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Standard Terminology Relating to Hydrogen Embrittlement Testing[1]

This standard is issued under the fixed designation F 2078; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This terminology covers the principal terms, abbreviations, and symbols relating to mechanical methods for hydrogen embrittlement testing. These definitions are published to encourage uniformity of terminology in product specifications.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 6 Terminology Relating to Methods of Mechanical Testing

E 8~~Test Methods for Tension Testing of Metallic Materials~~[3]

~~E812Test Method for Crack Strength of Slow Bend, Precracked Charpy Specimens of High-Strength Metallic Materials~~[3] Test Methods for Tension Testing of Metallic Materials

E 1823 Terminology Relating to Fatigue and Fracture Testing

F 1624 Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

G 15 Terminology Relating to Corrosion and Corrosion Testing

3. Significance and Use

3.1 The terms used in describing hydrogen embrittlement have precise definitions. The terminology and its proper usage must be completely understood to communicate and transfer information adequately within the field.

3.2 Some of the terms are defined in other terminology standards, which are respectively identified in parentheses following the definition.

4. Terminology

4.1 *Definitions:*

baking—heating to a temperature at least 50°F below the tempering or aging temperature of the metal or alloy to remove hydrogen before embrittlement occurs by the formation of microcracks.

Discussion—No metallurgical changes take place as a result of baking. **(A 941)**

brittle—the inability of a material to deform plastically before fracturing.

crack strength—the maximum value of the nominal stress that a cracked specimen is capable of sustaining. **(E 1823)**

ductile—the ability of a material to deform plastically before fracturing. **(E 6)**

embrittle~~—to make brittle; that is, to lose ductility.~~ —see **embrittlement**.

embrittlement~~—the loss of ductility or toughness of a metal or alloy.~~ —the severe loss of ductility or toughness, or both, of a material, usually a metal or alloy. **(G 15)**

environmental hydrogen embirttlement (EHE)— generally caused by hydrogen introduced into the steel from the environment after exposure to an externally applied stress.

Discussion—Embrittlement as a result of hydrogen introduced into steel from external sources while under stress. Tests are conducted in an environment. **(STP 962)**

Discussion—Found in plated parts that cathodically protect the metal from corroding. Generates hydrogen at the surface of the metal. Produces a

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* ~~, Vol 01.01.~~volume information, refer to the standard's Document Summary page on the ASTM website.

clean, intergranular fracture surface. Not reversible. (The subtle differences between IHE and EHE are detailed in Appendix X1.) **(STP 543)**

environmentally assisted cracking (EAC)~~—generic, crack growth as a result of exposure to the environment.~~ — see **stress corrosion cracking**.

fracture strength~~—the load at the beginning of fracture during a tension test divided by the original cross-sectional area.~~ —the normal stress at the beginning of fracture.

gaseous hydrogen embrittlement (GHE)—a distinct form of EHE caused by the presence of external sources of high pressure hydrogen gas; cracking initiates on the outer surface.

heat treatment—heating to a temperature that produces metallurgical changes in the steel that alter the mechanical properties and microstructure of the metal. **(A 941)**

hydrogen-assisted stress cracking (HASC)— crack growth as a result of the presence of hydrogen; it can be either IHE or EHE and sometimes is referred to as hydrogen stress cracking (HSC).

hydrogen embrittlement—a permanent loss of ductility in a metal or alloy caused by absorption of hydrogen in combination with stress, either an externally applied or an internal residual stress. **(G 15)**

hydrogen-induced stress cracking—see **hydrogen-assisted stress cracking**.

hydrogen stress cracking—see **hydrogen-assisted stress cracking**.

hydrogen susceptibility ratio (Hsr)—the ratio of the threshold for the onset of hydrogen-assisted cracking to the tensile strength of the material.

internal hydrogen embrittlement (IHE)— hydrogen embrittlement caused by absorbed atomic hydrogen from any chemical process that introduces hydrogen into the steel before exposure to an externally applied stress.

DISCUSSION—Embrittlement results from the formation of microcracks with time and is often referred to as "time-delayed embrittlement." Once microcracks have been formed, ductility cannot be restored. Tests are generally conducted in air. **(STP 543)**

DISCUSSION—This type of embrittlement is referred to as the classic type of hydrogen embrittlement in steel, although IHE has also been observed in a wide variety of other materials including nickel base alloys and austenitic stainless steels provided that they are severely charged with hydrogen. **(STP 543)**

DISCUSSION—For steels, IHE is most severe at room temperature. The problem primarily results from electroplating. Other sources of hydrogen are the processing treatments, such as melting and pickling. **(STP 543)**

notched tensile strength—the maximum nominal (net section) stress that a notched tensile specimen is capable of sustaining. **(E 1823)**

process—a defined event or sequence of events in plating or coating that may include pretreatments and posttreatments.

reaction hydrogen embrittlement (RHE)~~—hydrogen can react with itself, with the matrix, or with a foreign element in the matrix and form new phases that are usually quite stable, and embrittlement is not reversible.~~

~~DISCUSSION—Quite distinct from the other types in that the hydrogen may react near the surface or diffuse a substantial distance before it reacts. (STP543)~~ **— irreversible embrittlement caused by the reaction of hydrogen with metal to form a stable hydride.**

sharp-notch strength—the maximum nominal (net section) stress that a sharply notched specimen is capable of sustaining. **(E 1823)**

stress corrosion cracking (SCC)—a cracking process that requires the simultaneous action of a corrodent and sustained tensile stress.

DISCUSSION—This excludes corrosion-reduced sections that fail by fast fracture and intercrystalline or transcrystalline corrosion, which disintegrate an alloy without either applied or residual stress. **(G 15)**

DISCUSSION—Considered to occur while under anodic polarization. Not reversible. Produces an oxidized, intergranular fracture surface. **(STP 543)**

stress–intensity factor, K, K_I, K_{II}, K_{III},—the magnitude of the ideal crack–tip stress field (stress field singularity) for a particular mode in a homogeneous linear–elastic body. **(E 1823)**

susceptibility to hydrogen embrittlement— is a material property that is measured by the threshold stress intensity parameter for hydrogen induced stress cracking, K_{Iscc}, K_{IHE} , or K_{EHE}, which is a function of hardness and microstructure.

threshold (th)—a point, separating conditions that will produce a given effect, from conditions that will not produce the effect; the lowest load at which subcritical cracking can be detected.

threshold stress (σ_{th})~~—a stress below which no hydrogen stress cracking will occur and above which time-delayed fracture will occur; in Test Method F1624, the threshold is identified as the maximum load at the onset of cracking that cuases a 5% drop in load of NSF(B)$_{F1624}$ under displacement control.~~ — a stress below which no hydrogen stress cracking will occur and above which time-delayed fracture will occur.

threshold stress intensity (K_{th})—a stress intensity below which no hydrogen stress cracking will occur and above which, time-delayed fracture will occur.

time-delayed embrittlement—see **internal hydrogen embrittlement**.

4.2 *Symbols:*

P—applied load