Titanium

Application

posco

Contents

1. Aerospace

Aircraft Component

Why Titanium?

- Superior corrosion resistance, High specific strength (to 400~500˚C)
- Making an aircraft light, Reduction in weight, the size of engines, the cost of fuel and management
- Increase of the proportion of titanium alloy to 15% replacing aluminum with titanium
- Pylons which are fitted with an engine and components which are fitted with landing gears should be made of the material that has high mechanical strength, elongation, fracture toughness, and fatigue strength.
- Mainly Ti-6Al-4V alloy

Application

- Structural beam of landing gear, Flap tracks, Spoiler, Engine nacelle, Bulkhead, Spar, Fastener, Bolt, Nut, Leading edge, Front window frame of cockpit, Door, Pressure gauge, etc.
- Fitting of main wings and tails, Hinge of the door, Pylon
- Ex) Boeing B777, Airbus A380

Boeing B777 landing gear

Airbus A380

1. Aerospace

Aero Engine

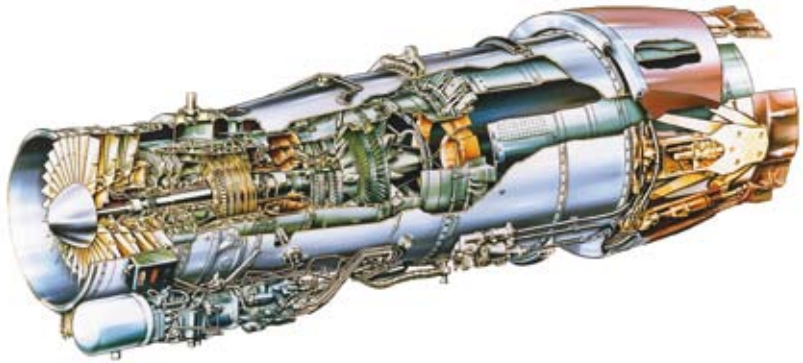
Why Titanium?

- The bigger the components, the heavier the static weight, the more dynamic overload by centrifugal force → Adoption of a titanium alloy which is light and strong
- If fan blades (bodies of rotation) are too heavy, rotational stress hurts the disk which supports blades.
- Titanium alloys occupy 40% of the whole weight of aero jet engines.

Application

- Aero engine duct, Turbine blade
- Rotating parts (Intake fans, Blades, Blades for compressors),
  Static parts (Inhalers, Burners, Discs, Vanes, Shafts)

Airbus A380 engine



Mimetic diagram of aero engine

1. Aerospace

Helicopter

Why Titanium?

- Components for helicopters should be light, solid, and superior in fatigue strength and corrosion resistance.
  → Titanium alloys are excellent.
- For a helicopter gunship, titanium alloys occupy 10% of the whole weight of the body.

Application

- Components of rotors/flying control, Components of structure/hydraulics, Transmission components
- Ex : Westland Super Lynx, US Rah-66 Comanche, V-22 Osprey which is propelled by tilt rotors

CH-53E Super Stallion (Titanium rotor)

V-22 Osprey's tilt rotor

1. Aerospace

Space

Why Titanium?

- Importance of high strength and light weight (It should endure the limit of stress in a short time → Specific strength and thermal resistance are important.)
- It should keep the strength at a high temperature (High speed → Increase of surface temperature).
- The lighter the body, the better performance of rockets, The importance of fracture toughness to endure shocking load → Use of titanium alloys for components of rockets because of high specific strength and ductility
- Corrosion resistance is needed to endure oxidizers in a fuel tank.
- Use of components which are complexly shaped for maximizing functions in a limited space → Demands for metals superior in formability → Titanium alloys are suitable

Application

- Titanium alloys for aero-structures and engines of high temperature
- Fuel tank (Satellite), Chamber of rocket, Rocket booster, Wings
- Impeller for liquid fuel engines, Motor case for the top of engines, High-pressure tank for space shuttles and pipes for oil pressure

B747 Engine fan

External fuel tank of space shuttle

Space shuttle

2. Military

Space

Why Titanium?

