TITAN Grade 23 TiAl6V4 ELI

3.7165 – Titan Grade 23 EN TiAl6V4 / ASTM B348 and F 136
Titanium alloy for the medical field, micro-engineering, watch making, etc.

Features and Particularities

Titan Grade 23 is the ELI (Extra Low Interstitials) version of Ti Grade 5, the worldwide most used Titanium alloy. Titan Grade 23 is a clean alloy, VAR melted and remelted. The contents of the interstitials elements and Fe are kept low. This alloy has a good corrosion resistance, particularly in chloride containing mediums. This Titan Grade 23 is used when severe requirements must be met, as for implants for example. It is biocompatible. It can be easily anodic oxidized. It permits the realization of a broad spectrum of decorative colors and wear resistant TiO_2 protective oxide layers. The Titan Grade 23 is ROHS compatible.

Uses

The Titan Grade 23 is used as implant material, in the micro-mechanical engineering, and in the medical, surgical and dental fields, as well as for components for watch movements and the watch exterior. It has a good corrosion resistance in seawater and marine environment. Its resistance in chloride mediums indicates it for the chemical industry. The easiness of its anodic oxidation permits to produce a rich color spectrum of nuanced anodic oxidation colors and wear resistant oxide layers, that indicates it for jewelry, decorative and wear resistant parts.

Standards

Material Number	3.7165
EN	TiAl6V4
ISO	5832-2
AFNOR	T 6 V
ASTM	B 348, F 136
UNS	R 56401

Chemical composition ($\%_{Gwt.}$)

C	Al	V	Y	Fe	O	N	H	Ti
max. 0.08	5.50 6.50	3.50 4.50	max. 0.005	max. 0.25	max. 0.13	max. 0.05	max. 0.012	balance

Dimensions and Executions

- Bars: 3m (2m), cold drawn, ground polished; Rugosity: Ra ≤ 0.8 µm, N6
  Tolerance: ISO h6 (h7), other tolerances on request
  ø > 2.0 mm: pointed and chamfered
  Straightness: max. 0.5 mm/m
  SWISSLINE: ø > 6.0 mm
  Cracking proof test: according to DIN/EN 10277-1, Tab. 1
  Ø < 2.00 mm: Class 1
  ø ≥ 2.00 mm: Class 3

Other executions on request

Availability

Dimensions courantes en stock, see: Delivery program

Mechanical properties

According to ISO and/or ASTM:

Strength UTS/Rm	≥ 900 MPa
Yield strength $R_{0.2}$:	≥ 795 MPa
Elongation A:	≥ 10%

Machining

Cutting speed:	Vc ≈ 20-40 m/min
Feed:	0.08-0.15 mm/U
Rake angle:	-100/120°
Lubricant-coolant:	individual choice

- The optimal cutting conditions depend on the machine tool, the cutting tools, the chip dimensions, the lubricant-cooling fluid, as well as the tolerances and surface the roughness to be achieved.

