Designation: B 593 – 96

Standard Test Method for Bending Fatigue Testing for Copper-Alloy Spring Materials[1]

This standard is issued under the fixed designation B 593; 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 describes procedures for the determination of the reversed or repeated bending fatigue properties of copper alloy flat-sheet or strip-spring materials by fixed cantilever, constant amplitude of displacement-type testing machines. This method is limited to flat stock ranging in thickness from 0.005 to 0.062 in. (0.13 to 1.57 mm), to a fatigue-life range of 10^5 to 10^8cycles, and to conditions where no significant change in stress-strain relations occurs during the test.

NOTE 1—This implies that the load-deflection characteristics of the material do not change as a function of the number of cycles within the precision of measurement. There is no significant cyclic hardening or softening.

1.2 The values stated in inch-pound units are to be regarded as the standard. SI values given in parentheses are for information only.

1.3 *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 206 Definitions of Terms Relating to Fatigue Testing and the Statistical Analysis of Fatique Data[2]

E 468 Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials[3]

3. Terminology

3.1 For terminology relating to this test method, refer to Definitions E 206 and Practice E 468.

4. Summary of Test Method

4.1 A prepared test specimen of a specific wrought copper alloy flat-sheet or strip-spring material is mounted into a fixed cantilever, constant-deflection type fatigue testing machine. The specimen is held at one end, acting as a cantilever beam, and cycled by flexure followed by reverse flexure until complete failure. The number of cycles to failure is recorded as a measure of fatigue-life.

5. Significance and Use

5.1 The flexural fatigue test described in this test method provides information on the ability of a copper alloy flat-spring material to resist the development of cracks or general mechanical deterioration as a result of a relatively large number of cycles (generally in the range 10^5 to 10^8) under conditions of constant displacement.

5.2 This test method is primarily a research and development tool which may be used to determine the effect of variations in materials on fatigue strength and also to provide data for use in selecting copper alloy spring materials for service under conditions of repeated strain cycling.

5.3 The results are suitable for direct application in design only when all design factors such as loading, geometry of part, frequency of straining, and environmental conditions are known. The test method is generally unsuitable for an inspection test or a quality control test due to the amount of time and effort required to collect the data.

6. Apparatus

6.1 *Testing Machine*—The fatigue testing machine is a fixed-cantilever, constant-deflection type. In this machine (Fig. 1) the test specimen shall be held as a cantilever beam in a clamp at one end and deflected by a concentrated load applied near the other end of the apex of the tapered section (Fig. 2). Either the clamp or the loading member may be adjusted so that the deflection of the free end of the cantilever is either completely reversed (mean displacement equal to zero) or greater in one direction of bending (mean displacement not equal to zero).

6.2 A suitable counter and monitoring circuit is required to provide a direct readout of the number of cycles to complete failure, that is, separation into two pieces.

7. Test Specimen

7.1 The test specimen shall be of the fixed-cantilever type. Several such specimens which have been used successfully are shown in Fig. 2.

[1] This test method is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.06 on Methods of Test.

