

Titanium in Naval Ship Applications; Examples and Considerations

Current Examples of Unalloyed and Alloyed Titanium.

Factors Impeding Greater Use of Titanium.

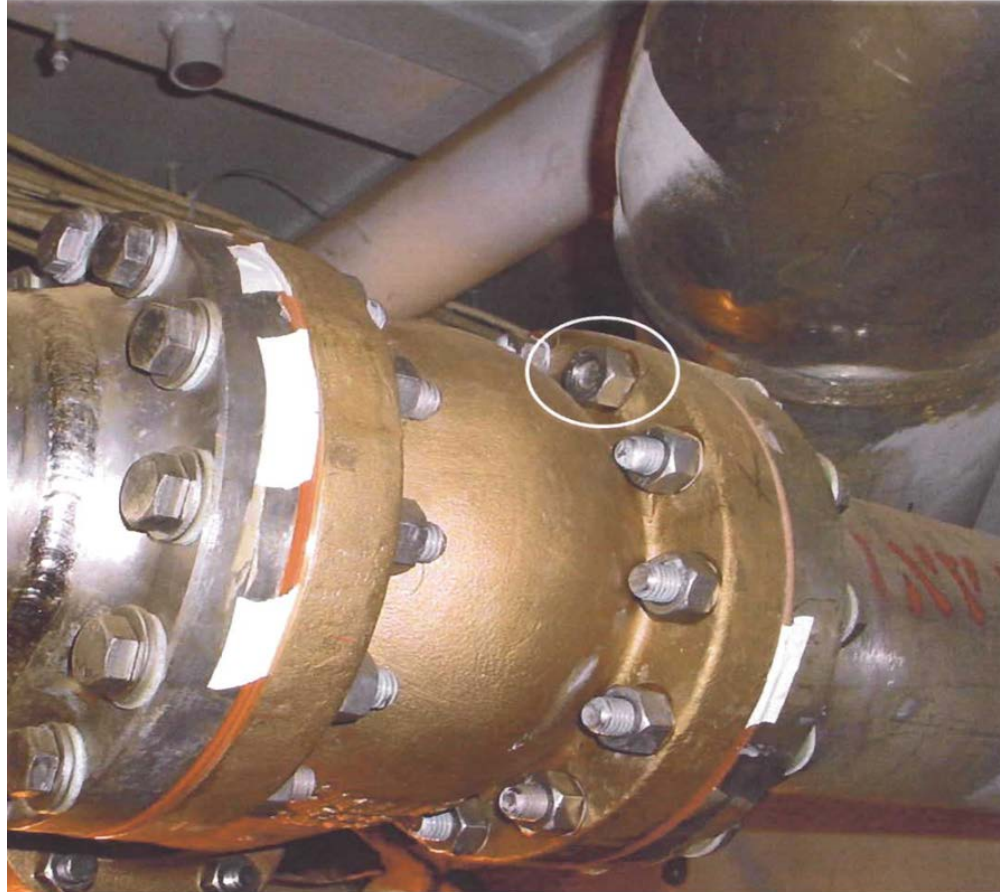
Needed Improvements In Material Characterization Methods

Titanium Applications

- LPD 17 Class Amphibious Transport Ships Seawater Piping:
- Over 10,000 feet of Grade 2 titanium pipe is used in each of the first 6 LPD 17 class ships.
 - Pipe sizes up to 12" NPS.
 - Ti selected because of improved corrosion and erosion resistance, and associated life cycle costs savings vs traditional copper nickel (CuNi) alloys.
 - At the time of design, the cost of Grade 2 pipe was approximately equal to CuNi pipe.
 - The increased fabrication cost of Ti vs CuNi was also acceptably low
- Piping system design employs bronze valves with electrical isolation (Brz valve to Ti pipe, and Ti pipe to ship structure) to preclude galvanic corrosion
 - Bronze was used because of high cost of titanium valves (5X+)
 - Smaller branch piping (<2.5" NPS) also remained CuNi in many cases due, in part, to higher cost of smaller piping and fittings and welding.