Modifications will not be adjusted automatically.
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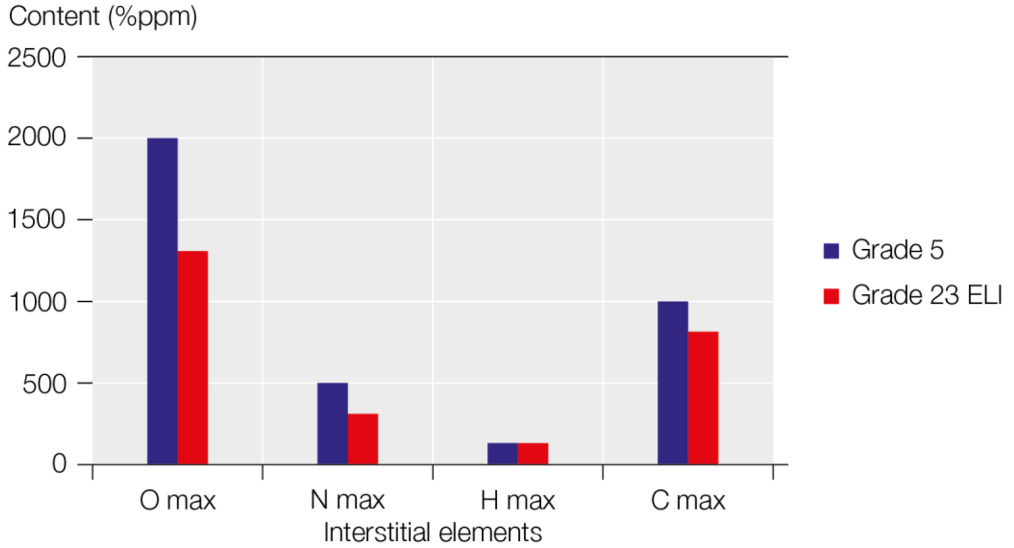
Figure 1
Comparison of the Ti6Al4V alloys

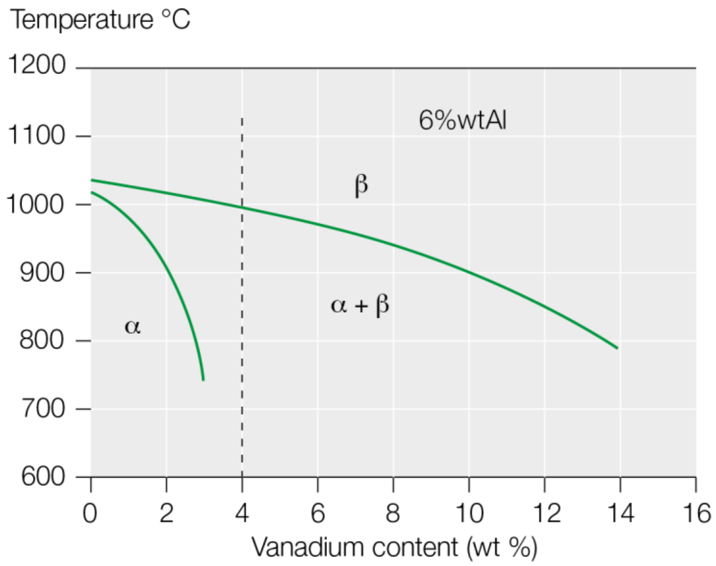


Contents of the Interstitials elements

In addition to the Al and V alloying elements, the interstitials elements C, O, N and H play a very important role in the achievemnet of the properties of Titan Grade 23. Figure 1 shows a comparison of the tolerated maximum contents of Grade 23 compared to Grade 5. The limited interstitial contents of Grade 23 permit to aobtain a superior thoughness and strainig capability and capacity. The machining is also improved.

Figure 2
Pseudo-binary Equilibrium diagram

The dashed line of Figure 2 shows the position of the Ti6Al4V alloy, or of Titan Grade 5 and Titan Grade 23 in the pseudo-binary equilibrium diagramm. A vast range of α+ß mixed microstructures can be produced by thermal annealing.



Microstructure

Above 1000°C:	ß body centered structure
Below 1000°C:	α hexagonal structure, variable α + ß mixed structure
α & ß phase partition:	according to the annealing temperature

