Nickel Based Superalloy Incoloy 800 (UNS N08800)

Nickel-Iron-Chromium alloy Incoloy 800 has fine strength and suitable resistance to oxidation and carburization at high temperatures. It offers elevated temperature performance in the petrochemical industry as it prevents the formation of embrittling sigma phase subsequent to prolong use up to 1200oF or 649oC. Alloy 800 is used in the industrial incinerators, heat processing equipments, chemical processing industries etc.

The compositional elements of **Incoloy** series are the refined elements that have established industrial standards in the high temperature operations by offering suitable creeping and rupturing characteristics. Incoloy 800 is a nickel- iron-chromium alloy with the supreme resistance to corrosion. The resistance to heat and corrosion even with the limited nickel concentration makes this alloy a strategic product.

Alloy 800 has been used in the extensive series of operations due to its vital resistance to oxidation, carburization and other corrosions that occur in the elevated temperature conditions. Its application series includes furnace operations and manufacturing equipments, petrochemical furnace cracker vessels, pigtails and headers and shielding for electrical heating elements.

Chemical Composition

The carbon content present in Incoloy 800 alloy is proportional to creeping and cracking properties of alloy such that more carbon content, more are the creeping and cracking properties. Therefore carbon is added significantly in the alloy on the base of special application requirements. Carbon is added by 0.05% to 0.10% in the ASTM and ASME limits.

Aluminum (Al)	0.15 to 0.60 %
Carbon (C)	0.10 %
Chromium (Cr)	19 to 23 %
Copper (Cu)	0.75 %
Iron (Fe)	39.5 %
Manganese (Mn)	1.5 %
Nickel (Ni)	30 to 35 %

Silicon (Si)	1 %
Sulfur (S)	0.015 %
Titanium (Ti)	0.15 to 0.60 %

Physical Properties

Density	7.94 gm per cubic cm or 0.287 lb per inch3
Ultimate tensile strength	600 MPa or 87000 psi
	500 MPa at 550oC or 72500 psi at 1020oF
Yield strength	275 Mpa or 39900 psi
	213 Mop at 550oC or 30900 psi at 1020oF
Elongation %	45 %
	35 % at 550oC or 1020oF
Electrical resistivity	0.0000989 ohm-cm
Magnetic Permeability	1.014
Curie temperature	-115oC or -175oF
Linear coefficient of thermal expansion	14.4 micro-m/m-oC at 20oC to 100oC
	8 micro-inch/inch-oF at 68oF to 212oF
Specific heat capacity	0.460 J/goC or 0.110 BTU/lb-oF
Thermal conductivity	11.5 W/m-K or 79.8 BTU-in/hr-ft2-oF
Melting point	1357 to 1385oC or 2475 to 2525oF
Solidus point	1357oC or 2475oF
Liquidus	1385oC or 2525oF

Modulus of Elasticity

Temperature oF	Tensile Modulus, 10(3)ksi	Shear Modulus,10(3)ksi	Poisson's Ratio
-310 oF	30.55 x 10(3) ksi	11.45 x 10(3) ksi	0.334
75 oF	28.50 x 10(3) ksi	10.64 x 10(3) ksi	0.339
200 oF	27.82 x 10(3) ksi	10.37 x 10(3) ksi	0.341
400 oF	26.81 x 10(3) ksi	9.91 x 10(3) ksi	0.353
600 oF	25.71 x 10(3) ksi	9.47 x 10(3) ksi	0.357

Electric & Thermal Properties

Temperature		Electrical Resistivity		Thermal Conductivity		Coef. Of Expansion	
70 oF	20 oC	595 ohm•circ mil/ft	0.989 micro-ohm.cm	80 Btu•in/ft(2) in/in/°F	11.5 W/moC	-	-
100 oF	37 oC	600 ohm•circ mil/ft	1.035 micro-ohm.cm	83 Btu•in/ft(2) in/in/°F	13 W/moC	-	14.4 mm/m/oC
200 oF	93 oC	620 ohm•circ mil/ft	1.089 micro-ohm.cm	89 Btu•in/ft(2) in/in/°F	14.7 W/moC	7.9 X 10(-6) in/ in/ °F	15.9 mm/m/oC

