INCONEL® alloy 725HS

INCONEL® alloy 725HS (UNS N07725) is a higher strength version of INCONEL alloy 725. It is a nickel-chromium-molybdenum-niobium alloy that is highly resistant to corrosion and is age hardenable. It has essentially the same corrosion resistance as INCONEL alloys 625 and 725, which are widely used in a broad range of severely corrosive environments. The strength of age-hardened INCONEL alloy 725HS is of the order of 2.3 times that of annealed alloy 625 and has at least 20 ksi (138 MPa) higher yield strength than alloy 725. This is accomplished by grain refinement and optimizing the age-hardening heat treatment. Because the strength of alloy 725HS is developed by heat treatment, not by cold work, ductility and toughness remain high. Also, strength can be imparted to large or non-uniform sections that cannot be strengthened by cold work.

The chemical composition of INCONEL alloy 725HS is given in Table 1. High levels of nickel and chromium provide corrosion resistance in reducing and oxidizing environments. The substantial molybdenum content enhances resistance to reducing media and provides a high degree of resistance to pitting and crevice corrosion. Additionally, the combination of elements makes the alloy resistant to hydrogen embrittlement and stress-corrosion cracking.

The properties of INCONEL alloy 725HS are useful for a range of applications that require outstanding corrosion resistance along with high strength. The alloy is used for hangers, landing nipples, safety valves, side pocket mandrels and polished bore receptacles in sour gas service, where it resists the effect of hydrogen sulfide, chlorides and carbon dioxide.

The resistance to corrosion by seawater of INCONEL alloy 725HS is essentially the same as that of INCONEL alloys 625 and 725. Alloy 725HS offers an optimum combination of corrosion-resistance, strength, and fracture toughness for fasteners and other components requiring high strength for ship construction and other marine fabrication.

Table 1 - Chemical Composition, wt %

Nickel	55.0-59.0
Chromium	19.0-22.5
Molybdenum	7.0-9.5
Niobium	2.75-4.0
Titanium	1.0-1.7
Aluminum	0.35 max.
Carbon	0.03 max.
Manganese	0.35 max.
Silicon	0.20 max.
Phosphorus	0.015 max.
Sulfur	0.010 max.
Iron	Balance

Physical Properties

Some representative physical properties of INCONEL alloy 725HS are given in Table 2. All values for physical properties are for material in the age-hardened condition.

Table 2 - Physical Properties

Density, lb/in³	0.300
g/cm³	8.31
Melting Range, °F	2320-2449
°C	1271-1343
Permeability at 200 oersted (15.9 kA/m)	<1.001
Young's Modulus, ksi x 10³	29.6
GPa	204
Shear Modulus, ksi x 10³	11.3
GPa	78
Poisson's Ratio	0.31

Mechanical and Thermal Properties

In the age-hardened condition, INCONEL alloy 725HS displays high strength along with excellent ductility and toughness. Tables 3, 4 and 5 give typical tensile properties, hardness, and impact strength.

Table 3 - Typical Room-Temperature Mechanical Properties (mean values)

Form	Condition	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Reduction of Area	Charpy V-Notch Impact	
		ksi	MPa	ksi	MPa	%	%	ft•lbf	J
Round	Age Hardened	149.2	1029	199.0	1372	22.3	35.9	35.5	48

Table 4 - Typical Elevated Temperature Tensile, Hot Rolled Solution Annealed & Aged Bar

Temperature		Yield Strength, ksi	Tensile Strength, ksi	Reduction of area, %	Elongation, %
°F	°C				
300	150	144.5	186.5	43.7	25.3
400	200	141.5	183.2	45.3	27.4
500	260	142.5	180.6	45.8	28.4
70	21	150.3	198.6	40.3	22.4

Table 5 - Typical Fracture Toughness, K_{EE}*

ksi (in)½	MPa (m)½
274.4	301.6

*Tested at 0°F (32°C) per ASTM E399 (Linear Elastic Methodology) and ASTM E992 (Equivalent Energy Methodology for determining the estimated plane strain fracture toughness of the material, K_{EE}).

Corrosion Resistance

High nickel, chromium and molybdenum contents enable INCONEL alloy 725HS to resist a broad range of corrosive environments. The alloy is especially resistant to media containing carbon dioxide, chlorides and hydrogen sulfide, such as those encountered in deep sour gas wells. In such environments, INCONEL alloy 725HS resists corrosion, pitting, hydrogen embrittlement and stress-corrosion cracking. Tables 5 and 6 show the performance of the alloy in NACE tests (TM0177 and TM0198) used to determine resistance to sulfide stress cracking (hydrogen embrittlement) in a sour well environment.

