INTERNATIONAL STANDARD

ISO 11782-1

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Corrosion of metals and alloys — Corrosion fatigue testing —

Part 1:
Cycles to failure testing

Corrosion des métaux et alliages — Essais de fatigue-corrosion —

Partie 1: Essais cycliques à la rupture

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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 11782-1 was prepared by Technical Committee ISO/TC 156, *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

The study of cycles to failure testing uses plain or notched specimens to provide data on the intrinsic corrosion fatigue crack like behaviour of a metal or alloy and can be used to develop criteria for engineering design to prevent fatigue failures.

The study of cycles to failure can be applied to a wide variety of product forms including plate, rod, wire, sheet and tubes as well as to 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. The combination of material/load/environmental may not be directly comparable to the application. For these cases engineering judgement must be applied.

Corrosion of metals and alloys — Corrosion fatigue testing —

Part 1:
Cycles to failure testing

1 Scope

1.1 This International Standard provides guidance and instruction on corrosion fatigue testing of metals and alloys in aqueous or gaseous environments and is concerned with cycles to failure testing. Crack propagation testing is considered in ISO 11782-2.

1.2 Corrosive or otherwise chemically active environments can promote the initiation of fatigue cracks in metals and alloys and increase the rate of fatigue crack propagation. Corrosion fatigue processes are not limited to specific metal/environment systems and reliable estimates of fatigue life for all combinations of loading and environment cannot be made without data from laboratory tests.

1.3 This International Standard is not intended for application to corrsion fatigue testing of components or parts; nevertheless many of the general principles will apply.

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 stress amplitude, S_a, in fatigue loading: One half of the range of a cycle (also known as the alternating stress):

$$S_a = \frac{S_{max} - S_{min}}{2}$$

3.3 mean stress, S_m, in fatigue loading: Algebraic average of the maximum and minimum stresses in constant amplitude loading or of individual cycles in spectrum loading:

$$S_m = \frac{S_{max} + S_{min}}{2}$$

3.4 maximum stress, S_{max}, in fatigue loading: That stress having the highest algebraic value:

$$S_{max} = S_m + S_a$$

3.5 minimum stress, S_{min}, in fatigue loading: That stress having the lowest algebraic value:

$$S_{min} = S_m - S_a$$

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

$$R = \frac{S_{min}}{S_{max}}$$

NOTE — The stress ratio, R, is equal to the load ratio P_{min}/P_{max}, where P_{min} and P_{max} are the minimum and maximum loads in the cycle, respectively.

3.7 S-N diagram: Plot of stress against the number of cycles to failure.

The stress can be the maximum stress, S_{max}, minimum stress, S_{min}, stress range, ΔS or S_r, or alternating stress, S_a. The diagram indicates the S-N relationship for a specified value of S_m, R and a specified probability of survival. For N, a log scale is almost always used. For S, a linear scale or a log scale is used.

3.8 fatigue notch factor, K_f: Ratio of the fatigue strength of a specimen with no stress concentrator to that of a specimen with a stress concentrator for the same percent survival at N cycles for the same loading and environmental conditions.

NOTE — In specifying K_f, it is necessary to specify the geometry and the values of stress amplitude, mean stress and N for which it is computed.

3.9 stress concentration factor, K_t: Ratio of the greatest stress in the region of a notch or other stress concentrator as determined by the theory of elasticity to the corresponding nominal stress.

K_t becomes invalid when the stress at the notch root exceeds the yield strength.

3.10 cycle (in fatigue): 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.

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

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

3.13 fatigue strength at N load cycles, S_N: Value of stress for failure at exactly N load cycles as determined from an S-N diagram. The value of S_N thus determined is subject to the same conditions as those that apply to the S-N diagram.

NOTES

1 The value of S_N is also known as the median fatigue strength for N cycles.

2 In a corrosive environment the fatigue strength is likely to be reduced compared with that in air.

3.14 fatigue strength limit, S_f**:** Limiting value of the median fatigue strength as the fatigue life, N, becomes very large. Most materials and environments preclude the attainment of well defined fatigue limits.

4 Test

4.1 Principle

In the presence of an aggressive environment the fatigue strength of a metal or alloy is reduced to an extent which depends on the nature of the environment and the test conditions. For example, the well-defined fatigue strength limit observed for steels in air may no longer be evident as illustrated in figure 1. Interpretation of results is then based on the assumption of an acceptable life of the component.

