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Metallic materials — Rotating bar bending fatigue testing

Matériaux métalliques — Essais de fatigue par flexion rotative de barreaux

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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*.

The third edition cancels and replaces the second edition (ISO 1143:2010), which has been technically revised.

The main changes compared to the previous edition are as follows:

— A new Clause 13, Measurement uncertainty, has been added;

— a new Annex B, Example of a test report, has been added.

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 — Rotating bar bending fatigue testing

WARNING — This document does not address safety or health concerns, should such issues exist, that may be associated with its use or application. It is the responsibility of the user of this document to establish any appropriate safety and health concerns, as well as to determine the applicability of any national or local regulatory limitations regarding the use of this document.

1 Scope

This document specifies the method for rotating bar bending fatigue testing of metallic materials. The tests are conducted at room temperature or elevated temperature in air, the specimen being rotated.

Fatigue tests on notched specimens are not covered by this document, since the shape and size of notched specimens have not been standardized. However, fatigue test procedures described in this document can be applied to fatigue tests of notched specimens.

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 376, *Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines*

ISO 1099, *Metallic materials — Fatigue testing — Axial force-controlled method*

ISO 12106, *Metallic materials — Fatigue testing — Axial-strain-controlled method*

ISO 12107, *Metallic materials — Fatigue testing — Statistical planning and analysis of data*

ISO 23718, *Metallic materials — Mechanical testing — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1099, ISO 12106, ISO 12107, ISO 23718 and the following apply.

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

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

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

3.1
fatigue
process of changes in properties which can occur in a metallic material due to the repeated application of stresses or strains and that can lead to cracking or failure

3.2
fatigue life
N_f
number of applied cycles to achieve a defined failure criterion

3.3
***S-N* diagram**
diagram that shows the relationship between stress and *fatigue life* (3.2)

3.4
bending moment
M
multiplication between force and length of lever arm at test temperature

3.5
section modulus
W
ratio of the moment of inertia of the cross-section of a beam undergoing flexure to the greatest distance of an element of the beam from the neutral axis

3.6
machine lever ratio
M_{lr}
ratio between the force applied to the weight hanger and the *bending moment* (3.4) applied to the specimen

3.7
length of lever arm
L
distance between the supporting point and the loading point

Note 1 to entry: See Figures 1 to 7.

Note 2 to entry: Since these distances are length of level arm, $L_1 = L_2 = L$.

4 Symbols

Symbols and corresponding designations are given in Table 1.

Table 1 — Symbols

Symbol	Designation	Unit
D	Diameter of gripped or loaded end of specimen	mm
d	Diameter of specimen where stress is maximum	mm
L	Length of lever arm	mm
M	Bending moment	N·mm
M_{lr}	Machine lever ratio	/
N_f	Fatigue life, cycles to failure	cycle
r	Radius at ends of test section that starts transition from test diameter, *d*	mm
W	Section modulus	mm^3

5 Principle of test

Nominally identical specimens are used, each being rotated and subjected to a constant bending moment. The forces giving rise to the bending moment do not rotate. The specimen may be mounted as a cantilever, with single-point or two-point loading, or as a beam, with four-point loading. The test is continued until the specimen fails or until a pre-determined number of stress cycles have been achieved, a stress cycle corresponds to a complete rotation of the specimen.

