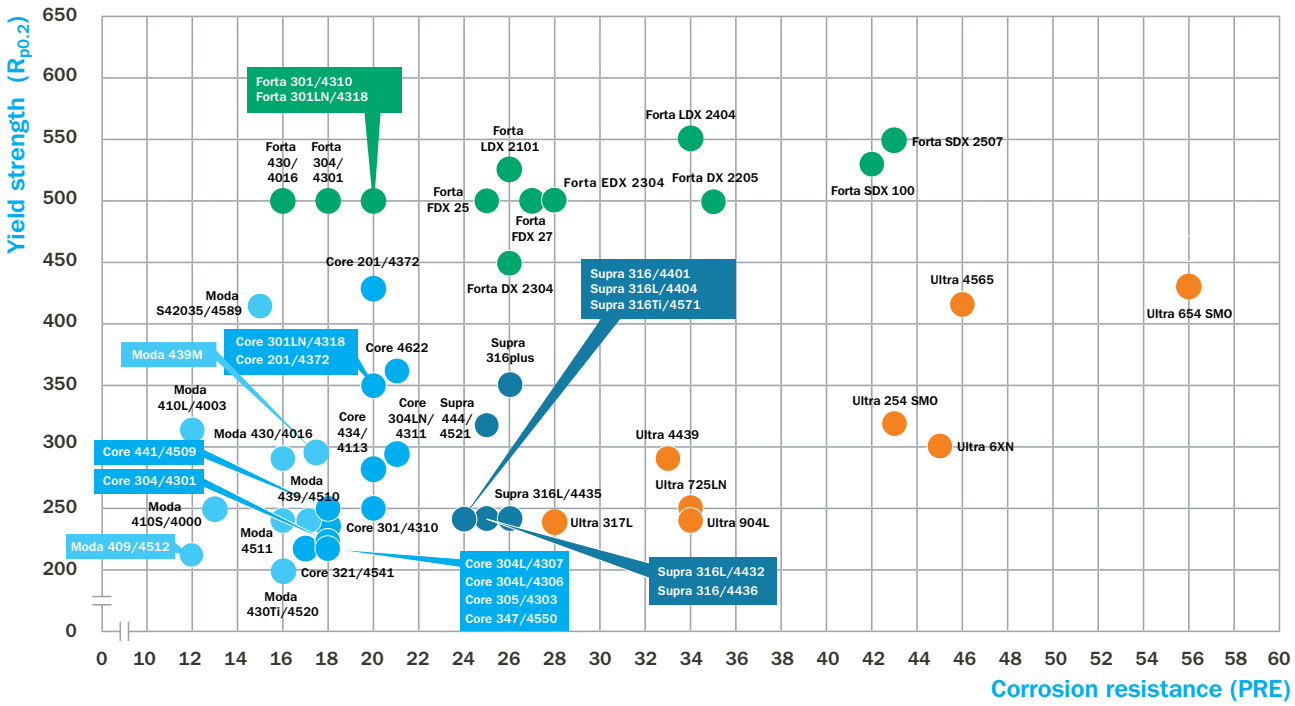
Product forms:
C = Cold rolled coil and sheet
H = Hot rolled coil and sheet
P = Quarto plate
B = Bar
R = Wire rod
S = Semi-finished (bloom, billet, ingot & slab)
T = Pipe

Products and dimensions

To find the minimum and maximum thickness and width by surface finish for a specific product in the Forta range, please visit **steelfinder.outokumpu.com**

