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Hip Prosthesis: Ti-6Al-7Nb

Purpose: To inform the audience about the alloy and product, while explaining the connection between the product’s use and its composition.

1. Introduction: Time, use, and accidents can wear on our bodies until they no longer function. Then what do you do? Using their vast knowledge of metals, properties, and manufacturing, engineers and metallurgists have recreated some of these structures that are compatible to work within our body. A very common problem in older people is worn hips. We use our hips all of the time even when we are lying down. One of the structures created is a hip replacement, or more specifically the femoral component of a hip prosthesis. It is made of the alloy Ti-6Al-7Nb.

[Pictures of femoral component]

1. Composition of Ti-6Al-7Nb
   1. Aluminum: 5.5 – 6.5%
      1. Alpha stabilizer
   2. Niobium: 6.5 – 7.5%
      1. Beta stabilizer
      2. Niobium is more biocompatible than Vanadium
         1. Vanadium release metal ions that irritate tissue
         2. Vanadium produces toxic oxides to the body
   3. Impurities
      1. Causes alloy to assimilate undesirable properties
      2. Fit into the gaps between larger molecules
      3. Ta: < 0.5%
      4. Fe: < 0.25%
      5. N2: < 0.05%
      6. O2: < 0.2%
         1. Lowers fracture toughness
         2. Has a very high affinity for titanium
      7. C: < 0.08%
         1. Reduces ductility
         2. Increases strength
      8. H2: < 0.009%
   4. Titanium: ~Remaining %
      1. High biocompatibility
      2. Corrosion resistance
      3. Low density
      4. Similar elastic modulus to human bones
2. Properties
   1. Chemical Properties
      1. Needs to be biocompatible so the body doesn’t reject
         1. Cell behavior: Cells accept the alloy
         2. High protein absorption via porous surface
         3. Protective, stable oxide coating naturally forms (inert)
      2. Superior atmospheric corrosion
         1. Ensures that the prosthesis will last
         2. Elements, such as oxygen, won’t cause deterioration
      3. Allotropic: alpha-beta
         1. Higher strength
         2. Respond to heat treat
         3. Less formable than alpha
      4. Highly reactive metal surface to form inert coating
   2. Stress/Strain Properties

[Video of how hip works]

* + 1. Tensile strength is 145ksi
    2. Hardness values
       1. Rockwell A – 66.5
       2. Rockwell C – 32
       3. Rockwell D – 49.0
    3. High compressive strength (156-158 ksi)
       1. Must withstand weight and movement of recipient
    4. Elongation (9.4 – 13.2%) Applied only in extreme conditions
    5. Fracture toughness
       1. 61.9 – 68.3 ksi. in1/2
       2. Resists cracks from getting worse
       3. Not as high as it ideally should be
    6. Fatigue Strength
       1. 72500 psi (10 Million Cycles, Rotating bend motion)
       2. Lasts a long time (10 year guarantee)
    7. Yield Strength (114 – 130 ksi)
  1. Mechanical & Physical Properties
     1. ½ Density of steel
        1. Density is 4.52g/cm3
        2. Lightweight like a bone
     2. Low friction
        1. Less wear
        2. More range of motion
        3. Use Natural lubrication
     3. Ductile: Only matters if you jump off a building

1. Manufacturing Process of Hip Implant
   1. Isothermal Forging
      1. Closed dye forging with equal temperature throughout process
      2. Cut an ingot to a precise length
      3. Heated to about 900ºC
      4. Die inserts (usually nickel) are heated to the forging temperature
      5. Fed into hydraulic press with a specific tool to form
         1. Have net shape
         2. Accurate precision
   2. Heat Treat of Isothermal Forging
      1. Annealed
      2. Temperature: 700ºC for 1 hour
      3. Air cooled, which allows for less deformation
   3. Hot-pressing in molds
      1. Loose powder placed into mold
         1. Powder uses 90% of raw material
         2. Can avoid/limit machining
         3. Used for materials with high melting point
         4. Hotter pressing temperature causes higher relative density
         5. Hotter pressing temperature causes higher hardness
      2. Occurs in a vacuum
   4. Chemical/Heat Treat after Hot-pressing
      1. Improves biocompatibility
         1. Reduces metal ion release
         2. Reduces water contact angle (increases wettability)
         3. Helps to absorb body fluids (containing proteins)
      2. Grit blasting
         1. Makes surface abrasive
         2. For plasma coating
      3. Passivation in nitric acid to remove any pathogens/diseases
      4. Placed in an alkaline solution to form oxide coating (termed anodize)
2. Other Information
3. Conclusion: These are some of the applications of our alloy Ti-6Al-7Nb but the major one is the one in the middle for our particular research. If you think of all the ways we use our legs and hips each day it is perplexing how much wear and tear your body can take. One hundred years ago if your hip failed on you, you were a cripple possibly in a wheel chair. Now we have the ability to recreate your hip and you still have full control over it. We all take for granted our legs and how we can move whenever we want. This is why hip replacement is so amazing: it keeps people mobile so they can keep doing what they love.