Hastelloy C-2000 (UNS N06200)

Hastelloy C-2000 is a versatile alloy that provides high resistance to variety of chemicals including sulfuric acid, hydrochloric acid and other strong acidic media. It offers great resistance in both reducing and oxidizing environments. It suitably resists localized corrosion.

Chemical Composition

Carbon (C)	0.01 %
Chromium (Cr)	23 %
Molybdenum (Mo)	16 %
Nickel (Ni)	Rem %
Silicon (Si)	0.08 %
Iron (Fe)	3 %
Copper (Cu)	1.6 %
Aluminum (Al)	0.5 %
Manganese (Mn)	0.5 %

Physical Properties

Density	At room temperature	8.50 g/cm3
Thermal Conductivity	At room temperature	9.1 W/m•K
Mean Coefficient of Thermal Expansion	77oF to 200oF	12.4 m/m•K
Electrical Resistivity	At room temperature	128 microhm-m
Thermal Diffusivity	At room temperature	0.025 cm^2/s
Specific Heat	At room temperature	428 J/kg.°C
Dynamic Modulus of Elasticity	At room temperature	207 GPa
Melting Point	1328-1358°C	

Electrical Resistivity

Temp, oC	Micro-ohm.meter	Temp, oF	Micro-ohm.inches

Room temp	1.28	Room temp	50.6
100 oC	1.29	200 oF	50.8
200 oC	1.30	400 oF	51.2
300 oC	1.31	600 oF	51.6

Thermal Conductivity

600 oC	1.35	1200 oF	53.0
Temp, oC	W/m.°C	Temp, of	btu.in/h.ft².°F
RT	9.1	RT	63
100 oC	10.8	200 oF	74
200 oC	12.6	400 oF	88
300 oC	14.1	600 oF	99
400 oC	16.1	800 oF	114
500 oC	18.0	1000 oF	133
21.6	1200 oF	162	

Mean Coefficient of Thermal Expansion

Temp, oC	Micro-meter/meter.°C	Temp, of	Micro-inch/inch.°F
25 oC to 100 oC	12.4	77 oF to 200 oF	6.9
25 oC to 200 oC	12.4	77 oF to 400 oF	6.9
25 oC to 300 oC	12.6	77 oF to 600 oF	7.0
25 oC to 400 oC	12.9	77 oF to 800 oF	7.2
25 oC to 500 oC	13.2	77 oF to 1000 oF	7.4
25 oC to 600 oC	13.3	77 oF to 1200 oF	7.6

Thermal Diffusivity

Temp, oC	cm²/sec	Temp, of	ft²/hour
RT	0.025	RT	0.10
100 oC	0.029	212°F	0.11
200 oC	0.033	392°F	0.13
300 oC	0.036	572°F	0.14
400 oC	0.040	752°F	0.16
500 oC	0.043	932°F	0.17
600 oC	0.047	1112°F	0.18

Specific Heat

Temp, oC	Joule/kg.°C	Temp, of	btu/lb.°F
RT	428	RT	0.10
100 oC	434	212 of	0.10
200 oC	443	392 of	0.11
300 oC	455	572 of	0.11
400 oC	468	752 of	0.11
500 oC	486	932 of	0.12

600 oC	536	1112 of	0.13

Dynamic Modulus of Elasticity

oC	GPa	oF	psi
RT	207 GPa	RT	30.0 x 10 6 psi
316°C	190 GPa	600°F	27.5 x 10 6 psi
427°C	177 GPa	800°F	25.6 x 10 6 psi
538°C	171 GPa	1000°F	24.8 x 10 6 psi
649°C	162 GPa	1200°F	23.5 x 10 6 psi

Critical crevice and pitting temperatures

Critical crevice and critical pitting temperature in acidic ferric chloride

Alloy	Critical crevice temp.		Critical pitting temp.	
	oC	of	oC	oF
SS 316L	0 oC	32 of	15 oC	59 of
254SMO	30 oC	86 of	60 oC	140 of
In 625	40 oC	104 of	100 oC	212 of
Hastelloy C22	80 oC	176 of	Above 120	Above 248
Hastelloy C 276	55 oC	131 of	Above 120	Above 248
Hastelloy C2000	80 oC	176 of	Above 120	Above 248

Corrosion Resistance

To make the nickel alloy resistant to corrosive media, it needs the high concentration of chromium by which the alloy becomes able to resist the wider oxidizing media like ferric acids, cupric ions and more. The reducing media like hydrated hydrochloric or sulfuric acid needs high concentration of molybdenum as well as tungsten.