Product performance comparison

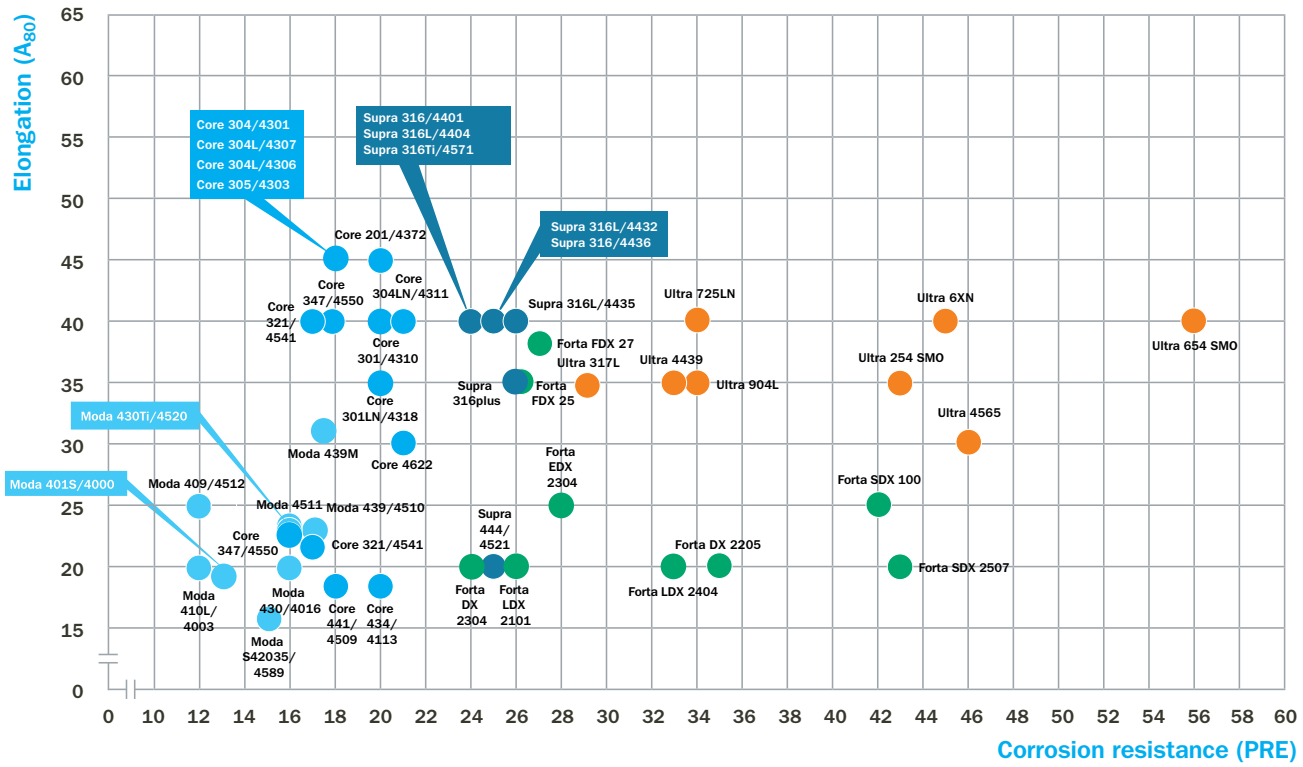
Yield strength vs. corrosion resistance



- Moda – Mildly corrosive environments (PRE up to 17)
- Core – Corrosive environments (PRE 17 to 22)
- Supra – Highly corrosive environments (PRE 22 to 27)
- Forta – Duplex and other high strength (PRE 18 to 43)
- Ultra – Extremely corrosive environments (PRE > 27)

PRE calculation = %Cr + 3.3 x % Mo + 16 x %N
Note: PRE values shown are Outokumpu typical values. Yield strength ($R_{p0.2}$) according to EN 10088-2 minimum values for cold rolled strip. Yield strength for temper rolled products ranges from 500-2000 MPa. Forta range temper rolled products' yield strengths according to strength classes in EN 10088-2 do not have an influence on corrosion resistance. For more values by product, please see **steelfinder.outokumpu.com**

Fracture elongation vs. corrosion resistance



- Moda – Mildly corrosive environments (PRE up to 17)
- Core – Corrosive environments (PRE 17 to 22)
- Supra – Highly corrosive environments (PRE 22 to 27)
- Forta – Duplex and other high strength (PRE 18 to 43)
- Ultra – Extremely corrosive environments (PRE > 27)

PRE calculation = %Cr + 3.3 x % Mo + 16 x %N
Note: PRE values shown are Outokumpu typical values. Elongation (A_{80}) % according to EN 10088-2 minimum value for cold rolled strip. For more values by product, please **see steelfinder.outokumpu.com**

Chemical composition

The chemical composition is given as % by mass.

Outokumpu name	C	Cr	Ni	Mo	N	Others	Family
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking							
Forta DX 2205	0.02	22.4	5.7	3.1	0.17	–	D
Forta LDX 2101	0.03	21.5	1.5	0.3	0.22	5Mn Cu	D
Forta DX 2304	0.02	23.0	4.8	0.3	0.1	Cu	D
Forta EDX 2304	0.02	23.8	4.3	0.5	0.18	Cu	D
Forta LDX 2404	0.02	24.0	3.6	1.6	0.27	3Mn Cu	D
Forta SDX 100	0.02	25.4	6.9	3.8	0.27	W Cu	D
Forta SDX 2507	0.02	25.0	7.0	4.0	0.27	–	D
Forta FDX 25	≤0.05	19.0-20.5	0.8-1.5	0.1-0.6	0.16-0.26	2.0-4.0Mn	D
Forta FDX 27	≤0.04	19.0-22.0	2.0-4.0	0.6-1.4	0.14-0.24	≤2.5Mn	D
H-series products with high strength and ductility							
Forta H400	0.035	17.5	4.0	–	0.20	6.8Mn	A
Temper rolled products with high strength and high hardness							
Forta 430/4016	0.05	16.2	–	–	–	–	F
Forta 301LN/4318	0.02	17.7	6.5	–	0.14	–	A
Forta 301/4310	0.1	17	7	–	–	–	A
Forta 304/4301	0.04	18.1	8.1	–	–	–	A
Forta 304L/4307	0.02	18.1	8.1	–	–	–	A
Forta 316/4401	0.04	17.2	10.1	2.1	–	–	A
Forta 316L/4404	0.02	17.2	10.1	2.1	–	–	A
Forta 316plus	0.02	20.3	8.6	0.7	0.19	–	A
Forta 316Ti/4571	0.04	16.8	10.9	2.1	–	Ti	A

Table uses Outokumpu typical values. The required standard will be fully met as specified in the order.