6 Shape and size of specimen

6.1 Forms of the test section

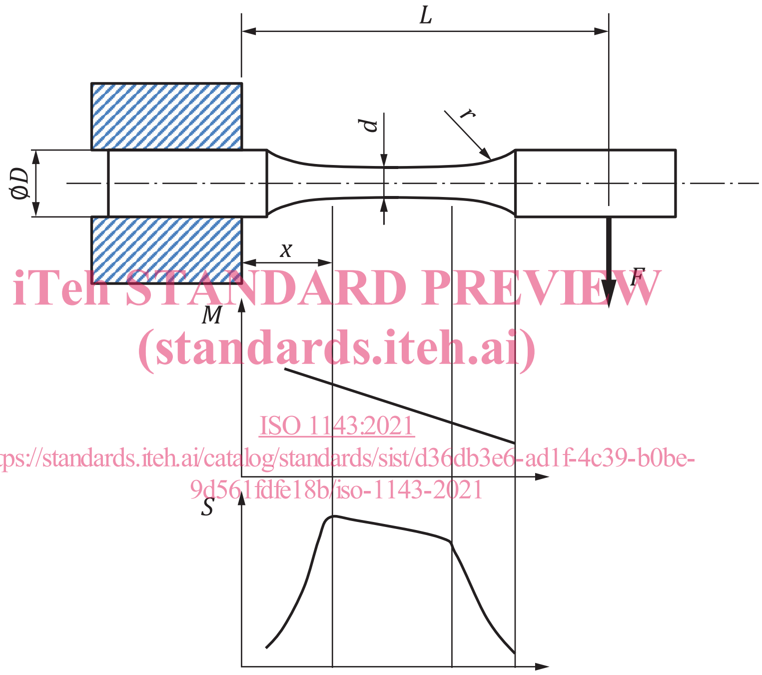
The test section may be

a) cylindrical, with tangentially blending fillets at one or both ends (see Figures 1, 4 and 5),

b) tapered (see Figure 2), or

c) hourglass-type (see Figures 3, 6 and 7).

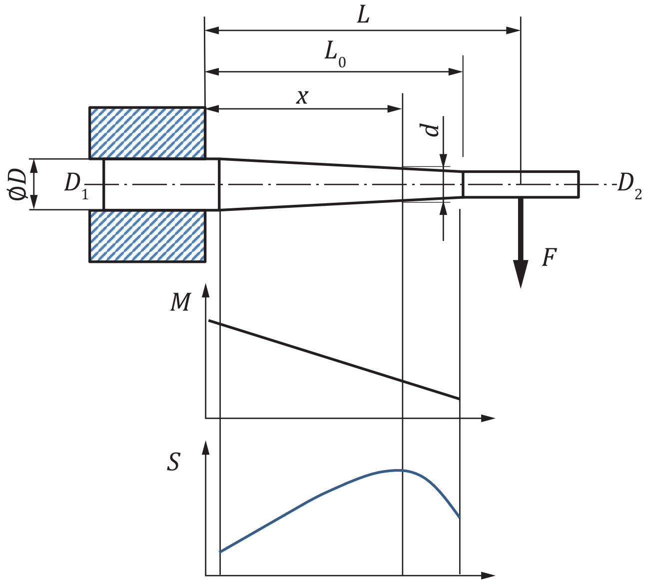
NOTE A volume of material is tested in the gauge portion of a parallel specimen in two-point and four-point loading conditions. This volume is equally under maximum stress. For all other loading conditions and for both parallel and hourglass specimens, only a thin planar element of material is submitted to the maximum stress at the minimum cross-section.



Key

D diameter of gripped or loaded end of specimen
d diameter of specimen where stress is maximum
F applied force
L length of lever arm
M bending moment
r radius (see Table 1)
S stress
x distance along specimen axis from fixed bearing face to maximum stress plane

