Designation: G 129 – 00

Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking[1]

This standard is issued under the fixed designation G 129; 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 practice covers procedures for the design, preparation, and use of axially loaded, tension test specimens and fatigue pre-cracked (fracture mechanics) specimens for use in slow strain rate (SSR) tests to investigate the resistance of metallic materials to environmentally assisted cracking (EAC). While some investigators utilize SSR test techniques in combination with cyclic or fatigue loading, no attempt has been made to incorporate such techniques into this practice.

1.2 Slow strain rate testing is applicable to the evaluation of a wide variety of metallic materials in test environments which simulate aqueous, nonaqueous, and gaseous service environments over a wide range of temperatures and pressures that may cause EAC of susceptible materials.

1.3 The primary use of this practice is to furnish accepted procedures for the accelerated testing of the resistance of metallic materials to EAC under various environmental conditions. In many cases, the initiation of EAC is accelerated through the application of a dynamic strain in the gage section or at a notch tip or crack tip, or both, of a specimen. Due to the accelerated nature of this test, the results are not intended to necessarily represent service performance, but rather to provide a basis for screening, for detection of an environmental interaction with a material, and for comparative evaluation of the effects of metallurgical and environmental variables on sensitivity to known environmental cracking problems.

1.4 Further information on SSR test methods is available in ISO 7539 and in the references provided with this practice **(1-6)**.[2]

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Furthermore, in some cases, special facilities will be required to isolate these tests from laboratory personnel if high pressures or toxic chemical environments, or both, are utilized in SSR testing.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]
B 557 Test Methods for Tension Testing of Wrought and Cast Aluminum and Magnesium-Alloy Products[4]
D 1193 Specification for Reagent Water[5]
E 4 Practices for Load Verification of Testing Machines[6]
E 6 Terminology Relating to Methods of Mechanical Testing[6]
E 8 Test Methods for Tension Testing of Metallic Materials[6]
E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials[6]
E 602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens[6]
E 616 Terminology Relating to Fracture Testing[6]
E 647 Test Method for Measurement of Fatigue Crack Growth Rates[6]
E 1681 Test Method for Determining a Threshold Stress Intensity Factor for Environmentally-Assisted Cracking of Metallic Materials[6]
G 15 Terminology Relating to Corrosion and Corrosion Testing[7]
G 49 Practice for Preparation and Use of Direct Tension Stress Corrosion Test Specimens[7]
G 111 Guide for Corrosion Tests in High Temperature or High Pressure Environment, or Both[7]
G 142 Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both[7]

[1] This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.06 on Stress Corrosion Cracking and Corrosion Fatigue.

Current edition approved Nov. 10, 2000. Published November 2000. Originally published as G 129 – 95. Last previous edition G 129 – 95.

[2] Boldface numbers refer to the list of references at the end of this standard.

[3] *Annual Book of ASTM Standards*, Vol 01.03.
[4] *Annual Book of ASTM Standards*, Vol 02.02.
[5] *Annual Book of ASTM Standards*, Vol 11.01.
[6] *Annual Book of ASTM Standards*, Vol 03.01.
[7] *Annual Book of ASTM Standards*, Vol 03.02.

2.2 *ISO Standard:*
7539, Part 7, Slow Strain Rate Testing[8]

3. Terminology

3.1 For purposes of this practice the following terms are defined:

3.2 *control environment*—an environment in which SSR specimens are tested that has been shown not to cause EAC or excessive corrosion of the material. The results of tests conducted in this environment may be used as a basis for comparison with corresponding tests conducted in the test environment(s), usually at the same temperature as the test environment.

3.3 *environmentally assisted cracking (EAC)*— cracking of a material caused by the combined effects of stress and the surrounding environment, for example, stress corrosion cracking, hydrogen embrittlement cracking, sulfide stress cracking and liquid metal embrittlement.

3.4 *slow strain rate (SSR)*—a dynamic slowly increasing strain imposed by an external means on the gage section or notch tip of a uniaxial tension specimen or crack tip of a fatigue pre-cracked specimen for purposes of materials evaluation. The strain rate for a plain or smooth specimen (given in units of extension divided by the gage length per unit time) or the strain rate at a notch tip of a notched tension specimen or crack tip of a fatigue pre-cracked specimen is applied through the application of a slow constant extension rate (given in units of extension per unit time). The slow constant extension rate produces a gage section strain rate, which is usually in the range from 10^{-4} to $10^{-7}/s^{-1}$. Rigorous analytical solutions of the local strain rate at a notch tip of a tension specimen or at a crack tip of a fatigue pre-cracked specimen are not available. The average or local strain rate should be slow enough to allow time for certain corrosion processes to take place, but fast enough to produce failure or cracking of the specimen in a reasonable period of time for evaluation purposes. In cases where extremely slow strain rates are being utilized (that is, 10^{-7} to $10^{-8}/s^{-1}$ for smooth tension specimens), an interrupted SSR test can be employed whereby the specimen is strained into the plastic range at the intended strain rate followed by more rapid straining to failure.