Microstructue limit according to ISO 20160, 2006: A1-A2

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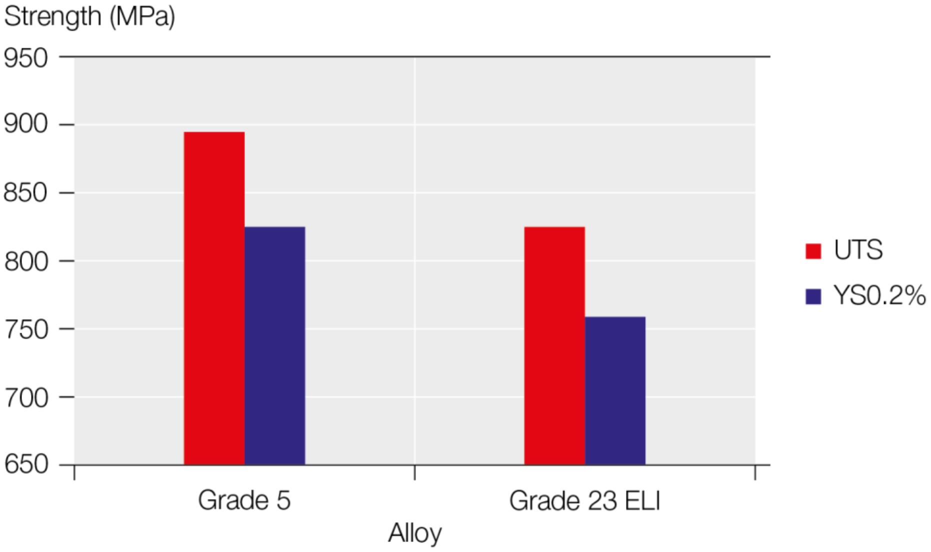
Figure 3
Comparison of the mechanical properties Titanium Grades 5 &s 23



The shown values of Rm and $R_{0.2}$ values shown in Figure 2 are indicative only. Still higher strengths can be reached by sequencing cycles of cold deformation and intermediate anneals.

Forming-shaping

Warm:	rough forging:	950-980°C
	final forging:	900-970°C
Cold:	feasible, but (very) difficult	
Intermediate T:	intermediate temperature of 450-650°C can help	

Annealing

705-730°C/1-4h/slow cooling to 565°C/air

Hardening

950-955°C/up to 5h/low cooling to 565°C/air

Stress relieving

480-650°C/up to 4h/air

Cold treatment

Cryogenic treatment: -196°C (N_2, liquid nitrogen)

Long-term operation

-196 – 400°C

Negative role of H2

Hydrogen diffuses easily in titanium where it causes H2 embrittlement. H_2 contamination must be avoided by any means. Contamination sources are often the protective atmospheres and the chemical and electrochemical reactions producing H_2.

Passivation
Corrosion resistance

The thickness of the spontaneously formed oxide film in presence of oxygen containing atmosphere or mediums is approximately <1-2 nm. This oxide layer is responsible for the very good corrosion resistance of TITAN Grade 23. The thickness of this oxide layer can be massively increased by an anodic oxidation.

Biocompatibility

The biocompatibility of TITAN Grade 23 can under circumstances, be questioned. Because, this alloy contains not biocompatible Vanadium as an alloying element. In cases of doubt, the TITAN Grade Nb (Ti6Al7Nb) should be used.

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Figure 4
Anodic oxidation

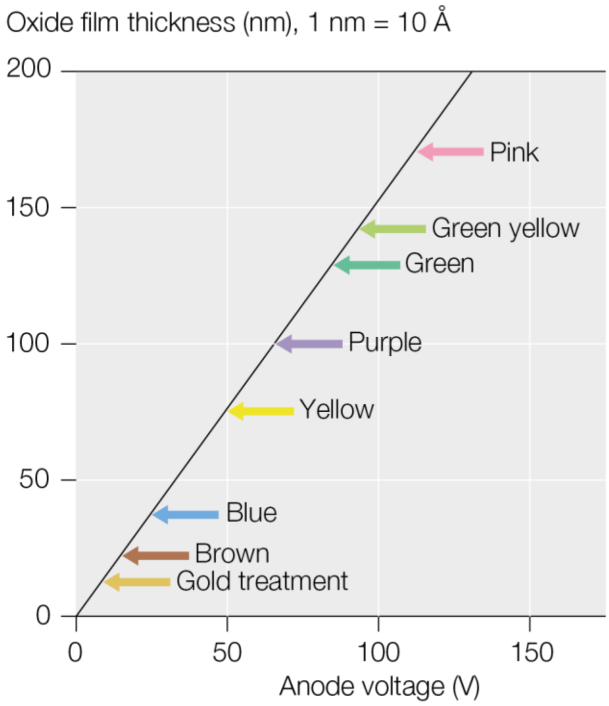

Table 1
Relation between the thickness of the oxide film and the resulting colors

