outokumpu
high performance stainless steel

Stainless steels for mildly corrosive environments

Outokumpu Moda range datasheet

General characteristics and properties

Moda range products are designed for applications in mildly corrosive environments, with a Pitting Resistance Equivalent (PRE) value of up to 17. This range contains the well known Moda 430/4016 as well as several alternatives and low-chromium options, see Table 1.

Chemical composition

Table 1

Moda

Steels with PRE up to 17, for mildly corrosive environments.

Outokumpu Classic family

Steel designations				Performance				Typical chemical composition, % by mass					
		ASTM			A *)	$R_{p0.2}$	Grade						
Outokumpu name	EN	Type	UNS	PRE	%	MPa	family	C	Cr	Ni	Mo	N	Others
Moda 430/4016	1.4016	430	S43000	16	20	280	F	0.05	16.2	–	–	–	–
Alternatives													
Moda 439/4510	1.4510	439	S43035	17	23	240	F	0.02	17.0	–	–	–	Ti
Moda 430Ti/4520	1.4520	430Ti	–	16	24	200	F	0.02	16.2	–	–	–	Ti
Moda 4589	1.4589	–	S42035	15	16	420	F	0.045	14.0	1.65	0.25	–	Ti
Low-Cr alternatives													
Moda 410L/4003	1.4003	410L	S40977	12	20	320	F	0.02	11.5	0.5	–	–	–
Moda 409/4512	1.4512	409	–	12	25	220	F	0.02	11.5	0.2	–	–	Ti

Grade family: F = ferritic. *) Elongation reference varies between different standards, information referenced here denotes A_{80} – otherwise see footnote for specific grade or inquire to reference alternative standard.

PRE = %Cr + 3.3 x %Mo + 16 x %N. Values for $R_{p0.2}$ yield strength and for A_{80} elongation are according to EN 10088-2 min. values for cold rolled strip. Chemical compositions and PRE calculations are based on Outokumpu typical values. Please see values for other product forms at **steelfinder.outokumpu.com**

Moda range products are available with the following surface finishes: 1, 2B, 2D, 2E and Deco range special surfaces.

Products

Table 2

Outokumpu name	Typical applications	Product forms
Moda 430/4016 (EN 1.4016/UNS S43000) A classic ferritic stainless steel used in mildly corrosive environments.	• Kitchen equipment • Household appliances • Sinks • Elevators • Flanges and valves	• Cold rolled coil and sheet • Hot rolled coil and sheet • Precision strip
Moda 439/4510 (EN 1.4510/UNS S43035) A stabilized ferritic steel with improved corrosion resistance, formability, and weldability compared to Moda 430/4016.	• Automotive exhaust systems • Sugar industry equipment • Household appliances	• Cold rolled coil and sheet • Hot rolled coil and sheet • Precision strip
Moda 430Ti/4520 (EN 1.4520) An alternative to Moda 430/4016 with better formability and weldability for stamping, drawability applications, and complex shapes.	• Counter tops • Flue induction connectors • Automotive applications	• Cold rolled coil and sheet • Hot rolled coil and sheet
Moda 4589 (EN 1.4589/UNS S42035) A product with a small amount of titanium for elevated strength, making it suitable for structural parts exposed to loads that demand higher yield points.	• Conveyor chains • Railroad cars	• Cold rolled coil and sheet • Hot rolled coil and sheet
Moda 410L/4003 (EN 1.4003/UNS S40977) A weldable ferritic stainless steel with elevated yield strength and resistance to abrasion. Its better corrosion resistance compared to carbon steels enables lower maintenance costs and longer service life. This grade has also improved low temperature impact toughness.	• Railroad and road vehicles • Shipping containers • Industrial applications • Mining conveyors	• Cold rolled coil and sheet • Hot rolled coil and sheet
Moda 409/4512 (EN 1.4512) A weldable ferritic stainless steel with good oxidation resistance in dry air. This product is also available as low-carbon Moda 409L.	• Automotive applications • Industrial exhaust systems	• Cold rolled coil and sheet • Hot rolled coil and sheet

