Technical Datasheet CARPENTER

Unit Display: English

Printer Friendly Datasheet

E-Mail Datasheet
Add to My Materials

CP Titanium Grade 2

Type Analysis

Carbon	0.10 %	**Titanium**	99.31 %
Nitrogen	0.03 %	**Iron**	0.30 %
Oxygen	0.250 %	**Hydrogen**	0.015 %
Other, Total	0.40 %		

*For ASTM B 348-99 Carbon = 0.08% maximum and ASTM F 67-95 = 0.1% maximum.
"Other, Each" = 0.1% maximum and "Other, Total" = 0.4% maximum values applicable for ASTM B 348-99 only.

General Information

Description

Pure titanium undergoes an allotropic transformation from the hexagonal close-packed alpha phase to the body-centered cubic beta phase at a temperature of 882.5°C(1620.5°F).

Commercially pure, or CP, titanium is unalloyed. At service temperature it consists of 100% hcp alpha phase. As a single-phase material, its properties are controlled by chemistry (iron and interstitial impurity elements) and grain size. CP Titanium is classified into Grades 1 through 4 depending on the yield strength and allowable levels of the elements iron, carbon, nitrogen, and oxygen. CP Ti Grade 2 has a minimum yield strength of 275 Mpa (40 ksi), and relatively low levels of impurity elements, which places it between Grades 1 and 3 in terms of strength.

Grade 2 is widely used because it combines excellent formability and moderate strength with superior corrosion resistance. This combination of properties makes CP Grade 2 titanium a candidate for a large variety of chemical and marine as well as aerospace and medical applications.

Applications

CP Titanium Grade 2 may be considered in any application where formability and corrosion resistance are important, and strength requirements are moderate. Some examples of aerospace applications have included airframe skins in "warm" areas, ductwork, brackets, and galley equipment. CP Ti Grade 2 has also been widely used in marine and chemical applications such as condensers, evaporators, reaction vessels for chemical processing, tubing and tube headers in desalinization plants, and cryogenic vessels. Other uses have included items such as jigs, baskets, cathodes and starter-sheet blanks for the electroplating industry, and a variety of medical applications.

Corrosion Resistance

The corrosion resistance of CP Ti Grade 2 is based on the presence of a stable, continuous, tightly adherent oxide layer. This layer forms spontaneously and immediately upon exposure to oxygen. If damaged, it re-forms readily as long as there is some source of oxygen (air or moisture) in the environment. In general, the higher the purity of CP Ti, the greater the corrosion resistance. CP Ti Grade 2, with its relatively low impurity levels, has been widely used because it is capable of performing well in many corrosion-critical applications such as marine environments and chemical processing. In seawater, it is fully resistant to corrosion at temperatures up to 315ºC (600ºF). The possibility of crevice corrosion must be considered, however, and components appropriately designed to avoid tight crevices.

CP Ti Grade 2 is highly resistant to many chemical environments including oxidizing media, alkaline media, organic compounds and acids, aqueous salt solutions, and wet or dry hot gases. It also has sufficient corrosion resistance in liquid metals, nitric acid, mildly reducing acids, and wet chlorine or bromine gas (as long as a minimal amount of oxygen or water is present).

Conditions under which CP Ti Grade 2 is susceptible to corrosion are strongly reducing acids, alkaline peroxide solutions, and molten chloride salts. Crevice corrosion can occur in hot halide or sulfate solutions (>1000 ppm at 75ºC or higher), which can be a consideration in marine applications.

CP Ti Grade 2 is fully resistant to stress-corrosion cracking (SCC) in aqueous solutions, and is largely immune to SCC in general. Conditions under which CP Ti Grade 2 is susceptible to SCC include anhydrous methanol or methanol/halide solutions, red fuming nitric acid, nitrous oxide, liquid or solid cadmium and liquid mercury.

