INCONEL® nickel-iron-chromium alloy 706 (UNS N09706) is a precipitation-hardenable alloy that provides high mechanical strength in combination with good fabricability. The characteristics of the alloy are similar to those of INCONEL alloy 718 except that alloy 706 is more readily fabricated, particularly by machining. (The properties of alloy 718 are described in the publication "INCONEL alloy 718," on the website www.specialmetals.com.)

The limiting chemical composition of INCONEL alloy 706 is listed in Table 1. The substantial nickel and chromium contents provide good resistance to oxidation and corrosion. The primary precipitation-hardening constituents of the alloy are niobium and titanium. The aluminum content also contributes to the hardening response.

The precipitation-hardening system in INCONEL alloy 706 provides the desirable characteristic of delayed hardening response during exposure to precipitation temperatures. That characteristic gives the alloy excellent resistance to postweld strain-age cracking.

INCONEL alloy 706 is used for a variety of applications that require high strength combined with ease of fabrication. In the aerospace field, the alloy is used for turbine discs, shafts, and cases; diffuser cases; compressor discs and shafts; engine mounts; and fasteners. In addition to aerospace applications, the alloy is used for turbine discs in large industrial gas turbines.

Property values in this publication are given in both United States customary units and the International System of Units (SI). The SI unit of stress is the pascal (Pa), which is equivalent to newton per square meter. The approximate relationship between the pascal and the pound per square inch (psi) is 1 Pa = 0.0001450 psi, or 1 psi = 6,895 Pa.

Table 1 - Limiting Chemical Composition, %, of INCONEL alloy 706

Nickel (Plus Cobalt)	39.0-44.0
Chromium	14.5-17.5
Iron	Balance[b]
Niobium (plus Tantalum)	2.5-3.3
Titanium	1.5-2.0
Aluminum	0.40 max.
Carbon	0.06 max.
Copper	0.30 max.
Manganese	0.35 max.
Silicon	0.35 max.
Sulfur	0.015 max.
Phosphorus	0.020 max.
Boron	0.006 max.
Cobalt[a]	1.00 max.

[a]Determination not required for routine acceptance.

[b] Reference to the 'balance' of a composition does not guarantee this is exclusively of the element mentioned but that it predominates and others are present only in minimal quantities.

Physical Constants and Thermal Properties

Some physical constants for INCONEL alloy 706 are listed in Table 2. Thermal and electrical properties are reported in Table 3. Values shown for thermal conductivity were calculated from measurements of electrical resistivity. Specific-heat values were calculated from chemical composition. All values given for thermal and electrical properties were determined for precipitation-hardened material.

Modulus of elasticity and Poisson's ratio for precipitation-hardened material at various temperatures are shown in Table 4. The modulus data were determined by the dynamic method. Poisson's ratio was calculated from moduli of elasticity.

INCONEL alloy 706 undergoes a small amount of contraction during precipitation hardening. The amount of contraction is typically 0.09%.

Table 2 - Physical Constants

Density	
Annealed, lb/in³	0.291
Mg/m³	8.05
Precipitation-Hardened, lb/in³	0.292
Mg/m³	8.08
Melting Range, °F	2434-2499
°C	1334-1371
Specific Heat, 70°F, Btu/lb•°F	0.106
21°C, J/kg•°C	444
Permeability at 200 oersted (15.9 kA/m)	
Annealed	
74°F (23°C)	1.011
-109°F (-78°C)	1.020
-320°F (-196°C)	Magnetic
Precipitation-Hardened	
74°F (23°C)	1.010
-109°F (-78°C)	1.040
-320°F (-196°C)	Magnetic
Curie Temperature, °F	<-109
°C	<-78

INCONEL® alloy 706

Table 3 - Thermal Properties

Temperature	Electrical Resistivity	Thermal Conductivity[a]	Coefficient of Expansion[b]	Specific Heat[c]
°F	ohm •circ mil/ft	Btu•in/ft² •hr•°F	10^{-6} in/in/°F	Btu/lb•°F
-320	527	55	-	-
70	592	87	-	0.106
200	610	96	7.40	0.110
300	622	103	7.83	0.113
400	635	110	8.07	0.117
500	647	117	8.25	0.120
600	659	124	8.42	0.124
700	671	130	8.50	0.127
800	683	136	8.57	0.131
900	695	141	8.64	0.134
1000	707	147	8.73	0.138
1100	717	152	8.84	0.141
1200	-	-	8.97	0.145
1300	-	-	9.11	0.148
°C	µΩ•m	W/m•°C	µm/m/°C	J/kg•°C
-196	0.876	7.9	-	-
20	0.985	12.5	-	444
100	1.015	14.0	13.46	461
150	1.035	14.8	14.11	473
200	1.055	15.9	14.53	490
250	1.075	16.7	14.85	502
300	1.090	17.6	15.08	515
350	1.110	18.5	15.25	528
400	1.130	19.2	15.39	536
450	1.145	19.9	15.50	553
500	1.160	20.6	15.59	565
550	1.180	21.3	15.79	582
600	1.195	22.1	15.97	595
650	-	-	16.20	607
700	-	-	16.42	620

[a]Calculated from electrical resistivity.
[b]Average coefficient between 78°F (26°C) and temperature shown.
[c]Calculated from chemical composition.

Table 4 - Modulus of Elasticity[a]

Temperature	Tensile Modulus	Shear Modulus	Poisson's Ratio[b]
°F	10^3 ksi	10^3 ksi	
-320	31.6	11.6	0.362
70	30.4	11.0	0.382
200	29.9	10.8	0.387
400	29.0	10.4	0.393
600	27.9	10.0	0.395
800	27.0	9.6	0.405
1000	25.9	9.3	0.395
1200	24.7	8.8	0.403
1300	24.0	8.5	0.417
°C	GPa	GPa	Poisson's Ratio[b]
-196	218	80	0.362
20	210	76	0.382
100	206	74	0.389
200	200	72	0.389
300	194	70	0.392
400	188	67	0.405
500	181	65	0.404
600	174	63	0.395
700	166	59	0.415

[a]Determined by dynamic method on precipitation-hardened material.
[b]Calculated from moduli of elasticity.