- Corrosion → No worries about inspection of components and exchange
- Low thermal expansion → Low transformation against heat load
- Corrosion resistance and lightness simultaneously
- High specific strength → Efficiency of structure
- Low elasticity and density → Crashworthiness for high survival rate
- Superior bullet-proof property, Various weldability and production

Application

- Used in combat aircraft about 7~8% of usage throughout the world (1/3 of the entire U.S. usage)
- Ground gear : Armor plate, Hatch, Cannon, Barrel of rifle, Bullet-proof material, etc.
- Maritime gear : Submarine, Warship, Aircraft carrier's catapult, Destroyer, etc.

K-11 (Titanium alloy at a barrel of a gun)

M2A3 (Titanium armor)

SR-71 (Titanium 95% of the total weight)

3. Vehicle

- The rise of problems related to environment, energy, durability, and reliability → Improvement of fuel efficiency and adoption of new nonferrous materials have become key technologies.
- High specific strength and specific ductility → Promising material for car body which should be light and crashworthy
- Superior specific fatigue strength → Good for engine components

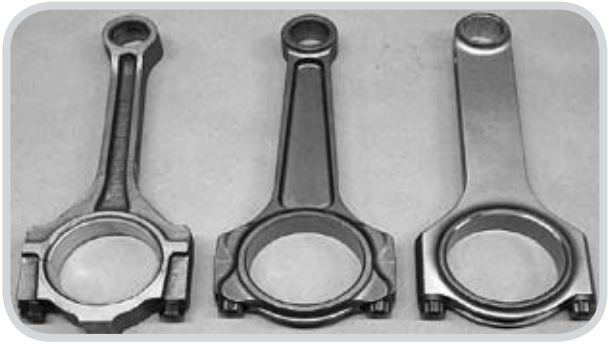
Car Components

Connecting Rod

- Promotion of lightness → Reduction of inertial mass → Realization of miniaturization and lightness
- High power, Reduction of noise and vibration by reduction of friction, Improvement of fuel efficiency
- Weakness : Transformation, Fatigue failure of bolt, Abrasion by difficulty of lubrication

Valve

- The most widely used among car components
- Light weight → Improvement of fuel efficiency → Improvement of reducing noise → Realization of high power
- Need for efforts to reduce price and save costs



Connecting rod

Valve

3. Vehicle

Valve retainer

- Possible to manufacture with simple forging and machining
- Promising in its economical aspect. Easy to apply
- Improvement of engine efficiency because of light weight
- Now using in a high-class motorcar and sports car
- Expanding application parts to body and sash

Spring

- High specific strength, Relatively low modulus elasticity → Possible to manufacture car springs which have high fatigue strength and light weight

Exhaust silencer

- Light weight, High specific strength, High corrosion resistance, Artistic surface treatment
- High ductility, High strength → Reduction in thickness and weight of components
- Lightness → Contribution to improve fuel efficiency and protect environment

Titanium valve retainer set

Porche 911 Coupe (Titanium valve retainer)

Titanium exhaust silencer

Spring

3. Vehicle

Bike Silencer

- A component which decides external beauty
- Commercialized as a material for bike silencers by artistic surface treatment, corrosion resistance against high temperature, and anti-oxidation properties
- Having a great ripple effect on improving the whole performance including fuel efficiency and driving
- Low thermal expansion coefficient, Favorable in terms of fatigue characteristics of thermal cycle
- Special appearance in terms of design, Increase of sales by hundreds of tons per a year
- The most successful application as a single product for bikes

Titanium silencer

A bike applied titanium silencer

4. Shipbuilding

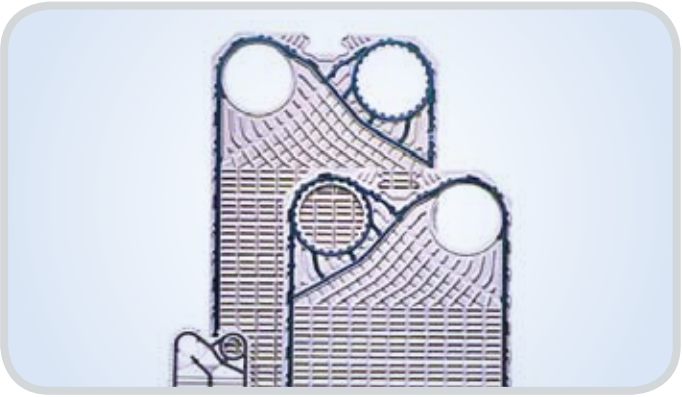
Body

- Lightness → Possible to make engines small → Increase of fuel efficiency more than 20%
- Saving maintenance costs (Ex : Marishiten Ⅱ(yacht for racing), Titan ready, Ashahi Maru Ⅱ, Sho Maru)

