Standard Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials[1]

This standard is issued under the fixed designation E 468; 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 practice covers the desirable and minimum information to be communicated between the originator and the user of data derived from constant-force amplitude axial, bending, or torsion fatigue tests of metallic materials tested in air and at room temperature.

NOTE 1—Practice E 466, although not directly referenced in the text, is considered important enough to be listed in this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 6 Terminology Relating to Methods of Mechanical Testing

E 8 Test Methods for Tension Testing of Metallic Materials

E 206 Definitions of Terms Relating to Fatigue Testing and the Statistical Analysis of Fatigue Data[3]

E 466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials

E 467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System

2.2 *Special Technical Publications:*

STP 91 A Guide for Fatigue Testing and the Statistical Analysis of Fatigue Data[4]

STP 588 Manual on Statistical Planning and Analysis[5]

3. Terminology Definitions and Nomenclature

3.1 The terms and abbreviations used in this practice are defined in Terminology E 6 and in Definitions E 206. In addition, the following nomenclature is used:

3.2 *criterion of failure*—complete separation, or the presence of a crack of specified length visible at a specified magnification. Other criteria may be used but should be clearly defined.

3.3 *run-out*—no failure at a specified number of load cycles.

4. Significance and Use

4.1 Fatigue test results may be significantly influenced by the properties and history of the parent material, the operations performed during the preparation of the fatigue specimens, and the testing machine and test procedures used during the generation of the data. The presentation of fatigue test results should include citation of basic information on the material, specimens, and testing to increase the utility of the results and to reduce to a minimum the possibility of misinterpretation or improper application of those results.

5. Listing of Basic Information About Fatigue Test Specimen

5.1 *Specification and Properties of Material*:

5.1.1 *Material Prior to Fatigue Test Specimen Preparation*—The minimum information to be presented should include the designation or specification (for example, A 441, SAE 1070, and so forth) or proprietary grade; form of product (for example, plate, bar, casting, and so forth); heat number; melting practice; last mechanical working and last heat treatment that produced the material in the "as-received" condition (for example, cold-worked and aged, annealed and rolled, and so forth); chemical composition; and surface condition (for example, rolled and descaled, ground, and so forth).

5.1.1.1 It is desirable but not required (unless by mutual consent of the originator and user of the data) to list the raw material production sequence, billet preparation, results of cleanliness analysis, or a combination thereof, when applicable.

5.1.2 *Material in the Fatigue Test Specimen*:

5.1.2.1 *Mechanical Properties*—The minimum data on the mechanical properties of the material in a condition identical to that of the fatigue test specimen should include the tensile strength, yield point or yield strength at a specified onset; elongation in a specified gage length; reduction of area when applicable; and the designation of the test used to procure the

[1] This practice is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.05 on Cyclic Deformation and Fatigue Crack Formation.

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

[3] Withdrawn.

[4] *A Guide for Fatigue Testing and the Statistical Analysis of Fatigue Data, ASTM STP 91 A,* ASTM International, 1963. Out of print; available from University Microfilms, Inc., 300 N. Zeeb Rd., Ann Arbor, MI 48106.

[5] *Manual on Statistical Planning and Analysis, ASTM STP 588,* ASTM International, 1975.

mechanical properties (for example, Test Methods E 8, Tension Testing of Metallic Materials, and so forth). If notched fatigue tests were conducted, the notched tensile strength also should be listed.

5.1.2.2 *Metallography*—It is desirable but not required (unless by mutual consent of the originator and user of the data) to list the grain size (when applicable), phases, and dispersions characteristic of the fatigue test specimen in the "ready-to-test" condition.

5.1.2.3 It is desirable but not required (unless by mutual consent of the originator and user of the data) to show the locations, in the parent material, from which the specimens were taken.

