Industeel

ArcelorMittal

UR™ 2205Mo

UR™ 2205Mo: A 22Cr 3Mo duplex stainless steel with PREN ≥ 35

UR™ 2205Mo is a nitrogen alloyed (> 0.15%) austenitic - ferritic stainless steel with improved structure stability and high general, localised and stress corrosion resistance. **UR™ 2205Mo** with 22% Cr and 3.1% Mo additions, performs much better than 316L grade in almost all corrosive media. The yield strength is about twice that of austenitic stainless steels. This allows the designer to save weight and makes the alloy more cost competitive when compared to 316L grade. Typical operating temperatures are - 50°C/+ 280°C (- 58°F/+536°F). Lower temperature could be considered but require additional precautions for welded structures.

UR™ 2205Mo is a multi - purpose material which can be used in various corrosive media.

Typical applications are

- **> pulp and paper industry,**
- **> oil and gas industry,**
- **> pollution control equipments,**
- **> chemical industry and chemical tankers.**

PROPERTIES

STANDARDS

> EURONORM: **EN 1.4462 X2 Cr Ni Mo 22 - 5 - 3**

> ASTM: **A240 - UNS S31803/UNS S32205**

CHEMICAL ANALYSIS - WEIGHT %

Typical values

C	Cr	Ni	Mo	N
0.020	22.5	5.8	3.1	0.17

PREN = [Cr%] + 3.3 [Mo%] + 16 [N%] ≥ 35

PHYSICAL PROPERTIES

Density: 7.85 kg/dm³

Interval temperature (°C)	Thermal expansion $\alpha \times 10^{-6} K^{-1}$	T (°C)	(µΩ.cm)	Thermal conductivity ($W m^{-1} K^{-1}$)	Specific heat ($J kg^{-1} K^{-1}$)	Young modulus E (GPa)	Shear modulus G (GPa)
		20	80	17	450	200	75
20 - 100	13.5	100	86	18	450	190	73
20 - 200	14	200	92	19	500	180	70
20 - 300	14.5	300	100	20	550	170	67

Density: 0.282Lb/in^3

Interval temperature (°F)	Thermal expansion α x10^{-6}°F^{-1}	T (°F)	(μΩ.cm)	Thermal conductivity (Btu.hr^{-1}.ft^{-1}.°F^{-1})	Specific heat xIO^6 (Btu.lb^{-1}.°F^{-1})	Young modulus E xIO^6 (psi)	Shear modulus G xIO^6 (psi)
		68	31.5	11	0.11	29	10.9
70 - 210	7	212	33.8	11.5	0.12	28	10.5
70 - 400	7.5	392	36.2	12	0.12	27	10.1
70 - 600	8	572	39.3	12.5	0.13	26	9.7

MECHANICAL PROPERTIES

Tensile properties - Minimum values

°C	$R_{p0.2}$ (MPa)	$R_{p1.0}$ (MPa)	R_m (MPa)	°F	YS 0.2% (ksi)	YS 1.0% (ksi)	UTS (ksi)	A/ Elongation (%)
20	460	490	680	68	67	71	98	25
50	430	470	660	122	62	68	96	25
100	360	400	630	212	52	57	92	25
150	340	380	605	302	49	54	88	20
200	320	360	590	392	46	52	86	20
250	305	345	590	482	44	50	86	20
300	290	330	590	572	42	48	86	20

For solution annealed condition and plate thickness ≤ 50 mm (2"). UR™ 2205Mo grade should not be used over 280°C (530°F) for long periods.

