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Metallic materials — Fatigue testing — Axial force-controlled method

Matériaux métalliques — Essais de fatigue — Méthode par force axiale contrôlée

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Foreword

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 5, *Fatigue testing*.

This third edition cancels and replaces the second edition (ISO 1099:2006), which has been technically revised.

It shall be noted that this document does not address safety or health concerns, should such issues exist, that may be associated with its use or application. The user of this document has the sole responsibility 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.

Introduction

This document is intended to provide guidance for conducting axial, constant-amplitude, force-controlled, cyclic fatigue tests on specimens of a metal for the sake of generating fatigue-life data (i.e. stress vs. cycles to failure) for material characterization.

Nominally identical specimens are mounted in an axial force-type fatigue-testing machine and subjected to the required cyclic force conditions that introduce any one of the types of cyclic stress as illustrated in Figure 1. The test waveform should be of constant amplitude and sinusoidal unless otherwise specified.

The force being applied to the specimen is along the longitudinal axis passing through the centroid of each cross-section. The test is continued until the specimen fails or until a predetermined number of stress cycles have been exceeded (See Clauses 4 and 13). Tests are typically conducted at ambient temperature (ideally between 10 °C to 35 °C).

NOTE The results of a fatigue test can be affected by atmospheric conditions and where controlled conditions are required, ISO 554:1976, 2.1 applies.

Metallic materials — Fatigue testing — Axial force-controlled method

1 Scope

This document specifies the conditions for conducting axial, constant-amplitude, force-controlled, fatigue tests at ambient temperature on metallic specimens, without deliberately introduced stress concentrations. The object of testing while employing this document is to provide fatigue information, such as the relation between applied stress and number of cycles to failure for a given material condition, such as hardness and microstructure, at various stress ratios.

While the form, preparation and testing of specimens of circular and rectangular cross-section are described, component testing and other specialized forms of testing are not included in this document.

NOTE 1 Fatigue tests on notched specimens are not covered by this document since the shape and size of notched test pieces have not been standardized. However, fatigue-test procedures described in this document can be applied to fatigue tests of such notched specimens.

NOTE 2 Throughout this document, the engineering stress is employed. Engineering stress is defined as the quotient of the axially applied force to the cross-sectional area of the test specimen, S = Force/Area, at the test temperature.

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 4965-1, *Metallic materials — Dynamic force calibration for uniaxial fatigue testing — Part 1: Testing systems*

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

ISO 23788, *Metallic materials — Verification of the alignment of fatigue 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:

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

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

3.1
test specimen diameter
d
diametric distance or width of the specimen or test piece where the stress is at a maximum

3.2
grip diameter
D
diameter of the specimen at grip end

3.3
thickness of test section
t
thickness of reduced section of rectangular test specimen

3.4
width of test section
w
width of reduced section of rectangular test specimen

3.5
parallel length
L_p
length in the gauge test section of a specimen or test piece that has equal test diameter or test width and is parallel

3.6
specimen length
L_z
overall length of test specimen

3.7
fillet radius
r
radius between the parallel length and the grip end of test specimen

Note 1 to entry: The curve need not be a true arc of a circle over the whole of the distance between the end of the parallel length and the start of the grip end.

3.8
maximum stress
S_{max}
greatest algebraic value of stress in a stress cycle

Note 1 to entry: See Figure 2.

3.9
mean stress
S_m
one-half the algebraic sum of the maximum stress and the minimum stress in a stress cycle

Note 1 to entry: See Figure 2.

3.10
minimum stress
S_{min}
least algebraic value of stress in a stress cycle

Note 1 to entry: See Figure 2.

3.11
stress amplitude
S_a
one-half the algebraic difference between the maximum stress and the minimum stress

Note 1 to entry: See Figure 2.

3.12
stress range
ΔS
algebraic difference between the maximum and minimum stress

$$\Delta S = S_{max} - S_{min}$$

Note 1 to entry: See Figure 2.

3.13
stress ratio
R_S
ratio of minimum to maximum stress during any single cycle of fatigue operation

$$R_S = S_{min}/S_{max}$$

Note 1 to entry: See Figure 2.

3.14
stress cycle
variation of stress with time, repeated periodically and identically

Note 1 to entry: See Figure 2.

3.15
number of cycles
N
number of smallest segments of the force-time, stress-time, etc., function that is repeated periodically

3.16
fatigue life
N_f
number of applied cycles to achieve a defined failure criterion

3.17
fatigue strength at *N* cycles
S_N
value of the stress amplitude at a stated stress ratio under which the specimen would have a life of N cycles

4 Test plan

4.1 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 5.1);

b) the R-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 life;

— 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 un-failed specimen shall be terminated;

f) the testing temperature if different from the requirements given in 5.2.

In the light of recent research, it is of importance to note that metals generally do not exhibit a "fatigue limit" *per se*, that is, a stress below which the metal will endure an "infinite number of cycles". Typically, the "plateau(s)" in stress-life are referred to as the conventional "fatigue limit(s)", but failures below these levels have been reported and do occur. See, for example, References [6] to[9].

4.2 Presentation of fatigue results

4.2.1 General

The design of the investigation and the use to be made of the results, govern the choice of the most suitable method of presenting the results from the many available, graphically and otherwise. The results of fatigue tests are usually presented graphically. In reporting fatigue data, the test conditions should be clearly defined. In addition to graphical presentations, tabulated numerical data are desirable where the presentation format permits.

