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Corrosion of metals and alloys — Stress corrosion testing —

Part 9:
Preparation and use of pre-cracked specimens for tests under rising load or rising displacement

Corrosion des métaux et alliages — Essais de corrosion sous contrainte —

Partie 9: Préparation et utilisation des éprouvettes préfissurées pour essais sous charge croissante ou sous déplacement croissant

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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).

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This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 262, *Metallic and other inorganic coatings,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 7539-9:2003), which has been technically revised.

The main change compared to the previous edition is as follows: the formula for K in Figure 9 has been corrected.

A list of all parts in the ISO 7539 series can be found on the ISO website.

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.

Corrosion of metals and alloys — Stress corrosion testing —

Part 9:
Preparation and use of pre-cracked specimens for tests under rising load or rising displacement

1 Scope

1.1   This document specifies procedures for designing, preparing and using pre-cracked specimens for investigating the susceptibility of metal to stress corrosion cracking (SCC) by means of tests conducted under rising load or rising displacement. Tests conducted under constant load or constant displacement are dealt with in ISO 7539-6.

The term "metal" as used in this document includes alloys.

1.2   Because of the need to confine plasticity at the crack tip, pre-cracked specimens 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.

1.3   Pre-cracked specimens can be stressed quantitatively with equipment for application of a monotonically increasing load or displacement at the loading points.

1.4   A particular advantage of pre-cracked specimens is that they allow data to be acquired from which critical defect sizes, above which stress corrosion cracking can occur, can be estimated for components of known geometry subjected to known stresses. They also enable rates of stress corrosion crack propagation to be determined.

1.5   A principal advantage of the test is that it takes account of the potential impact of dynamic straining on the threshold for stress corrosion cracking.

1.6   At sufficiently low loading rates, the threshold stress intensity factor for susceptibility to stress corrosion cracking, K_{ISCC}, determined by this method can be less than or equal to that obtained by constant load or displacement methods and can be determined more rapidly.

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 7539-6, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of precracked specimens for tests under constant load or constant displacement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7539-6 as well as the following 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 https://www.iso.org/obp.

3.1
rate of change of crack opening displacement at loading plane
$\dot{V}_{LL}$
deflection at the loading point access measured over a fixed period

3.2
stress intensity factor at crack initiation
$K_{\text{I-init}}$
stress intensity applied at the commencement of measurable crack growth

3.3
displacement rate
dq/dt
rate of increase of the deflection either measured at the loading point axis or away from the loading line

4 Principle

4.1 The use of pre-cracked specimens acknowledges the difficulty of ensuring that crack-like defects introduced during either manufacture or subsequent service are totally absent from structures. Furthermore, the presence of such defects can cause a susceptibility to stress corrosion cracking which in some materials (e.g. titanium) may not be evident from tests under constant load on smooth specimens. The principles of linear elastic fracture mechanics can be used to quantify the stress situation existing at the crack tip in a pre-cracked specimen or structure in terms of the plane strain-stress intensity.

4.2 The test involves subjecting a specimen in which a crack has been developed from a machined notch by fatigue to an increasing load or displacement during exposure to a chemically agressive environment. The objective is to quantify the conditions under which environmentally-assisted crack extension can occur in terms of the threshold stress intensity for stress corrosion cracking, K_{ISCC}, and the kinetics of crack propagation.

4.3 Tests may be conducted in tension or in bending. The most important characteristic of the test is the low loading/displacement rate which is applied.

4.4 Because of the dynamic straining which is associated with this method the data obtained may differ from those obtained for pre-cracked specimens with the same combination of environment and material when the specimens are subjected to static loading only.

4.5 The empirical data can be used for design or life prediction purposes in order to ensure either that the stresses within large structures are insufficient to promote the initiation of environmentally-assisted cracking at whatever pre-existing defects may be present or that the amount of crack growth which would occur within the design life or inspection periods can be tolerated without the risk of unstable failure.

4.6 Stress corrosion cracking is influenced by both mechanical and electrochemical driving forces. The latter can vary with crack depth, opening or shape because of variations in crack-tip chemistry and electrode potential and may not be uniquely described by the fracture mechanics stress intensity factor.