5.2 *Minimum Information to Be Presented on Design of Fatigue Test Specimen in the "Ready-To-Test" Conditions*:

5.2.1 *Shape, Size, and Dimensions*—A drawing showing shape, size, and dimensions of the fatigue test specimen should be presented including details on test section, grip section, fillets, radii, swaged portions, holes, and orientation of the fatigue test specimen with respect to the direction of maximum working of the material. When reporting the test results of notched fatigue specimens, the geometry of the notch, its dimensions and stress concentration factor, the method of derivation of the stress concentration factor, and whether the stress concentration factor is based on the gross or net area of the test section should be presented.

5.3 *Listing of Information on Specimen Preparation*:

5.3.1 The minimum information to be presented should list, in chronological order, the operations performed on the fatigue test specimen, including the type of process used to form the specimen (for example, milling, turning, grinding, etc.), thermal treatment (for example, stress relieving, aging, etc.), and surface treatment (for example, shot-peening, nitriding, coating, etc.). If the final specimen surface treatment is polishing, the polishing sequence and direction should be listed. If deterioration of the specimen surface is observed during storage, after preparation but prior to testing, the procedures that were used to eliminate the defects and changes, if any, in shape, dimensions, or mechanical properties should be listed.

5.3.1.1 It is desirable but not required (unless by mutual consent of the originator and user of the data) to include details of the operations performed (for example, feed, speed, depth of cut and coolants, thermal cycles, etc.), and the surface residual stresses of the specimen, if measured.

5.3.2 *Condition of Specimens Prior to Fatigue Testing*—It is desirable but not required to list the environment in which the specimens were stored, type of protection applied to the specimens, and method used to remove that protection. It is desirable but not required to list the average and range of surface roughness, surface hardness, out-of-flatness, out-of-straightness or warpage, or a combination thereof, of all fatigue specimens.

6. Listing of Information on Test Procedures

6.1 *Design of the Fatigue Test Program*:

6.1.1 If statistical techniques were used to design the fatigue test program, the design plan and list of statistical techniques (for example, randomization of test sequence, blocking, etc.) used to accommodate expected or observed heterogeneities should be presented. Statistical techniques are described in STP 91 and STP 588.

6.2 *Fatigue Testing Machine*:

6.2.1 Minimum information to be presented should include the type of testing machine, the functional characteristic (for example, electrohydraulic, crank and lever, rotating mass, etc.), frequency of force application, and forcing function (for example, sine, square, etc.). If tests were performed on more than one machine, the number of testing machines used should be listed.

6.2.2 Minimum information should include the method of dynamic force verification and force monitoring procedures.

NOTE 2—For guidance on axial load machines, refer to Practice E 467.

6.3 *Fatigue Test*:

6.3.1 Minimum information to be presented should include the type of test (axial, rotary bending, plane bending, or torsion), the derivation (or method of computation) of the test section dynamic stresses, and, when applicable, the experimental stress analysis techniques (for example, electric resistance strain gages, photoelastic coating, etc.) used. The failure criterion and number of cycles to run-out used in the test program should be presented.

6.3.1.1 It is desirable but not required (unless by mutual consent of the originator and user of the data) to include the procedure for mounting the specimen in the testing machine, grip details, and precautions taken to ensure that stresses induced by vibration, friction, eccentricity, etc., were negligible.

6.4 *Ambient Conditions During the Fatigue Test*—Minimum information to be presented should include the average value and ranges of both temperature and relative humidity that were observed in the laboratory during the test program.

6.5 *Results of Post-Test Examination*—Minimum information to be presented for each fatigue test specimen should include the reason for test termination, either achievement of the failure criterion or run-out, and, if applicable, a description of the failure surface appearance and location of the crack origin.

7. Presentation of Fatigue Test Results

7.1 *Tabular Presentation*—It is desirable but not required (unless by mutual consent of the originator and user of the data) that the fatigue test results be reported in tabular form. When used, the tabular presentation should include specimen identification, test sequence (that is, chronological order of testing), dynamic stresses (any two of the following: maximum, minimum, mean, amplitude or range, and stress ratio), fatigue life or cycles to end of test, cause of test termination, and results of post-test examination (see 6.5), when applicable, for each fatigue test specimen. If test frequency varies from specimen to specimen, it should also be included in the tabular presentation. If more than one machine was used, the tabular presentation should also include machine identification for each specimen.