LPD 17 Seawater Titanium Pipe & Brz Valve

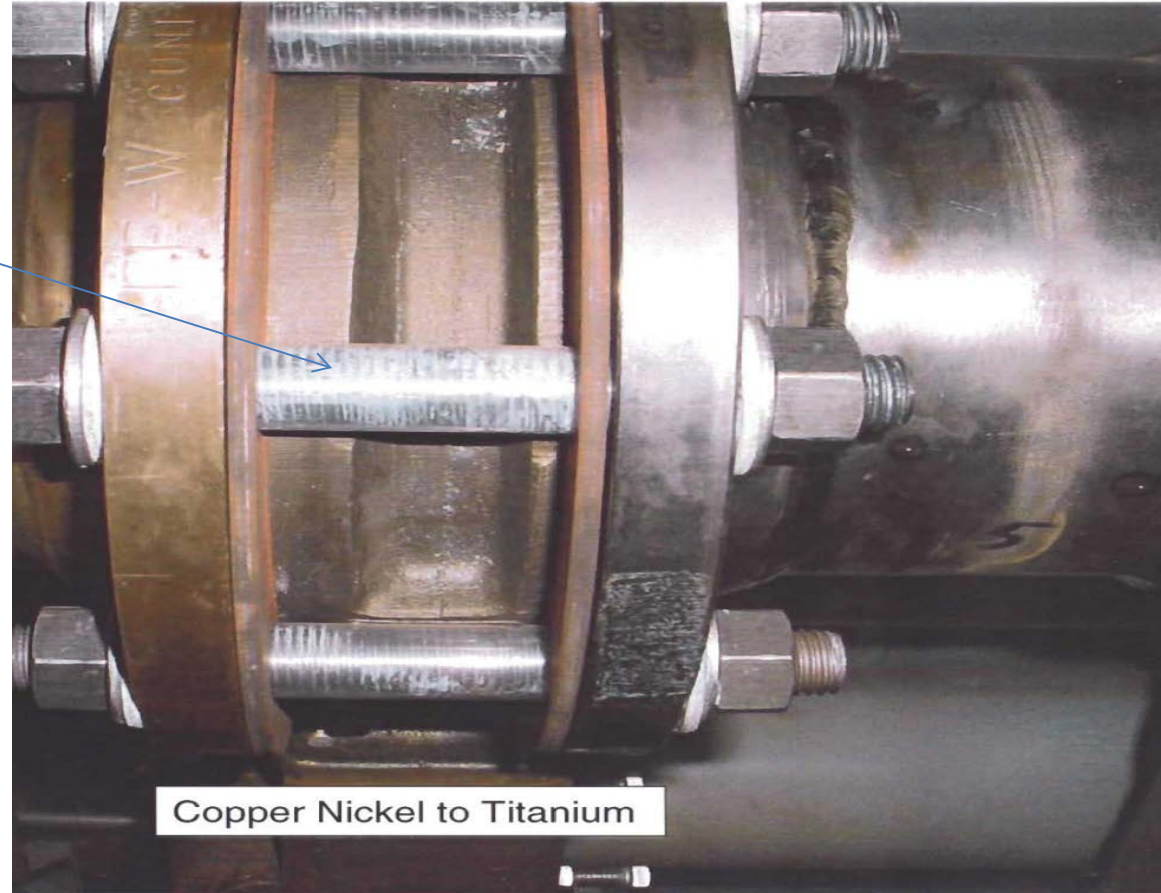
Photo from "Application of Titanium for Shipboard Seawater Piping Systems", Kriedt, Mountford II, Scaturro; Mega Rust 2009



LPD 17 Seawater Ti Pipe, Bronze Valve and CuNi Flange w/Insulation Sleeve

Photo from "Application of Titanium for Shipboard Seawater Piping Systems", Kriedt, Mountford II, Scaturro; Mega Rust 2009

Insulating Sleeve



LPD 17 Class Amphibious Transport Ships; CP-2 Ti Seawater Piping

- Electrical isolation of valves and pipe was unexpectedly difficult for shipbuilders to achieve due to installation problems with isolation kits, isolation measurement problems, etc.
- Electrical isolation of the system has been difficult to maintain during service due to factors including:
 - Chafing/failure of pipe hanger insulators
 - Grounding of bulkhead penetrations
 - Failure of flange isolation parts
 - Errors by ship's crew and repair yards during maintenance of the titanium system
 - Locations of grounds are very difficult to locate

