DAXUN

Titanium Alloy Ti 6Al-4V

Type Analysis

Single figures are nominal except where noted.

Carbon (Maximum)	0.10 %	**Titanium**	Balance
Aluminum	5.50 to 6.75 %	**Vanadium**	3.50 to 4.50 %
Nitrogen	0.05 %	**Iron (Maximum)**	0.40 %
Oxygen (Maximum)	0.020 %	**Hydrogen (Maximum)**	0.015 %
Other, Total (Maximum)	0.40 %		

* Other, Each (Maximum) = 0.1%

** For AMS 4928 (Bar, Billet, Forgings) Hydrogen = 0.0125% and Iron = 0.3%

General Information

Description

DAXUN is a Ti 6AL 4V-Grade 5-TC4 UNS R56400 Alloy Titanium Plate Manufacturer and Supplier from China! With the goal of creating the world's high-performance titanium alloy plates. We deliver quickly worldwide - ASTM B265 Grade 2, Grade 5 Titanium Plates. DAXUN produces and stocks alloy titanium plates Grade 5 (UNS R56400) with thicknesses ranging from 0.5mm to 300mm (0.5mm-6.0mm is cold rolled. 6.0-50mm is hot rolled, and 50mm and above are forged). Grade 5 titanium plate (Ti-6Al-4V) is the " workhorse" of titanium alloy materials. It combines high strength, ductility and excellent corrosion resistance, high temperature resistance, thus being favored by many general and military industries. Compliant with: ASTE, ASME, AMS, GB, GJB, MIL, JIS, EN, etc.

Ti-6Al-4V grade 5 titanium plate contains 90% titanium, 6% aluminum and 4% vanadium. It is an α-β titanium alloy in which aluminum stabilizes the α phase and vanadium stabilizes the β phase. The main features of Ti-6Al-4V titanium alloy plate are excellent comprehensive performance and good process performance. TC4 titanium alloy has excellent room temperature and high temperature strength, good creep resistance and thermal stability, high fatigue performance and crack growth resistance in seawater, as well as satisfactory fracture toughness and hot salt stress corrosion performance. Ti-6Al-4V titanium plate also has excellent process plasticity and superplasticity, suitable for various processing methods, and various ways of welding and machining.

Ti-6Al-4V grade 5 titanium plate is mainly used in aerospace, military industry, power industry, vehicle armor, rocket precision guidance parts, marine industry, etc.

Applications

Ti-6AL-4V titanium plates and sheets are mainly used for parts that require corrosion resistance, stress corrosion resistance and high strength (400-450°C), with good ductility and lateral strength. 1. Jet engine compressor blades, disks and rings, fuselage components such as wings, fuselages, turbine disks, doors, bulkheads, military aircraft and hardware heat shields, engine nozzles, landing gear doors, fuselage superplastic forming parts, etc. 2. Military applications include: armor, guidance, shell casings, etc. 3. Spacecraft components, including rocket engines and heat shields, etc. 4. Medical and surgical instruments. 5. Sports equipment, including bicycle frames and golf clubs. 6. Other uses that require a high strength-to-weight ratio.

DAXUN Grade 5 Titanium Plate

DAXUN is a metal expert focused on small and large pure titanium plate and 6-4 titanium alloy plate projects. DAXUN is your reference point and long-term partner, ready to provide you and your business with grade 5 titanium plates and any technical assistance you may need. You can think of DAXUN not only as your industrial pure titanium plate and titanium alloy plate supplier, but also as your strategic partner to help you meet any challenges and needs you may encounter, ultimately allowing you to achieve your project goals.

DAXUN's service center in China has 6al 4v titanium plate products in stock and can quickly process orders. Through basic processing, water jet cutting and plate nesting products, we provide added value to our customers, saving them time and costs.

Continuous investment in DAXUN's production facilities and capacity agreements with partners ensure that DAXUN is at the forefront of titanium plate quality now and in the future.