Mechanical Properties

The high-strength of precipitation-hardened INCONEL alloy 706 is maintained at temperatures up to 1300°F (705°C). Optimum mechanical properties for the intended service temperature are achieved by the use of one of two heat treatments.

HEAT TREATMENTS

The heat treatments used for alloy 706 are designed to produce either high tensile properties for room- and moderate-temperature applications or high stress-rupture properties for applications up to 1300°F (705°C).

For optimum creep and rupture properties, the alloy receives a three-part heat treatment:

Heat Treatment A

Solution Treatment - 1700-1850°F (925-1010°C) for a time commensurate with section size, air cool.

Stabilizing Treatment - 1550°F (845°C)/3 hr, air cool.

Precipitation Treatment - 1325°F (720°C)/8 hr, furnace cool at 100°F (55°C)/hr to 1150°F (620°C)/8 hr, air cool.

For tensile-limited applications, a two-part treatment is used:

Heat Treatment B

Solution Treatment - 1700-1850°F (925-1010°C) for a time commensurate with section size, air cool.

Precipitation Treatment - 1350°F (730°C)/8 hr, furnace cool at 100°F (55°C)/hr to 1150°F (620°C)/8 hr, air cool.

The heat treatments described above are based on metal temperatures and are derived from batch rather than continuous furnace operations. The solution-treatment procedures may not be applicable to continuous operations since continuous heat treating is normally performed by short-time exposure in the hot zone of a furnace set at higher temperatures.

TENSILE PROPERTIES

Room-temperature tensile properties of cold-rolled sheet in the solution-treated and precipitation-hardened conditions are given in Table 5. All specimens were from the transverse direction.

Typical room-temperature tensile properties of hot-finished material given Heat Treatments A and B are listed in Table 6. The data illustrate the improvement in tensile properties, particularly yield strength, provided by Treatment B. All of the tests were performed on longitudinal specimens.

Tensile properties of forged discs at room temperature and 1200°F are listed in Table 7. Data showing the effects of forging temperature on mechanical properties are given in the section on hot forming.

Table 5 - Room-Temperature Tensile Properties of Cold-Rolled Sheet

Thickness		Heat Treatment	Tensile Strength		Yield Strength (0.2% Offset)		Elong-ation, %
in	mm		ksi	MPa	ksi	MPa	
0.040	1.02	Solution Treated	109.8	757	55.5	383	47
0.040	1.02	A	186.0	1282	148.5	1024	22
0.040	1.02	B	193.5	1334	161.3	1112	24
0.062	1.57	A	189.0	1303	153.5	1058	18
0.062	1.57	B	191.0	1317	159.0	1096	20

Table 6 - Typical Room-Temperature Tensile Properties of Hot-Finished Material

Form	Size		Heat Treatment	Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %	Reduction of Area, %
	in	mm		ksi	MPa	ksi	MPa		
Rod	0.562 Dia.	14.3	A	186.0	1282	144.0	993	19	28
Rod	8.0 Dia	203	A	189.0	1303	146.0	1007	18	28
Flat	1.250 Thick	31.8	B	193.5	1334	161.5	1114	20	38
Rod	0.562 Dia.	14.3	B	193.0	1331	158.0	1089	21	55

Table 7 - Tensile Properties of Forged Discs

Temperature		Heat Treatment	Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %	Reduction of Area, %
°F	°C		ksi	MPa	ksi	MPa		
70	20	Solution Treated	108.0	745	41.7	288	50	55
70	20	A	180.5	1245	142.0	979	17	19
1200	650	A	143.5	989	119.5	824	21	27
70	20	B	183.0	1262	157.4	1085	22	43

Table 8 shows the effects of temperatures from -320°F (-196°C) to 900°F (480°C) on the tensile properties of precipitation-hardened hot-finished rod. The tests were performed on longitudinal specimens from 0.562-in. (14.3-mm) rod heat-treated as indicated.

INCONEL alloy 706 retains substantial strength at elevated temperatures. Figures 1 and 2 show tensile properties to 1400°F (760°C) of cold-rolled sheet given Heat Treatments A and B. The specimens were from 0.040-in. (1.02-mm) sheet and were tested in the transverse direction.

Table 8 - Tensile Properties of Precipitation-Hardened Hot-Finished Rod[a]

Temperature		Heat Treatment	Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %	Reduction of Area, %
°F	°C		ksi	MPa	ksi	MPa		
-320	-196	A	232.5	1603	169.0	1165	24	29
		B	236.5	1631	174.0	1200	28	54
-65	-54	A	207.5	1431	163.0	1124	18	29
		B	208.5	1438	161.0	1110	22	52
70	20	A	192.0	1324	155.5	1072	16	32
		B	193.0	1331	158.0	1089	21	55
900	480	A	168.0	1158	134.5	927	15	38
		B	165.5	1141	135.5	934	20	52

[a]0.562-in. (14.3-mm) diameter.

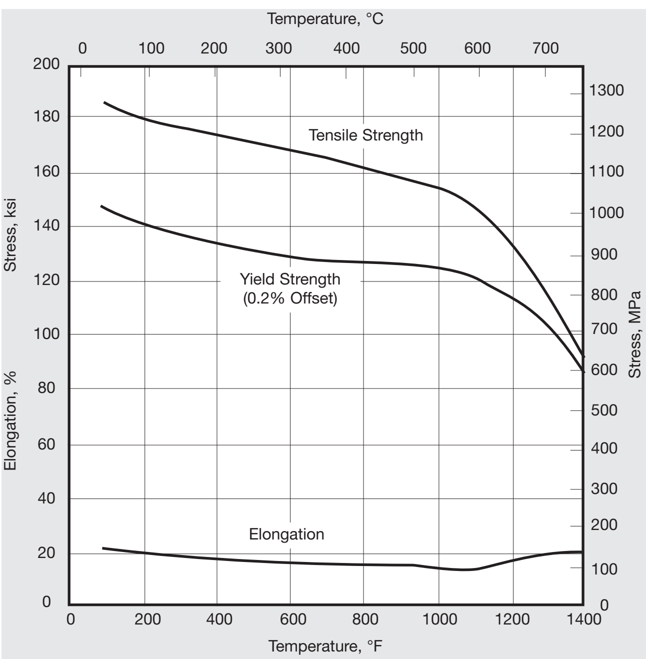

Figure 1. High-temperature tensile properties of cold-rolled sheet given Heat Treatment A.