With the help of high content of chromium, C-2000 corrosion resistance alloy offers excellent resistance to oxidizing media like nitric acid and solutions like ferric ions, cupric ions and dissolved oxygen.

Corrosion resistance in the various media

Media	Content Wt %	Temperature		Mean corrosion rate					
		oC	oF	C2000		C4		C22	
HCl	1 %	boiling	Boiling	0.01 mmy	0.2 mpy	0.48 mmy	18.8 mpy	0.06 mmy	2.2 mpy
	5 %	79 oC	175 oF	< .01 mmy	0.1 mpy	0.98 mmy	38.6 mpy	1.44 mmy	56.6 mpy
	10 %	38 oC	100 oF	< .01 mmy	<0.01 mpy	0.19 mmy	7.3 mpy	0.01 mmy	0.4 mpy
	20 %	38 oC	100 oF	.16 mmy	6.3 mpy	0.14 mmy	5.4 mpy	0.20 mmy	7.7 mpy
HBr	2.5 %	Boiling	Boiling	.01 mmy	0.2 mpy	0.08 mmy	3.3 mpy	0.02 mmy	0.6 mpy
	5 %	93 oC	200 oF	.01 mmy	0.2 mpy	0.76 mmy	29.9 mpy	0.01 mmy	0.3 mpy
	7.5 %	93 oC	200 oF	< .01 mmy	0.1 mpy	0.76 mmy	29.9 mpy	0.45 mmy	17.8 mpy

	10 %	79 oC	175 oF	< .01 mmy	<.01 mpy	0.53 mmy	20.9 mpy	0.01 mmy	0.3 mpy
	20 %	66 oC	150 oF	< .01 mmy	<.01 mpy	0.35 mmy	13.7 mpy	0.46 mmy	18.2 mpy
HF	1 %	79 oC	175 oF	0.18 mmy	7 mpy	N/T	N/T	0.21 mmy	8.2 mpy
	5 %	52 oC	125 oF	0.09 mmy	3.7 mpy	N/T	N/T	0.15 mmy	6 mpy
	10 %	52 oC	125 oF	0.22 mmy	8.7 mpy	N/T	N/T	0.33 mmy	13.1 mpy
	20 %	52 oC	125 oF	0.48 mmy	18.8 mpy	N/T	N/T	0.53 mmy	21 mpy
Sulfuri c Acid	10 %	93 oC	200 oF	0.02 mmy	0.8 mpy	0.19 mmy	7.3 mpy	0.04 mmy	1.6 mpy
	20 %	93 oC	200 oF	0.03 mmy	1 mpy	0.38 mmy	15.1 mpy	0.28 mmy	11 mpy
	30 %	93 oC	200 oF	0.04 mmy	1.5 mpy	0.54 mmy	21.3 mpy	.68 mmy	26.8 mpy
	40 %	79 oC	175 oF	0.01 mmy	0.5 mpy	0.38 mmy	15 mpy	0.31 mmy	12.3 mpy
	50 %	79 oC	175 oF	0.02 mmy	0.7 mpy	0.63 mmy	24.7 mpy	0.40 mmy	15.9 mpy
	60 %	79 oC	175 oF	0.02 mmy	0.9 mpy	0.67 mmy	26.4 mpy	0.67 mmy	26.4 mpy
	70 %	66 oC	150 oF	0.01 mmy	0.2 mpy	0.14 mmy	5.7 mpy	0.28 mmy	11 mpy
	80 %	66 oC	150 oF	0.06 mmy	2.2 mpy	0.13 mmy	5.1 mpy	N/T mmy	N/T
	90 %	79 oC	175 oF	0.07 mmy	2.9 mpy	0.71 mmy	27.9 mpy	N/T mmy	N/T
Nitric Acid	20 %	Boiling	Boiling	0.02 mmy	0.7 mpy	0.38 mmy	15 mpy	0.06 mmy	2.3mpy
	40 %	Boiling	Boiling	0.24 mmy	9.5 mpy	1.27 mmy	50 mpy	0.26 mmy	10.4mpy
	60 %	93 oC	200 oF	0.19 mmy	7.4 mpy	0.73 mmy	28.7 mpy	0.19 mmy	7.6 mpy
Phosp horic Acid	50 %	Boiling	Boiling	0.03 mmy	1.1 mpy	0.27 mmy	10.7 mpy	0.03 mmy	1.3 mpy
	60 %	Boiling	Boiling	0.08 mmy	3.2 mpy	0.11 mmy	4.3 mpy	0.56 mmy	21.9 mpy
	70 %	Boiling	Boiling	0.15 mmy	6 mpy	0.13 mmy	5.1 mpy	1.04 mmy	41 mpy
	80 %	Boiling	Boiling	0.40 mmy	15.6 mpy	0.26 mmy	10.3 mpy	3.02 mmy	119 mpy
Chrom ic Acid	10 %	66 oC	150 oF	0.10 mmy	3.9 mpy	N/T	N/T	0.13 mmy	5 mpy
	20 %	66 oC	150 oF	0.61 mmy	24.1 mpy	N/T	N/T	0.68 mmy	26.7 mpy
Acetic acid	99 %	Boiling	Boiling	< 0.01 mmy	<0.1 mpy	< 0.01 mmy	0.1 mpy	Below 0.01 mmy	0.1 mpy
Formic acid	88 %	Boiling	Boiling	0.01 mmy	0.4 mpy	0.05 mmy	2 mpy	0.02 mmy	0.9 mpy
ASTM G 28A		Boiling	Boiling	0.67 mmy	26.3 mpy	3.52 mmy	138.6 mpy	1.02 mmy	40 mpy
ASTM G 28B		Boiling	Boiling	0.11 mmy	4.2 mpy	N/T	N/T	0.20 mmy	8 mpy