Performance

Strength vs. Corrosion resistance

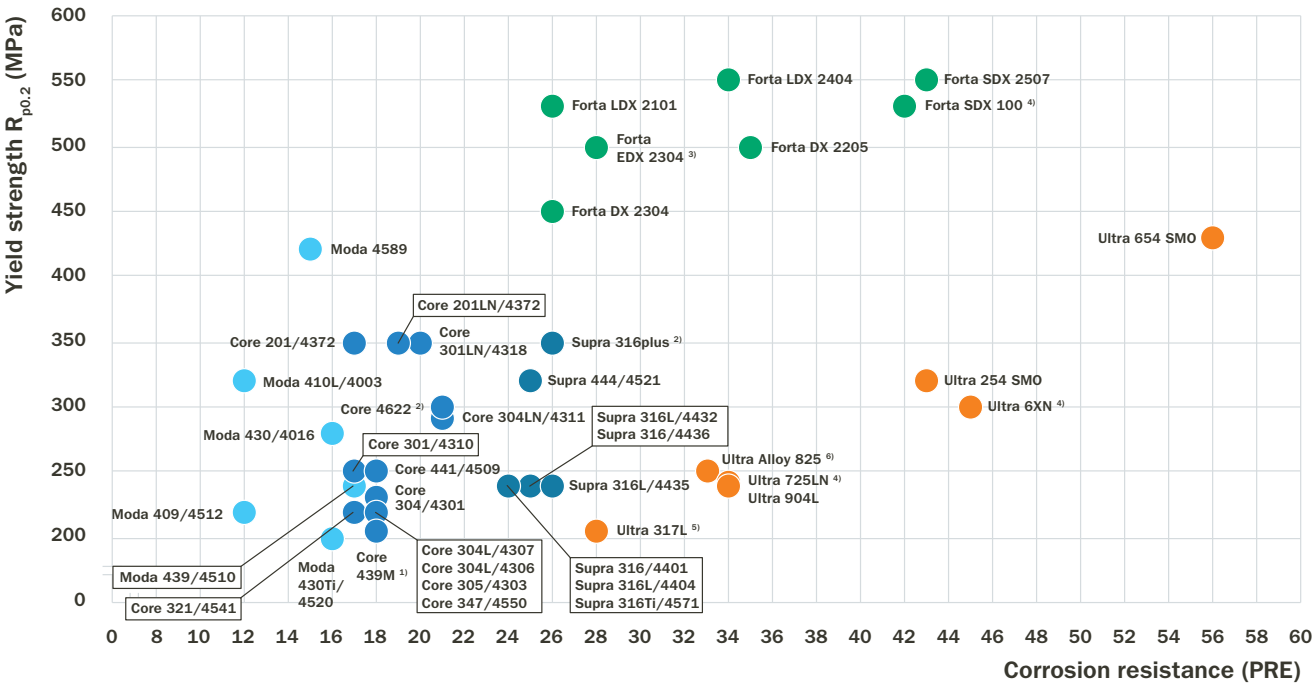

Fig. 1. Strength vs. Corrosion resistance.