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	Humidity	Excellent

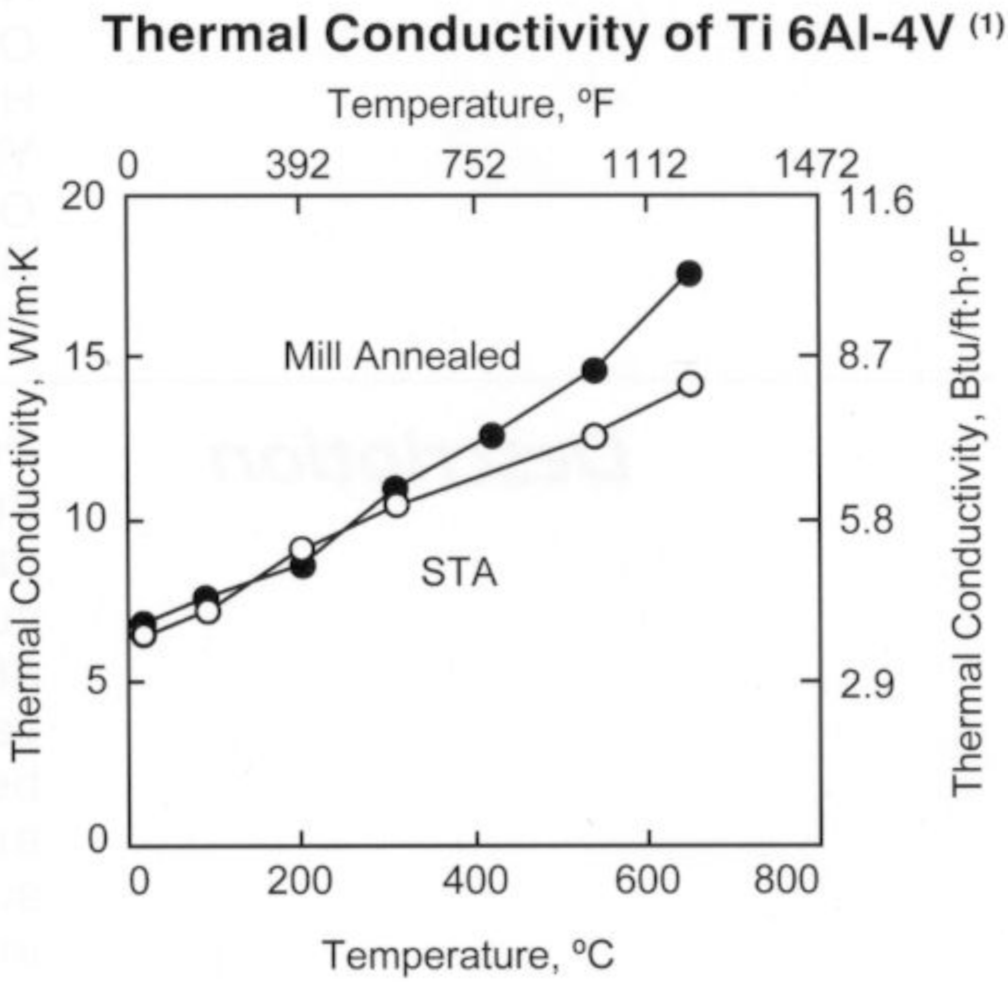
Ti 6Al-4V: General Corrosion Rates in Various Media

Medium	Concentration %	Temperature		Corrosion Rate	
		ºC	ºF	mm/yr	mils/yr
Sea Water	n/a	room	room	nil	nil
Hydrochloric Acid	2	37.8	100	nil - .030	nil - 1.2
Hydrochloric Acid	10	37.8	100	0.508 - 1.02	20.0 - 40.0
Hydrochloric Acid + 5% CrO_3	10	65.6	150	nil - 0.005	nil - 0.2
Hydrochloric Acid	vapors	37.8	100	8.33 - 1.04	328 - 408
Nitric Acid	65	boiling	boiling	0.076 - 0.13	3.0 - 5.0
Sulfuric Acid	2	37.8	100	0.396 - 0.549	15.6 - 21.6
Sodium Hydroxide	25	boiling	boiling	0.046 - 0.051	1.8 - 2.0