4.2.2 Wöhler or *S-N* curve

The most general method of presenting the results graphically is to plot the number of cycles to failure, N, as abscissa and the values of stress amplitude or, depending on the type of stress cycle, those of any other stress, as ordinate. The curve drawn smoothly as an approximate middle line through the experimental points is called a Wöhler or *S-N* curve. A logarithmic scale is used for the number of cycles and the choice of whether a linear or logarithmic scale is used for the stress axis lies with the experimenter. Individual curves are plotted for each set of tests for each R-ratio. Experimental results are usually plotted on the same figure. An example of these graphical representations is shown in Figure 3, where a linear stress scale is used.

4.2.3 Mean stress diagrams

The fatigue strengths derived from the Wöhler or *S-N* curve are plotted in fatigue strength diagrams as constant life lines. The results can be represented by a graph giving directly, for particular fatigue lives, the stress amplitude against the mean stress, as shown in Figure 4; or by plotting the maximum and minimum stresses against the mean stress, as shown in Figure 5; or by plotting the maximum stress against the minimum stress, as shown in Figure 6. Experimental results may be plotted on the same figure.

5 Shape and size of specimen

5.1 Form of specimens

Generally, a specimen having a fully machined test section is of the type shown in Figure 7 for a smooth cylindrical-type gauge section.

The specimens may be of the following:

— circular cross-section with tangentially blending fillets between the test section and the ends, or with a continuous radius between the ends (i.e. "hourglass" specimen);

— rectangular cross-section of uniform thickness over the test section with tangentially blending fillets between the test section and the gripped ends (see Figure 8).

Specimens commonly known as "hourglass" specimens may be employed for testing with caution. In such specimens, there is a continuous radius between grip ends with a minimum diameter or width of the test section centrally located between these ends for cylindrical and flat specimens respectively. Unlike a smooth, constant diameter or width, gauge section where a volume of material is equally under stress, the hourglass specimen permits sampling only of a thin planar element of material at the minimum cross section. Thus, the fatigue results produced may not represent the response of the bulk material where, particularly in the long-life fatigue regime, inclusions govern behaviour in high hardness metals and there is a duality in crack initiation from surface to subsurface[9]. In fact, such results may be non-conservative particularly in the longer life regime where the largest micro discontinuity may not lie in the planar section of greatest stress.

It is important to note that for specimens of rectangular cross-section, it may be necessary to reduce the test section in both width and thickness. If this is necessary, then blending fillets will be required in both the width and thickness directions. Also, for a rectangular-section specimen, where it is desired to take account of the surface condition in which the metal will be used in actual application, then at least one surface of the test section of the test piece should remain unmachined. It is often the case, for fatigue tests conducted using a rectangular-section piece, that the results are not always comparable to those determined on cylindrical specimens because of the difficulty in obtaining an adequate surface finish or because fatigue cracks initiate preferentially at the corner(s) of the rectangular test piece.

5.2 Specimen temperature measurement

Tests are typically conducted at ambient temperature (ideally between 10 °C to 35 °C). For tests conducted at non-ambient temperatures, the specimen temperature shall be fully documented and measured using thermocouples or other appropriate devices in contact with the specimen surface, be accurate to within ±2 °C.

6 Geometry

6.1 Bars and flat sheets >5 mm thick

The gauge portion of the specimen in a fatigue test represents a volume element of the material under study. This implies the geometry of the specimen shall not affect the use of the test results.

This geometry shall fulfil the following conditions:

— provide a uniform cylindrical gauge portion;

— minimize the risk of buckling in compression to avoid failure initiation at the transition radius;

— provide a uniform stress (strain) distribution over the whole gauge portion.

There shall be no undercutting due to machining of the parallel length at the transition radii or elsewhere on the gauge section. This feature may be checked with an optical comparator at reasonable magnification (i.e. ~10 to 25X) to assure this is true.

Taking into account these requirements, the experience gained by a large number of laboratories and the results of calculations taken from different types of specimens (see References [10] to [19]), the following geometric dimensions (see Figure 7) are recommended:

a) diameter of cylindrical gauge length: $5\text{ mm} \leq d \leq 10\text{ mm}$

b) parallel length: $L_p \geq 2d$

c) transition radius (from parallel length to grip end): $r \geq 2d$

d) diameter of grip end: $D \geq 2d$

e) length of reduced section: $L_r \leq 8d$

Other geometric cross-sections and gauge lengths may be used for specimens provided that uniform distribution of stress in the gauge length is ensured.

Recommended end connections are as follows:

— smooth cylindrical connection (with hydraulic jaws);

— button-end connection.

The test fixture should locate the specimen, provide axial alignment and exclude backlash. Design of the test fixture will depend on the specimen end details. A number of examples are given in Figure 9.

Designs of fatigue specimens in which alignment may depend on screw threads are not recommended.

6.2 Flat sheets

6.2.1 General

In general, the considerations discussed in the preceding paragraphs also apply to tests on the above products. However, these tests require specific geometries and fixtures in order to avoid problems of buckling.

Because low forces are generally applied, more sensitive force transducers than usual may be required. The gripping system may necessitate the use of flat mechanical or hydraulic jaws. However, with the latter type of assembly it is difficult to ensure correct alignment.

In general, the width of the specimen is reduced in the gauge length to avoid failures at the specimen/grip interface or within the grips. In some applications, it might be necessary to add end tabs to increase the grip end thickness as well as to avoid failure in the grips (see Figure 10).

In the case of flat specimens located in grips with parallel-sided jaws, care should be taken to make sure they are centrally aligned within the jaws. Index marks or stops may facilitate this.

6.2.2 Thicknesses between 5 mm and 2,5 mm

It is possible to conduct these tests without anti-buckling restraints.

