

Methods for

Calibration of bonded electrical resistance strain gauges

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- ERA Technology Ltd.
- GAMBICA (BEAMA Ltd.)
- Ministry of Defence
- Society of British Aerospace Companies Ltd.
- Welding Institute

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Society for Strain Measurements
- City University
- Institute of Physics
- Institution of Production Engineers

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Foreword

This British Standard has been prepared under the direction of the Iron and Steel and the Non-ferrous Metals Standards Committees. It supersedes DD 6:1972, which is withdrawn. The standard describes methods for calibration of bonded electrical resistance strain gauges in widespread use for a variety of applications in the mechanical testing of components and structures.

In preparing this standard, consideration has been given to comments made on DD 6:1972 and to corresponding documents prepared by the American Society for Testing Materials (ASTM), the Aerospace Industry Association of America Inc., and the International Committee for Legal Metrology (OIML) namely ASTM Designation E251-67¹⁾ "Standard methods of test for performance characteristics of bonded resistance strain gauges", NAS 942²⁾, "Strain gauges, bonded resistance", and "Performance characteristics of metallic resistance strain gauges".

This standard is essentially concerned with establishing the performance characteristics of strain gauges during manufacture and also takes into account the bonding requirements which are necessary to ensure that the strain gauges when in service are permanently attached to the surface of the component or structure under test. However, this standard may also be applied by the user of strain gauges in order to verify that performance characteristics are satisfactory for the purposes for which the strain gauge is to be employed and also to compare the performance of different types of strain gauge.

Recommendations concerning testing equipment are given in Appendix A.

Recommendations for production quality control are given in Appendix B.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ Available from the Library, BSI, Linford Wood, Milton Keynes MK14 6LE.

²⁾ Available from the National Standards Association Inc., 5161 River Road, Bethesda, MD 20816, USA.

1 Scope

This British Standard describes methods for calibration procedures to determine the performance characteristics of bonded electrical resistance strain gauges that have metallic elements. It defines the terms used, and states the accuracies required for instrumentation used for calibration purposes.

The calibration of semi-conductor strain gauges is outside the scope of this standard.

NOTE 1 In Appendix A to Appendix C recommendations are given for design of suitable calibration rigs, sampling and quality control testing of production strain gauges and procedures to determine optional performance characteristics.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1 Strain

2.1.1 strain

change in length per unit length in a specified direction of a specimen of a material, i.e. dL/L , where L is the initial length in the specified direction and dL is the dimensional change in that direction (in mm)

NOTE Strain is normally expressed in micrometres per metre (colloquially known as microstrain, and represented by the symbol, $\mu\epsilon$).

2.1.2 mechanical strain

the strain in a testing specimen resulting from changes in mechanical forces

2.1.3 thermal strain

the strain in a testing specimen that is free to move at all its boundaries resulting from a change in temperature, which is uniform throughout the material

NOTE For a homogeneous material, the thermal strain per unit change of temperature corresponds to the linear coefficient of thermal expansion of the material of the testing specimen.

2.1.4 real strain

the total strain in a testing specimen due to the summation of the mechanical and thermal strains

2.2 Strain gauge

2.2.1 bonded electrical resistance strain gauge

a device, which when strained after bonding to a surface gives a change in electrical resistance proportional to strain in the surface

NOTE 1 Representative arrangements of foil and wire strain gauges are shown in Figure 1 which illustrates the definitions given in 2.2.3 to 2.2.10.

NOTE 2 In this standard the term "strain gauge" is used to denote the bonded electrical resistance strain gauge.

2.2.2 rosette

a rosette is a multiple strain gauge having two or more measurement axes associated with two or more sensing elements mounted on the same common matrix (see Figure 2)

2.2.3 terminals

small wires, tags or tabs by which lead wires are attached

2.2.4 lead wires

the wires between the strain gauge terminals and the instrumentation used to measure the resistance change of the strain gauge assembly

2.2.5 active grid element

the portion of the strain sensing material of a strain gauge which changes resistance when the strain gauge is subjected to strain

2.2.6 active strain gauge length

the length of the active grid element in the direction of the measurement axis. For configurations with end loops, the length is measured from the inside of the loops

2.2.7 active grid width

the overall dimension of the active grid element in the direction of the transverse axis

2.2.8 matrix³⁾

an electrically non-conductive layer of material used to support a strain gauge grid

NOTE The two main functions of the matrix are to act as an aid to bonding the strain gauge to a structure and to provide electrical insulation from the structure.

