Inconel 601 Alloy

Inconel 601

Inconel 601 alloy is a suitable raw material for the production of various types of thermal processing equipments. It offers adequate resistance to heat and corrosion due to oxidation and other media at the high temperature limits. It resists the aqueous corrosion and offers suitable mechanical strength. It can be easily formed. The alloy 601 offers good welding character.

Chemical composition of Inconel 601 alloy:

Nickel	58.0-63.0 %
Chromium	21.0-25.0 %
Iron	Bal.
Aluminum	1.0-1.7 %
Carbon	0.10 %
Manganese	1.0 %
Sulfur	0.015 %
Silicon	0.50 %
Copper	1.0 %

Physical properties of Inconel 601 alloy:

Density	8.11 Mg/m3
Melting Range	1360-1411 °C
Specific Heat, 70°F,	448, J/kg-°C
Permeability at 200 oersted (15.9 kA/m) at 24°C	1.003
Curie Temperature °C	-196

Thermal and electrical characteristics of Inconel 601 alloy:

Temperature,°F	Electrical Resistivity ohm-circ mil/f	Thermal Conductivity Btu-in./ft 2-hr°F	Coeff. Of Expansion 10-6 in./in./°F	Specific Heat Btu/lb-°F
70	710	78	-	0.107
200	716	87	7.60	0.112
400	727	100	8.01	0.119
600	735	113	8.11	0.126
800	741	126	8.30	0.133

Strength of Inconel 601

The Inconel 601 alloy offers excellent mechanical strength. The strengthening scale offered by alloy 601 varies with the variation in the alloy forms and conditions. The particular condition depends on the type of operation and temperature. Basically, the solution processed alloy is used in the crack oriented operations at the high temperatures up to 1000oF.

Inconel 601 Alloy

The annealed Inconel 601 is implemented in the operations that need high tensile strength. It retains its strength and other features even at the elevated temperatures.

The tensile strength features of annealed wire are mentioned in the below table:

Form	Annealing Temp. °F	Tensile Strength, ksi	Yield Strength, ksi	Elongation,%
Hot-Finished Rod	2000	107.5	42.1	47
Hot-Finished Rod	1800	112.0	66.0	41
Hot-Finished Bar	2000	102.8	37.6	46
Hot-Finished Plate	2000	99.7	40.7	46
Cold-Rolled Sheet	2000	97.9	42.3	46

The tensile properties of alloy rod and bar in the warm finished form are described in the below table:

Size (mm)	Tensile Strength, ksi	Yield Strength, ksi	Elongation, %
64 x 64	93.0	60.0	40
51 x 51	97.5	44.0	49
76 Dia	98.0	50.5	45

The tensile properties of the hot treated and annealed rod at temperature of 2000oF are provided at the below for temperature limits to 1000oF or 540oC:

Temperature, oF	Tensile Strength, ksi	Yield Strength , ksi	Elongation,%
70	107.5	42.1	47
200	102.0	36.5	44
400	99.5	34.1	43
600	97.5	32.0	47
800	94.3	31.7	45

Creeping Strength of Inconel 601

The **Inconel 601 alloy** introduces superior creep rupturing strength and is extensively utilized in the apparatus that operate under high temperatures for extended periods. It is significantly used for these purposes as it offers excellent resistance to oxidation and other kinds of corrosion conditions at the elevated temperatures. The cracking strength of alloy solution processed at the various temperature ranges is demonstrated by the Larson Miller parameter.

The creep and rupture strengths of alloy are concluded at the heat processing temperature about 2100oF or 1150oC for one hour. The transverse specimen with the hardness of 86 Rb and the grain size of ASTM 8 are utilized for evaluation. The tensile characters are Yield strength 59.5 ksi, Tensile Strength, 111 ksi, and Elongation, 36%.

Structure of Inconel 601

The Inconel 601 is a face centered cubic solid alloy that consists of large value of metallurgical stabilization. The normal phases available in the microstructure of alloy consist of chromium carbides and titanium nitrides. The wider block structure visible in the photomicrograph is a tiny unit of titanium nitride. The dispersed small units are chromium carbide.

Corrosion resistance properties

The **Inconel alloy 601** has described the full fledge unavailability of embrittling intermetallic forms like sigma. The content of nickel and chromium in Inconel 601 in combination with the concentration of aluminum offers the superior resistance to corrosion at the high temperatures. The excellent features of alloy is its resistance to oxidation at the high temperatures about 2200oF or 1200oC. The concentration of chromium and aluminum offers exclusive spaling resistance during the cyclic thermal work.

Inconel 601 Alloy

The alloy 601 offers excellent resistance to oxidation at the high temperatures. It creates the protective oxide layer that inhibits scaling in the rigorous environments of cyclic exposure to the temperature. The alloy offers extensive resistance to cyclic oxidation at the temperature of 2000oF or 1095oC. It is subjected in the cyclic exposure to 2000oF or 1095oC for 15 minutes and quick air cooling for five minutes. The difference in the weight is noticed regularly.