400 oF	204 oC	657 ohm•circ mil/ft	1.127 micro-ohm.cm	103 Btu•in/ft(2) in/in/°F	16.3 W/moC	8.8 X 10(-6) in/ in/ °F	16.2 mm/m/oC
600 oF	315 oC	682 ohm•circ mil/ft	1.157 micro-ohm.cm	115 Btu•in/ft(2) in/in/°F	17.9 W/moC	9.0 X 10(-6) in/ in/ °F	16.5 mm/m/oC
800 oF	426 oC	704 ohm•circ mil/ft	1.191 micro-ohm.cm	127 Btu•in/ft(2) in/in/°F	19.5 W/moC	9.2 X 10(-6) in/ in/ °F	16.8 mm/m/oC
1000 oF	537 oC	722 ohm•circ mil/ft	1.223 micro-ohm.cm	139 Btu•in/ft(2) in/in/°F	21.1 W/moC	9.4 X 10(-6) in/ in/ °F	17.1 mm/m/oC
1200 oF	648 oC	746 ohm•circ mil/ft	1.251 micro-ohm.cm	152 Btu•in/ft(2) in/in/°F	22.8 W/moC	9.6 X 10(-6) in/ in/ °F	17.5 mm/m/oC
1400 oF	760 oC	758 ohm•circ mil/ft	1.266 micro-ohm.cm	166 Btu•in/ft(2) in/in/°F	24.7 W/moC	9.9 X 10(-6) in/ in/ °F	18 mm/m/oC
1600 oF	871 oC	770 ohm•circ mil/ft	1.283 micro-ohm.cm	181 Btu•in/ft(2) in/in/°F	27.1 W/moC	10.2 X 10(-6) in/ in/ °F	-
1800 oF	982 oC	776 ohm•circ mil/ft	1.291 micro-ohm.cm	21.4 Btu•in/ft(2) in/in/°F	31.9 W/moC	-	-
2000 oF	1093 oC	788 ohm•circ mil/ft	-	-	-	-	-

Mechanical Properties

The mechanical features of incoloy 800/800HT are paired with their resistance to corrosion properties at the elevated temperatures that makes the Incoloy alloys extremely purposeful for using in the different high temperature and long term oriented operations. These alloys are also significantly used in the variety of corrosive media. The chemical composition limits of Incoloy 800H and 800HT reside within the limits of INCOLOY alloy 800.

Alloy 800 comprises of large mechanical strength over high temperatures. It is suitable for using up to 1500oF. The vital difference between Incoloy alloy series depends on the difference of their mechanical properties. The difference in the mechanical properties is due to difference in their chemical composition and the different temperature annealing. Generally **Incoloy 800 alloy** possesses higher mechanical properties at the room temperatures and minimum to high temperature exposures. On the other side the Incoloy 800H and 800HT alloys offer high creep and stress rupture strength at the higher temperature exposures.

Tensile Properties

Incoloy 800 alloy offers high tensile features at the room and high temperatures. The tensile characteristics at room temperature and 1200oF to 1800oF of extruded pipe and tubing are described as following:

Temp.	Tensile	0.2% Yield Strength	1.0% Yield Strength	Elongation

		Strength						A5%
oC	oF	N/mm^2	Ksi	N/mm^2	Ksi	N/mm^2	Ksi	
RT	RT	500 N/mm^2	72.5 Ksi	170 N/mm^2	24.7 Ksi	200 N/mm^2	29.0 Ksi	Transverse
93 oC	200 of	-	-	141 N/mm^2	20.4 Ksi	161 N/mm^2	23.3 Ksi	30
100 oC	212 of	<425> N/mm^2	-	140 N/mm^2	20.3 Ksi	160 N/mm^2	23.2 Ksi	Longitudinal
200 oC	392 of	<400> N/mm^2	-	115 N/mm^2	16.7 Ksi	135 N/mm^2	19.6 Ksi	35
204 oC	400 of	-	-	113 N/mm^2	16.4 Ksi	133 N/mm^2	19.3 Ksi	
300 oC	572 of	<390> N/mm^2	-	95 N/mm^2	13.8 Ksi	115 N/mm^2	16.7 Ksi	
316 oC	600 of	-	-	93 N/mm^2	13.5 Ksi	113 N/mm^2	16.4 Ksi	
400 oC	752 of	<360> N/mm^2	-	80 N/mm^2	11.6 Ksi	100 N/mm^2	14.5 Ksi	
538 oC	1000 of	-	-	77 N/mm^2	11.2 Ksi	97 N/mm^2	14.1 Ksi	
593 oC	1100 of	-	-	75 N/mm^2	10.9 Ksi	95 N/mm^2	13.8 Ksi	
600 oC	1112 of	<300> N/mm^2	-	75 N/mm^2	10.9 Ksi	95 N/mm^2	13.8 Ksi	

Corrosion Resistance

Incoloy 800 alloy offers excellent resistance to the chloride ion stress corrosion cracking and embrittlement in precipitation sigma phase. It offers superior resistance to corrosion in the different media. In the solution annealed form, it offers high creep stress rupturing features. It can be sensitized to intergranular corrosion in the rigorous conditions.

In an analysis, alloy 800 is subjected to boiling nitric acid of 65% concentration for 5 hours that determines alloy's inclination to sensitization. When Incoloy 800 is set to heat from welding or other processes, precautions should be made to prevent sensitization when it needs to be pickled or kept in the various severe conditions. The sensitization of alloy is not an issue in the various elevated temperature operations.

Incoloy 800H and 800HT offer extremely high creep and cracking strength properties as compare to Incoloy 800. These alloys possess almost similar chemical composition such that the content % of the basic elements like nickel, chromium and iron is same. But, the composition varies in terms of concentration of carbon, titanium and aluminum. The concentration of carbon in Incoloy 800 is 0.10%. Outstanding resistance to chloride ion stress corrosion cracking, oxidation and carburization.

