Designation: E 1561 – 93 (Reapproved 1998)

Standard Practice for Analysis of Strain Gage Rosette Data[1]

This standard is issued under the fixed designation E 1561; 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

There can be considerable confusion in interpreting and reporting the results of calculations involving strain gage rosettes, particularly when data are exchanged between different laboratories. Thus, it is necessary that users adopt a common convention for identifying the positions of the gages and for analyzing the data.

1. Scope

1.1 The two primary uses of three-element strain gage rosettes are (*a*) to determine the directions and magnitudes of the principal surface strains and (*b*) to determine residual stresses. Residual stresses are treated in a separate ASTM standard, Test Method E 837. This practice defines a reference axis for each of the two principal types of rosette configurations used and presents equations for data analysis. This is important for consistency in reporting results and for avoiding ambiguity in data analysis—especially when computers are used. There are several possible sets of equations, but the set presented here is perhaps the most common.

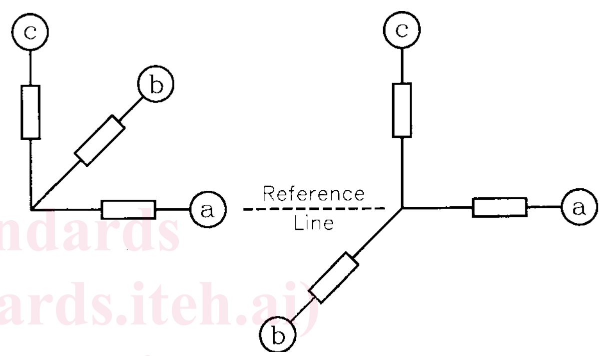

FIG. 1 0° – 45° – 90° Rosette

2. Referenced Documents

2.1 *ASTM Standards:*

E 6 Terminology Relating to Methods of Mechanical Testing[2]

E 837 Test Method for Determining Residual Stresses by the Hole-Drilling Strain-Gage Method[2]

3. Terminology

3.1 The terms in Terminology E 6 apply.

3.2 Additional terms and notation are as follows:

3.2.1 *reference line*—the axis of the *a* gage.

3.2.2 *a, b, c*—the three-strain gages making up the rosette. For the 0° – 45° – 90° rosette (Fig. 1) the axis of the *b* gage is located 45° counterclockwise from the *a* (reference line) axis and the *c* gage is located 90° counterclockwise from the *a* axis. For the 0° – 60° – 120° rosette (Fig. 2) the axis of the *b* gage is located 60° counterclockwise from the *a* axis and the *c* axis is located 120° counterclockwise from the *a* axis.

3.2.3 ϵ_a, ϵ_b, ϵ_c—the strains measured by gages *a, b,* and *c*, respectively, positive in tension and negative in compression. After corrections for thermal effects and transverse sensitivity have been made, the measured strains represent the surface strains at the site of the rosette. It is assumed here that the elastic modulus and thickness of the test specimen are such that mechanical reinforcement by the rosette are negligible. For test objects subjected to unknown combinations of bending and direct (membrane) stresses, the separate bending and membrane stresses can be obtained as shown in 4.4.

3.2.4 ϵ'_a, ϵ'_b, ϵ'_c—reduced membrane strain components (4.4).

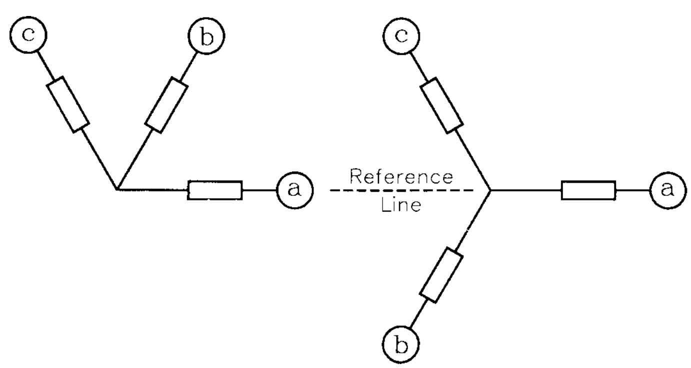

FIG. 2 0° – 60° – 120° Rosette

[1] This practice is under the jurisdiction of ASTM Committee E-28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.14 on Strain Gages.

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

3.2.5 $\epsilon''_a, \epsilon''_b, \epsilon''_c$—reduced bending strain components (4.4).

3.2.6 ϵ_1—the calculated maximum (more tensile or less compressive) principal strain.

3.2.7 ϵ_2—the calculated minimum (less tensile or more compressive) principal strain.

3.2.8 γ_M—the calculated maximum shear strain.

3.2.9 θ_1—the angle from the reference line to the direction of ϵ_1. This angle is less than or equal to 180° in magnitude.

3.2.10 *C, R*—values used in the calculations. *C* is the location, along the ϵ-axis, of the center of the Mohr's circle for strain and *R* is the radius of that circle.