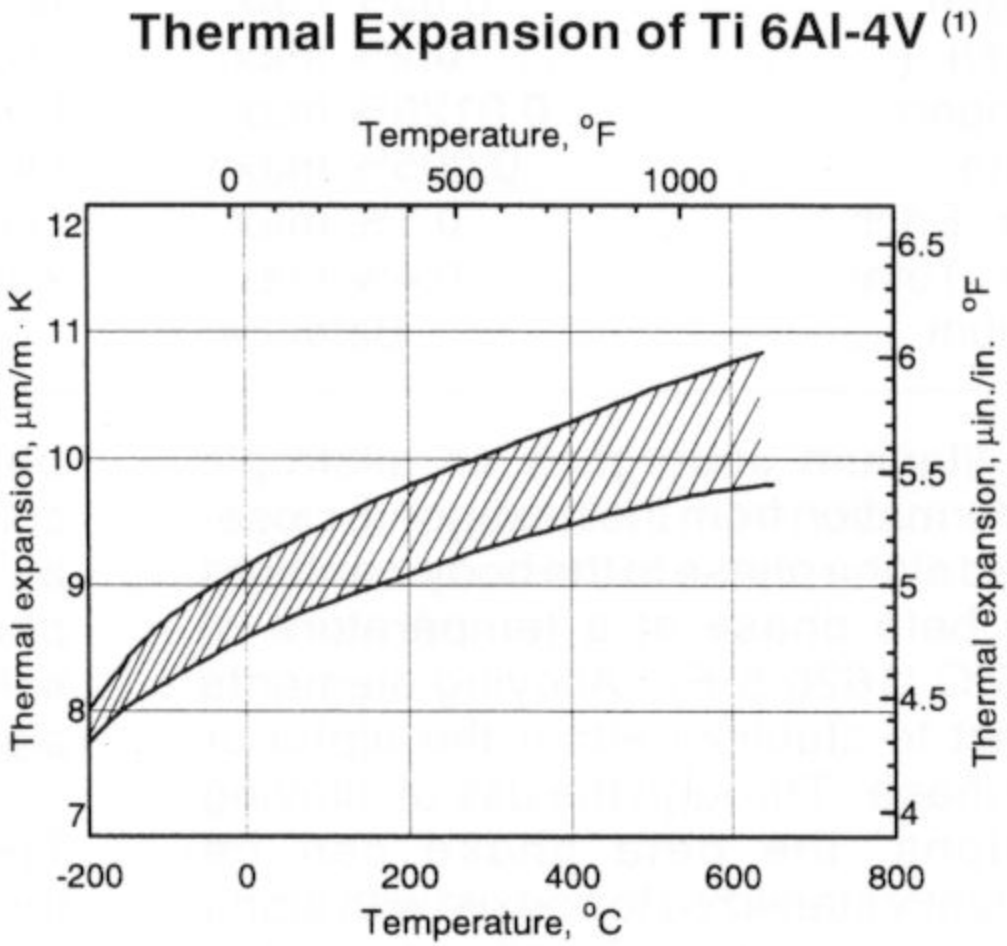
Properties

Physical Properties

Specific Gravity	0.160



Modulus of Elasticity (E)	15.2	x 10^3 ksi
Beta Transus	1800 to 1850	°F
Liquidus Temperature	2976 to 3046	°F
Solidus Temperature	2900 to 2940	°F
Electrical Resistivity		
-418°F	902.5	ohm-cir-mil/ft
73°F	1053	ohm-cir-mil/ft
986°F	1143	ohm-cir-mil/ft



Magnetic Properties

Magnetic Attraction

• None

Typical Mechanical Properties

Typical Room-Temperature Strengths for Annealed Ti 6Al-4V:
Ultimate Bearing Strength 1380-2070 MPa (200-300 ksi)
Compressive Yield Strength 825-895 MPa (120-130 ksi)
Ultimate Shear Strength 480-690 MPa (70-100 ksi)

Fatigue Limits:
High-cycle fatigue limits for Ti 6Al-4V are greatly influenced by both microstructure and surface conditions. Some generalize fatigue limits for annealed wrought material are provided below.

Fatigue Limit Ranges for Ti 6Al-4V (Axial Fatigue, R = 0.06 to 0.1)
Smooth 400-700 MPa (60-100 ksi)
Notched (KT = 3) 140-270 MPa (20-40 ksi)

Fracture Toughness:
The fracture toughness (KIc) of Ti 6Al-4V lies between that of aluminum alloys and steels. Microstructures that tend to have higher toughness are those with greater amounts of lamellar alpha/beta and coarser structures in general. The ELI grade of Ti 6Al-4V exhibits toughness superior to the standard grade.