7.2 *Graphical Presentation:*

7.2.1 *S-N Diagram*—The most common graphical presentation of fatigue test data is the *S-N* (stress life) diagram, Fig.

1. The dependent variable, fatigue life *N* in cycles, is plotted on the abscissa, a logarithmic scale. The independent variable, maximum stress S_{max}, stress range S_r, or stress amplitude S_a in psi, ksi, MN/m^2 or MPa, is plotted on the ordinate, an arithmetic or logarithmic scale. A line is fitted by regression analysis or similar mathematical techniques to the fatigue data. The fatigue test results may be expressed adequately by two straight lines, one of which is a horizontal line representing the fatigue limit (or fatigue strength at run-out), a hyperbola, asymptotic to the fatigue limit (or fatigue strength at run-out), a sigmoid, asymptotic to both the tensile strength and the fatigue limit (or fatigue strength at run-out), or by a more general curvilinear relation. If the data are fitted by regression analysis, the equation of the stress-life relation and concomitant statistical measures of dispersion (for example, standard error of estimate) should be presented.

NOTE 3—The above described procedure develops the *S-N* diagram for 50 % survival when the logarithms of the lives are described by a normal distribution. However, similar procedures may be used to develop *S-N* diagrams for probabilities of survival other than 50 %.

7.2.1.1 Graphical presentation of the *S-N* diagram should include all of the test results as well as the faired or fitted curve. Minimum information to be presented on the *S-N* diagram should include the designation, specification or proprietary grade of the material, tensile strength, surface condition of specimen, stress concentration factor of notch when applicable, type of fatigue test, and citation of dynamic stress parameter held constant during generation of the *S-N* curve data (for example, in Fig. 1, stress ratio), test frequency, environment, and test temperature.

7.2.2 *Constant Life Diagrams*—*S-N* diagrams present fatigue life as a function of stress. On the other hand, constant life diagrams present the maximum and minimum stresses (Fig. 2) or the stress amplitude and mean stress (Fig. 3) for a given fatigue life. A third type of constant life diagram superimposes the stress amplitude-mean stress diagram of Fig. 3 on the maximum stress-minimum stress diagram of Fig. 2 by plotting stress amplitude on the ray $R = -1$ and mean stress on the ray $R = +1$.

7.2.2.1 When a constant life diagram is presented, it should be accompanied by the *S-N* diagrams from which it was constructed. Minimum information to be presented on a constant-life diagram should include the designation, specification, or proprietary grade of the material, tensile strength, surface condition of specimen, stress concentration factor of notch when applicable, type of fatigue test, and fatigue life (cycles) for each constant life shown, test frequency, environment, and test temperature.