For the chemical composition list for different standards by stainless steel product, see **steelfinder.outokumpu.com**

Corrosion resistance

Outokumpu name	PRE
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking	
Forta DX 2205	35
Forta LDX 2101	26
Forta DX 2304	26
Forta EDX 2304	26
Forta LDX 2404	34
Forta SDX 100	42
Forta SDX 2507	43
Forta FDX 25	25
Forta FDX 27	27
H-series products with high strength and ductility	
Forta H400	18
Temper rolled products with high strength and high hardness	
Forta 430/4016	16
Forta 301LN/4318	20
Forta 301/4310	17
Forta 304/4301	18
Forta 304L/4307	18
Forta 316/4401	24
Forta 316L/4404	24
Forta 316plus	25
Forta 316Ti/4571	24

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

Surface finish and other factors determine the actual corrosion resistance of a particular product. Contact us at outokumpu.com/contacts to discuss what product is right for your next project.

Forta range duplex products

Uniform corrosion

Uniform corrosion is relatively easily measured and predicted, making disastrous failures relatively rare. It can be limited or prevented by an appropriate choice of material. In many cases, it is undesirable only from an appearance point of view. Uniform corrosion is characterized by a uniform attack on the steel surface that has come into contact with a corrosive medium. Thanks to their high chromium content, duplexes offer excellent corrosion resistance in many media, especially in alkaline solutions.

Pitting and crevice corrosion

Pitting and crevice corrosion should be taken into account in applications like heat exchangers, water heaters, offshore equipment, and storage tanks. In chloride solutions Forta LDX 2101 has better resistance to this type of corrosion than Core 304L/4307, and in some cases as good as Supra 316L/4404. In most cases Forta DX 2304 is equivalent to Supra 316L/4404, while the other more highly alloyed duplex steels exhibit even better resistance.

Chloride and sulfide-induced stress corrosion cracking

Chloride and sulfide induced stress corrosion cracking are relevant in applications like boreholes and gas wells. Duplex stainless steels have much better resistance than standard austenitic stainless steels to chloride-induced stress corrosion cracking, which means they can tolerate higher chloride content at elevated temperatures. In the presence of hydrogen sulfide and chlorides (for example, sour conditions in bore holes and gas wells) the risk of stress cracking increases at low temperatures. In these environments, Forta range duplex products, especially Forta DX 2205 and Forta SDX 2507, have demonstrated good resistance.

Corrosion fatigue and intergranular corrosion

Their combination of high mechanical strength and very good resistance to corrosion gives duplex stainless steels superior corrosion fatigue strength. The duplex microstructure and low carbon content give them good resistance to intergranular (intercrystalline) corrosion.

Erosion corrosion

In general, stainless steel offers good resistance to erosion corrosion. Duplex stainless steels are especially good due to their combination of high surface hardness and good overall corrosion resistance.

Galvanic corrosion

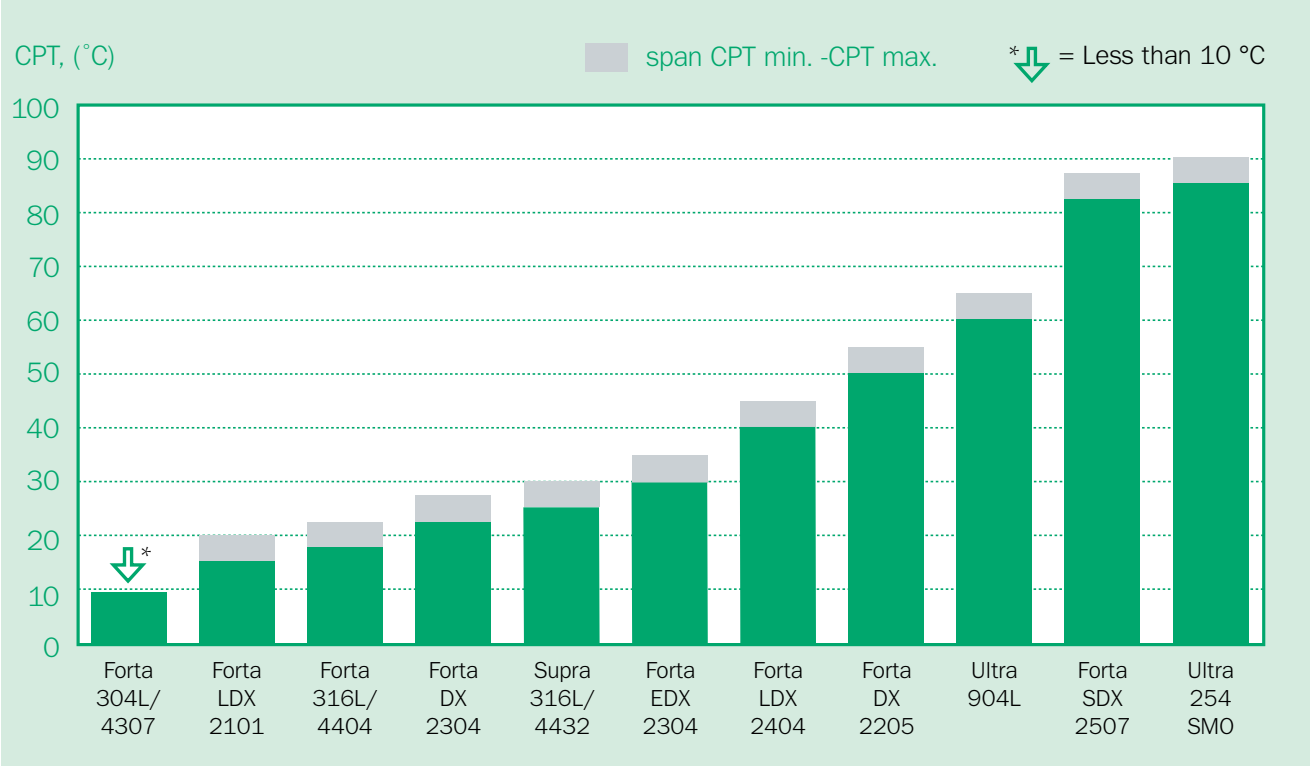
Galvanic corrosion can occur when two dissimilar metals are electrically connected (for example, by welding) in an electrolyte. In most cases stainless steel is more noble than other metallic materials. The more noble metal is protected, while the less noble metal is more severely attacked by corrosion. The electrolyte, area ratio, and the less noble metal determine the corrosion rate. Stainless steel in contact with carbon steel rebars fully cast in concrete does not cause galvanic corrosion of the carbon steel reinforcement due to the high pH of concrete. Galvanic corrosion does not occur between different stainless steels as long as both steels are in a passive state.

