Introduction to Titanium

"The two most useful properties of the metal form are corrosion resistance, and the highest strength-to-weight ratio of any metal.[4] In its unalloyed condition, titanium is as strong as steel, but 45% lighter.[5] There are two allotropic forms[6] and five naturally occurring isotopes of this element; ^{46}Ti through ^{50}Ti with ^{48}Ti being the most abundant (73.8%).[7] Titanium's properties are chemically and physically similar to zirconium."
(Source: wikipedia.org)

"Titanium is the fourth most abundant metallic element in the earth's crust. It occurs chiefly as an oxide ore. The commercially important forms are **rutile** (titanium dioxide) and **ilmeite** (titanium-iron oxide), the former being richest in titanium content. Metallic titanium was first isolated in impure form in **1887** and with higher purity in 1910. However, it was not until the **1950's** that it began to come into use as a structural material. This was initially stimulated by aircraft applications. A modern and comprehensive document on the subject is the second edition of the classic ***CORROSION BASICS*** textbook.

"Although the aerospace industry still provides the major market, titanium and titanium alloys are finding increasingly widespread use in other industries due to their many desirable properties. Titanium is a unique material, as strong as steel with less than 60% of its density but with excellent corrosion resistance. Traditional applications are in the aerospace and chemical industries. More recently, especially as the cost of titanium has fallen significantly, the alloys are finding greater use in other industry sectors, such as offshore.

"Titanium is a very reactive metal that shows remarkable corrosion resistance in oxidizing acid environments by virtue of a passive oxide film. Following its commercial introduction in the 1950's, titanium has become an established corrosion resistant material. In the chemical industry, the grade most used is commercial-purity titanium. Like stainless steels, it is dependent upon an oxide film for its corrosion resistance. Therefore, it performs best in oxidizing media such as hot nitric acid. The oxide film formed on titanium is more protective than that on stainless steel, and it often performs well in media that cause pitting and crevice corrosion in the latter (e.g., seawater, wet chlorine, organic chlorides). While titanium is resistant to these media, it is not immune and can be susceptible to pitting and crevice attack at elevated temperatures. It is, for example, not immune to seawater corrosion if the temperature is greater than about 110^{o}C (230^{o}F)."
(Source: www.corrosion-doctors.org)

"The most noted chemical property of titanium is its excellent resistance to corrosion; it is almost as resistant as platinum, capable of withstanding attack by acids, moist chlorine gas, and by common salt solutions.[6] Pure titanium is not soluble in water but is soluble in concentrated acids.[21]

"This metal forms a passive and protective oxide coating (leading to increased corrosion-resistance) when exposed to elevated temperatures in air, but at room temperatures it resists tarnishing.[18] When it first forms, this protective layer is only 1–2 nm thick but continues to slowly grow; reaching a thickness of 25 nm in four years.[8]"
(Source: wikipedia.org)

"Titanium is nearly twice as flexible as steel.

"Titanium has been recognized as an element for over 200 years. As the Earth's fourth most abundant structural metal, the current worldwide supply of titanium is virtually unlimited. Its unique combination of lightweight, high strength, low modulus and corrosion resistance has made this a desirable metal for critical applications. Titanium and titanium alloys offer engineering advantages such as:

- High strength to weight ratio,
- Low Density – approximately half the weight of steel,nickel and copper alloys,
- Inherent Flexibility – an elastic modulus that is approximately 55% of steel,
- Extended Fatigue Life – more than twice that of steel,
- Exceptional Corrosion Resistance – resists chlorides, seawater, sour and oxidizing environments,
- Superior Erosion Resistance – erosion corrosion, cavitation and impingement in flowing turbulent fluids,
- Non-magnetic.

(Source: Titanium Drill Pipe for Ultra-Deep and Deep Directional Drilling; Jackie E. Smith, SPE, Grant Prideco; R. Brett Chandler, SPE, Grant Prideco; Patrick L. Boster, SPE, RTI Energy Systems)

"Titanium will frequently be competitive on first cost, and will always be the winner in the life cycle cost contest.