Impact strength (KV minimum values)

Temp.	- 50°C	- 20°C	+20°C	- 60°F	0°F	+ 70°F
Single	75J	90J	120J	54ft.lbs	65ft.lbs	87ft.lbs
Average (5)	90J	120J	150J	65ft.lbs	87ft.lbs	109ft.lbs

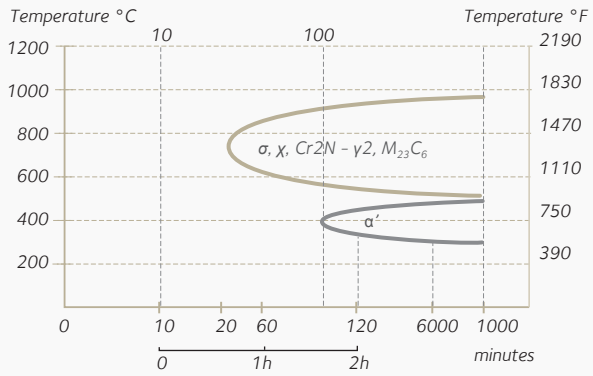
Hardness values - Typical values

Average (5)	HV_{10} 210 - 260	HB: 210 - 240	HRC: 15 - 20

HEAT TREATMENT

UR™ 2205Mo is a duplex stainless steel; its chemical composition is optimized in order to present, after a solution annealing treatment at 1040 - 1080°C (1900 - 1975°F) followed by water quenching, a nearly 50% α /50% γ microstructure. Heat treatments performed at 1100°C (2010°F). A higher temperature may result in an increase of the ferrite content. Typical TTP - diagram (temperature time precipitation) shows the two - phase transformation areas. At high temperature: 600° - 1000°C (1110/1830°F), the a phase may transform in σ, ϰ ,... intermetallic phases which makes the alloy brittle. At lower temperatures (300 - 500°C - 570 - 930°F) the a phase transforms in α' resulting in a hardening of the structure after several hours holding time.

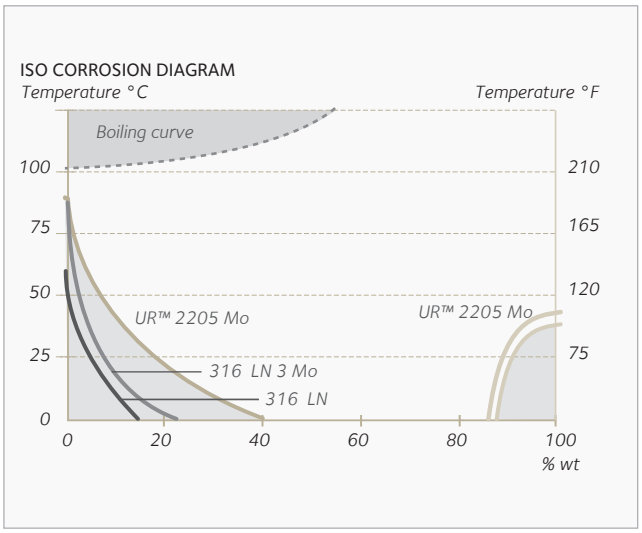
TTP DIAGRAM OF UR™ 2205MO DUPLEX STAINLESS STEEL



