This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

**Designation: E466 – 21**

# Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials[1]

This standard is issued under the fixed designation E466; 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 procedure for the performance of axial force controlled fatigue tests to obtain the fatigue strength of metallic materials in the fatigue regime where the strains are predominately elastic, both upon initial loading and throughout the test. This practice is limited to the fatigue testing of axial unnotched and notched specimens subjected to a constant amplitude, periodic forcing function in air at room temperature.

1.2 The use of this test method is limited to specimens and does not cover testing of full-scale components, structures, or consumer products.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

NOTE 1—The following documents, although not directly referenced in the text, are considered important enough to be listed in this practice:

E739 Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (ε-N) Fatigue Data

STP 566 Handbook of Fatigue Testing[2]

STP 588 Manual on Statistical Planning and Analysis for Fatigue Experiments[3]

STP 731 Tables for Estimating Median Fatigue Limits[4]

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[5]

E3 Guide for Preparation of Metallographic Specimens
E467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System
E468 Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials
E606/E606M Test Method for Strain-Controlled Fatigue Testing
E739 Practice for Statistical Analysis of Linear or Linearized Stress-Life (***S-N***) and Strain-Life (ε-***N***) Fatigue Data
E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application
E1823 Terminology Relating to Fatigue and Fracture Testing

## 3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this practice shall be as defined in Terminology E1823.

## 4. Significance and Use

4.1 The axial force fatigue test is used to determine the effect of variations in material, geometry, surface condition, stress, and so forth, on the fatigue resistance of metallic materials subjected to direct stress for relatively large numbers of cycles. The results may also be used as a guide for the selection of metallic materials for service under conditions of repeated direct stress.

4.2 In order to verify that such basic fatigue data generated using this practice is comparable, reproducible, and correlated among laboratories, it may be advantageous to conduct a round-robin-type test program from a statistician's point of

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[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] *Handbook of Fatigue Testing*, *ASTM STP 566*, ASTM, 1974.

[3] Little, R. E., *Manual on Statistical Planning and Analysis, ASTM STP 588*, ASTM, 1975.

[4] Little, R. E., *Tables for Estimating Median Fatigue Limits*, *ASTM STP 731*, ASTM, 1981.

[5] 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.

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view. To do so would require the control or balance of what are often deemed nuisance variables; for example, hardness, cleanliness, grain size, composition, directionality, surface residual stress, surface finish, and so forth. Thus, when embarking on a program of this nature it is essential to define and maintain consistency a priori, as many variables as reasonably possible, with as much economy as prudent. All material variables, testing information, and procedures used should be reported so that correlation and reproducibility of results may be attempted in a fashion that is considered reasonably good current test practice.

4.3 The results of the axial force fatigue test are suitable for application to design only when the specimen test conditions realistically simulate service conditions or some methodology of accounting for service conditions is available and clearly defined.

## 5. Specimen Design

5.1 The type of specimen used will depend on the objective of the test program, the type of equipment, the equipment capacity, and the form in which the material is available. However, the design should meet certain general criteria outlined below:

5.1.1 The design of the specimen should be such that failure occurs in the test section (reduced area as shown in Fig. 1 and Fig. 2). The acceptable ratio of the areas (test section to grip section) to ensure a test section failure is dependent on the specimen gripping method. Threaded end specimens may prove difficult to align and failure often initiates at these stress concentrations when testing in the life regime of interest in this practice. A caveat is given regarding the gage section with sharp edges (that is, square or rectangular cross section) since these are inherent weaknesses because the slip of the grains at sharp edges is not confined by neighboring grains on two sides. Because of this, a circular cross section may be preferred if material form lends itself to this configuration. The size of the gripped end relative to the gage section, and the blend radius from gage section into the grip section, may cause premature failure particularly if fretting occurs in the grip section or if the radius is too small. Readers are referred to Ref (**1**) should this occur.

5.1.2 For the purpose of calculating the force to be applied to obtain the required stress, the dimensions from which the area is calculated should be measured to the nearest 0.001 in. (0.03 mm) for dimensions equal to or greater than 0.200 in. (5.08 mm) and to the nearest 0.0005 in. (0.013 mm) for dimensions less than 0.200 in. (5.08 mm). Surfaces intended to be parallel and straight should be in a manner consistent with 8.2.

