Designation: E 837 – 01

An American National Standard

Standard Test Method for Determining Residual Stresses by the Hole-Drilling Strain-Gage Method[1]

This standard is issued under the fixed designation E 837; 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.

INTRODUCTION

The hole-drilling strain-gage method measures residual stresses near the surface of a material. The method involves attaching strain gages to the surface, drilling a hole in the vicinity of the gages, and measuring the relieved strains. The measured strains are then related to relieved principal stresses through a series of equations.

1. Scope

1.1 This test method covers the procedure for determining residual stresses near the surface of isotropic linearly-elastic materials. Although the concept is quite general, the test method described here is applicable in those cases where the stresses do not vary significantly with depth and do not exceed one half of the yield strength. The test method is often described as "semi-destructive" because the damage that it causes is very localized and in many cases does not significantly affect the usefulness of the specimen. In contrast, most other mechanical methods for measuring residual stress substantially destroy the specimen. Since the test method described here does cause some damage, it should be applied only in those cases either where the specimen is expendable or where the introduction of a small shallow hole will not significantly affect the usefulness of the specimen.

1.2 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages[2]

3. Summary of Test Method

3.1 A strain gage rosette with three or more elements of the general type schematically illustrated in Fig. 1 is placed in the area under consideration. The numbering scheme for the strain gages follows a clockwise (CW) convention **(1)**.[3]

NOTE 1—The gage numbering convention used for the rosette illustrated in Fig. 1 differs from the counter-clockwise (CCW) convention used for some designs of general-purpose strain gage rosettes and for some other types of residual stress rosette. If a strain gage rosette with CCW gage numbering is used, the residual stress calculation methods described in this test method still apply. The only change is a reversal in the assignment of the direction of the most tensile principal stress. This change is described in Note 7. All other aspects of the residual stress calculation are unaffected.

3.2 A hole is drilled at the geometric center of the strain gage rosette to a depth of about 0.4 of the mean diameter of the strain gage circle, D.

3.2.1 The residual stresses in the area surrounding the drilled hole relax. The relieved strains are measured with a suitable strain-recording instrument. Within the close vicinity of the hole, the relief is nearly complete when the depth of the drilled hole approaches 0.4 of the mean diameter of the strain gage circle, D.

3.3 Fig. 2 shows a schematic representation of the residual stress and a typical surface strain relieved when a hole is drilled into a material specimen. The surface strain relief is related to the relieved principal stresses by the following relationship:

[1] This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.13 on Residual Stress Measurement.

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] The boldface numbers in parentheses refer to the list of references at the end of this test method.