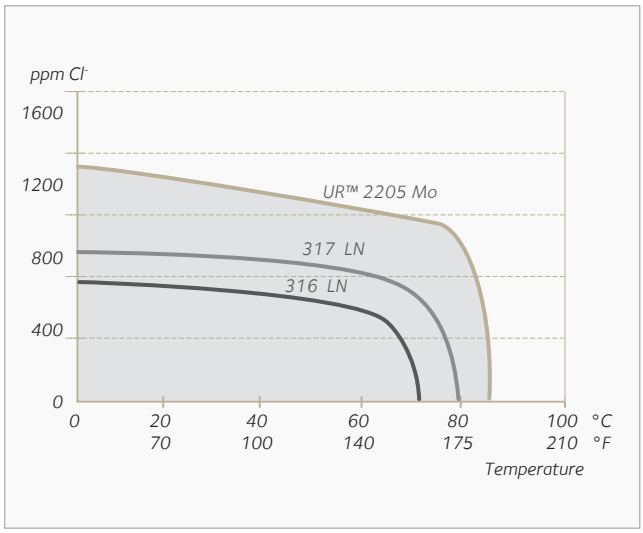
CORROSION RESISTANCE

General corrosion resistance

a) Sulfuric and phosphoric acids



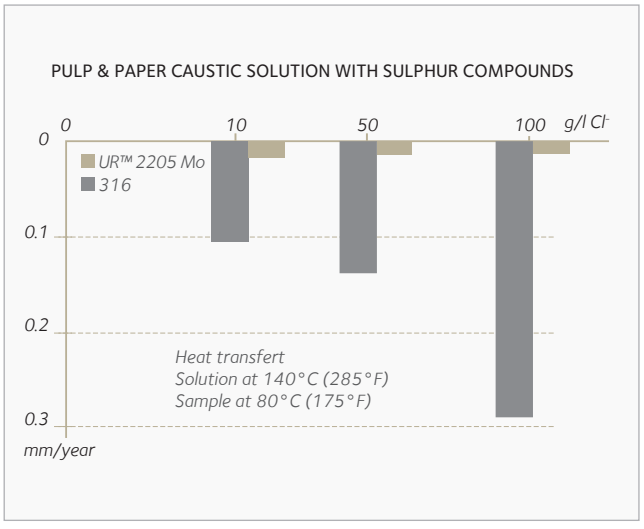
% H_2SO_4 + 2000ppm Cl - Industrial solution

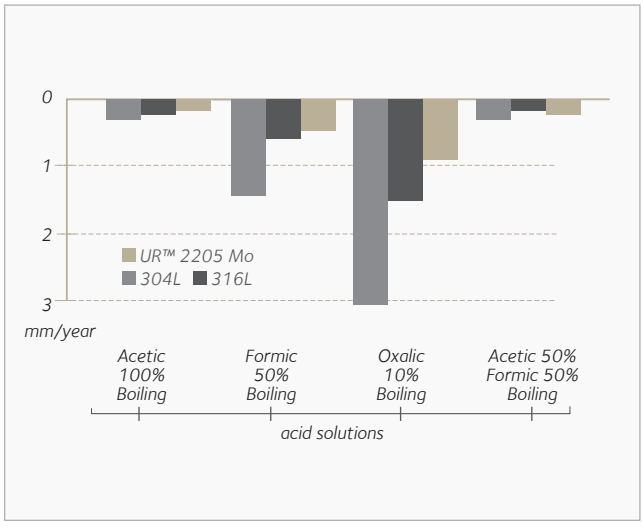


54%$P_2O_5$2% - H_2SO_4 +0.2%HF+1.6%H_2SIF_6 Industrial solution

General corrosion resistance of UR™ 2205Mo are generally much better than austenitic 316L and 317LN. UR™ 2205Mo is now used extensively in newly designed chemical tankers.

b) Caustic media (pulp and paper) and organic acids

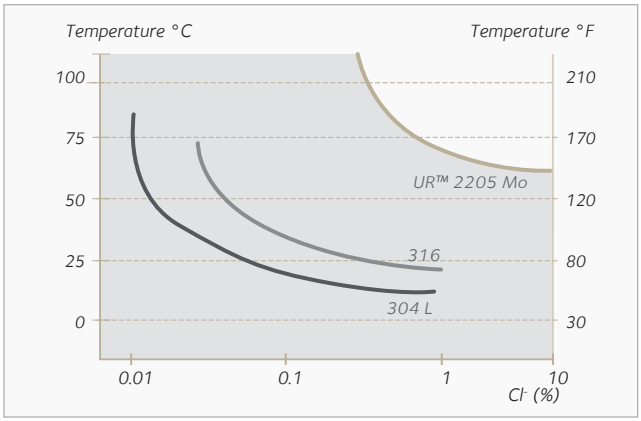




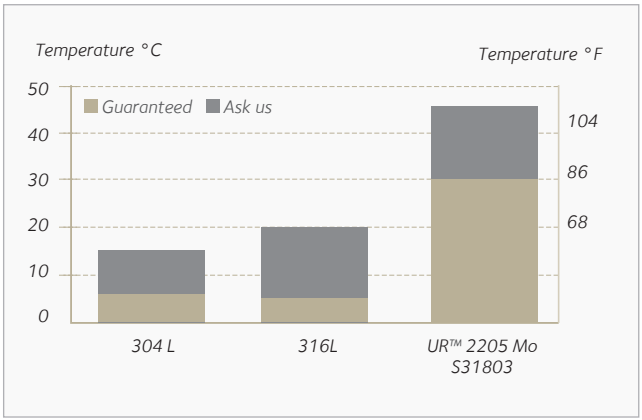
General corrosion resistance in organic solutions or caustic solutions is improved by the use of UR™ 2205Mo instead of 304 or 316L grades. UR™ 2205Mo is now extensively used in chemical industry (organic and inorganic) and in the pulp and tpaper industry.