NOTE 2—Measurements of dimensions presume smooth surface finishes for the specimens. In the case of surfaces that are not smooth, due to the fact that some surface treatment or condition is being studied, the dimensions should be measured as above and the average, maximum, and minimum values reported.

5.2 *Specimen Dimensions:*

5.2.1 *Circular Cross Sections*—Specimens with circular cross sections may be either of two types:

5.2.1.1 *Specimens with tangentially blended fillets between the test section and the ends* (Fig. 1)—The diameter of the test section should preferably be between 0.200 in. (5.08 mm) and 1.000 in. (25.4 mm). To ensure test section failure, the grip cross-sectional area should be at least 1.5 times but, preferably for most materials and specimens, at least four times the test section area. The blending fillet radius should be at least eight times the test section diameter to minimize the theoretical stress concentration factor, $K_t$ of the specimen. The test section length should be approximately two to three times the test section diameter. For tests run in compression, the length of the test section should be approximately two times the test section diameter to minimize buckling.

5.2.1.2 *Specimens with a continuous radius between ends* (Fig. 3)—The radius of curvature should be no less than eight times the minimum diameter of the test section to minimize $K_t$. The reduced section length should be greater than three times the minimum test section diameter. Otherwise, the same dimensional relationships should apply, as in the case of the specimens described in 5.2.1.1.

5.2.2 *Rectangular Cross Sections*—Specimens with rectangular cross sections may be made from sheet or plate material and may have a reduced test cross section along one dimension, generally the width, or they may be made from material requiring dimensional reductions in both width and thickness. In view of this, no maximum ratio of area (grip to test section) should apply. The value of 1.5 given in 5.2.1.1 may be considered as a guideline. Otherwise, the sections may be either of two types:

5.2.2.1 *Specimens with tangentially blended fillets between the uniform test section and the ends* (Fig. 4)—The radius of the blending fillets should be at least eight times the specimen test section width to minimize $K_t$ of the specimen. The ratio of specimen test section width to thickness should be between two and six, and the reduced area should preferably be between

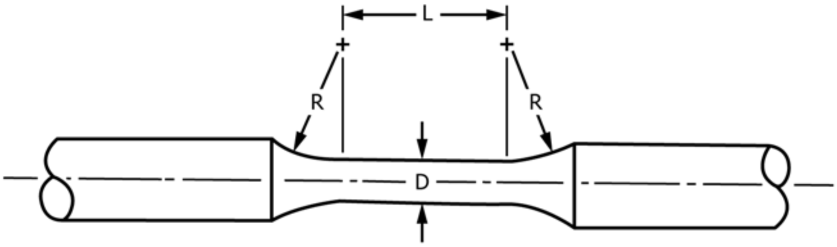

**FIG. 1 Specimens with Tangentially Blending Fillets Between the Test Section and the Ends**

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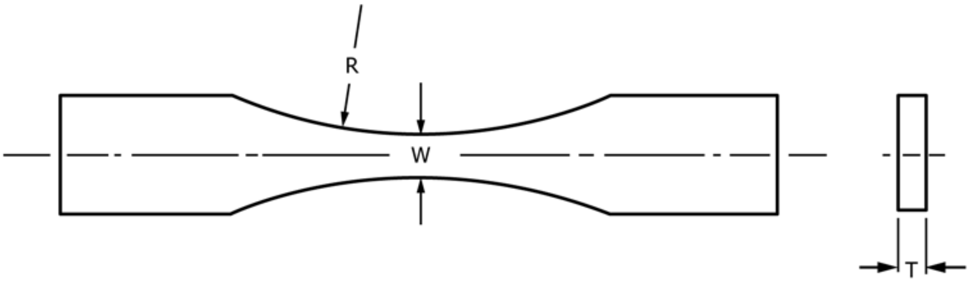

