PREFERRED RELIABILITY PRACTICES

CONTROLLING STRESS CORROSION CRACKING IN AEROSPACE APPLICATIONS

Practice:

This practice presents considerations that should be evaluated and applied concerning stress corrosion and subsequent crack propagation in mechanical devices, structural devices, and related components used in aerospace applications. Material selection, heat treat methods, fabrication methodology, testing regimes, and loading path assessments are presented as methods to reduce the potential for stress corrosion cracking (SCC) in a material's operational environment.

Benefits:

Selection of materials, heat treating methods, fabrication methodologies, testing regimes, and loading paths that are not susceptible to stress corrosion cracking will promote fewer failures due to SCC and will eliminate downtime due to the change-out of components.

Programs That Certified Usage:

Saturn IB, Saturn V, Lunar Roving Vehicle, Space Shuttle Solid Rocket Booster, Space Shuttle External Tank, Space Shuttle Solid Rocket Motor, Material Experiments Assembly, Inertial Upper Stage, Skylab, High Energy Astronomy Observatory, Hubble Space Telescope.

Center to Contact for More Information:

Marshall Space Flight Center (MSFC)

Implementation:

Numerous materials have been tested for susceptibility to SCC in a 3.5 percent NaCl alternate immersion bath, a 5 percent NaCl salt fog cabinet and a 90-100 percent relative humidity cabinet. These tests resulted in the development of a specification on, Design Criteria for Controlling Stress Corrosion[3]. The information contained in the specification is based upon laboratory tests in which specimens were either sprayed with salt water or periodically immersed and withdrawn; by exposure of the specimen to simulated seacoast or mild industrial environments; and by service experience with fabricated hardware. This specification also lists materials that have a high resistance, a

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moderate resistance, or a low resistance to SCC. MSFC's Material Selection List for Space Hardware[4] also lists materials that have a high resistance to SCC.

To avoid failure, the tensile stress in service must be maintained at a safe level. Since stresses are additive, all sources of stress (see Table 1) must be considered to ensure that the threshold stress (the stress level which will result in a failure if stress corrosion is present) is not exceeded. There is not an absolute threshold stress for stress corrosion as there is with other material properties. Therefore, estimates of the stress corrosion threshold for a specific service application must be determined for each alloy and heat treatment by using a test piece, a stressing procedure, and a corrosive environment that are appropriate for the material's intended application. A simplified stress corrosion test fixture with a round tensile specimen installed is illustrated on Figure 1 in a simulated corrosion environment. A masking material is applied to the test fixture to ensure that the specimen alone is exposed to the corrosive environment. The tensile specimen is stressed to a desired level (typically 25, 50, 75 or 90 percent yield strength). The specimen is then submerged in a 3.5 percent NaCl alternate immersion bath, in a 5 percent NaCl salt spray (fog), or in a 90-95 percent relative humidity test. Test duration is typically three months for low alloy steels and aluminum alloys, and six months for stainless steel.

The most common processing methods for production of wrought metal are rolling, forging and extruding. These processing

Table 1. Sources of Stress

1. Operational
2. Transportation
3. Storage
4. Assembly
   a. Improper tolerances during buildup
   b. Over-torquing
   c. Press fits
   d. High interference fasteners
   e. Welding
5. Residual stress
   a. Machining
   b. Forming
   c. Heat treating operations

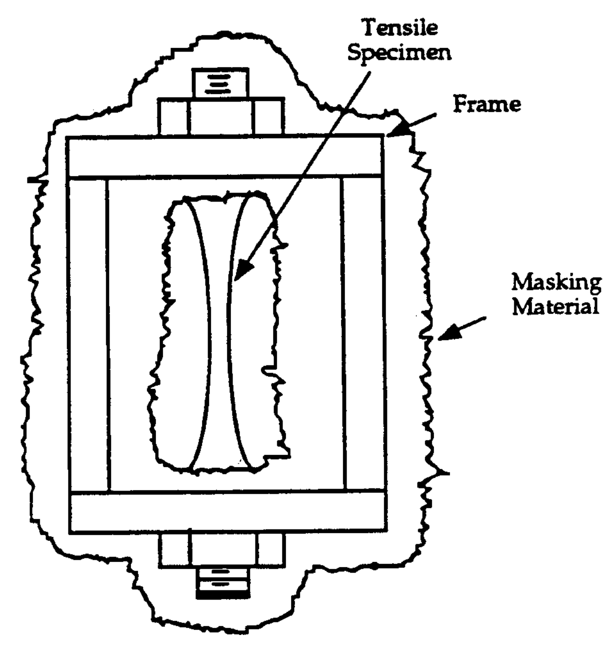

Figure 1. Stress Corrosion Test Setup for the SRB Forward Separation Bolt

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methods produce a granular structure which is parallel to the flow of metal. As shown on Figure 2, grain orientation is parallel to the longitudinal direction of rolling, extrusion or drawing. When thin shapes are rolled or extruded, grains are oriented in a short transverse or long transverse direction as shown on Figure 2. The resistance of metals to SCC is always less when tension is applied in a transverse direction. It is least for the short transverse direction. Stress corrosion is aggravated when tensile stresses due to assembly have been applied in the short transverse direction. Table 2 lists typical materials and environments that may cause stress corrosion.

