Technical Information

Materials - Titanium

Chemical, physical and mechanical characteristics of Titanium

Titanium is a metallic, non-magnetic element which is present in nature as oxide (TiO_2) and represents the fourth element in structural materials present on the Earth's crust; its costs are not connected with its availability but are associated with the complexity of the mining process and manufacturing difficulties.

Pure titanium (sponge) is obtained:

- After TiO_2 chlorination by thermochemical reduction of $TiCl_4$ (Kroll and Hunter process).
- After TiO_2 chlorination by electrolytic reduction of $TiCl_4$ into mineral salts.

The resultant titanium sponge can be produced in blooms, ingots and billets. These products are further processed by rolling, drawing and extrusion to produce the main products available on the market: bars, tapes, wires, sheets and pipes.

The wide range of properties that distinguish titanium and its alloys, and in particular the combination of their physical and mechanical properties, among which strength (comparable to the strength of steel and twice that of aluminum) and corrosion resistance, allow their use and application in a wide range of fields such as aeronautic and aerospace (both civil and military applications), chemical and automotive industry, energy (for example off-shore plants) and medical applications.

The main chemical-physical characteristics of titanium and its alloys are:

- Low density, and therefore lightness (4.5 kg/dm^3), but with mechanical properties comparable to that of structural steels (in this case the same product requires half the material in terms of weight)
- High corrosion resistance to oxidizing acid (in particular in nitric acid), in saline environment (as sea water), and in organic solutions (food products and medical field)
- High resistance to abrasion, impact cutting, and UV rays
- High thermic inertia (thermal conductivity of 16W/mK) and good heat resistance due to the high melting point that allow the use at high temperature.
- Good workability and weldability
- Anti-static and nonmagnetic element
- Non-polluting and not-toxic
- Recyclable

These properties are achieved through the addition of alloy elements which, depending on the type of alloy, allow the improvement of some properties. Improvements can also be achieved also by the use of different heat treatments and working processes. This allows its use in a wide range of applications.

Titanium is available on the market as pure titanium or as alloy.

Pure titanium has a crystalline structure of alpha type (compact hexagonal) and it is classified in 6 types, each one of them including a different quantity of impurities (interstitial elements).

Grades with greater purity, defined by a reduced quantity of interstitial substances, are characterized by a low content of interstitial substances, and by lower hardness and resistance, but greater ductility.

Grade 1 is the most pure (99.5% of titanium); from gr. 1 to gr. 5 the quantity of substances decreases but the resistance increases.

The addition of alloying elements allows to achieve alpha, beta and alpha+beta type alloys with different characteristics compared with pure titanium, but more popular material due to the better relationship between weight and resistance and can be used in a wider number of applications.

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About a half the production of titanium in represented by titanium gr. 5 (Ti-6Al-4V) characterized by an alpha+beta structure and it contains both alpha stabilizer (6% of aluminum) and beta—stabilizer (4% vanadium) elements, and other alloy elements in lower quantities.

Because of its physical and mechanical characteristics, it is largely employed in the manufacture of screws and mechanical components.

The following tables show:

Chemical composition of various types of pure titanium and some of its most commonly used alloys

- Relative physical and mechanical characteristics

	Physical and mechanical characteristics of titanium	
	Commercially pure titanium	Titanium alloy
Grade	**Grade 2**	**Grade 5**
Rm (MPA)	345	900
Rp 0.2 (MPA)	275	830
Elongation%	20	10
Hardness	160 HB/30	36 HRC
Weight kg/dm³	4.51	4.4
Tensile strength Min/Max MPA	345/450	895/1100
Yield 0.2% MPA	275	825
Modulus of elasticity (GPA)	103	110
Shear modulus (GPA)	40	40
Melting point °C	1668	1650
Thermal conductivity (cal/cm²-°C/cm)	0.052	0.024
Electrical resistance (μ-Ω-cm)	55	175
Weldability	Excellent	Good
KCU resilience (J)	40-80	15-20
Coefficient of thermal exposure (/°C)	$8.4x10^{-6}$	$8.5x10^{-6}$
Specific heat (cal/g°C)	0.124	0.138
Forging temperature (°C)	870-930	950-980
Molding temperature (°C)	815-870	900-950
Beta transus (°C+/-25°C)	900	1000

Commercially pure titanium and titanium alloys specifications

AFNOR	AIR	DIN	ALEM ANDES LW	ENGLISH DTD	ENGLISH BSTA	AICMA	AMS	MIL-T	ASTM B 265 348 381 337 338 382
T40	9182	17850 17860 17862 17863 17864	37034 37035	5073	2, 3, 4, 5	TiP02	4902 4951 4941	type 9046 comp A	Grade 2
TA6V	9183	18850/51 18860/62/4	LW 37164	-	10-11-12-13-28-56	TiP63	4928 4935 4965 4911 4906 4954	9046 type 3 comp C 9047 class 6	Grade 5

Tightening moment “M” for titanium GR5 and Al 7075 Screws

Screw diameter	Tit. GR5 M (Nm)	Al 7075 M (Nm)
M3	1.73	0.75
M4	3.57	1.50
M5	6.90	3.00
M6	11.10	5.20
M8	28.30	12.30
M10	57.60	25.00
M12	97.50	42.40
M14	155.20	67.50
M16	235.70	102.50

The values shown in the table are recommended values that can help to prevent too low or too high torques, which could lead to loosening or breakage and deformity.