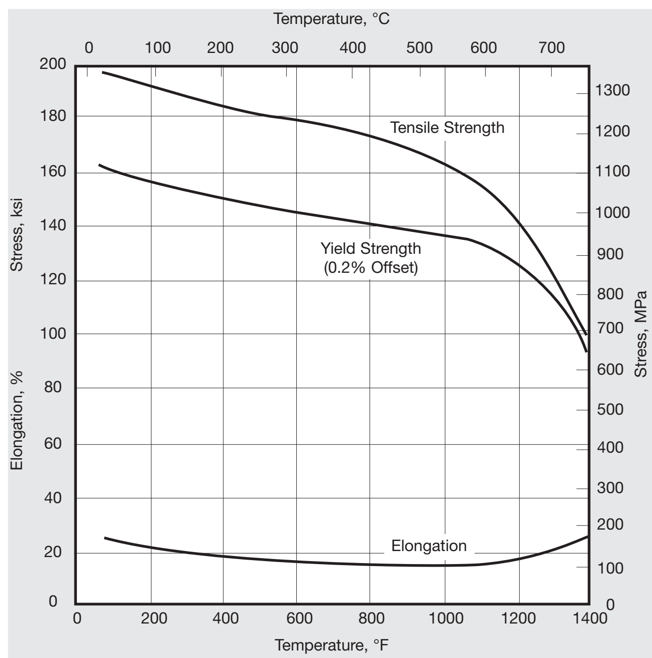

Figure 2. High-temperature tensile properties of cold-rolled sheet given Heat Treatment B.

Table 9 - Room-Temperature Compressive and Tensile Properties

Form	Heat Treatment	Compressive Yield Strength (0.2% Offset)		Tensile Yield Strength (0.2% Offset)		Tensile Strength		Elongation, %
		ksi	MPa	ksi	MPa	ksi	MPa	
Hot-Rolled Rod	A	159.9	1102	148.0	1020	189.0	1303	19
	B	160.4	1106	153.4	1058	190.2	1311	26
Hot-Rolled Plate	A	160.4	1106	148.0	1020	190.5	1313	19
	B	156.6	1080	155.4	1071	192.0	1324	22

The strength of alloy 706 in compression is somewhat higher than its strength in tension. Table 9 is a comparison of compressive yield strength and tensile properties.

SHEAR AND BEARING STRENGTH

The shear strength of INCONEL alloy 706 in various forms and conditions is shown in Table 10. The values are from guillotine shear tests in which the specimens were loaded in double shear. Tensile properties of the specimens are included for comparison.

Alloy 706 sheet has high bearing properties. Table 11 gives bearing yield strength and ultimate strength of specimens from precipitation-hardened cold-rolled sheet. The data are from pin-type bearing tests. The specimen was subjected to tensile stress while supported by a 0.250-in. (6.35-mm) diameter pin inserted with a tight fit through a hole whose center was 0.375-in. (9.52-mm) from the edge of the specimen (edge distance ratio of 1.5).

Table 10 - Room-Temperature Shear Strength and Tensile Properties

Form	Heat Treatment	Shear Strength		Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %
		ksi	MPa	ksi	MPa	ksi	MPa	
Hot-Rolled Rod	A	127.0	876	189.0	1303	148.0	1020	19.0
	B	130.4	899	190.2	1311	153.4	1058	26.0
Hot-Rolled Plate	A	115.0	793	190.5	1313	148.0	1020	19.0
	B	122.3	843	192.0	1324	155.4	1071	22.0
Cold-Rolled Sheet	A	115.0	793	189.0	1303	147.5	1017	15.5
	B	119.7	825	196.5	1355	163.5	1127	19.5

Table 11 - Bearing Strength[a] of Strength

Sheet Thickness		Heat Treatment	Specimen Orientation	Bearing Yield Strength (0.2% Offset)		Bearing Strength		Tensile Yield Strength (0.2% Offset)		Tensile Strength	
in.	mm			ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
0.062	1.57	A	Transverse	220.1	1518	299.8	2067	142.9	985	179.2	1236
		B	Longitudinal	232.3	1602	316.3	2181	162.3	1119	201.1	1387
		B	Transverse	234.7	1618	318.7	2197	161.1	1111	192.1	1324
0.089	2.26	A	Transverse	204.3	1409	279.7	1928	147.5	1017	189.0	1303
		B	Longitudinal	234.3	1615	304.9	2102	159.5	1100	198.5	1369
		B	Transverse	229.6	1583	308.3	2126	163.5	1127	196.5	1355

[a]Pin diameter of 0.250 in. (6.35 mm). Edge distance ratio of 1.5.

FATIGUE STRENGTH AND FRACTURE TOUGHNESS

The rotating-beam fatigue strength at room temperature and 1200°F (650°C) of alloy 706 in the two precipitation-hardened conditions is shown in Figures 3 and 4. As illustrated by the curves, Heat Treatment B produces higher fatigue strength. Longitudinal specimens from 0.562-in. (14.3-mm) diameter rod were used for the tests. The specimens were polished with 500-grit paper before being tested. The material given Heat Treatment A (Figure 3) had a grain size of ASTM 7.5 and the following room-temperature tensile properties:

Tensile Strength, 186 ksi (1282 MPa)
Yield Strength (0.2% Offset), 144 ksi (993 MPa)
Elongation, 19%

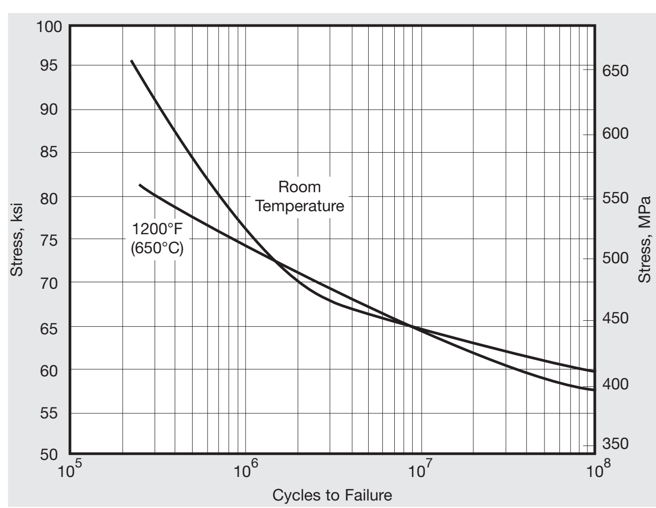

Figure 3. Rotating-beam fatigue strength of hot-rolled rod given Heat Treatment A.

