outokumpu

Stainless steels for mildly corrosive environments

Outokumpu Moda range datasheet

General characteristics

The Moda range contains nine stainless steel products meant for mildly corrosive environments (PRE up to 17).

Key product

Outokumpu name	Typical applications	Product forms
Moda 430/4016 A classic 16% chromium ferritic stainless steel used in mildly corrosive environments.	• Kitchen equipment • Household appliances • Sinks • Elevators • Flanges and valves	C, H, B, R, S

Alternatives

Outokumpu name	Typical applications	Product forms
Moda 4511 A niobium-stabilized 16% chromium ferritic steel with improved formability and weldability compared to Moda 430/4016.	• Welded parts • Food processing industry equipment	C, H, S
Moda 439/4510 A titanium-stabilized 17% chromium ferritic steel with improved corrosion resistance, formability, and weldability compared to Moda 430/4016.	• Automotive exhaust systems • Sugar industry equipment • Household appliances	C, H, S
Moda 439M Very similar to Core 441/4509, but dual stabilized with titanium and niobium for a more even surface appearance and enhanced weldability. With 1% more chromium, it also has slightly better corrosion resistance.	• Automotive exhaust systems • Sugar industry equipment • Household appliances	C, H, S
Moda 430Ti/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	C, H, S
Moda 4589 A 14% chromium product with a small amount of niobium for elevated strength, making it suitable for structural parts exposed to loads that demand higher yield points.	• Conveyor chains • Railroad cars	C, H, S

Low-chromium alternatives

Outokumpu name	Typical applications	Product forms
Moda 410L/4003 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.	• Railroad and road vehicles • Shipping containers • Industrial applications • Mining conveyors	C, H, P, S
Moda 409/4512 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	C, H, S
Moda 410S/4000 Moda 410S/4000 is a 13% chromium general-purpose stainless steel that is used widely where corrosion is not severe. When supplied in the age hardened condition Moda 410S/4000 can be used where moderate corrosion and higher strength is required, while retaining its machinability.	• Bearings • Bushings • Dies • Fasteners • Pump shafts • Valves and valve components	C, H, P, S

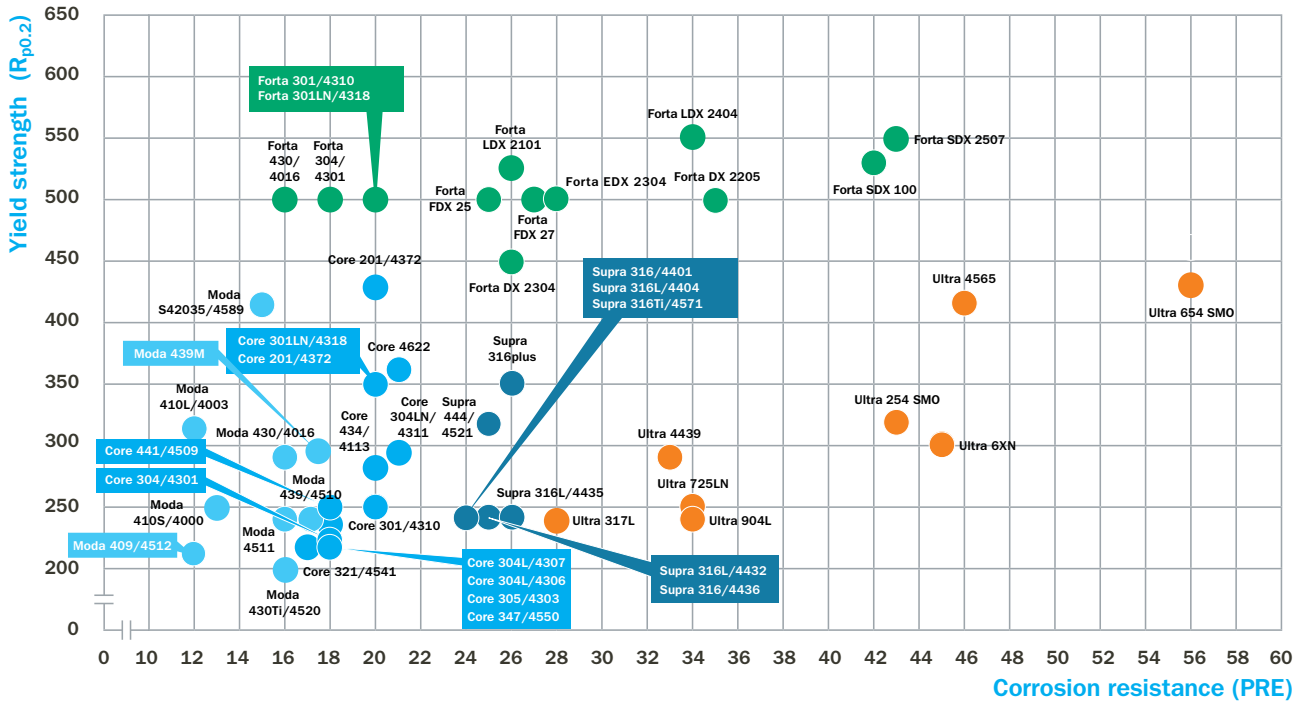
Product forms:
C = Cold rolled coil and sheet, H = Hot rolled coil and sheet, P = Quarto plate, B = Bar, R = Wire rod, S = Semifinished (bloom, billet, ingot & slab), T = Pipe

