High Performance Nickel Base Temp Alloy

HPAlloy X

JANUARY 2010

HPAlloy X Product Description

Heat Resistant (UNS N06002)

HPAlloy X is a nickel-chromium-iron-molybdum alloy with high strength and oxidation resistance to 2200 °F as well as good carburization and nitriding resistance. It has also been found to have good resistance to stress-corrosion cracking in some petrochemical applications. It has an ASME Boiler and Pressure Vessel code case.

Alloy X has excellent forming and welding characteristics, resistance to oxidizing, reducing, and neutral atmospheres. It can be forged and exhibits good ductility after prolonged service temperatures of 1200 °F through 16,000 hours.

Alloy X is one of the most widely used Ni based super alloys for gas turbine engine components, both flying and land based. It is used for such components as combustor cans, transition ducts, flame holders, and after-burners.

Alloy X is also suitable for internal structural components in industrial furnaces such as rolls, retorts, baffles, flash drier components, and muffles. It is a good choice for material for heat treating components such as trays and fixtures due to its excellent resistance to oxidizing atmospheres.

Available in many forms and sizes makes this alloy very attractive for its variety of applications. Alloy X is produced in such forms as sheet, plate, bar, billet, forgings, pipe, tubing, and various wire forms.

Questions?? Call (800)HPALLOY

Solution Annealed 2250 °F, Air Cooled
Density 0.303 lb/in
Specific Heat (@ 72 °F) 0.101 Btu/lb./°F
Thermal Conductivity (32° to 212 °F)
103 Btu-in./sq. ft.-hr.-°F
Electrical Resistivity (68 °F)
546 Ohms/ cir. mil. ft.

Chemistry

Ni	Cr	Mo	Fe	W	Si	Mn	Co	C
Bal.	21	9.0	19.0	0.5	0.5	0.5	1.0	0.10

Mechanical Properties

Ultimate	Yield	Elongation	Hardness
(ksi)	(ksi)	(%)	(Rockwell)
110	55	44	B 96

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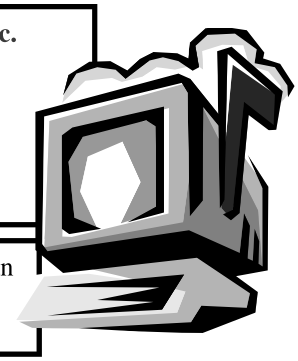

Any questions or comments can also be sent via E-Mail to: Sales@HPAlloys.com

Machining

Machinability Rating
27% of B-1112

Typical
Stock Removal Rate
45 surface feet/minute with high speed tools, 125 surface feet/minute with carbide.

Comments:

Care must be taken to make sure there are rigid machine setup and sharp tools, so that work hardening and surface glazing do not occur.

HPAlloy X is machinable in both the wrought and cast form. Low cutting speeds and an ample flow of coolant are required.

Suggested tool angles for single point tungsten carbide tools are 8 to 10-Deg. side-rake angle from cutting edge, 5 to 8 -Deg. back-rake angle, 5 to 7-Deg. end relief angle, and 15 to 30-Deg. side cutting-edge angle. Nose radius should be 1/32 to 1/16 inch.

High-speed steel drills should be ground to an included angle of 135 to 140 Deg. with a clearance angle of 10 degrees. The web should be thinned down to about one-third the web-thickness of a standard drill.

Better finishes can be obtained by increasing the speed and decreasing the feed. Automatic screw machines are not recommended because speeds are generally excessive and carbide-tipped tools will not hold up.

A sulfur-base cutting fluid should be used for machining this alloy. All traces of cutting fluid should be removed prior to heat-treatment or high temperature service.

The table above may be used as a guide in machining HPAlloy X. The figures will be modified by such factors as tool size and type, type of machining equipment, size of stock, and nature of cut.

Fusion Welding

Welding
HPAlloy X can be welded by metallic-arc, inert-gas-shielded arc, submerged-melt, and SIGMA methods.

Cleaning
The welding surface and adjacent area should be thoroughly cleaned down to bright metal before welding. All grease, oil, crayon marks, and other foreign matter should be removed by scrubbing with trichlorethylene or some other suitable solvent. The surface should be wiped clean before welding.

Weld Joints
Normally, a V joint is used for butt welds in plate thicknesses up ¼ in. and a U joint for greater thicknesses. The V or U joint is used where the welded material will be exposed to high stresses. These joints will cause the stress to act axially. The lap or tee joint may be used for conditions of lower stress. The U joint is preferred for material greater than ¼ in. in thickness. While the cost of preparation may be increased by this type of joint, the amount of welding materials and man-hours needed for welding will be much less than if a V joint is used. The amount of residual stress will also be lower since less weld material is required and less transverse shrinkage is incurred.