Elongation vs. Corrosion resistance

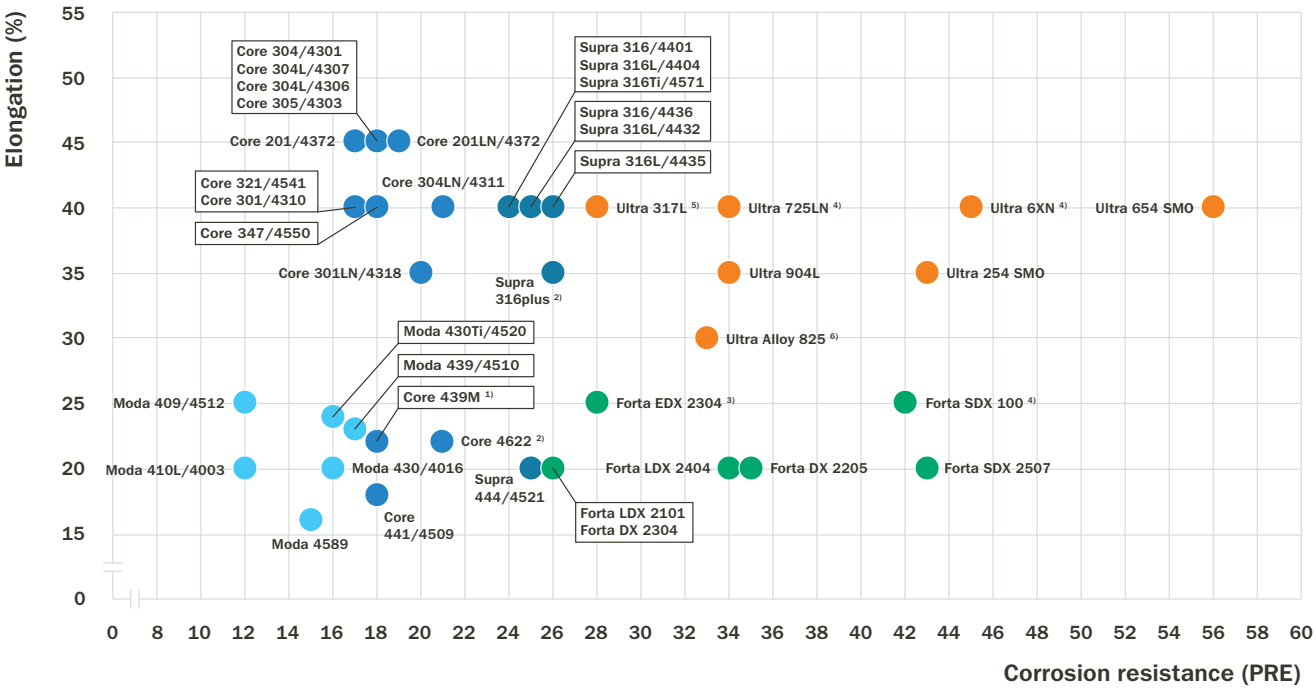

Fig. 2. Elongation vs. corrosion resistance.

- Moda – Stainless steels for mildly corrosive environments (PRE ≤17)
- Core – Stainless steels for corrosive environments (PRE 17–22)
- Supra – Stainless steels for highly corrosive environments (PRE 22–26)
- Forta – Duplex stainless steels (PRE 26–43)
- Ultra – Stainless steels and nickel base alloys for extremely corrosive environments (PRE > 27)

PRE = %Cr + 3.3 x %Mo + 16 x %N.
Values for $R_{p0.2}$ yield strength and for A_{80} elongation are according to EN 10088-2 min. values for cold rolled strip. Chemical compositions and PRE calculations are based on Outokumpu typical values.

[1] Elongation reference varies between different standards, for coil the standard typically uses A_{80} – otherwise see footnote for specific grade.
[2] Min. values acc. to EN 10028-7.
[3] Outokumpu MDS-D35 for EDX 2304.
[4] Min. values for plate acc. to EN 10088-2.
[5] Min values acc. to ASTM A240.
[6] Min. values hot-rolled and cold-rolled acc. to ASTM B424.

Please see values for other product forms at **steelfinder.outokumpu.com**

Corrosion resistance

Chemical composition

Table 3

Outokumpu name	EN	ASTM		PRE
		Type	UNS	
Moda 430/4016	1.4016	430	S43000	16
Moda 439/4510	1.4510	439	S43035	17
Moda 430Ti/4520	1.4520	430Ti	–	16
Moda 4589	1.4589	–	S42035	15
Moda 410L/4003	1.4003	410L	S40977	12
Moda 409/4512	1.4512	409	–	12

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.