3.5 The terminology found in Test Methods and Definitions A 370, Test Method B 557, and Test Method E 602 along with the definitions given in Terminologies E 6, E 616, and G 15 shall apply to the terms used in this practice.

4. Summary of Practice

4.1 This practice describes the use of tension and fatigue pre-cracked specimens for the determination of resistance to EAC of metallic materials. The procedure involves the application of very slow strain rates, which are achieved by a constant extension rate on the specimen while monitoring load and extension of the specimen. The SSR test always produces fracture of the test specimen. Typically, the results from tests conducted in the test environment are compared to corresponding test results for the same material in a control environment. The degree of susceptibility to EAC is generally assessed through observation of the differences in the behavior of the material in tests conducted in a test environment from that obtained from tests conducted in the control environment. For smooth tension specimens, either changes in time-to-failure, or specimen ductility, or visual indications of EAC, or often some combination of these methods, are utilized in determining susceptibility to EAC. For notched tension specimens, changes in the notch tensile strength and visual indications of EAC on the primary fracture surface are used in determining susceptibility to EAC. For fatigue pre-cracked specimens, changes in the threshold stress intensity factor and visual indications of EAC on the primary fracture surface are used in determining susceptibility to EAC.

5. Significance and Use

5.1 The slow strain rate test is used for relatively rapid screening or comparative evaluation, or both, of environmental, processing or metallurgical variables, or both, that can affect the resistance of a material to EAC. For example, this testing technique has been used to evaluate materials, heat treatments, chemical constituents in the environment, and temperature and chemical inhibitors.

5.2 Where possible, the application of the SSR test and data derived from its use should be used in combination with service experience or long-term EAC data, or both, obtained through literature sources or additional testing using other testing techniques. In applications where there has been little or no prior experience with SSR testing or little EAC data on the particular material/environment combination of interest, the following steps are recommended:

5.2.1 The SSR tests should be conducted over a range of applied extension rates (that is, usually at least one order of magnitude in applied extension rate above and below 10^{-6} in/s (2.54×10^{-5} mm/s) to determine the effect of strain rate or rate of increase of the stress or stress intensity factor on susceptibility to EAC.

5.2.2 Constant load or strain EAC tests should also be conducted in simulated service environments, and service experience should be obtained so that a correlation between SSR test results and anticipated service performance can be developed.

5.3 In many cases the SSR test has been found to be a conservative test for EAC. Therefore, it may produce failures in the laboratory under conditions which do not necessarily cause EAC under service application. Additionally, in some limited cases, EAC indications are not found in smooth tension SSR tests even when service failures have been observed. This effect usually occurs when there is a delay in the initiation of localized corrosion processes. Therefore, the suggestions given in 5.2 are strongly encouraged.

5.4 In some cases, EAC will only occur in a specific range of strain rates. Therefore, where there is little prior information available, tests should be conducted over a range of strain rates as discussed in 5.2.

6. Apparatus

6.1 *Testing Machines*:

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

6.1.1 Tension testing machines used for SSR testing shall conform to the requirements of Practices E 4.

6.1.2 The loads used in SSR testing shall be within the calibrated load ranges of the testing machine in accordance with Practices E 4.

6.1.3 The testing machines used for SSR testing shall be capable of accurate application of extension rates in the range of interest for evaluation of EAC. These extension rates are usually between 10^{-4} and 10^{-7} in/s (2.54×10^{-3} and 2.54×10^{-6} mm/s).

6.1.4 An example of a SSR testing machine setup including the load frame, instrumentation, and local test cell is shown in Fig. 1. Another example of a SSR machine setup with a metal test cell or autoclave can be found in Test Method G 142. The test specimen is loaded with a grip assembly and load frame inside the autoclave. The autoclave is equipped with a tensile loading feed-through to provide transmission of loads from the tensile machine to the specimen using a pull rod in combination with the feed-through. Some SSR testing machines may be able to test more than one specimen at a time in a particular environment. However, this type of machine should only be used if it can be shown that failure of one or multiple specimens does not influence the behavior of the other specimens.