"A pilot project in 1994 by Elf Petroleum Norge for the Frigg platform produced results showing that the installed cost of titanium on a 200m by 15cm 2MNm-2 sea water line was 20% below that of carbon steel. The use of cold bending, eliminated more than 80% of the welding work. Fewer bends and fittings were needed and there was less welding. Flanged joints were made by cold flaring of the pipe ends. The low weight of the titanium pipe considerably eased installation - one man can handle a 6m length of 15cm diameter schedule 10s pipe without assistance. Post installation surface treatments, shot blasting and painting of the titanium were not required."
(Source: Titanium for Offshore Applications)

"The high strength and low density of titanium (~40% lower than that of steel) provide many opportunities for weight savings. The best example of this is its use on the landing gear of the Boeing 777 and 787 aircraft and the Airbus A380. Figure 1 shows the landing gear on the 777 aircraft.1 All of the labeled parts are fabricated from Ti-10V-2Fe- 3Al. This alloy is used at a minimum tensile strength of 1,193 MPa; it is used in replacement of a high-strength low alloy steel, 4340M, which is used at 1,930 MPa. This substitution resulted in a weight savings of over 580 kg. The Boeing 787 used the next-generation high-strength titanium alloy, Ti-5Al- 5V-5Mo-3Cr, which has slightly higher strength and some processing advantages. The use of titanium in landing gear structure should also significantly reduce the landing gear maintenance costs due to its corrosion resistance. The low density and high strength make it very attractive for reciprocating parts, such as connecting rods for automotive applications."
(Source: Attributes, Characteristics, and Applications of Titanium and Its Alloys)

"When British clergyman and mineralogist William Gregor discovered titanium in Cornwall, United Kingdom in 1791, little did he know about the implications of his unique find. He had no idea that this unknown metal - that was later named after the Titans of Greek mythology - would be his legacy. Gregor succumbed to tuberculosis on June 11, 1817, but his discovery lives on. Today, titanium is known as a space-age metal because of its many uses. Chief among these is the metal's use in aerospace engineering.

"Why is titanium an ideal engineering material in the aerospace industry? There are several reasons, many lying with titanium's unique properties. This metal has a high strength to weight ratio, making it strong as some steels but 45 percent lighter. When alloyed or combined with iron, vanadium, molybdenum and other elements, titanium can make strong, lightweight materials for jet engines and spacecraft.

"Due to its ability to resist corrosion and high temperatures without creeping or deforming, titanium is widely used in aircraft, armor plating, ships and missiles. Titanium alloys are also utilized for various components like structural parts, fire walls, landing gear, exhaust ducts, and hydraulic systems.

"About two-thirds of all titanium made finds its way in aircraft engines and frames. A good example is the Lockheed SR-71 "Blackbird," an advanced, long range reconnaissance aircraft that first hit the skies in 1966. Designed by aircraft engineer Clarence Leonard "Kelly" Johnson, the Blackbird was fast enough to outrace threats and served the U.S. Air Force up to 1998.

"The Boeing 777 or "Triple Seven" is another aircraft that carries 5.9 metric tons or 130,000 pounds of titanium. Made by Boeing Commercial Airlines, the Triple Seven is the world's largest twinjet and has room for over 300 passengers. Other aircraft with titanium are the Boeing 747 (45 metric tons), the Boeing 737 (18 metric tons), the Airbus A340 (32 metric tons), and the Airbus A330 (18 metric tons). In engine systems, titanium is used in rotors, compressor blades, and hydraulic system components, among others. Indeed, Gregor is no longer with us but his legacy lives on."
(Source: Why Titanium Is Used In Aerospace Engineering)

“Titanium is as strong as steel, but 45% lighter. It is 60% heavier than aluminum, but twice as strong.

“Alloys of titanium are principally used for aircraft and missiles where lightweight strength and ability to withstand extremes of temperature are important.

“Titanium has potential use in desalination plants for converting sea water into fresh water. The metal has excellent resistance to sea water and is used for propeller shafts, rigging, and other parts of ships exposed to salt water.”
(Source: Los Alamos National Laboratory's Chemistry Division)