Products and dimensions

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

Product performance comparison

Yield strength vs. corrosion resistance



- Moda – Mildly corrosive environments (PRE to 17)
- Core – Corrosive environments (PRE 17 to 22)
- Supra – Highly corrosive environments (PRE 22 to 27)
- Forta – Duplex & other high strength
- 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. 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
Key product							
Moda 430/4016	0.05	16.2	–	–	–	–	F
Alternatives							
Moda 4511	0.02	16.2	–	–	–	Nb	F
Moda 439/4510	0.02	17.0	–	–	–	Ti	F
Moda 439M	0.014	17.6	–	–	–	Nb Ti	F
Moda 430Ti/4520	0.02	16.2	–	–	–	Ti	F
Moda 4589	0.045	14.0	1.65	0.25	–	Ti	F
Low-chromium stainless steels							
Moda 410L/4003	0.02	11.5	0.5	–	–	–	F
Moda 409/4512	0.02	11.5	0.2	–	–	Ti	F
Moda 410S/4000	0.03	12.5	–	–	–	–	F

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

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

Corrosion resistance

Outokumpu name	PRE
Key product	
Moda 430/4016	16
Alternatives	
Moda 4511	16
Moda 439/4510	17
Moda 439M	18
Moda 430Ti/4520	16
Moda 4589	15
Low-chromium stainless steels	
Moda 410L/4003	11
Moda 409/4512	12
Moda 410S/4000	13

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.

Corrosion resistance of Moda range products

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 that has come into contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/0.004 in per 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.

The corrosion resistance of Moda 430/4016 is highest when it has a smooth and clean surface.

Pitting and crevice corrosion

Pitting and crevice corrosion is possible 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 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 of material 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. This has given a considerable reduction in such problems.

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 an element (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 uniform corrosion resistance, please refer to the corrosion tables in the Outokumpu Corrosion Handbook, available from our sales offices.

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]**
Key product						
Moda 430/4016	7.7	220	10	25	460	0.6
Alternatives						
Moda 4511	7.7	220	10	25	460	0.6
Moda 439/4510	7.7	220	11	25	460	0.6
Moda 430Ti/4520	7.7	220	10.4	20	430	0.7
Moda 4589	7.7	220	10.5	25	460	0.6
Low-chromium stainless steels						
Moda 410L/4003	7.7	220	10.4	25	430	0.6
Moda 409/4512	7.7	220	10.5	25	460	0.6
Moda 410S/4000	7.7	220	10.5	30	460	0.6