The corrosion resistances of Moda range ferritic stainless steels are superior to that of carbon steel because of their higher chromium content.

Uniform corrosion

Uniform corrosion is characterized 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 (0.004 in/year). 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.

The corrosion resistance of Moda 410L/4003 in strong acids is limited compared to standard austenitic steels and it should be used only in mildly corrosive environments without any additional protection. Moda 430/4016 has good corrosion resistance to a large variety of media including nitric acid and some organic acids. Moda 430/4016 is also resistant to most domestic liquids such as detergents and soaps when rinsed properly, 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.

Pitting and crevice corrosion

Pitting and crevice corrosion may occur in chloride-containing environments, depending on various parameters such as chloride concentration, temperature, pH value, redox potential, and crevice geometry. When compared to austenitic stainless steels like Core 304/4301 or Core 304L/4307, the ferritic stainless steels such as Moda 430/4016 show a lower resistance to localized corrosion in chloride containing media.

Stress corrosion cracking

Stress corrosion cracking (SCC) is characterized by the cracking of materials that are subject to both tensile stress and corrosive environments. The environments that most frequently cause SCC in stainless steels are aqueous solutions containing chlorides. Apart from the presence of chlorides and tensile stresses, an elevated temperature (> 60 °C/140 °F) is normally required for SCC to occur in stainless steels. The risk of SCC is strongly affected by both the nickel content and the microstructure. Both high and low nickel content gives a better resistance to SCC. Nickel-free ferritic steels therefore have excellent resistance to chloride-induced SCC.

Intergranular corrosion

This type of corrosion is also called grain boundary attack and is characterized by corrosion in a narrow band along the grain boundaries. A low carbon content extends the time required for significant sensitization. Modern steel making methods enable much lower carbon contents to be achieved, which reduces the risk of intergranular corrosion.

Operations that increase the risk of intergranular corrosion are welding of heavy gauges, heat treatment operations within the critical temperature interval (900–950 °C/1650–1740 °F), and slow cooling after heat treatment or hot forming. The risk of intergranular corrosion can be reduced by decreasing the carbon content and/or by stabilizing the steel, i.e. alloying with titanium or niobium that forms more stable carbides than chromium. For example, the titanium and niobium alloying of Moda 409/4512 reduces its sensitivity to intergranular corrosion.

Atmospheric corrosion

Atmospheric corrosion refers to both indoor and outdoor, and all local forms of corrosion. This type of corrosion occurs on a steel surface in the thin, wet film created by a combination of humidity and impurities in the air. Moda range products can be used in mildly corrosive atmospheric environments.

Moda 410L/4003 and Moda 409/4512 are best suited for non-severe conditions, such as inside the home, where they are not exposed to water or are regularly wiped dry. They are also used in outdoor applications where aesthetics are not a key requirement. They corrode more slowly compared to carbon steel. Alternatively, corrosion-protective coatings like epoxy or acrylic-based paint can be applied.

Moda 430/4016 has good resistance to atmospheric corrosion in indoor applications and mildly corrosive outdoor environments. In the case of an aggressive environment a product with higher chromium and/or molybdenum content from the Core or Supra range is recommended.

For further information on corrosion resistance, please see the Outokumpu Corrosion Handbook, available from our sales offices.