A possible geometry for a flat specimen is shown in Figure 8.

6.2.3 Thicknesses <2,5 mm

The use of anti-buckling restraints may be necessary and may limit the maximum test temperature.

A number of precautions are required to limit the increase in force induced by friction between the restraint and specimen. This friction shall not at any time create a force increase greater than 2 %. The use of a polytetrafluoroethylene (PTFE) film approximately 1 mm thick, for example, offers a partial solution to this problem, as does boron nitride powder as a dry lubricant. Hydrocarbon-based lubricants are not recommended as they may affect the test results.

The frictional forces may vary from one specimen to another. They shall be measured before each test from the force-displacement curves recorded in the elasticity range of the material in tension with and without anti-buckling restraints. An example of an anti-buckling restraint is shown in Figure 11.

6.3 Preparation of specimens

In any 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 deviation from these recommendations is possible if the test program aims to determine the influence of a specific factor (surface treatment, oxidation, etc.) that is incompatible with these recommendations. In all cases, these deviations shall be noted in the test report.

6.3.1 Machining procedure

The machining procedure selected may produce residual stresses on the specimen surface likely to affect the test results. These stresses may be induced by heat gradients at the machining stage or they may be associated with deformation of the material or microstructural alterations. Their influence is less marked in tests at elevated temperatures because they are partially or totally relaxed once the temperature is maintained. However, using an appropriate final machining procedure, especially prior to a final polishing stage, should reduce such residual stresses. For harder materials, surface grinding rather than tool operation (turning or milling) may be preferred.

— Grinding: from 0,1 mm of the final diameter at a rate of no more than 0,005 mm/pass.

— Polishing: remove the final 0,025 mm with papers of decreasing grit size. It is recommended that the final direction of polishing be along the specimen axis.

NOTE 1 Alteration in the microstructure of the material.

This phenomenon can be caused by the increase in temperature and by the strain-hardening induced by machining. It can be a matter of a change in metallurgical phase or, more frequently, of surface recrystallization.

The immediate effect of this is to render the test invalid as the material tested is no longer the initial material. Every precaution should therefore be taken to avoid this risk.

NOTE 2 Introduction of contaminants.

The mechanical properties of certain materials deteriorate in the presence of certain elements or compounds. Examples of this are the effect of chlorine and hydrogen on steels and titanium alloys. These elements should therefore be avoided in the products used (cutting fluids, cleaning fluids such as alcohols, acidic compounds, etc.). Rinsing and degreasing of the specimens in appropriate fluids prior to storage is recommended.

6.3.2 Sampling 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 carried out with full knowledge of the situation. A sampling drawing, attached to the test report, should indicate clearly

— the position of each of the specimens,

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

— the marking/identifying of each of the specimens.

The specimens shall carry a mark/identification during each different stage of their preparation. Such a mark/identification 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 (e.g. both ends of the test piece).

6.3.3 Surface condition of the specimen

The surface conditions of the specimens have an effect on the test results. This effect is generally associated with one or more of the following factors:

— the specimen surface roughness;

— the presence of residual stresses;

— alteration in the microstructure of the material;

— introduction of contaminants.

The recommendations below allow the influence of these factors to be reduced to a minimum.

The surface condition is commonly quantified by the mean roughness or equivalent (e.g. ten-point roughness or maximum height of irregularities). The influence of this variable on the results obtained depends largely on the test conditions, and its influence is reduced by surface corrosion of the specimen or plastic deformation. It is preferable, whatever the test conditions, to specify a mean surface roughness of less than 0,2 µm R_a (or equivalent). See ISO 4287 and ISO 4288.

Another important parameter not covered by mean roughness is the presence of localized machining scratches. Finishing operations on cylindrical specimens should eliminate all circumferential scratches produced during turning. Final grinding followed by longitudinal mechanical polishing is particularly recommended. A low magnification check (~ ×20) shall not show any circumferential scratches within the gauge length.

If heat treatment is to be carried out after rough finishing of the specimen, it is preferable to carry out the final polishing after the heat treatment. If this is not possible, the heat treatment should be carried out in a vacuum or in inert gas to prevent oxidation of the specimen. This treatment shall not alter the microstructural characteristics of the material under study. The specific conditions of heat treatment and machining procedure shall be reported with the test results.

6.3.4 Dimensional checks

The dimensions should be measured on completion of the final machining stage using a method of metrology that does not alter the surface condition.

6.3.5 Storage and handling

After preparation, the specimens should be stored so as to prevent any risk of damage (scratching by contact, oxidation, etc.). The use of individual boxes or tubes with end caps is recommended. In certain cases, storage in a vacuum or in a desiccator filled with silica gel is necessary.

Handling should be reduced to the minimum necessary. Particular attention shall be given to marking the specimens. Identification shall be applied to each end of the specimen before testing.

7 Apparatus

7.1 Test machine

The tests shall be conducted using a tension-compression machine designed for a smooth start-up with no backlash when passing through zero. The machine shall have lateral rigidity and accurate alignment (see ISO 23788, Annex C).

The complete machine-loading system (including force transducer, grips, specimen, etc.) shall have lateral rigidity and be capable of controlling and measuring force when applying the recommended wave cycle.

The testing machine force-measuring system shall be verified statically in accordance with ISO 7500-1, Class 1. It shall be ensured that incremental dynamic force-measurement errors do not exceed ±1 % of the demanded force range. It is recommended that ISO 4965-1 is used as a method to make the check.