LPD 17 Class Amphibious Transport Ships; CP-2 Ti Seawater Piping

- Bronze valves and CuNi branch piping are aggressively corroding in some instances.
 - System reliability can be compromised
 - Repair costs and frequency are far too high
- Remediation measures include:
 - Replacement of select bronze valves with titanium valves
 - Qualification of robust, coated fasteners to replace flange isolation sleeves
 - Development of isolation connections for joining titanium run pipe to CuNi branch piping
 - Development programs to lower cost of titanium valve parts

LPD 17 Class Amphibious Transport Ships; CP-2 Ti Seawater Piping

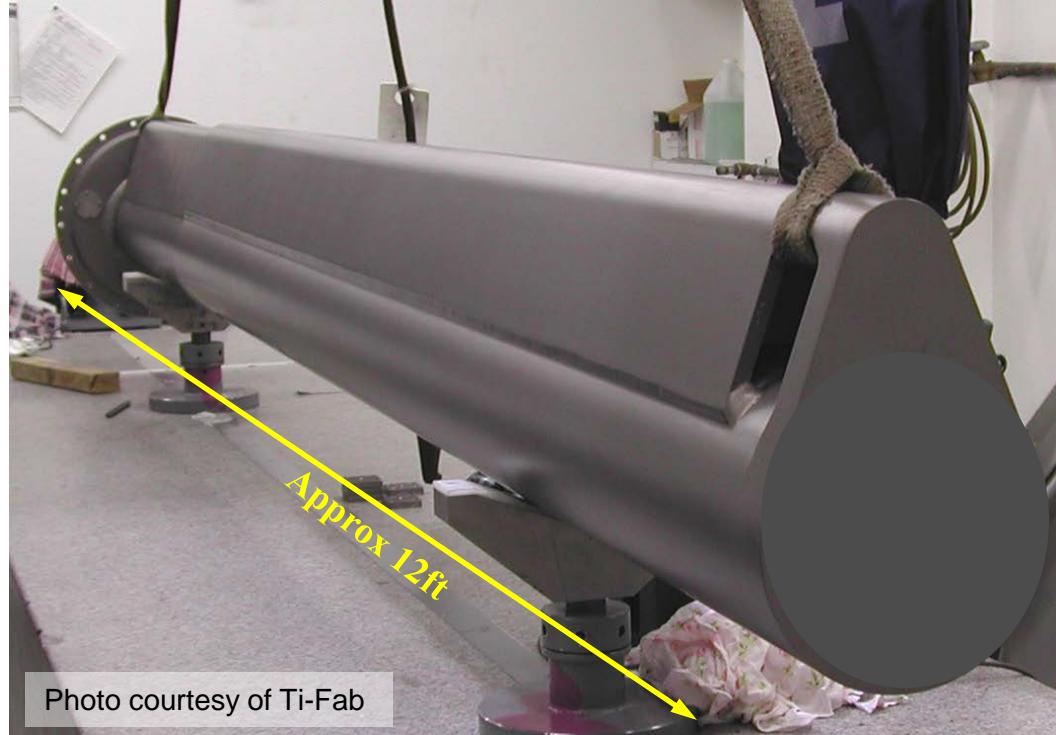


Ferrous alloy coated fasteners used for isolation in industry

Titanium Applications

A Submarine HDR Antenna Mast is Made from Ti-5111.

- Ti-5111 has a nominal composition of 5Al-1Sn-1Zr-1V-0.8Mo; it is designated as Grade 32 in various ASTM specifications
- Ti-5111 was developed by TIMET and the US Navy in the 1980's. Base materials and welds possess the following characteristics:
 - Tensile strength – 100 ksi (689 MPa) minimum
 - Yield strength - 85 ksi (586 Mpa) minimum
 - Very high fracture toughness
 - High resistance to stress corrosion cracking
- Cost can be comparable to Ti- 6Al-4V ELI.
- Installed on over 30 submarines.



**Ti-5111 HDR mast being
fabricated at Ti-Fab**



HDR mast

Public Domain Photo

Upgraded Deep Diving Submersible, ALVIN



A preliminary view of the upgraded submersible, Alvin , when the new personnel sphere and other additions are in place. (Illustration by Megan Carroll, Woods Hole Oceanographic Institution)



Ladish Forging in Cudahay, WI, heated and shaped 6 Al- 4V ELI titanium ingots into discs which were then formed into hemispheres (Photo courtesy of Woods Hole Institution)



Personnel sphere outside of hydrostatic testing chamber.
Photo by Bruce Strickrott, Woods Hole Oceanographic Institution

Other Titanium Applications Include:

- Wide variety of heat exchangers.
- Fire pumps
- Small pressure vessels.
- Minor piping systems.