4.7 The mechanical driving force includes both applied and residual stresses. The possible influence of the latter should be considered in both laboratory testing and the application to more complex

geometries. Gradients in residual stress in a specimen may result in non-uniform crack growth along the crack front.

4.8 K_{ISCC} is a function of the environment, which should simulate that in service, and of the conditions of loading.

5 Specimens

5.1 General

5.1.1 A wide range of standard specimen geometries of the type employed in fracture toughness tests may be used, those most commonly employed are described in ISO 7539-6. The particular type of specimen used will be dependent upon the form, the strength and the susceptibility to stress corrosion cracking of the material to be tested and also on the objective of the test.

5.1.2 A basic requirement is that the dimensions shall 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, both the crack length, a, and the thickness, B, should be not less than

$$2,5\left(\frac{K_{Ic}}{R_{p0,2}}\right)^2$$

and that, where possible, larger specimens where both a and B are at least

$$4\left(\frac{K_{Ic}}{R_{p0,2}}\right)^2$$

should be used to ensure adequate constraint.

From the view of fracture mechanics, a minimum thickness from which an invariant value of K_{ISCC} is obtained cannot currently be specified. The presence of an aggressive environment during stress corrosion may reduce the extent of plasticity associated with fracture and hence the specimen dimensions needed to limit plastic deformation. However, in order to minimize the risk of inadequate constraint, it is recommended that similar criteria to those employed during fracture toughness testing should be employed regarding specimen dimensions, i.e. both a and B should be not less than

$$2,5\left(\frac{K_I}{R_{p0,2}}\right)^2$$

and preferably should be not less than

$$4\left(\frac{K_I}{R_{p0,2}}\right)^2$$

where K_I is the stress intensity to be applied during testing.

As a test for its validity, the threshold stress intensity value eventually determined shall be substituted for K_I in the first of these formulae.

5.1.3 If the specimens are to be used for the determination of K_{ISCC}, the initial specimen size should be based on an estimate of the K_{ISCC} of the material. In the first instance, it is better to over-estimate the K_{ISCC} value and therefore use a larger specimen than that which may eventually be found necessary. Where the service application involves the use of material of insufficient thickness to satisfy the conditions for

validity, it is permissible to test specimens of similar thickness, provided that it is clearly stated that the provisional value of K_{ISCC} obtained, K_{QSCC}, is of relevance only to that specific application. Where it is required to determine stress corrosion crack growth behaviour as a function of stress intensity, the specimen size should be based on an estimate of the highest stress intensity at which crack growth rates are to be measured.

5.1.4   A wide choice of specimen geometries is available to suit the form of the test material, the experimental facilities available and the objectives of the test. Two basic types of specimen can be used:

a)   those intended for being loaded by means of a tensile force;

b)   those intended for being loaded by means of a bending force.

This means that crack growth can be studied under either bend or tension loading conditions. The specimens can be used for either the determination of K_{ISCC} by the initiation of a stress corrosion crack from a pre-existing fatigue crack using a series of specimens and for measurements of crack growth rates. Since the specimens are loaded during exposure to the test environment the risk of unnecessary incubation periods is avoided.

5.1.5   Crack length measurements can be made readily with a number of continuous monitoring methods such as the electrical resistance technique (see Annex C).

5.1.6   Bend specimens can in principle be tested in relatively simple cantilever beam equipment but specimens subjected to tension loading require a tensile test machine.

5.2   Specimen design

5.2.1   The specimens can be subjected to either tension or bend loading. Depending on the design, tension loaded specimens can experience stresses at the crack tip which are predominantly tensile, as in remote tension types such as the centre-cracked plate, or contain a significant bend component, as in crack-line loaded types such as compact tension specimens. The presence of significant bending stress at the crack tip can adversely affect the crack path stability during stress corrosion testing and can facilitate crack branching in certain materials. Bend specimens can be loaded in 3-point, 4-point or cantilever bend fixtures.

5.2.2   The occurrence of crack-line bending with an associated tendency for crack growth out of plane can be curbed by the use of side grooves.

5.2.3   A number of specimen geometries have specific advantages which have caused them to be frequently used for rising load/displacement stress corrosion testing. These include

a)   compact tension (CTS) specimens which minimize the material requirement;

b)   cantilever, three-point, and four-point bend specimens which are easy to machine and inexpensive to test;

c)   C-shaped specimens which can be machined from thick walled cylinders in order to study the radial propagation of longitudinally oriented cracks.