Usually, V joints should be beveled to 75- to 80° included angle; U joints beveled to 30° included angle with a minimum bottom radius of 3/16 in. J grooves should have a 15° bevel with a minimum bottom radius of 3/8 in. Tee joints between dissimilar material thicknesses should have a bevel of 45°. The type of joint chosen will not necessarily be affected by a change of welding process since these joint designs are standard. To make these joints suitable for automatic stressed material before welding operations, such as inert-gas-shielded arc, certain slight modifications may be necessary.

Edge Preparation
Use of a machine tool in beveling is the surest way to obtain correct fits although hand grinding can also yield satisfactory results. When sheared sheet or plate is used, the sheared edges should be ground back approximately 1/16 in. to remove any stressed material before the edge is prepared for welding. In all instances, the edges should be squared, aligned properly, and tacked before welding. Any misalignment causes variation in gap width and bead contour, which results in stresses in the weld area. These factors contribute to cracking in the weld joint. Careful preparation to assure good welds is well justified. Thermal cutting and beveling of plates can be done, but, with the exception of HELIARC cutting, these are not recommended procedures.

Weld Penetration
For good penetration, material 12-gage and heavier should be beveled and welded from both sides. When joining material of dissimilar thicknesses, the heavier section should always be beveled for ease of welding. Material thinner than 12-gage may be welded from one side by using proper edge spacing to allow full penetration. Care should be exercised to eliminate non-uniform penetration. This condition can leave undesirable crevices and voids in the underside of the joint which may contribute to areas of accelerated corrosion. Non-uniform penetration in material used for high-temperature applications creates stress raisers which may serve as focal points for mechanical failure.

Welding from both sides is recommended wherever possible. When this is not practical, the joint spacing should be increased and copper backing bar used. Currents slightly higher than normal are then used to obtain complete penetration. HPAlloy X does not have the same thermal conductivity as steel, therefore, when using a standard groove, it is necessary to use a slightly larger clearance than would be needed for steel. This larger clearance insures complete penetration of the weld.

Jigs and Fixtures
Proper jigging and clamping of the weld joint holds buckling and warping to a minimum. The use of a backing bar helps to obtain a more uniform bead penetration. The bar also serves as a chill to the base metal and helps prevent excessive bead penetration. When the arc process is used, the portion of the fixture contacted by the arc should be copper. The bar should have a groove of the proper contour to permit good penetration and bead contour. For arc welding, the grooves should be of a minimum depth, usually from 1/16 to 3/32 in., and approximately 3/16 in. wide. The corners of the groove should be rounded. Square corners cause poor bead contour, flux pockets, and non-uniform bead transfer. Jigs and fixtures can be used to particular advantage when using the inert-gas-shielded arc process.

Metallic-Arc Welding
Direct current with reversed polarity produces the best mechanical properties. When joint design permits, rapid travel with as little “weaving” as possible is preferred in order to minimize heat. To avoid overheating when starting or stopping a bead, minimum currents that are consistent with the gage or size of the parts should be used. To prevent crater-cracking it may be desirable to strike the arc on a tab adjacent to the weld joint. The arc may be broken on a similar tab, however, doubling back on the bead with a slant arc is the accepted practice. Because of the fluidity of the alloy, position welding is somewhat difficult. Whenever possible, therefore, welding should be done in the flat position.

Inert-Gas-Shielded Arc Welding
In general, a minimum of heat input should be used, followed by a rapid cooling of the weld deposit. The welding currents are dictated by the thickness of the sheet or plate to be welded, not by the wire diameter. Use an electrode whose diameter is smaller than the thickness of the material to be welded. This method is not recommended for welding plate over 3/8 inch thick.

HPAlloy X

HPAlloy X • HX • UNS N06002 • 21-19-9

Specifications List

Super Alloy Nickelvac HX
Alloy HX
Altemp HX
HPAlloy X
Nicrofer® 4722 Co
Pyromet Alloy 680

UNS N06002
AMS 5536 Sheet, Strip & Plate
AMS 5754 Bars, Forgings & Rings
AMS 5390 Investment Castings (As-Cast)
AMS 5798 Welding Wire (Cold Drawn)
AMS 5799 Coated Welding Electrodes
GE B50T83A Sheet
GE B50A436A Sheet, Plate
GE B50TF24A Sheet, Low Temp
GE B50TF25A Sheet
PWA 1038 Sheet, Strip & Plate, Low Temp
PDS 15102QE Sheet
ASTM B 435 Plate, Sheet & Strip
ASME SB-435 Plate, Sheet & Strip
ASTM B 572 Rod
ASME SB-572 Rod
ASTM B 619 WELD Pipe
ASME SB-619 WELD Pipe
ASTM B 622 SMLS Pipe
ASME SB-622 SMLS Pipe
ASTM B 626 Tubing
ASME SB-626 Tubing
ASME SFA-5.14 ERNiCRrMo-2 Weld Wire

ASME Boiler and Pressure Vessel Code

The use of HPAlloy X sheet, plate, rod, and bar in the construction of unfired pressure vessels in accordance with the requirements of the ASME Boiler and Pressure Vessel Code Section VIII has been approved under Case 1321 (Special Ruling). Alloy X is approved for use at temperatures up to 1650 °F.