Mechanical properties

Mechanical properties at 20 °C, values according to EN 10088-2

Table 4

Metric

Outokumpu name	EN	ASTM		Product form	Yield strength $R_{p0.2}$ (MPa)	Tensile strength R_m (MPa)	Elongation A (%)	Elongation A_{80} (%)
		Type	UNS					
Moda 430/4016	1.4016	430	S43000	Cold rolled coil and sheet	280	430 – 600	20	20
				Hot rolled coil and sheet	260	430 – 600	18	18
Moda 439/4510	1.4510	439	S43035	Cold rolled coil and sheet	240	420 – 600	23	23
				Hot rolled coil and sheet	240	420 – 600	23	23
Moda 430Ti/4520	1.4520	430Ti	–	Cold rolled coil and sheet	200	380 – 530	24	24
Moda 4589	1.4589	–	S42035	Cold rolled coil and sheet	420	550 – 750	16	16
				Hot rolled coil and sheet	380	550 – 750	14	14
Moda 410L/4003	1.4003	410L	S40977	Cold rolled coil and sheet	320	450 – 650	20	20
				Hot rolled coil and sheet	320	450 – 650	20	20
				Quarto plate	280	450 – 650	18	18
Moda 409/4512	1.4512	409	–	Cold rolled coil and sheet	220	380 – 560	25	25
				Hot rolled coil and sheet	220	380 – 560	25	25

*) Outokumpu typical value.

A_{80} initial length = 80 mm, A initial length = $5.65\sqrt{S_0}(A_5)$

More product forms may be available than are shown in the table.

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

Mechanical properties at 20 °C, values according to ASTM A240

Table 5

Metric

Outokumpu name	EN	ASTM		Product form	Yield strength $R_{p0.2}$ (MPa)	Yield strength $R_{p0.2}$ (ksi)	Tensile strength R_m (MPa)	Tensile strength R_m (ksi)	Elongation A_{50} (%)
		Type	UNS						
Moda 430/4016	1.4016	430	S43000	Cold rolled coil and sheet & Hot rolled coil and sheet	205	30	450	65	22
Moda 439/4510	1.4510	439	S43035	Cold rolled coil and sheet & Hot rolled coil and sheet	205	30	415	60	22
Moda 430Ti/4520	1.4520	430Ti	–	Cold rolled coil and sheet *)	360	38	430	62	–
				Hot rolled coil and sheet *)	310	45	460	67	–
Moda 4589	1.4589	–	S42035	Cold rolled coil and sheet & Hot rolled coil and sheet	380	55	550	80	16
Moda 410L/4003	1.4003	410L	S40977	Cold rolled coil and sheet & Hot rolled coil and sheet	280	41	450	65	18
Moda 409/4512	1.4512	409	–	Cold rolled coil and sheet & Hot rolled coil and sheet	170	25	380	55	20

*) Outokumpu typical value.

A_{50} initial length = 50 mm

More product forms may be available than are shown in the table.

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

Physical properties

In Tables 6–7 physical properties are given for Moda range grades.

Metric values according to EN 10088-1 [1)]

Table 6

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 x K)]	Thermal capacity at 20 °C [J/(kg x K)]	Electrical resistivity at 20 °C [Ω x mm²/m]	Magnetizable
Moda 430/4016	7.7	220	10.0	25	460	0.60	Yes
Moda 439/4510	7.7	220	10.0	25	460	0.60	Yes
Moda 430Ti/4520	7.7	220	10.4	20	430	0.70	Yes
Moda 4589	7.7	220	10.5	25	460	0.60	Yes
Moda 410L/4003	7.7	220	10.4	25	430	0.60	Yes
Moda 409/4512	7.7	220	10.5	25	460	0.60	Yes

[1)] For corresponding EN grade numbers see Table 1. [2)] Value given by Outokumpu.

Imperial values converted from Table 6

Table 7

Outokumpu name	Density [lbm/in³]	Modulus of elasticity [psi]	Coefficient of thermal expansion 68–212 °F [µin / (in x °F)]	Thermal conductivity [Btu/(hr x ft x °F)]	Thermal capacity [Btu/(lbm x °F)]	Electrical resistivity [µΩ x in]	Magnetizable
Moda 430/4016	0.278	32 x 10^6	5.6	14.5	0.110	23.62	Yes
Moda 439/4510	0.278	32 x 10^6	5.6	14.5	0.110	23.62	Yes
Moda 430Ti/4520	0.278	32 x 10^6	5.8	11.6	0.103	27.56	Yes
Moda 4589	0.278	32 x 10^6	5.8	14.5	0.110	23.62	Yes
Moda 410L/4003	0.278	32 x 10^6	5.8	14.5	0.103	23.62	Yes
Moda 409/4512	0.278	32 x 10^6	5.8	14.5	0.110	23.62	Yes