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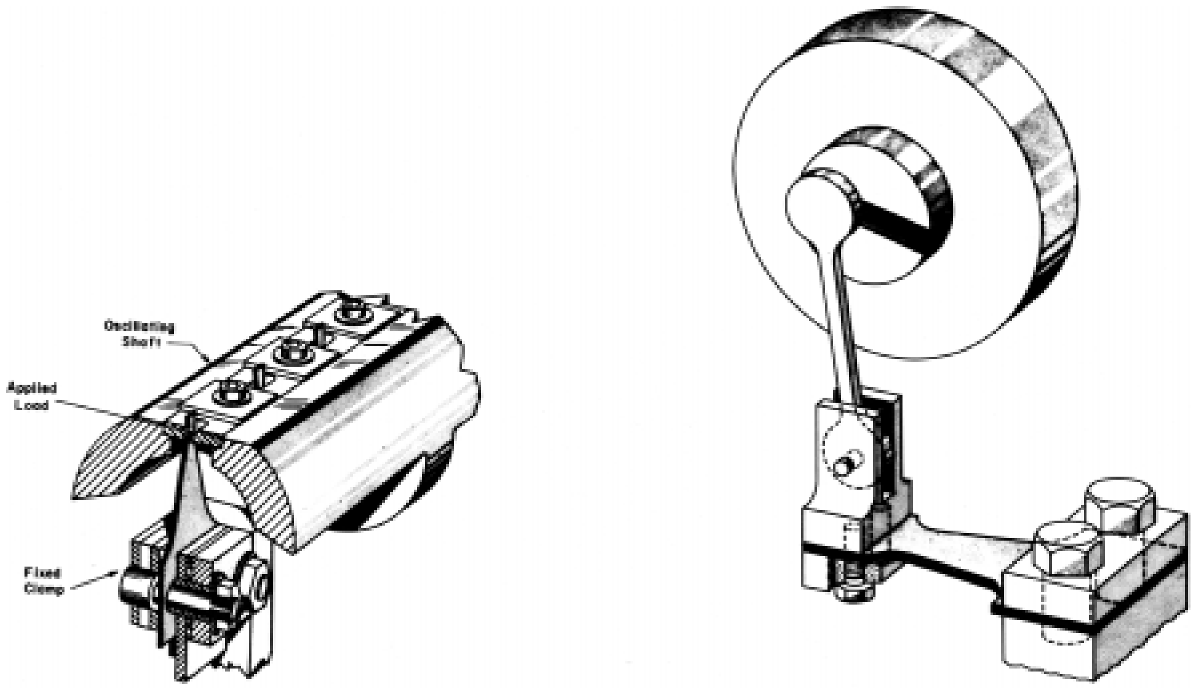
[2] Discontinued, see 1986 *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Part 03.01.

*A Summary of Changes section appears at the end of this standard.



(a) Fatigue Machine (Bell Laboratories Type) Force Applied by Oscillating Shaft

(b) Fatigue Machine (Krouse Type) Force Applied by Cam and Linkage

FIG. 1 Fatigue Machines

7.2 It is important, therefore, that care be exercised in the preparation of test specimens, particularly in machining, to assure good workmanship. Improperly prepared test specimens cause unsatisfactory test results.

7.2.1 The specimens are best prepared by cross milling a stack, approximately 0.75 in. (19 mm) thick, including back-up plates, for which 0.12-in. (3-mm) thick brass sheet stock may be used.

7.2.1.1 It is necessary to ensure that any cutting or machining operation required to either rough cut the test specimen from the blank, or to machine it to size does not appreciably alter the metallurgical structure or properties of the material. All cuts taken in machining should be such as to minimize work hardening of the test specimen.

7.2.1.2 In selecting cutting speeds and feed rates, due regard should be paid to the test-specimen material, and for finishing cuts, to the quality of the surface finish required.

NOTE 2—It is not practicable to recommend a single procedure for feeds, speeds, and depth of cut, since this will vary with the material tested. The procedure used, however, should be noted in reporting test results, since differences in procedure may produce variability in test results among different laboratories.

7.3 The test specimen surface shall be in the as-received condition. The edges shall not be roughed or smoothed, since this tends to give an apparent higher fatigue strength.[4] Burrs, however, may be removed by light stoning.

7.4 Test specimens from material that is used in a thermally treated condition, such as precipitation hardened or stress relieved, shall be treated in a manner reflecting the way the material will be used. The procedure used should be noted in reporting test results.

8. Calculation of Stress

8.1 The maximum bending stress is calculated by using the simple beam equation:

$$S = 6PL/bd^2 \quad (1)$$

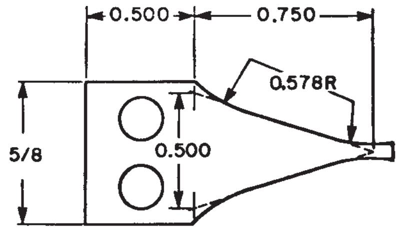
where:

S = desired bending stress, lb/in.^{2},
P = applied load at the connecting pin (apex of triangle), lb,
L = distance between the connecting pin and the point of stress, in.,
b = specimen width at length L from point of load application, in., and
d = specimen thickness, in.

