Ti-6Al-4V, Ti-6Al-4V ELI & Ti-6Al-4V-.1Ru

TIMETAL® 6-4, 6-4 ELI & 6-4-.1Ru

MEDIUM TO HIGH STRENGTH GENERAL-PURPOSE ALLOYS

TIMETAL 6-4 is a general-purpose alpha-beta alloy in widespread use. It contains a favorable balance of properties with moderately high tensile strength, good fatigue strength, with intermediate fracture toughness. Reasonable properties are retained up to about 350°C (660°F). Most properties are affected by the microstructure, which is determined by the thermo-mechanical history. This alloy is hardenable in sections up to 1.0" thick and is weldable by various methods provided the joint area is clean before welding. In most of the welding methods, an inert gas or vacuum environment is required during welding. *TIMETAL* 6-4 alloy is highly resistant to general corrosion in sea water. This alloy is offered in several variants. The ELI (ASTM Grade 23) variant is available for fracture critical applications. The 0.1Ru ELI variant (ASTM Grade 29) of this alloy is available for enhanced corrosion resistance. *TIMETAL* 6-4 alloy and its variants has been used in air-frames, jet engine & rocket components, pressure vessels, fasteners, prosthetic implants, geothermal-well casings, automotive components and sports equipment. This alloy is available in most common product forms including billet, bar, wire, plate, and sheet.

TABLE 1

CHEMICAL COMPOSITION

ELEMENT	WEIGHT %					
	TIMETAL *6-4* *ASTM Grade 5* *Mil T-9047*		TIMETAL *6-4 ELI* *ASTM Grade 23* *AMS 4981*		TIMETAL *6-4-.1Ru* *ASTM Grade 29*	
	Min.	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
Aluminum	5.5	6.75	5.5	6.5	5.5	6.5
Vanadium	3.5	4.5	3.5	4.5	3.5	4.5
Nitrogen	—	0.05	—	0.03	—	0.03
Carbon	—	0.08	—	0.08	—	0.08
Oxygen	—	0.20	—	0.13	—	0.13
Iron	—	0.40	—	0.25	—	0.25
Hydrogen	—	0.015	—	0.0125	—	0.015
Ruthenium	—	—	—	—	0.08	0.14
Resid. Elements, ea.	—	0.1	—	0.1	—	0.1
Resid. Elements, tot.	—	0.4	—	0.4	—	0.4

FIGURE 1

ELEVATED TEMPERATURE TENSILE PROPERTIES

TYPICAL TENSILE STRENGTHS VS TEMPERATURE

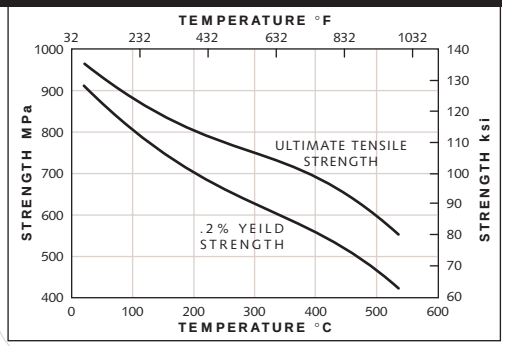


TABLE 2

PHYSICAL PROPERTIES

Property	*T (°F)*	*T (°C)*	*Value*	*Value (SI)*
Density	72	22	0.160 lb in^{-3}	4.42 g cm^{-3}
Beta Transus	1825±25	996±14		
Melting (liquidus) Point	3000-3020±25	1650-1660±14		
Thermal Conductivity Mil Annealed	68 600 1200	20 315 650	3.8 Btu hr^{-1} ft^{-1} $°F^{-1}$ 6.1 Btu hr^{-1} ft^{-1} $°F^{-1}$ 10.1 Btu hr^{-1} ft^{-1} $°F^{-1}$	6.6 W m^{-1} K^{-1} 10.6 W m^{-1} K^{-1} 17.5 W m^{-1} K^{-1}
Specific Heat	68 800 1600	20 425 870	0.140 Btu lb^{-1} $°F^{-1}$ 0.160 Btu lb^{-1} $°F^{-1}$ 0.220 Btu lb^{-1} $°F^{-1}$	0.580 J g^{-1} K^{-1} 0.670 J g^{-1} K^{-1} 0.930 J g^{-1} K^{-1}
Electrical Resistivity	32 600 1200	0 315 650	66 μΩ•in 73 μΩ•in 74 μΩ•in	1.68 μΩ•m 1.86 μΩ•m 1.89 μΩ•m
Magnetic Permeability			1.00005 at 20 oersteds	
Mean Coefficient of Thermal Expansion	32-212 70-800 70-1200	0-100 20-425 20-650	5.0 x 10^{-6} in in^{-1} $°F^{-1}$ 5.2 x 10^{-6} in in^{-1} $°F^{-1}$ 5.4 x 10^{-6} in in^{-1} $°F^{-1}$	9.0 x 10^{-6} m m^{-1} $°C^{-1}$ 9.4 x 10^{-6} m m^{-1} $°C^{-1}$ 9.7 x 10^{-6} m m^{-1} $°C^{-1}$
Young's Modulus (Dependent on texture and heat treatment)	68 450	20 230	15.5-17.7 Msi 13.8-16.2 Msi	107-122 GPa 95-111 GPa
Shear Modulus	68	20	5.9-6.5 Msi	41-45 GPa
Poisson's Ratio	68	20	.31	.31