0	46.0	92.0	137.9
3.1	49.0	95.0	141.0
6.1	52.1	98.1	144.1
9.2	55.2	101.1	147.1
12.3	58.2	104.2	150.2
15.3	61.3	107.3	153.3
18.4	64.4	110.3	156.3
21.5	67.4	113.4	159.4
24.5	70.5	116.5	162.5
27.6	73.6	119.5	165.5
30.7	76.6	122.6	168.6
33.7	79.7	125.7	171.6
36.8	82.8	128.7	174.7
39.8	85.8	131.8	
42.9	88.9	134.9	

Titan grade 23 can easily be anodic oxidized in oxidant acid baths, such the phosphoric acid (H_3PO_4) or sulfuric acid (H_2SO_4). As shown by Figure 3, a large spectrum of interference colors can be produced in function of the concentration of the selected oxidant acid, i.e. 4M H3PO4, the temperature and the applied voltage. No additive or coloration pigment is necessary. The colors observed are pure interference colors.

Color spectrum

The interference colors arise by the reflexion and refraction of the incident visible light on the surface of the metal. As shown in Table 1, anodic oxidation can produce a large spectrum of nuanced colors.

Reinforced Biocompatibility

The good biocompatibility of TITAN Grade 23 is due to its capacity and capability to spontaneously passivize in the presence of oxygen to form a TiO_2 oxide layer. This layer as shown in Table 1 is very thin < 1-2 nm. Thicker layers as produced by anodic oxidation, reinforce the biocompatibility and corrosion resistance.

Corrosion resistance

The corrosion resistance of titanium Grade 4 is excellent. It can still be reinforced by the formation of a thicker TiO_2 oxide layer produced by an anodic oxidation.

Resistance to fretting

The thicker TiO_2 oxide layers produced by anodic oxidation improve the gliding properties. These oxide layers can be exploited to improve the gliding properties, the wear and fretting resistances. These improvements can be exploited to enhance the gliding properties during forming operations of TITAN Grade 23.

Exploitation of the color spectrum

The large color spectrum produced by the anodic oxidation can be used for the benefit of the jewelry industry (Table shows 58 various distinct colors), and for fast recognition or identification purposes, as for example in the medical field.

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Physical properties

Properties	Unit	Temperature (°C)				
		20	200	300	400	500
Density	g cm^{-3}	4.43-4.47				
Young modulus E	GPa	113-115	92	85	78	72
Compression modulus	GPa	107				
Shear modulus G	GPa	44				
Poisson Coefficient	-	0.34				
Thermal conductivity	$W.m^{-1}.K^{-1}$	6.7		6.8		7.1
Electrical resistance	$\Omega.mm^2.m^{-1}$	0.55	0.58	0.595	0.605	0.615
Coefficient of thermal expansion	$W.m^{-1}.K^{-1}$ 10^{-6}	20–100°C 8.6	20–200°C 9.2	20–300°C 9.5	20–500°C 10	20–815°C 11
Relative magnetic susceptibility μr	10^{-6}	3.4	3.5	3.6	3.9	4.0
Specific Heat	$J.kg^{-1}.K^{-1}$	560				
Emissivity (1-10) visible light	-	0.3				
Coefficient of reflexion	-	0.56				
Melting range	°C	1605-1660				
Latent melting heat	kJ/kg	360-370				
Allotropic α/ß Transus	°C	988±14				
Relative magnetic permeability μr	1.6 kA/m	1.00005				

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