The material given Heat Treatment B (Figure 4) had a grain size of ASTM 6 and room-temperature tensile properties of:

Tensile Strength, 201 ksi (1386 MPa)
Yield Strength (0.2% Offset), 157.5 ksi (1086 MPa)
Elongation, 26%

Low-cycle fatigue properties of INCONEL alloy 706 given Heat Treatment B are shown in Figure 5. The tests were performed on transverse specimens from 0.250-in. (6.4-mm) plate. The specimens were polished with 500-grit paper. The grain size of the plate was ASTM 4, and room-temperature tensile properties were:

Tensile Strength, 180 ksi (1241 MPa)
Yield Strength (0.2% Offset), 143.5 ksi (989 MPa)
Elongation, 22%

Plane-strain fracture-toughness tests performed on five specimens from an 8.5-in. (216-mm) diameter hot-finished round produced an average K_{IC} value of 86.5 ksi $\sqrt{\text{in.}}$ (95.8 MPa $\sqrt{\text{m}}$). The tests were performed by the slow-bend method on precipitation-hardened (Heat Treatment A) material. Longitudinal specimens were used.

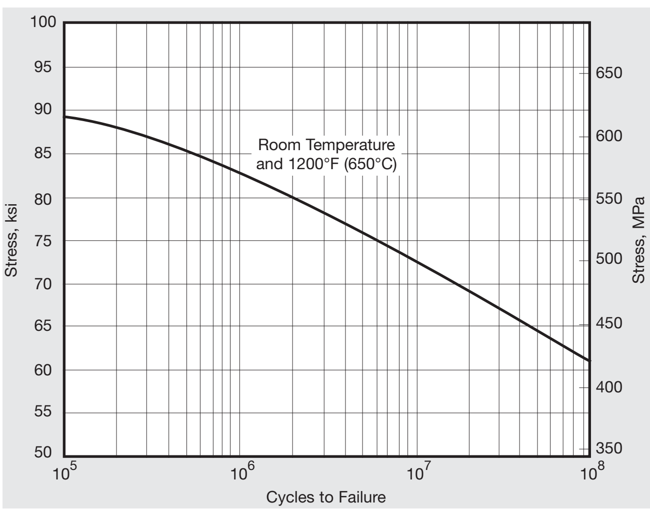

Figure 4. Rotating-beam fatigue strength of hot-rolled rod given Heat Treatment B.

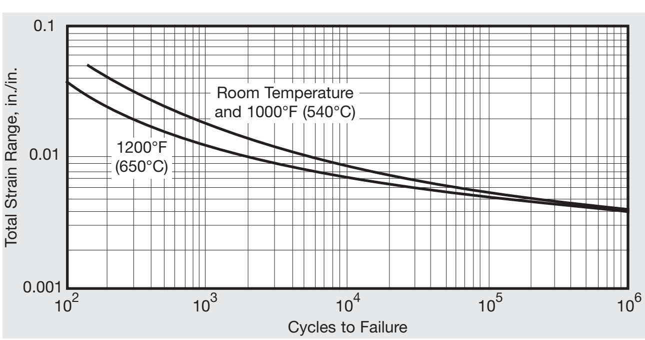

Figure 5. Low-cycle fatigue strength of hot-rolled plate given Heat Treatment B.

IMPACT STRENGTH

Precipitation-hardened INCONEL alloy 706 is metallurgically stable and is not embrittled by long-time exposure to high temperatures. Table 12 gives the results of room-temperature Charpy V-notch tests on hot-finished rod in the as-heat-treated condition and after exposure to 1000°F (540°C) and 1200°F (650°C) for up to 1000 hr. As indicated by the values, Heat Treatment B produces higher impact strength than does Heat Treatment A.

Charpy V-notch tests at -320°F (-196°C) yielded impact strengths of 16 ft•lb (22 J) for material given Heat Treatment A and 59 ft•lb (80 J) for material given Heat Treatment B. The tests were performed on specimens from 0.562-in. (14.3-mm) diameter rod.

Table 12 - Effect of High-Temperature Exposure on Room-Temperature Impact Strength

Exposure Temperature		Exposure Time, hr	Heat Treatment	Charpy V-Notch Impact Strength	
°F	°C			ft•lb	J
70	20	-	A	23	31
1000	540	200	A	23	31
		500	A	21	28
		1000	A	26	35
1200	650	200	A	28	38
		500	A	23	31
		1000	A	29	39
70	20	-	B	61	83
1000	540	200	B	63	85
		500	B	58	79
		1000	B	63	85
1200	650	200	B	59	80
		500	B	54	73
		1000	B	54	73

CREEP AND RUPTURE PROPERTIES

Because of its high creep-rupture strength, INCONEL alloy 706 is widely use for applications such as gas-turbine components that involve extended exposure to elevated temperatures. For creep- or rupture-limited applications, the alloy should be given the triple heat treatment (Heat Treatment A).

INCONEL alloy 706 is notch-ductile under stress-rupture conditions. The Larson-Miller parameter plot of Figure 6 compares rupture-strength curves for smooth-bar and notched-bar specimens. The notched specimens had a stress-concentration factor (K_t) of 4.0.

The creep strength of alloy 706 at temperatures of 1100°F to 1400°F (595°C to 760°C) is shown in Figure 7. Rupture strength of the alloy over the same temperature range is shown in Figure 8.

The creep and rupture properties of alloy 706 are further illustrated by Figures 9 and 10, which shown stresses to produced rupture and selected amounts of plastic strain in 100 hr and 1000 hr.