Apparatus

- Key, Shaft bracket: Light weight is favorable
- Engine condensing tube, Silencer : Better corrosion resistance against high temperature compared to aluminum, Light, Soundproof
- Tube and valve for seawater : Increase of corrosion resistance and lightness if made of titanium
- Plate heat exchanger, Inverter container, Yacht, Rescue equipment

118 Wally Power applied with titanium exhaust system



Titanium plate for plate heat exchanger

5. Ocean

- Used in ocean facilities and shipbuilding installed in the ocean to drill oil and gas from deep sea / particular purpose for weather research
- Cutting edge and higher value-added business mixed with shipbuilding and engineering technologies
- Use of titanium component in drilling ship, FPSO (Floating Production Storage and Offloading), leg ship. TLP, semi-submersible floating structure, equipment for submarine pipeline, floating loading and unloading facilities
- The amount of titanium in drilling industry : 3,000 tons (Annually increasing)
- Importance of weight working on deep sea → Replacement of components with titanium's in oil and gas drilling industries.
- Main characteristics
  - High tensile /compressive/specific strength in a static environment
  - Ductility by low elastic coefficient
  - High fatigue strength on welded part in low the seawater temperature
  - Resistance of chemical corrosion at a high temperature with oil (300°C), Corrosion resistance against seaward wind/dust
  - Superior fatigue strength, crashworthiness, and solidity against dynamic environment by sea wave

FPSO (Floating Production Storage and Offloading)

5. Ocean

Oil Drilling

Drilling Riser

- Use of a titanium alloy
- Need for lightness and high corrosion resistance to drill crude oil and gas, Necessary to endure kinetic fatigue
- Reduction in maintenance costs / Improvement of productivity → Economical although early investment costs are expensive

Drilling Pipe

- Need for ductility, high corrosion resistance and high tensile strength
- SRD (Short-radius Drill) : Use of an alloy (Increase of transformational ductility according to low elastic coefficient, Resistant against corrosion in seawater)
- Extended Reach Drilling Pipe : It should be able to endure tensile stress and deformation stress by seawater because it is linked to ocean floor.
- Trend to replace it with titanium's

Drill Pipe

Drill Riser

Statfjord Platform (operated since 1982)

5. Ocean

Heat Exchanger

- Excellent corrosion resistance against seawater
- Not getting dirty and rusty if used for a long time
- Appropriate for heat exchangers

Titanium plate used for plate heat exchanger

Plate heat exchanger

Others

- Seawater pipe, Valve, etc.

Titanium pipe

5. Ocean

Deep Submersible Vehicle/Submarine

Why Titanium?

- Possible to increase depth of exploration to 3,600m by replacing Fe, Al components (1,800m) with titanium's
- No corrosion in the sea, High tensile strength and fatigue strength

Application

- Pressure-resistant container

Haemiri (Deep submersible vehicle, Korea)

ShinKKai6500 (しんかい 6500, Deep submersible vehicle, Japan)

Project 705 Lira (Alfa class submarine, Russia)

5. Ocean

Desalination

Why Titanium?

- Global warming, Desertification → Acute shortage of water
- Need for drinking, agricultural and industrial water according to increase of the population → Consideration of ways to use seawater
- Pure titanium: Stable against interstitial corrosion and hydrogen embrittlement

