



BSI Standards Publication

Corrosion of metals and alloys — Corrosion fatigue testing

Part 2: Crack propagation testing using precracked specimens

National foreword

This British Standard is the UK implementation of EN ISO 11782-2:2008+A1:2024. It is identical to ISO 11782-2:1998, incorporating amendment 1:2024. It supersedes BS EN ISO 11782-2:2008, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO text carry the number of the ISO amendment. For example, text altered by ISO amendment 1 is indicated by A1 A1.

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2: Crack propagation testing using precracked specimens (ISO
11782-2:1998)

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Korrosion von Metallen und Legierungen - Prüfung der
Schwingungskorrosion - Teil 2: Rissausbreitungsprüfung an
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European foreword

The text of ISO 11782-2:1998 has been prepared by Technical Committee ISO/TC 156 "Corrosion of metals and alloys" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 11782-2:2008 by Technical Committee CEN/TC 262 "Metallic and other inorganic coatings" the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2008, and conflicting national standards shall be withdrawn at the latest by October 2008.

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Endorsement notice

The text of ISO 11782-2:1998 has been approved by CEN as a EN ISO 11782-2:2008 without any modification.

European foreword to amendment 1

This document (EN ISO 11782-2:2008/A1:2024) has been prepared by Technical Committee ISO/TC 156 "Corrosion of metals and alloys" in collaboration with Technical Committee CEN/TC 262 "Metallic and other inorganic coatings, including for corrosion protection and corrosion testing of metals and alloys" the secretariat of which is held by BSI.

This Amendment to the European Standard EN ISO 11782-2:2008 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2024, and conflicting national standards shall be withdrawn at the latest by November 2024.

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11782-2 was prepared by Technical Committee ISO/TC 158, *Corrosion of metals and alloys*.

ISO 11782 consists of the following parts, under the general title *Corrosion of metals and alloys — Corrosion fatigue testing*:

- *Part 1: Cycles to failure testing*
- *Part 2: Crack-propagation testing using precracked specimens*

Annex A of this part of ISO 11782 is for information only.

Introduction

Crack propagation testing employs precracked specimens to provide information on the threshold conditions and on rates of corrosion fatigue crack growth. These data can be used in the design and evaluation of engineering structures where corrosion fatigue crack growth can dominate component life.

Because of the need to maintain elastically constrained conditions at the crack tip, the precracked specimens used for crack propagation tests are not suitable for the evaluation of thin products such as sheet or wire and are generally used for thicker products including plate, bar and forgings. They can also be used for parts joined by welding.

The results of corrosion fatigue testing are suitable for direct application only when the service conditions exactly parallel the test conditions especially with regard to material, environmental and stressing considerations.

Corrosion of metals and alloys — Corrosion fatigue testing —

Part 2:

Crack propagation testing using precracked specimens

1 Scope

1.1 This part of ISO 11782 describes the fracture mechanics method of determining the crack growth rates of pre-existing cracks under cyclic loading in a controlled environment and the measurement of the threshold stress intensity factor range for crack growth below which the rate of crack advance falls below some defined limit agreed between parties.

1.2 This part of ISO 11782 provides guidance and instruction on corrosion fatigue testing of metals and alloys in aqueous or gaseous environments.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 11782. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11782 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7539-1:1987, *Corrosion of metals and alloys — Stress corrosion testing — Part 1: General guidance on testing procedures*.

3 Definitions

For the purposes of this part of ISO 11782, the following definitions apply.

3.1 corrosion fatigue: Process involving conjoint corrosion and alternating straining of the metal, often leading to cracking.

NOTE — Corrosion fatigue may occur when a metal is subjected to cyclic straining in a corrosive environment.

3.2 force, P : Force applied to the specimen considered positive when its direction is such as to cause the crack faces to move apart.

3.3 maximum force, $P_{\max}$: Algebraic maximum value of force during a loading cycle.

3.4 minimum force, $P_{\min}$: Algebraic minimum value of force during a loading cycle.

3.5 force range, ΔP : Difference between the algebraic maximum and minimum values of the force.

3.6 stress intensity factor, K_I : Function of applied load, crack length and specimen geometry having dimensions of stress (length)^{1/2} which uniquely defines the elastic stress field intensification at the tip of a crack subjected to opening mode displacements (mode I).

