Downhole Oil and Gas

In deep sour gas well applications, the exceptional resistance of titanium alloys to attack from H_2S, CO_2, and chloride-rich brines, combined with high strength and low density, make them especially attractive for applications such as packers, tubing strings, liners, safety valves and springs. Numerous titanium alloys are approved for sour service under the NACE MR-01-75 standard for sour brine service temperatures in excess of 250°C.

Petroleum Processing

The need for longer equipment life, coupled with requirements for reduced downtime and maintenance, favor the use of titanium in heat exchangers, vessels, columns and piping systems in refineries and liquid natural gas plants. It is immune to general attack and stress corrosion cracking from hydrocarbons, H_2S, CO_2, ammonia and chloride brines.

Marine Applications

Titanium provides an ideal solution to the problems that have traditionally characterized seawater applications. It is unsurpassed in corrosion immunity for marine service and is not subject to pitting, crevice corrosion, stress corrosion cracking or microbiologically influenced corrosion in natural seawater. Coupled with its low density, high strength and erosion resistance, this means unexcelled performance in terms of service life, weight savings and reduced maintenance costs for the marine design engineer. In fact, titanium performs so well that producers can offer warranties as long as100 years in certain seawater applications.

Beyond its metallurgical characteristics, its availability, low life cycle cost and ease of fabrication make titanium a prime candidate for ship propellers, shipboard heat exchangers, piping systems, and ballast, waste, drain and sprinkling systems. It is also being used on everything from ferries and fishing boats, to naval ships, deep-sea submersibles and submarines. A titanium commercial ship hull has been built and tested, and although its initial cost is higher than a conventional hull, its long life, lower maintenance costs, and reduced fuel consumption could make it more cost-effective over the life of the ship.

Desalination

Excellent resistance to corrosion/erosion and high condensation efficiency make titanium the most dependable material for critical segments of multi-stage evaporation desalination plants. Because welded titanium condenser tubing can be thin-walled, it is cost-competitive with copper-nickel, which it far surpasses in life. It is also used in the rejection, heat recovery and heat input stages.

Armor/Armament

The application of titanium in ballistic armor is focused on two areas: armored vehicles and ordnance, and personal armor. On tanks and ground vehicles, titanium reduces weight to enhance airlift transportability and fighting force mobility. In comparison to traditional rolled homogenous armor, titanium offers an excellent strength-to-weight ratio, good ballistic properties and multi-hit capacity, corrosion resistance and weldability /machinability. In addition to hull armor, titanium is used for turrets, hatches and suspensions, which, when made of steel, can account for over 50% of a tank's weight. Titanium is also being used in field guns, notably the Ultralightweight Field Howitzer (UFH) where helicopter, transporter aircraft and ship can transport its 3,745kg weight.

Metal Recovery and Finishing

Hydrometallurgical extraction of metals such as nickel from ores in titanium reactors is an environmentally safe alternative to smelting. Extended lifespan, increased energy efficiency and greater product purity are promoting the use of titanium electrodes in electro-winning and electro-refining of metals like copper, gold, manganese and manganese dioxide.

Chlor-Alkali Processing

The unique electrochemical properties of titanium make it the most energy efficient choice for dimensional stable anodes (DSA's) used for the production of chlorine, chlorate and hypochlorite.

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Pulp and Paper

Due to the recycling of waste fluids and the need for greater equipment reliability and lifespan, titanium has become the standard material for drum washers, diffusion bleach washers, pumps, piping systems and heat exchangers in the bleaching section of pulp and paper plants. This is particularly true for equipment developed for chlorine dioxide bleaching systems.

Flue Gas Desulphurization

Laboratory studies and field experience have proven titanium has exceptional corrosion/erosion resistance in scrubber systems, ducting and stacks used to remove pollutants from waste gases. Its long life makes it a prime candidate for pollution control systems.

Food and Pharmaceutical

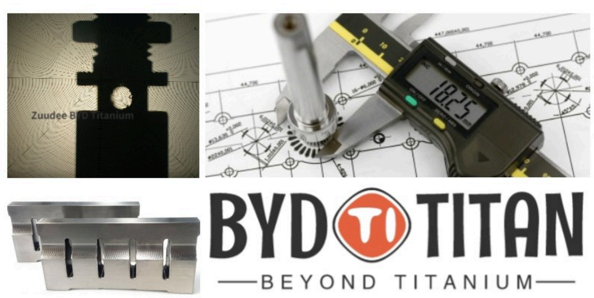
Titanium demonstrates excellent corrosion resistance, not only to various food products and pharmaceutical chemicals, but also to the cleaning agents utilized. As equipment life becomes a more critical factor in financial evaluations, titanium equipment is replacing existing stainless steel apparatus. Titanium can also eliminate the problems of metal contamination.

Nuclear Waste Storage

Nuclear waste must be stored safely for hundreds of thousands of years. Titanium's proven resistance to attack from naturally occurring geologic fluids, as well as its extremely short half-life, makes it a prime candidate for multi-barrier disposal systems.

High Technology

Titanium's temperature and corrosion resistance and strength have created a major role for the metal in such applications as sputter targets (for integrated circuits); super-conducting alloys (50%Nb - 50%Ti used in electromagnets and energy storage and transmission); shape memory alloys (50%Ni – 50%Ti used in spring coils in solenoids and linear motors); computers (hard drive substrates); and optical systems.