The results of relaxation tests performed at three different temperatures with an initial stress of 60 ksi (414 MPa) are given in Table 13. The alloy showed no loss of strength and good ductility after completion of the tests. A specimen relaxation-tested for 13,377 hr at 1100°F (595°C) and an initial stress of 60 ksi (414 MPa) had the following room-temperature tensile properties:

Tensile Strength, 190 ksi (1310 MPa)
Yield Strength (0.2% Offset), 150.5 ksi (1038 MPa)
Elongation, 11.5%
Reduction of Area, 33.5%

All creep and rupture data reported here are for material given Heat Treatment A.

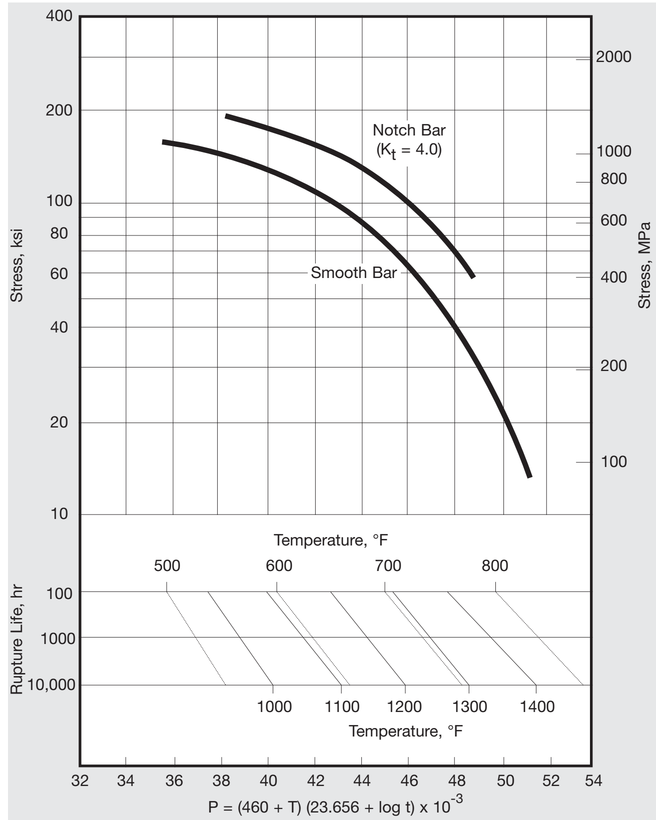

Figure 6. Larson-Miller parameter plot of rupture strength of precipitation-hardened (Heat Treatment A) INCONEL alloy 706. In the parameter, T is temperature in °F and t is time in hours.

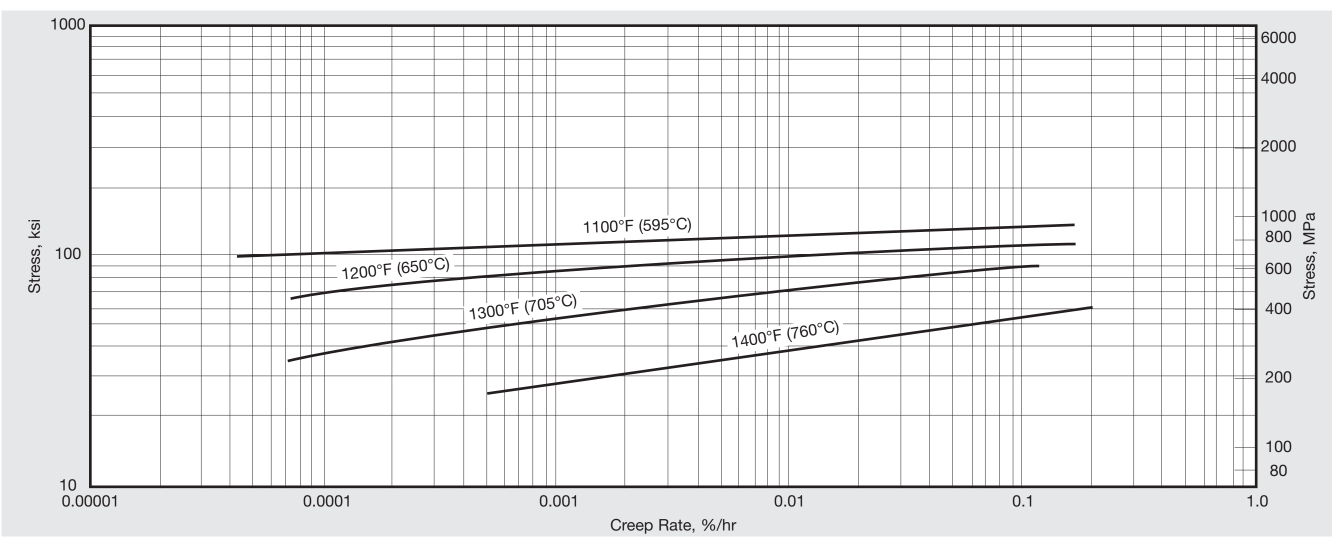

Figure 7. Typical creep strength of precipitation-hardened (Heat Treatment A) material.