Fabrication

Formability

Moda range products can be readily cold formed by all standard methods. Their forming properties are similar to those of low-alloyed carbon steels. Their deep drawability is comparable to that of deep drawing quality carbon steels. The stabilized product Moda 409/4512 is particularly suitable for deep drawing. An indicator of deep drawability is the limiting drawing ratio (LDR), which is the ratio of the maximum blank diameter to the cup diameter. Good deep drawability is characterized by a high LDR value. The LDR depends on the thickness of the sheet.

The drawability of a material can be described with the average plastic strain ratio r and the planar anisotropy Δr values. The value of planar anisotropy indicates the amount of uneven elongation in a deep drawing operation and is generally referred to as earing. A low earing tendency is characterized by a Δr–value close to zero. The height of the ears can be 5–10% of the height of the cup, depending on the grade, thickness, and grain size.

Roping is characterized by visual surface undulations parallel to the rolling direction of the sheet. Roping can be reduced by selecting a titanium-stabilized product such as Moda 439/4510.

The stretchability of Moda range products is comparable to that of low-alloyed carbon steels.

The minimum bending radius for Moda range products equals the sheet thickness. For sheets thinner than 1 mm/0.04 in, a bending radius of half the sheet thickness may be used. Sharp bends should be positioned perpendicular to the rolling direction.

The ductility of Moda range stainless steels usually decreases when the temperature falls below room temperature. Demanding cold forming operations should therefore be carried out with room-temperature material.

Machining

Moda range products are relatively easy to machine. Their machining characteristics are similar to those of low-alloyed carbon steels with tensile strength of 500 MPa. Consequently, the guidelines regarding the machining parameters and tools given for low-alloyed carbon steels can be used.

Welding

Most Moda range ferritic stainless steels are readily weldable with conventional welding methods, including:

- Shielded metal arc welding (SMAW, MMA)
- Gas tungsten arc welding (GTAW, TIG)
- Gas metal arc welding (GMAW, MIG/MAG)
- Plasma arc welding (PAW)
- Laser welding
- Resistance welding
- High frequency welding (HF)

Weldability

Low interstitial levels and added stabilizers have made enormous improvements to the welding characteristics of ferritic stainless steels. In addition, due to their lower thermal expansion and higher thermal conductivity, distortion and buckling is much lower during welding when compared to that of austenitic or duplex stainless steels. The microstructures of ferritics diverge quite a lot depending on the chemical composition of a particular product, mostly due to the effects of chromium, carbon, nitrogen, titanium, and niobium. Low and medium-chromium unstabilized stainless steels usually consist of a mixture of austenite and ferrite at elevated temperatures during welding, and subsequently transform into martensite and ferrite during cooling.

The traditional high-carbon product Moda 430/4016 produces many undesirable phenomena in the weld region, like grain boundary martensite, grain coarsening, and sensitization. This product is not intended for use in the as-welded condition. A post-weld heat treatment at 750–800 °C/1380–1470 °F is required for adequate ductility and corrosion resistance in the weld region.

The low-chromium product Moda 410L/4003 is essentially a low-carbon lath martensitic in the as-welded condition, which is preferred. The high austenite content restricts the grain coarsening efficiently, while lath martensite prevents sensitization by preventing chromium carbide precipitation. Due to its excellent toughness properties in the as-delivered and as-welded conditions, Moda 410L/4003 is the most suitable product for structural use and is included in Eurocode 3.