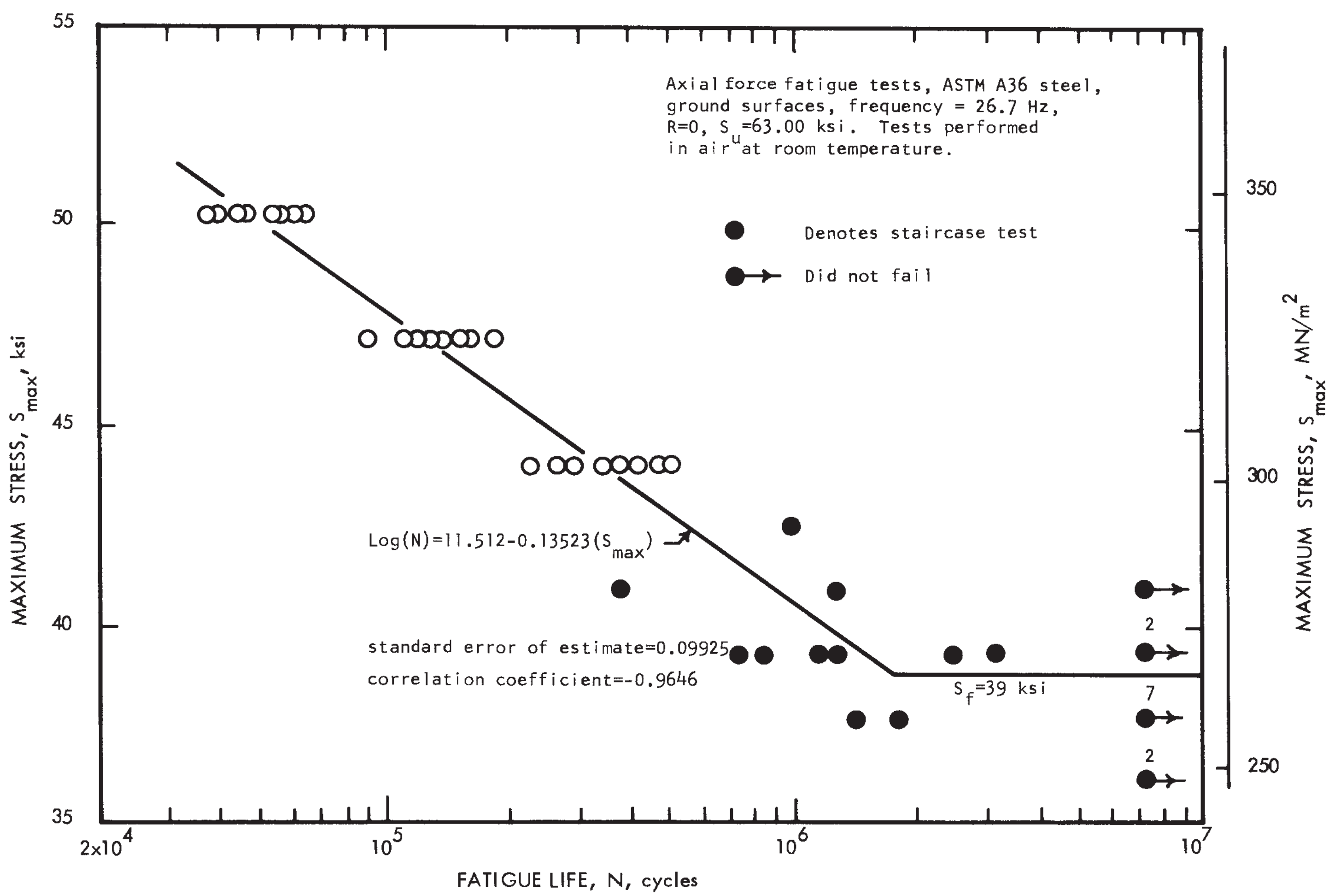


FIG. 1 *S-N* Diagram

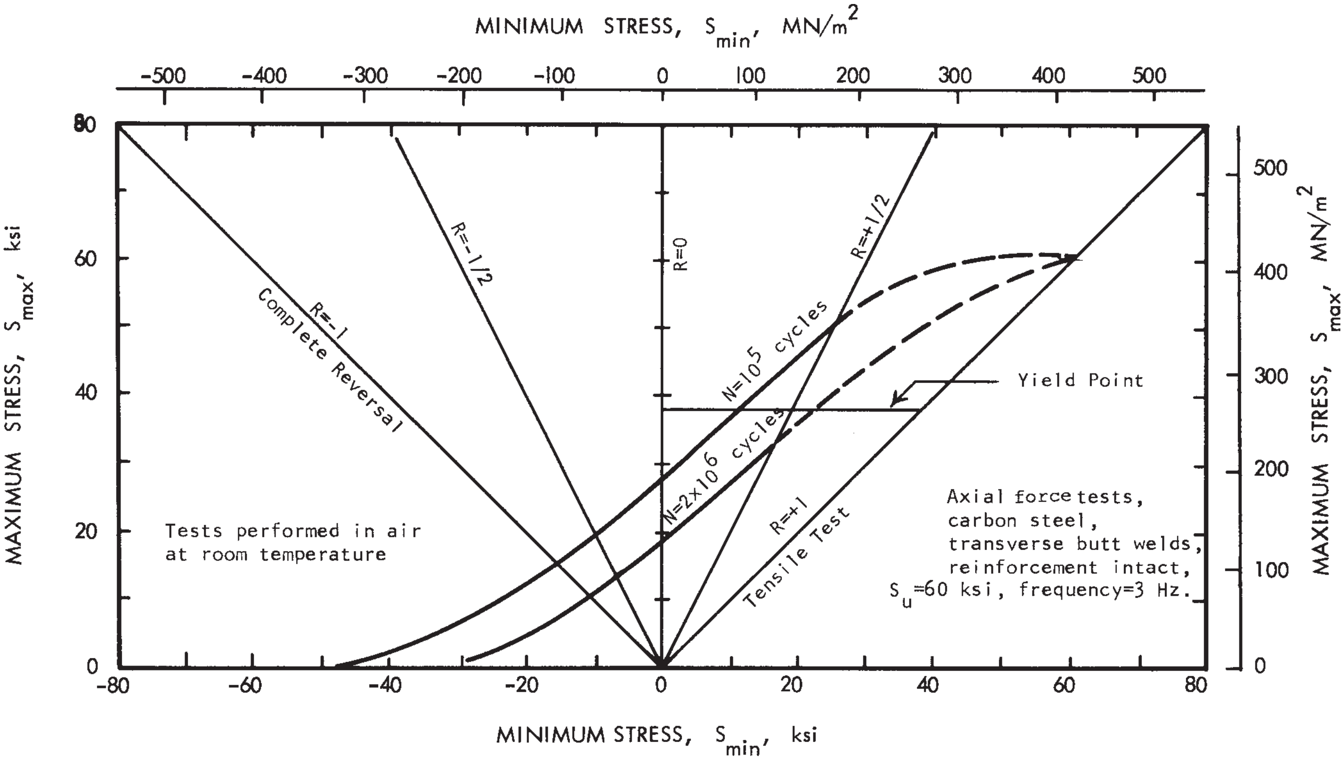


FIG. 2 Constant-Life Diagram

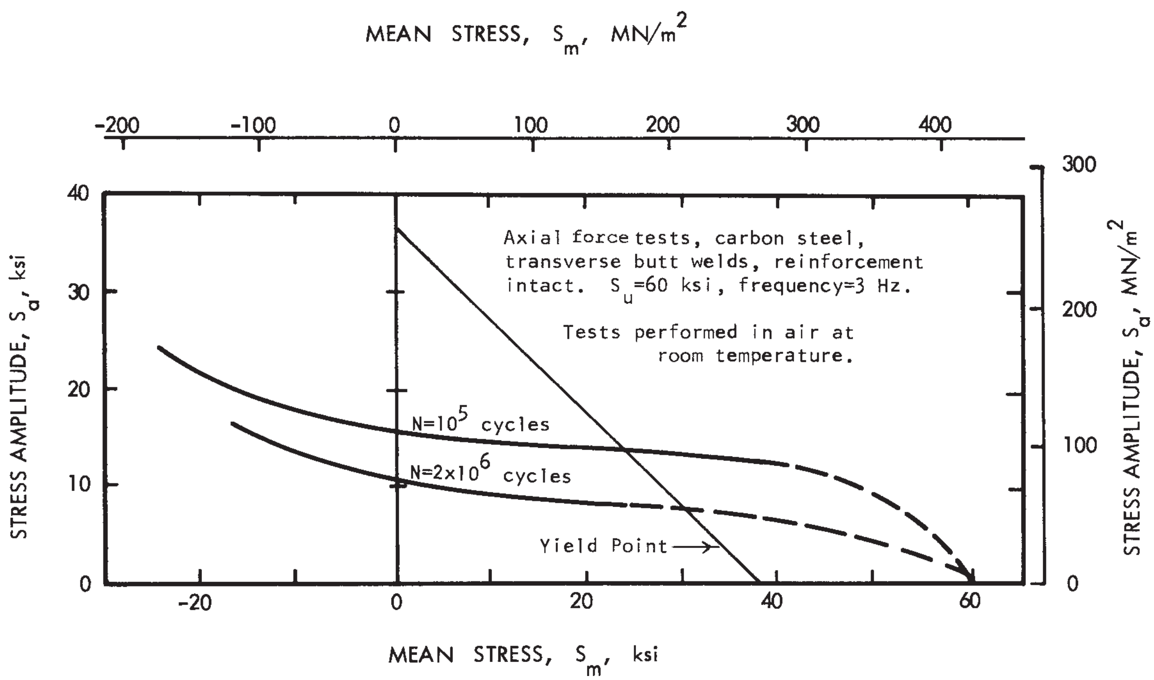


FIG. 3 Constant-Life Diagram

8. Example of Fatigue Data Presentation

8.1 Data for axial force fatigue tests of A36 structural carbon steel are presented in a suggested form in the Appendix.

APPENDIX

(Nonmandatory Information)