Atmospheric corrosion

Atmospheric corrosion is not a unique form of corrosion, but a collective term to denote the corrosion of surfaces in the atmosphere. When stainless steel is exposed to an aggressive atmosphere it is primarily stained. This is sometimes referred to as tea staining, but it can also be attacked by localized corrosion over time, particularly at high chloride levels such as those in marine atmospheres. Today there are duplex stainless steels available for any type of atmosphere.

Forta range H-series products

H-series products are only approved for use when painted. The H-series steels were developed for lightweight components in transport applications; these products cannot therefore be handled in the same way as traditional stainless steels, which have a different alloying system. The corrosion system is optimized to combine the passivation layer of the surface with a cathodic dip coating. In this condition the results after stone chipping or lattice



Typical critical pitting corrosion temperatures (CPT) in 1M NaCl measured according to ASTM G150 using the Avesta Cell. Test surfaces wet ground to 320 mesh. CPT varies with product form and surface finish.

cutting in an alternating climate test show no corrosion attacks or disbanding of the coating.

Forta H-series products do not require additional corrosion protection such as a zinc or AlSi coating in comparison to other construction steels, which results in good weldability and good behavior of welded seams after corrosion tests. In the absence of a zinc-coated layer, the problem of liquid metal embattlement can be avoided.

Forta range temper rolled products

Forta 430/4016 has good resistance to atmospheric corrosion in indoor applications and mildly corrosive outdoor applications, and is generally resistant to most domestic liquids such as detergents, soaps, and organic acids present in food as long as the surface is kept clean. As a ferritic stainless steel, it is not susceptible to chloride-induced stress corrosion cracking and has good resistance to many alkaline solutions, a wide range of diluted organic acids, as well as to aqueous solutions that do not contain halides, i.e. those that are free from chlorides, fluorides, bromides, and iodides.

Forta 301/4310, Forta 301LN/4318, Forta 304/4301 and **Forta 304L/4307** have good corrosion resistance in solutions of many halogenfree organic and inorganic compounds over a wide temperature and concentration range. They can withstand many organic and sufficiently diluted mineral acids depending on the temperature of the solution. Pitting and crevice corrosion is possible in chloride-containing solutions, depending on various parameters such as chloride concentration, temperature, pH value, redox potential, and crevice geometry. The best material performance can usually be achieved through appropriate design, correct post-weld treatment, and regular cleaning during use (if applicable).

Forta 316/4401, Forta 316L/4404 and **Forta 316Ti/4571** have excellent corrosion resistance in solutions of many halogen free organic and inorganic compounds over a wide temperature and concentration range. They can withstand many organic and diluted mineral acids depending on the temperature and concentration of the solution. These products may suffer from uniform corrosion in strong mineral acids and hot, strong alkaline solutions.

Mechanical properties

Metric						
Outokumpu name	**Product form**	**Yield strength $R_{p0.2}$ (MPa)**	**Yield strength $R_{p1.0}$ (MPa)**	**Tensile strength R_m (MPa)**	**Elongation A (%)**	**Elongation A_{80} (%)**
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking						
Forta DX 2205	C	500	–	700–950	20	20
	H	460	–	700–950	25	25
	P	460	–	640–840	25	25
	R*	510	–	750	35	–
	B*	650	–	850	12	–
Forta LDX 2101	C	530	–	700–900	30	20
	H	480	–	680–900	30	30
	P	450	–	650–850	30	30
	R*	480	–	700	38	–
	B*	500	–	700	20	–
Forta DX 2304	C	450	–	650–850	20	20
	H	420	–	650–850	20	20
	P	400	–	630–800	25	25
	R*	500	–	700	35	–
	B*	–	–	–	–	–
Forta EDX 2304	C*	600	–	770	30	–
	H*	600	–	750	30	–
Forta LDX 2404	C	550	–	750–900	25	20
	H	550	–	750–900	25	–
	P	480	–	680–900	25	–
	B*	700	–	900	20	–
Forta SDX 100	P	530	–	730–930	25	25
Forta SDX 2507	C	550	–	750–1000	20	20
	H	550	–	750–1000	20	20
	P	530	–	730–930	20	20
	B*	–	–	–	–	–
Forta FDX 25	C*	610	647	810	–	39
Forta FDX 27	C*	620	655	830	–	37
H-series products with high strength and ductility						
Forta H400	C	400	420	600–900	40	40
	H	400	420	600–900	40	40
Forta H500	C*	530	–	900	–	51
Forta H800	C*	800	–	1000	–	31
Forta H1000	C*	1000	–	1200	–	13

Note: Figures according to EN 10088-2 minimum values unless marked otherwise.

