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# Products | Alloys | Cast Titanium Alloys

All titanium castings have compositions based on the common wrought alloys. There is no commercial titanium alloy developed strictly for casting applications. This is unusual, because in other metallic systems alloys have been developed specifically as casting alloys, often to overcome certain problems such as poor cast-ability of a wrought-alloy composition. Customers often fail to differentiate between a wrought alloy and cast alloy. No peculiar problems regarding cast-ability or fluidity have been encountered in any of the titanium metals cast to date.

## Classification of Titanium Alloys

Titanium alloys are classified according to the phases in their microstructure. Alloys that consist mainly of the α phase are called **a alloys**, whereas those that contain principally the α phase along with small amounts of β-stabilizing elements are termed as **near a titanium alloys**. Alloys that consist of mixtures of phases are classified as **a -b alloys**. Finally, titanium alloys in which the β phase is stabilized at room temperature after cooling from solution heat treatment are classified as **b alloys**. Table 1 gives a representative comparison of cast titanium alloys. Ti-6Al-4V is the most popular titanium alloy used in the industry worldwide.

**Table 1: Cast Titanium Alloys**

| Alloys | O % | N % | H % | Al % | Fe % | V % | Cr % | Sn % | Mo % | Zr % | Special properties |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ti-6Al-4V** | 0.18 | 0.015 | 0.006 | 6 | 0.13 | 4 | | | | | General purpose |
| **Ti-6Al-4V, ELI** | 0.11 | 0.010 | 0.006 | 6 | 0.10 | 4 | | | | | Cryogenic toughness |
| **Commercially pure titanium, Grade 2** | 0.25 | 0.015 | 0.006 | | 0.15 | | | | | | Corrosion resistance |
| **Ti-6Al-2Sn-4Zr-2Mo** | 0.10 | 0.010 | 0.006 | 6 | 0.15 | | | 2 | 2 | 4 | Elevated-temperature creep |
| **Ti-6Al-2Sn-4Zr-6Mo** | 0.10 | 0.010 | 0.006 | 6 | 0.15 | | | 2 | 6 | 4 | Elevated-temperature strength |
| **Ti-5Al-2.5Sn** | 0.16 | 0.015 | 0.006 | 5 | 0.2 | | | 2.5 | | | Cryogenic toughness |
| **Ti-3Al-8V-6Cr-4Zr-4Mo** | 0.10 | 0.015 | 0.006 | 3.5 | 0.2 | 8.5 | 6 | | 4 | 4 | Strength |
| **Ti-15V-3Al-3Cr-3Sn** | 0.11 | 0.015 | | 3 | 0.2 | 15 | 3 | 3 | | | Strength |

## Properties

α and near-α alloys are generally, non-heat-treatable and weldable. They have medium strength, good notch toughness, and good creep resistance at elevated temperatures.

Most of the α-β alloys are heat-treatable to a moderate increase in strength. Their strength levels are medium to high. They also have good forming properties, but do not have good creep resistance at elevated temperatures as α and near-α alloys.

The β-rich alloys are heat-treatable to very high strengths and are readily formable. However, these alloys have relatively high density and in the high-strength condition have low ductility. Because of these disadvantages, they are not used much at present.

Alloying with about 30% Mo greatly increases resistance to hydrochloric acid. Small amount of tin reduces scaling losses during hot-rolling. Small additions of palladium, platinum, and other noble metals increase resistance to moderately reducing mediums. One such commercial titanium alloy contains 0.15% palladium. These alloys are made by Acme Alloys, to meet customers' specific application needs and takes more time than usual alloys to manufacture it, due to the high price and difficulty in availability of rare earth metals. Many elements alloy with titanium of which commercial alloys include aluminium, chromium, iron, manganese, molybdenum, tin, vanadium and zirconium.

Table 2 is summary of room-temperature tensile properties for various alloys. These properties, which are typical, vary depending on microstructure as influenced by foundry parameters such solidification rate and heat treatment.

**Table 2: Typical room-temperature tensile properties of titanium alloy castings**

| Alloys (Bars machined from castings) | Yield Strength MPa | Ultimate Strength MPa | Elongation % | Reduction of area % |
|---|---|---|---|---|
| Commercially pure (Grade 2) | 448 | 552 | 18 | 32 |
| Ti-6Al-4V, annealed | 855 | 930 | 12 | 20 |
| Ti-6Al-4V, ELI | 758 | 827 | 13 | 22 |
| Ti-6Al-2Sn-4Zr-2Mo, annealed | 910 | 1006 | 10 | 21 |
| Ti-6Al-2Sn-4Zr-6Mo, STA | 1269 | 1345 | 1 | 1 |
| Ti-3Al-8V-6Cr-4Zr-4Mo, STA | 1241 | 1330 | 7 | 12 |
| Ti-15V-3Al-3Cr-3Sn, STA | 1200 | 1275 | 6 | 12 |

## Weld Repair

Weld repair of titanium castings is a normal facet of the manufacturing process and is used to eliminate surface-related defects. Tungsten inert-gas (TIG) welding practice in argon filled glove boxes is used with weld filler wire of the same composition as parent metal. Generally, all weld-repaired castings are stress relief annealed. Excellent quality weld deposits are routinely obtained in proper welding procedure and practice. Weld deposits may have strength but lower ductility than the parent metal because of micro-structural differences due to the fast cooling rate

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of the welding process. Those differences may be eliminated by a post-weld solution heat treatment, but standard practice is for stress relief or anneal only.