INCONEL alloy 725HS is approved under NACE MR0175 for use in sour gas wells.

Table 7 shows the excellent performance of the alloy in "Mobile Bay Type Environments" with Slow Strain Rate Testing at two different temperatures.

Additional corrosion testing was in progress at the time of printing this datasheet.

Table 5 - NACE TM0177 - Method A (NACE Standard Tensile Test) Specimen Tested at 100% of Yield Strength Galvanically Coupled to Steel in the Standard Solution

Heat Identification	Specimen Properties							Time hours to Failure, NF = No Failure at 720 hours (Duplicate Specimens Tested)
	Yield Strength[a]		Tensile Strength		Elongation, %	Reduction of Area, %	Hardness, HRC	100% Yield Strength
	ksi	MPa	ksi	MPa				
Heat 1	160.1	1104	201.8	1391	23.6	39.9	43	NF
	158.5	1093	197.1	1359	23.9	39.6	43	NF
Heat 2	149.5	1031	195.8	1350	24.9	45.6	43	NF
	148.9	1027	195.8	1350	23.9	44.2	42	NF
Heat 3	152.3	1050	198.7	1370	23.5	43.6	43	NF

[a]Yield Strength is assumed to be at 0.2% offset unless otherwise indicated.

Table 6 - Testing in Accordance with NACE Slow Strain Rate Test TM0198
Slow Strain Rate Data NACE Level VI Environment
Partial pressure H_2S, kPa (psia): 3,500 (508); Partial pressure CO_2, kPa (psia): 3,500 (508); NaCl, wt %: 20; Temperature, °C (°F): 175 (347)

Heat Identification	Room Temperature Mechanical Properties				Hardness, HRC	Inert Values		Values in Environment		SSR Ratio[b]		Visual Rating (Class)[c]
	Yield Strength[a]		Tensile Strength			Elongation, %	Reduction of Area, %	Elongation, %	Reduction of Area, %	Elongation Ratio	Reduction of Area Ratio	
	ksi	MPa	ksi	MPa								
Heat 1	158.5	1093	197.1	1359	43	23.9	39.6	29.1	40.1	1.16	0.88	1
	158.5	1093	197.1	1359	43	23.9	39.6	27.9	39.7	1.11	0.87	1
	160.1	1104	201.8	1391	43	23.6	39.9	25.1	42.6	1.02	0.88	1
Heat 2	149.5	1031	195.8	1350	43	24.9	45.6	25.3	44.0	0.93	0.97	1
	149.5	1031	195.8	1350	43	24.9	45.6	26.5	39.1	0.96	0.95	1
Heat 3	152.6	1052	200.5	1382	43	23.2	42.2	27.1	33.4	1.14	0.84	1
	152.6	1052	200.5	1382	43	23.2	42.2	23.9	32.5	1.01	0.82	1
	152.3	1050	198.7	1370	43	23.5	43.6	22.9	39.6	0.98	0.84	1

[a]Yield Strength is assumed to be at 0.2% offset unless otherwise indicated.
[b]See paragraph 9.3.4 of TM0198.
[c]See paragraph 9.2.2 of TM0198, Class 1: Normal ductile behavior (comparable to a specimen tested in air) with no indication of SCC on the primary fracture surface and no indication of secondary cracking.

Table 8 - INCONEL alloy 725HS Slow Strain Rate Test Data in "Mobile Bay Type Environments"

Slow Strain Rate Test Data for INCONEL alloy 725HS, Evaluated in the 100,000 ppm Chloride[a] Environment at **350°F (175°C)**

Test	Time to Failure (h)	Time to Failure Ratio	Reduction of Area, %	Reduction of Area Ratio	Elongation, %	Elongation Ratio	Secondary Cracking
Inert	21.4	-	49.6	-	25.6	-	-
Environment[b]	22.2	1.04	47.8	0.96	27.3	1.07	No

[a]100,000 ppm Cl^- (as NaCl) + 200 psig H_2S + 200 psig CO_2, gas pressures at test temperature. Strain rate = 4 x 10^{-6} sec^{-1}.
[b]The Environment tests are an average of 3 specimens.

Slow Strain Rate Test Data for INCONEL alloy 725HS, Evaluated in the 100,000 ppm Chloride[a] Environment at **400°F (205°C)**

Test	Time to Failure (h)	Time to Failure Ratio	Reduction of Area, %	Reduction of Area Ratio	Elongation, %	Elongation Ratio	Secondary Cracking
Inert	22.9	-	45.9	-	28.2	-	-
Environment[b]	23.1	1.01	45.0	0.98	28.5	1.01	No

[a]100,000 ppm Cl^- (as NaCl) + 200 psig H_2S + 200 psig CO_2, gas pressures at test temperature. Strain rate = 4 x 10^{-6} sec^{-1}.
[b]The Environment tests are an average of 3 specimens.