Room Temperature Mechanical Properties

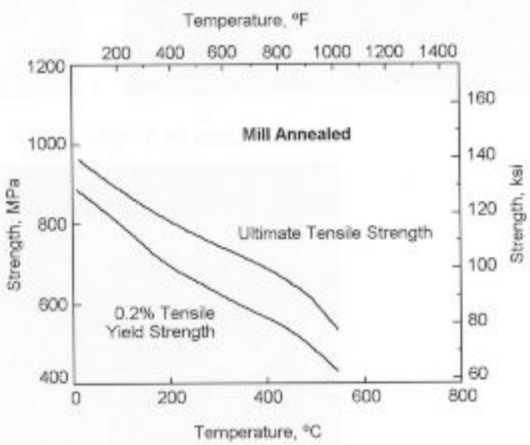
Condition	*UTS*	*YS*	*%El*	*%RA*
Minimum Specified Tensile Properties				
Annealed	*896 MPa (130 ksi)*	*827 MPa (120 ksi)*	*10*	*25*
STA (depending on diameter)	*1035–1135 MPa (150–165 ksi)*	*965–1070 MPa (140–155 ksi)*	*10*	*20*
Typical Tensile Properties				
Annealed	*965–1090 MPa (140–158 ksi)*	*875–995 MPa (127–144 ksi)*	*16*	*46*
STA (depending on diameter)	*1100–1220 MPa (160–177 ksi)*	*1035–1130 MPa (150–164 ksi)*	*15*	*52*

One reason that Ti 6Al-4V has found such widespread use is its relatively high strength for a lightweight material.

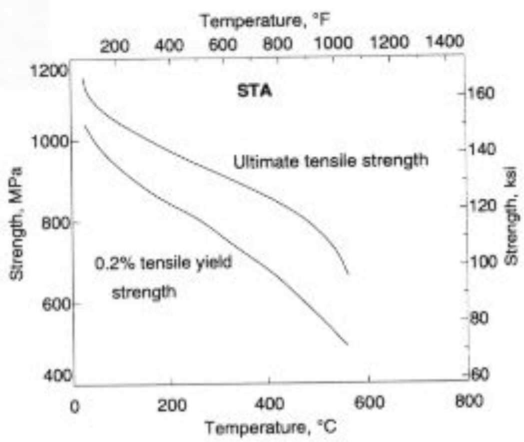
Specific strength (strength/density) provides a means to compare materials on this basis.

Material	UTS		Specific Strength	
	MPa	ksi	m x 10^3	in x 10^6
Ti 6Al-4V STA	1172	170	27.0	1063
Ti 6Al-4V Annealed	924	134	21.3	838
4130 Steel	1379	200	17.9	707
7075-T6 Aluminum	538	78	19.6	772
2024 T3 Aluminum	441	64	16.1	634
Inconel 718	1276	185	15.3	603

Tensile Strengths - Mill Annealed [1]



Tensile Strengths - STA [1]



Heat Treatment

Ti 6Al-4V wrought products are typically used in either a mill annealed or solution treated and aged condition. Rapid quenching following solution treatment (water quench or equivalent) is important in order to maximize the formation of alpha' martensite phase, which in turn maximizes the aging response. Other heat treatments used on Ti 6Al-4V include stress relieving for formed or welded parts, and beta annealing, which is used for improving damage tolerance.

Ti 6Al-4V, like other titanium alloys, has a high affinity for gases including oxygen, nitrogen and hydrogen. Absorption of oxygen results in the formation of an extremely hard, brittle oxygen-stablized alpha phase layer known as alpha case upon heating in air.

Intermediate and final annealing of Ti 6Al-4V mill products 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 Descaling (Cleaning) Notes).