Application

- Pipe for heat exchanger
- Heat pipe, Condensing tube, Pressure container

Shipment of desalination facilities

Desalination plant being constructed in Saudi Arabia by Doosan Heavy

Tube heat exchanger

5. Ocean

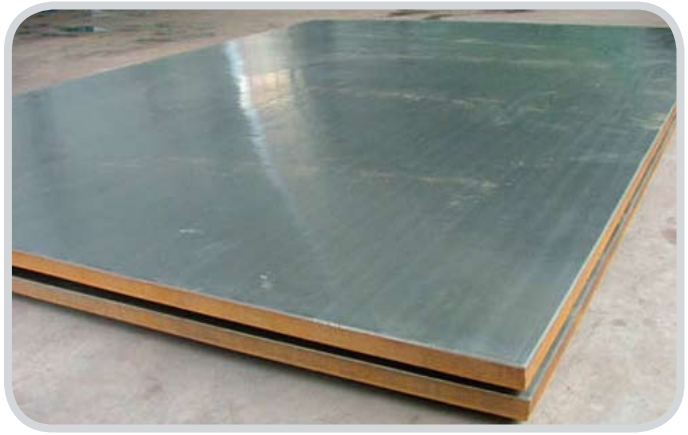
Ocean Engineering

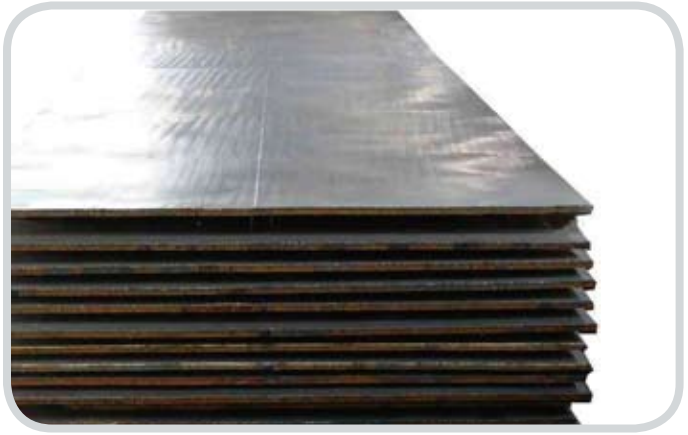
Why Titanium?

- Increase of landfast bridge buildings linking land and islands → Time to have interest in design and construction using titanium for long life

Application

- Clad lining : Impossible to weld with steel → Use of clad plates for physical combination (Not found problems about corrosion for 20 years)
- Offshore platform, Corrosion-resistant structure including tunnel under the sea, Lining of pier





Titanium clad plate

6. Plant

Condensing Facilities

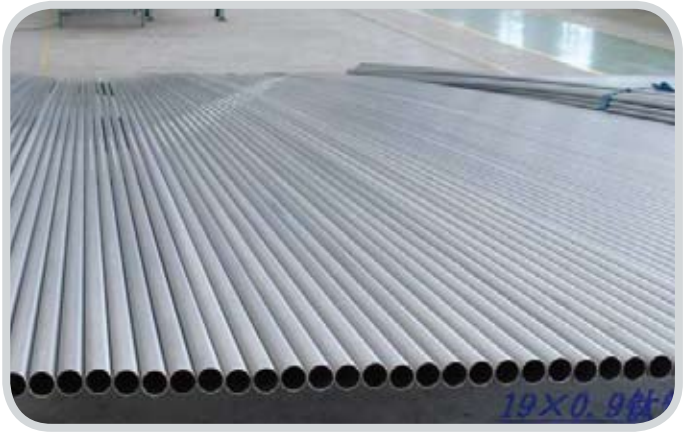
Why Titanium?

- Need for superior corrosion resistance against seawater used for cooling water → Use of large quantities of tubes made of pure titanium grade 2
- Use of pure titanium or titanium-clad materials for plates combined with tubes
- Improvement of thermal efficiency (No problems with corrosion, abrasion, attachment of seaweed)

Application

- Manufacturing components for turbines and condensers of secondary system
  〈cf〉 Primary system : Conversion of energy input
  Secondary system : Production of vapor → Generation of electricity using turbine → Exchange of heat
- Materials of condenser tubes, plates for fixing tubes, and steam turbine's wings of low-pressure area
- Plate for fixing tubes : Maintaining condensing system at the entrance of seawater
  Use of titanium grade 1 (Good for fabrication)

Tube heat exchanger for condenser



Titanium tube for condenser

6. Plant

Nuclear Plant

Why Titanium?

- Stable materials should be used in corrosive environment because safety is the first priority.
- Not radiated if exposed to radioactivity, Short half-life of a radioactive isotope
- Located near the sea to procure cooling water → Use of welded tubes made of pure titanium as cooling pipes for absolute stability against corrosion (More than 100 tons of welded titanium tubes per a plant)
- Making wings of the turbine light enables wings to be longer → Increase of thermal efficiency → Possible to make a generator small → Expected to increase usage considering the increase of oil price

Application

- Wings of steam turbine's low-pressure area in secondary system, Tube condenser for heat exchange, Plate for supporting condenser tubes

Modern nuclear plant

Condenser for nuclear plant

7. Chemistry

- Main area of consume in Korea
- Key components in chemical industry manufacturing products which should be operated in acid environment
- Almost pure titanium
- Development of chemical industry which produces various products, Time to change existing chemical plants' old facilities → Increase of usage in chemical plants' facilities including titanium heat exchangers

Chemical Plant

Why Titanium?

