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Standard Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System[1]

This standard is issued under the fixed designation E467; 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 procedures for the dynamic verification of cyclic force amplitude control or measurement accuracy during constant amplitude testing in an axial fatigue testing system. It is based on the premise that force verification can be done with the use of a strain gaged elastic element. Use of this practice gives assurance that the accuracies of forces applied by the machine or dynamic force readings from the test machine, at the time of the test, after any user applied correction factors, fall within the limits recommended in Section 9. It does not address static accuracy which must first be addressed using Practices E4 or equivalent.

1.2 Verification is specific to a particular test machine configuration and specimen. This standard is recommended to be used for each configuration of testing machine and specimen. Where dynamic correction factors are to be applied to test machine force readings in order to meet the accuracy recommended in Section 9, the verification is also specific to the correction process used. Finally, if the correction process is triggered or performed by a person, or both, then the verification is specific to that individual as well.

1.3 It is recognized that performance of a full verification for each configuration of testing machine and specimen configuration could be prohibitively time consuming and/or expensive. Annex A1 provides methods for estimating the dynamic accuracy impact of test machine and specimen configuration changes that may occur between full verifications. Where test machine dynamic accuracy is influenced by a person, estimating the dynamic accuracy impact of all individuals involved in the correction process is recommended. This practice does not specify how that assessment will be done due to the strong dependence on owner/operators of the test machine.

1.4 This practice is intended to be used periodically. Consistent results between verifications is expected. Failure to obtain consistent results between verifications using the same machine configuration implies uncertain accuracy for dynamic tests performed during that time period.

1.5 This practice addresses the accuracy of the testing machine's force control or indicated forces, or both, as compared to a dynamometer's indicated dynamic forces. Force control verification is only applicable for test systems that have some form of indicated force peak/valley monitoring or amplitude control. For the purposes of this verification, the dynamometer's indicated dynamic forces will be considered the true forces. Phase lag between dynamometer and force transducer indicated forces is not within the scope of this practice.

1.6 The results of either the Annex A1 calculation or the full experimental verification must be reported per Section 10 of this standard.

1.7 This practice provides no assurance that the shape of the actual waveform conforms to the intended waveform within any specified tolerance.

1.8 This standard is principally focused at room temperature operation. It is believed there are additional issues that must be addressed when testing at high temperatures. At the present time, this standard practice must be viewed as only a partial solution for high temperature testing.

1.9 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.10 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *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.*

[1] This practice is under the jurisdiction of ASTM Committee E08 on Fatigue and Fractureand is the direct responsibility of Subcommittee E08.03 on Advanced Apparatus and Techniques.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

E4 Practices for Force Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E1823 Terminology Relating to Fatigue and Fracture Testing

E1942 Guide for Evaluating Data Acquisition Systems Used in Cyclic Fatigue and Fracture Mechanics Testing

2.2 *Military Standard:*[3]

1312-B Fastener Test Methods

2.3 *ANSI Standard:*[4]

Z540-1-1994 Calibration Laboratories and Measuring and Test Equipment—General Requirements

2.4 *NCSL Standard:*[4]

Publication 940830/1600 NCSL Glossary of Metrology—Related Terms

3. Terminology

3.1 Terminology used in this practice is in accordance with Terminology E1823. Definitions provided in this practice are considered either unfamiliar or not included in Terminology E1823.

3.2 *Definitions:*

3.2.1 *accuracy, n*—The quantitative difference between a test measurement and a reference value.

3.2.2 *amplitude, n*—one-half the peak-to-peak measurement of the cyclic waveform.

3.2.3 *cal factor, n*—the conversion factor between the dynamometer force and the indicated force.

3.2.4 *conditioned force, n*—the high level voltage or digital data available from the dynamometer or force transducer's signal conditioning instrumentation; it is frequently of value during dynamic verification as it can be more conveniently monitored by stand alone measurement instrumentation.

3.2.5 *corrected force, n*—the force obtained after applying a dynamic correction factor to the force transducer's indicated force.