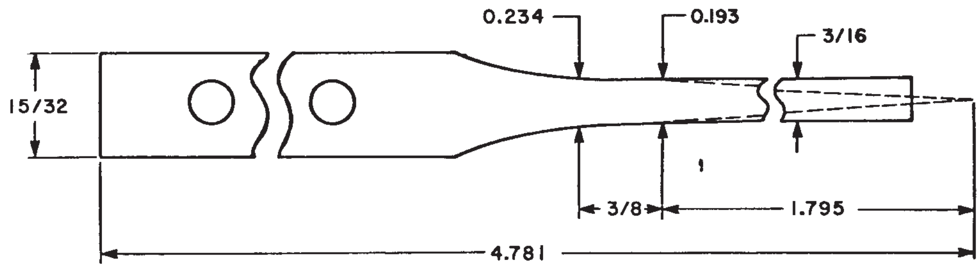
9. Machine Calibration

9.1 A loading fixture such as that shown in Fig. 3 may be used to determine the load-deflection characteristics of the specimen. In this fixture the specimen deflection and change in moment arm under load are measured with the two micrometers for a given load. The vertical micrometer measures the deflection of loading pin, *d*, which follows the motion of the apex formed by the tapered sides. The horizontal micrometer, *e*, measures the foreshortening of the moment arm as applied to the same locus. An average load-deflection curve is then

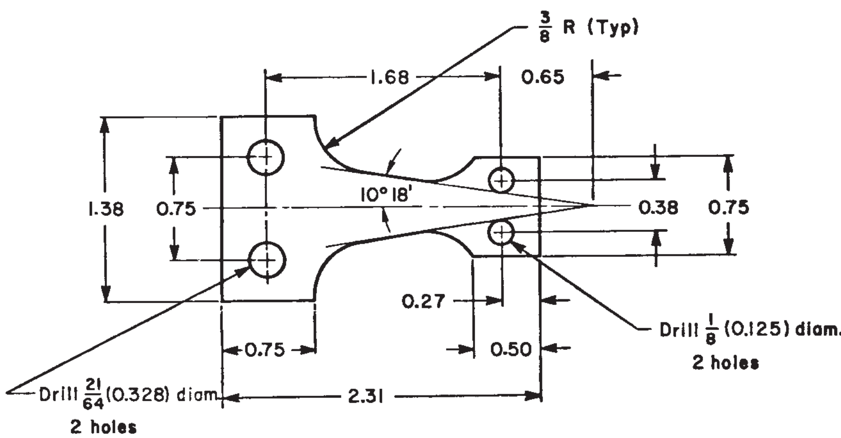
[4] George, R. G., and Mantle, J. B., "The Effect of Edge Preparation on the Fatigue Life of Flat-Plate Specimens", *Materials Research and Standards*, MTRSA, Am. Soc. Testing Mats., December 1962, p. 1000.



(*a*) Sheet or Strip Fatigue Test Specimen (Bell Telephone Laboratories Type) for Thickness Ranging from 0.005 to 0.015 in. (0.127 to 0.381 mm)



(*b*) Sheet or Strip Fatigue Test Specimen (Bell Telephone Laboratories Type) for Thickness Ranging from 0.015 to 0.062 in. (0.381 to 1.575 mm)



(*c*) Sheet or Strip Fatigue Test Specimen (Krouse Type) for Thickness Ranging from 0.008 to 0.031 in. (0.203 to 0.787 mm)

(Gage length is increased for thicker material.)

NOTE 1—All dimensions are in inches: in. × 25.4 = mm.

FIG. 2 Sheet or Strip Fatigue Test Specimens

plotted from this corrected data. A minimum of three specimens should be used in this determination, representing the minimum, mean, and maximum thicknesses of the material.

9.1.1 Electrical resistance strain gages may be attached to the specimen for simultaneous strain measurement. Adequate correction should be made, however, to compensate for gage thickness and possible stiffening of the test specimen, especially for thin stock.[5]

9.1.2 Measure the machine displacement under dynamic conditions. This may be accomplished by optical means. Use specimens having foil-type electrical resistance strain gages mounted on the tapered area to verify that static and dynamic strains gages mounted on the tapered area to verify that static and dynamic strains are identical for a given displacement. From the load-deflection curve, plot a stress versus deflection curve using as an approximation the distance from the load point to the center of the tapered specimen area and the width at that point for L and b, respectively.

NOTE 3—Since the specimen normally fails in the tapered region which is designed to have a very nearly uniform outer fiber strain, the error between this calculated stress value and that at the point of failure is small.

10. Procedure

10.1 Mount the test specimens in the machine and flex to failure, that is, separation into two pieces. Determine the number of specimens and displacement levels required for a given sample by consulting ASTM STP 91-A.[6]

[5] Perry, C. C., and Lissner, H. R., *Strain Gage Primer*, McGraw-Hill, New York, NY.