The test involves subjecting a series of specimens to the number of stress cycles required for a fatigue crack to initiate and grow large enough to cause failure during exposure to a corrosive or otherwise chemically active environment at progressively smaller alternating stresses in order to define either the fatigue strength at N cycles, S_N, from an S-N diagram or the fatigue strength limit as the fatigue life becomes very large.

The test is used to determine the effect of environment, material, geometry, surface condition, stress, etc, on the corrosion fatigue resistance of metals or alloys subjected to applied stress for relatively large numbers of cycles. The test may also be used as a guide to the selection of materials for service under conditions of repeated applied stress under known environmental conditions.

4.2 Specimens

4.2.1 General

The design and type of specimen used depends on the fatigue testing machine used, the objective of the fatigue study and the form of the material from which the specimen is to be made. Fatigue test specimens are designed according to the mode of loading which can include axial stressing, plane bending, rotating beam, alternate torsion or combined stress.

Specimens may have circular, square, rectangular, annular or, in special cases, other cross-sections.

The gripped ends may be of any shape to suit the holders of the test machine. Problems may arise unless the gripped portion of the specimen is isolated from the corrosive test environment.

The test section of the specimen shall be reduced in cross-section to prevent failure in the grip ends and should be of such a size as to use the middle to upper ranges of the load rating of the fatigue machine to optimize the sensitivity and response of the system.

The transition from the gauge section to the gripped ends of the specimen shall be designed to minimize any stress concentration. It is recommended that the radius of the blending fillet shall be at least eight times the specimen test section diameter or width. The cross-sectional area of the gripped ends shall, where possible, be at least four times that of the test section area.

The test section length shall be greater than three times the test section diameter or width.

For tests run in compression, the length of the test section shall be less than four times the test section diameter or width in order to minimize buckling.

For the purposes of calculating the load to be applied to obtain the required stress, the dimensions from which the area is calculated shall be measured to within 0,02 mm.

Specimens shall be identified by an indelible marking method, such as stamping, on surface areas, preferably on the plain ends, without having an influence on the test results.

Specimens shall be stored after appropriate cleaning under desiccated conditions prior to testing in order to avoid corrosion which may influence the test results.

4.2.2 Cylindrical specimens

Two types of specimens with circular cross-section are frequently used for corrosion fatigue tests:

a) specimens with tangentially blending fillets between the test section and the grip ends (see figure 2); these are suitable where axial loading is employed;

b) specimens with a continuous radius between the grip ends with the minimum diameter at the centre (see figure 3); these are suitable for rotating bend tests.

A minimum cross-section diameter of 5 mm is preferred.

4.2.3 Flat sheet or plate specimens

Flat specimens for fatigue tests are reduced in width in the test section and may have thickness reductions.

If the specimen thickness is less than 2,5 mm, and the tests are performed in compression, provisions for lateral support should be made to prevent buckling without affecting the applied load by more than 5 %.

The most commonly used types include:

a) specimens with tangentially blending fillets between the test section and the grip ends (see figure 4);

b) specimens with a continuous radius between the grip ends (see figure 5).

4.2.4 Notched specimens

The effect of machined notches on corrosion fatigue strength can be determined by comparing the S-N curves of notched and unnotched specimens.

The data for notched specimens are usually plotted in terms of nominal stress based on the net cross-section of the specimen.

The effectiveness of the notch in decreasing the fatigue limit is expressed by the fatigue notch factor, K_f (the ratio of the fatigue limit of unnotched specimens to the fatigue limit of notched specimens).

The notch sensitivity of a material in fatigue is expressed by the notch sensitivity factor, q:

$$q = \frac{K_f - 1}{K_t - 1}$$

where

K_t is the stress concentration factor;

q = 0 for a material that experiences no reduction in fatigue limit due to a notch;

