INTERNATIONAL

Designation: ~~E1949 – 03 (Reapproved 2014)^ε1^~~ E1949 – 21

Standard Test Method for Ambient Temperature Fatigue Life of Metallic Bonded Resistance Strain Gages[1]

This standard is issued under the fixed designation E1949; 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.

~~ε1 NOTE—Section 7.2.1 and Footnote 3 were editorially corrected in August 2014.~~

1. ~~Scope~~ Scope*

1.1 This test method covers a uniform procedure for the determination of strain gage fatigue life at ambient temperature. A suggested testing equipment design is included.

1.2 This test method does not apply to force transducers or extensometers that use metallic bonded resistance strain gages as sensing elements.

1.3 Strain gages are part of a complex system that includes structure, adhesive, strain gage, lead wires, instrumentation, and (often) environmental protection. As a result, many things affect the performance of strain gages, including user technique. A further complication is that strain gages, once installed, normally cannot be reinstalled in another location. Therefore, it is not possible to calibrate individual strain gages; performance characteristics are normally presented on a statistical basis.

1.4 This test method encompasses only fully reversed stain cycles.

1.5 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to ~~its~~ use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E6 Terminology Relating to Methods of Mechanical Testing

E1237 Guide for Installing Bonded Resistance Strain Gages

3. Terminology

3.1 Definitions of terms common to mechanical testing:

[1] This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.01 on Calibration of Mechanical Testing Machines and Apparatus.

Current edition approved ~~April 1, 2009~~Feb. 1, 2021. Published ~~August 2014~~March 2021. Originally approved in 1998. Last previous edition approved in ~~2009~~2014 as E1949 – 03~~(2009).~~(2014)^ε1^. DOI: ~~10.1520/E1949-03R14E01.~~10.1520/E1949-21.

[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.

***A Summary of Changes section appears at the end of this standard**

3.1.1 The terms accuracy, extensometer, gage factor, lead wire, metallic bonded resistance strain gage, and resolution are used as defined in Terminology E6.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *strain gage, n*—the term "strain gage" is equivalent to the longer, but more accurate, "metallic bonded resistance strain gage."

3.2.2 *strain gage fatigue life, n*—the number of fully reversed strain cycles corresponding to the onset of degraded gage performance, whether due to excessive zero shift or other detectable failure mode (see 9.6).

4. Significance and Use

4.1 Strain gages are the most widely used devices for measuring strains and for evaluating stresses in structures. In many applications there are often cyclic loads ~~which~~that can cause strain gage failure. Performance ~~parameters~~characteristics of strain gages are affected by both the materials from which they are made and their geometric design.

4.2 The determination of most strain gage ~~parameters~~ performance characteristics requires mechanical testing that is destructive. Since strain gages tested for fatigue life cannot be used again, it is necessary to treat data statistically. In general, longer and wider strain gages with lower resistances will have greater fatigue life. Optional additions to strain gages (integral ~~leads~~ lead wires are an example) will often reduce fatigue life.

4.3 To be used, strain gages must be bonded to a structure. Good results, particularly in a fatigue environment, depend heavily on the materials used to clean the bonding surface, to bond the strain gage, and to provide a protective coating. Skill of the installer is another major factor in success. Finally, instrumentation systems ~~must~~shall be carefully selected and calibrated to ensure that they do not unduly degrade the performance of the strain gages.

~~4.4 This test method encompasses only fully reversed strain cycles.~~

4.4 Fatigue *failure* of a strain gage ~~may~~ often does not involve visible cracking or fracture of the strain gage, but merely sufficient zero shift to compromise the accuracy of the strain gage output for static strain components.

5. Interferences

5.1 In order to ensure that strain gage test data are within a defined accuracy, the strain gages must be properly bonded and protected with acceptable materials. Aids in the strain gage installation and ~~verification thereof~~ validation can be found in Guide E1237. ~~It is important to note that good~~ Good performance in cyclic applications requires the best installations possible.

6. Hazards

6.1 **Warning—**In the specimen surface cleaning, strain gage bonding, and protection steps of strain gage installations, hazardous chemicals are often employed. Users of these test methods are responsible for contacting manufactures of such chemicals for applicable Material Safety Data Sheets, and adhering to ~~adhere to~~ the required precautions.

7. Apparatus

7.1 *Test Measurement Requirements:*

7.1.1 For strain gage fatigue life determination the uncertainty of the relative resistance change measurement shall not exceed ±5 ~~μΩ/Ω~~μΩ/Ω or ±0.1 % of the actual value, whichever is greater.