Localised corrosion resistance

a) Pitting corrosion



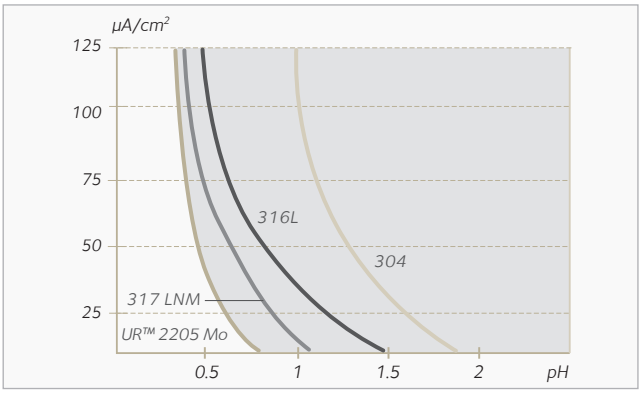
Sensitivity to pitting corrosion. Effects of temperature and chloride content



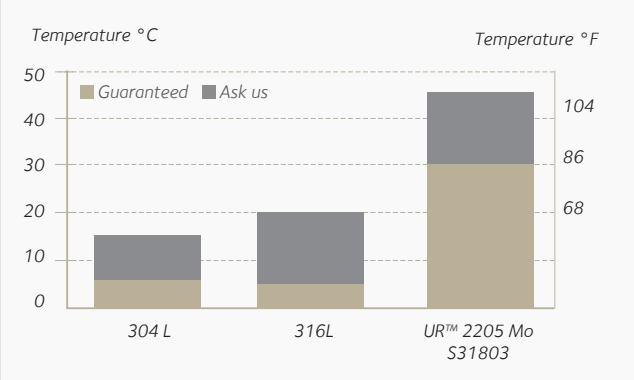
ASTM G48A Test results
10%$FeCl_3$ 6H_2O solution

The high chromium (22%) and molybdenum (3%) combined with 0.16% nitrogen additions explain why UR™ 2205Mo duplex grade behaves particularly well when considering pitting corrosion resistance.
UR™ 2205Mo performs much better than 304 and 316L grades, even in very oxydizing and acid solutions.