Details of standard specimen designs for several of these types of specimen are given in Figures 1 to 3. Further examples for other geomteries including three-point bend can be found in Reference [7].

Dimensions in millimetres, surface roughness values in micrometres

Key

a   effective crack length, $a = 0,45W$ to $0,55W$

B   thickness, $B = 0,5W$

l   effective notch length, $l = 0,25W$ to $0,45W$

N   notch width, $N = 0,065W$ maximum (if $W > 25$ mm) or 1,5 mm maximum (if $W \leq 25$ mm)
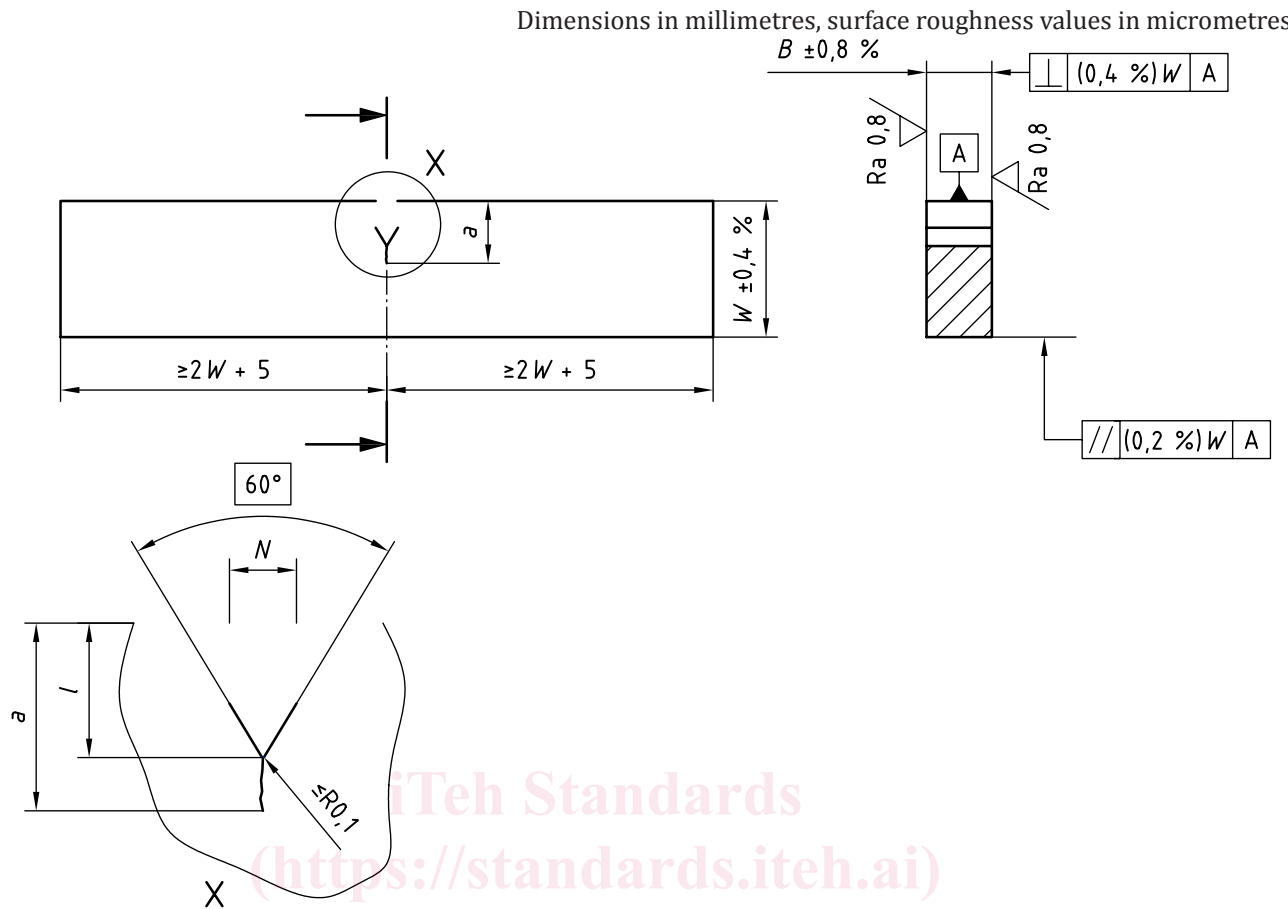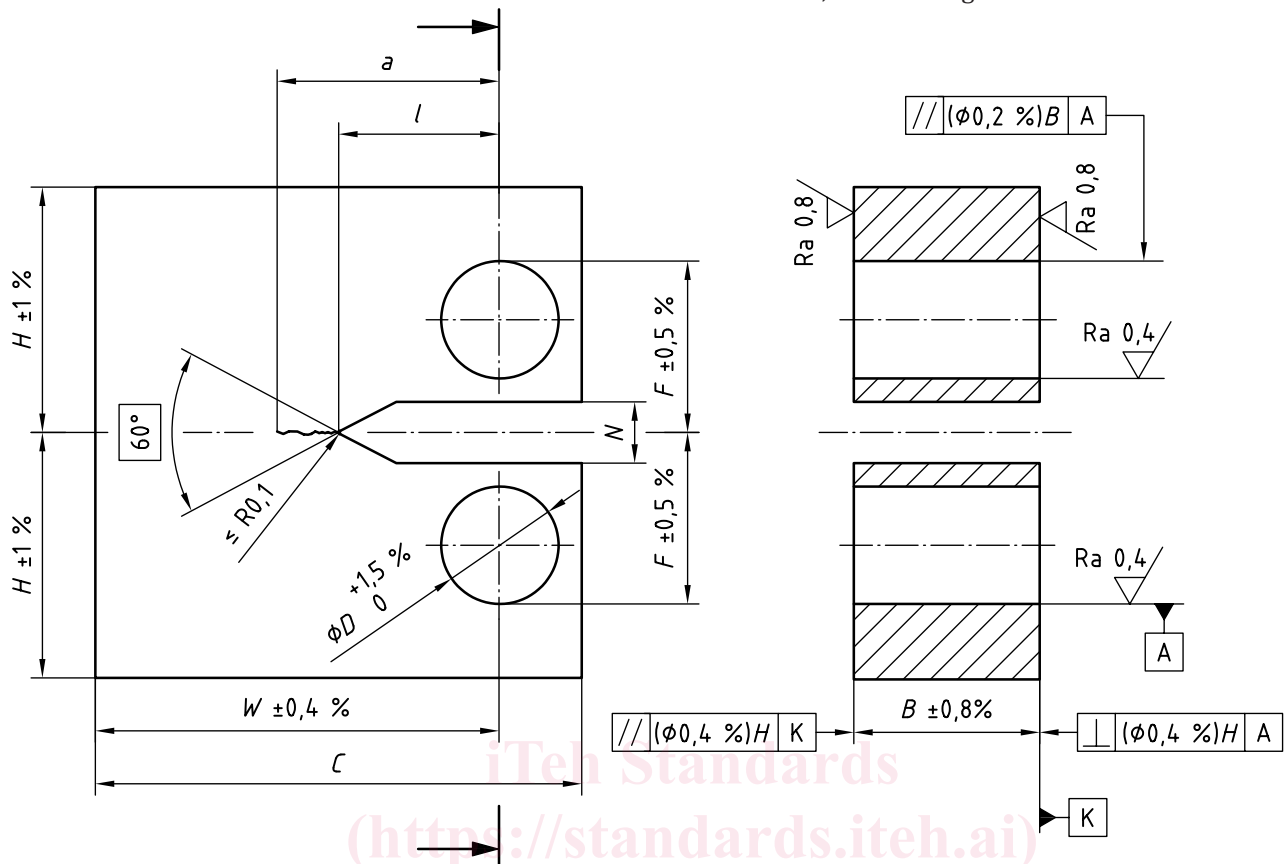
W   width

Figure 1 — Proportional dimensions and tolerances for cantilever, three-point and four-point bend test pieces

Dimensions in millimetres, surface roughness values in micrometres

Key

a effective crack length, $a = 0,45W$ to $0,55W$

B thickness, $B = 0,5W$

C total width, $C = 1,25W$ minimum

D hole diameter, $D = 0,25W$

F half-distance between hole outer edges, $F = 1,6D$

H half-height, $H = 0,6W$

l effective notch length, $l = 0,25W$ to $0,40W$

N notch width, $N = 0,065W$ maximum

W net width

Figure 2 — Proportional dimensions and tolerances for compact tension test pieces