X1. SUGGESTED FORM FOR PRESENTATION OF FATIGUE TEST RESULTS OF METALLIC MATERIALS

MATERIAL

Grade Designation: A36 Structural Carbon Steel

Heat Number: 490T1481 Form of Product: ⅜ in. (9.5 mm) thick plate

Melting Practice: Air-melted, semi-killed Surface Condition: As-rolled

Last Mechanical and Thermal Treatment: Hot-rolled and air-cooled

Chemical Composition: 0.22 % C, 0.52 % Mn, 0.008 % P, 0.013 % S, 0.029 % Cu

Tensile Strength: 63 000 psi (434 MPa) Yield Point: 37 800 psi (261 MPa)

Elongation: 40.1 % in 2-in. (51-mm) gage length.

Reduction of Area: 64.8 %

Remarks: ASTM micrograin size number, 8.5 (surface and center of plate). Mechanical test performed in accordance with Test Methods E 8, Tension Testing of Metallic Materials, on round tension test specimens, Fig. 8, Test Methods E 8.

FATIGUE SPECIMEN

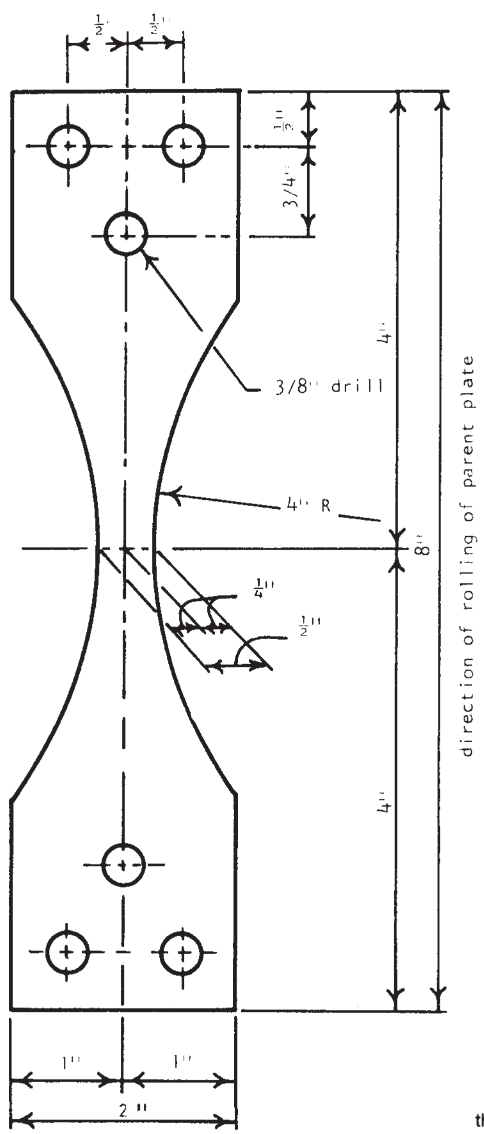
Shape, Size, and Dimensions: see Fig. X1.1.