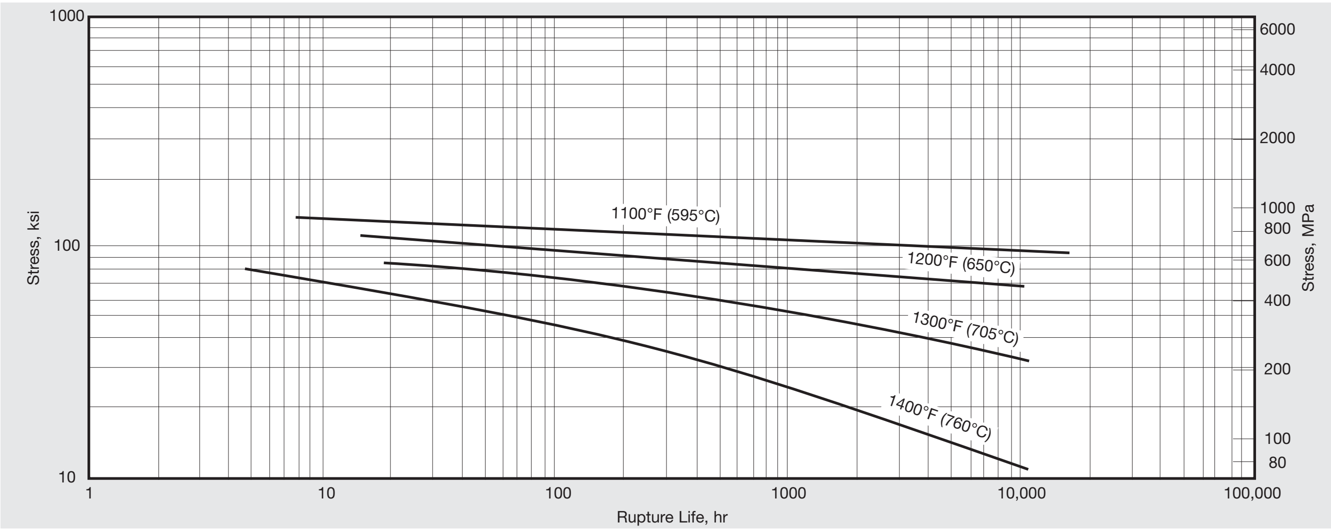

Figure 8. Typical rupture strength of precipitation-hardened (Heat Treatment A) material.

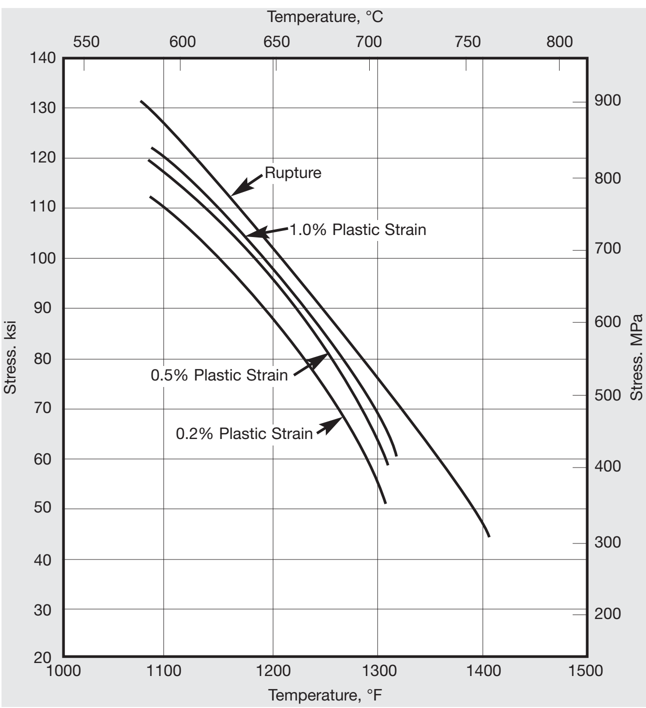

Figure 9. Typical 100-hr creep-rupture properties of precipitation-hardened (Heat Treatment A) INCONEL alloy 706.

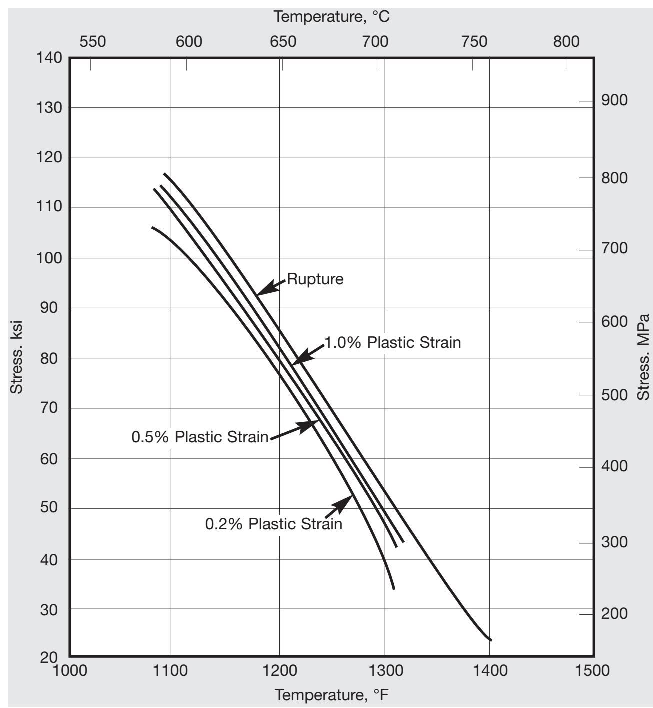

Figure 10. Typical 1000-hr creep-rupture properties of precipitation-hardened (Heat Treatment A) INCONEL alloy 706.

Table 13 - Relaxation of Precipitation-Hardened (Heat Treatment A) Material

Temperature		Stress to Maintain Constant Strain									
		0 hr		10 hr		100 hr		1000 hr		10,000 hr	
°F	°C	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1000	540	60.0	414	60.5	417	61.0	421	61.8	426	62.0[a]	427
1100	595	60.0	414	65.0	448	63.5	438	62.0	427	62.0	427
1200	650	60.0	414	57.0	393	57.0	393	56.0	386	-	-

[a]Extrapolated. Test discontinued at 6600 hr.

Microstructure

INCONEL alloy 706 is a precipitation-hardenable alloy with a face-centered-cubic crystal structure. The alloy is strengthened by the precipitation of a gamma prime or gamma double-prime phase during heat treatment in the 1100-1400°F (595-760°C) temperature range. Heat Treatment A produces both the gamma prime, which has a face-centered-cubic structure, and the gamma double prime, which has a body-centered-tetragonal structure. Heat Treatment B normally produces only the gamma prime phase. The phases have a Ni_3 (Nb, Ti, Al) composition. They are not visible at magnifications achieved by optical microscopy; electron microscopy is required for resolution. Overaging or extended service at precipitation-hardening temperatures results in a transformation of the phases to a needle-shaped, orthorhombic Ni_3Nb structure. That structure may be visible with optical microscopy.

Corrosion Resistance

The composition of INCONEL alloy 706 enables it to resist corrosion in various environments. The alloy's chromium content provides resistance to oxidizing media, and its nickel content provides resistance to reducing environments. Table 14 lists corrosion rates for the alloy in several acid solutions at boiling temperatures. Other tests have shown the alloy to have poor resistance to boiling 50% sulfuric acid and to boiling 38% and concentrated hydrochloric acid.