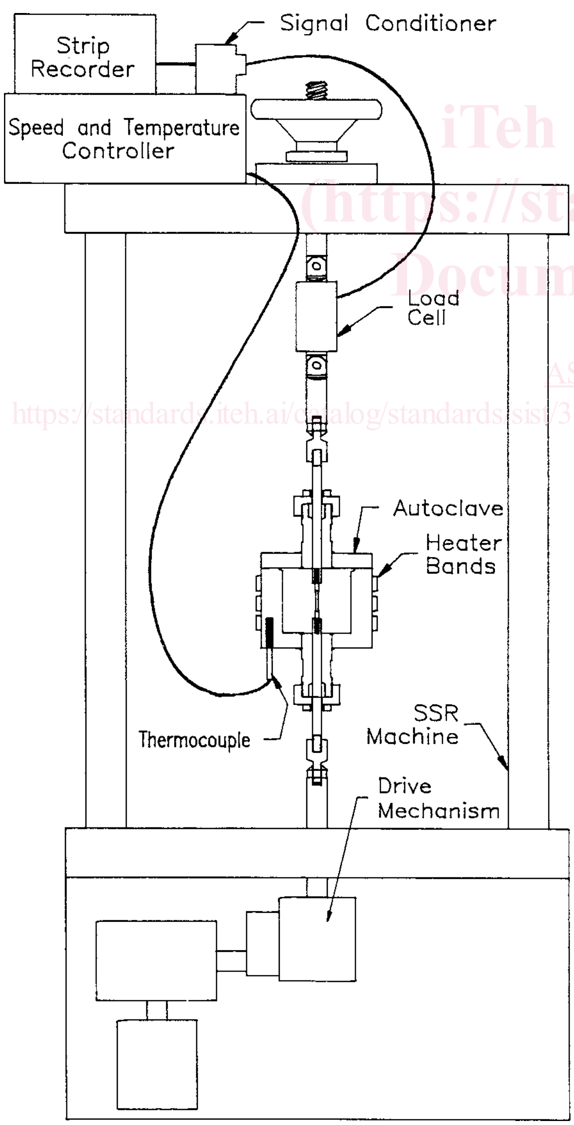

FIG. 1 An Example of a SSR Testing Machine.

6.2 *Gripping Devices*—The types of gripping devices that may be used to transmit the applied load from the testing machine to the tension specimen conform to those described in Test Methods E 8. Alignment procedures are provided in Test Method E 8.

6.3 *Clevices and Fixtures*—A loading clevis that is suitable for loading pre-cracked compact specimens should conform with clevices described in Test Method E 399. A bend test fixture for loading pre-cracked bend specimens should conform with bend fixtures described in Test Method E 399. It is important that attention be given to achieving good load train alignment through careful machining of all clevices and fixtures.

6.4 *Displacement Gages*—An electronic crack mouth opening displacement (CMOD) gage attached to the front face of pre-cracked specimens and spanning the crack starter notch to detect crack growth during testing should be in accordance with displacement gages described in Test Method E 399. Alternatively, the displacements can be transferred outside the environmental test cell in the case of tests conducted in high temperature or severely corrosive environments. An extensometer placed outside the test cell can be used to detect the crack growth. A displacement gage can be attached to the specimen at alternative locations to detect crack growth if the proper compliance-crack length relationship has been determined for the measurement location on the specimen.

6.5 *Environmental Test Cells*—Test cells shall be constructed in a manner to facilitate handling and monitoring of the test environment while allowing testing of the tension specimen. This will require the incorporation of a suitable low-friction feed-through in the vessel for application of load to the test specimen. Additionally, the test cell shall be able to safely contain the test environment with adequate accommodation for the temperature and pressure under which the SSR tests will be conducted.

6.5.1 Test cells shall be effectively inert (that is, have a low corrosion rate and not susceptible to EAC in the test environment so that they do not react with or contaminate the environment).

6.5.2 The test cell size should be such that a solution volume-to-exposed specimen surface area is not less than 30 mL/cm^2.

6.6 *Galvanic Effects*—Eliminate galvanic effects between the test specimen and various metallic components of the gripping fixtures and test cell by electrically insulating or isolating these components unless it is specifically desired to simulate galvanic interactions found in service conditions and their effects on EAC. Check electrical isolation with an ohmmeter, if required, prior to testing. It should be noted that, in some cases, electrical insulation may be bridged by deposits of conductive or semiconductive solid corrosion products during the test, thereby introducing galvanic effects into the SSR test.