Stress Concentration Factor: unnotched

Preparation:

Forming: Edges milled, thickness reduced by Blanchard grinding

Thermal Treatment: None Surface Treatment: None



in.	mm
¼	6.3
⅜	9.5
½	12.7
¾	19.0
1	25.4
2	50.8
4	101.6
8	203.2

thickness = 0.10 in. (2.5 mm)

FIG. X1.1 Axial Force Fatigue Test Specimen

TABLE X1.1 Fatigue Test Data

Test Sequence	Specimen Mark	Dynamic Stresses Maximum, ksi (MPa)	Dynamic Stresses Minimum, ksi (MPa)	Fatigue Life, kilocycles	Remarks[A]
1	67	37.8 (261)	zero	1 437.8	failed
2	58	36.2 (249)	zero	10 000.0	did not fail
3	40	37.8 (261)	zero	8 520.0	did not fail
...	...	... ...	...	...	...
22	24	36.2 (249)	zero	8 934.0	did not fail
23	22	37.8 (261)	zero	8 000.0	did not fail
24	8	50.4 (347)	zero	63.5	failed
25	34	47.2 (325)	zero	162.6	failed
26	18	50.4 (347)	zero	44.9	failed
27	1	44.1 (304)	zero	228.4	failed
...	...	... ...	...	...	...
47	19	50.4 (347)	zero	46.2	failed

[A] All fractures were initiated at one corner of minimum transverse cross section (0.5 in. (12.7 mm) wide) of specimen.

Remarks: surface roughness: average, 40 µin. (1.0 µm) rms, range, 32 to 47 µin. (0.8 to 1.2 µm); out of flatness: average, 0.008 in. (0.20 mm), range, 0 to 0.034 in. (0.86 mm).

FATIGUE TESTS

Fatigue Testing Machine: 5000 lbf (22 000 N) Krouse double-direct stress machine, crank-and-lever with hydraulic load maintainer.

Type of Test: axial Number of Machines Used: 1 Test Frequency: 26.7 Hz

Dynamic Force Verification: Dynamic forces were verified according to the procedures set forth in Practice E 467, for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing Machine.

Dynamic Force Monitoring Procedures: Four-arm electric resistance strain gage bridge on load train in series with specimen, ac transducer conditioner-amplifier, and oscilloscope.

Failure Criterion: complete fracture Run-out: 7 million cycles

Number of Specimens Tested: 47 Stress Ratio, R: 0

Laboratory Temperature: average, 73°F (23°C); range, ±2°F (±1°C)

Laboratory Relative Humidity: average, 40 %, range, ±3 %

Remarks: specimens gripped by bolts, fixed against rotation about both axes. Dynamic stresses are computed by dividing dynamic force by area measured at reduced section. Specimens were stored in laboratory environment without protection prior to testing.

FATIGUE DATA

Fatigue Test Data: See Table X1.1.

Remarks: Specimen test sequence 1 to 23, "staircase" test to estimate mean fatigue limit (mean fatigue strength at 7 million cycles). Test sequence 24 to 47, 8 specimens at each of 3 stress levels tested in sequence randomized with respect to stress level. Regression analysis performed on these 24 specimens resulting in

$$\log (N) = 11.512 - 0.13523 (S_{max}) \quad (X1.1)$$

with standard error of estimate, 0.09925, and correlation coefficient, − 0.9646.