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Metallic materials — Fatigue testing — Axial plane bending method

Matériaux métalliques — Essais de fatigue — Méthode par flexion plane axiale

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 4, *Fatigue, fracture and toughness testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Metallic materials — Fatigue testing — Axial plane bending method

1 Scope

This document specifies the conditions for conducting the plane bending fatigue test on an axial machine, constant-amplitude, force or displacement controlled, at room temperature (ideally between 10 °C and 35 °C) on metallic specimens, without deliberately introduced stress concentrations. This document does not include the reversed/partially loading test. The purpose of the test is to provide relevant results, such as the relation between applied stress and number of cycles to failure for a given material condition, expressed by hardness and microstructure, at various stress ratios.

Although the shape, preparation and testing of specimens of rectangular and bevelled cross-section are specified, component testing and other specialized forms of testing are not included in this document.

Fatigue tests on notched specimens are not covered by this document since the shape and size of notched test pieces have not been specified in any standard so far. Guidelines are given in Annex A. However, the fatigue-test procedures described in this document can be used for testing such notched specimens.

It is possible for the results of a fatigue test to be affected by atmospheric conditions. Where controlled conditions are required, ISO 554:1976, 2.1 applies.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ASTM E2309/E2309M, *Standard Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
thickness of test section
δ
thickness of reduced section of rectangular test specimen

Note 1 to entry: See Figure 1.

3.2
width of test section
w
width of reduced section of rectangular test specimen

Note 1 to entry: See Figure 1.

3.3
specimen length
L_z
overall length of test specimen

3.4
specimen cross-section
S
surface of the specimen cross-section

3.5
corner radius
r_c
radius of the corner of rectangular cross-section specimen

3.6
distance between inner loading points
d_1
distance between the axes of the two inner rollers

Note 1 to entry: See Figure 3.

3.7
distance between outer loading points
d_2
distance between the axes of the two outer rollers

Note 1 to entry: See Figure 3.

3.8
roller diameter
D_R
diameter of the four rollers

3.9
stress cycle
smallest segment of stress-time that is repeated identically

Note 1 to entry: See Figure 4.

3.10
maximum stress
σ_{max}
greatest algebraic value of stress in a stress cycle

Note 1 to entry: See Figure 4.

3.11
mean stress
σ_m
one-half the algebraic sum of the maximum stress and the minimum stress in a stress cycle

Note 1 to entry: See Figure 4.

3.12
minimum stress
σ_{min}
least algebraic value of stress in a stress cycle

Note 1 to entry: See Figure 4.

3.13
stress amplitude
σ_a
one-half the algebraic difference between the maximum stress and the minimum stress in a stress cycle

Note 1 to entry: to entry:

$$\sigma_a = \Delta\sigma/2$$

Note 2 to entry: See Figure 4.

3.14
stress range
$\Delta\sigma$
arithmetic difference between the maximum and minimum stress

Note 1 to entry: to entry:

$$\Delta\sigma = \sigma_{max} - \sigma_{min}$$

Note 2 to entry: See Figure 4.

3.15
stress ratio
R_σ
ratio of minimum to maximum stress during any single cycle of fatigue operation

Note 1 to entry: to entry:

$$R_{\boldsymbol{\sigma}} = \sigma_{min}/\sigma_{max}$$

Note 2 to entry: See Figure 5.

3.16
load ratio
R_F
ratio of minimum to maximum load during any single cycle of fatigue operation

Note 1 to entry: to entry:

$$R_F = F_{min}/F_{max}$$

Note 2 to entry: See Figure 5.

3.17
number of cycles
N
number of smallest segments of the force-time, stress-time, strain-time, etc., function that is repeated periodically

3.18
fatigue life
N_f
number of applied cycles to achieve a defined failure criterion

3.19
applied force
F
force applied during the test (for force-controlled test)

3.20
bending moment
M
constant moment between the inner rollers, calculated with the applied force and the distances between the rollers (d_1 and d_2)

Note 1 to entry: to entry:

$$M = \frac{F}{4}(d_2 - d_1)$$

4 Symbols

4.1 Symbols related to specimen geometry

Symbol	Designation	Unit
δ	Thickness of test section	mm
δ_1	Reduced thickness of the bevelled specimen	mm
w	Width of test section	mm
w_1	Reduced width of the bevelled specimen	mm
L_z	Specimen length	mm
I	Second moment of area	mm^4
d_{nba}	Maximum distance from the neutral bending axis	mm
S	Specimen cross-section	mm^2
r_c	Corner radius	mm

4.2 Symbols related to testing device

Symbol	Designation	Unit
d_1	Distance between inner loading points	mm
d_2	Distance between outer loading points	mm
D_R	Roller diameter	mm

4.3 Symbols related to fatigue test

Symbol	Designation	Unit
β_{hi}	Stress homogeneity for load *i*	
σ_{max}	Maximum stress	MPa

Symbol	Designation	Unit
σ_m	Mean stress	MPa
σ_{min}	Minimum stress	MPa
σ_a	Stress amplitude	MPa
$\Delta\sigma$	Stress range	MPa
σ	Test stress	MPa
R_σ	Stress ratio	
R_F	Load ratio	
N	Number of cycles	cycles
N_f	Fatigue life	cycles
F	Applied force	N
M	Bending moment	N-m

5 Principle of test

The principle of the test is to place a specimen between four rollers as shown in Figure 3. Then a constant amplitude cyclic force is applied so that a constant amplitude tension stress is applied to the tested surface of the specimen. The test is then continued until the specimen fails or until a predetermined number of stress cycles is reached.

Nominally identical specimens are mounted on a fatigue testing machine and subjected to the loading condition required to introduce cycles of plane bending stress. Any one of the types of cyclic stress illustrated in Figure 5 may be used. The test waveform shall be constant-amplitude sinusoidal.

6 Test plan

6.1 General outline

Before commencing testing, the following shall be agreed by the parties concerned, unless specified otherwise in the relevant product standard:

a) The form of specimen to be used (see 7.1);

b) The stress ratio(s) to be used;

c) The objective of the tests, i.e., which of the following is to be determined:

— the fatigue life at a specified stress amplitude;

— the fatigue strength at a specified number of cycles;

— a full Wöhler or S-N curve;

d) The number of specimens to be tested and the testing sequence;

e) The number of cycles at which a test on an unfailed specimen shall be terminated.

7 Specimen

7.1 Shape of specimens

The specimens are generally fully machined with a rectangular cross-section of uniform thickness over the test section. In order to avoid crack initiation from corners, two solutions may be considered:

— machining of a radius on each corner (Figure 1);