Heat Treatment

Mill Anneal	705-790ºC (1300-1450ºF) 1-4 hours - air cool (or equivalent)
Solution Treat + Age (STA)	940-970ºC (1725-1775ºF) 10 min. - water quench (or equiv.) plus 480-595ºC (900-1100ºF) 2-8 hours - air cool (or equivalent)
Stress Relief	480-650ºC (900-1200ºF) 1-4 hours - air cool (or equivalent)
Beta Anneal	1035ºC (1900ºF) 30 min. - air cool plus 730ºC (1350ºF) 2 hours - air cool

Workability

Hot Working

Ti 6Al-4V can be hot worked by standard methods such as hot rolling, forging, and hot pressing. Typically, hot working is done high in The alpha/beta temperature range is approximately 870-980ºC (1600-1800ºF). To avoid excessive formation of the alpha phase, it is important to take precautions and eliminate it after processing. Sheet material is typically hot formed at temperatures around 650ºC (1200ºF). Ti6Al-4V has been successfully processed by superplastic forming at temperatures between 850ºC and 1560ºF.

Typical Machining Speeds and Feeds – Titanium Alloy Ti-6Al-4V

The speeds and feeds in the following charts are conservative recommendations for initial setup. Higher speeds and feeds may be attainable depending on machining environment.

Turning—Single-point and Box Tools

Depth of Cut (Inches)	High Speed Tools			Carbide Tools (Inserts)				
	Tool Material	Speed (fpm)	Feed (ipr)	Tool Material	Speed (fpm) Brazed	Speed (fpm) Throw Away	Speed (fpm) Coated	Feed (ipr)
Annealed								
.150		60	.010	C2	145	195	-	.008
.025	T15, M42	70	.005	C3	170	225	-	.005
Aged								
.150		55	.010	C2	135	165	-	.008
.025	T15, M42	65	.005	C3	160	190	-	.005

Turning—Cut-Off and Form Tools

Tool Material		Speed (fpm)	Feed (ipr)						
			Cut-Off Tool Width (Inches)				Form Tool Width (Inches)		
High Speed Tools	Carbide Tools		1/16	1/8	1/4	1/2	1	1 ½	2
Annealed									
T15, M42		55	.001	.0015	.002	.0025	.0015	.001	.001
	C2	110	.001	.0015	.002	.0025	.0015	.001	.001
Aged									
T15, M42		40	.001	.0015	.002	.002	.0015	.001	.001
	C2	85	.001	.0015	.002	.002	.0015	.001	.001

Rough Reaming

High Speed		Carbide Tools		Feed (ipr) Reamer Diameter (inches)					
Tool Material	Speed (fpm)	Tool Material	Speed (fpm)	1/8	1/4	1/2	1	1 ½	2
Annealed									
T15, M42	65	C2	200	.003	.006	.010	.012	.014	.016
Aged									
T15, M42	30	C2	160	.003	.007	.010	.012	.014	.016

Drilling

Tool Material	Speed (fpm)	High Speed Tools — Feed (inches per revolution) Nominal Hole Diameter (inches)							
		1/16	1/8	1/4	1/2	3/4	1	1 ½	2
Annealed									
T15, M42	35	-	.002	.004	.006	.007	.008	.010	.012
Aged									
T15, M42	30	-	.002	.003	.005	.006	.007	.009	.010

Die Threading

Tool Material	FPM for High Speed Tools — 7 or less, tpi	8 to 15, tpi	16 to 24, tpi	25 and up, tpi
Annealed				
M1, M2, M7, M10	5 – 20	9 – 25	10 – 30	15 – 40
Aged				
M1, M2, M7, M10	5 – 20	9 – 25	10 – 30	15 – 40

Milling, End-Peripheral

Depth of Cut (inches)	High Speed Tools						Carbide Tools					
	Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)				Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)			
			1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2
Annealed												
.050	T15	90	.002	.003	.005	.006	C2	260	.002	3	.006	.008
Aged												
.050	T15	75	.002	.003	.004	.006	C2	200	.002	.003	.006	.008

Tapping

High Speed Tools — Tool Material	Speed (fpm)
Annealed	
M1, M7, M10 Nitrided	7 - 20
Aged	
M1, M7, M10 Nitrided	3 - 10

Broaching

High Speed Tools — Tool Material	Speed (fpm)	Chip Load (ipt)
Annealed		
T15, M42	8	.003
Aged		
T15, M42	5	.002

When using carbide tools, surface speed feet/minute (SFPM) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%.

Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.

Typical Minimum Stock Removal Requirements for Ti Alloys (after Thermal Exposure in Air)

Heat Treatment	Thermal Cycle	Removal Required
Mill Anneal	760ºC (1400ºF) 2 hrs.	.038 mm (.0015 in.)
Solution Treat + Age (STA)	954ºC (1750ºF) 10 min. + 480ºC (900ºF) 4 hrs	.107 mm (0.0042 in.)

Weldability

Ti6Al-4V can be welded with Ti6Al-4V filler metal. Inert gas shielding must be used to prevent oxygen absorption and embrittlement in the weld area. Gas tungsten arc welding is the most common welding process for Ti6Al-4V. Gas metal arc welding is used for thick sections. Various welding methods, including plasma arc, spot welding, electron beam, laser beam, resistance welding, and diffusion welding, have proven successful in Ti6Al-4V welding applications.

Other Information

Wear Resistance

Ti 6Al-4V, and Ti alloys in general, have a tendency to gall and are not recommended for wear applications.

Descaling (Cleaning)

After heat treating in air, it is critical to remove the surface oxide scale and the underlying brittle alpha case layer. This material can be removed using mechanical procedures such as grinding or machining or descaling (using molten salts or abrasives), followed by pickling in an anhydrous/hydrofluoric acid mixture. Titanium alloys are susceptible to hydrogen embrittlement, so it is important to avoid excessive hydrogen absorption during heat treatment, pickling, and chemical milling. If machining or pickling is to be avoided, the finished part must be subjected to final heat treatment under vacuum. Cleanliness of vacuum heat treated parts is critical. Even under vacuum, oils, fingerprints, or residues left on the surface can cause alphacase to develop. In addition, the presence of chlorides in various cleaning products has been linked to SCC in titanium. To clean heat treated parts, follow these steps: Clean thoroughly with a non-chlorinated solvent or aqueous cleaning solution, rinse with deionized or distilled water to remove any cleaning agents, and allow to dry. After cleaning, parts should be handled wearing clean gloves to prevent surface contamination.

Applicable Specifications

- A5.16 (ERTi-5) (Weld Wire)
- AMS 4920 (Forgings)
- AMS 4963 (Bar, Wire, Forgings, Ring, Heat Treatable)
- AMS 4967 (Bar, Wire, Forgings, Ring, STA)
- ASTM B367 (Castings)
- ISO 5832-3
- AMS 4911 (Sheet, Strip, Plate)
- AMS 4928 (Bar, Wire, Forgings, Ring, Annealed)
- AMS 4965 (Bar, Wire, Forgings, Ring, STA)
- ASTM B348 (Bar, Billet)
- ASTM F1472 (All Forms, Annealed)

Forms Manufactured

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

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

References

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

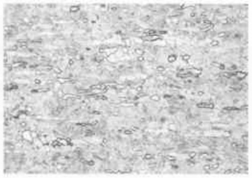
Materials Properties Handbook: Titanium Alloys, ASM International, 1994
Aerospace Structural Metals Handbook, Volume 4, CINDAS/Purdue University, 1998
Titanium: a Technical Guide, ASM International, 1988
Metals Handbook, Desk Edition, ASM International, 1984
Specifications Book, International Titanium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

Ti 6Al-4V specimens can be prepared for metallographic examination by standard methods. Abrasive cutting, especially of small samples, is not recommended due to the tendency to burn the surface and produce alpha case. Kroll's reagent (1–3% hydroflouric acid plus 2–6% nitric acid in water) is commonly used for determination of general microstructure. For detection of alpha case, Kroll's etch is followed by an ammonium biflouride solution which stains the entire sample with the exception of any alpha case. Some typical microstructures are illustrated below.

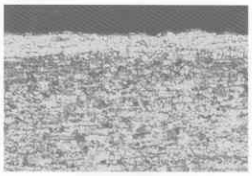
Microstructures of Ti 6Al-4V (approximate magnification 200X)

Ti 6Al-4V Mill Annealed Condition

Ti 6Al-4V STA Condition



Alpha Case in Ti 6Al-4V



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