NOTE 1 It is very important to recognize the importance of dynamic (inertia force) errors introduced by the mass between the force transducer and the test specimen. Inertia force error = the grip mass multiplied by its local acceleration. Inertial force errors, expressed as a percentage of force range, can be expected to vary with the square of the frequency and are influenced strongly by specimen compliance. The testing machine (rigid body) resonance on its mountings can be a dominant error source.

The test machine with the specific force transducer, grips and couplings used for dynamic testing and a strain-gauged specimen or dynamometer, of similar compliance to the test specimens, should be verified for dynamic force measurement over the frequency range of interest.

NOTE 2 To avoid dynamic errors > ±1 % of the force range, it may be necessary to create an error table to correct the dynamic force range of the testing machine.

The machine shall be equipped with a cycle-counting system accurate to 1 % and with error trips to shut down the machine when the specimen fails.

When reversed force is involved in the test series, the load-train shall be free from backlash.

7.2 Alignment check

Bending in a test machine due to misalignment in rigid-grip systems is generally caused by angular or lateral offsets of the grips or a combination of both. Bending due to misalignment in rigid-grip systems is generally caused by:

a) an angular offset of the specimen grips,

b) a lateral offset of the loading bars (or test piece grips) in an ideally rigid system,

c) an offset in the force-train assembly with respect to a non-rigid system, or

d) in the case of servo-hydraulic machines, an actuator rod with side-play in the bearings.

The test machine alignment shall be checked before each series of tests and any time a change is made to the load train in accordance with ISO 23788 *Metallic materials — Verification of the alignment of fatigue testing machines*.

7.3 Force transducer

The force transducer shall have axial and lateral rigidity. Its capacity shall be suitable for the forces applied during the test. It shall be fatigue rated and suitable for the forces applied during the test. The indicated force as recorded at the output from the computer in an automated system, or from the final output recording device in any non-automated system, shall be within the specified permissible variation from the actual force. The force transducer capacity shall be sufficient to cover the range of forces measured during a test to an accuracy of better than 1 % of the reading. The force transducer shall be temperature compensated and not have zero drift or sensitivity variation greater than 0,002 % of full scale per 1 °C.

7.4 Gripping of specimen

The gripping device shall transmit the cyclic forces to the specimen without backlash along its longitudinal axis. The distance between the grips shall be as small as possible to avoid the tendency of the specimen to buckle. The geometric qualities of the device shall ensure correct alignment in order to meet the requirements specified in 7.2. It is therefore necessary to limit the number of components of which these gripping devices are composed, and to reduce the number of mechanical interfaces to a minimum.

The gripping device shall ensure that the assembly of the specimen is reproducible. It shall have surfaces ensuring the alignment of the specimen and surfaces, allowing transmission of tensile and compressive forces without backlash throughout the duration of the test.

8 Instrumentation for test monitoring

8.1 Recording systems

It is common for modern fatigue test equipment to be computer controlled and equipped with digital data acquisition systems. Basic software platforms provided in modern digital systems provide accurate test control as well as report generation. They are typically equipped to provide real-time numerical displays in either the digital or analog domain of test data as well as generation and storage of graphical and tabular test results.

In such a typical digital system, the sampling frequency of stress (force)-time data points shall be sufficient to ensure correct definition of the peak stresses (forces) imposed upon the specimen.

Since there are a number of analog systems still in use, the following shall be considered a minimum requirement for the analog recording of data:

— a recorder for stress (force) – time;

— a peak-to-peak detector.

8.2 Cycle counter

A cycle counter is essential for recording the number of cycles.

9 Checking and verification

The testing machine and its control and measurement systems should be checked regularly.

Specifically, each transducer and associated electronics shall always be checked as a unit.

The temperature measuring system(s) shall be verified according to the relevant ISO or national standard.

10 Mounting of specimen

Care should be taken to ensure that each test piece is located in the upper and lower grips so that the force is applied axially, and that the intended stress pattern is properly imposed. With rectangular test pieces, it may be important to ensure that the force is evenly distributed over the test piece cross-section. Although not recommended, where test pieces of circular cross-section are screw-type at the ends, the grip design shall ensure that no (or minimal) torsional stress is imparted to the test piece due to tightening of the locking nuts. In instances where threaded-end specimens are used, some forced mating of flats and of a concentric surface may be employed along the threads to minimize possible tightening torques.

11 Rate of testing

The frequency of the force cycle will depend upon the type of testing machine employed and, in many cases, upon the stiffness of the test piece.

The frequency chosen shall be that most suitable for the particular combination of material, test piece and testing machine. If the frequencies are determined from the dynamic characteristics of the test piece and testing machine combination, it may be necessary to measure the stiffness of the test piece before testing is started.

NOTE 1 The frequency range of axial force controlled fatigue-testing machines in common use is approximately 1 Hz to 300 Hz.

At high frequencies, substantial heating of the specimen can occur that could affect the test result of fatigue life and strength. If heating occurs, it is advisable to decrease the test frequency. If the specimen temperature exceeds 35 °C, the temperature shall be recorded.

NOTE 2 If the influence of the environment is significant, the test result is likely to be frequency dependent.

12 Application of force

The general procedure for attaining full-force running conditions shall be the same for each test piece. The mean force and force range shall be maintained to within ±1 % of the force range, over and above the static errors specified in ISO 7500–1. See Clause 8.

13 Recording of temperature and humidity

The maximum and minimum air temperature and humidity shall be recorded daily for the duration of the test.

14 Criterion of failure and test termination

14.1 Criterion of failure

Unless agreed otherwise, the criterion of failure shall be test piece separation.

