Industeel

ArcelorMittal

SOLEIL™ A2

SOLEIL™ A2: A 13% Cr high strength martensitic stainless steel (410 grade)

SOLEIL™ A2 has combined chromium (about 13%) and carbon (about 0.10%) additions to provide an excellent combination of high mechanical properties and improved corrosion resistance properties. The grade has a martensitic microstructure. The final mechanical properties may be optimised by selecting an appropriate heat treatment. In the annealed conditions the alloy presents ductility and may be formed. Chromium additions (about 13%) improve the corrosion resistance, particularly in wet conditions when compared to C-Mn steels. Slightly acidified and abrasion conditions are considered.
The main applications concern mechanical industry, oil and gas industry, sugar industry and constructional components.

PROPERTIES

STANDARDS

> EURONORM	EN 1.4006	X12 Cr13
> ASTM	A240 TP410 - UNS S41000	

CHEMICAL ANALYSIS - WEIGHT %

Typical values

C	Cr	Mn	Si
.12	12.5	.5	.4

PHYSICAL PROPERTIES

Density: 7.7 kg/dm³

Temperature interval (°C)	Thermal expansion ($\alpha x10^{-6} K^{-1}$)	°C	°F	Resistivity (μΩ.cm)	Thermal conductivity ($W.m^{-1}.K^{-1}$)	Young modulus E (GPa)
20-100	10.5	20	68	60	25	212
20-200	11	100	212	66	25.5	205
20-300	11.5	200	392	75	26	200
20-400	12	300	572	82	27	190
20-500	12	400	752	95	28	185
		700	1292	110		

Room temperature properties. Specific heat : 460 $J.kg^{-1}.K^{-1}$. The alloy is magnetic.

MECHANICAL PROPERTIES

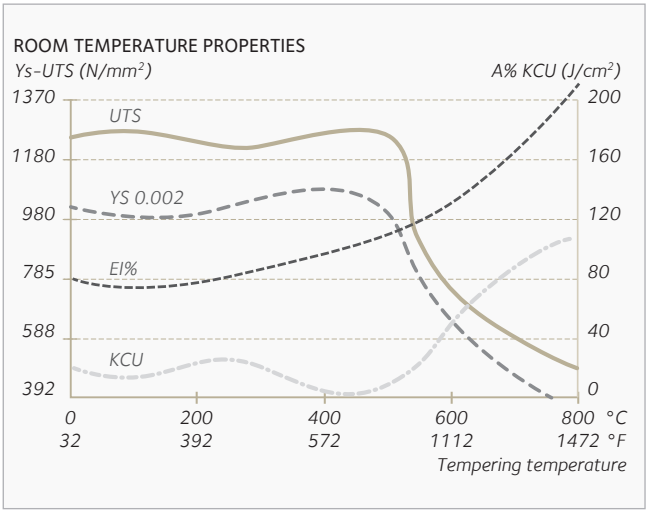
Room temperature properties (+20°C 68°F)

Toughness and hardness values depend upon heat treatment and testing conditions. Guaranteed values must be agreed upon. Industeel can optimize the heat treatment following customer request. The two EN 10088 standard delivering conditions for plate thicknesses included in the 5-75 mm range are as follow :

Heat treatment	Y.S. 0.2%		UTS		Elongation	Toughness	Hardness
	MPa	ksi	MPa	ksi	% min	J (long)	(HB)
QT550	> 400	> 57	550-750	79-108	15	85*	160*
QT650	> 450	> 64	650-850	93-122	12	70*	190*

** Typical values*

Soleil™ A2 (410 - 1.4006) is a quenched-tempered grade which properties depend upon the heat treatment. Typical mechanical properties dependance with tempering treatment are presented in the figure hereafter. Higher tempering conditions result in lower yield and ultimate tensile strength while elongation and thoughness are increased. Those data depend upon quenching and tempering conditions.



Tensile properties minimum guaranteed values

Temperature		Yield Strength 0.2%	
°C	° F	MPa	ksi
20	68	450	65
100	212	420	62
200	392	400	59
300	572	365	54
400	752	305	45

Minimum guaranteed values following EN 10088 hot rolled plates. The EN guaranteed values are valid for a thickness from 5 up to 75 mm (.20 to 2.95")
Heat treatment : quenched and tempered 650°C (1202°F).

HEAT TREATMENT

Indicative conversion points are :
AC_1 : 850°C (1562°F)
AC_3 : 920°C (1688°F)
M_S : 350°C (662°F)
Heat treatment so as to obtain mechanical properties combined with optimal corrosion resistance:

- **> Quenching: 950 - B1000°C (1742 - 1832°F)**
- **> Oil or air cooling**
- **> Tempering: 250°C or 600 - 780°C (1112 - 1436°F), air cooling. (optimised depending on requested mechanical properties)**

Tempering heat treatment performed in the 300 - 600°C (572 - 1112°F) temperature range will be avoided because it results in higher susceptibility to stress corrosion attack and embrittlement. Time/temperature conditions in the 600 - 780°C (1112 - 1436°F) will be optimised in order to obtain the requested ductility/ hardness compromise. The maximum annealing conditions are obtained with a heat treatment at 900 - 950°C (1652 - 1742°F) followed by low cooling rate.