[6] *A Guide for Fatigue Testing and the Statistical Analysis of Fatigue Data*, Second Edition, *ASTM STP 91-A*, AST-TA, 1963.

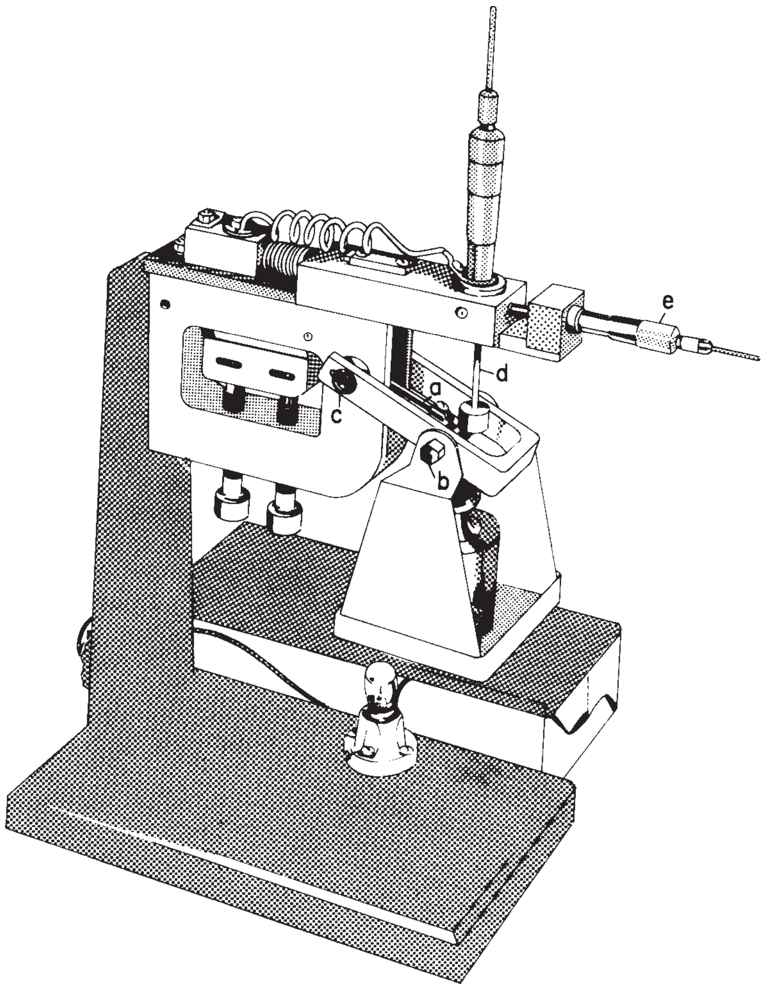


FIG. 3 Load deflection test fixture for standard Bell Telephone Laboratories sheet metal fatigue test specimen

11. Report

11.1 Prepare reports in accordance with Practice E 468.

12. Precision and Bias

12.1 *Precision*—The following parameters are reported to impact upon the precision of this test method:

12.1.1 Characteristics of the specimen such as orientation of grains relative to the axial stress, grain size, residual stress, previous strain history, dimensions.

12.1.2 Testing conditions such as alignment of the specimen, temperature variations, conditions of test equipment, ratio of error in load to the range in load values.

12.2 *Bias*—A statement of bias of this method requires reference standard values for one or more materials based on many measurements or round robin test data.[7,8] Such standard reference values or test data are presently not available.

13. Keywords

13.1 bending fatigue; bending fatigue testing; copper alloy flat strip; copper alloy spring; fatigue testing

[7] Torrey, M. N., and Gohn, G. R., "A Study of the Statistical Treatments of Fatigue Data", *Proceedings ASTM*, Vol 56, p. 1091, 1956.

[8] Torrey, M. N., Gohn, G. R., and Wilk, M. B., "A Study of The Variability in The Mechanical Properties of Alloy A Phosphor Bronze Strip", *Proceedings ASTM*, Vol 58, p. 893, 1958.

SUMMARY OF CHANGES

Committee B-5 has identified the location of selected changes to this standard since the last issue (B 593-85 (1990)) that may impact the use of this standard.

(1) Added Summary of Test Method and Keywords sections.

(2) Revised other sections to accomodate current ASTM form and style requirements.