NOTE In particular applications, other criteria, for example, occurrence of a visible fatigue crack, plastic deformation of the test piece, rate of crack propagation or frequency change can be adopted.

14.2 Test termination

The test is terminated when either the specimen fails or a predetermined number of cycles have been applied, as agreed upon by the concerned parties.

15 Test report

The test report shall include the following information for the test series, if available:

a) a reference to this document, i.e. ISO 1099;

b) material tested, its metallurgical characteristics, mechanical properties and any heat treatment given to the test piece(s);

c) location of the test piece(s) in the parent material;

d) form and nominal dimensions of the test piece(s);

e) surface condition of the test piece(s).

The test report shall include the following information for each individual test piece:

— cross-sectional dimensions;

— minimum and maximum peak force applied;

— applied stress conditions;

— frequency and fatigue life;

— description of testing machine used: type, serial number, load cell and serial number, number and load train description;

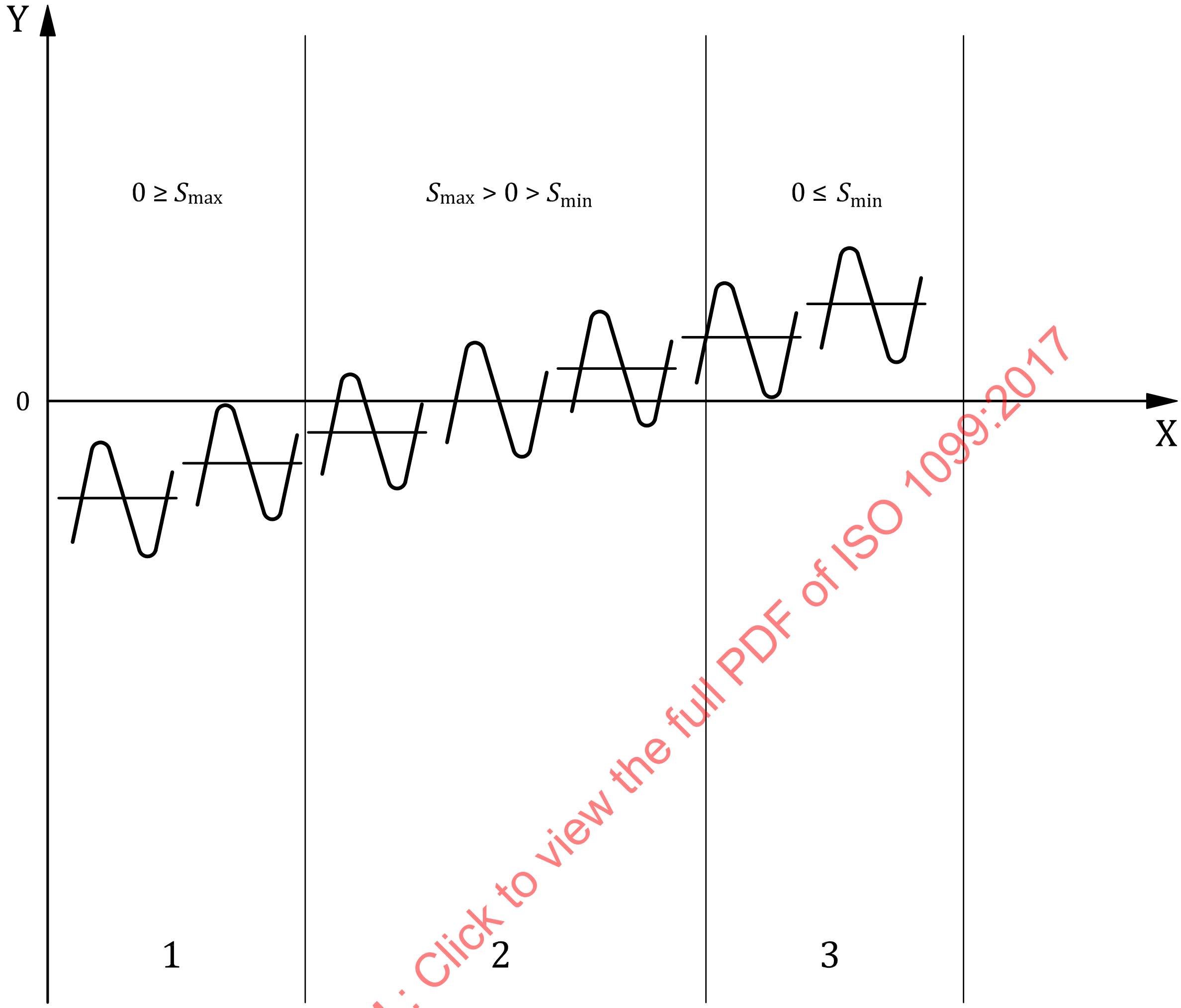
— temperature of the test piece if heating occurs (i.e. >35 °C);

— maximum and minimum air temperature and relative humidity;

— criterion of the end of the test, i.e. its duration (for example, 10^7 cycles), or complete failure of the test piece, or any other criterion;

— any special observations or deviations from the required test conditions.

Additionally, the test results can be presented graphically.