Factors Impeding Greater Use of Titanium for Naval Applications

- Potential applications of titanium include:
 - Seawater piping and associated valves
 - Deckhouse structure
 - Watertight doors and hatches
- Despite potential life cycle cost savings, if acquisition cost are too high, titanium can not be used.
- Acquisition cost include both material cost, the cost of fabrication (e.g. welding) and consideration of in-service maintenance (e.g. repair welding for damage)
- **Regarding base material cost:** The Navy is continuing to follow, and explore technologies for lowering base material cost (low cost powder, additive manufacturing, microwave consolidation, etc)

Factors Impeding Greater Use of Titanium for Naval Applications

- **Regarding high fabrication cost:** For large structure shielding the back side of joints such as stiffener to plating welds, double-sides butt welds, etc. is expensive.
 - A coating/flux applied to the back side of a 2-sided weld, to preclude oxidation, would reduce cost, particular if GMAW welding was used.
 - Coating should be easily removable or ideally could be directly welded over.
 - Such a coating would also lower welding cost of fillet joints in larger piping sizes.
- Coating could enable Ti welding cost to approach other alloys such as aluminum, Inconel and stainless steel.

Factors Impeding Greater Use of Titanium for Naval Applications

- Other means of lowering fabrication cost include:
 - Use of higher deposition welding process such as GMAW vs GTAW
 - Development of flux cored welding consumables to reduce shielding
 - Increased use of automation and robotics .
- Other factors increasing the final cost of titanium include:
 - Yards (new construction and repair yards) not familiar
 - Lack of smart long term procurement strategies enabling volume purchasing

Needed Improvements in Methodology for Characterization of Engineering Properties

- **Case 1: Characterization of Engineering Properties for Ti-5111 for a Submarine Antenna Application.**
- The first large scale use of Ti-5111 in welded, and forged and large diameter bar forms was for a submarine antenna application.
- Qualification of Ti-5111 required extensive characterization testing to establish/confirm various engineering properties such as:
 - Static and dynamic fracture toughness
 - Tensile and compressive strength
 - Fatigue
 - Fatigue crack growth
 - Stress corrosion cracking thresholds
 - Creep; etc

Needed Improvements in Methodology for Characterization of Engineering Properties

- Developing a reliable understanding of these properties involved testing and analysis of representative material.
- This testing involved considerable expense and time to accomplish.
- Computational modeling to develop a reliable understanding of material behavior in such cases plays almost no role, if any at all.

Needed Improvements in Methodology for Characterization of Engineering Properties

- **Case 2. Developing a design value for Kiscc for Kmonel (Alloy 500)**
- Alloy 500 is a nickel- copper alloy that precipitation hardens to a nominal yield strength of 90,000 psi and over.
- Due to its high strength, good general sea water corrosion resistance, and high toughness, it is used in a wide variety of marine applications
- Under certain conditions of cathodic protection, in ambient temperature sea water, Alloy 500 can fail by stress corrosion cracking.
- Due to very low diffusion rates of hydrogen in Alloy 500, material variability, and other factors, developing a Kiscc has been problematic.

Needed Improvements in Methodology for Characterization of Engineering Properties

- Developing a K_{ISCC} value for Alloy 500 has almost exclusively been performed by testing of representative material
- Very little computational modeling has been involved.
- These examples illustrate the general state of affairs not only in the marine industry but in many other fields also; i.e.
 - There are very few if any instances of where material modeling is being used for reliably characterizing and developing engineering properties of structural materials.

Needed Improvements in Methodology for Characterization of Engineering Properties

- This condition exists despite an enormous amount of world-wide R&D in the mechanistic response of structural materials, at various scale levels, in their environment, over the last 50 years (or so).
- Doesn't this undesirable condition suggest the need for:
 - An improved degree of overarching coordination of R&D that is devoted towards increasing the role of computational modeling for engineering material characterization; and
 - By this coordination, establishment of material modeling baselines, from which direction could be applied to guide R&D towards continual improvement of modeling capability into an engineering tool.