DATA SHEET No 1
Titanium Alloy Ti-6Al-4V ELI
High Stress Applications in Sea Water

(Revision 03 Oct 1998)

Titanium and most of its alloys are highly resistant to stress corrosion cracking, (SCC) in sea water. Ti-6Al-4V ELI, (ASTM Grade 23) a variant of the most widely available alloy, will not exhibit SCC in either smooth or smooth notched components in sea water or brackish waters and is regularly selected for applications where high strength and corrosion resistance are required.

Ti-6Al-4V ELI (Extra Low Interstitial Alloy Content) is the grade of the alloy most commonly specified for thick walled highly stressed parts such as the pressure hulls of deep diving submersibles such as the French "Nautile", and the Japanese "Shinkai", for taper stress joints and for the Heidrun drilling riser. In extensive evaluation Ti-6Al-4V ELI has satisfied all criteria for flexible riser applications.

The standard grade of Ti-6Al-4V has been used for diving bell hatch doors, encapsulation for deep sea cameras and electronics packages, and for sonar devices. No failures resulting from inadequate toughness have been reported for any application.

The allowable stress for fatigue critical welded structures must be based on the performance of welds. Welds made by the TIG process, most commonly used for titanium, intrinsically contain small, (sub-millimetre) internal defects, which may serve as sites for fatigue crack initiation. The relative reduction of fatigue strength arising from these defects is greater for titanium than for steel. Compared to steel however, the lower modulus of titanium provides for a reduction of stress and bending moment in displacement controlled loading applications such as stress joints and flexible risers. For good quality welds, this factor compensates for the weld related effect, so that overall TIG welded titanium structures have superior fatigue performance to their steel counterparts in such applications.

Other methods of welding, currently under investigation, may provide welds tolerant to higher levels of allowable stress than are possible with the TIG process.

Designer Check List for Ti-6Al-4V Sea Water Applications

- Specify the ELI Grade for all critical highly stressed components. Request grades containing .05% palladium or .10% ruthenium where metal temperature in service exceeds 80^{o}C and crevice or under deposit corrosion is a possibility.

- Ensure that stressed component surfaces are smooth and free of flaws and cracks.

- Use the ASME Design Code for maximum allowable stress, which should not exceed one quarter of the specification minimum tensile strength. Weld fatigue strength may impose a limit on allowable stress in designs based on a higher utilisation factor.

- Note that the ASME Design Code max. allowable stress is well below the fatigue limits for titanium and its alloys. Fatigue crack initiation is insensitive to the presence of sea water. Crack propagation is only accelerated by sea water, (corrosion fatigue), if there are periods of stress dwell, or if the stressing frequency is less than 10Hz.

- Consider the possible effects of galvanic coupling in mixed metal structures (Refer to TIG Data sheet No.6 -"Connecting Titanium to Other Metals)

- Restrictions apply to the use of methanol and hydrofluoric acid in conjunction with titanium components (TIG Data Sheets 5, 7 and 15 refer).

- Note that typical levels of strength and fracture toughness for Ti-6Al-4V and Ti-6Al-4V ELI are shown over:-

Alloy ASTM Grade	**Min Tensile Strength, MPa**	**Toughness MPam$^{1/2}$ $K_{1C(air)}$**	**Toughness MPam$^{1/2}$ $K_{1scc(sea\ water)}$**
Standard Grade 5	895	55 - 75	35 - 65
ELI Grade 23	828	85 -110	75 - 90

- Note that higher values of fracture toughness are obtainable by use of the material with a transformed beta Widmanstatten structure, rather than the normal alpha + beta structures for which the lower values typically apply.

- Manufacturers must ensure that at no stage of processing is the metal allowed to slow cool between 760^{o}C and 480^{o}C

FOR FURTHER INFORMATION CONTACT

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