Figure 1 — Parallel specimen — Single-point loading



Key

D diameter of gripped or loaded end of specimen

d diameter of specimen where stress is maximum

F applied force

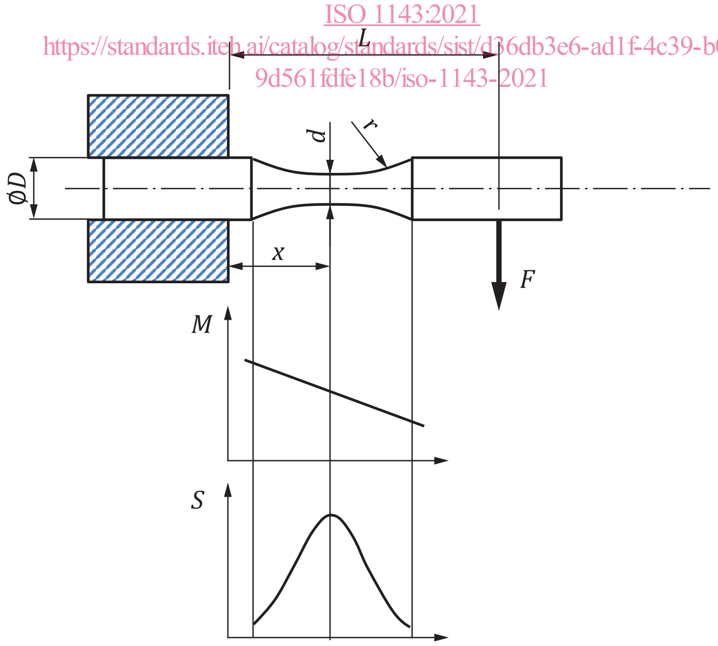
L length of lever arm

M bending moment

S stress

x distance along specimen axis from fixed bearing face to maximum stress plane

Figure 2 — Tapered specimen — Single-point loading



Key

D diameter of gripped or loaded end of specimen

d diameter of specimen where stress is maximum

F applied force

L length of lever arm

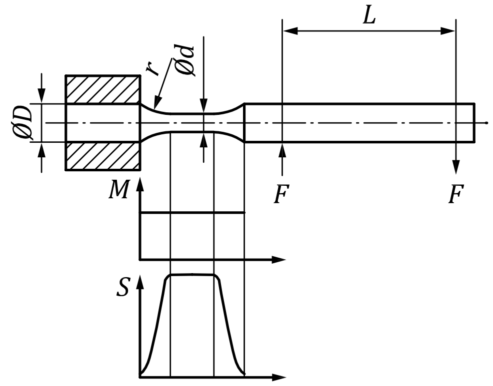
r radius (see Table 1)

M bending moment

S stress

x distance along specimen axis from fixed bearing face to maximum stress plane

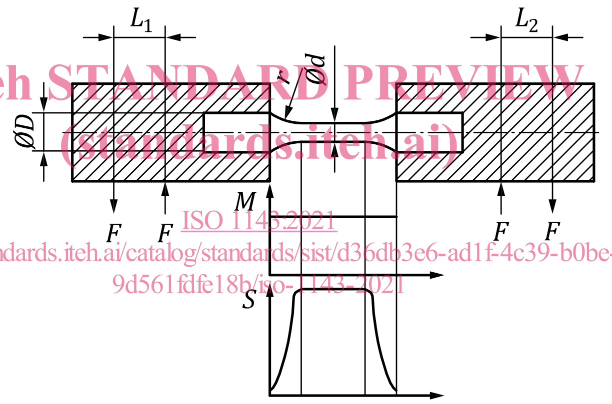
Figure 3 — Hourglass specimen — Single-point loading



Key

D diameter of gripped or loaded end of specimen
d diameter of specimen where stress is maximum
F applied force
L length of lever arm
M bending moment
S stress
r radius (see Table 1)

Figure 4 — Parallel specimen — Two-point loading

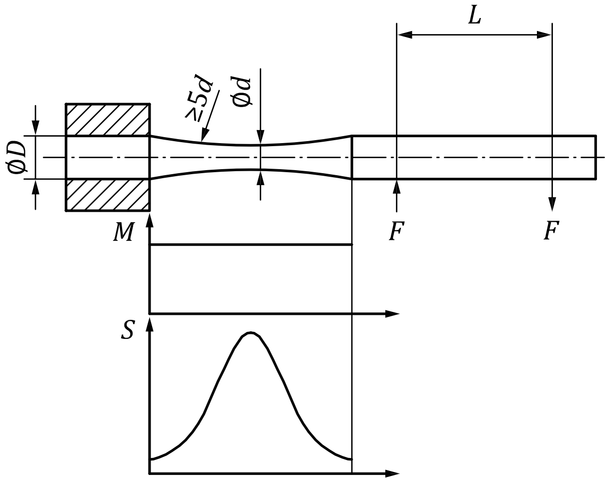


Key

D diameter of gripped or loaded end of specimen
d diameter of specimen where stress is maximum
F applied force
L_1, L_2 length of lever arm
M bending moment
S stress
r radius (see Table 1)