*Outokumpu typical values

A80 initial length = 80 mm, A initial length = $5.65\sqrt{S0}$

Product forms: cold rolled coil and sheet (C), hot rolled coil and sheet (H), Quarto plate (P), wire rod (R), cold drawn bar, 10 < d ≤ 16mm (B). More product forms may be available than shown in table

For more information, please see **steelfinder.outokumpu.com**

Imperial					
Outokumpu name	**Product form**	**Yield strength $R_{p0.2}$ (ksi)**	**Yield strength $R_{p1.0}$ (ksi)**	**Tensile strength R_m (ksi)**	**Elongation A_{50} (%)**
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking					
Forta DX 2205	C	65	–	90	25
	H	65	–	95	25
	P	65	–	90	25
	R*	74	–	109	–
Forta LDX 2101	C	65	–	94	30
	H	65	–	94	30
	P	65	–	94	30
	R*	70	–	102	–
Forta DX 2304	C	58	–	87	25
	H	58	–	87	25
	P	58	–	87	25
	R*	73	–	102	–
Forta EDX 2304	C*	87	–	112	–
	H*	87	–	109	–
Forta LDX 2404	C	78	–	107	25
	H	78	–	107	25
	P	70	–	99	25
Forta SDX 100	C	80	–	109	25
	H	80	–	109	25
	P	80	–	109	25
Forta SDX 2507	C	80	–	115	15
	H	80	–	115	15
	P	80	–	115	15
Forta FDX 25	C*	88	94	117	41
Forta FDX 27	C*	90	95	120	39
H-series products with high strength and ductility					
Forta H400	C*	59	66	107	–
	H*	59	67	104	–

Note: Figures according to ASTM A240 minimum values unless marked otherwise.

*Outokumpu typical values

A50 initial length = 50 mm

Product forms: cold rolled coil and sheet (C), hot rolled coil and sheet (H), Quarto plate (P), wire rod (R). More product forms may be available than are shown in the table.

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Imperial				
Outokumpu name	**Product form**	**Yield strength $R_{p0.2}$ (ksi)**	**Yield strength $R_{p1.0}$ (ksi)**	**Tensile strength R_m (ksi)**
Temper rolled products with high strength and high hardness				
Forta 430/4016	C	30	–	65
	H	30	–	65
	P	30	–	65
	R*	41	–	65
Forta 301LN/4318	C	35	–	80
	H	35	–	80
	P	35	–	80
Forta 301/4310	C	30	–	75
	H	30	–	75
	P	30	–	75
	R*	44	48	116
Forta 304/4301	C	30	–	75
	H	30	–	75
	P	30	–	75
	R*	42	48	87
Forta 304L/4307	C	25	–	70
	H	25	–	70
	P	25	–	70
	R*	41	46	84
Forta 316/4401	C	30	–	75
	H	30	–	75
	P	30	–	75
	R*	28	32	73
Forta 316L/4404	C	25	–	70
	H	25	–	70
	P	25	–	70
	R*	32	38	77
Forta 316plus	C	45	–	92
	H	45	–	92
	P	45	–	92
Forta 316Ti/4571	C	30	–	75
	H	30	–	75
	P	30	–	75

Note: Figures according to ASTM A240 minimum values unless marked otherwise.

*Outokumpu typical values

A50 initial length = 50 mm

Product forms: cold rolled coil and sheet (C), hot rolled coil and sheet (H), Quarto plate (P), wire rod (R). More product forms may be available than are shown in the table.

For more information, please see **steelfinder.outokumpu.com**

Temper rolled products strength classification

Outokumpu name	Tensile strength EN	Yield strength EN
Temper rolled products with high strength and high hardness		
Forta 430/4016	C700	CP350
	C850	CP500
Forta 301LN/4318	C700	CP350
	C850	CP500
	C1000	CP700
	C1150	CP900
Forta 301/4310	C700	CP350
	C850	CP500
	C1000	CP700
	C1150	CP900
	C1300	CP1100
	C1500	CP1300
	C1700	CP1500
	C1900	CP1700
Forta 304/4301	C700	CP500
	C850	CP700
	C1000	CP900
	C1150	CP1100
	C1300	CP1300
Forta 304L/4307	C700	CP500
	C850	CP700
	C1000	CP900
	C1150	CP1100
Forta 316/4401	C850	CP700
	C1000	CP900
	C1150	CP1100
	C1300	–
Forta 316L/4404	C700	CP500
	C850	CP700
	C1000	CP900
	C1150	CP1100
	C1300	–
Forta 316plus	–	1040*
Forta 316Ti/4571	C700	CP500
	C850	CP700
	C1000	CP900
	C1150	CP1100
	C1300	–

