AEROSPACE RECOMMENDED PRACTICE

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc. 485 Lexington Ave., New York, N.Y. 10017

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MINIMIZING STRESS CORROSION IN WROUGHT HEAT TREATABLE TITANIUM ALLOY PRODUCTS

1. PURPOSE:

1.1 The purpose of this recommended practice is to provide the aerospace industry with recommendations concerning minimizing of stress corrosion cracking in wrought titanium alloy products.

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

2. GENERAL: Stress corrosion failures of wrought titanium alloy parts are possible if the following combination of factors is met:

a) presence of a sustained surface tensile stress developed as a result of assembly stresses and/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,

b) an existence, in the product, of a metallurgical condition which makes the product susceptible to stress corrosion cracking,

c) environmental conditions which are conducive to crack initiation and/or propagation.

2.1 There are three 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) Elevated temperature environments in which both crack initiation and propagation may occur:

1. Halide and sulfide salts above 500 F (260 C) (oxygen and water vapor are contributing factors). In general, all titanium alloys are believed to exhibit susceptibility to hot salt cracking. Typical alloy compositions which have evidenced susceptibility are listed below:

Ti-5Al-2.5Sn	Ti-6Al-4V
Ti-7Al-12Zr	Ti-6Al-6V-2Sn
Ti-5Al-5Sn-5Zr	Ti-5Al-2.75Cr-1.25Fe
Ti-5Al-5Sn-5Zr-1Mo-1V	Ti-3Al-11Cr-13V
Ti-2.25Al-11Sn-5Zr-1Mo-0.25Si	Ti-6Al-2Sn-4Zr-2Mo

2. Liquid metals or metals which may amalgamate or form eutectics with alloying constituents above 600 F (316 C) (silver, cadmium, and mercury):

Ti-6Al-4V (in Ag or Hg)	Ti-4Al-4Mn (in Cd)
Ti-8Al-1Mo-1V (in Ag)	Ti-8Mn (in Cd)
Ti-7Al-4Mo (in Ag)	Ti-3Al-11Cr-13V (in Hg)
Ti-5Al-2.5Sn (in Ag)	Ti-75A (in Hg)

b) Room temperature or slightly elevated temperature environments in which both crack initiation and propagation may occur:

1. Unalloyed titanium and Ti-6Al-4V in pure methyl alcohol and in methyl alcohol acidified with HC1 or H_2SO_4.

2. Ti-6Al-4V in N_2O_4 containing no measurable amounts of NO in the temperature range of 85 to 165 F (29.4 to 73.9 C).

It is very likely that other alloys will crack when exposed to these specific environmental conditions and that other similar environmental conditions will also cause cracking.

c) Room temperature environments (water, aqueous chloride solutions, mercury) in which cracks will not initiate but will propagage under conditions of plane strain:

Ti-8Mn
*Ti-2.5Al-1Mo-10Sn-5Zr
Ti-3Al-11Cr-13V
Ti-4Al-4Mn
Ti-5Al-2.5Sn
*Ti-6Al-2.5Sn
Ti-6Al-4V
*Ti-6Al-1Sn-4V
*Ti-6Al-2Co-4V
*Ti-6Al-2.5Sn-6V
Ti-7Al-2Cb-1Ta
*Ti-7Al-3Cb
*Ti-7Al-3Mo
*Ti-7Al-3Cb-2Sn
Ti-8Al-1Mo-1V
*Ti-8Al-3Cb-2Sn

*Denotes experimental compositions.

It must be emphasized that the above conditions for susceptibility to stress cracking were determined by laboratory experiments. The number of actual service failures is extremely small.

3. RECOMMENDATIONS:

3.1 Environmental Compatibility: If possible, alloys should be selected which are the most resistant to stress cracking in the environments to which they may be subjected under stress. Among the alloys most resistant to hot salt cracking are Ti-4Al-3Mo-1V, Ti-2.5Al-1Mo-10Sn-5Zr, and Ti-2Al-4Mo-4Zr. Alloys that are resistant to seawater crack propagation under plane strain are Ti-2Al-4Mo-4Zr, Ti-4Al-3Mo-1V, Ti-5Al-2Mo-2Sn-2V, Ti-6Al-2Mo, Ti-6Al-1Mo-2Sn-1V, Ti-6Al-1Mo-2Sn-3V, Ti-6Al-2Cb-0.8Mo-1Ta, Ti-6.5Al-5Zr-1V, and Ti-7Al-2.5Mo.

3.1.1 Processing and Heat Treatments: Studies now in progress have indicated that heat treatment and processing variables play a major role in sensitizing titanium alloys to stress corrosion cracking. In general, beta processing followed by normal heat treatments or normal processing plus beta heat treatments reduces or eliminates sensitivity to stress corrosion cracking. The effectiveness of these treatments varies with the alloy grades. In addition, the treatments require careful control of temperatures and cooling rates. TTT curves for the various alloys are now being worked out and several proprietary heat treatments based on these curves markedly reduce susceptibility to stress corrosion cracking, particularly for the Ti-8Al-1Mo-1V alloy. Research is continuing to develop optimum processing and heat treatments for other titanium alloys.

3.2 Design Stresses: Sustained surface tensile stresses should not exceed the hot salt threshold stress for the respective alloys which are used at elevated temperatures. Since many titanium alloys are highly susceptible to crack propagation in relatively mild environments, emphasis should be placed on preventing crack initiation by other mechanisms such as quench cracking of welds and fatigue. Unless the minimum time for the initiation of fatigue cracks is well established and the useful life of the titanium alloy part is less than that value, the fatigue endurance limit for those alloys susceptible to sea water crack propagation should be used as the design limit for cyclic loads.

3.2.1 Surface Compressive Stressing: The two above mentioned design limitations are generally raised when surface compressive stresses are introduced such as by shot peening.