## Heat Treating of Titanium Alloys

Titanium and titanium alloys are heat-treated in order to:

- Reduce residual stresses developed during fabrication/casting process (stress relieving)
- Produce an optimum combination of ductility, machinability, and dimensional and structural stability (annealing)
- Increase strength (solution treating and ageing)
- Optimise special properties such as fracture toughness, fatigue strength, and high-temperature creep strength

Various types of annealing treatments (single, duplex, β, and re-crystallization annealing, for example), and solution treating and aging treatments, are imposed to achieve selected mechanical properties. Stress relieving and annealing may be employed to prevent preferential chemical attack in some corrosive environments, to prevent distortion (a stabilization treatment), and to condition the metal for subsequent forming and fabrication operations.

## Why choose titanium castings instead of a wrought titanium product?

The key reason for selecting titanium casting instead of a wrought titanium product is the **cost**. This cost advantage may be attained through increased design flexibility, better utilization of available metal or reduction in the cost of machining or forming parts.

**Properties comparable to wrought. The term castings, often connotes products with properties inferior to wrought products. This is not true with titanium cast parts. They are generally comparable to wrought products in all respects and quite often superior.**

Titanium castings are unlike castings of other metals in strength to their wrought counterparts. Strength guarantees in most specifications for titanium castings are the same for wrought forms. Properties associated with crack propagation and creep resistance are superior to those of wrought products. **Eventually**, **titanium castings can be reliably substituted for forged and machined parts in demanding applications**. This is due to several unique properties of titanium alloys. One of the α+ β to β allotropic phase transformations at a temperature range of 705°C to 1040°C (1300°F -1900°F), which is well below the solidification temperature of the alloys. As a result, the cast dendritic β structure is eliminated during the solid state cooling phase transformation, leading to a α+β platelet structure, which is also typical of β processes wrought alloy. In addition, the convenient allotropic transformation temperature range of most titanium alloys enables the as-cast microstructure to be improved by means of post cast cooling rate changes and subsequent heat treatment.

**Typical ductility of cast products, as measured by elongation and reduction in area, is lower than typical values for wrought products of the same alloys. Its fracture toughness and crack–propagation resistance is equal to or exceeds those of corresponding wrought**

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**material**. The fatigue strength of cast titanium is inferior to that of wrought titanium. However, processing and heat treatment could enhance fatigue strength of a cast titanium alloy product even further.

## Where are titanium alloys used?

Titanium castings are used **primarily** in **three areas of application: aerospace products, marine service and industrial (corrosion) service**. Commercially pure titanium (ASTM grade 1, 2 or 3) is used for the vast majority of corrosion applications, where as Ti-6Al-4V is the dominant alloy for

aerospace and marine applications. Ti-6Al-2Sn-4Zr-2Mo-Si is being selected with increasing frequency for elevated temperature service. Titanium castings are now used extensively in the aerospace industry and to lesser but increasing measure in the chemical-process, marine, and other industries.

Current aerospace applications include major structural fittings weighing over 45 kg each, and small switch guards weighing less than 30 g each, for the space shuttle wings, engine components, brake components, optical-sensor housings, ordnance and other parts of military aircraft and missiles; and engine and brake components for commercial aircraft. Additional aerospace applications include rotor hubs for helicopters, flap tracks for fighters, gas-turbine compressors, and various missile and ordnance parts are actively under development.

Titanium possesses three outstanding characteristics that account for much of its applications in corrosive service particularly the chemical-process industry and petrochemical plants. These are resistance to

- Seawater and other chloride solutions
- Hypochlorites and wet chlorine
- Nitric acid including fuming acids

Such salts as $FeCl_3$ and $CuCl_2$ that tend to pit most other metals and alloys actually inhibit corrosion of titanium. It is not resistant to relatively pure sulphuric acid and hydrochloric acids but does a good job in many of these acids are heavily contaminated with heavy metal ions such as ferric and cupric. Titanium shows surprisingly low two-metal effects because it readily passivates. Titanium shows a pyrophoric tendency in red fuming nitric acid with high $NO_2$ and low water content and, also, in dry halogens.

In the chemical-process industry, components for pumps, valves and compressors are made of cast titanium alloys.

Marine applications include water-jet inducers for hydrofoil propulsion and sea water ball valves for submarines. Titanium castings are also used in various other industrial applications, such as well-logging hardware for petroleum industry, special automotive parts, boat deck hardware and in medicine industry as medical implants. Cast titanium is increasingly being specified for medial prostheses because of its inertness to body fluids, elastic modulus approaching that of bone, and the net shape design flexibility of the casting process. Custom-designed knee and hip implant components are routinely produced in volume. Some of them are subsequently coated

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with diffused bonded porous surface to facilitate bone in-growth or an eventual fixation of the metal implant with the patient's bone structure.