Designation: E 229 – 97

Standard Test Method for Shear Strength and Shear Modulus of Structural Adhesives[1]

This standard is issued under the fixed designation E 229; 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.

1. Scope

1.1 This test method covers the determination of the shear strength and shear modulus of structural adhesives as they occur in thin gluelines restrained by the relatively higher modulus adherends.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents (SI) of inch-pound units may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

E 4 Practices for Force Verification of Testing Machines[2]

E 83 Practice for Verification and Classification of Extensometers[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *shear modulus*—the ratio of the shear stress to the corresponding shear strain for shear stresses below the proportional limit in shear of the adhesive.

3.1.2 *shear strength*—the maximum shear stress existing in the adhesive prior to failure.

4. Summary of Test Method

4.1 Torsional shear forces are applied to the adhesive through a circular specimen which produces a peripherally uniform stress distribution. The maximum stress in the adhesive at failure represents the shear strength of the adhesive. By measuring the adhesive strain as a function of load, a stress-strain curve can be established. The test specimen is made from the same materials as used in production. Production cleaning and bonding processes should be used when applicable.

5. Significance and Use

5.1 The basic material properties obtained from this test method can be used in the control of the quality of adhesives, in the theoretical equations for designing bonded joints, and in the evaluation of new adhesives.

6. Apparatus

6.1 *Testing Machines*— Machines used for shear testing shall conform to the requirements of Practices E 4. The loads used in determining shear strength and yield strength or yield point shall be within the loading range of the testing machine as defined in Practices E 4.

6.2 *Adhesive Torsional Shear Apparatus*—The adhesive torsional shear jig shall apply a torsional shear load to the specimen without inducing bending, peeling, or transverse shear stresses in the bondline. Loading can be accomplished with torsion-test equipment or by means of a jig that can be used in a universal testing machine. Such a jig is shown in Fig. 1. Take adequate precautions to ensure a minimum of frictional loss of torque (as by careful bearing design) or to provide a direct measurement of the applied torque (as by a load cell) and to prevent the application of axial forces.

6.3 *Extensometers*— Since the shear strain of a thin bondline will normally be very small, an ASTM Class A or Class B-1 extensometer, as described in Practice E 83, is used (Note 1). An optical lever system is especially adaptable to this test method. The Amsler mirror extensometer (Marten's System) is shown in Fig. 2. A second mirror is used to measure any movements of the stationary loading block. Miniature electrical resistance strain gages can be used to measure the shear strain. Several rosettes are placed across the bondline at different locations around the circumference.

NOTE 1—Most adhesives will require a Class A extensometer to determine shear modulus and shear yield strengths due to experience of low strain.

7. Test Specimens

7.1 The specimen consists of two large loading blocks with a thin narrow ring bonded between them, simulating the torque loading of a large-diameter, thin-walled tube (Fig. 3). The loading blocks and interlaminar adherend ring are typical of the materials to be used in production when applicable; otherwise, 2024-T4 aluminum is used. The preparatory cleaning and bonding processes should be identical with those to be used in production. Take adequate precautions to ensure uniformity of loading around the circumference by careful fabrication, particular attention being paid to tolerances on location and fit of the alignment pins.

7.2 The bondline thickness is determined within an accuracy of 10 %. This can be determined by subtracting the

[1] This test method is under the jurisdiction of ASTM Committee D-14 on Adhesives and is the direct responsibility of Subcommittee D14.80 on Metal Bonding Adhesives.

Current edition approved July 10, 1997. Published April 1998. Originally published as E 229 – 63 T. Last previous edition E 229 – 92.