*Outokumpu tested value, MPa

Physical properties

Metric						
Outokumpu name	**Density [kg/dm³]**	**Modulus of elasticity at 20 °C [GPa]**	**Coefficient of thermal expansion 20–100 °C [10⁻⁶ / K]**	**Thermal conductivity at 20 °C [W/(m*K)]**	**Thermal capacity at 20 °C [J/(kg*K)]**	**Electrical resistivity at 20 °C [Ω*mm² / m]**
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking						
Forta DX 2205	7.8	200	13	15	500	0.8
Forta LDX 2101	7.8	200	13	15	500	0.8
Forta DX 2304	7.8	200	13	15	500	0.8
Forta EDX2304	7.8	200	13	15	500	0.8
Forta LDX 2404	7.7	205	13	14.5	500	0.8
Forta SDX 100	7.8	200	13	15	500	0.8
Forta SDX 2507	7.8	200	13	15	500	0.8
Forta FDX 25	7.7	205	12.5	14.5	500	0.8
Forta FDX 27	7.7	205	12.5	14.5	500	0.8
H-series products with high strength and ductility						
Forta H400	7.9	200	16	15	500	0.73
Temper rolled products with high strength and high hardness						
Forta 430/4016	7.7	220	10	25	460	0.6
Forta 301LN/4318	7.9	200	16	15	500	0.73
Forta 301/4310	7.9	200	18	15	500	0.73
Forta 304/4301	7.9	200	16	15	500	0.73
Forta 304L/4307	7.9	200	16	15	500	0.73
Forta 316/4401	8	200	16	15	500	0.75
Forta 316L/4404	8	200	16	15	500	0.75
Forta 316plus	7.9	200	16	15	500	0.75
Forta 316Ti/4571	8	200	16.5	15	500	0.75

Imperial						
Outokumpu name	**Density [lbm/in³]**	**Modulus of elasticity [psi]**	**Coefficient of thermal expansion 68–212 °F [µin / (in* °F)]**	**Thermal conductivity [Btu/(hr*ft* °F)]**	**Thermal capacity [Btu/(lbm* °F)]**	**Electrical resistivity [µΩ*in]**
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking						
Forta DX 2205	0.282	$29 * 10^6$	7.22	8.7	0.119	31.5
Forta LDX 2101	0.282	$29 * 10^6$	7.22	8.7	0.119	31.5
Forta DX 2304	0.282	$29 * 10^6$	7.22	8.7	0.119	31.5
Forta EDX2304	0.282	$29 * 10^6$	7.22	8.7	0.119	31.5
Forta LDX 2404	0.278	$29 * 10^6$	7.22	8.3	0.119	31.5
Forta SDX 100	0.282	$29 * 10^6$	7.22	8.7	0.119	31.5
Forta SDX 2507	0.282	$29 * 10^6$	7.22	8.7	0.119	31.5
Forta FDX 25	0.278	$29 * 10^6$	6.94	8.3	0.119	31.5
Forta FDX 27	0.278	$29 * 10^6$	6.94	8.3	0.119	31.5
H-series products with high strength and ductility						
Forta H400	0.285	$29 * 10^6$	8.89	8.7	0.119	28.74
Temper rolled products with high strength and high hardness						
Forta 430/4016	0.278	$31.9 * 10^6$	5.56	14.4	0.11	23.62
Forta 301LN/4318	0.285	$29 * 10^6$	8.89	8.7	0.119	28.74
Forta 301/4310	0.285	$29 * 10^6$	10	8.7	0.119	28.74
Forta 304/4301	0.285	$29 * 10^6$	8.89	8.7	0.119	28.74
Forta 304L/4307	0.285	$29 * 10^6$	8.89	8.7	0.119	28.74
Forta 316/4401	0.289	$29 * 10^6$	8.89	8.7	0.119	29.53
Forta 316L/4404	0.289	$29 * 10^6$	8.89	8.7	0.119	29.53
Forta 316plus	0.285	$29 * 10^6$	8.89	8.7	0.119	29.53
Forta 316Ti/4571	0.289	$29 * 10^6$	9.17	8.7	0.119	29.53

Fabrication

Fabrication advice	
Cutting, shearing	Maximum thickness for shearing and punching is 80-85% of that of austenitic steel.
Roll bending	More bending force will be needed compared to other stainless steels. Through the downgauging, this effect will however be smaller than anticipated. The springback due to the higher strength is large when roll bending.
Break bending	Avoid sharp bending radius. Minimum ratio between inner radius to sheet thickness should not be less than 2.
Deep drawing	If drawing is dominant, formability is comparable to austenitic stainless steel. If stretching is dominant, formability is closer to ferritic steels.
Roll forming	The high strength of the sheet has to be considered in the design of the rolls. If properly designed there are no problems in roll forming duplex.
Tooling use	Strong, durable tools (hardness, HRC larger than 500, Ra-value preferably lower than 0.2 micrometers).
Lubrication	Because of the high strength of duplex and extreme pressure needed, additives are useful in complex forming operations.

Forta range duplex products

Forta range duplex stainless steels offer excellent possibilities for the construction of challenging and durable structures. However, due to their high strength the forming process is somewhat different than with austenitic or ferritic steels. Outokumpu can assist you with all technical aspects of fabrication. We can provide you with the necessary training, computer simulations, and detailed instructions.