- Incorrodible in bromide solvent of high temperature and pressure → Use of large quantities of titanium in a condenser (A component of main process)

Scenery of Samsung chemical plant (Daesan, Korea)

Application

- Manufacturing industry: Manufacturing and collecting terephthalic acid, acetaldehyde, acetate and bleaching pulp
- Mostly used in terephthalic acid manufacturing plants (200 tons of titanium per one terephthalic acid plant)
  〈cf〉 Terephthalic acid: Raw material for polyester fibers and PET bottles

Terephthalic acid plant

7. Chemistry

Heat Exchanger

Why Titanium?

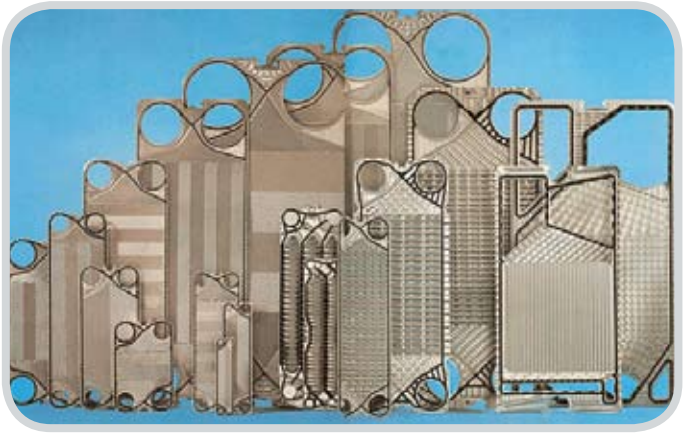
- Superior corrosion resistance against seawater
- Reduction in maintenance costs

Application

- Tube heat exchanger : Application to big facilities including oil refinery, chemical plant, Multi-Stage Flash desalination
- Little loss of pressure, Able to endure high pressure
- Plate heat exchanger : Light, Possible to make it small (Mainly made of grade 1 having good ductility for complicated wave-patterned fabrication)
- Plant, Oil refinery, Chemical plant, Desalination facilities, Vapor compressor, Offshore facilities, Submarine, Pool, etc.

Tube heat exchanger

Plate heat exchanger



Plates for heat exchanger of various forms

7. Chemistry

Nickel Refining Plant

Why Titanium?

- Insufficient corrosion resistance against sulfuric acid, but good under the existence of oxide ion
- Good corrosion and erosion resistance against chloride
- Chosen as the most excellent material comprehensively

Pulp, Paper

Why Titanium?

- Chemically stable material
- A material for light components for consecutive process and miniaturization
- A material of a closed circuit system to prevent pollution
- Considered as the best material according to price competitiveness against persisting period

Application

- Used in bleaching process
- Diffuser screen, Revolving scraper, Shaft, Cleaning pipe, Nozzle, etc.
- Mainly pure titanium grade 2, Use of an alloy when needed strength (Bolt, Key)

Others

- Caustic soda
  〈cf〉 Caustic soda : Main material to produce a soap. Basic chemical material used in various manufacturing industries
- Chemical equipment : Valve, Pump, Tube, Connecting components, Heater, etc.

8. Food

- Not being flowed out of metal ion and corroded by processing with heat and maturity → No response to food
  → No change of flavor and nutrition
- No worries about corrosion by microorganism, Harmless when eating it with food

General Food Processor

Why Titanium?

- Particularly strong corrosion resistance against large quantity chloride and strong acid → Used for a material of various food processors (Ex : Processors for soy sauce, mayonnaise and ketchup sauce)

Application

- Coffee roaster, Coffee maker
- Tanks of various forms, Pipe, Stirring screw, Valve
- Plate heat exchangers are used in the process of making beer and juice that need heating and cooling

Titanium coffee maker

Titanium blender

8. Food

Brewing

- Titanium tanks to exclude ferrous ion from liquor
- The wine manufactured in pure titanium container is matured faster.
- Used in containers to make wine matured in Russia

Alkali-ion Water Purifier

- Use of platinum-plated titanium electrode
- A highly corrosion-resistant titanium is used because elution happens from electrode first and it reduces the life of water purifier.