Metal Matrix Composites

Titanium is being researched as a matrix material for industrial, and potentially, aerospace applications. While offering an elevated-temperature resistant, ductile base, titanium can be further strengthened with the addition of ceramic or intermetallic compounds in fiber or particulate form to produce properties beyond those achieved by alloying alone. Current developments using SiC fiber reinforcements could permit titanium base composites to replace nickel and steel alloys in higher temperature and higher modulus applications.

Titanium Aluminides

This class of materials, typically with titanium-aluminum ratios of 1:1 to 1:3, represents the next generation of alloys intended to push the applications of titanium beyond the traditional 1100°F barrier. Two types of aluminides are currently under investigation. The alpha 2 aluminide, typified by the Ti_3Al intermetallic compound, shows potential in gas turbine engines; the gamma aluminides, represented by the TiAl formula, are the research material of choice for all other applications. Variations of both types, containing a variety of alloying elements, are being studied to overcome the inherent low ductility and fabricability of these compounds, which have prevented significant applications.

Ferro-Titanium

The low quality portion of available titanium scrap is recycled to make ferrotitanium, which is mainly used as an microalloy additive to steel and stainless steel. Ti acts as a "getter" to tie up unwanted interstitial elements (oxygen, nitrogen, carbon, and sulfur) for improved ductility and formability. In ferritic carbon steels, it is also used for the production of high strength low alloy (HSLA) steels using the strengthening effect of TiC precipitation in the ferrite. Total Ti additions may range from 0.005% to 0.15% by weight.

Other Industrial Applications

These include anodes for cathodic protection (used to prevent corrosion of other metals); electro-chemical processes (such as electro-plating and anodizing); deep drilling (as in geothermal energy exploration); hand tools; tool and machinery coatings (to enhance high speed performance and extend life); and heating elements. $TiCl_4$ is also used as an active ingredient in the catalysis of high density and linear low density polyethylene according to the Sclairtech process.

Commercial and Consumer: Adding Value in Hundreds of Common Uses

A combination of factors is expanding the traditional uses for titanium to encompass a wider and wider range of applications. The titanium industry has done extensive missionary work, increased capacity to meet growing demand and there is a better understanding of how to work with the metal.

Sporting Goods

One of the first and most visible consumer uses of the metal was in titanium golf clubs. Because it is light and strong, club heads from titanium can be bigger, affording a larger "sweet spot" to improve distance and accuracy.

The Ti-3Al-2.5V alloy has cost-effectively demonstrated the properties needed for other successful sports applications: good strength-to-weight ratio, low modulus of elasticity and excellent dampening characteristics. For these reasons, bicycle frames and parts, tennis racquet frames, skis, pool cue shafts and baseball bats are all currently being fabricated from the metal. Lacrosse sticks and snowshoes are also made of titanium.

Consumer Goods

Titanium's inherent beauty and unique blend of physical properties make it a natural choice for many consumer uses, including jewelry, wrist watches, eyeglass frames, wedding rings, camera bodies, and even loudspeakers and non-stick coatings.

Medicine

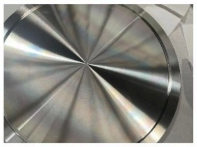
With complete resistance to attack by body fluids, plus high strength and low modulus, titanium is the most biocompatible of all metals. It was first used in surgery in the 1950'sand now is widely used for human prosthetic and replacement devices (hip replacements, expandable rib cages, spinal implants, etc.) Titanium will actually allow bone growth to adhere to the implants, so they last longer than those made of other materials. Reconstructive titanium plates and mesh that support broken bones are also commonly used today. Pace-maker cases and artificial heart valves are being fabricated from titanium, as are dental fixtures (replacement teeth, crowns, braces, etc.). Durability and lightweight have led to its use in wheelchairs. The metal is also widely used to fabricate surgical devices and centrifuges.

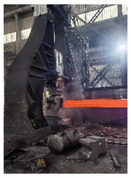
Architecture/Construction

As a building material, titanium out performs every other architectural metal and is gaining rapid acceptance. Due to its mechanical and physical properties, corrosion resistance and attractive appearance, it is used for exterior cladding, roofs, fascia, canopies and dozens of other building purposes. It is also used in outdoor art and sculptures, for its weather resistance and striking beauty. Because it is totally immune to corrosion in all environments, including marine and industrial, it is a highly practical choice when life cycle and maintenance costs are considered. Commercially pure titanium, ASTM Grade 1, is most often specified for architectural applications.

Automotive

With the sheer size of the world automotive market, even a small amount of titanium in every car would create a huge demand for the metal. Because cost is a major factor in passenger vehicles, the industry's emphasis has been on developing low cost titanium products. Designs that exploit titanium's unique characteristics can yield parts that more than pay for themselves with better performance and a longer life. Factors such as fuel economy, emissions legislation and longer warranties are compelling automotive engineers to consider titanium as a "value engineering" solution.





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In commercial engines, evaluations have demonstrated that titanium valve trains can improve fuel efficiency by 4% and they are being evaluated in several engines. Suspension springs, engine springs, exhaust systems and brake pads are all being investigated. Small quantities of titanium are being used in high-end cars such as a muffler on the Corvette and springs on a VW model.

Effort is also being placed in the racing market. Titanium is now used for high performance vehicle components such as valves, valve springs, rocker arms, connecting rods and frames, due to its high strength, low weight and corrosion resistance. Titanium was used in recent years for the fuselage skin of a test vehicle that broke the world land speed record. The automotive and motorcycle after markets are also active.