FIG. 2 Specimens with Continuous Radius Between Ends

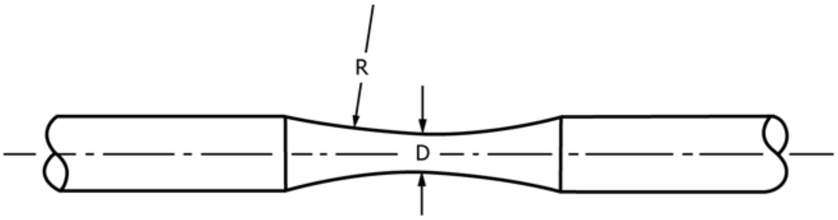

FIG. 3 Specimens with a Continuous Radius Between Ends

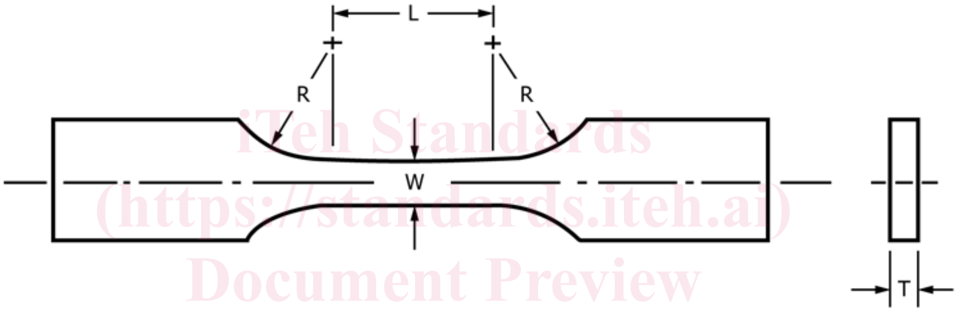

FIG. 4 Specimens with Tangentially Blending Fillets Between the Uniform Test Section and the Ends

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0.030 in.$^2$ (19.4 mm$^2$) and 1.000 in.$^2$ (645 mm$^2$), except in extreme cases where the necessity of sampling a product with an unchanged surface makes the above restrictions impractical. The test section length should be approximately two to three times the test section width of the specimen. For specimens that are less than 0.100 in. (2.54 mm) thick, special precautions are necessary particularly in reversed loading, such as $R = -1$. For example, specimen alignment is of utmost importance and the procedure outlined in Practice E606/E606M would be advantageous. Also, Refs **(2-5)**, although they pertain to strain-controlled testing, may prove of interest since they deal with sheet specimens approximately 0.05 in. (1.25 mm) thick.

5.2.2.2 *Specimens with continuous radius between ends (*Fig. 2*)*—The same restrictions should apply in the case of this type of specimen as for the specimen described in 5.2.1.2. The area restrictions should be the same as for the specimen described in 5.2.2.1.

5.2.3 *Notched Specimens*—In view of the specialized nature of the test programs involving notched specimens, no restrictions are placed on the design of the notched specimen, other than that it must be consistent with the objectives of the program. Also, specific notched geometry, notch tip radius, information on the associated $K_t$ for the notch, and the method and source of its determination should be reported.

## 6. Specimen Preparation

6.1 The condition of the test specimen and the method of specimen preparation are of the utmost importance. Improper methods of preparation can greatly bias the test results. In view of this fact, the method of preparation should be agreed upon prior to the beginning of the test program by both the originator and the user of the fatigue data to be generated. Since specimen preparation can strongly influence the resulting fatigue data, the application or end use of that data, or both, should be considered when selecting the method of preparation. Appendix X1 presents an example of a machining procedure that has been employed on some metals in an attempt to minimize the variability of machining and heat treatment upon fatigue life.

6.2 Once a technique has been established and approved for a specific material and test specimen configuration, change should not be made because of potential bias that may be introduced by the changed technique. Regardless of the machining, grinding, or polishing method used, the final metal removal should be in a direction approximately parallel to the long axis of the specimen. This entire procedure should be clearly explained in the reporting since it is known to influence fatigue behavior in the long-life regime.

6.3 The effects to be most avoided are fillet undercutting and residual stresses introduced by specimen machining practices. One exception may be where these parameters are under study. Fillet undercutting can be readily determined by inspection. Assurance that surface residual stresses are minimized can be achieved by careful control of the machining procedures. It is advisable to determine these surface residual stresses with X-ray diffraction peak shift or similar techniques, and that the value of the surface residual stress be reported along with the direction of determination (that is, longitudinal, transverse, radial, and so forth).

6.4 *Storage*—Specimens that are subject to corrosion in room temperature air should be accordingly protected, preferably in an inert medium. The storage medium should generally be removed before testing using appropriate solvents, if necessary, without adverse effects upon the life of the specimens.