NOTE — It has been found that stress intensity factors, calculated assuming that specimens respond purely elastically, correlate the behaviour of real cracked bodies provided that the size of the zone of plasticity at the crack tip is small compared to the crack length and the length of the uncracked ligament. In this standard, mode I is assumed and the subscript I is implied everywhere.

3.7 maximum stress intensity factor, $K_{\max}$, in fatigue: Highest algebraic value of the stress intensity factor in a cycle corresponding to the maximum load.

3.8 minimum stress intensity factor, $K_{\min}$, in fatigue: Lowest algebraic value of the stress intensity factor in a cycle.

NOTE — This value corresponds to the minimum load when the stress ratio, R , is greater than zero and is set equal to zero when R is less than or equal to zero.

3.9 range of stress intensity factor, ΔK , in fatigue: Algebraic difference between the maximum and minimum stress intensity factors in a cycle:

$$\Delta K = K_{\max} - K_{\min}$$

3.10 threshold stress intensity factor range, ΔK_{th} , in fatigue: Value of the stress intensity factor range below which the rate of crack advance becomes insignificant for the application.

3.11 stress ratio, R , in fatigue loading: Algebraic ratio of the minimum and maximum force in a cycle

$$R = \frac{P_{\min}}{P_{\max}} = \frac{K_{\min}}{K_{\max}}$$

3.12 cycle: Smallest segment of the load- or stress-time function which is repeated periodically. The terms fatigue cycle, load cycle and stress cycle are also commonly used.

3.13 fatigue crack growth rate, da/dN : Rate of crack extension caused by fatigue loading and expressed in terms of crack extension per cycle.

3.14 stress intensity factor coefficient, Y : Factor derived from the stress analysis for a particular specimen geometry which relates the stress intensity factor for a given crack length to the load and specimen dimensions.

3.15 plane strain fracture toughness, K_{Ic} : The critical value of K at which the first significant environmentally independent extension of the crack occurs under the influence of rising stress intensity under conditions of high constraint to plastic deformation.

3.16 specimen orientation: The fracture plane of the specimen identified in terms of firstly the direction of stressing and secondly the direction of crack growth expressed with respect to three reference axes. These are identified by the letters X, Y and Z.

where

Z is coincident with the main working force employed during manufacture of the material (short-transverse axis);

X is coincident with the direction of grain flow (longitudinal axis);

Y is normal to the X and Z axes (see figure 1).

3.17 crack length, a : Effective crack length measured from the crack tip to either the mouth of the notch or the loading point axis depending on the specimen geometry.

3.18 specimen width, W : Effective width of the specimen measured from the back face to either the face containing the notch or the loading plane depending on the specimen geometry.

3.19 waveform: Shape of the peak-to-peak variation of load as a function of time.

3.20 cyclic frequency: Number of cycles per unit time, usually expressed in terms of cycles per second (Hz).

4 Test

4.1 Principle of corrosion fatigue crack propagation testing

A fatigue pre-crack is induced in a notched specimen by cyclic loading. As the crack grows the loading conditions are adjusted until the values of ΔK and R are appropriate for the subsequent determination of ΔK_{th} or crack growth rates and the crack is of sufficient length for the influence of the notch to be negligible.

Corrosion fatigue crack propagation tests are then conducted using cyclic loading under environmental and stressing conditions relevant to the particular application. During the test, crack length is monitored as a function of elapsed cycles. These data are subjected to numerical analysis so that the rate of crack growth, da/dN , can be expressed as a function of the stress intensity factor range, ΔK .

Crack growth rates presented in terms of ΔK are generally independent of the geometry of the specimen used. The principle of similitude allows the comparison of data obtained from a variety of specimen types and allows da/dN versus ΔK data to be used in the design and evaluation of engineering structures provided that appropriate mechanical, chemical and electrochemical test conditions are employed. An important deviation from the principle of similitude can occur in relation to short cracks because of crack-tip chemistry differences, microstructurally sensitive growth and crack tip shielding considerations.