CP Grade 2 titanium is susceptible to hydrogen embrittlement due to the formation of hydrides. Specifications for CP Ti Grade 2 mill products typically specify a maximum hydrogen limit of 150 ppm, but it is possible for degradation to occur at lower levels, especially in the presence of a notch. The presence of a notch or other stress raiser increases the detrimental effect, as hydrogen migrates to the notch area, raising the local concentration of hydrides. It is important to minimize hydrogen pickup during processing, particularly heat treating and acid pickling.

Important Note: *The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities,* *aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

Sulfuric Acid	Moderate	Acetic Acid	Excellent
Sodium Hydroxide	Moderate	Salt Spray (NaCl)	Excellent
Sea Water	Excellent	Sour Oil/Gas	Moderate
Humidity	Excellent		

- Erosion/Corrosion in Sea Water
- General Corrosion Rates in Various Media

Properties

Physical Properties

Density		
--	0.1630	lb/in³
Mean Specific Heat		
73°F	0.1250	Btu/lb/°F

- Thermal Conductivity

Modulus of Elasticity (E)		
--	15.0	x 10^3 ksi
Beta Transus		
--	1650 to 1700	°F
Alpha Transus		
--	1610 to 1660	°F
Liquidus Temperature		
--	3020 to 3040	°F
Electrical Resistivity		
104°F	294.8	ohm-cir-mil/ft
210°F	367.0	ohm-cir-mil/ft
606°F	601.7	ohm-cir-mil/ft

- Thermal Expansion

Magnetic Properties

Magnetic Attraction

- None

Typical Mechanical Properties

- Elevated Temperature Mechanical Properties
- Fatigue Limits
- Room Temperature Mechanical Properties
- Typical Mechanical Strengths Graph and Effect of Processing on Hardness Graph

Heat Treatment

Heat treatments used for CP Ti are annealing and stress relieving. Annealing is used to fully soften the material and remove all residual stresses. Annealing of wrought products at typical temperatures (below the beta transus) results in a fully recrystallized equiaxed alpha structure. Precise control of grain size (and mechanical properties) can be achieved by adjusting the anneal temperature.

Stress relieving is used to remove some or most of the residual stresses from forming, or to recover compressive yield strength after stretching.

Titanium and its alloys have a high affinity for gases including oxygen, nitrogen and hydrogen. When CP Ti is heated in air, oxygen absorption results in the formation of an extremely hard, brittle, oxygen-stablized alpha phase layer known as alpha case.

Intermediate and final annealing of CP Ti is often performed in a vacuum or inert gas atmosphere to avoid alpha case formation and the associated material loss. Vacuum annealing can also be used to remove excess hydrogen pickup, a process known as vacuum degassing. Parts to be vacuum heat treated must be thoroughly cleaned (see Cleaning Notes).

- Typical Heat Treatments

Workability

Hot Working

CP Ti Grade 2 can be processed by conventional techniques such as hot rolling, forging, and hot pressing. Temperatures for initial roughing may be as high as 30-50°C (50-100°F) above the beta transus, and temperatures for finish processing are typically in the alpha/beta phase field, ranging from about 815°C (1500°F) to about 900°C (1650°F).

CP Ti Grade 2 can be formed by standard methods such as hot rolling, forging, spin forming, hydroforming, and hot pressing. Typically, more severe forming is done in the temperature range of 480-540ºC (900-1000ºF) and milder forming from 200-315ºC (400-600ºF). Care must be taken to prevent the formation of excessive alpha case, and alpha case must be removed after processing.

Cold Working

CP Ti Grade 2 has good ductility and can be formed at room temperature by various standard methods including bending, stretch forming, heading, stamping, and drawing. CP Ti work hardens fairly rapidly, which is a limitation in some operations, such as cold drawing. The Bauschinger effect results in a drop of up to 25% in compressive yield strength upon stretching at room temperature; this drop can be recovered by stress relieving. Due to the low modulus of titanium, springback allowances are significant. Hot sizing after cold forming is often used to correct for variations in springback.