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

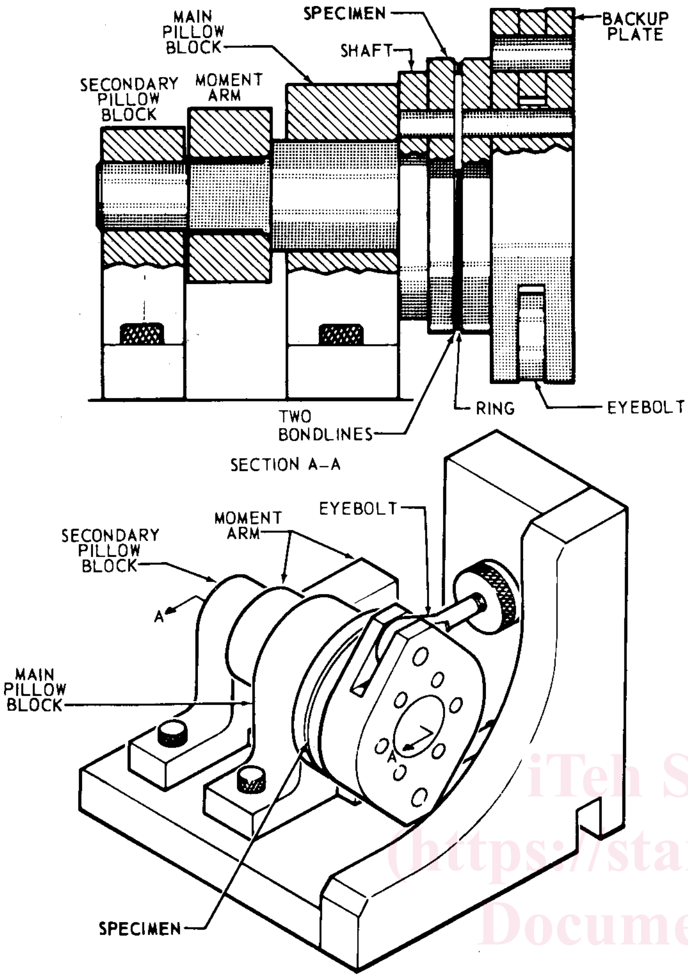

FIG. 1 Adhesive Torsional Shear Apparatus

thickness of interlaminar rings from the total gap between loading blocks after bonding. The thicknesses of the bondlines are held constant within ±10 % of the nominal bondline thickness. This can be accomplished by (*1*) maintaining the flatness and thickness tolerances given in Fig. 3, (*2*) applying a uniform thickness of adhesive, and (*3*) maintaining a uniform pressure over the surface of the specimen during bonding. In order to obtain the desired bondline thickness, it may be necessary to use a reduced bonding pressure and thin strands of spacer materials such as fiberglass. Some adhesives may form a significant fillet (Note 2) on inner or outer, or both, edges of the interlaminar adherend ring. Such fillets shall be removed unless it can be proven that the fillets do not significantly influence the test results. The hole in the center of the specimen (Fig. 3) has been made large enough to allow the insertion of a cutter for the removal of such a fillet. The bonding surfaces of the loading blocks and interlaminar adherend ring should be held flat and smooth to 125 rms.

NOTE 2—The shear strains in such a fillet will be very small unless the bondline is quite thick or if the adhesive in the fillet has an exceptionally high modulus of elasticity.

7.3 If the adhesive has a high modulus of rigidity and the bondline is quite thin, several bondline thicknesses may be required in order to obtain measurable bondline deformations. The number of bondlines can be adjusted by increasing the number of interlaminar adherend rings. In some cases, a single bondline specimen (Fig. 4) is adequate and should be used, as it significantly simplifies bonding of the specimen.

7.4 Test at least three specimens to determine the shear strength and shear modulus of a given adhesive.

8. Procedure

8.1 *Measurement of Specimens*—Measure the loading blocks and interlaminar adherend ring prior to bonding to ensure conformance to the dimensional tolerances shown in Figs. 3 and 4.

8.2 *Cleaning and Bonding*—Clean and bond in accordance with the applicable production or comparison specification. Premature adhesion failures are indicative of poor cleaning.

8.3 *Alignment*—Align the loading blocks, interlaminar adherend ring, and adhesive accurately about a common axis during the bonding operation. The interlaminar adherend ring alignment screws as shown in Fig. 3 are used to locate and maintain proper alignment of the interlaminar adherend ring. The alignment shaft and pins (Fig. 3) are used to maintain alignment of the loading blocks. The uniformly distributed bonding pressure serves to clamp the assembly together during the bonding operation.

8.4 *Load and Deflection*—Make simultaneous measurements of load (torque) and deflection and record the data. Take care to correct for jig deflections if any occur.

8.5 *Speed of Testing*— Load the specimen so as to produce failure in 2 to 5 min.

8.6 *Temperature*— This test method is limited to room-temperature testing.

9. Calculation

9.1 *Shear Strength*— Calculate the shear strength (τ_{max}) as follows (Note 3):

$$\tau_{max} = Tr/I_p \quad (1)$$

where:

I_p	=	$\pi(r_o^4 - r_i^4)/2$, polar moment of inertia, in.^{4}(m^4),
T	=	applied torque at failure, lbf·in. (N·m),
r	=	radius to midpoint of interlaminar adherend ring, in. (m),
r_o	=	radius to outside of interlaminar adherend ring, in. (m),
r_i	=	radius to inside of interlaminar adherend ring, in. (m), and
τ_{max}	=	maximum shear stress or shear strength of the adhesive, psi (Pa).

NOTE 3—For non-Hookian solids, the formula given may be off by 2½ %.

9.2 *Adhesive Circumferential Displacement*—Calculate the adhesive deformations (Δ_b) as follows:

$$\Delta_b = \Delta - \Delta_r \quad (2)$$