7.1.2 ~~Several methods are available~~ Any method for measuring the change of ~~gage resistance with sufficient resolution and accuracy. In general, any method~~ strain gage resistance that is convenient may be used after it has been shown that the particular combination of instruments or components used produces a measurement system with the required resolution and accuracy.

7.1.3 ~~Many types of instruments are available for obtaining~~ Measurement systems that obtain strain data directly from a ~~resistance~~

~~strain gage. These instruments use various types of excitation and read-out systems. Such indicators may be used~~ strain gage may be used, but only after their resolution, accuracy, and stability have been verified by connecting a resistor that can be varied in accurately known increments in place of the strain gage and calibrating the ~~strain indicator~~measurement system over the entire range for which it will be used. The calibrating resistor steps shall be accurate to 0.1 % of the resistance change or ~~2~~2×10^{-6} ~~ppm~~ of the total resistance, whichever is greater. Effects from the following influences on measurement accuracy ~~must~~shall be quantified and found within limits that preserve the required overall measurement system accuracy: thermal emfs within the bridge circuit and within the strain gage ~~leadwire,~~ lead wire, reactive changes within the bridge and lead wire circuits, initial bridge unbalance, and battery conditions or power line fluctuations.

7.2 *Mechanical Equipment Requirements:*

7.2.1 A ~~suggested~~ cantilever test beam ~~is~~ like that shown in Fig. 1~~. The beam must have a fatigue life exceeding that of the strain gages to be tested. One material which meets this requirement is CYPLY 1002~~ should be used, because it provides ~~, which is a unidirectional glass-reinforced epoxy composite material, with all fibers aligned with the long axis of the beam. Surface spalling of metallic test beams and crazing of plastic specimens are examples of beam failures that will produce faulty, misleadingly low, strain gage fatigue life.~~a range of strain levels that are nearly linear along its length in a single test.

7.2.1.1 The fatigue life of the cantilever test beam shall exceed that of the strain gages to be tested.

NOTE 1—One material that meets this requirement is CYPLY 1002[3], which is a unidirectional glass-reinforced epoxy composite material, with all fibers aligned with the long axis of the cantilever test beam. Surface spalling of metallic cantilever test beams and crazing of plastic cantilever test beams are examples of beam failures that will produce faulty, misleadingly low, strain gage fatigue life.

7.2.1.2 ~~Beam specimens must~~ Epoxy composite cantilever test beams shall be cut such that the glass fibers are aligned with the long dimension of the ~~specimen. A cantilever specimen is recommended for this testing because it provides a range of strain levels in a single test. (A consequence is that the specimen's strain level near the clamp is very high. Normal structural materials will not survive such high levels and may fail in ways that imply strain gage failure when such is not the case.) A test beam should be used for one test only.~~cantilever test beam.

NOTE 2—The strain level near the cantilever test beam clamp is very high. Normal structural materials will not survive such high levels and can fail in ways that imply strain gage failure when such is not the case.)

7.2.1.3 A cantilever test beam should be used for one test only.

7.2.2 A fatigue testing machine similar to the one illustrated in Fig. 2 should be used. For a cantilever test beam with overall dimensions as shown in Fig. 1 and a thickness of 9.5 mm, the crank should deflect the beam approximately 15 mm to produce a suitable strain range from ±500 µm/m to ±3500 µm/m.

NOTE 3—A loading rate of 1800 cycles/min has proven efficient, but not so fast as to cause higher mode bending.

7.2.3 ~~A suggested~~ The fatigue testing machine ~~is illustrated in Fig. 2. For a specimen with overall dimensions as shown in Fig. 1 and a thickness of 9.5 mm (0.375 in.), the crank should deflect the beam approximately 15 mm (0.6 in.) to produce a suitable strain range from ±500 µm/m to ±3500 µm/m. A loading rate of 1800 cycles/min has proven efficient, but not so fast as to cause~~

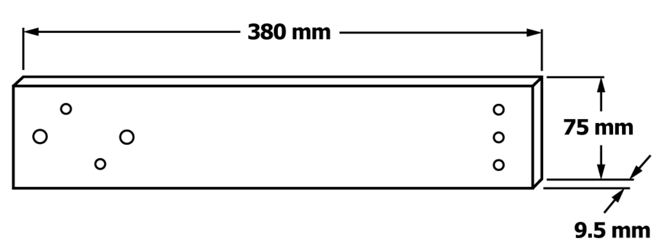

FIG. 1 Cantilever Test Beam

[3] The trademark and sole source of supply of this material known to the committee at this time is Cytec Engineered Materials, 5 Garret Mountain Plaza, Woodland Park, NJ 07424. If you aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