³⁾ Sometimes referred to as "backing".

**2.2.9
measurement axis**

the axis of the strain gauge along which it is designed to have a maximum strain sensitivity

**2.2.10
transverse axis**

the axis of the strain gauge, in the plane of the strain gauge, at 90° to the measurement axis along which the strain gauge is designed to have minimum strain sensitivity

**2.2.11
testing specimen**

a specimen, of specified material and dimensions, on which a strain gauge is bonded for the purpose of establishing the characteristics of the strain gauge (see Figure 3 to Figure 5)

**2.2.12
strain gauge installation**

a strain gauge, bonded to the surface of a testing specimen with lead wires attached

**2.2.13
adhesive cure**

the setting of the adhesive by chemical reaction or solvent evaporation

**2.2.14
active strain gauge**

a strain gauge used to effect strain measurement

**2.2.15
temperature compensating dummy strain gauge**

a strain gauge not subject to mechanical strain installed to experience the same environmental conditions as an active strain gauge and used to cancel out environmental effects on the active strain gauge

**2.2.16
strain gauge family**

strain gauges that have similar structural features and performance characteristics, but are not necessarily identical in size or geometry

**2.2.17
strain gauge type**

strain gauges of the same family having no physical, dimensional or manufacturing differences but whose elements are not necessarily from the same melt of alloy

**2.2.18
strain gauge lot**

a group of strain gauges, not necessarily of the same type, with the active grid element (see 2.2.5) manufactured from the same melt and which during manufacture, have been subjected together to the same mechanical and thermal processes

**2.2.19
strain gauge batch**

a group of strain gauges of the same type having the active grid element (see 2.2.5) manufactured from the same lot and which, during manufacture, have been subjected, together, to the same mechanical and thermal processes

2.3 Strain gauge characteristics**2.3.1
characteristic**

a property or feature of a strain gauge that can be given a numerical value by measurement

**2.3.2
nominal characteristic**

a nominal value of the characteristic ascribed to a type or family of strain gauges by the manufacturer

**2.3.3
average characteristic**

the average value of a specific characteristic determined on several strain gauges of the same batch

**2.3.4
tolerance**

the maximum difference between values determined for a specific characteristic of individual strain gauges and the average value of that characteristic usually expressed as a percentage of the value of the average characteristic

**2.3.5
initial strain gauge resistance**

the electrical resistance at a stated temperature of a strain gauge, normally flat, prior to its application to a specimen

NOTE Common nominal values of strain gauge resistance are 60, 120, 350, 600 and 1 000 Ω .

**2.3.6
installed strain gauge resistance**

the electrical resistance at a stated temperature of a strain gauge bonded to an unstrained testing specimen

2.3.7**insulation**

the electrical resistance between one of the strain gauge terminals and the testing specimen or structure on which the strain gauge is bonded

2.3.8**strain limit**

the maximum mechanical strain that may be imposed on a strain gauge installation on a specified material at a specified temperature without causing strain gauge failure or a change of characteristic outside a stated tolerance

2.3.9**strain gauge drift**

the change of strain gauge resistance with time when the strain gauge is bonded to a strain-free stable specimen and held at a constant temperature

2.3.10**strain gauge creep**

the change in strain gauge resistance with time, determined on a drift free strain gauge installation on a stable specimen held at a constant temperature, when the surface of the specimen is strained and held at a constant value of strain for a set period

2.3.11**operating temperature limits**

the limiting temperatures for predictable performance

NOTE An individual type of strain gauge may be assigned more than one set of operating temperature limits for different levels of performance.

2.3.12**fatigue life**

the number of mechanical strain cycles that may be imposed on a strain gauge installation without mechanical or electrical breakdown occurring, and without the strain gauge resistance at any part of the cycle varying more than a specified amount from the strain gauge resistance value at the corresponding point in the first strain cycle. The minimum and maximum mechanical strain levels are to be specified

2.3.13**strain gauge factor**

the ratio of the proportional change of resistance of a strain gauge installation ($\Delta R/R_0$) to the strain ($\Delta L/L_0$) on the surface to which it is bonded when the strain is induced by uniaxial stress applied in the direction of the measurement axis, all other variables remaining constant, i.e. strain gauge factor

$$K = \frac{\Delta R/R_0}{\Delta L/L_0}$$

where

R_0 is the strain gauge resistance at zero or reference strain (in $\mu\epsilon$);

L_0 is the strain gauge length at zero or reference strain (in $\mu\epsilon$).