Resistance to Oxidation

The outstanding oxidation resistance of HPAlloy X is described below. Tests were conducted by exposing samples to dry air at 2000 °F. and to dry air pressurized to 300 psi at 1750 °F. Two criteria for evaluating oxidation resistance are weight change and depth of corrosion penetration. HPAlloy X excels in both respects due to the formation of a protective, tenacious oxide film.

Resistance to Carburization and Nitriding

HPAlloy X also resists carburization and nitriding, two common conditions which often lead to early failure in high-temperature alloys. After 100 hours in petroleum coke, four other materials were completely penetrated by carburization; whereas, Alloy X specimens showed no carburization at all. Often materials evaluated in an atmosphere of hydrogen, nitrogen and ammonia at 1100 °F. and 15,000 psi for 64 days, Alloy X had a nitride case less than one-fourth as thick as the closest competitive material without intergranular attack.

Heat Treating and Furnace Equipment

HPAlloy X is recommended especially for use in furnace applications because it has unusual resistance to oxidizing, reducing, and neutral atmospheres. Furnace rolls made of this alloy were still in good condition after operating for 8700 hours at 2150 °F. Furnace trays, used to support heavy loads, have been exposed to temperatures up to 2300 °F. in an oxidizing atmosphere without bending or warping. HPAlloy X is also used for retorts, muffles, catalyst support grids, furnace baffles, tubing for pyrolysis operations and flash drier components.

Gas turbine combustion cans and ducting, heat-treating equipment.

Alloy X has wide use in gas turbine engines for combustion zone components such as transition duct, combustor cans, spray bars and flame holders as well as in afterburners, tailpipes and cabin heaters.

Easily Fabricated
HPAlloy X can be forged and, because of its good ductility, can be cold-worked. It can be welded by both manual and automatic welding methods including shielded metal-arc (coated electrodes), gas tungsten-arc (TIG), and gas metal-arc (MIG). Alloy X can also be resistance-welded.

Heat-Treatment
Wrought forms of HPAlloy X are furnished in the solution heat-treated condition unless otherwise specified. Alloy X is solution heat-treated at 2150 °F (1177 °C) and rapid cooled. Bright annealed products are cooled in hydrogen. Other heat-treatment temperatures also may be effective for certain forms and conditions.

Forging
Forging of HPAlloy X billets is carried out at temperatures of from 1750 to 2200 °F. The minimum temperature is dependent on the nature and degree of working. Here are some general rules that should be followed in forging HPAlloy X:

Soak billets or ingots one hour at forging temperature for each inch of thickness.

Reheat the alloy each time temperature drops to a point where further reduction might tend to fracture the metal.

Do not raise forging temperature to compensate for loss of heat. This may cause incipient melting.

In forging ingots, use light, rapid blows until cast structure is broken up. After cast structure is broken up, heavy blows may be used.

Do not attempt to change the general shape of an ingot, as from square to round, during the initial stages of forging. Work from square to octagon. Then round off the octagon using V-shaped bottom die.

Remove any cracks or tears that develop during forging. Very often this can be done while the metal is still under the hammer.

Descaling and Pickling
HPAlloy X is relatively inert to cold acid pickling solutions. After heat-treatment, the oxide film is more adherent than that on stainless steels. Molten caustic baths followed by acid pickling have been found to be most efficient. Two such molten caustic methods employ the use of baths of “Virgo” descaling salt (Hooker Electrochemical Company).

Hot Working
Same as forging.

Cold Working
Readily cold worked in a manner similar to that for austenitic (300 series) stainless steels except that this alloy is somewhat “stiffer” and may require more forming pressure. After severe cold working the product can be solution annealed as indicated in “Heat Treating”.

Aging
The alloy can be aged, after solution heat treatment, at temperatures of 1200 to 1600 °F.

Aging will result in a slight increase in strength and hardness with the effect being related to hours of exposure at the aging temperature- the longer the time the greater the effect.

Hardenability
Hardened by cold working and somewhat by aging. This alloy is not hardenable by conventional heating an quenching as with plain carbon steels.

Hardness is typically 200 BHN (Rockwell B96) and never higher than 241 BHN by specification. The material is usually used in the solution treated (annealed) condition. Grain structure remains austenitic at both low and elevated temperatures.

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