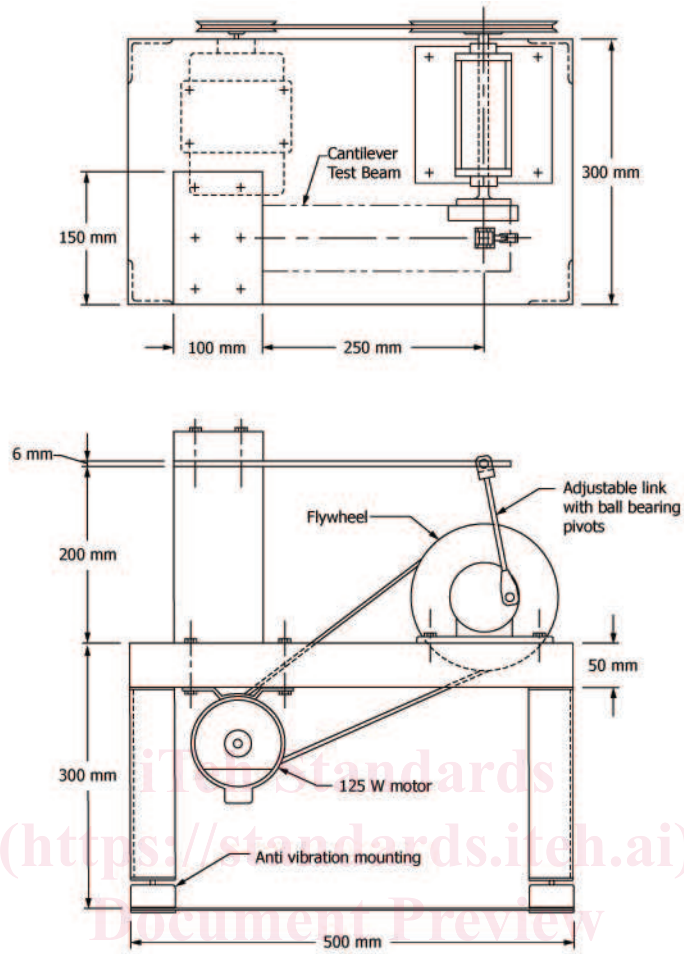

FIG. 2 Strain Gage Fatigue ~~Rig~~Testing Machine

~~higher mode bending. While not absolutely essential, there are several~~ should implement features that provide for ~~a safer and more accurate machine, as follows:~~safety and accuracy.

7.2.3.1 A thick plastic shield ~~to~~should prevent injury in case of ~~specimen or~~ cantilever test beam or fatigue testing machine failure.

7.2.3.2 A shut off device consisting of micro switches positioned above and below the ~~specimen~~ cantilever test beam (near the crank) and wired in the motor power circuit ~~to~~should shut off power in case of ~~specimen rupture; and~~cantilever test beam rupture.

7.2.3.3 An electric counter geared to the drive system, or some other counting ~~device appropriately~~ device, should be connected to the fatigue testing machine, so the machine can be programmed to shut off or take data at preselected intervals.

8. Conditioning

8.1 *Ambient (Room Temperature) Conditions*—The nominal temperature and relative humidity shall be ~~23°C (73°F)~~23 °C (73 °F) and 50 %, respectively. In no case shall the temperature be less than ~~18°C (64°F)~~18 °C (64 °F) or greater than ~~25°C (77°F)~~25 °C (77 °F) and the relative humidity less than 35 % or more than 60 %.

9. Procedure

9.1 ~~Strain~~ Alternating strain range levels for the test should be selected based on the expected fatigue life for the test strain gages. Typical values ~~might be~~ are ±2000 µm/m, ±2400 µm/m, and ±2800 µm/m. ~~(It may be necessary to select at least one substantially lower strain level if~~ If it is desirable to indicate a no-failure strain ~~level; see~~level, (see 9.6.2) ~~Normally six or more strain gages are tested at each~~ select at least one substantially lower strain level.

9.1.1 Test six or more strain gages at each alternating strain range level.

9.2 *Strain Gage Attachment Requirements:*

9.2.1 The attachment conditions shall correspond exactly to the instructions published by the strain gage manufacturer and discussed in Guide E1237. ~~Most fatigue failures occur in the tab and transition areas.~~ Use care in attaching ~~leadwires.~~lead wires.