TABLE 3

MINIMUM TENSILE PROPERTIES OF TIMETAL 6-4

Product (in)	Condition	Specification	Dir.	Temperature °F (°C)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation %	Reduction in Area %
0.025-1.000 Sheet & Plate	Annealed[a]	ASTM B265	L & LT	68 (20)	130 (895)	120 (828)	10[b]	—
≤3.00 RD or Thk.	Annealed	ASTM B348	L	68 (20)	130 (895)	120 (828)	10	25
≤4.00 RD or Thk.	Annealed	Mil-T-9047G[c]	All	68 (20)	130 (896)	120 (827)	10	25
>4.00-6.00	Annealed	Mil-T-9047G[c]	All	68 (20)	130 (896)	120 (827)	10	20
<0.500	STD[d]	Mil-T-9047G		68 (20)	165 (1137)	155 (1068)	10	20
>0.500-1.000	STD[d]	Mil-T-9047G		68 (20)	160 (1103)	150 (1034)	10	20
>1.000-1.500	STD[d]	Mil-T-9047G		68 (20)	155 (1068)	145 (999)	10	20
>1.500-2.000	rd., sq., hex	Mil-T-9047G		68 (20)	150 (1034)	140 (965)	10	20
>2.000-3.000	rd., sq., hex	Mil-T-9047G		68 (20)	140 (965)	130 (896)	10	20

MINIMUM TENSILE PROPERTIES OF TIMETAL 6-4 ELI

0.025-1.000 Sheet & Plate	ST	ASTM B265	L & LT	68 (20)	120 (828)	110 (759)	10	—
≤3.00 RD or Thk.	Annealed	ASTM B348	L	68 (20)	120 (828)	110 (759)	10	25
≤1.75 RD or Thk.	Annealed[a]	ASTM F136	L	68 (20)	125 (860)	115 (795)	10	25[e]
1.75-2.50	Annealed[a]	ASTM F136	L & LT	68 (20)	120 (825)	110 (760)	8	20
2.50-4.00	Annealed[a]	ASTM F136	L, LT & ST	68 (20)	120 (825)	110 (760)	8	15

[a] 1300°F/1hr/AC or slower. [b] For materials less than .025 thick, the elongation must be negotiated with the manufactur er. [c] Partial list of tensile requirements from the specification. [d] Solution Treat and Age (1650-1775°F)/2-120 min/WQ + 900-1275°F/2-8hr/AC [e] Only for 0.187-<1.75" thick material

FIGURE 2

FATIGUE PROPERTIES

Ti 6Al-4V AXIAL FATIGUE OF UN-NOTCHED STA PLATE

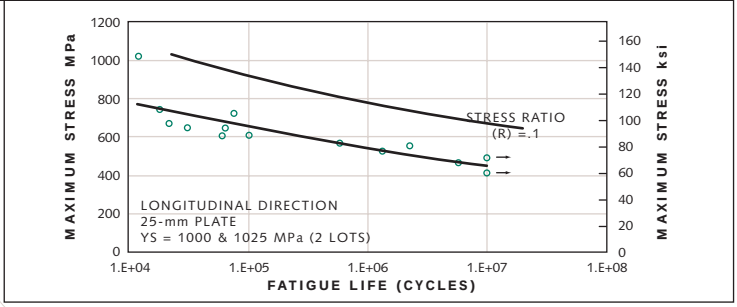
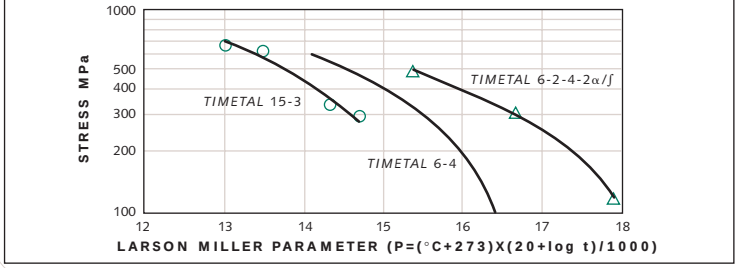


FIGURE 3

CREEP COMPARISON

.2% CREEP COMPARISON BETWEEN TIMETAL 6-4, TIMETAL® 6-2-4-6 AND TIMETAL® 15-3



The data and other information contained her ein are derived from a variety of sour ces which TIMET believes are reliable. Because it is not possible to anticipate specific uses and operating conditions, TIMET ur ges you to consult with our technical service personnel on your particular applications.

References

(1) Timet Booklet, "Properties and Processing Ti-6Al-4V", 1986.
(2) Boyer, Rodney; Welsch, Gerhard; Collings, E.W. , "Ti-6Al-4V", Materials Properties Handbook: Titanium Alloys, pp 483 –636,1994.
(3) ASTM B265-95a, Titanium and Titanium Alloy Strip, Sheet, and Plate
(4) ASTM B348-95a, Titanium and Titanium Alloy Bars and Billets
(5) Mil-T-9047G, Military Specification Titanium and Titanium Alloy Bars (Rolled or Forged) and Reforging Stock, Aircraft Quality
(6) ASTM F136-96, Wrought Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) Alloy (R56401) for Sur gical Implant Applications

For more information, please contact the TIMET Sales Office/Service Center nearest you, TIMET's Technical Laboratories or TIMET's Website @ www.timet.com

NORTH AMERICA

Hartford, CT	860-627-7051
Toronto, OH	740-537-5600
St. Louis, MO	800-753-1250
Dallas, TX	817-329-5035
Tustin, CA	714-573-1000

EUROPE

Birmingham, England	44-121-356-1155
Savoie, France	33-4-79-89-73-73
Düsseldorf, Germany	49-211-230-880

TECHNICAL SUPPORT

Henderson, NV	702-566-4416
Birmingham, England	44-121-332-5381

TIMET® *First in Titanium Worldwide*

TITANIUM MEMBER