b) Crevice corrosion resistance

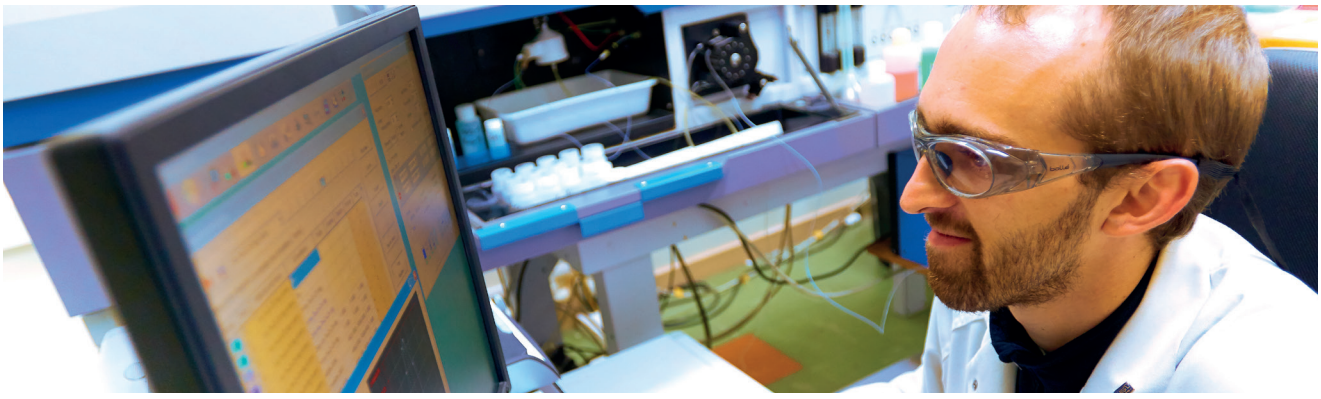


Depassivation conditions of several stainless steels
Solution: 30 g/l NaCl 20°C

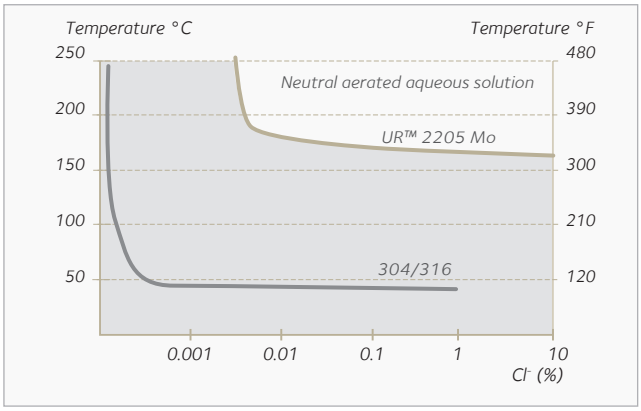


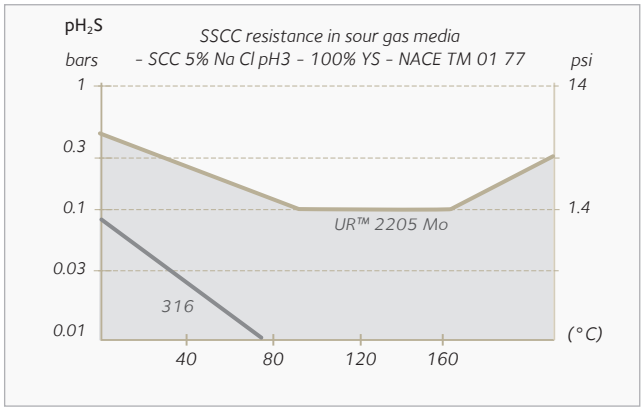
ASTM G78 - Crevice
10% $FeCl_3$ solution

The improved crevice corrosion resistance of UR™ 2205Mo explains its use in chloride/fluoride processes containing deposits. Typical applications are Pulp and Paper industry, Pollution Control equipments, On/Offshore applications.



c) Stress corrosion cracking resistance



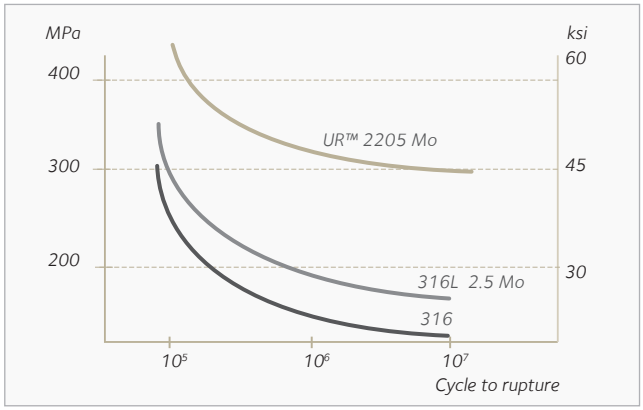


The duplex microstructure is known to improve the stress corrosion cracking resistance of stainless steels and in sour gas conditions in the oil and gas industry. UR™ 2205Mo alloy has been extensively used for welded pipe.

Corrosion fatigue resistance

Duplex steels combine high mechanical and corrosion resistance properties. The fatigue corrosion data presented are very attractive results since after 107 cycles, fatigue limit remains at least twice that of 316 austenitic stainless steels.