Machinability

The machining characteristics of CP Ti Grade 2 are similar to those of austenitic stainless steels. In general, low cutting speeds, heavy feed rates, and copious amounts of cutting fluid are recommended. Sharp tools and rigid setups are also important. Because of the strong tendency of titanium to gall and smear, feeding should never be stopped while the tool and workpiece are in moving contact. Non-chlorinated cutting fluids are generally used to eliminate any possibility of chloride-induced stress-corrosion cracking. It should be noted that titanium chips are highly combustible and appropriate safety precautions are necessary.

Following are typical feeds and speeds for CP Ti Grade 2.

- Machinability Tables
- Typical Minimum Stock Removal Requirements

Weldability

CP Ti Grade 2 can be welded using CP Ti filler metal. Inert gas shielding techniques must be employed to prevent oxygen pickup and embrittlement in the weld area. Gas tungsten arc welding is the most common welding process for CP Ti. Gas metal arc welding is used for thick sections. Plasma arc welding, spot welding, electron beam, laser beam, resistance welding, and diffusion welding have all been used successfully in CP Ti welding applications.

Other Information

Wear Resistance

Commercially pure Ti has a tendency to gall and is not recommended for wear applications.

Descaling (Cleaning)

Following heat treatment in air, it is extremely important to completely remove not only the surface scale, but the underlying layer of brittle alpha case as well. This removal can be accomplished by mechanical methods such as grinding or machining, or by descaling (using molten salt or abrasive) followed by pickling in a nitric/hydroflouric acid mixture.

Titanium is also susceptible to hydrogen embrittlement, and care must be taken to avoid excessive hydrogen pickup during heat treating and pickling/chemical milling.

Final heat treatments on finished parts must be performed in vacuum if machining or pickling is to be avoided.

The cleanliness of parts to be vacuum heat treated is of prime importance. Oils, fingerprints, or residues remaining on the surface can result in alpha case formation, even in the vacuum atmosphere. In addition, chlorides found in some cleaning agents have been associated with SCC of titanium alloys. Parts to be vacuum heat treated should be processed as follows: thorough cleaning using a non-chlorinated solvent or aqueous cleaning solution, followed by rinsing with copious quantities of deionized or distilled (not regular tap) water to remove all traces of cleaning agent, and finally, drying. Following cleaning, parts must be handled with clean gloves to prevent recontamination of the surface.

Applicable Specifications

- AMS 4902 (Sheet, Strip, Plate)
- AMS 4941 (Welded Tubing)
- AMS 4942 (Seamless Tubing)
- AMS 4951 (Weld Filler Metal Wire)
- ASTM B265 (Sheet, Strip, Plate)
- ASTM B348 (Bar, Billet)
- ASTM B367 (Castings)
- ASTM F67 (Unalloyed Ti for Surgical Implants)
- AWS A5.16-70 (Weld Filler Metal Wire and Rod)

Forms Manufactured

*SMART Coil is a registered trademark of Dynamet Holdings, Inc. licensed to Dynamet Incorporated.

- Bar-Rounds
- Bar-Shapes
- Dynalube Coil
- Ingot
- Plate
- Sheet
- SMART Coil® Titanium Coil
- Weld Wire
- Wire
- Wire-Shapes

References

The information in this publication was compiled from a variety of sources, including the following:

Materials Properties Handbook: Titanium Alloys, ASM International, 1994
Aerospace Structural Metals Handbook, Volume 4, CINDAS/Purdue University, 1998
Titanium: a Technical Guide, ASM International, 1988
Metals Handbook, Desk Edition, ASM International, 1984
Specifications Book, International Titanium Association, 1999
Metcut Research Associates Inc. data
Dynamet technical papers and unpublished data

- Metallography - Microstructure Images

Disclaimer:
The information and data presented herein are typical or average values and are not a guarantee of maximum or minimum values. Applications specifically suggested for material described herein are made solely for the purpose of illustration to enable the reader to make his/her own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes. There is no representation that the recipient of this literature will receive updated editions as they become available.

Edition Date: 07/01/2000