Alkali-ion water purifier having titanium electrode

9. Construction

- Installation of construction considering environment and beauty of the city is increasing although expensive
- Growing usage of titanium applying to various constructions led by developed countries

Why Titanium?

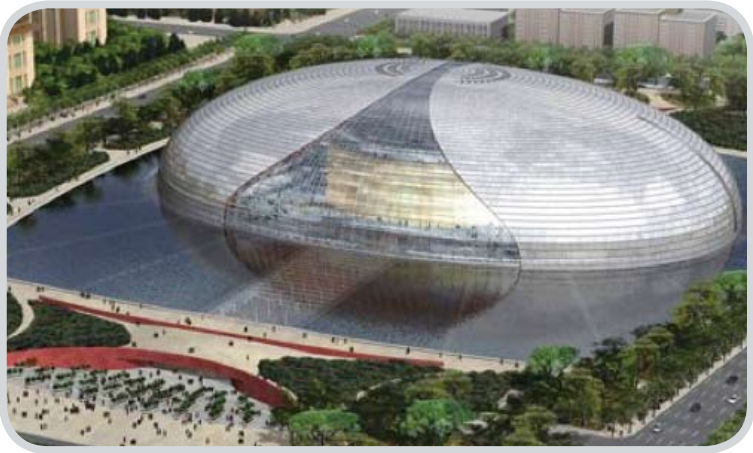
- Corrosion resistance: Resistant to sulfur including acid rain, emission gas, and interstitial corrosion
- High specific strength, Lightness : Appropriate for roofs of the construction in snowy area
- Nonflammability : Low thermal conductivity and expansion, Resistant to transforming and stress by climate, Appropriate for decoration of the building, Fire-resisting material
- Processability : Strong but ductile, Easy to be transformed because of low elastic coefficient, but restored when stress is removed
- Weldability : Possible to weld various forms of structures in atmosphere which controls a reaction to oxygen
- Design : Various colors according to the thickness of coating, Various surface treatment
- Anti-climate and eco-friendly: No oxidation against changes of climate and temperature with strong oxide coating. Keeping beautiful surface for a long time
- Chemistry resistance : No response in corrodible gas atmosphere including sulfur
- Saving maintenance costs

Titanium roof that is applied to Kyushu National Museum, Japan

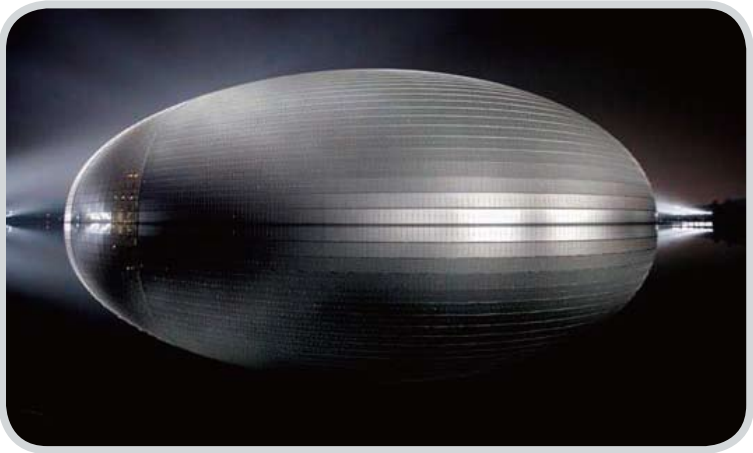
Application

- Outer wall, Roof, Decoration, Interior, Monument, Handrail, Tube, etc.