The threshold stress intensity factor range for corrosion fatigue, ΔK_{th} may be higher or lower than the threshold in air depending on the particular metal/environment conditions. It may be determined by a controlled reduction in load range (see 6.3) until the rate of growth becomes insignificant for the specific application. Practically, from a measurement perspective it is necessary to assign a value to this (see 8.5).

NOTE — Both crack growth rate measurements and threshold stress intensity factor range determinations can be markedly affected by residual stresses. Thermal stress relief should, therefore, be considered prior to testing, but if this is not acceptable, the possibility of an effect should be recognized in the interpretation of the results. In particular, the presence of residual stresses can lead to an apparent dependence of ΔK_{th} on specimen thickness. Thickness effects can also arise in principle in relation to hydrogen charging and also where through-thickness transport of fluid occurs in flowing aqueous solutions. In the latter case it should be recognized that solution transport via the crack sides in the through-thickness direction is an artifact of the fracture mechanics specimen and may not be representative of cracking in service.

Results of corrosion fatigue crack growth rate tests for many metals have shown that the relationship between da/dN and ΔK can differ significantly from the three-stage relationship usually observed for tests in air, as shown in figure 2. The shape of the curve depends on the material/environment system and for some cases time-dependent (as distinct from cycle-dependent) cracking modes can ensue which can enhance crack growth producing frequency-dependent growth rate plateaux as shown in figure 2.

4.2 Specimens for corrosion fatigue crack propagation testing

4.2.1 General

A wide range of standard specimen geometries of the type used in fracture toughness testing may be used. The particular type of specimen selected will be dependent upon the form of the material to be tested and the conditions of test.

Pin-loaded specimens such as compact tension (CT) specimens are not suitable for tests with R values of zero or less than zero because of backlash effects. For such purposes four-point single edge notch bend (SENB4) or centre cracked tension (CCT) specimens loaded by friction grips are suitable.

A basic requirement is that the dimensions of the specimens be sufficient to maintain predominantly triaxial (plane strain) conditions in which plastic deformation is limited in the vicinity of the crack tip. Experience with fracture toughness testing has shown that for a valid K_{Ic} measurement a , B and $(W-a)$ should not be less than

$$2,5 \left[\frac{K_{Ic}}{\sigma_y} \right]^2$$

where σ_y is the yield strength.

It is recommended that a similar criterion be used to ensure adequate constraint during corrosion fatigue crack growth testing where K_{max} is substituted for K_{Ic} in the above expression.

4.2.2 Specimen design

Specimen geometries which are frequently used for corrosion fatigue crack growth rate testing include the following:

- a) three-point single edge notch bend (SENB3);
- b) four-point single edge notch bend (SENB4);
- c) compact tension (CT);
- d) centre-cracked tension (CCT).

Details of standard specimen designs for each of these types of specimen are given in figures 3 to 6 and permitted notch geometries are given in figure 7. Suitable machining tolerances are given in table 1.

Table 1 — Dimensions of specimens with tolerances

Dimension	Tolerances	Surface finish, squareness and parallelism
L G H F_1	$\pm 0,01 W$	Surfaces shall be perpendicular and parallel as applicable to within 0,002 W (Total indicator reading) Surface finish of faces perpendicular to the line of the notch root to be Ra 0,8 μm
F	$\pm 0,004 W$	Notch to be equidistant about centre-line to within 0,01 W
D	$+0,004 W$	Holes to be square to faces within $\pm 0,0075 W$ and parallel within $\pm 0,0005 W$ Surface finish Ra 0,4 μm

A1

4.2.3 Stress intensity factor considerations

It can be shown, using elastic theory, that the stress intensity factor acting at the tip of a crack in specimens or structures of various geometries can be expressed by relationships of the form:

$$K_I = Q\sigma\sqrt{a}$$

where

Q is the geometrical constant;

σ is the applied stress;

a is the crack length.

Stress intensity factors can be calculated by means of a dimensionless stress intensity coefficient, Y , related to crack length expressed in terms of a/W (where W is the width of the specimen) through a stress intensity factor function of the form:

$$K_I = \frac{YP}{BW^{1/2}}$$

NOTE — Where $P \leq 0$, $K = 0$. Nevertheless, it should not be assumed that negative loading will have no influence on the rate of crack growth.

The values of Y appropriate to the four specimen geometries discussed above are given in tables 2 to 5.