Designation: 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.

1. 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, health, and environmental practices and determine the applicability of regulatory limitations prior to 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:

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 that can cause strain gage failure. Performance 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 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 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

[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.

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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.

*A Summary of Changes section appears at the end of this standard bond the strain gage, and to provide a protective coating. Skill of the installer is another major factor in success. Finally, instrumentation systems shall be carefully selected and calibrated to ensure that they do not unduly degrade the performance of the strain gages.

4.4 Fatigue *failure* of a strain gage 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 validation can be found in Guide E1237. 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 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 or ±0.1 % of the actual value, whichever is greater.

7.1.2 Any method for measuring the change of 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 Measurement systems that obtain strain data directly from a 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 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 2×10^{-6} of the total resistance, whichever is greater. Effects from the following influences on measurement accuracy 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 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 cantilever test beam like that shown in Fig. 1 should be used, because it provides 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.

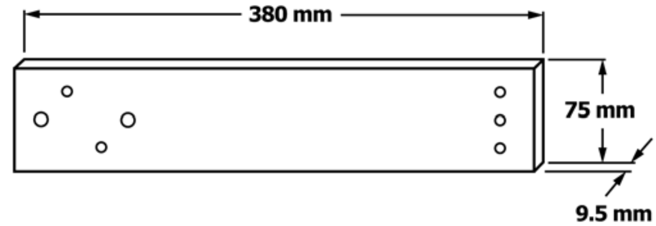

FIG. 1 Cantilever Test Beam

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 Epoxy composite cantilever test beams shall be cut such that the glass fibers are aligned with the long dimension of the 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 The fatigue testing machine should implement features that provide for safety and accuracy.

7.2.3.1 A thick plastic shield should prevent injury in case of 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 cantilever test beam (near the crank) and wired in the motor power circuit should shut off power in case of cantilever test beam rupture.

7.2.3.3 An electric counter geared to the drive system, or some other counting 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) and 50 %, respectively. In no case shall the temperature be less than 18 °C (64 °F) or greater than 25 °C (77 °F) and the relative humidity less than 35 % or more than 60 %.

[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.

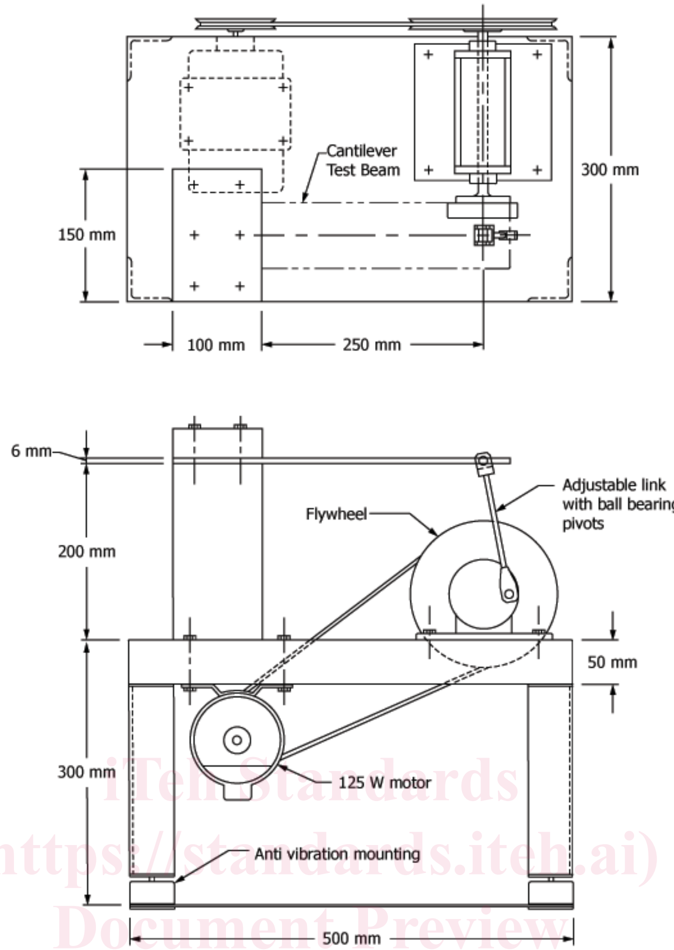

FIG. 2 Strain Gage Fatigue Testing Machine

9. Procedure

9.1 Alternating strain range levels for the test should be selected based on the expected fatigue life for the test strain gages. Typical values are ±2000 µm/m, ±2400 µm/m, and ±2800 µm/m. If it is desirable to indicate a no-failure strain level, (see 9.6.2) 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. Use care in attaching lead wires.

9.2.2 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 *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.)

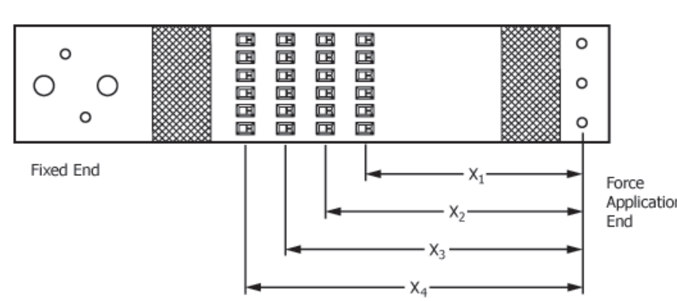

FIG. 3 Strain gage Layout on Cantilever Test Beam (No Strain gages in Cross-Hatched Areas)