Designation: E 143 – 02

Standard Test Method for Shear Modulus at Room Temperature[1]

This standard is issued under the fixed designation E 143; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of shear modulus of structural materials. This test method is limited to materials in which, and to stresses at which, creep is negligible compared to the strain produced immediately upon loading. Elastic properties such as shear modulus, Young's modulus, and Poisson's ratio are not determined routinely and are generally not specified in materials specifications. Precision and bias statements for these test methods are therefore not available.

1.2 Values stated in inch-pound units are to be regarded as the standard. SI units are provided for information only.

1.3 *This standard may involve hazardous materials, operations, and equipment. 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 6 Terminology Relating to Methods of Mechanical Testing[2]

E 8 Test Methods of Tension Testing of Metallic Materials[2]

E 111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus[2]

E 1012 Practice for Specimen Alignment Under Tensile Loading [2]

3. Terminology

3.1 *Definitions*:

3.1.1 *shear modulus* $[FL^{-2}]$—the ratio of shear stress to corresponding shear strain below the proportional limit, also called torsional modulus and modulus of rigidity. (See Fig. 1.)

NOTE 1—The value of shear modulus may depend on the direction in which it is measured if the material is not isotropic. Wood, many plastics and certain metals are markedly anisotropic. Deviations from isotropy should be suspected if the shear modulus, G, differs from that determined by substituting independently measured values of Young's modulus, E, and Poisson's ratio, μ in the relation

$$G = \frac{E}{2(1 + \mu)} \quad (1)$$

NOTE 2—In general, it is advisable, in reporting values of shear modulus to state the stress range over which it is measured.

3.1.2 *torque, [FL]*—a moment (of forces) that produces or tends to produce rotation or torsion.

3.1.3 *torsional stress* $[FL^{-2}]$—the shear stress in a body, in a plane normal to the axis or rotation, resulting from the application of torque.

3.1.4 *angle of twist (torsion test)*— the angle of relative rotation measured in a plane normal to the torsion specimen's longitudinal axis over the gage length.

3.1.5 For definitions of other terms used in this test method, refer to Terminology E 6.

4. Summary of Test Method

4.1 The cylindrical or tubular test specimen is loaded either incrementally or continuously by applying an external torque so as to cause a uniform twist within the gage length.

4.1.1 Changes in torque and the corresponding changes in angle of twist are determined either incrementally or continuously. The appropriate slope is then calculated from the shear stress-strain curve, which may be derived under conditions of either increasing or decreasing torque (increasing from pretorque to maximum torque or decreasing from maximum torque to pretorque).

5. Significance and Use

5.1 Shear modulus is a material property useful in calculating compliance of structural materials in torsion provided they follow Hooke's law, that is, the angle of twist is proportional to the applied torque. Examples of the use of shear modulus are in the design of rotating shafts and helical compression springs.

NOTE 3—For materials that follow nonlinear elastic stress-strain behavior, the value of tangent or chord shear modulus is useful for estimating

[1] This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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

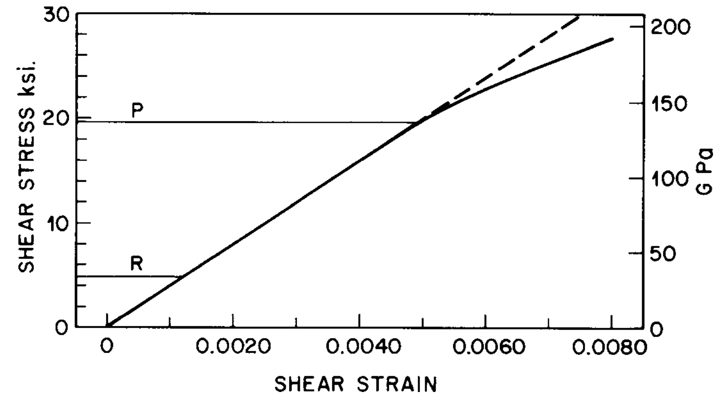

FIG. 1 Shear Stress-Strain Diagram Showing a Straight Line, Corresponding to the Shear Modulus, Between *R* , a Pretorque Stress, and *P* , the Proportional Limit

the change in torsional strain to corresponding stress for a specified stress or stress-range, respectively. Such determinations are, however, outside the scope of this standard. (See for example Ref (**1**).)[3]

5.2 The procedural steps and precision of the apparatus and the test specimens should be appropriate to the shape and the material type, since the method applies to a wide variety of materials and sizes.

5.3 Precise determination of shear modulus depends on the numerous variables that may affect such determinations.

5.3.1 These factors include characteristics of the specimen such as residual stress, concentricity, wall thickness in the case of tubes, deviation from nominal value, previous strain history and specimen dimension.

5.3.2 Testing conditions that influence the results include: axial position of the specimen, temperature and temperature variations, and maintenance of the apparatus.

5.3.3 Interpretation of data also influences results.

6. General Considerations

6.1 Shear modulus for a specimen of circular cross-section is given by the equation[4]

$$G = TL/J\theta \quad (2)$$

where:

G = shear modulus of the specimen,
T = torque,
L = gage length,
J = polar moment of inertia of the section about its center, and
θ = angle of twist, in radians.

6.1.1 *For a solid cylinder*:

$$J = \pi D^4/32 \quad (3)$$

where:

D = diameter.

6.1.2 *For a tube*:

$$J = \frac{\pi}{32}(D_0^4 - D_i^4) \quad (4)$$

where:

D_0 = outside diameter, and
D_i = inside diameter.

7. Apparatus

7.1 *Testing Machine*—The torsion testing machine, which is to be used for applying the required torque to the specimen, shall be calibrated for the range of torques used in the determination. Corrections may be applied for demonstrated systematic errors. The torques should be chosen such as to bring the error ΔG in shear modulus, due to errors in torque ΔT, well within the required accuracy (see 12.3.1).

7.2 *Grips*—The ends of the specimen shall be gripped firmly between the jaws of a testing machine which have been designed to produce a state of uniform twist within the gage length. In the case of tubes, closely fitting rigid plugs, such as are shown in Fig. 11 (Metal Plugs for Testing Tubular Specimens) of Test Methods E 8 may be inserted in the ends to permit tightening the grips without crushing the specimen. The grips shall be such that axial alignment can be obtained and maintained in order to prevent the application of bending moments. One grip shall be free to move axially to prevent the application of axial forces.

7.3 *Twist Gages*—The angle of twist may be measured by two pairs of lightweight but rigid arms, each pair fastened diametrically to a ring attached at three points to the section at an end of the gage length and at least one diameter removed from the grips. The relative rotational displacement of the two sections may be measured by mechanical, optical, or electrical means; for example, the displacement of a pointer on one arm relative to a scale on the other (**2**)**,** or the reflection of a light beam from mirrors or prisms attached to the arms (**3**)**.** Readings should be taken for both sets of arms and averaged to eliminate errors due to bending of the specimen (see 12.3.2).

8. Test Specimens

8.1 *Selection and Preparation of Specimens*:

8.1.1 Specimens shall be chosen from sound, clean material. Slight imperfections near the surface, such as fissures which would have negligible effect in determining Young's modulus, may cause appreciable errors in shear modulus. In the case of machined specimens care shall be taken to prevent changing the properties of the material at the surface of the specimen.

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

[4] See any standard text in Mechanics of Materials.