TITANIUM ENGINEERS

a TEI International Company

MP35N Alloy
(UNS R30035)

Chemical Composition										
Ph	Si	C	Ni	Bo	Mn	S	Cr	Mo	Ti	Co
0.015	0.15	0.02	33-37	0.01	0.15	0.01	19-21	9-10.5	1.0	Balance

(maximum values unless range is shown)

MP35N is a nickel-cobalt base multiphase alloy that exhibits extremely high strength characteristics combined with very high toughness, ductility, and excellent corrosion resistance. The alloy primarily gets its strength from cold working, followed by aging. It is capable of reaching strength levels of 1790 – 2090 MPa (260-300 ksi) in its full strength condition. MP35N alloy resists corrosion in hydrogen sulfide, salt water and other chloride solutions, and mineral acids such as nitric, hydrochloric, and sulfuric acid. It also has excellent resistance to crevice corrosion cracking in a variety of severe environments including seawater. The amount of cold working can be controlled in order to achieve the best balance of strength and resistance to stress corrosion cracking.

Metallurgy

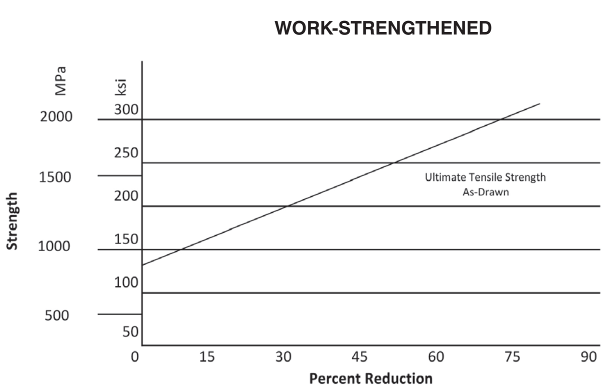
MP35N alloy is produced generally by vacuum induction melting (VIM) followed by vacuum arc remelting (VAR) to enable a closely controlled chemical analysis, high level of purity, and preferred ingot solidification.

MP35N alloy has a face-centered cubic matrix of cobalt and nickel in which the chromium and molybdenum are soluble at elevated temperatures. The face-centered cubic structure persists upon cooling to room temperature and below. Working the alloy at temperatures below the equilibrium transformation temperature of approximately 850⁰F (454⁰C) causes local shear transformation to form very small platelets of the hexagonal close-packed structure. The transformation does not appear to have an M_S temperature at which it occurs on cooling, such as martinsite in steel. It does occur, however, as a strain-induced transformation – the amount of transformed product being a function of the amount of strain deformation and working temperature.

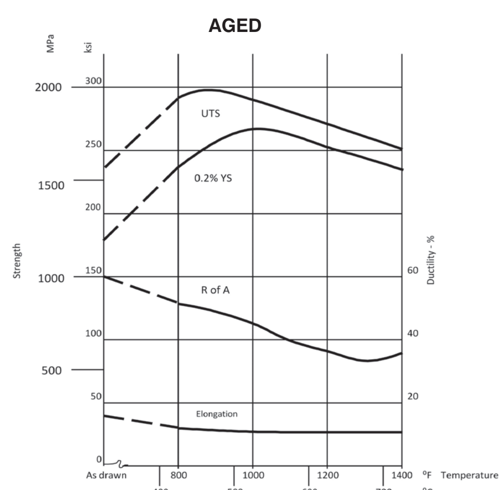
Work strengthening can be accomplished by extruding, rolling, swaging, drawing, or a combination of these manufacturing processes. The transformation occurs readily with cold work (at room temperature), but will also occur at elevated temperatures to the upper limit of the transformation zone. The amount of strain deformation obtainable, and thus the strength level, will be limited in some cases by the size and configuration of the material. The hexagonal close-packed platelets that are formed are stable in the face-centered cubic matrix and the resultant structures exhibit the unique combination of excellent mechanical properties and corrosion resistance. Work-strengthened material is usually aged to obtain even higher strength levels through precipitation strengthening.