Hastelloy C-2000 solves the alloy design dilemma. Large magnitude of chromium is mixed with molybdenum and copper, adequate to offer resistance to the reducing conditions while no loss of metallurgical consistency. In the hot reducing concentration of sulfuric acid, alloy C-2000 offers better performance than alloy C-276. Hastelloy C-2000 also offers excellent resistance to the boiling and hydrated hydrochloric acid. On the other side the rate of corrosion increases to 20 mpy at the concentration between 1 to 1.5 wt %. Hastelloy C-2000 offers superior resistance to corrosion at the concentration of 3% weight.

Pitting and Crevice corrosion resistance

Hastelloy C-2000 corrosion resistance alloy also offers resistance to pitting and crevice corrosion that is widely introduced in the commercial processes. In order to determine the pitting and crevice corrosion resistance provided by Hastelloy C-2000, it is evaluated at the critical crevice and pitting temperature in the acidic medium of 6 % ferric chloride by following the ASTM G 48 procedures.

ALLOY	Critical Crevice Temperatures, oC	Critical Pitting Temperatures, oC
316L	0	15
254SMO	30	60
625	40	100
C-22	80	>120
C-276	55	>120
C-2000	80	>120

The above data shows the minimum temperature at which the pitting and crevice corrosion occurs in the acidic ferric chloride in 72 hours. Another acidic solution is 11.5 % sulfuric acid, 1.2 % hydrochloric acid, 1 % ferric chloride and 1 % cupric chloride that is widely used to evaluate the resistance to pitting corrosion. This solution is called as green death.

Seawater corrosion resistance

Seawater is one of the strongest corrosive media that consists of aqueous salts. It is bumped into marine operations and seashore oil refineries as well as used as coolant in the coastal industries. The crevice test is conducted in the still and dynamic water at 29oC or 3oC. Double samples of every testing alloy in the still and dynamic water are evaluated for 180 days. Every sample consists of double crevice spots.

