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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.

~~ε1 NOTE— Equations 17 and 18, Sections 9.2.2, 9.2.3, 11.2.5 , 11.2.6 and Table 2 were editorially upated in January 2002.~~

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.~~

The hole-drilling strain-gage method determines residual stresses near the surface of an isotropic linear-elastic material. It involves attaching a strain rosette to the surface, drilling a hole at the geometric center of the rosette, and measuring the resulting relieved strains. The residual stresses within the removed material are then determined from the measured strains using a series of equations.

1. Scope

~~1.1This 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.~~

1.1 *Residual Stress Determination* :

1.1.1 This test method specifies a hole-drilling procedure for determining residual stress profiles near the surface of an isotropic linearly elastic material. The test method is applicable to residual stress profile determinations where in-plane stress gradients are small. The stresses may remain approximately constant with depth ("uniform" stresses) or they may vary significantly with depth ("non-uniform" stresses). The measured workpiece may be "thin" with thickness much less than the diameter of the drilled hole or "thick" with thickness much greater than the diameter of the drilled hole. Only uniform stress measurements are specified for thin workpieces, while both uniform and non-uniform stress measurements are specified for thick workpieces.

1.2 *Stress Measurement Range*:

1.2.1 The hole-drilling method can identify in-plane residual stresses near the measured surface of the workpiece material. The method gives localized measurements that indicate the residual stresses within the boundaries of the drilled hole.

1.2.2 This test method applies in cases where material behavior is linear-elastic. In theory, it is possible for local yielding to occur due to the stress concentration around the drilled hole, for isotropic (equi-biaxial) residual stresses exceeding 50 % of the yield stress, or for shear stresses in any direction exceeding 25 % of the yield stress. However, in practice it is found that satisfactory results can be achieved providing the residual stresses do not exceed about 60 % of the material yield stress.

1.3 *Workpiece Damage*:

1.3.1 The hole-drilling method is often described as "semi-destructive" because the damage that it causes is localized and often does not significantly affect the usefulness of the workpiece. In contrast, most other mechanical methods for measuring residual stresses substantially destroy the workpiece. Since hole drilling does cause some damage, this test method should be applied only

[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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in those cases either where the workpiece is expendable, or where the introduction of a small shallow hole will not significantly affect the usefulness of the workpiece.

1.4 *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:* [2]

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

3. Summary of Test Method

3.1A 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)** .

NOTE1—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.

3.2A 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.

3.2.1The 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.

3.3Fig. 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:

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

Terminology

3.1 *Symbols*:

[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* , Vol 03.01.volume information, refer to the standard's Document Summary page on the ASTM website.

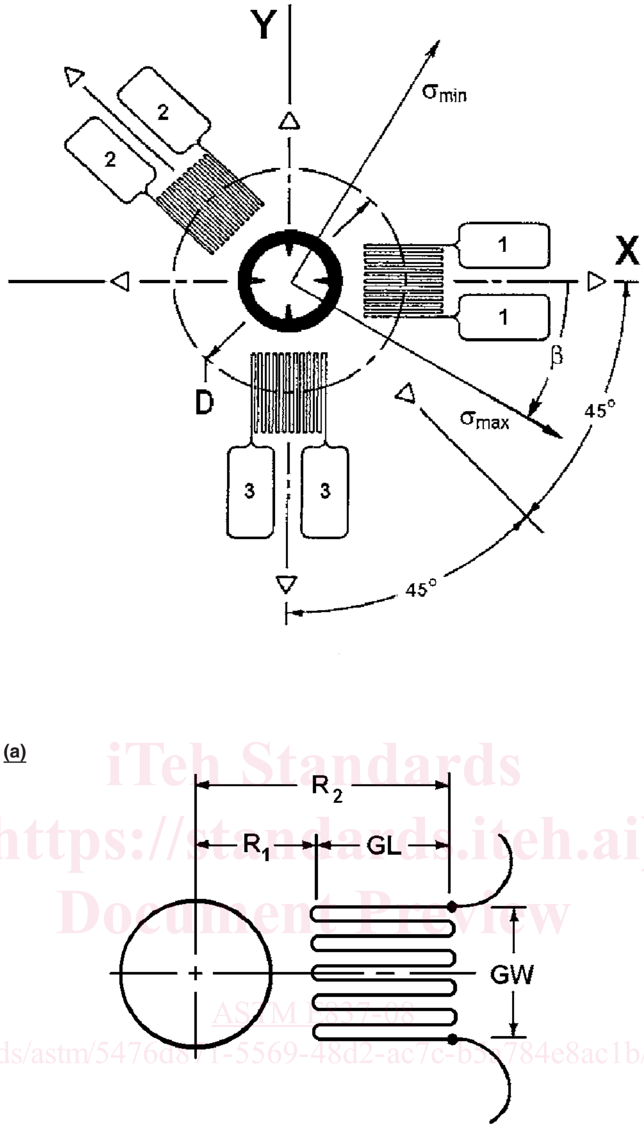

FIG. 1 2 Schematic Diagram Showing the Geometry of a Typical Three-Element Clockwise (CW) St Hole-Draillin Gage Rosette f, (a) Rorsethte H Layole-ut, (b) Dretaill of a Strain Gag Method

(b)

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