Key

X time

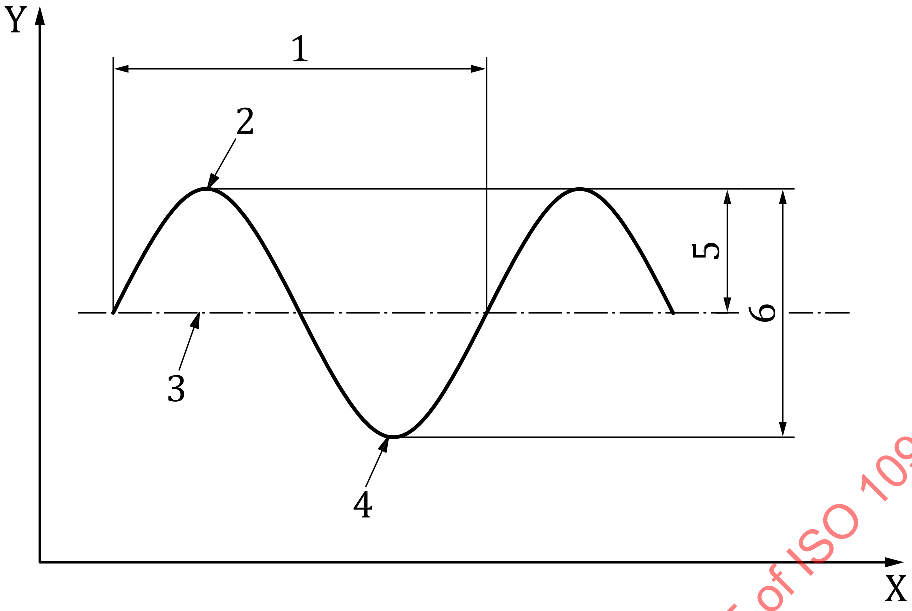
Y stress

1 fluctuating compression

2 reversed

3 fluctuating tension

Figure 1 — Types of cyclic stress



Key

X time

Y stress

1 one stress cycle

2 maximum stress, S_{max}

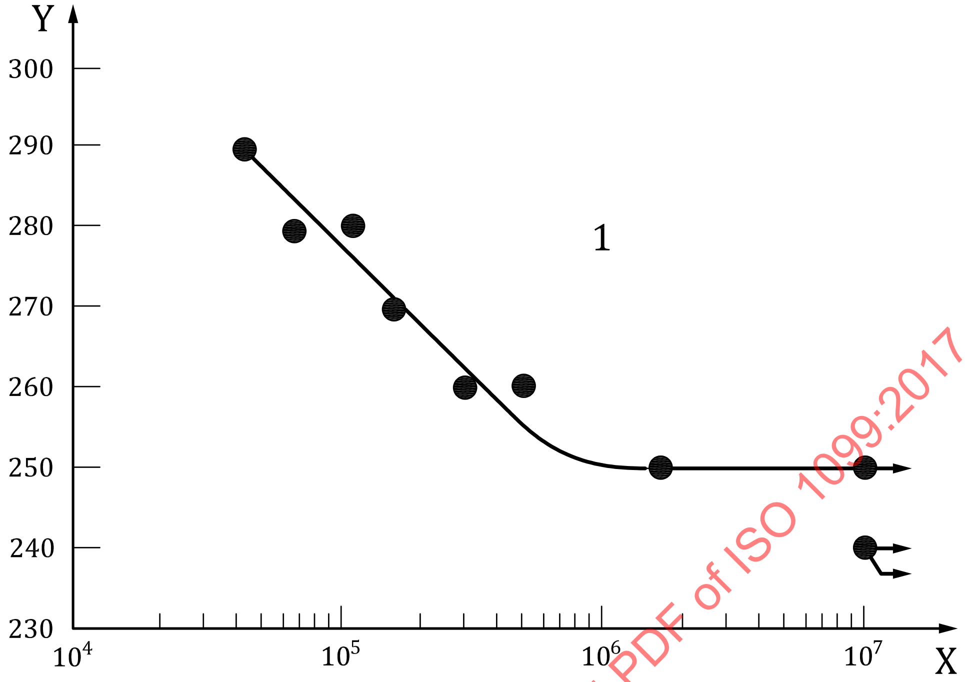
3 mean stress, S_m

4 minimum stress, S_{min}

5 stress amplitude, S_a

6 stress range, ΔS_a

Figure 2 — Fatigue stress cycle



Key

