HYDROGEN EMBRITTLEMENT TESTING
Is Your Product at Risk

A Miami Valley Materials Testing Center Whitepaper
Hydrogen Embrittlement Testing: Is Your Product at Risk

Hydrogen embrittlement is one of the most insidious and sinister types of material failure. Hydrogen embrittlement testing provides product manufacturers with an additional measure of quality assurance that their product will not likely fail during operation due to faulty or improperly controlled plating/coating processes.

Hydrogen embrittlement can occur in moderate to high strength steels when exposed to hydrogen during the plating/coating process. Hydrogen, being the smallest of atoms, easily diffuses through most materials, often accumulating in areas of high stress, such as notches, grooves, holes, etc. This accumulation contributes to the formation and growth of micro cracks, usually resulting in rapid, unexpected fracture.

Failures that occur at stress levels below the ultimate tensile strength of the material, are almost always time delayed, and therefore occur after assembly and during operation. Test methods exist to help determine a part's susceptibility.

The most sited hydrogen embrittlement test is ASTM Standard F519, “Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments.” In essence, this is the method plating manufacturers use for quality assurance purposes.

Round, notched, and plated specimens made from AISI 4340 steel heat treated to 260-280 ksi tensile strength are subjected to sustained loads for 200 hours (>8 days). Actual test time can extend to 2-4 weeks due to post-test nondestructive testing inspection. This is an extensive amount of time to wait to release a product to market. Also, cost of this test can be very high.

To reduce the cost and time required, another method exists as allowed by Annex A3 of ASTM Standard F519. This method is ASTM Standard F1624, “Standard Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique.” This method is used to rapidly determine the effects of residual hydrogen caused by processing or qualify the susceptibility of a specific material under a fixed set of conditions. It provides an acceptable method to measure the threshold stress required for the onset of hydrogen induced cracking within one day.

This test method establishes a procedure to determine the susceptibility of steels to time delayed failure that may be caused by hydrogen. It is not restricted to AISI 4340 steel heat treated to 260-280 ksi tensile strength. Different steel compositions of different heat treat conditions can be evaluated.

Also, this method is not restricted to the effect of residual hydrogen introduced by the plating process alone. With this method, the effect of residual hydrogen introduced by external sources such as fluids, cleaners, maintenance chemicals, petroleum products, etc. can be evaluated. Additionally, this method can be used to evaluate effects of different steel processing such as melting practice, thermal and/or mechanical working.

MVMTC engineers can customize testing for your application. This is accomplished by tensile testing ASTM Standard F519, types 1a.1 or 1a.2 unplated/unprocessed specimens to establish the Notch Fracture Strength (NFS). Plated/processed specimens are subsequently incrementally step loaded (15/5/1 + 5/5/2) per ASTM Standard F1624. To pass the test, the specimen must withstand a stress level of 90% of the Notched Fracture Strength for two hours or more. Results are known within 20 hours, compared to 2-4 weeks plus.
One might ask what is the equivalence between ASTM Standard F519 [sustained load test (SLT)] and ASTM Standard F1624 [incremental step load test (ISL)]?

**Per ASTM F519:**

Section A3.5.1, "The equivalence between the SLT and the ISL test methods has not been established in accordance with ASTM Practice E691. However, it has been demonstrated that unplated specimens tested in air using the ISL method will fracture at 90% of NFS. In so far as this represents a nominally hydrogen free state, it is reasonably assumed that plated/coated specimens that sustain 90% NFS for 2 hours can be considered to be non-embrittled."

Section A3.6.1, "For test specimens that meet or exceed 90% of their ISL NFS for 2 hours or more using the (15/5/1 + 5/5/2) step protocol, the plating/coating process is considered to be non-embrittling."