NOTE The strain gauge factor determined by application of a uniaxial stress is dependent on the Poisson's ratio and possibly other mechanical properties of the material on which the strain gauge is installed.

2.3.14**temperature coefficient of strain gauge factor**

the incremental or decremental change of strain gauge factor per unit change in temperature

NOTE This value is not constant over the entire operating range of most strain gauges but a linear increase between two set temperatures is usually an adequate assumption.

2.3.15**apparent strain**

the combined reversible effects of the change in resistance and thermoelectric output resulting from a change in temperature of a strain gauge installation on a specimen free from constraint

NOTE Apparent strain (sometimes referred to as thermal output) is different for similar strain gauges installed on different materials or for different strain gauges installed on the same material.

2.3.16**transverse sensitivity**

the response of a strain gauge to a uniaxial strain in the direction of the transverse axis expressed as a percentage of the strain gauge factor

2.4 Strain gauge excitation**2.4.1****excitation**

the electrical supply (a.c. or d.c., constant current or constant voltage) connected to the strain gauge to effect measurement of strain

2.4.2

safe excitation limit

the highest continuous excitation at which the strain gauge characteristics can be maintained. The limit is dependent upon both the strain gauge and its environment

2.4.3

maximum excitation

the highest continuous excitation at which the strain gauge installation will not suffer permanent damage

3 Performance characteristics of strain gauges

3.1 General

Performance characteristics are listed in 3.2, and provide the information needed by a user to select the most suitable strain gauge for a given task. The procedures described for evaluating the characteristics and for presentation of the results are described in the clauses indicated for each characteristic.

3.2 Performance characteristics

The following performance characteristics shall be determined for all strain gauges:

- a) strain gauge resistance (6.2);
- b) strain gauge factor (6.4);
- c) transverse sensitivity (6.5);
- d) thermal output of strain gauge installed on test material (6.6);
- e) strain gauge factor change with temperature (6.7).

NOTE The following additional characteristics may also be evaluated (see Appendix C):

- a) characteristics for high mechanical strain applications:
 - i) strain limit;
 - ii) fatigue life at ambient temperature.
- b) characteristics for elevated temperature applications:
 - i) insulation change with temperature;
 - ii) drift change with temperature;
 - iii) creep.
- c) additional characteristics for cryogenic applications:
 - i) as listed in b) but for low temperature conditions.

4 Strain gauge installation for calibration tests

4.1 General

The strain gauge shall be installed on the testing specimen in accordance with the strain gauge manufacturer's instructions, and the information in 4.2 to 4.5, where appropriate, shall be recorded.

NOTE For any particular type of strain gauge, certain performance characteristics may be modified by the type of adhesive, the testing specimen material and by the techniques employed in applying the strain gauge to the testing specimen. It is therefore essential that the record of all performance data be accompanied by the relevant details given in 4.2 to 4.5, and be available to the user.

4.2 Surface preparation

The materials and procedure used for preparation of the surface of the testing specimen on which the strain gauge is to be installed shall be stated.

4.3 Adhesion

If an adhesive is used, the name of the manufacturer, the type and designation, together with other relevant information, e.g. shelf life, storage conditions (temperature and humidity), mixing proportions, "pot" life and age of the adhesive, shall be stated. The age of the adhesive shall not exceed the shelf life.

The temperature and time of cure of the installation, and the clamping pressure and method of clamping shall be recorded.

NOTE Care should be taken to avoid the use of curing temperatures that would alter the characteristics of the material of the testing specimen.

If the strain gauge is welded to the testing specimen, the welding device and technique, including the values of the control settings, e.g. voltage and current, shall be recorded.

4.4 Lead wires

A temperature-compensating three lead wire system shall be used and the details of the system recorded.

4.5 Lead attachment

The type of connection between the lead wires and the terminals, e.g. solder, weld, and the materials used shall be recorded. The materials and procedure used in making the connection shall be recorded.

5 Measuring equipment and strain gauge excitation

5.1 Electrical measuring equipment

The electrical measuring equipment used in the tests required by this standard shall have an accuracy and repeatability sufficient to establish to better than ± 0.1 % the values of voltage, current and resistance. The calibration of measuring equipment shall be traceable to the National Physical Laboratory either directly or indirectly through a hierarchical chain provided by British Calibration Service laboratories according to the accuracy demanded.