Welding

Duplex stainless steels can be welded with most of the methods used for austenitic stainless steel:

- Shielded metal arc welding (SMAW)
- Gas tungsten arc welding (GTAW, TIG)
- Gas metal arc welding (GMAW, MIG)
- Flux-cored arc welding (FCAW)
- Plasma arc welding (PAW)
- Submerged arc welding (SAW)
- Others: Laser, resistance, and high frequency (HF) welding

In general, the main challenge when welding Forta range duplex products is maintaining the phase balance in the heat-affected zone (HAZ) without precipitation. The chemical composition balances the microstructure. Therefore, it is important to use the correct welding consumable and procedure.

The following general instructions should be followed when welding Forta range duplex products:

1. Weld without preheating.
2. Allow the material to cool between passes, preferably to below 150 °C/300 °F (for Forta SDX 2507 ≤ 100 °C/210 °F).
3. Duplex filler material is required and recommended with the exception of Forta LDX 2101, which can be welded without filler material in some cases.

Welding consumables	
Outokumpu name	**Consumable ISO designation**
Duplex, high strength, high corrosion resistance and enhanced resistance to stress corrosion cracking	
Forta DX 2205	22 9 3 NL
Forta LDX 2101	23 7 NL, 22 9 3 NL
Forta DX 2304	23 7 NL, 22 9 3 NL
Forta EDX 2304	22 9 3 NL
Forta LDX 2404	22 9 3 NL
Forta SDX 2507	25 9 4 NL
Forta FDX 25	23 / NL, 22 9 3 NL
Forta FDX 27	22 9 3 NL

4. The recommended arc energy should be kept within specified limits.
5. The heat input should be adapted to the product and adjusted to the thickness of the welded material.
6. The edge preparation angle should be about 10° greater and the land should be somewhat smaller than when welding standard austenitics.
7. If welded with filler, post-weld annealing is not necessary. In cases where heat treatment is considered, for example for stress relieving, it should be carried out in accordance with the temperatures stated below, but with the minimum temperature increased by 30–50 °C/80–120 °F in order to secure full dissolution of the intermetallic phase in the weld metal.
8. For GTAW and PAW methods, the addition of nitrogen (1–2%) to the shielding/purging gas is recommended.

Welding to other steels, including carbon steels

Forta range duplex stainless steels are readily weldable to other steels, including carbon steels. The filler type can be duplex. When duplex steels are welded to carbon steels, one alternative is to use a 23Cr13Ni2Mo type filler. In most cases duplex fillers offer more strength and better corrosion resistance. When welding duplex to super austenitic steels, please contact Outokumpu for assistance.

Post-weld treatment

In order to restore the stainless steel surface and achieve good corrosion resistance, it is necessary to perform a post-weld treatment. There are both mechanical methods (for example, brushing, blasting, and grinding) and chemical methods (for example, pickling) available. The most appropriate method depends on the type of imperfections to be removed, as well as corrosion resistance, hygiene, and aesthetic requirements.

Forming

Forta range duplex products are suitable for all forming techniques. The higher strength and lower elongation compared with austenitic stainless steel will however impose some differences in forming behavior: Generally a higher force is needed. On the other hand, since duplex design often implies down-gauging, the force level can be similar to austenitics. If the forming technique is not already decided, we recommend choosing the most appropriate one for duplex stainless steels.

Forta FDX 25 and Forta FDX 27

The Forta range FDX products exhibit substantially improved formability. The elongation after fracture is typically about 40%

compared with about 30% for other duplex stainless steels, which make them more suitable for advanced forming.

Machining

Stable setup

Due to the higher strength the cutting forces will be higher, which increases the risk of vibrations. The trick is to have a stable setup. Use the shortest possible tool extension, good and rigid clamping

Sharp tools

Use cutting tools with a positive geometry. Duplex stainless steels are prone to work hardening, a dull geometry will generate a hard surface and decrease the tool life.

Avoid edge build up

Stainless steels have a tendency to stick to the tool. Problems occur when the cutting speed is too low. The main difference between carbon steel and stainless steels when machining is that you face problems if you run too slowly. The result will be poor surface finish and short tool life. The problem is solved by increasing the cutting speed.

Forta LDX 2101

The lean duplex product Forta LDX 2101 has superior machinability compared with other duplex stainless steels. Even compared with low-alloyed standard austenitic stainless steel, Forta LDX 2101 is easier to machine.

Forta range H-series products

Forta H400 and H500 are readily weldable with all conventional welding methods. When welding with filler materials, 1.4316 should be used for welds with similar materials and 1.4370 for welds with unalloyed steels. No preheating or post-weld treatment is required. For applications in particularly critical conditions, temper colors or scaling should be removed chemically (for example, by pickling) and/or mechanically (for example, by grinding).

Other joining methods like bonding, weld bonding, and mechanical joining methods such as riveting are also possible.

One advantage of the special balanced austenitic microstructure of H-series products can be demonstrated under dynamic loading in welded areas.

Considering the hardness values in the bend area with those of the original state, it can be shown that the TWIP effect of H-series steels restarts under loading. The effect is significant in the weld areas, and therefore the welding zone is not the weak point during a crash. The complete material area subtends a hardening to the crash load. The mentioned property is tremendously important for intrusion-relevant passenger safety components like b-pillars in automotive applications.

