Austral Wright Metals

at the cutting edge

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INTRODUCTION TO TITANIUM & TITANIUM ALLOYS

The use of titanium alloys is expanding from military and aerospace applications. Their unique combination of strength to weight ratio and excellent corrosion resistance, combined with reducing cost, is being increasingly used in the chemical process industries. Titanium and alloys are used for their corrosion resistance, and the high strength of the alloys, which allows the use of light sections.

Titanium has four outstanding characteristics:

- Corrosion resistance, especially in oxidising conditions (used in chemical process equipment, heat exchangers)
  - Titanium and its alloys are resistant to aggressive corrodents such as:
    - Seawater and other chloride salt solutions
    - Hypochlorites and wet chlorine
    - Nitric acid, including fuming acids
- Erosion resistance (used in heat exchangers)
  - Superior resistance to erosion, cavitation or impingement attack make titanium attractive for pumps, piping and high velocity heat exchangers.
- Strength to weight ratio
  - The material is intermediate between steels and aluminium alloys, hence many of the initial applications of titanium alloys in aerospace (used in airframes, landing gear, engine parts)
- Elevated temperature performance
  - Most titanium alloys are satisfactory for continuous service up to 420°C, and some can be used up to 540°C, well above the limit of 120°C for light metals (used in engine parts, chemical processing equipment, heat exchangers)

The excellent corrosion resistance of titanium is due to a thin, stable, protective, highly adherent surface film which forms instantly when a fresh surface is exposed to air and moisture. The strong affinity of titanium for oxygen causes any damage to the film to heal almost instantly, if a trace of moisture or oxygen is present.

Titanium's density is about 55% that of steel, and alloys can be aged to strengths close to high strength steel. Titanium alloys are used extensively in highly loaded structures in aerospace applications. The corrosion resistance of titanium is based on the formation of a tight stable oxide layer on the surface that prevents the corrosive media attacking the base metal.

Chemical Composition
(ASTM B265 – Titanium & titanium alloy strip, sheet & plate

Element	Grade 2	Grade 7	Grade 12	Grade 5
Titanium	Balance	Balance	Balance	Balance
Nitrogen	0.03 max	0.03 max	0.03 max	0.05 max
Carbon	0.08 max	0.08 max	0.08 max	0.08 max
Hydrogen	0.015 max	0.015 max	0.015 max	0.015 max
Iron	0.30 max	0.30 max	0.30 max	0.40 max
Oxygen	0.25 max	0.25 max	0.25 max	0.20 max
Palladium	–	0.12 – 0.25	0.12 – 0.25	0.12 – 0.25
Molybdenum	–	–	0.2 – 0.4	0.2 – 0.4
Nickel	–	–	0.6 – 0.9	0.6 – 0.9
Aluminium	–	–	–	5.5 – 6.75
Vanadium	–	–	–	3.5 – 4.5

Specified Minimum Mechanical Properties

(ASTM B265 – Titanium & titanium alloy strip, sheet & plate

	Grade 2	Grade 7	Grade 12	Grade 5
0.2% Proof Stress, MPa	275 – 450	275 min	345 min	828 min
Tensile Strength, MPa	345 min	345 - 450	483 min	895 min
Elongation, % min	20	20	18	10

COMMON GRADES

The grades commonly used in Australia are the commercially pure 2, and the lightly alloyed 7 and 12. These are all alpha alloys. The alloy grade most frequently used is the alpha - beta alloy containing 6% aluminium and 4% vanadium, commonly known as grade 5 titanium.

Grade 2 (UNS R50400) is commercially pure titanium: it is used for corrosion resistance in the chemical and marine industries, and where ease of forming is needed. Weldability is good.

Grade 7 (UNS R52400) is commercially pure titanium with a small addition of palladium for improved corrosion resistance. It is similar to grade 2, with improved performance in hydrochloric, phosphoric and sulphuric acids. It is used in the chemical industry where media are mildly reducing or vary between oxidising and reducing.

Grade 12 (UNS R53400) is commercially pure titanium with added molybdenum (0.3%) and nickel (0.8%). It is used in the chemical industry where media are mildly reducing or vary between oxidising and reducing. This alloy is particularly resistant to crevice corrosion in hot brines.

Grade 5 (UNS R56400) is the most widely used titanium alloy. It has useful creep resistance up to 300^{o}C and excellent fatigue strength, with fair weldability. It is used for aircraft gas turbine disks and blades, airframe components, prosthetic implants and chemical processing plant.

Austral Wright Metals can supply titanium and alloys as sheet, plate, welded or seamless tube and pipe, bar, castings and forgings.

ASTM Product Specifications

Specification	Title
B265	Titanium and Titanium Alloy Strip, Sheet and Plate
B337	Seamless and Welded Titanium and Titanium Alloy Pipe
B338	Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
B348	Titanium and Titanium Alloy Bars and Billets
B363	Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
B367	Titanium and Titanium Alloy Castings
B381	Titanium and Titanium Alloy Forgings

Structure: Titanium has two crystal structures. Pure titanium at room temperature is hexagonal close packed, known as "alpha" (a) titanium. At 883^{o}C the alpha phase transforms into a body centred cubic phase known as "beta" (ß). The numerous titanium alloys are based on the manipulation of these phases by alloying and thermo-mechanical work.

Alpha alloys contain elements such as aluminium and tin, which stabilise the a structure. The a alloys have better creep properties than beta alloys and are preferred for high temperature applications. The absence of the ductile-brittle transition, which occurs in ß alloys, also makes the a alloys suitable for cryogenic applications. a alloys have adequate strength and ductility, toughness and weldability, but have poor forgeability. a alloys cannot be strengthened by heat treatment.

Alpha - beta alloys have a mixed structure of both a and ß phases, with ß varying 10 - 50 %. The most common alpha - ß alloy, Grade 5 or Ti-6Al-4V, has 6% aluminium and 4% vanadium,. It is difficult to form, but most other a - ß alloys are readily formed. These alloys can be strengthened by solution annealing and aging to high strength. The aging treatment results in the precipitation of alpha, giving a matrix of a and ß phases.

Beta alloys contain additions such as vanadium, niobium and molybdenum, which decrease the temperature of the a to ß phase change, thus promoting the formation of ß. These alloys have excellent forgeability over a wide range of forging temperatures. ß alloy sheet is cold formable in the solution treated condition. ß alloys have excellent hardenability and respond readily to heat treatment, typically solution treatment at 955 – 970^{o}C followed by aging at 450 - 650^{o}C. This treatment results in dispersed particles of a in the retained ß matrix.