ALLOY	Still water	Still water	Dynamic water	Dynamic water
	No. of spots	Depth, mm	No. of spots	Depth, mm
316L	2	1.80	2	0.32
254SMO	2	1.25	2	0.01
625	2	0.11	2	<0.01
C-22	0	0	0	0
C-276	1	0.12	0	0
C-2000	0	0	0	0

Stress Corrosion Cracking:

Boiling solution of 45% magnesium chloride is used to evaluate the resistance to stress corrosion cracking offered by Hastelloy C-2000. The following table shows the time needed to cause cracks in the different alloy's materials:

Alloy	Cracking Period
316L	2 hours
254MO	2 hours
625	No cracks in 1008 hours
C-22	No cracks in 1008 hours
C-276	No cracks in 1008 hours
C-2000	No cracks in 1008 hours

High Temperature Tensile Properties

Temperature		Yield strength		Tensile Strength		Elongation
oC	oF	MPa	Ksi	Mpa	Ksi	%
93 oC	200 oF	319 MPa	46.3 Ksi	724 MPa	105 Ksi	70.3 %
149 oC	300 oF	308 MPa	44.7 Ksi	684 MPa	99.2 Ksi	68.8 %
204 oC	400 oF	283 MPa	41 Ksi	676 MPa	98 Ksi	69.3 %
260 oC	500 oF	260 MPa	37.7 Ksi	641 MPa	93 Ksi	67.9 %
316 oC	600 oF	243 MPa	35.3 Ksi	616 MPa	89.3 Ksi	72.7 %
371 oC	700 oF	234 MPa	33.9 Ksi	605 MPa	87.8 Ksi	69.8 %
427 oC	800 oF	216 MPa	31.3 Ksi	609 MPa	88.3 Ksi	73 %
482 oC	900 oF	223 MPa	32.4 Ksi	585 MPa	84.9 Ksi	72.6 %
538 oC	1000 oF	214 MPa	31 Ksi	586 MPa	85 Ksi	75.3 %
649 oC	1200 oF	209 MPa	30.3 Ksi	554 MPa	80.3 Ksi	70.7 %

Charpy Notch Impact Strength

Temperature		Condition	Impact strength	
oC	of		J	Ft.lbf
Room temp	Room temp	Annealed	Above 358	Above 264
-196 oC	-320 of	Annealed	Above 358	Above 264
Room temp	Room temp	Annealed + Aged for 100 hours at 260oC or 500oF	Above 358	Above 264
-196 oC	-320 of	Annealed + Aged for 100 hours at 260oC or 500oF	342	252
Room temp	Room temp	Annealed + Aged for 100 hours at 538oC or 1000oF	224	165
-196 oC	-320 of	Annealed + Aged for 100 hours at 538oC or 1000oF	174	128

Fabrication

Hastelloy C-2000 alloy offers superior fabrication properties and cold forging is the recommended method for shaping. It can be conveniently work processed due to its high ductility. It is normally stiffer as compare to the austenitic stainless steels so more energy is needed while cold forging.

Heat Processing

Wrought Hastelloy C – 2000 is kept into solution annealed form, if specified. The standard solution annealing processing includes heating up to 1135oC, subsequently air or water quenching is performed. The components that are hot forged are solution annealed before final forging.

Welding

Alloy C-2000 has similar welding, forming, and machining features equivalent to C-276 alloy. In order to weld the Hastelloy C- series alloys, basically three methods are followed.

For sheet welds and plate root passes, GTAW or Gas tungsten arc welding process is recommended. For plate welding, the gas metal arc welding method is recommended.

For field welding, the shielded metal arc process is preferred by using the coated electrodes. The submerged arc welding process is not preferred because it is featured with extensive heating of the primary metal and slow weld quenching. In order to decrease the precipitation of second phase in the heat affected welding zones, high interpass temperature up to 93oC is preferred. In these processes, welding of the cold treated alloy is not preferred because these may get sensitized quickly and cause residual stress. The quenching by water after the complete solution annealing is preferred for cold processed alloy prior to welding. The grease, oil and other contaminated particles should be removed.

Filler Metal

Hastelloy C-2000 filler wire is preferred for gas tungsten arc and gas metal arc welding. Hastelloy C-2000 electrodes are preferred for shielded metal arc welding.

Available Forms

Wire, mesh, strip, foil, plate, sheet, rod, bar, tubing, pipe, flanges