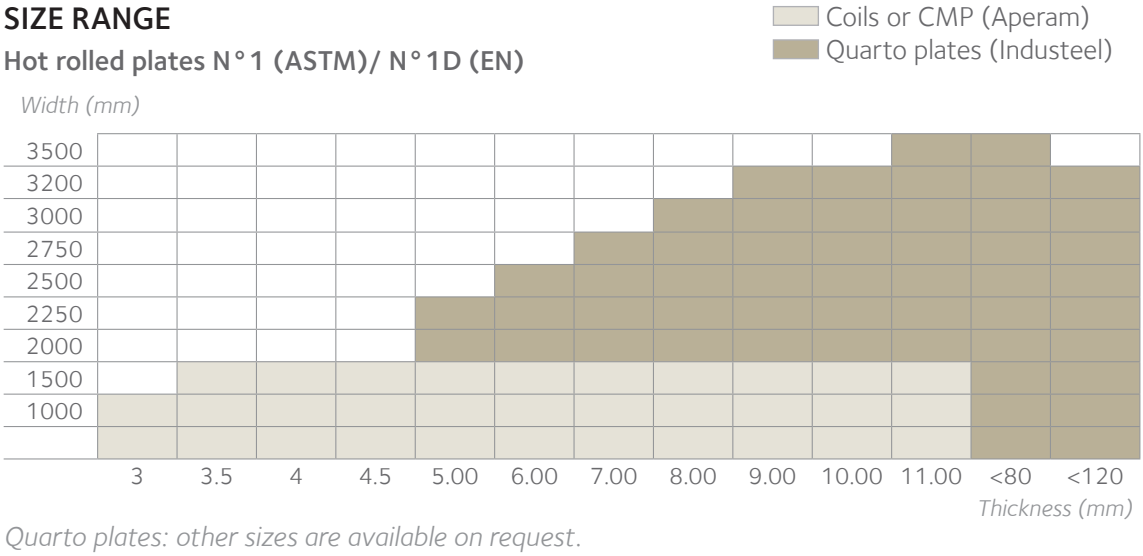
Synthetic sea water rotating beam bending of smooth samples



DELIVERY CONDITIONS

SIZE RANGE

Hot rolled plates N°1 (ASTM)/ N°1D (EN)



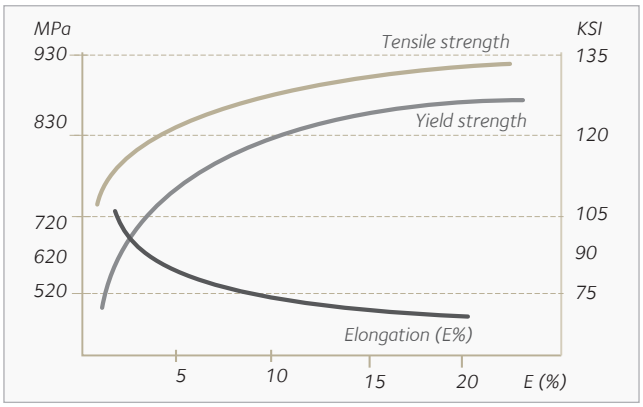
Quarto plates: other sizes are available on request.
Maximum plate length up to 12000 mm (472").

HOT FORMING

Hot forming should be carried out in a temperature range of 950/1150°C (1750/2100°F) after the piece has been uniformly heated. At temperatures lower than 950°C (1750°F), the alloy is very prone to intermetallic phase precipitation such as sigma phase. This affects the toughness and corrosion resistance of UR™ 2205Mo. A final full annealing heat treatment (1040/1080°C - 1900/1975°F) followed by rapid quench is required (to restore phase balance, mechanical and corrosion resistance properties). Special precautions must be taken during heat treatment to avoid deformation.

COLD FORMING

UR™ 2205Mo can be cold formed without any problem using equipments suited to work stainless steel. The duplex UR™ 2205Mo alloy requires more power than austenitic stainless steels due to its higher mechanical properties and work hardening (which is lower than for austenitic steels). Cold working ratios exceeding 20% require an intermediate full annealing heat treatment (1040/1080°C - 1900/1975°F). Such heat treatment is also recommended after cold forming of more than 10% in order to restore its properties.



PICKLING

Pickling solutions or pastes acceptable for alloy 316L may be used. The pickling time required is at least twice that of 316 L. A slight increase of the temperature of the pickling bath reduces the pickling time. Typical pickling conditions are (10% HNO_3 - 2% HF) 60°C (140°F). Passivation decontamination treatments may be performed with a 10 - 25% nitric acid solution.