4. Procedure

4.1 Fig. 3 shows a typical Mohr's circle of strain for a 0° – 45° – 90° rosette. The calculations when ϵ_a, ϵ_b, ϵ_c, are given are:

$$C = \frac{\epsilon_a + \epsilon_c}{2} \quad (1)$$

$$R = \sqrt{(\epsilon_a - C)^2 + (\epsilon_b - C)^2} \quad (2)$$

$$\epsilon_1 = C + R \quad (3)$$

$$\epsilon_2 = C - R$$

$$\gamma_M = 2R$$

$$\tan 2\theta_1 = 2\,(\epsilon_b - C) / \epsilon_a - \epsilon_c \quad (4)$$

4.1.1 If $\epsilon_b < C$, then the ϵ_1-axis is clockwise from the reference line.

4.1.2 If $\epsilon_b > C$, then the ϵ_1-axis is counterclockwise from the reference line.

4.2 Fig. 7 shows a typical Mohr's circle of strain for a 0° – 60° – 120° rosette. The calculations when ϵ_a, ϵ_b, ϵ_c, are given are:

$$C = \frac{\epsilon_a + \epsilon_b + \epsilon_c}{3} \quad (5)$$

$$R = \sqrt{2/3[(\epsilon_a - C)^2 + (\epsilon_b - C)^2 + (\epsilon_c - C)^2]} \quad (6)$$

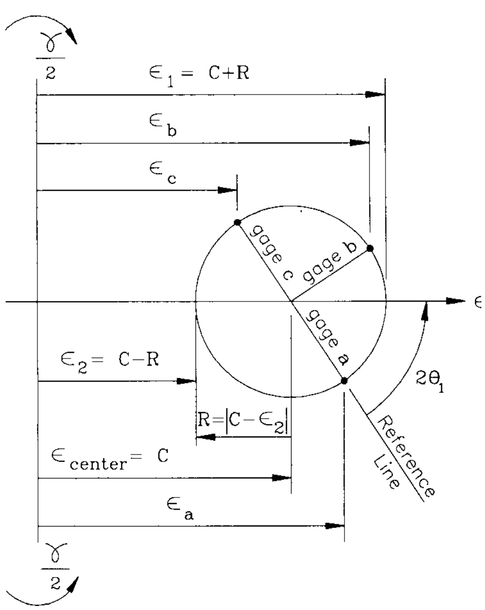

FIG. 3 Typical Mohr's Circle of Strain for a 0° – 45° – 90° Rosette

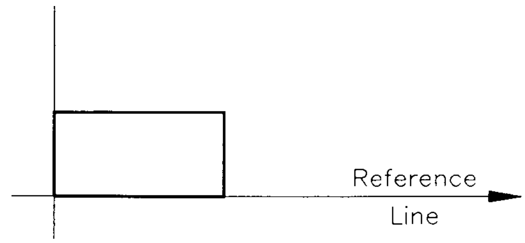

FIG. 4 Differential Element on the Undeformed Surface

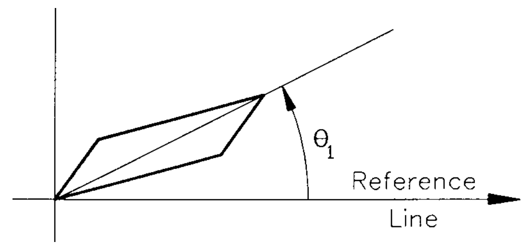

FIG. 5 Deformed Shape of Differential Element

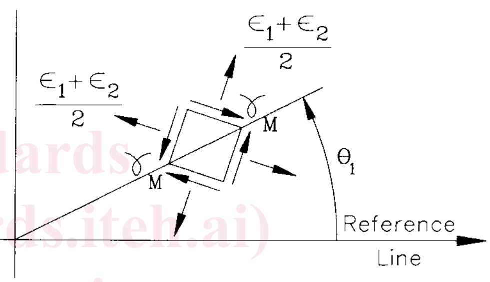

FIG. 6 Planes of Maximum Shear Strain

$$\epsilon_1 = C + R \quad (7)$$

$$\epsilon_2 = C - R$$

$$\gamma_M = 2R$$

$$\tan 2\theta_1 = \frac{(\epsilon_b - \epsilon_c)}{\sqrt{3}(\epsilon_a - C)} \quad (8)$$

4.2.1 If $\epsilon_c - \epsilon_b < 0$, then the ϵ_1-axis is counterclockwise from the reference line.

4.2.2 If $\epsilon_c - \epsilon_b = 0$, then $\theta_1 = 0°$.

4.2.3 If $\epsilon_c - \epsilon_b > 0$, then the ϵ_1-axis is clockwise from the reference line (see Note 1).

4.3 *Identification of the Maximum Principal Strain Direction*:

4.3.1 Care must be taken when determining the angle θ_1 using (Eq 4) or (Eq 8) so that the calculated angle refers to the direction of the maximum principal strain ϵ_1 rather than the minimum principal strain ϵ_2. Fig. 10 shows how the double angle $2\theta_1$ can be placed in its correct orientation relative to the reference line shown in Fig. 1 and Fig. 2. The terms "numerator" and "denominator" refer to the numerator and denominator of the right-hand sides of (Eq 4) and (Eq 8). When both numerator and denominator are positive, as shown in Fig. 10, the double angle $2\theta_1$ lies within the range $0° \leq 2\theta_1 \leq 90°$ counterclockwise of the reference line. Therefore, in this particular case, the corresponding angle θ_1 lies within the range $0° \leq \theta_1 \leq 45°$ counterclockwise of the reference line.

4.3.2 Several computer languages have arctangent functions that directly place the angle $2\theta_1$ in its correct orientation in