3.2.6 *data acquisition equipment, n*—the equipment used to convert a conditioned force to an indicated force.

3.2.7 *dynamic dynamometer forces, n*—the maximum and minimum forces produced in the dynamometer during a portion of a dynamic test.

3.2.8 *dynamic errors, n*—errors in the force transducer's corrected force output that occur due to dynamic operation (with specimen bending errors intentionally corrected out).

3.2.9 *dynamic indicated forces, n*—the maximum and minimum forces reported by the test machine during a portion of a dynamic test. These values are typically obtained using an oscilloscope, peak-valley meter, or files generated by computerized data acquisition.

3.2.10 *dynamometer, n*—an elastic calibration device used to indicate the forces applied by a fatigue testing system during dynamic operation. A strain gaged specimen is often used as the dynamometer. Suitable transducer instrumentation is also required to provide accurate readings over the intended frequency and force range. (Refer to Practice E467, Annex A2 for detailed information about the dynamometer and instrumentation.)

3.2.11 *dynamometer force, n*—the force value provided by the dynamometer's readout.

3.2.12 *endlevel, n*—either a maximum or minimum level for a cyclic waveform.

3.2.13 *fatigue testing system, n—for the purpose of this practice*, a device for applying repeated force cycles to a specimen or component, which applies repeated force cycles of the same span, frequency, waveshape, mean level, and endlevels.

3.2.14 *force command, n*—the desired force to be applied to the specimen or dynamometer by the testing machine.

3.2.15 *force transducer, n*—a measuring device that can provide an output signal proportional to the force being applied.

3.2.16 *indicated force, n*—the force value provided by the force transducer or dynamometer's readout (for example, a numeric or graphical output for reading by a human including a peak picking capability); these values are typically obtained from a digital volt meter (DVM) or files generated by a computerized data acquisition.

3.2.17 *instrumentation, n*—the electronics used with a transducer providing excitation for the transducer, conditioning of the measured signal, and readout of that signal; typically the conditioned signal is a voltage and the readout is a numerical display or printout.

3.2.18 *peak, n*—the maximum endlevel of a cycle.

3.2.19 *peak picking, n*—the process of determining the peak or valley of a cyclic waveform.

3.2.20 *repeatability, n*—the closeness of agreement among repeated measurements of the dynamic forces under the same conditions.

3.2.21 *span, n*—the absolute value of the peak minus the valley for a cyclic waveform.

3.2.22 *transducer, n*—a measuring device which has an output signal proportional to the engineering quantity being measured.

3.2.23 *true force, n*—the actual force applied to the specimen or dynamometer.

3.2.24 *UUT, n*—Unit Under Test

3.2.25 *valley, n*—the minimum endlevel of a cycle.

4. Significance and Use

4.1 It is well understood how to measure the forces applied to a specimen under static conditions. Practices E4 details the

[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] Available from the U.S. Government Printing Office, Washington, DC 20402.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

required process for verifying the static force measurement capabilities of testing machines. During dynamic operation however, additional errors may manifest themselves in a testing machine. Further verification is necessary to confirm the dynamic force measurement capabilities of testing machines.

NOTE 1—The static machine verification accomplished by Practices E4 simply establishes the reference. Indicated forces measured from the force cell are compared with the dynamometer conditioned forces statically for confirmation and then dynamically for dynamic verification of the fatigue testing system's force output.

NOTE 2—The dynamic accuracy of the force cell's output will not always meet the accuracy requirement of this standard without correction. Dynamic correction to the force cell output can be applied provided that verification is performed after the correction has been applied.

NOTE 3—Overall test accuracy is a combination of measurement accuracy and control accuracy. This practice provides methods to evaluate either or both. As control accuracy is dependent on many more variables than measurement accuracy it is imperative that the test operator utilize appropriate measurement tools to confirm that the testing machine's control behavior is consistent between verification activities and actual testing activities.

4.2 Dynamic errors are primarily span dependent, not level dependent. That is, the error for a particular force endlevel during dynamic operation is dependent on the immediately preceding force endlevel. Larger spans imply larger absolute errors for the same force endlevel.