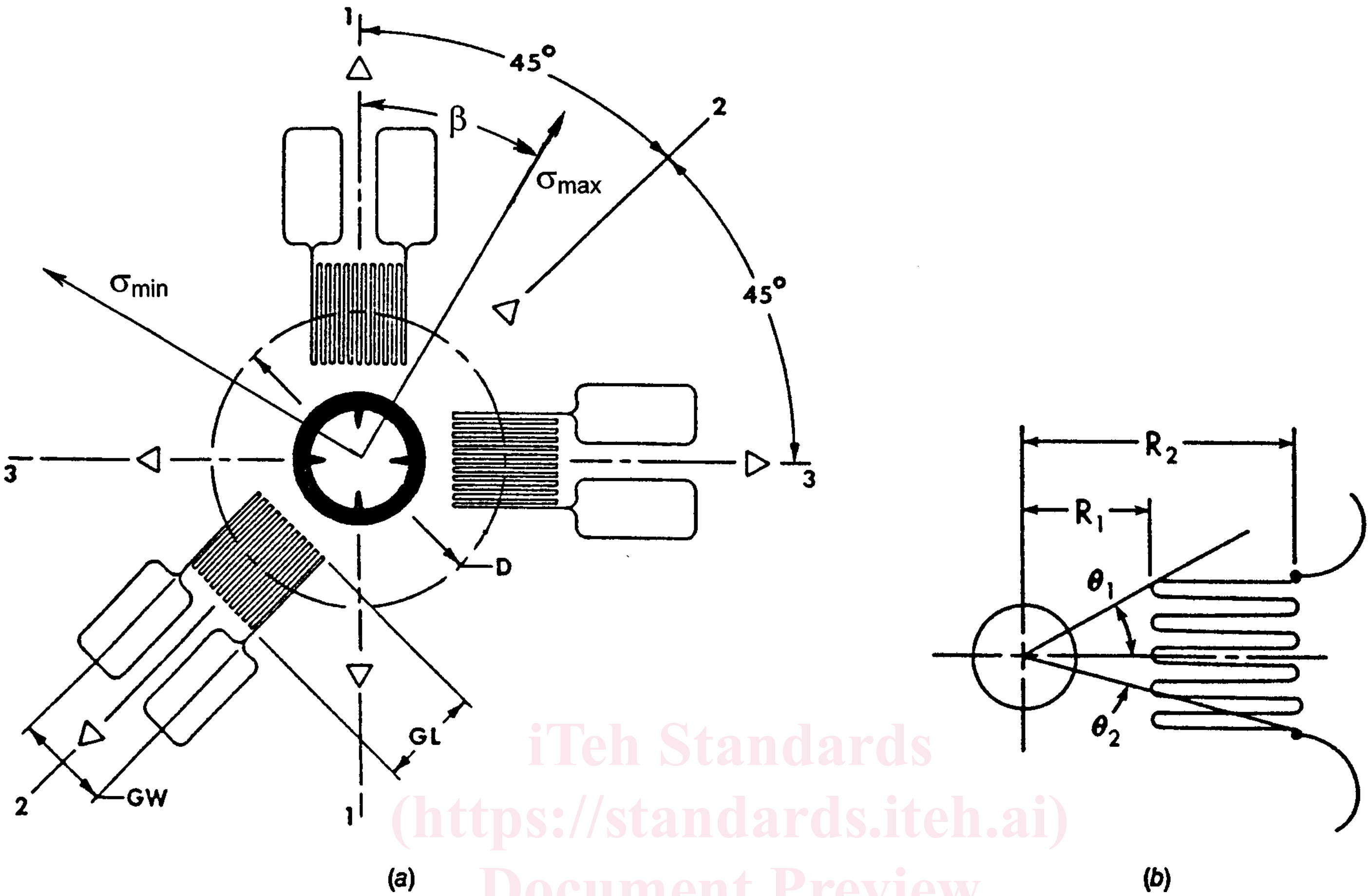

FIG. 1 Schematic Diagram Showing the Geometry of a Typical Three-Element Clockwise (CW) Strain Gage Rosette for the Hole-Drilling Method

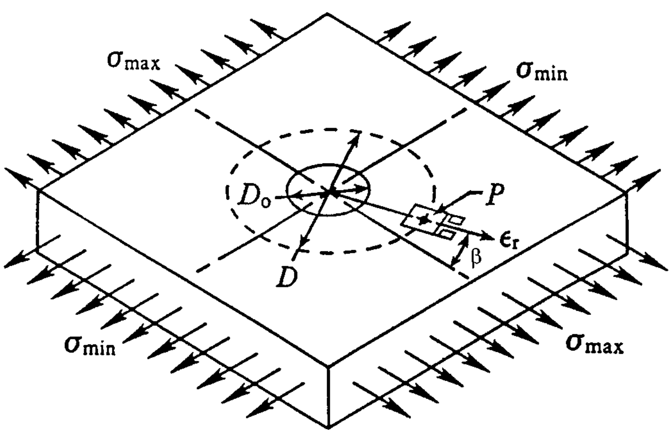

FIG. 2 Definitions of Symbols

$$\epsilon_r = (\bar{A} + \bar{B}\cos 2\beta)\sigma_{max} + (\bar{A} - \bar{B}\cos 2\beta)\sigma_{min} \quad (1)$$

where:

ϵ_r = relieved strain measured by a radially aligned strain gage centered at P,
$\bar{A},\bar{B}$ = calibration constants,
σ_{max} = maximum (most tensile) and
σ_{min} = minimum (most compressive) principal stresses present at the hole location before drilling,
β = angle measured clockwise from the direction of gage 1 to the direction of σ_{max},
D = diameter of the gage circle,
D_0 = diameter of the drilled hole.

3.3.1 The following equations may be used to evaluate the constants $\bar{A}$ and $\bar{B}$ for a material with given elastic properties:

$$\bar{A} = -\bar{a}\,(1+v) / (2E) \quad (2)$$

$$\bar{B} = -\bar{b} / (2E) \quad (3)$$

where:

E = Young's modulus,
v = Poisson's ratio, and

$\bar{a}$ and $\bar{b}$ are dimensionless, almost material-independent constants (see Note 2). Slightly different values of these constants apply for a through-thickness hole made in a thin specimen and for a blind hole made in a thick specimen. The