The excellent resistance to oxidation provided by alloy 601 is based on the concentration of nickel, aluminum and chromium. At the elevated temperature, these elements produce the secured oxide layer on the material's surface. Moreover the minor internal oxidation offers more chromium concentration in the surface oxide. The **Inconel 601 alloy** also offers excellent resistance to carburization. The below table shows the consequences of carburization analysis made at variable temperatures:

Alloy	Weight Gain in 100 hr, mg/cm2	
	1700°F (925°C)	1800°F (980°C)
INCONEL alloy 600	2.66	-
INCONEL alloy 601	2.72	4.32
INCOLOY alloy 800	4.94	11.6

Resistance to Sulfidation

The resistance to sulfidation provided by **Inconel 601 alloy** in the presence of hydrogen sulfide and hydrogen is very high at the temperature of 1200oF to 1400oF or 650oC to 760oC. The loss of weight determines the complete degradation of alloy after hundred hour's introduction to open atmosphere.

The following table shows the corrosion rate of Inconel 601 alloy in the presence of different media:

Condition	Time	Corrosion rate	
Percentage	days	Mpy	Mm per year
Acetic Acid (10%)	7	<0.1	<0.002
Acetic Acid (10%)+ -Sodium Chloride (0.5%)	30	2.18	0.554
Acetic acid (10%)+sulfuric acid(0.5%)	7	45.7	1.161
Alum (5%)	7	28.6	0.726
Aluminum sulfate(5%)	7	<0.1	<0.002
Ammonium Chloride (5%)	30	0.1	0.002
Ammonium Hydroxide (5%)	7	Negligible	Negligible
Ammonium Hydroxide (10%)	7	Negligible	Negligible
Ammonium Sulfate (5%)	7	0.1	0.002
Barium Chloride (10%)	30	0.1	0.002
Calcium Chloride (5%)	30	0.1	0.002
Chromic Acid (5%)	7	3.6	0.091
Citric Acid (10%)	7	<0.1	<0.002
Copper Sulfate (10%)	7	Negligible	Negligible
Ferric Chloride (5%)	7	354	8.99
Ferrous Ammonium Sulfate (5%)	7	Negligible	Negligible

Processing of Inconel 601

Inconel 601 alloy is easily forged, machined and welded by following the standard processes. The unnecessary materials like grease, oil and dust should be eradicated from the material prior to heating.

Inconel 601 Alloy

The alloy is heated in the conditions of lower concentration of sulfur. The fuel for open heating should include minor sulfur content. In order to avoid the massive oxidation of alloy, the furnace conditions should be reduced slowly. The Inconel 601 alloy is not strengthened by heat processing. The wide range of forces and hardness can be obtained from it by the mixture of cold processing and annealing. The impact of annealing temperature on the tensile strength of cold treated Inconel alloy is shown in the below table:

Annealing Temperature °F	Tensile Strength, ksi	Yield Strength, ksi	Elongation%
1750	174.0	166.0	5
1800	114.0	56.5	32
1850	113.5	53.5	34
1900	105.0	43.0	37
1950	107.0	41.0	36
2000	104.0	43.0	39

The presence of aluminum and chromium offers capability to Inconel 601 alloy to produce the refractory surface oxide while heating that cannot be annealed in the commercial furnaces. The pickling is essential to produce the bright layers on the alloy sections that are heated. The specialized pickling processes are essential for alloy 601 due to its resistance to the chemical processes. The light oxide on the material that are annealed and cooled in absence of air can be eradicated by the nitric or hydrochloric acid solution.

Hot Forging of Inconel 601

The temperature of hot forging of **Inconel 601 alloy** is 1600 to 2250oF or 870-1230oC. The hot processing operations that consist of wider distortions should be conducted at temperature of 1900oF to 2250oF or 1040oC to 1230oC. The Inconel alloy has low ductile nature at higher temperature of 1200 to 1600oF or 650-870oC so it is not recommend to process in this temperature range. Minor processing is done at temperature lower than 1200oF or 650oC to obtain the high tensile strength.

The **Inconel 601 alloy** is cold treated by following the traditional methods. Its toughening rate is slightly more than the 600 alloy and 800 alloy rate. The below table shows the tensile character of cold drawn alloy subsequent to different amounts of cold reduction.

Cold reduction Temp. °F	Tensile Strength-ksi	Yield Strength-ksi	Elongation,%
45	174.0	166.0	5
68	192.0	185.0	4
77.5	197.0	183.0	4
83	202.0	193.0	3

Impact Strength of Inconel 601

In the below table the impact strength of alloy 601 is demonstrated when it is exposed to 1000oF to 1600oF or 540oC to 870oC and it shows even higher impact strength after the exposure for 1000 hours.