The nickel content of alloy 706 gives it resistance to both chloride-ion and hydroxyl-ion stress-corrosion cracking. Stressed specimens did not crack in 30 days of exposure to boiling 42% magnesium chloride. A test in boiling 50% sodium hydroxide resulted in a cracking time of 5 days.

Table 14 - Corrosion Rates in Boiling Acid Solutions

Solution	Material Condition	Corrosion Rate	
		mpy[a]	mm/a
10% H_2SO_4	Annealed	123	3.12
40% H_3PO_4	Annealed	55	1.40
70% HNO_3	Annealed	14	0.356
70% HNO_3	Age Hardened	60.6	1.54
25% HNO_3	Age Hardened	1.7	0.043

[a]Mils penetration per year.

Working Instructions

INCONEL alloy 706 has good working characteristics and is readily fabricated by conventional procedures for high-strength alloys. Of particular significance are the machinability and weldability of the alloy.

HEATING AND PICKLING

INCONEL alloy 706, like other high-nickel alloys, must be clean before it is heated and must be heated in a low-sulfur atmosphere. To prevent possible contamination of the metal, all foreign substances such as grease, oil, paint, and shop soil must be removed prior to a heating operation. Fuels for open heating must be low in sulfur, and the furnace atmosphere should be slightly reducing to prevent excessive oxidation of the material.

Annealing procedures for alloy 706 depend on the section size of the workpiece and the amount of cold work to which it has been subjected. Figure 11 shows the effects of various annealing temperatures on the tensile properties of cold-rolled 0.060-in. (1.5-mm) sheet with 37.5% cold reduction. The material was held at temperature for 5 min and air-cooled.

Procedures for solution treatment and precipitation hardening are discussed in the section on mechanical properties

The aluminum, titanium, and chromium in INCONEL alloy 706 produce refractory oxides during most heating operations, and the alloy normally must be pickled if a bright surface is required.

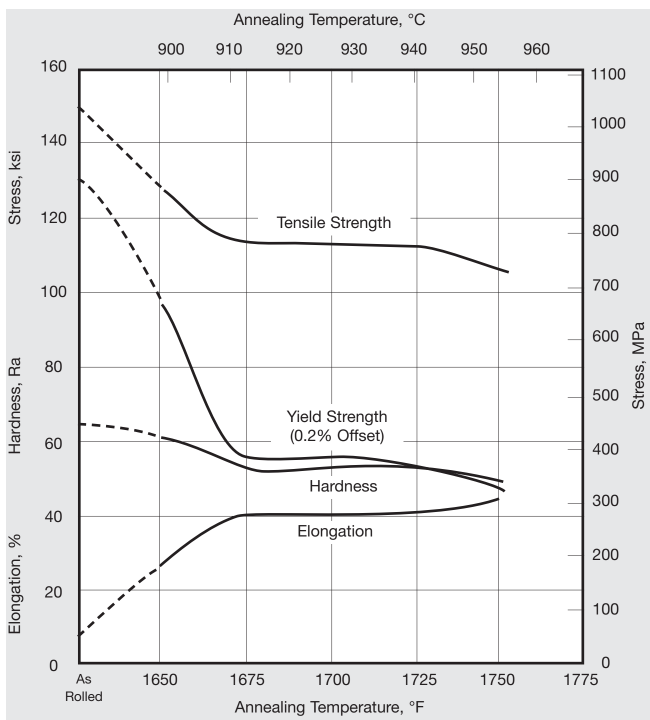

Figure 11. Effect of annealing temperature on mechanical properties of cold-rolled sheet. Specimens were held at temperature for 5 min and air-cooled before being tested.

HOT AND COLD FORMING

INCONEL alloy 706 has excellent hot formability at temperatures from 1600°F (870°C) to 2100°F (1150°C). Test results indicate, however, that optimum mechanical properties are obtained with hot-working temperatures in the 1800°F (980°C) to 2100°F (1150°C) range. Tables 15 and 16 show the effects of forging temperature on mechanical properties at room temperature and 1200°F (650°C). The specimens were from 6-in. (150-mm) hot-rolled squares that had been upset-forged from 4-in. (100-mm) to 1.375-in. (35-mm) thick. The forgings were given Heat Treatment A before being tested.

Forging at temperatures in the lower portion of the hot-working range to develop high mechanical properties, a procedure often required with similar alloys, is not necessary for INCONEL alloy 706. The higher finish-forging temperature increases die life and enables parts to be forged closer to the finished size.

Cold forming of alloy 706 is performed by standard methods for high-nickel alloys. The work-hardening rate of the alloy is shown in Figure 12. The cold-forming characteristics of alloy 706 are similar to those of INCONEL alloy 718. Alloy 706, however, is somewhat softer in the annealed condition and requires lower forces for deformation.

Additional information on fabricating is available in the Special Metals publication "Fabricating" on the website, www.specialmetals.com.

Table 15 - Effect of Forging Temperature on Room-Temperature Properties of Precipitation-Hardened[a] Material

Temperature		Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %	Reduction of Area, %	Hardness, Rc	ASTM Grain Size
°F	°C	ksi	MPa	ksi	MPa				
1800	980	175.0	1207	134.0	924	14	19	36	6.5
1900	1040	178.0	1227	140.0	965	16	18	35	7.5
2000	1095	177.5	1224	142.5	983	17	16	38	7.0
2100	1150	176.0	1213	140.5	969	16	19	36	6.5

[a]All material received Heat Treatment A after being forged.

Table 16 - Effect of Forging Temperature on High-Temperature Properties of Precipitation-Hardened[a] Material

Forging Temperature		Tensile Properties at 1200°F (650°C)						Rupture Properties at 1200°F (650°C) and 105 ksi (724 MPa)		
		Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %	Reduction of Area, %	Rupture Life, hr	Elongation, %	Reduction of Area, %
°F	°C	ksi	MPa	ksi	MPa					
1800	980	142.0	979	123.0	848	23	48	28.1	22	38
1900	1040	143.5	989	124.0	855	21	46	24.4	25	43
2000	1095	144.0	993	125.0	862	23	54	62.2	22	29
2100	1150	146.0	1007	123.0	848	20	43	39.2	14	31

[a]All material received Heat Treatment A after being forged.