9.2.2 ~~In many applications strain gage damage will occur in the lead attachment/tab areas first. Consequently sensor survival will be enhanced by placing the solder tabs in the lowest possible strain field. When conducting fatigue tests, orient the tabs~~ Orient the tabs toward the low-strain end of the cantilever test beam.

NOTE 4— Most fatigue failures occur in the tab and transition areas. In many applications strain gage damage will occur in the lead wire attachment/tab areas first. Consequently, strain gage survival will be enhanced by placing the solder tabs in the lowest possible strain field.

9.3 ~~The rectangular beam of Fig. 1 is convenient in providing a nearly linear strain variation from one end to the other. If it is important to test at precisely known strain levels, the beam should first be surveyed with linear strain gages to determine locations of the desired strain levels. Survey gages are placed at regular intervals along the length of the beam; installed with the major measurement axis of the gage aligned with the long axis of the beam. The beam is deflected an amount equal to the maximum test deflection and the strain levels recorded. If necessary, linear interpolation can be used to locate strain levels in between two survey gage locations. Test gages are installed with the major measurement axis of the gage aligned with the long axis of the beam at the predetermined locations. The center of the gage grid should coincide with the line of desired strain, as shown in Fig. 3. (Do not scribe the beam. This will produce a strain concentration within the gage grid area.) In some cases, an exact cyclic strain level is not important and test gages are installed where experience indicates the approximate desired strain is located. To achieve the most precise and consistent test results (by staying within the well defined strain area of the beam), test gages should be installed at least 50 mm (2 in.) from either the beam restraining clamp or the loading area. For best survival rate, route instrumentation leads 90 degrees from the long axis of the beam and anchor them firmly to the gage tab and beam with a suitable coating.~~*Preparation of the cantilever test beam.*

9.3.1 If it is important to test at precisely known alternating strain range levels, survey the cantilever test beam with linear strain gages to determine locations of the desired strain levels. Place survey strain gages at regular intervals along the length of the cantilever test beam. Align the major measurement axis of the survey strain gage with the long axis of the cantilever test beam. Deflect the cantilever test beam an amount equal to the maximum test deflection and record the strain levels. Linear interpolation may be used to locate strain levels in between two survey strain gage locations.

9.3.2 Install test strain gages with the major measurement axis of the strain gage aligned with the long axis of the cantilever test beam at the predetermined locations. The center of the strain gage grid should coincide with the line of desired strain, as shown in Fig. 3. (Do not scribe the beam. This will produce a strain concentration within the strain gage grid area.) If an exact cyclic strain level is not important, install the test strain gages where experience indicates the approximate desired strain is located. To achieve the most precise and consistent test results (by staying within the well defined strain area of the cantilever test beam), test strain gages should be installed at least 50 mm (2 in.) from either the cantilever test beam restraining clamp or the loading area. For best survival rate, route lead wires 90° from the long axis of the cantilever test beam and anchor them firmly to the strain gage tab and cantilever test beam with a suitable coating.

9.4 ~~Each~~ Record each strain gage's zero reading and alternating strain range ~~must be recorded~~ using an ~~instrumentation~~measurement system with sufficient resolution and accuracy. Since the fatigue failure of a strain gage is typically defined as a zero reading shift of ~~100~~100 µm ~~µin./in.,~~ /m, the measurement system ~~must~~shall be able to accurately resolve a minimum of ~~10~~10 µm ~~µin./in.~~

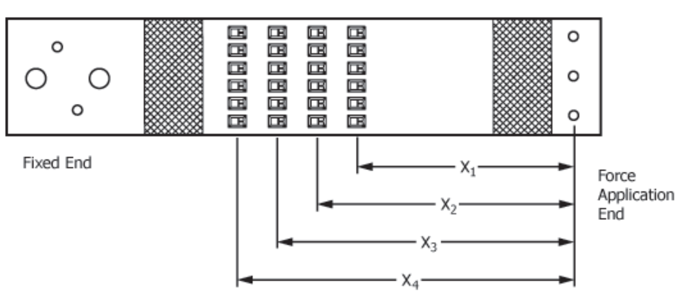

FIG. 3 ~~Gage~~ Strain gage Layout on ~~Fatigue~~Cantilever Test Beam (No ~~Gages~~ Strain gages in Cross-Hatched Areas)