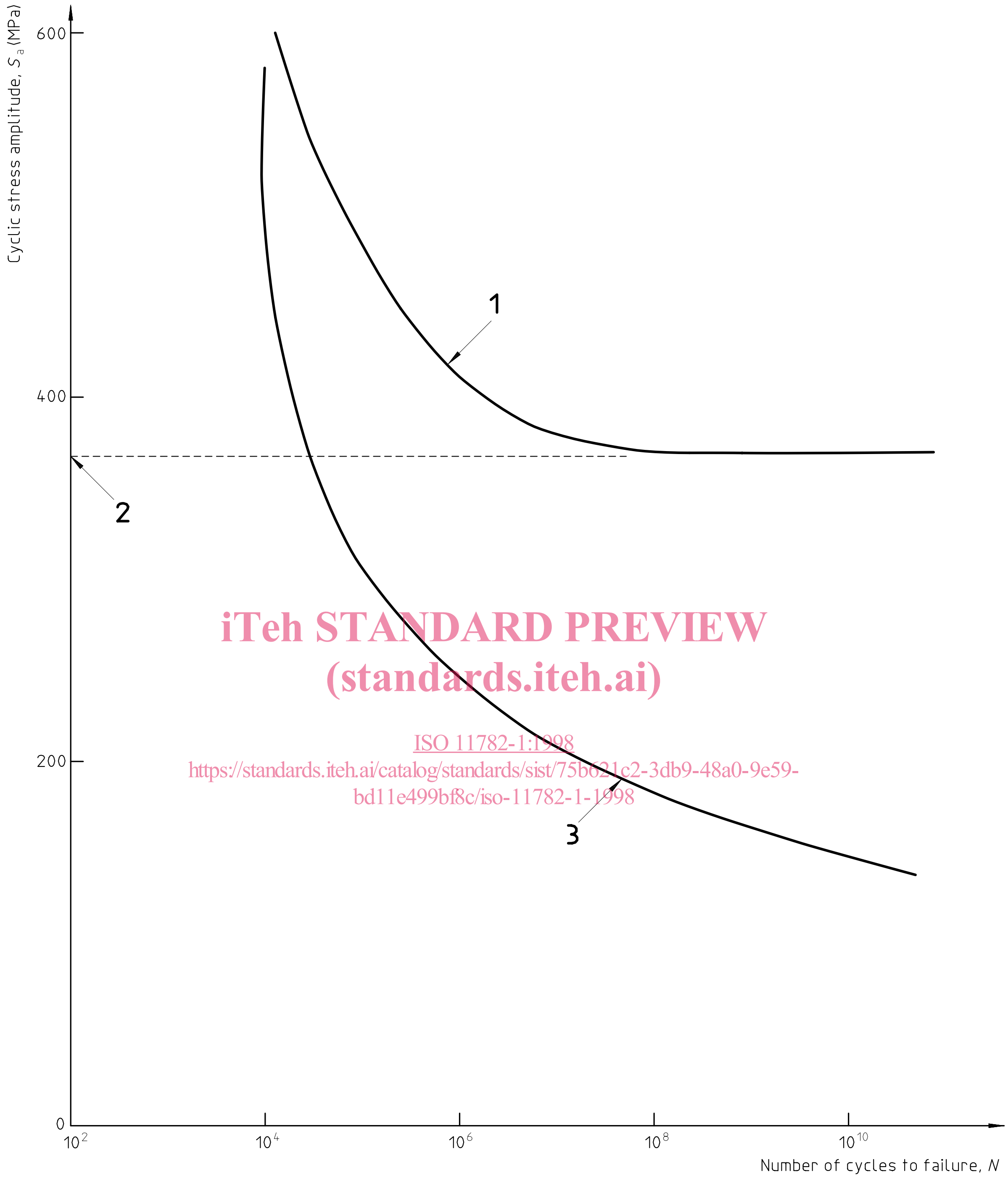
q = 1 for a material where the notch exerts its full theoretical effect.

If the standard size cannot be met other specimen configurations can be used with appropriate caution.

4.2.5 Specimen size effects

Size effects can be important in fatigue for several reasons which include residual stress distribution, variations in stress gradient across the diameter (plain or notched specimens in bending or tension and notched specimens in axial tension-compression loading), variations in surface area, variations in hydrogen concentration gradient (in appropriate environmental conditions). There is a tendency for the fatigue strength to decrease as the specimen size increases but this may not always be the case.

The size effect means that it can be difficult to predict the fatigue performance of large components directly from the results of laboratory tests on small specimens.



Key

1 Fatigue in air
2 Fatigue limit in air
3 Corrosion fatigue (no fatigue limit)

Figure 1 — Schematic comparison of *S-N* behaviour during fatigue and corrosion fatigue for steel