Heat Treatment

INCONEL alloy 725HS is strengthened by precipitation of gamma prime (γ') and gamma double-prime (γ'')phase during an aging heat treatment.

Machining

INCONEL alloy 725HS is an age hardenable alloy. Machining may be accomplished in the annealed or aged conditions.
Cemented carbide tools produce the highest cutting rates and are recommended for most turning operations involving uninterrupted cuts. High speed steel tools may be used for interrupted cuts, finishing to close tolerances, finishing with the smoothest surfaces, and cutting with the least amount of work hardening.
The unit power factor of INCONEL alloy 725HS is 1.75 and 1.85 net horsepower/in^3/min (0.080 and 0.084 W/mm^3/min, respectively) in the solution annealed and solution annealed + aged conditions, respectively.

Reaming

Operating speeds for reamers should be about two-thirds of the speeds used for drilling. The reamer feed into the work should be 0.0015-0.004 in (0.04-0.1 mm) per flute per revolution. Feed rates too low will result in glazing and excessive wear. Conventional fluted reamers, flat solid reamers and insert tools for built-up reamers are made of high-speed steel. Composite tools with steel shanks tipped with cemented carbide are recommended.

Table 9 - Typical Machining Parameters for INCONEL alloy 725HS*

High Speed Steel		Coated Carbide	Feed
Surface Speed	Feed	Insert	
ft/min (m/min)	in/rev. (mm/rev.)	ft/min (m/min)	in/rev. (mm/rev.)
12-30 (3.7-5.5)	0.005-0.020 (0.25)	40-105 (12.2-18.3)	0.005-0.020 (0.25)

*Annealed or aged material. Water base, oil emulsion or chemical solution as cutting fluid.

Chip Control

When machining INCONEL alloy 725HS, it is important to obtain good full turn chips. High speed steel tools may require chip curlers or lipped tools. The lip should be wider and deeper for the material in the annealed condition. Typical dimensions, for chip breakers, operating at 0.01 in/min (0.25 mm/min), are 0.020 inches (0.51 mm) deep and 0.080 inches (2.03 mm) wide.

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Threading

Lathe threading. Standard single-point lathe threading practices are adequate for threading INCONEL alloy 725HS in the annealed or aged conditions. Recommended threading speeds are 3.0-3.5 ft/min (91-107 cm/min). The depth of cut will vary, becoming less as the work progresses.

Die head threading. Threading dies should be made of molybdenum high-speed steel (Grade M-2 or M-10). A chaser throat angle of 15 to 20° is recommended for producing V threads where no shoulder is involved. When close-to-shoulder threading must be done, a 15° rake angle is recommended. The speeds given for lathe threading also apply to die threading.

Thread grinding. External threads can be produced in INCONEL alloy 725HS by form grinding with aluminum oxide (150-320 grit) vitrified-bonded grinding wheels. The recommended coolant is a high-grade grinding oil of about 300 seconds viscosity at 70°F (21°C). Extreme care must be taken to prevent overheating during grinding.

Thread rolling. Maximum tensile properties may be obtained by thread rolling after aging. However, usually it is preferred to thread roll as-drawn or annealed material, and then age harden. Material in the un-aged condition is more easily threaded, and subsequent aging tends to stress relieve the cold-worked threads.

Drilling

Steady feed rates minimize excessive work hardening during drilling. Heavy duty, high speed drills with heavy webs are recommended. For twist drilling, recommended surface speeds are 10-12 ft/min (305-366 cm/min) for the annealed condition, and 8-10 ft/min (244-305 cm/min) for the aged condition. Feed rates range from 0.005 to 0.015 in/rev. (0.13 to 0.38 mm/rev.) depending on the drill size.

For gun drills, sizes from 1/16 to 2 inches (1.6 to 51 mm), a feed rate of 0.0001-0.003 in/rev. (0.003-0.08 mm/rev.) is recommended for both the annealed and aged conditions. The surface speed should be kept at about 100 ft/min (30.5 m/min) for annealed material and 60 ft/min (18.3 m/min) for material in the aged condition.

Warping

Stresses produced during the machining process may result in distortion or warping. This can be minimized by reducing the machining speed and/or the depth of cut.

Available Products

INCONEL alloy 725HS is available as bar in a range of sizes.

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