Heat Treatment

MP35N should be aged at the proper temperature in order to achieve the final required mechanical properties. The aging treatment that should be used is generally defined by the amount of cold work that has been put into the material. For full strength (heavily cold worked) material meeting AMS 5844, the alloy should be aged at 1000⁰F -1200⁰F for 4 hours. For best sulfide stress corrosion cracking resistance, less heavily cold worked material can be aged at 1300⁰F-1350⁰F for 4 hours or at 1425⁰F for 6 hours as noted in NACE MR-0175. The 1425⁰F aging treatment provides optimum sulfide stress corrosion cracking resistance however strength is generally lower as a result. It is important that the alloy not be exposed to temperatures much above the recommended aging temperature as the metallurgical structure created in the alloy by the cold working process can be reversed to the softer structure of annealed material. This change is non-recoverable without the reintroduction of additional cold work.



This figure shows the effect of work strengthening (by cold drawing) on MP35N alloy tensile strength



This shows the effect of aging 4 hours at temperature on tensile properties of MP35N alloy work strengthened before aging by cold drawing to 240 ksi

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Advantages of MP35N

- Excellent corrosion resistance and ductility
- Can be cold worked in bars to yield strength levels above 1380 MPa (200 ksi)
- Conforms to NACE MR 0175/ISO 15156

Typical Mechanical Properties

	Typical Properties of Solution Treated (Annealed) MP35N	Typical Properties of AMS 5844 Product after 4 Hour Age at 1050°F (566°C)*	AMS 5844 Specification Requirements after Aging 4 Hours at 1000-1200°F (538-648°C)
Ultimate Tensile Strength	130 ksi (896 MPa)	290 ksi (2000 MPa)	260 ksi (1795 MPa), min
0.2% Offset Yield Strength	55 ksi (379 MPa)	280 ksi (1931 MPa)	230 ksi (1585 MPa), min
Elongation in 4D	65%	10%	8%, min.
Reduction of Area	75%	45%	35%, min.
Hardness	90 HRB	51 HRC	-
Shear Strength**	-	-	150 ksi (1034 MPa), min

The above data are longitudinal properties
*Tensile Properties will change depending on product size
**Not required by AMS 5844, but this is the guaranteed shear strength

Corrosion Resistance

MP35N alloy has excellent corrosion resistance at very high strength levels. The alloy is resistant to most inorganic acids, hydrogen sulfide (HsS), and sea water/salt spray environments. The alloy exhibits excellent resistance to stress corrosion and hydrogen embrittlement.

HYDROGEN EMBRITTLEMENT TEST OF MP35N ALLOY Unnotched C-ring Specimens stressed to 0.2% yield point. Coupled to carbon steel. Room Temperature Tests	**Solution** 5% NaCl + .5% Acetic Acid Sat. with H_2S	Condition Aged at 1425-1450°F (774-787°C) to 180-200 ksi 0.2YS (1241-1379 MPa)	**Results** No cracking or evidence of corrosion in 720 days
	5% H_2SO_4 +4 mg As_20_2/liter charged with H_2 at 20 ma/cm^2	Annealed Cold Worked to 200 ksi 0.2YS (1379 MPa) Aged at 1425-1450°F (774-787°C) to 230 ksi 0.2 YS (1586 MPa)	Results No evidence of cracking in 72 hours
STRESS CORROSION TEST OF MP35N ALLOY **U-Bend Specimens** **192 Hour Test**	**Solution** Boiling 42% $MgCl_2$	**Condition** Aged to 300 ksi, UTS (2068 MPa)	**Results** No cracks or visible effects

Source Test Data/Tables: Latrobe Steel

Applications

MP35N has been used in the oil and gas industry for seals, shafts, springs and other components that require high strength in very severe environments. It is also used in non-magnetic electrical components which are subject to extremely corrosive environments.

Machinability

MP35N is generally difficult to machine in any condition. It can be compared in machinability to other cobalt containing Super alloys such as Waspaloy® or Rene 41.

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