Average corrosion rate in a variety of corrosive media

Media	Test time	Corrosion rate, mpy
10% C2H4O2	7 days	0.01 mpy
5% Al2(SO4)3 • 18H2O	7 days	0.01 mpy
5% NH4Cl	42 days	0.02 mpy
10% NH4OH	7 days	0.01 mpy
5% (NH4)2 SO4	7 days	Nil

10% $BaCl_2$	42 days	0.03 mpy
5% $CaCl_2$	42 days	0.01 mpy
5% H_2CrO_4	7 days	1.6 mpy
10% $C_6H_8O_7$	7 days	Nil
10% $CuSO_4$	7 days	Nil
5% $FeCl_3$	42 days	420 mpy
10% $C_3H_6O_3$	7 days	0.04 mpy
CH_3OH	7 days	Nil
10% $C_2H_2O_4$	7 days	11 mpy
5% $C_6N_6FeK_3$	7 days	0.04 mpy
5% $NaHSO_3$	7 days	0.03 mpy
20% Na_2CO_3	7 days	Nil
NaCl	42 days	0.34 mpy
5% NaOCl	42 days	8 mpy
5% Na_2SO_4	7 days	Nil
10% $C_4H_6O_6$	7 days	0.02 mpy
10% $ZnCl_2$	42 days	0.01 mpy

Fabrication

Different machined forms of Incoloy 800 are forged into the end products and equipments by following the ordinary methods. Alloy 800 is readily forged by hot or cold processing and it has superior welding and machining character.

Heating and Pickling

The heating specimen should be clean that whole oil, grease, dust and other unwanted materials should be removed before beginning the heating process. Heating is preferred in the nominal sulfur conditions. The open heating in the nominal sulfur content and furnace conditions should be done in the reducing medium to avoid the extensive oxidation. Due to eagerness of chromium to get oxidized in a refractory oxide or water, it is tough to bright anneal the Incoloy 800 in the common commercial annealing furnace. In the limited conditions, the Incoloy alloy can be bright annealed in arid, pure hydrogen atmosphere.

Incoloy 800 is annealed in the muffle furnaces by utilizing reducing media. The contended atmosphere is produced by products of combustion from minor sulfur natural gas burnt with minimum air. It creates thin, long standing and green black oxide layer on alloy. The oxidizing media create heavy oxide scale that is tough to clean. Such type of cleaning needs grinding to some extent. The certain annealing processes are based on the quantity of cold processing of specimen.

The mechanical features of severely cold processed alloy are nominally influenced at temperatures lower than 1000oF. The stress release starts from 1000oF and fulfills after 1.5

hours at 1600oF. The softening of alloy is done by annealing up to 1400oF and is completed after 10 – 15 minutes heating up to 1800oF.

The suitable grain growth starts at 1800oF. The suitable annealing can be done by heating Incoloy 800 up to 1900oF for 2-5 minutes. The annealing temperature influences the grain size and room temperature mechanical characteristics of alloy 800. The alloy material is held at temperature for 15 minutes and air quenching is done prior to analysis. The oxide layer and scale produced are cleaned through pickling process. As the Incoloy 800 resists the chemical corrosion therefore specific pickling methods are followed.

Hot and cold Fabrication of Incoloy 800

The hot fabrication of Incoloy 800 is performed at temperatures from 1600oF to 2200oF. The heavy forging is performed at 1850oF to 2200oF. The forging done at 1200oF to 1600oF may cause cracking in the material. The quenching rate followed after hot forging is not significant in correspondence to thermal cracking.

Incoloy 800 alloy is subjected to carbide precipitation at 1000oF to 1400oF and it should be quenched quickly while preventing sensitization. The cold processing is performed by following processes that are followed for processing of Inconel 600 and stainless steel grades. The work toughening rate of Incoloy 800 is more than the mild steel rate however it is lesser than steel 304. The work toughening rate of alloy 800 is almost similar with the Inconel 600.

Machining of Incoloy 800

Incoloy 800 is readily machined by following the standard processes. The turning can be done by large metal eradication rates, high apparatus service life and excellent surface finish and by utilizing coated carbide equipments. The coated carbide equipments provide enhanced service life at seizing rate of 110-190 sfpm and 0.20 to 0.89 mm per rev. The large speed steel equipments provide extended life at the cutting speed of 35-95 sfpm and input rate of 0.008 to 0.035 ipr.

Welding Features of Incoloy 800 alloy:

Incoloy 800 offers excellent welding character. It can be welded by whole welding methods.

The alloy that needs to be welded should be cleaned and accurate joined layouts should be utilized. The Inco Weld A electrode is a preferred welding product that is used in the shielded metal arc welding. Inconel filer metal 82 is used in gas tungsten arc welding method. The incoflux 4 submerged arc flux is utilized in the submerged arc method. These materials are utilized for unlike welding needs for Incoloy 800.

Available forms

Wire, mesh, strip, foil, bar, rod, pipe, tube, plate, sheet and flanges