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Standard Terminology Relating to Hydrogen Embrittlement Testing[1]

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1. Scope

1.1 This terminology covers the principal terms, abbreviations, and symbols relating to mechanical methods for hydrogen embrittlement testing, which are present in more than one of the standards under the jurisdiction of ASTM Committee F07 on Aerospace and Aircraft. These definitions are published to encourage uniformity of terminology in product specifications.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 904 Terminology Relating to Chemical-Resistant Nonmetallic Materials

D 4848 Terminology Related to Force, Deformation and Related Properties of Textiles

E 6 Terminology Relating to Methods of Mechanical Testing

E 8 Test Methods for Tension Testing of Metallic Materials

E 631 Terminology of Building Constructions

E 1823 Terminology Relating to Fatigue and Fracture Testing

F 109 Terminology Relating to Surface Imperfections on Ceramics

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 The terms defined in other terminology standards, are respectively identified in parentheses following the definition.

4. Terminology

4.1 *Definitions:*

baking—heating to a temperature, not to exceed 50°F (27.8°C) below the tempering or aging temperature of the metal or alloy, in order to remove hydrogen before embrittlement occurs by the formation of microcracks.

DISCUSSION—No metallurgical changes take place as a result of baking.

brittle—see **brittleness**.

brittleness—the tendency of a material to break at a very low strain, elongation, or deflection, and to exhibit a clean fracture surface with no indications of plastic deformation. **(E 631)**

crack—line of fracture without complete separation. **(F 109)**

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

ductile—see **ductility**.

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

embrittle—see **embrittlement**.

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

environmental hydrogen embrittlement (EHE)—hydrogen embrittlement caused by hydrogen introduced into a steel/metallic alloy from an environmental source coupled with stress either residual or externally applied.

DISCUSSION—Produces a clean intergranular fracture and is not reversible. For the subtle differences between EHE and IHE, see Table X1.1.

environmentally assisted cracking (EAC)—see **stress corrosion cracking**.

fracture strength—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.

[1] This terminology standard is under the jurisdiction of ASTM Committee F07 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.04 on Hydrogen Embrittlement.

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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* volume information, refer to the standard's Document Summary page on the ASTM website.

heat treatment—heating and cooling processes that produce metallurgical changes in the metallic alloy which alter the mechanical properties and microstructure of the metal.

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

hydrogen embrittlement (HE)—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.

hydrogen embrittlement relief—see **baking**.

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 into the steel/metallic alloy from an industrial hydrogen emitting process coupled with stress, either residual or externally applied.

DISCUSSION—For the subtle differences between IHE and EHE see Table X1.1.

notched tensile strength (NTS)—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)—irreversible embrittlement caused by the reaction of hydrogen with metal to form a stable hydride.

residual stress—stress in a metal in the absence of external forces.

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

strain—deformation of a material caused by the application of an external force. **(D 4848)**

strain rate—the rate of relative length deformation with time due to an applied stress. **(C 904)**

stress—the resistance to deformation developed within a material subjected to an external force. **(D 4848)**

stress concentration factor (k_t)—the ratio of the greatest stress in the region of a notch or other stress concentrator, as determined by the theory of elasticity or by experimental procedures that give equivalent values, to the corresponding nominal stress. **(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. It also excludes intercrystalline or transcrystalline corrosion, which can disintegrate an alloy without either applied or residual stress (G 15). In essence the process of SCC and EAC are equivalent.

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

DISCUSSION—K_I=for a Mode I (opening mode) loading condition that displaces the crack faces in a direction normal to the crack plane.
K_{II}=for a Mode II (sliding mode) loading condition where the crack faces are displaced in shear sliding in the crack plane and in the primary crack propagation direction.
K_{III}=for a Mode III (tearing mode) loading condition where the crack faces are displaced in shear tearing in the crack plane but normal to the primary crack propagation direction.

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.

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

P_c—critical load required to rupture a specimen using a continuous loading rate

P_i—crack initiation load for a given loading and environmental condition using an incrementally increasing load under displacement control

P_{th}—threshold load in which P_i is invariant with respect to loading rate; P_{th} is the basis for calculating the threshold stress or the threshold stress intensity

σ—applied stress

σ_{net}—net stress based on area at minimum diameter of notched round bar

σ_i—stress at crack initiation

$\sigma_{th\text{-}IHE}$—threshold stress—test conducted in air—geometry dependent

$\sigma_{th\text{-}EHE}$—threshold stress—test conducted in a specified environment—geometry dependent

K—stress-intensity factor

K_{th}—threshold stress intensity

K_t—stress concentration factor

K_{Iscc}—threshold stress intensity for stress corrosion cracking

K_{IHE}—threshold stress intensity for IHE

K_{EHE}—threshold stress intensity for EHE

R_{sb}—ratio of specimen crack strength to yield strength in bending