Welding naturally increases the grain size in the heat-affected zone (HAZ), but fortunately the carbide and nitride precipitates restrict the grain coarsening in a similar manner to that of austenite in unstabilized grades. Stabilization prevents chromium carbide precipitation, which could otherwise lead to sensitization embrittlement. Consequently, the stabilized grades are practically immune to intergranular corrosion in the as-welded condition.

Filler metals

Standard austenitic filler metals are normally used due to their availability, excellent toughness, and good corrosion resistance. Ferritic fillers are preferred under thermal stresses, in sour environments, or in situations where stress corrosion cracking could occur. Toughness is limited when using ferritic filler metals, although high service temperatures can tolerate the use of these fillers. Ferritic fillers should only be used for single-pass welds due to the increased risk of grain growth in the weld metal.

Shielding gases

Shielding gases for ferritic steels are usually argon-based with an additional 1–2% O_2/CO_2. Helium is sometimes used alongside argon when higher welding speeds are preferred. Due to the limited dissolution of interstitials in ferrite, higher additions of oxygen or carbon dioxide should be avoided. Nitrogen or hydrogen gases should not be used when welding ferritics. Nitrogen increases the interstitial content of the weld metal and adjacent HAZ, while hydrogen promotes hydrogen-induced cracking (cold cracking), which is a common problem with all ferritic grades.

Post-fabrication treatments

Welding reduces the resistance to localized corrosion, and therefore various surface-cleaning methods are preferred. Mechanical cleaning such as brushing or grinding gives some improvement, but the best results are usually obtained with chemical cleaning methods like pickling pastes or baths. As mentioned previously, post-weld heat treatment can be used for improving the mechanical and corrosion properties of some products.

For Moda 430/4016, heat treatment at 750–800 °C/1380–1470 °F improves the ductility of the weld region by tempering the hard and brittle martensite. Heat treatment time depends on material thickness, but usually 1–2 hours is preferred. Furthermore, this treatment allows chromium back-diffusion, which restores intergranular corrosion resistance.

For low-interstitial or stabilized ferritic stainless steels, post-weld heat treatment is generally unnecessary and often undesirable; however, a low-temperature heat treatment (e.g. a few hours at 200 °C/390 °F) can be effective in restoring the ductility of hydrogen-embrittled regions.

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

outokumpu.com/contacts

Surface finishes

A wide variety of surface finishes are available on our Moda range. Many are produced at the mill, and other surface finishes can be applied later during processing either at a service center or after fabrication.

The classic mill finishes offered on our Moda range include 1D/2D, 2B, 1E/2E and 2R/BA. In case a more demanding finish is required, polishing (2G, 2K / ASTM No. 3 and 4) or brushing (2J) is an efficient technique to upgrade the surface which can also be applied directly on the coil. Within our Deco range, Outokumpu offers a selection of high-class surface finishes, e.g. various patterns (2M), Deco 3N and 4N, Deco Rolled-On or Deco Scotch Brite with very distinguished properties on our popular Moda 430/4016. Temper rolled 2H finishes are available in the Forta range. The surface finish also plays an important role in influencing the corrosion resistance of the stainless steel, especially in the case of atmospheric corrosion or where splashing is common. A smooth surface finish increases the resistance to corrosion initiation.

In general, the roughness of the hot rolled (1D) surface is higher than cold rolled surfaces. The bright annealed surface (2R/BA) is highly reflective and very smooth compared to the cold rolled, annealed, pickled, and skin-passed (2B) surface.

More information about surface finishes can be found in the Deco range brochure or on our website, **outokumpu.com**.

Products and dimensions

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

Standards, specifications and approvals

For a list of international standards by product, see **steelfinder.outokumpu.com**

For a 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

Own notes

Own notes

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Working towards a world that lasts 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			outokumpu pro					
Moda	Core	Supra	Forta	Ultra	Dura	Therma	Prodec	Deco
Mildly corrosive environments	Corrosive environments	Highly corrosive environments	Duplex & other high strength	Extremely corrosive environments	High hardness	High service temperatures	Improved machinability	Special surfaces

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