4.3 Due to the many test machine factors that influence dynamic force accuracy, verification is recommended for every new combination of potential error producing factors. Primary factors are specimen design, machine configuration, test frequency, and loading span. Clearly, performing a full verification for each configuration is often impractical. To address this problem, dynamic verification is taken in two parts.

4.3.1 First, one or more full verifications are performed at least annually. The main body of this practice describes that procedure. This provides the most accurate estimate of dynamic errors, as it will account for electronic as well as acceleration-induced sources of error.

4.3.2 The second part, described in Annex A1, is a simplified verification procedure. It provides a simplified method of estimating acceleration-induced errors only. This procedure is to be used for common configuration changes (that is, specimen/grip/crosshead height changes).

4.4 Dynamic verification of the fatigue system is recommended over the entire range of force and frequency over which the planned fatigue test series is to be performed. Endlevels are limited to the machine's verified static force as defined by the current static force verification when tested in accordance with Practices E4.

NOTE 4—There is uncertainty as to whether or not the vibration in a frame will be different when operating in compression as opposed to tension. As a consequence, this practice recommends performing verifications at maximum tension and maximum compression endlevels. The total span does not need to be between those two levels, but can be performed as two tests.

NOTE 5—Primary electronic characteristics affecting dynamic measurement accuracy are noise and bandwidth. Excessive noise is generally the dominant effect at the minimum test frequency. Insufficient bandwidth-induced errors are generally most significant at the maximum test frequency.

5. Apparatus

5.1 *Dynamometer Construction*—A dynamometer is required. The strongly preferred dynamometer is an actual specimen, suitably strain gaged to provide a signal when loaded axially. Where a strain gaged specimen is not practical, an alternative dynamometer must be made. Annex A2 provides more detailed instructions on the preparation of a typical dynamometer.

5.2 *Dynamometer Instrumentation*—Dynamometer instrumentation is also required. The overall accuracy of the dynamometer and the associated instrumentation shall contribute less than 25 % of the total error of the dynamic measurement being made. Refer to Annex A2 for guidance on suitable instrumentation for both the dynamometer and the machine being verified. Calibration of the dynamometer instrumentation must be current and traceable to the National Institute of Standards and Technology (NIST) or some other recognized national standards organization.

5.3 *Dynamometer Static Calibration*—An absolute calibration of the dynamometer as tested in accordance with Practices E4 is not required. It is only necessary to statically calibrate the dynamometer indicated forces to the force transducer indicated forces at the force levels corresponding to the desired dynamic force endlevels. It is this relationship that will be verified under dynamic conditions to assure acceptable levels of additional errors due to dynamic operation. Details of the static calibration of the dynamometer are included in Section 6 as an integral part of the practice.

6. Procedure—Full Verification

NOTE 6—The objective of a full verification is to show that the force transducer corrected force accuracy is within an acceptable range when all sources of dynamic error have been taken into account.

6.1 *Designing the Test*—Prepare a matrix of configurations, test frequencies, and loading spans which address the following issues:

6.1.1 *Machine Configurations*—Ideally, the machine should be configured exactly as it will be used for material testing including grips or fixturing, or both. Where it is not practical to test all expected configurations, test the configuration(s) with the largest expected acceleration errors. In this case, Annex A1 must be used to verify additional test set-ups. It is recommended that at least two machine configurations be verified, and that the ability to detect acceleration errors against the true errors measured with the full verifications be tested.

6.1.2 *Test Frequencies*—Where the testing machine will only be used at a few discrete frequencies, perform the verification at those frequencies. Where the machine will be used at a variety of frequencies, the minimum and maximum frequencies must be verified using the full verification procedure. Any operating frequency between those frequencies may be verified using Annex A1. A dynamic error graph may prove useful for identifying sources of dynamic errors and is recommended though not required. See Annex A3 for an example.

6.1.3 *Loading Spans*—A recommended test would be with the machine configured for minimum motion and another would be with the machine configured for maximum motion. Also, due to the uncertainty of differences in machine vibration