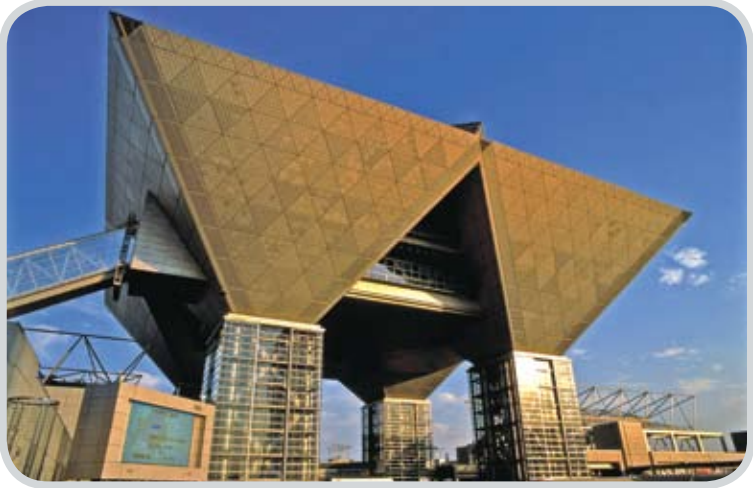
9. Construction



National Grand Theatre, Beijing



National Grand Theatre, Beijing



Big Sight, Tokyo

Marques de Riscal Winery Hotel, Spain

9. Construction

Reference: Guggenheim Bilbao Museum, Spain

Overview

- Architect : (Frank O. Gehry)
- Lot area : 32,700㎡
- Exhibition space : 10,560㎡
- Construction period : 7 years
- Production costs : $150,000,000
- Exterior : 30,000 sheets of titanium plates (Thickness : 0.5mm)

Modifier of the museum

- Museum itself is more famous than exhibits.
- Creation of the word “Bilbao Effect”
- 3rd largest membership in Europe.
  (1st : Louvre, Paris / 2nd : Tate Modern, London)
- Museum which makes the Basque Provinces, industrial city gone downhill world-wide sightseeing city (1 million tourists visit here a year)

Evaluation

- A model of deconstruction which broke stereotype of rectangular parallelepiped
- Different colors according to different weathers and angles
- Despite public worries about waste of budget and cultural subordination, long-term perspective, invest, bold decision of the government and unremitting practice created “Bilbao Effect”.

10. Medical Device

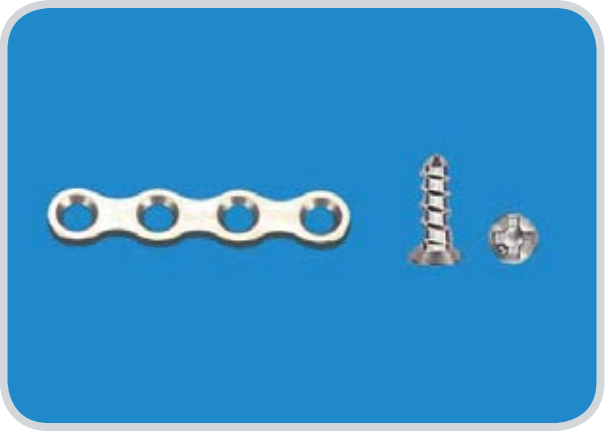
Why Titanium?

- Corrodible atmosphere like seawater in body fluid
- Although used in the body for a long time, ingredients of equipment should not be disassembled and flowed in the body.
- Non-toxic, Superior bioaffinity

Application

- Used to replace functions of bones → Trying to develop a new alloy having low elastic coefficient because its elastic coefficient is higher than bone's.
- Increasing usage to replace functions of bones (Not forming fibrous tissues in the body)
- Implant, Artificial bone/joint, Operating equipment, Superconducting magnet for MRI

Implant



Titanium bones and plates

Mechanical heart

11. Sports, Leisure

Golf Club

- Mostly used gear among sporting equipment (More than 60% of sales in ball games market)
- Use of titanium alloys in head of a driver and part of a putter
- Favored as a material of a driver because light and strong titanium speeds swing and increases repulsive power
- Large amount of impact when hit a ball → Ought to be strong and have low elastic coefficient not to be broken → Use of titanium alloys

Scuba Diving

- Light, strong, wearable and corrosion-resistant against seawater
- Application : Valve of oxygen cylinder, Regulator, Knife and watch for scuba diving, Underwater camera

Regulator

Knife for scuba diving

11. Sports, Leisure

Fishing Gear

- Excellent corrosion resistance against seawater
- Use of pure titanium and alloys
- In Japan, nets are made of titanium wires and used in cultivation of fish in an inclosing net. Almost permanently used
- Application: Reel for sea fishing, Fishing gut, Fish hook, Artificial bait (Using good coloring and fabricating properties)

Reel

Bicycle

- Importance of weight in racing bicycle's case
- Superior quality is more preferred than price as consumption of bicycles for sports increases.
- Replacement of components made of steel with titanium's
- Application: Frame, Gearshift, Disk brake rotor, Hub spindle, Pedal spindle, Bolt, Nut, etc.