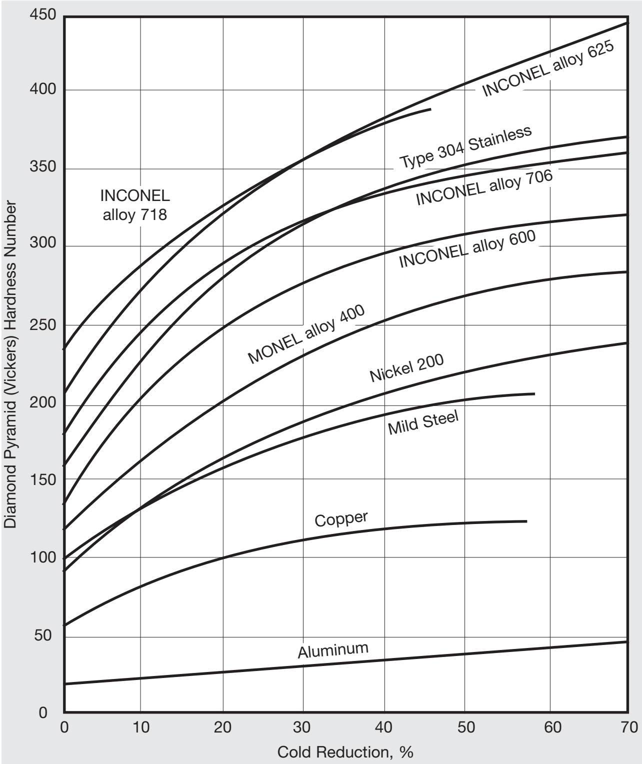

Figure 12. Effect of cold work on hardness of INCONEL alloy 706 and other materials.

MACHINING

Good machinability is one of the outstanding characteristics of INCONEL alloy 706. The superiority of alloy 706 over some other high-strength alloys is shown by the tool-life/cutting-velocity comparison in Figure 13.

Additional information on machining is available in the Special Metals publication "Machining" on the website, www.specialmetals.com.

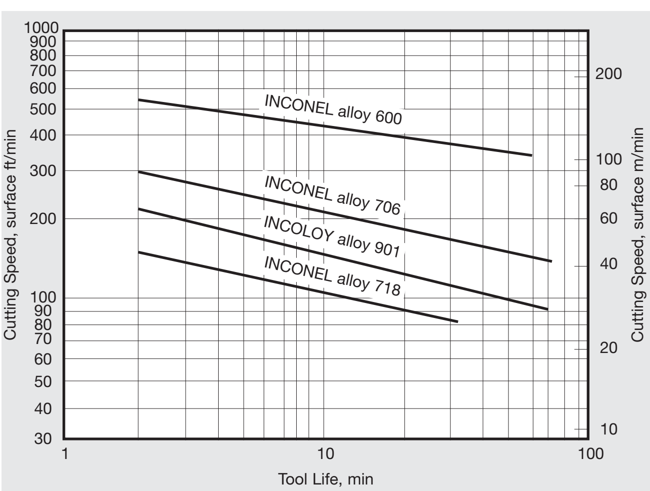

Figure 13. Machinability of annealed material. Specimens were machined with carbide tools and with water-soluble oil as coolant.

JOINING

INCONEL alloy 706 has excellent weldability. The alloy's niobium/titanium precipitation-hardening system provides a delayed response to precipitation-hardening temperatures. The sluggish aging response imparts a high degree of resistance to post-weld strain-age cracking. The alloy also resists underbead cracking (microfissuring). Most joints that are not highly restrained can be repair-welded and directly re-aged with no cracking. Pierce-Miller patch tests performed on four thicknesses of annealed sheet showed no cracking after specimens were welded, age-hardened, repair-welded, and re-aged. Repair welds in highly restrained joints, however, may require solution treatment before being re-aged.

Welding procedures for alloy 706 are the same as for INCONEL alloy 718. Gas-tungsten-arc welding with INCONEL Filler Metal 718 is the recommended process. The alloy has also been joined by the flash-butt process; sound welds were produced with less upset pressure than that needed for alloy 718.

Precipitation-hardened welds in alloy 716 exhibit high strength levels. Table 17 gives tensile properties of transverse specimens from autogenous gas-tungsten-arc welds in 0.062-in. (1.57-mm) sheet. Tensile properties of joints welded with the gas-tungsten-arc process and INCONEL Filler Metal 718 are listed in Table 18. The values are for transverse specimens from butt joints in 0.500-in. (13-mm) thick flats.

Additional information on joining is available in the Special Metals publication "Joining" on the website, www.specialmetals.com.

Table 17 - Transverse Tensile Properties of Autogenous Gas-Tungsten-Arc Welds[a]

Test Temperature		Heat Treat-ment	Tensile Strength		Yield Strength (0.2% Offset)	
°F	°C		ksi	MPa	ksi	MPa
85	30	A	153.0	1055	133.5	920
85	30	B	160.0	1103	144.0	993
1000	540	A	140.5	969	114.0	786
1200	650	A	126.0	869	113.0	779

[a]Specimens were from joints in 0.062-in. (1.57-mm) sheet. All specimens fractured in weld metal.

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Table 18 - Transverse Tensile Properties of Gas-Tungsten-Arc Welds Made with INCONEL Filler Metal 718[a]

Test Temperature		Heat Treatment	Tensile Strength		Yield Strength (0.2% Offset)	
°F	°C		ksi	MPa	ksi	MPa
85	30	A	176.0	1213	140.5	969
85	30	B	176.5	1217	144.0	993
1000	540	A	151.5	1045	123.5	852
1000	540	B	151.0	1041	122.5	845
1200	650	A	144.5	996	120.5	831

[a]Specimens were from butt joints in 0.500-in. (13-mm) thick flat. All specimens fractured in weld metal.

Available products and specifications

INCONEL alloy 706 is designated as UNS N09706. Alloy 706 is available as round bar and forging stock.

Rod, Bar, Wire, Forgings, and Forging Stock - SAE AMS 5701, AMS 5702, AMS 5703 (Bars, Forgings and Rings)

Plate, Sheet, and Strip - SAE AMS 5605 and AMS 5606 (Sheet, Strip and Plate),

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