6.5 *Inspection*—Visual inspections with unaided eyes or with low power magnification up to 20× should be conducted on all specimens. Obvious abnormalities, such as cracks, machining marks, gouges, undercuts, and so forth, are not acceptable. Specimens should be cleaned prior to testing with solvent(s) non-injurious and non-detrimental to the mechanical properties of the material in order to remove any surface oil films, fingerprints, and so forth. Dimensional analysis and inspection should be conducted in a manner that will not visibly mark, scratch, gouge, score, or alter the surface of the specimen.

## 7. Equipment Characteristics and Methodology

7.1 Generally, the tests will be performed on one of the following types of fatigue testing machines:

7.1.1 Mechanical (eccentric crank, power screws, rotating masses),

7.1.2 Electromechanical or magnetically driven, or

7.1.3 Hydraulic or electrohydraulic.

7.2 The test machines shall have a force-monitoring system, such as a transducer mounted in series with the specimen, or mounted on the specimen itself. It shall be confirmed that the accuracy of dynamic force measurement will be better than ± 2 % of the desired force amplitude at the test frequency applied, using an appropriate method such as that of Practice E467.

7.3 *Test Force Application*—The deviation of applied maximum and minimum force from the desired values should not exceed 2 % of desired amplitude for the duration of the test.

7.4 *Test Frequency*—The range of frequencies for which fatigue results may be influenced by rate effects varies from material to material. In the typical regime of $10^{-2}$ to $10^{+2}$ Hz over which most results are generated, fatigue strength is generally unaffected for most metallic engineering materials. It is beyond the scope of Practice E466 to extrapolate beyond this range or to extend this assumption to other materials systems that may be viscoelastic or viscoplastic at ambient test temperatures and within the frequency regime mentioned. As a cautionary note, should localized yielding occur, significant specimen heating may result and affect fatigue strength.

7.5 The action of the test machine should be analyzed to ensure that the desired form and magnitude of loading is maintained for the duration of the test. Force deviations of the applied maximum and minimum force greater than 2 % of the desired force amplitude should be reported.

## 8. Procedure

8.1 *Mounting the Specimen*—By far the most important consideration for specimen grips is that they can be brought into good alignment consistently from specimen-to-specimen (see 8.2). For most conventional grips, good alignment must come about from very careful attention to design detail. Every effort should be made to prevent the occurrence of misalignment, either due to twist (rotation of the grips), or to a displacement in their axes of symmetry.

8.2 *Alignment Verification*—To minimize bending stresses (strains), specimen fixtures shall be aligned such that the major axis of the specimen closely coincides with the load axis throughout each cycle. It is important that the accuracy of alignment be kept consistent from specimen-to-specimen. For cylindrical or rectangular specimens, alignment shall be determined using the procedure detailed in Practice E1012, Standard Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application. The points (stresses or strains) at which alignment verification data are obtained shall be fully documented. If compressive stresses (strains) are to be used in testing, the alignment must be verified in compression. Once a technique has been established and approved for a specific test program, changes should not be made because of potential bias that may be introduced by the changed technique. Any change in the force train configuration during the test program from that already shown to provide acceptable alignment necessitates a repeated measurement of the bending stresses (strains). The bending stresses (strains) so determined on either the cylindrical or rectangular cross section specimen shall not exceed 5 % of either the range, maximum or minimum stresses (strains) imposed during the test, or ± 100 microstrain, whichever is greater. Bending stresses (strains) shall be calculated using the method of Practice E1012, Section 10 (Calculation and Interpretation of Results). Alignment verification is required if the force train is changed. If there are no changes to the force train, then alignment verification is to be performed at least every 12 months.

The less the bending stresses (strains), the more repeatable the test results will be from specimen-to-specimen. This is especially important for materials with low ductility (that is, bending stresses (strains) should not exceed 5 % of the minimum stress (strain) amplitude). The bending stresses (strains) shall be reported since it is known to influence fatigue behavior particularly in the long-life regime.

NOTE 3—This section refers to Type A Tests, in Practice E1012.

NOTE 4—As referred to in this section, changes in the force train configuration typically refer to changes in the major components of a force train such as the force transducer, actuator, crosshead, or grip mounts. Some force train configurations require partial disassembly and reassembly during test specimen insertion. For such systems, the loading procedure must be well controlled and be demonstrated to result in bending stresses (strains) that shall not exceed 5 % of either the range,

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