



EMBRITTLEMENT AVOIDANCE

WSS-M99A3-A

1. SCOPE

This specification outlines the conditions that enhance the embrittlement risk of steel components, steel and aluminum fasteners, and cast iron. Mechanisms include hydrogen embrittlement, stress corrosion cracking, intergranular corrosion, and liquid metal embrittlement. The specification identifies requirements intended to minimize that risk.

2. APPLICATION

The requirements established by this specification apply to steel fasteners, aluminum fasteners, heat treated cast iron or steel components, and cold worked cast iron or steel components.

Hardness values in this specification are in the Vickers scale. All other readings are for reference only. The specified hardness refers to the hardness on the part drawing or product standard and not the actual part hardness. When hardness is not specified on the part drawing or product standard, parts shall be tested for hardness and the measured hardness shall be used to determine conformance to this standard.

2.1 HYDROGEN EMBRITTLEMENT

The risk of hydrogen embrittlement exists for parts:

- with high tensile strength or hardness, including surface hardening,
- which have, or may absorb diffusible hydrogen, and
- are under tensile stress.

Hydrogen embrittlement can cause delayed brittle fracture under stress and most often occurs as a result of hydrogen absorption during manufacturing processes such as acid cleaning, electroplating, phosphate coating, and heat treatment. Hydrogen absorbed during these manufacturing processes can be relieved by baking. Hydrogen absorption can also occur from exposure to corrosive environments where the reduction reaction may produce atomic hydrogen.

The susceptibility to embrittlement increases with increasing stress and increasing material strength, particularly for martensitic microstructures. Therefore, attention to the processes used for cleaning, finishing, and heat treatment, as well as the review of the application environment for hardened and cold worked steel components, are crucial in reducing the risk of embrittlement.

2.2 STRESS CORROSION CRACKING

Hardened steels are susceptible to brittle fracture when exposed to a corrosive environment under a sufficient tensile stress. This failure mode is called stress corrosion cracking (SCC). The higher the yield strength, the more susceptible the material is to SCC. Sensitivity varies with steel alloy, yield strength, corrosive environment and the applied tensile stress and residual manufacturing stress.

Date	Action	Revisions	Rev. 04
2016 01 11	Revised	See Summary of Revisions	G. Weber, NA
2015 05 28	Revised	See Summary of Revisions	C. Macna, NA
1987 09 18	Released	SM/ER 1209TC	J. P. Lines, EAO



2.3 INTERGRANULAR CORROSION OF ALUMINUM FASTENERS

Threaded aluminum fasteners are susceptible to intergranular corrosion. Care should be taken in designing bolted joints utilizing aluminum fasteners so that critical areas of the fastener are not exposed to corrosive environments.

2.4 LIQUID METAL EMBRITTLEMENT

Normally ductile metals can experience cracking and brittle fracture when they come into contact with liquid metals while subjected to a tensile stress. This failure mode is called liquid metal embrittlement (LME). LME can occur when parts with metallic plating are exposed to temperatures above their melting point during subsequent manufacturing processes or in use.

3. REQUIREMENTS

3.1 APPROVED SOURCES

This specification does not have approved sources.

3.2 CONTROL PLAN

Fasteners and components affected by this specification shall have a control plan that includes the requirements of this specification. The control plan shall include verification test(s) to demonstrate the effectiveness of the embrittlement relief procedures after electroplating. Verification procedures are not required for acid cleaning, phosphating, or mechanical plating. In cases where the electroplating process does not normally produce embrittlement, it may be necessary to establish verification tests based on proven methodology.

3.3 RESTRICTIONS ON PART USAGE

Due to high tensile stresses involved in fastened joints, all fasteners or threaded components with a maximum specified core or surface hardness greater than 390 HV (39 HRC) shall not be used in critical applications where there is a potential for corrosion. Critical applications are determined as those with an FMEA severity rating of 9 or 10 for fractures.

Fasteners and components used in non-critical applications where the maximum specified core or surface hardness is greater than 390 HV (39 HRC) shall not be used where exposed to the potential for corrosion without an appropriate FMEA. The FMEA shall include consideration of cracking mechanisms, such as hydrogen embrittlement, stress corrosion cracking, etc. as possible causes of fracture, as well as the need for corrosion protective finishes.

Carburization of through hardened components is not permitted unless specified on the Engineering Drawing. Unintentional carburization sometimes occurs when hardened components are subjected to a carbon rich atmosphere. In these cases, the surface hardness shall not be more than 30 HV above the measured core hardness. For property class 10.9 fasteners, any increase in hardness at the surface that indicates that the surface hardness exceeds 390 HV (39 HRC) is not acceptable.

3.4 ALUMINUM FASTENER USAGE

Externally threaded aluminum fasteners shall be free from intergranular corrosion in the under-head, radius transition, shank and shank-to-thread transition areas and the entire threaded length.



3.4.1 Grain Size (ASTM E112, Comparison Procedure)

The average grain size for aluminum fasteners must be Grain Size No. 2.5 or finer (150 micrometers) in the longitudinal direction and Grain Size 4.0 or finer (90 micrometers) in the transverse direction.

3.4.2 Laboratory Evaluation for Intergranular Corrosion (FLTM AB 110-01)

All joints using externally threaded aluminum fasteners shall be tested per FLTM AB 110-01 during the Design Validation (DV) phase. No intergranular corrosion (No IGC) or cracking of surface coatings is allowed.

3.4.3 Evaluation after Vehicle Corrosion Testing (CETP 00.00-R-343, FLTM AB 110-01, ISO 6157-3)

All aluminum fasteners from vehicles completing the Total Vehicle Corrosion Test, CETP 00.00-R-343, shall be cross-sectioned after test completion and evaluated using the criteria in FLTM AB 110-01. No intergranular corrosion (No IGC) or cracking of surface coatings is allowed.

3.4.4 All aluminum fasteners shall be evaluated for surface discontinuities per ISO 6157-3. Only allowable discontinuities may be present.

3.5 CLEANING PRIOR TO HEAT TREATMENT

All fasteners and components with a maximum specified core or surface hardness greater than 353 HV (35 HRC) must be cleaned prior to heat treatment to remove phosphorus-containing products or any other detrimental contaminants from the surface. The formation of a white, phosphorus enriched layer caused by penetration of phosphorus during the hardening process is not permissible.

Note: This is not applicable to induction hardened components due to the short time at temperature.

3.6 HEAT TREATMENT

All heat treatment operations, except embrittlement relief via baking (Section 3.8 Embrittlement Relief), shall be completed prior to plating or phosphate coating.

3.7 CLEANING AFTER HEAT TREATMENT OR COLD WORKING

Acid cleaning of fasteners and components which have been heat treated to a specified core or surface hardness greater than 353 HV (35 HRC) or have been highly stressed due to cold working, enhances the susceptibility to hydrogen embrittlement, and shall be minimized. If such fasteners and components are to be acid cleaned, an inhibited acid shall be used and a procedure shall be established that limits exposure to the acid bath to a maximum of 10 minutes. Fasteners and components that are acid cleaned and subsequently phosphate coated, mechanically plated, or electroplated, shall follow the requirements in section 3.8 Embrittlement Relief Table 1 as applicable. All other fasteners and components that are acid cleaned but not subsequently coated or plated, shall not be used for 48 hours, or these parts shall be baked for a minimum of 1 hour at 110 °C minimum following cleaning.

Note: Inhibited acids have inhibitors added to the acid to reduce the corrosive attack on the steel and absorption of hydrogen.