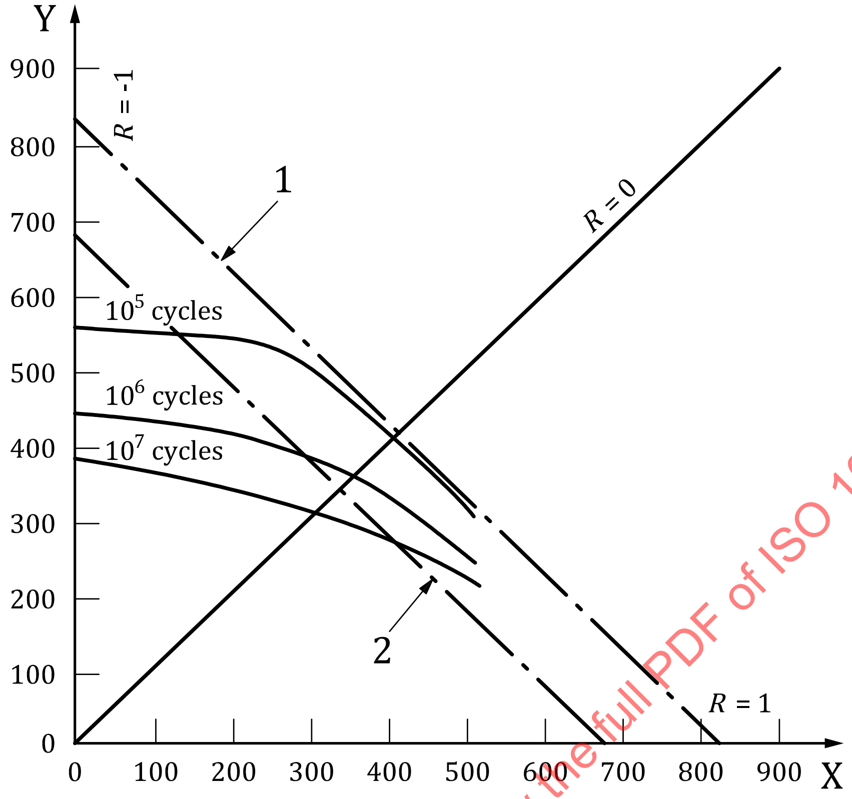
X number of cycles to failure, N

Y stress amplitude, S_a, N/mm²

1 $R_S = -1$

ambient temperature

Figure 3 — Wöhler or *S*-*N* curve



Key

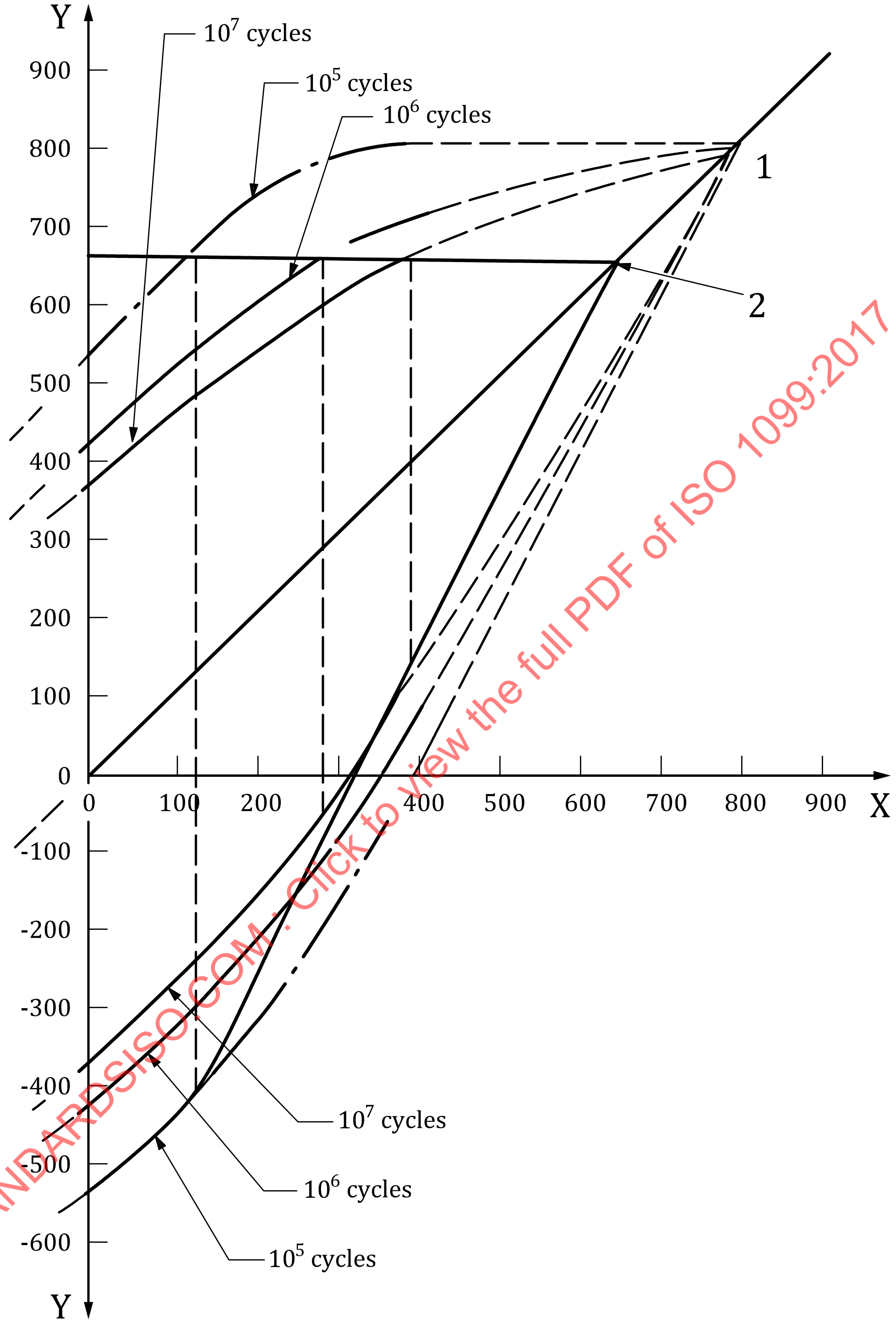
X mean stress, S_m, N/mm²

Y stress amplitude, S_a, N/mm²

1 tensile strength

2 0,2 % proof stress

Figure 4 — Stress amplitude (S_a) against mean stress (S_m), [Haigh diagram]