Dimensions in millimetres, surface roughness values in micrometres
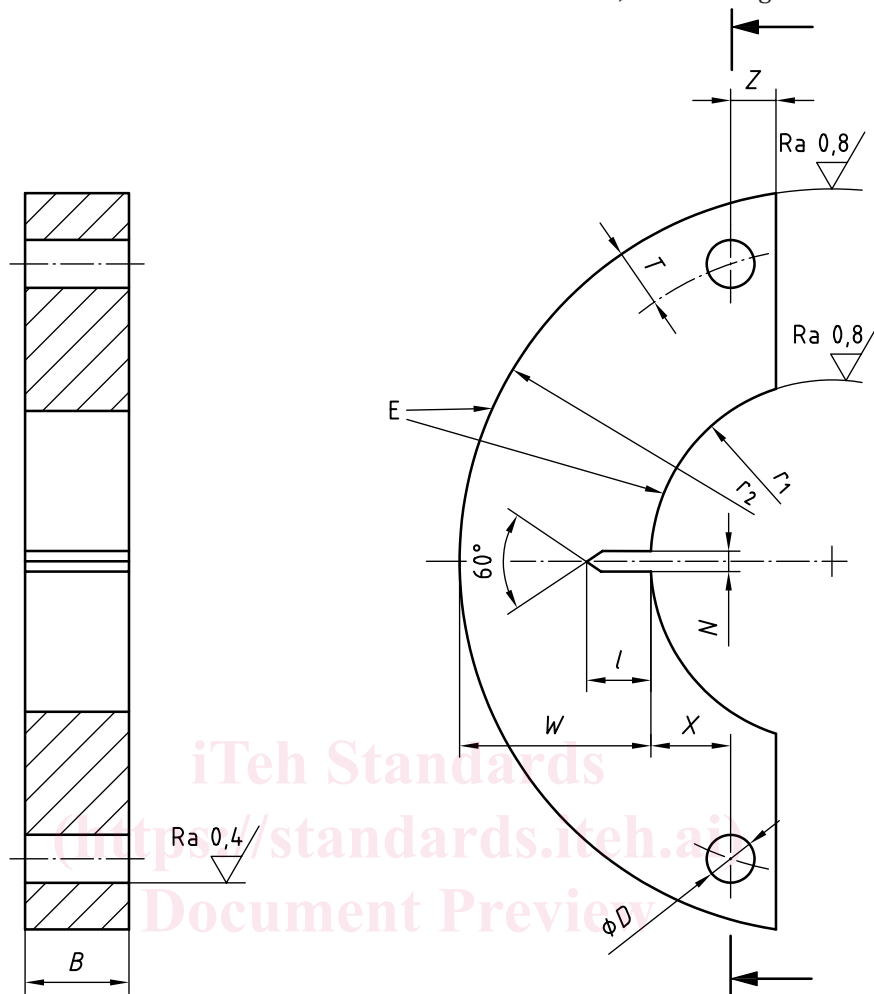
Key

B thickness, $B = 0,50W \pm 0,01W$

D diameter of holes, $D = 0,25W \pm 0,005W$

l effective notch length, $l = 0,3W$

N notch width, $N = 1,5$ mm minimum ($0,1W$ maximum)

r_1 internal radius

r_2 external radius

T Distance from the hole axis to outer surface, $T = 0,25W \pm 0,01W$

W net width

X distance from the hole axis to a tangent with the inner surface, $X = 0,50W \pm 0,005W$

Z distance from the hole axis to face of specimen, $Z = 0,25W \pm 0,01W$

All surfaces should be perpendicular and parallel, as applicable, to within $0,002W$ total indicator reading (TIR) and "E" surfaces should be perpendicular to "Y" surfaces to within $0,02W$ TIR.

Figure 3 — Proportional dimensions and tolerances for C-shaped test pieces

5.2.4 If required, for example if either fatigue crack initiation or propagation, or both, are difficult to control satisfactorily, a chevron notch configuration as shown in Figure 4 may be used. If required, its included angle may be increased from 90° to 120°.