NOTE $L_1 = L_2 = L$

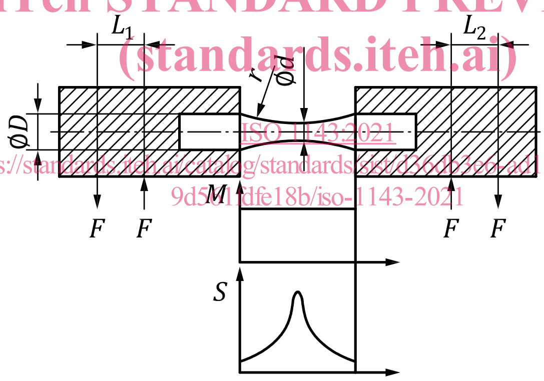
Figure 5 — Parallel specimen — Four-point loading



Key

D	diameter of gripped or loaded end of specimen
d	diameter of specimen where stress is maximum
F	applied force
r	radius (see Table 1)
L	length of lever arm
M	bending moment
S	stress

Figure 6 — Hourglass specimen — Two-point loading



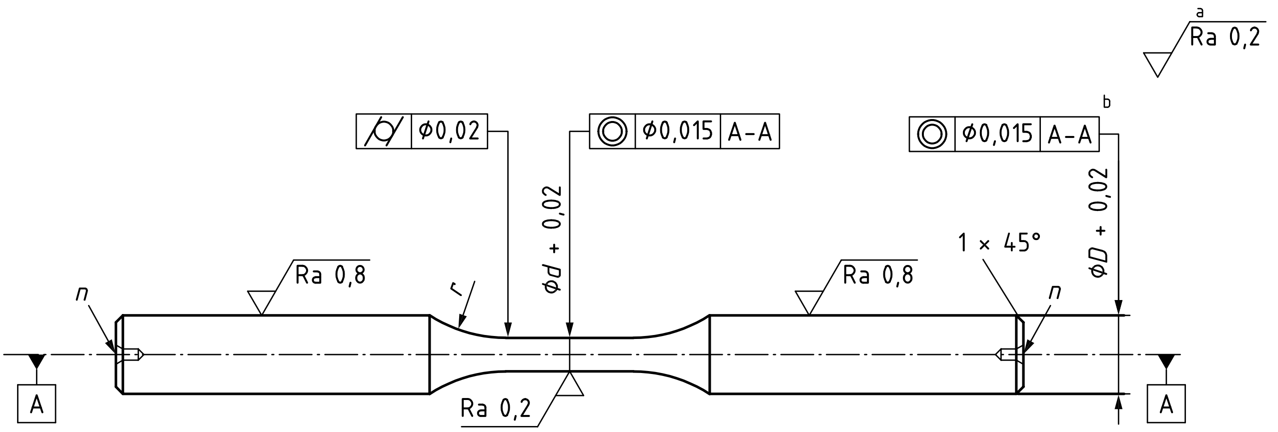
Key

D	diameter of gripped or loaded end of specimen
d	diameter of specimen where stress is maximum
F	applied force
L_1, L_2	length of lever arm
M	bending moment
r	radius (see Table 1)
S	stress

NOTE $L_1 = L_2 = L$.

Figure 7 — Hourglass specimen — Four-point loading

In each case, the test section shall be of circular cross-section. Typical parallel and hourglass specimen shapes and related dimensions are shown in Figures 8 and 9, respectively.



