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Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

FOREWORD

Changes in the revision are format/editorial only.

1. SCOPE:

Primarily to provide recommendations concerning minimizing stress-corrosion cracking in wrought titanium alloy products.

1.1 The detailed recommendations are based on laboratory experience and reflect those design practices and fabrication procedures which should obviate in-service stress-corrosion cracking of wrought titanium alloy products.

1.2 It must be emphasized that while stress-corrosion cracking in service has been observed, the chemical environmental conditions have, in all instances, been unusual and, although it is possible to produce stress-corrosion cracking of titanium alloys under more common conditions as discussed in these recommendations, there have been few, if any, failures in such environments.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP1795 Stress Corrosion of Titanium Alloys, Effect of Cleaning Agents on Aircraft Engine Materials

3. GENERAL:

All metal alloy systems are subject to stress-corrosion cracking under appropriate conditions; titanium alloys are no exception to this rule. Stress-corrosion failures of wrought titanium alloy parts are possible if the following combination of factors is met:

a. Presence of a sustained high surface tensile stress developed as a result of assembly stresses or residual stresses due to heat treatment or forming (or plane strain produced by the tensile stress concentration at the root of a pre-existing crack), and

b. Presence of environmental conditions (media, temperature, stress, time) specific to the material under consideration.

3.1 There are several types of environments in which stress cracking of titanium alloy parts may occur. These environments and the alloys currently known to be susceptible to cracking in each type are:

a. Environments in which both initiation and propagation may occur at low stress concentration factors; that is, cracking of smooth machined components may occur at sufficiently high applied stress.

a-1. Alkali halide salts (and halide salts of some other metal) above 500 °F (260 °C) (oxygen and water vapor are contributing factors). In general, all commercially available titanium alloys are believed to be susceptible to hot salt cracking.

a-2. Silver, cadmium, and mercury have been found to promote cracking in titanium alloys; temperature (even room) and stress limits for cracking have not been firmly established and caution should therefore be exercised.

a-3. Methyl alcohol. All titanium alloys are believed to be susceptible; cracking may occur at 70 °F (20 °C) but temperature limits have not been established. Probability of cracking is increased by the presence of alkali halide salts, HC1, or H_2SO_4. Cracking is inhibited by the presence of 1% or greater H_2O.

a-4. Nitrogen tetroxide (N_2O_4). Titanium 6Al-4V tankage holding N_2O_4 with no measurable amounts of NO in a temperature range of 85 to 165 °F (30 to 75 °C) has failed by stress corrosion. Other titanium alloys are also susceptible. Cracking is inhibited by presence of 0.4 to 0.8% NO in propellant grade N_2O_4.

a-5. Red fuming nitric acid caused one of the early stress-corrosion problems encountered with titanium. It has been determined that red fuming nitric acid with less than 1.5% water and less than 10 to 20% NO_2 will aggressively attack the metal and result in a pyrophoric reaction.

b. Environments in which brittle cracking may occur under high stress concentrations; that is, a pre-existing crack may propagate under applied stress, provided component geometry is such as to produce plane strain conditions. All titanium alloys are believed to be susceptible in some degree, with the exception of low-oxygen, low-iron titanium such as the commercially pure alloys used in corrosion applications in chemical plants. The following environments may produce this susceptibility:

3.1 (Continued):

b-1.Aqueous solutions of alkali halides; the lower limit of halide salt concentration has not been firmly established and caution, even in pure water, should be exercised.

b-2. Many organic liquids, notably anhydrous methanol and halogenated hydrocarbons, also produce susceptibility to some degree.

c-3. Mercury and cadmium.

3.2 Performance Under Service Conditions:

Severe stress-corrosion cracking of titanium alloys has been encountered in highly-stressed pressure vessels containing methyl alcohol or containing N_2O_4 free of NO. Also, small cracks have been seen in wrought titanium components exposed to halide salts during heat treatment. With these exceptions, stress-corrosion cracking has rarely, if ever, occurred under service conditions. The alloys Ti-6Al-4V ELI and Ti-6Al-2Sn-4Zr-2Mo in particular exhibit low susceptibility. While laboratory testing showing the possibility of stress-corrosion cracking indicates a need for caution, service experience with titanium alloys has been extremely good compared with other structural materials.

4. RECOMMENDATIONS:

4.1 Environmental Compatibility:

Alloys should be selected which offer adequate resistance to stress-corrosion for the environment in which they are to be used. Alloys with intermediate resistance are Ti-6Al-4V, Ti-6Al-6V-2Sn, and Ti-13V-11Cr-3Al. Although not commercially produced anymore, Ti-4Al-3Mo-1V is one of the most resistant alloys. Alloys that are highly resistant to seawater crack propagation under plane strain conditions include Ti-4Al-3Mo-1V, Ti-6Al-2Cb-1Ta-1Mo, and Ti-6Al-4V ELI.

4.1.1 Addition of small amounts of water to methyl alcohol and either water or nitrogen oxide (NO) to N_2O_4 tends to inhibit stress-corrosion by these environments.

4.2 Processing and Heat Treatments:

Studies have indicated that heat treatment and processing variables play a major role in sensitizing titanium alloys to stress-corrosion cracking. Beta processing followed by normal heat treatments, or normal processing plus beta heat treatments reduces or eliminates sensitivity to stress-corrosion cracking of most alloys in aqueous environments. However, beta structures often have lower tensile properties with reduced ductility. The effectiveness of these treatments varies with the alloy grades and does not necessarily apply to other forms of stress-corrosion. For example, beta processing or heat treatment generally increases the sensitivity of alloys to hot salt corrosion while imparting resistance to room temperature aqueous stress-corrosion cracking.