Key

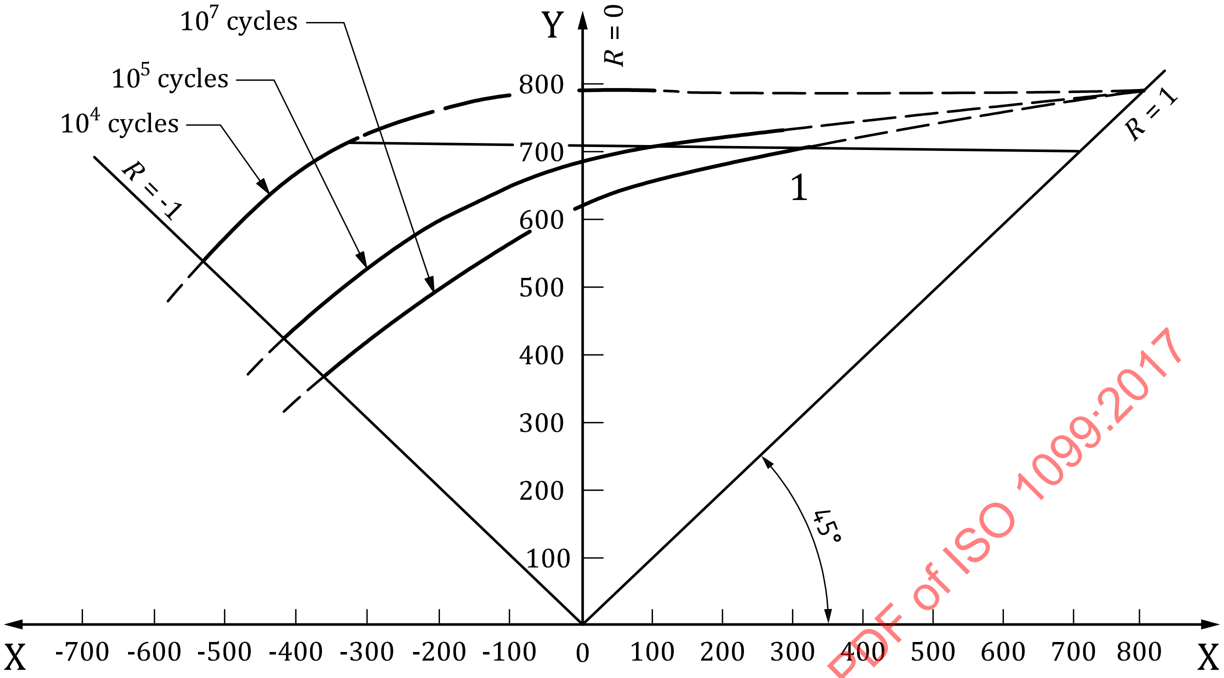
X mean stress, S_m, N/mm²

Y maximum and minimum stress, S_{max} and S_{min}, N/mm²

1 tensile strength

2 0,2 % proof stress

Figure 5 — Maximum and minimum stresses (S_{max} and S_{min}) against mean stress (S_m) [Smith diagram]



Key

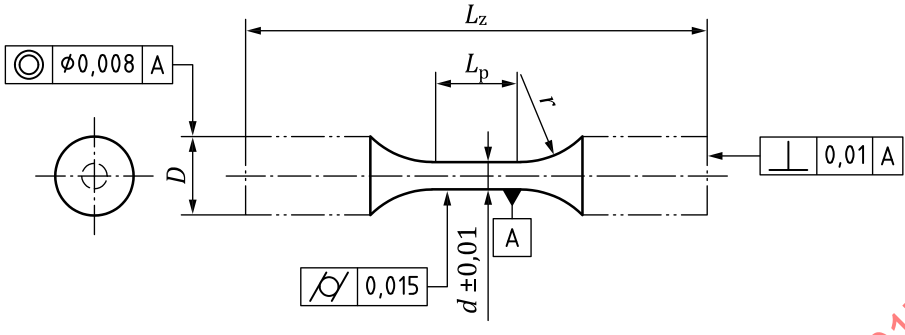
X minimum stress, S_{min}, N/mm2

Y maximum stress, S_{max}, N/mm2

1 0,2 % proof stress

Figure 6 — Maximum stress (S_{max}) against minimum stress (S_{min}) [Ros diagram]

Dimensions in millimetres

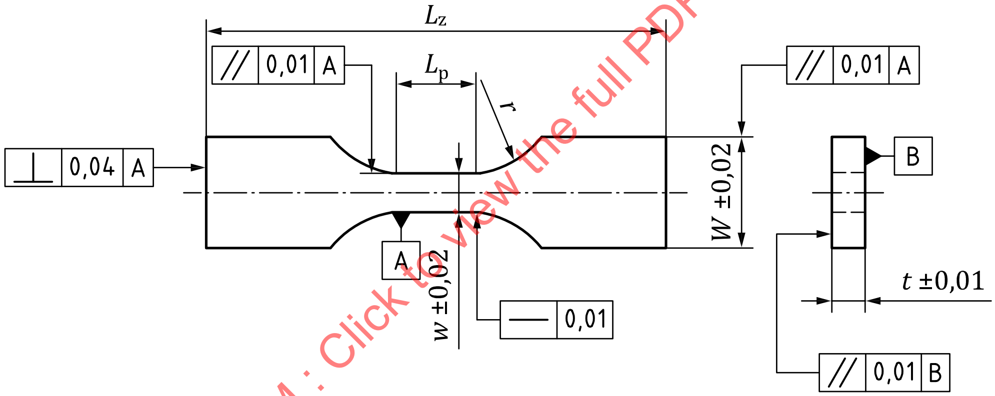


NOTE 1 For definitions of symbols for geometrical tolerances, see ISO 5459.

NOTE 2 The perpendicularity requirement applies to any gripping parts used for alignment.

Figure 7 — Recommended geometry of cylindrical specimen

Dimensions in millimetres



NOTE 1 For definitions of symbols for geometrical tolerances, see ISO 5459.

NOTE 2 The perpendicularity requirement applies to any gripping parts used for alignment.

Figure 8 — Possible geometry of flat-sheet specimen