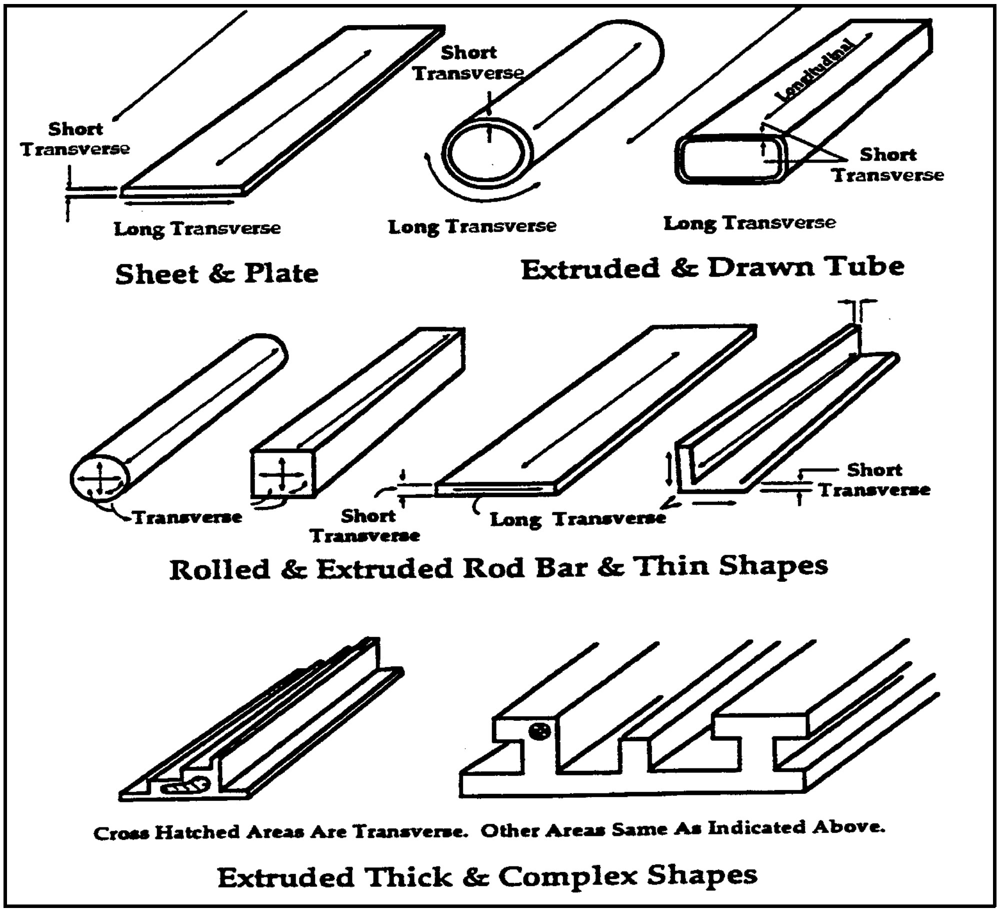

Figure 2. Grain Orientations in Standard Wrought Forms

Technical Rationale:

SCC is caused by the combined action of sustained tensile stress and corrosion which result in premature failure of materials. Certain materials are more susceptible than others. If a susceptible material is placed in service in a corrosive environment under a tension of sufficient magnitude, and the duration of service is sufficient to permit the initiation and growth of cracks, failure will occur at a stress lower than the material will normally be expected to withstand.

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Table 2. Environments That May Cause Stress Corrosion of Metals and Alloys

MATERIAL	ENVIRONMENT	MATERIAL	ENVIRONMENT
Aluminum alloys	NaCl-H_20_2 solution NaCl solution Sea water Air, water vapors	Ordinary Steels	NaOH solutions NaOH-Na_2SiO_2 solutions Calcium, ammonium, and sodium nitrate solutions Mixed acids HCN solutions Acidic H_2S solutions Sea water Molten Na-Pb alloys
Copper alloys	Ammonia vapors and solutions Amines Water, water vapor	Stainless steels	Acid cloride solutions NaCl-H_2O_2 solutions Sea water H_2S NaOH-H_2S solutions Condensing steam from chloride waters
Gold alloys	$FeCl_3$ solutions Acetic acid-salt solutions	Titanium alloys	Red fuming Nitric acid, sea water, N_2O_4, methonol-HCl
Inconel	Caustic soda solutions	Lead	Lead acetate solutions
Magnesium alloys	NaCl-K_2CrO_4 solutions	Monel	Fused caustic soda Hydrofluoric acid Hydrofluosilicic acid
Nickel	Fused caustic soda		

Impact of Nonpractice:

Failure to adhere to proven criteria for controlling SCC could result in hardware failure, which could result in schedule slippages, excessive resource expenditures, shortened mission life, mission failure, and, in extreme cases, loss of life.

Related Practices:

None

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