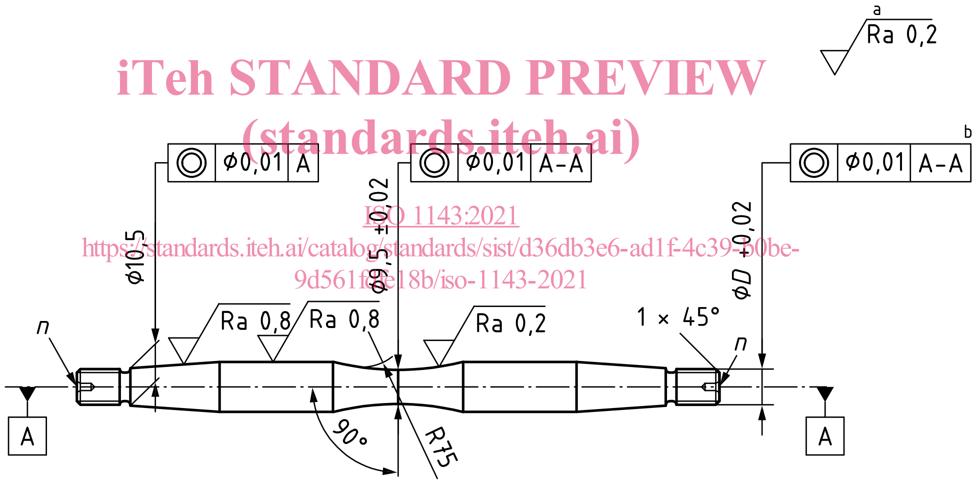
Key

n specimen code

a others

b two tops

Figure 8 — Cylindrical smooth specimen



Key

n specimen code

a others

b two tops

Figure 9 — Cylindrical hourglass specimen

The form of test section can be dependent on the type of loading to be employed. While cylindrical or hourglass-type specimens may be loaded as beams, or as cantilevers with either single-point or double-point loading, the tapered form of specimen is used only as a cantilever with single-point loading. Figures 1 to 7 show, in schematic form, the bending moment and nominal stress diagrams for the various practical cases.

The volumes of material subjected to greatest stresses are not the same for different forms of specimen, and they may not necessarily give identical results. The test in which the largest volume of material is highly stressed is recommended.

The use of single point loading machines should be done with great caution. One of the main drawbacks is that the bending moment is not constant along the specimen. The section where the stress is maximum and the corresponding stress depend not only on the specimen geometry but also on the length of level arm. For this type of machines, cylindrical hour glass specimen geometry is recommended because the higher stress is close to the one calculated for the minimum diameter section.

Experience has shown that a ratio of at least 2:1 between the cross-sectional areas of the gripping regions and the test portion of the specimen is recommended. The grips which do not lead up to large stress-concentration area are recommended.

In tests on certain materials, a combination of high stress and high speed may cause excessive hysteresis heating of the specimen. This effect may be reduced by subjecting a smaller volume of the material or by decreasing the test frequency (see 10.3). If the specimen is cooled, the test medium should be reported.

6.2 Dimensions of specimens

All the specimens employed in a test series for a fatigue-life determination shall have the same size, shape and tolerance of diameter.

For the purpose of calculating the force to be applied to obtain the required stress, the actual minimum diameter of each specimen shall be measured to an accuracy of 0,01 mm. Care shall be taken during the measurement of the specimen prior to testing to ensure that the surface is not damaged.

On cylindrical specimens subject to constant bending moment (see Figures 4 and 5), the parallel test section shall be parallel within 0,025 mm. For other forms of cylindrical specimen (see Figure 1), the parallel test section shall be parallel within 0,05 mm. For material property determination, the transition fillets at the ends of the test section should have a radius not less than $3d$. For hourglass-type specimens, the section formed by the continuous radius should have a radius not less than $5d$.

Figure 8 shows the shape and dimensions of a typical cylindrical specimen. The recommended values of d are 6 mm, 7,5 mm and 9,5 mm. The tolerance of diameter should be $0{,}005d$. Figure 9 shows a typical hourglass specimen suitable for fatigue testing at elevated temperature.

7 Preparation of specimens

7.1 General

In any rotating bar bending fatigue test program designed to characterize the intrinsic properties of a material, it is important to observe the following recommendations in the preparation of specimens. A possible reason for deviation from these recommendations is if the test program aims to determine the influence of a specific factor (surface treatment, oxidation, etc.) that is incompatible with the recommendations. In all cases, any deviation shall be noted in the test report.

7.2 Selection of the specimen and marking

The sampling of test materials from a semi-finished product or a component may have a major influence on the results obtained during the test. It is therefore necessary for this sampling to be recorded and a sampling drawing be prepared. This shall form part of the test report and shall indicate clearly

— the position of each of the specimens removed from the semi-finished product or component,

— the characteristic directions in which the semi-finished product has been worked (direction of rolling, extrusion, etc., as appropriate), and

— the unique identification of each of the specimens.

The unique mark or identification of each specimen shall be maintained at each stage of its preparation. This may be applied using any reliable method in an area not likely to disappear during machining or likely to adversely affect the quality of the test. Upon completion of the machining process, it is desirable for both ends of each specimen to be uniquely marked so that, after failure of a specimen, each half can still be identified.