Frame of a bicycle

Titanium bicycle

11. Sports, Leisure

Mountain-climbing Equipment

- Importance of weight when climbing high mountains
- Light, Strong, Crashworthy at low temperature
- Application : Climbing irons, Strap, Eyebolt, Spike, Cup, Tableware, Stove, Water bottle, etc.

Cup for climbing

Titanium pot

Titanium stove

Winter Sports Equipment

- Surface temperature is relatively high because of slow delivery of frictional heat of surface → Converting ice of the surface to water in a moment → Able to speed
- Lower thermal conductivity than steel → Slow delivery of low temperature
- Light weight, Low elastic coefficient → Favorable to jump in figure staking
- Application : Ski, Snowboard, Pole, Hook, Equipment of ice hockey, Blade of figure skate, etc.

Titanium skate

11. Sports, Leisure

Musical Instrument

- Low elastic coefficient → Different tone
- Light, Deep and rich toned and esthetic properties → Favorable reputation in the market
- Application : Drum, Vibration plate of the finest speakers, etc.

Titanium cornet

Camera

- Application : Camera case, Telescope case

Camera made of titanium

Safety Gear

- Light, Strong, Ductile
- Application : Protective equipment for policeman, guard and firefighter

Drum having titanium snare

11. Sports, Leisure

Racket

- Wide sweat area, Superior durability
- Superior crashworthiness and shock-absorbing against hitting

Others

- Face mask for kendo, Sticks for ski, Spike for baseball shoes, Horse's hoof, Helmet, Leisure boat, etc.

Racket

Spike

Horse's hoof

Helmet

12. Daily Necessities

- Light weight and strength, Corrosion resistance, Bioaffinity, Color formation
- Developing various products to appeal to customers

Watch

- Starting with the material of diver's watch
- Bioaffinity that does not provoke allergy, Easy to make unique hue and processing, Light when manufactured as a big size, Not corrodible and discolored by salt in sweat → Expanding to normal watches

Titanium watch

Titanium watch

Frame of Glasses

- Wearable because of high degree of transformation by high strength and low elastic coefficient
- Non-allergic, Light
- Plating with nickel on pure titanium and alloys

Titanium frames

Titanium frames

Inner Component

- Typically nonmagnetic material → Preferred because of prevention of malfunction given electronic mutual interference to IT appliances
- Light and strong material : Components for laptop hard disk drive

12. Daily Necessities

Case

- Camera case, MP3 Player case : Crashworthiness, Anti-scratches, Low thermal conductivity, Good texture
- Mobile phone case : Need for surface hardening because of low surface strength
- Case of home appliance : Refrigerator, Air conditioner, Oven, etc.

MP3 Player case

Mobile phone case

Bolt / Nut

- Properties of static/dynamic strength, and corrosion resistance
- Use of pure titanium for corrosion resistance / Use of strong alloys to increase solidity of combination among components

Titanium bolt

Titanium nut

12. Daily Necessities

Accessories

- Manufacturing thin oxide coating through anodizing
- Different tints according to different angles
- Biocompatibility, Coloring, Light weight → Favorable as a material of accessories, Increasing demand worldwide
- Ring, Bracelet, Necklace (No discoloration by sweat), Pendant, Watch case, Watch strap, etc.

Titanium necklace

Titanium ring

Cooking Utensils

- Solidity, Hygiene, Corrosion resistance, Lightness, Surface treatment, Novelty, Rarity → Becoming popularizing
- Possible to deep-draw, to bend into complicated shapes, and to connect and treat surface
- Titanium frying pan : 1/3 of steel pan's weight, Relief of fatigue, Advantage to cook fast at a higher temperature because of low thermal conductivity and concentrated heat at the part of heating compared to aluminum's

Titanium frying pan

Cooking utensils

Titanium knife

12. Daily Necessities

Others

A picture using color formation

Titanium card

Titanium wheelchair

Titanium mouse

Titanium

Application

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