DESIGN

UR™ 2205Mo is particularly cost effective when its high mechanical strength of the alloy are taken into account to design vessels.
Allowable design stress values: ASME boiler and pressure vessel codes. Section VIII - Division 1, Stress, MPa - ksi

Grade	- 30/40°C (- 20/100°F)		205°C (400°F)		260°C (500°F)	
	MPa	ksi	MPa	ksi	MPa	ksi
316L	108	15.7	74	10.8	68.9	10
904L	123	17.8	95	13.8	87	12.7
UR™ 2205Mo	155	22.5	144	20.9	141	20.4

These higher design stress values allow the fabricator to reduce the weight of the equipment which, combined with the high corrosion resistance properties, provide additional cost savings.

WELDING

> UR™ 2205Mo is easily welded by the following processes:

- TIG welding, both manual and automatic
- Plasma welding
- MIG welding
- SMAW
- SAW
- FCAW

> Austenitic - ferritic structure of UR™ 2205Mo steel (ferrite primary solidification) limits hot cracking risks in the HAZ.

> Special care must be taken in controlling the ferrite content of the weld deposit which is usually between 25 and 60% ; a lower ferrite content will be recommended (20 - 40% of α, for some welding procedures) i.e. for SMAW, SAW and FCAW.

> Chemical composition has to be adapted to stabilize austenite (generally, nickel or nitrogen overalloyings compared to the base metal). Cr and Mo overalloyed filler metals are also recommended in order to increase the corrosion resistance properties of welded structures.

> As for austenitic grades, no preheat is necessary prior to welding,

> The heat input must be controlled (about 10 to 25 kJ/cm is generally counselled). Consult our technical staff for more accurate information if needed. Optimum heat input is related to plate thicknesses.

> Interpass temperature must be limited to 150°C (302°F), preferably 120°C (248°F).

> Post weld heat treatment is normally not necessary. In some cases, it might be needed to obtain a low ferrite content when welding without filler metal. Heat treatment will be realised at a sufficient temperature to avoid phase transformation.

> Usual precautions including cleaning and degreasing of weld area, protection against weld spatters must be taken to ensure corrosion resistance of the finished product.

> Careful final mechanical or/and chemical cleaning of the weld is strongly recommended.

Plasma + TIG welding:

Typically used for thicknesses of 5 to 12 mm. If no filler metal is used for the plasma pass, Ar + (2 - 3)% N_2 will be used as shielding gas. Ferrite content will be between 30 and 60%. Complementary TIG welding will also be realised with a duplex or superduplex wire. The ferrite content will also be kept between 30 and 60%. Nitrogen additions (2 - 3%) in the protective gas improve the corrosion behaviour and stabilize the microstructure. Technical is available for special cases. Contamination of the shielding gas by hydrogen must be avoided.

Manual arc welding:

A standard duplex or super - duplex electrode will be used. The ferrite content is between 20 and 40%. Avoid hydrogen pick up (moisture, hydrogen containing gases...) which can result in cold cracking. For further information, please contact us (choice of the electrode depending on the application).

Submerged arc welding:

This process can be used for single pass or multipass welds for high thicknesses (≥10 mm) or to complete a plasma pass. The filler metal is a duplex wire, basic fluxes should be preferred. Ferrite content will be controlled between 20 and 40% in order to avoid cold cracking risks; Use only well dryed fluxes to avoid hydrogen uptake.

MACHINING

Machining is another example of a fabrication process where the techniques employed (eg. tools and lubricants) for UR™ 2205Mo are very similar to those used for conventional stainless steels).
Machining characteristics of UR™ 2205Mo are better than those of 316L.