IN SERVICE CONDITIONS

CORROSION

Soleil™ A2 (410-1.4006) grade with 13% chromium presents improved corrosion resistance properties when compared to C-Mn steels. This is the case for their use in weak or diluted acids, slightly chlorinated water and desaereted water. Nevertheless the grade is susceptible to chloride attack particularly in oxidising environments. Higher alloying grades are then to be considered.
The grade is also useful for oil and gas applications in desaereted and low H_2S conditions. The grade presents attractive combination of wear and corrosion resistance properties. Specific applications as abrasion-corrosion resistant grade are considered. The grade presents also improved resistance to oxidation up to about 700°C (1292°F).

DELIVERY CONDITIONS

SIZE RANGE

	Quarto plates	Clad plates
Thickness	5 to 150 mm 3/16" to 6"	6 to 150 mm 1/4" to 6"
Width	Up to 3800 mm Up to 150"	Up to 3900 mm Up to 154"
Length	Up to 16000 mm Up to 52.5 ft	Up to 16000 mm Up to 52.5 ft

Indicative dimensional programe. Width related to thickness. For specific request, please consult.

PLATE PROCESSING

HOT FORMING

Hot forming is typically performed in the 1150 - 750°C (2102 - 1382°F) temperature range followed by air cooling. Depending on the amount of deformation and plate thickness hot working may also be performed in the 700 - 800°C (1292 - 1472°F) temperature range. For the smaller deformations (bending...) preheated conditions 100 - 300°C (212 - 572°F) are also performed. After substantial deformation it is recommended to proceed at a reannealed treatment and at least at a stress relieving treatment at about 650°C (1202°F).

COLD FORMING

Cold forming is only to be performed in the heavily annealed grades (lowest hardness).

PICKLING

A nitro-hydrofluoric acid bath (120g/l HNO_3 - 15g/l HF) at 35°C (95°F) is used for the pickling treatment if required. Plates can be also delivered shot blasted.

CUTTING

> Thermal cutting (plasma, thermal sawing....)

> Mechanical cutting

After cutting a slow cooling or a stress relieving may avoid cracking on the edge of cutting area. Grinding are necessary to eliminate the oxide formed layer.

MACHINING

Machining procedures applied to plain carbon steels of a corresponding tensile strength may be used. Decontamination and passivation treatments are recommended after machining.

Operation	Tool	Lubrication	CONDITIONS		
			Depth (mm) (inch)	Feed (mm/t) (inch/t)	Speed (m/min) (feet/min)
Turning	High speed steel	Cutting oil	6 (0.23)	0.5 (0.019)	21-26 (69-86)
			3 (0.11)	0.4 (0.016)	27-32 (89-106)
			1 (0.04)	0.2 (0.008)	36-41 (119-135)
	Carbide	Dry or cutting oil	6 (0.23)	0.5 (0.019)	115-125 (380-413)
			3 (0.11)	0.4 (0.016)	145-165 (479-545)
			1 (0.04)	0.2 (0.008)	170-180 (561-595)
			Depth of cut (mm) (inch)	Feed (mm/t) (inch/t)	Speed (m/min) (feet/min)
Cutting	High speed steel	Cutting oil	1.5 (0.06)	0.03 - 0.05 (0.0012 - 0.0020)	23-28 (76-92)
			3 (0.11)	0.04 - 0.06 (0.0016 - 0.0024)	24-29 (79-96)
			6 (0.4)	0.05 - 0.07 (0.0020 - 0.0027)	25-30 (83-99)
			Drill Ø (mm) (inch)	Feed (mm/t) (inch/t)	Speed (m/min) (feet/min)
Drilling	High speed steel	Cutting oil	1.5 (0.06)	0.02 - 0.03 (0.0010 - 0.0012)	11-15 (36-49)
			3 (0.11)	0.06-0.07 (0.0024-.0024)	13-17 (43-56)
			6 (0.23)	0.09-0.10 (0.0031-.0040)	13-17 (43-56)
			12 (0.48)	0.10-0.20 (0.0039-0.008)	13-17 (43-56)
				Feed (mm/t) (inch/t)	Speed (m/min) (feet/min)
Milling profiling	High speed steel	Cutting oil		0.05 - 0.10 (0.002 - 0.004)	20-30 (66-99)

WELDING

The alloy can be welded by SMAW, GTAW and GMAW processes. Shielding gas with hydrogen addition must not be used. Well dried basic covered electrodes are recommended.
A preheating treatment is necessary (200 - 300°C / 392 - 572°F) One of following post-welding treatment is recommended:

> Tempering (stress relieving)

> Quenching and tempering so as to eliminate brittleness due to martensitic transformation during cooling

AWS 410 grade consumables are recommended to obtain characteristics close to base material. Austenitic filler metal (18-10 types) can also be used but in this case no post-weld heat treatment must be applied and lower tensile properties will be obtained in the weld metal.

APPLICATIONS

> Oil and Gas industry

> Food industry

> Constructional components

> Mechanical industry

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