Condition	Diameter (mm)	Charpy V-Notch Impact Strength (J)
Solution-Treated	19	184
Solution-Treated	16	176
Annealed	19	164
Annealed	16	140

The annealed **Inconel 601 alloy** offers enhanced fatigue potential as compare to solution processed alloy.

Inconel 601 Alloy

Machining of Inconel 601

Machining	Recommended initial rates
Single Point turning	Roughing - 0.15" depth, 0.015"/rev feed -175 SFM Finishing - 0.025" depth, 0.007"/rev feed - 200 SFM
Drilling	1/4" Dia hole - 0.004"/rev feed - 60 SFM
	1/2" Dia hole - 0.007"/rev feed - 60 SFM
	3/4" Dia hole - 0.010"/rev feed - 60 SFM
Reaming	Feed - same as drilling - 100 SFM
Side and Slot Milling	Roughing - 0.25" depth - 0.007"/tooth feed - 125SFM
	Finishing - 0.050" depth - 0.009"/tooth feed - 140SFM

Welding of Inconel 601

The **Inconel 601 alloy** obtains the superior welding character and it is easily connected by following the traditional welding products and methods. The welding forms are introduced with the higher joint efficiency and resistance to heat. The choice of welding form is based on the service conditions that are followed to produce the Inconel alloy parts for exposure. In the below table, standard instructions for choosing the welding form are provided:

Processing	Shielded Metal Arc Welding	Gas Tungsten Arc Welding	Gas Metal Arc Welding	Submerged Arc Welding
Up to 1800°F (980°C)	INCO-WELD A Welding Electrode or INCONEL Welding Electrode 117	INCONEL Filler Metal 82, 601, or 617	INCONEL Filler Metal 82 or 617	INCONEL Filler Me and INCOFLUX 4
1800°F (980°C) to 2100°F (1150°C)	INCONEL Welding Electrode 117	NCONEL Filler Metal 601 or 617	INCONEL Filler Metal 617	Not Suggested
Above 2100°F (1150°C)	Not Suggested	INCONEL Filler Metal 601	Not Suggested	Not Suggested
H2S or SO2 at all temperatures	Not Suggested	INCONEL Filler Metal 601	Not Suggested	Not Suggested

The assessment of rupture potential of Inconel 601 alloy with the Inconel 617 welding forms and Inconel 601 wrought materials is provided in the below table:

Welding Product	Temperature °F	Stress for Rupture in (ksi)		
		100 hr	1000 hr	10,000 hr
INCONEL Filler Metal 82	1000	60	51	39
INCONEL Welding Electrode 117 & INCONEL Filler Metal 617	1000	50	44	38

Applications of Inconel 601

The resistance to oxidation property of Inconel 601 alloy is significantly improved by adding aluminum. Its compositional features make it suitable for using in the heat treatment, chemical processing, controlling the pollution level, aircraft and other production fields. In the chemical treatment operations, Inconel 601 alloy is used in the heaters, condenser tubes in the sour water liners and insulted containers in the ammonia filters. The alloy is also utilized in the combustor components and catalyst grid assistance in the devices for preparing the nitric acid. In the chemical processing of petrol, Inconel 601 treats as catalyst regenerator and air pre – heating agent in producing the high density polyethylene.

Inconel 601 Alloy

In the pollution discarding operations, the Inconel 601 is utilized in the thermal reactors in exhaust equipments of gasoline engines as well as heating chambers in the solid waste burners. In the power production fields the alloy 601 is used in the superheater tube helpers, grid restrictors and maintenance equipments. The **Inconel 601 alloy** is also used in the jet engine igniters and combustion can liners, diffuser assembles and mixture rings in the turbines of aerospace industries as well as commercial and automobile operations.

Fasteners

The Inconel 601 fasteners are excellent resistant to heat and corrosion. These are used in the various applications due to their excellent anti corrosion properties.

Limitations:

Inconel 601 shouldn't be used in the vacuum furnaces.

Manufacturer:

Heanjia Super Metals Co., Ltd fabricates Inconel 601 alloy for the whole engineering purposes that demand excellent resistance to corrosion and high temperature properties. The alloy is offered in the varied forms. The specification of the forms is provided as following:

Wire	0.05mm to 15.0mm
Wire Mesh Screen	Mesh size:0.2 mesh/inch, thickness: 0.1 mm to 5.0mm, aperture rate: 10%-90%
Sheet and Plate	Thickness: above 1mm, width: 100mm-1700mm, length: 800mm-3000mm
Tape/Ribbon	Thickness: 0.05mm above, Width: 2mm above
Pipe and Tubing	Thickness-1-20mm, Out diameter:16-219mm
Strip	Thickness – 0.05mm above, Width- 2mm above
Rod and Bar	Diameter: 3mm above, length: 20mm above

Heanjia Super Metals Co., Ltd **Room 2108, 21/F, BLK128, Yinling International Zone, Wangjing West Rd, Chaoyang, Beijing, China (100102)**