Operation	Tool	Lubrication	CONDITIONS					
			Depth of cut mm (inch)	Feed mm/t (inch/t)	Speed (m/min) (feet/min)			
					18/8	18/12 Mo	UR™ 904	UR™ 2205Mo
Turning	High speed steel	Cutting oil	6 (0.23)	0.5 (0.019)	13 - 18 (427 - 59.1)	11 - 16 (36.1 - 52.5)	6 - 11 (19.7 - 36.1)	15 - 20 (49.2 - 65.6)
			3 (0.11)	0.4 (0.016)	20 - 25 (65.6 - 82)	18 - 23 (59.1 - 75.5)	9 - 14 (29.5 - 45.9)	23 - 28 (75.5 - 91.9)
			1 (0.04)	0.2 (0.008)	26 - 31 (85.3 - 101.7)	25 - 30 (82 - 98.4)	15 - 20 (49.2 - 65.6)	30 - 35 (98.4 - 114.8)
	Carbide	Dry or cutting oil	6 (0.23)	0.5 (0.019)	75 - 85 (246.1 - 278.9)	70 - 80 (229.7 - 262.5)	25 - 35 (82 - 114.8)	75 - 85 (246.1 - 278.9)
			3 (0.11)	0.4 (0.016)	90 - 100 (295.3 - 328.1)	85 - 95 (278.9 - 312.7)	45 - 55 (147.6 - 180.4)	90 - 100 (295.3 - 328.1)
			1 (0.04)	0.2 (0.008)	110 - 120 (360.9 - 393.7)	100 - 110 (328.1 - 360.9)	65 - 70 (213.3 - 229.7)	110 - 120 (360.9 - 393.7)
			Blade width mm (inch)	Feed mm/t (inch/t)	18/8	18/12 Mo	UR™ 904	UR™ 2205Mo
Parting off	High speed steel	Cutting oil	1.5 (0.06)	0.03 (0.0012)	21 - 26 (68.9 - 85.3)	17 - 22 (55.8 - 72.2)	10 - 13 (32.8 - 42.7)	23 - 28 (75.5 - 91.9)
			3 (0.11)	0.04 (0.0016)	22 - 27 (72.2 - 88.6)	18 - 23 (59.1 - 75.5)	11 - 14 (36.1 - 45.9)	24 - 29 (78.7 - 95.1)
			6 (0.23)	0.05 (0.0020)	23 - 28 (75.5 - 97.9)	19 - 24 (62.3 - 78.7)	12 - 15 (39.4 - 49.2)	25 - 30 (82 - 98.4)
			Drill Ø mm (inch)	Feed mm/t (inch/t)	18/8	18/12 Mo	UR™ 904	UR™ 2205Mo
Drilling	High speed steel	Cutting oil	1.5 (0.06)	0.25 (0.0010)	10 - 14 (32.8 - 45.9)	10 - 14 (32.8 - 45.9)	6 - 10 (19.7 - 32.8)	10 - 14 (32.8 - 45.9)
			3 (0.11)	0.06 (0.0024)	11 - 15 (36.1 - 49.2)	11 - 15 (36.1 - 49.2)	7 - 11 (23 - 26.1)	11 - 15 (36.1 - 49.2)
			6 (0.23)	0.08 (0.0031)	11 - 15 (36.1 - 49.2)	11 - 15 (36.1 - 49.2)	7 - 11 (23 - 26.1)	11 - 15 (36.1 - 49.2)
			12 (0.48)	0.10 (0.0039)	11 - 15 (36.1 - 49.2)	11 - 15 (36.1 - 49.2)	7 - 11 (23 - 26.1)	11 - 15 (36.1 - 49.2)
				Feed mm/t (inch/t)	18/8	18/12 Mo	UR™ 904	UR™ 2205Mo
Milling profiling	High speed steel	Cutting oil		0.05 - 0.10 (0.002 - 0.0039)	12 - 22 (39.4 - 72.2)	10 - 20 (32.8 - 65.6)	10 - 20 (32.8 - 65.6)	12 - 22 (39.4 - 72.2)

APPLICATIONS

> Oil and Gas industry including sour gas applications
> Pulp and Paper industry (digesters...)
> Chemical industry (reactor vessels...)
> Acetic acid distillation towers
> Urea Production
> Phosphoric acid plants (reactors...)
> Sulphuric acid processes (hydrometallurgy...)
> Pollution control equipments
> Truck, lorries
> Chemical tankers

YOUR CONTACTS

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