Outokumpu can assist you when using H-series products. Contact our automotive technical support team at **outokumpu.com/contacts**

Forming and machining

Forta H-series steels show good hot and cold forming behavior. All common cold forming processes can be used, including blending, deep drawing, spinning, and profiling. However, the increased yield strength of the material requires higher forming forces than typical chromium-nickel steels, while a higher degree of springback must also be taken into account. Given the material's work hardening tendency and relatively low thermal conductivity, high quality tool steel or hard metal tools should be used for machining.

Forta range temper rolled products

Forming and machining

The overall formability of austenitics is good. The required forces and the elastic return are bigger compared with carbon steels. Because of their high ductility and strong work hardening, it is recommended to use sharp tools, effective cooling, and an adequate feed tool.

Austenitics can be readily formed and fabricated using the full range of cold forming operations. They can be used in heading, drawing, and bending. Any cold forming operations will increase the strength and hardness of the material, and may leave it slightly magnetic. Work hardening is accentuated by the partial transformation of the austenite phase of the material to hard martensite.

Welding

Austenitic stainless steels in general have excellent weldability and are readily weldable with all conventional welding methods, including MMA, MIG, MAG, TIG, SAW, LBW and RSW, excluding gas welding. Austenitic steels have about 50% higher thermal expansion and lower heat conductivity compared with carbon steels. This means that larger deformation and higher shrinkage stresses may result from welding. Cleaning the weld seam is very important for maintaining corrosion resistance. Pickling is recommended. Because of the austenitic structure, the welded joints are tough down to low temperatures even in the as-welded condition.

For more information, see the Outokumpu Welding Handbook, available from our sales offices.

outokumpu.com/contacts

Standards and approvals

The most commonly used international product standards are given in the table below. For a full list of standards by product, see **steelfinder.outokumpu.com**

Temper rolled product standards

Standards	
Flat products	
EN ISO 18286	Hot-rolled stainless steel plates – Tolerances on dimensions and shape
EN 10051	Hot-rolled steel strip tolerances
EN 10088-1	Stainless steels – list of stainless steels
ISO 15510	Stainless steels – chemical composition
EN ISO 9445	Cold-rolled stainless narrow strip, wide strip, plate/sheet and cut lengths tolerances
ASTM A 480	General requirements for flat-rolled stainless and heat resisting steel
ASTM A 959	Harmonized standard grade compositions for wrought stainless
ASME IID	Materials – Physical properties tables
Flat and long products	
EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10088-2	Stainless steels – sheet/plate and strip for general purposes
EN 10088-3	Stainless steels – semi-finished products, bars, rods sections for general purposes
EN 10088-4	Technical delivery conditions for sheet/plate and strip
EN 10088-5	Technical delivery conditions for bars, rods wire, sections and bright products of corrosion resisting steels for construction purposes
EN 10095	Heat resisting steels and nickel alloys
EN 10151	Stainless steel strip for springs
EN 10302	Creep resisting steels, nickel and cobalt alloys
ASTM A 167	Stainless and heat-resisting Cr-Ni steel plate, sheet, and strip
ASTM A 176	Stainless and heat-resisting Cr steel plate, sheet, and strip
ASTM A 240	Heat-resisting Cr and Cr-Ni stainless steel plate, sheet and strip for pressure vessels
ASTM A276	Stainless steel and heat resisting steel bars and shapes
ASTM A479/479M	Stainless steel bars for boilers/pressure vessels
ASTM A493	Stainless steel and heat-resisting steel rod and wire for cold heading and forging
ASTM A555	General requirements for stainless and heat resistant steel wire and wire rod
ASTM A 666	Austenitic stainless steel sheet, strip, plate, bar for structural and architectural applications
ASME IIA	Materials. Part A – Ferrous Material Specifications

Duplex pressure vessel approvals

Forta DX 2304, Forta DX 2205, and Forta SDX 2507 are listed in EN 10028-7:2007.

European material approval EAM 0045-01:2012/01 for Forta LDX 2101 is available for cold rolled 0.5-6.4 mm and hot rolled 3.0–10.0 mm.

In ASME II-D 2013, Forta DX 2205 (S31803 and S32205). Forta EDX 2304 (S32304), Forta SDX 100 (S32760) and Forta SDX 2507 (S32750) are listed for general use in the temperature range -30 – 316 °C. Data for Forta LDX 2101 and Forta LDX 2404 can be found in ASME code case 2418-1 and 2780 respectively.

Certificates and approvals

Outokumpu meets the most common certifications and approvals including:

- AD 2000 Merkblatt
- Approval of Material Manufacturers
- Factory Production Control Certificate
- ISO 9001
- ISO 14001
- ISO 50001
- ISO/TS 16949
- NORSOK
- OHSAS 18001
- Pressure Equipment Directive (PED)

For the full list of certificates and approvals by mill, see **outokumpu.com/certificates**

Contacts and enquiries

Contact us

Our experts are ready to help you choose the best stainless steel product for your next project.

outokumpu.com/contacts

1562EN-GB:1. May 2015. Erweko, Finland.

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.

outokumpu classic

Moda	Core	Supra
Mildly corrosive environments	Corrosive environments	Highly corrosive environments

outokumpu pro

Forta	Ultra	Dura	Therma	Prodec	Deco
Duplex & other high strength	Extremely corrosive environments	High hardness	High service temperatures	Improved machinability	Special surfaces

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