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]**
Key product						
Moda 430/4016	0.278	$31.9 * 10^6$	5.56	14.4	0.11	23.62
Alternatives						
Moda 4511	0.278	$31.9 * 10^6$	5.56	14.4	0.11	23.62
Moda 439/4510	0.278	$31.9 * 10^6$	6.11	14.4	0.11	23.62
Moda 430Ti/4520	0.278	$31.9 * 10^6$	5.78	11.5	0.103	27.56
Moda 4589	0.278	$31.9 * 10^6$	5.83	14.4	0.11	23.62
Low-chromium stainless steels						
Moda 410L/4003	0.278	$31.9 * 10^6$	5.78	14.4	0.103	23.62
Moda 409/4512	0.278	$31.9 * 10^6$	5.83	14.4	0.11	23.62
Moda 410S/4000	0.278	$31.9 * 10^6$	5.83	17.3	0.11	23.62

Mechanical properties

Ferritic stainless steels have typically higher yield strength than austenitic stainless steels. Elongation and forming properties are equivalent to those of plain carbon steels.

Metric					
Outokumpu name	**Product form**	**Yield strength $R_{p0.2}$ (Mpa)**	**Tensile strength R_m (Mpa)**	**Elongation A (%)**	**Elongation A_{80} (%)**
Key product					
Moda 430/4016	C	280	430 – 600	20	20
	R*	280	450	25	–
	B*	300	480	8	–
Alternatives					
Moda 4511	C	240	420 – 600	23	23
Moda 439/4510	C	240	420 – 600	23	23
Moda 439M	C*	323	459	–	–
Moda 430Ti/4520	C	200	380 – 530	24	24
Moda 4589	C	420	550 – 750	16	16
Low–chromium stainless steels					
Moda 410L/4003	C	320	450 – 650	20	20
Moda 409/4512	C	220	380 – 560	25	25
Moda 410S/4000	C	250	400 – 600	19	19

Values according to EN 10088-2:2014 unless marked otherwise.

*Outokumpu typical value.

A_{80} 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 $10 < d \leq 16$mm (B). More product forms may be available than are shown in the 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)**
Key product				
Moda 430/4016	C	30	–	65
	H	30	–	65
	P	30	–	65
	R*	41	–	65
Alternatives				
Moda 4511	C*	46	49	69
Moda 439/4510	C	30	–	60
	H	30	–	60
	P	30	–	60
Moda 439M	C*	47	–	67
Moda 430Ti/4520	C*	38	41	62
	H*	45	49	67
Moda 4589	C*	68	74	87
	H*	74	80	94
Low-chromium stainless steels				
Moda 410L/4003	C	41	–	65
	H*	55	59	74
	P*	52	62	83
Moda 409/4512	C*	37	40	62
	H*	51	53	65
Moda 410S/4000	C	30	–	60
	H	30	–	60
	P	30	–	60

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

*Outokumpu typical value.

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**

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, namely 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 for Moda range products. Many are produced at the mill, and other surface finishes can be applied later during processing either at a service center or after fabrication.

Moda range finishes include 1D, 2B, 2E, and rolled finishes. Deco range offers Deco BA/2R, polished (#3 and #4), brushed, and patterned finishes. 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.

In general, the roughness of the hot rolled 1D surface is higher than cold rolled surfaces. The bright-annealed surface Deco BA/2R 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.

Standards and approvals

Standards	
EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10088-2	Stainless steels – Corrosion resisting sheet/plate/strip for general and construction purposes
EN 10088-3	Stainless steels – Corrosion resisting semi-finished products/bars/rods/wire/sections for general and construction purposes
EN 10088-4	Stainless steel flat products, technical delivery conditions, steels for constructions
EN 10217-7	Welded steel tubes for pressure purposes – Stainless steel tubes
EN 10296-2	Welded circular steel tubes for mechanical and general engineering purposes - Stainless Steel tubes
ASTM A182 / ASME SA-182	Forged or rolled alloy-steel pipe flanges, forged fittings etc. for high temperature service
ASTM A240 / ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purposes
ASTM A276	Stainless and heat-resisting steel bars/shapes
ASTM A479 / ASME SA-479	Stainless steel bars for boilers and other pressure vessels
Eurocode 3 / EN 1993-1-4	Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels
ISO 15510	Stainless steels – chemical composition

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

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 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

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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			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

outokumpu
high performance stainless steel

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