INTERNATIONAL STANDARD

ISO 7539-2

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Corrosion of metals and alloys — Stress corrosion testing —

Part 2: Preparation and use of bent-beam specimens

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

Partie 2: Préparation et utilisation des éprouvettes pour essais en flexion

Reference number
ISO 7539-2 : 1989 (E)

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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7539-2 was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys.*

ISO 7539 consists of the following parts, under the general title *Corrosion of metals and alloys — Stress corrosion testing*:

— *Part 1: General guidance on testing procedures*

— *Part 2: Preparation and use of bent-beam specimens*

— *Part 3: Preparation and use of U-bend specimens*

— *Part 4: Preparation and use of uniaxially loaded tension specimens*

— *Part 5: Preparation and use of C-ring specimens*

— *Part 6: Preparation and use of pre-cracked specimens*

— *Part 7: Slow strain rate testing*

— *Part 8: Preparation and use of welded specimens*

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Introduction

This part of ISO 7539 is one of a series giving procedures for designing, preparing and using various forms of test specimen to carry out tests to establish a metals resistance to stress corrosion.

Each of the standards in the series needs to be read in association with ISO 7539-1. This helps in the choice of an appropriate test procedure to suit particular circumstances as well as giving guidance towards assessing the significance of the results of the tests.

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Corrosion of metals and alloys — Stress corrosion testing —

Part 2: Preparation and use of bent-beam specimens

WARNING — Bent-beam specimens made from high strength materials may fracture rapidly; pieces may fly off at high velocity and can be dangerous. Personnel installing and examining specimens must be made aware of this possiblity and be protected against injury.

1 Scope

1.1 This part of ISO 7539 covers procedures for designing, preparing and using bent-beam test specimens for investigating the susceptibility of a metal to stress corrosion.

The term "metal" as used in this part of ISO 7539 includes alloys.

1.2 Bent-beam specimens may be used to test a variety of product forms. They are used principally for sheet, plate or flat extruded material, which conveniently provides flat specimens of rectangular cross-section, but may also be employed for cast material, wire or rod, or for machined specimens of circular cross-section. They can also be used for parts joined by welding.

1.3 Since the preparation of the specimens and the apparatus used for stressing them are both simple and inexpensive, bent-beam specimens are especially suitable for multiple testing and for atmospheric stress corrosion tests.

1.4 Bent-beam specimens are usually tested under nominally constant strain conditions but nominally constant load conditions may be employed. In either case local change of curvature in the specimen when cracking occurs results in changing conditions during crack propagation. The "test stress" is taken as the highest surface tensile stress existing at the start of the test.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 7539. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7539 are encouraged to investigate the possibility of applying the most recent editions of the standards 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.*

ISO 7539-4 : 1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 4: Preparation and use of uniaxially loaded tension specimens.*

3 Definitions

For the purposes of this part of ISO 7539, the definitions given in ISO 7539-1 are applicable.

4 Principle

4.1 The test consists of applying a bending stress to a beam specimen of rectangular or circular section and exposing the stressed specimen to a specified test environment.

4.2 The magnitude of the resultant applied tensile stress in the outer fibres of the bent-beam specimen is calculated from the dimensions and modulus of elasticity of the specimen and the bending deflection, as described in 5.4.

4.3 Bent-beam specimens are used only for testing at stress levels below the elastic limit since the formulae used for calculating stress in bent beams apply only within the elastic range.

4.4 The time required for cracks to appear after exposure of stressed specimens to the test environment or the threshold stress below which cracks do not appear can be used as a measure of the stress corrosion resistance of the material in the test environment at the stress level employed.

4.5 Wide variations in test results may be obtained for a given metal and environment even when testing nominally identical specimens and the replication of tests is frequently necessary.

4.6 The possiblity of relaxation during the exposure period should be considered especially when specimens are exposed at elevated temperatures. Relaxation can be estimated if creep data are available for a simultaneous effect of the test environment. The difference in thermal expansion should also be considered.

5 Specimens

5.1 General

5.1.1 Identification marks or numbers should be permanently inscribed at each end of the specimen. This is the region of lowest stress and the identification marks will therefore not initiate cracking.

5.1.2 Specimens for determination of mechanical properties shall be taken from the same heat treatment batch, and preferably from the same piece of material, as the stress corrosion specimens.

5.2 Types of specimens

5.2.1 Bent-beam stress corrosion specimens are usually flat strips of metal of uniform rectangular cross-section and uniform thickness. They may alternatively be lengths of wire or rod of uniform circular cross-section.

5.2.2 Bent-beam stress corrosion tests may also be carrried out on specimens having a gauge length of uniform rectangular or circular cross-section with threaded ends of larger cross-section as described in ISO 7539-4.

5.3 Surface finish

5.3.1 Wire or rod specimens and flat specimens cut from sheet, plate and extruded sections may be tested with the original surface retained. This is often desirable as the structure of the original surface may be different from that of the layers of metal beneath.

5.3.2 If it is desired to exclude the effects of variations in the original surface conditions for a comparison of different alloys, the specimens should be finished by grinding or machining to a depth of at least 0,25 mm. This is usually sufficient to eliminate original surface imperfections without completely removing any outer recrystallized layer. The maximum depth of machining or grinding of the surface should be decided after studying the structure of the material as shown in an etched metallographic section. It is desirable to remove the required amount of metal in several steps by alternatively machining or grinding opposite surfaces. This practice minimizes warping due to unequal residual stresses introduced by machining. All edges should be similarly ground or machined to remove any cold worked material remaining from shearing.

5.3.3 Chemical or electrochemical treatments are generally inappropriate for flat rectangular section specimens as attack at the edges tends to be greater and less easy to control than on the faces.

5.3.4 If chemical or electrochemical treatments are employed, care must be taken to ensure that the conditions used do not result in selective phase attack on the metal or leave a deposit of undesirable residues on the surface.

5.3.5 Chemical or electrochemical treatments that generate hydrogen on the specimen surface must not be used on materials that are susceptible to hydrogen-induced damage.

5.3.6 Before testing, the specimens should be degreased to remove surface contamination; they should then be tested immediately, or stored in such a way as to avoid contamination or deterioration until they can be tested.

5.4 Methods of stressing

5.4.1 Constant strain methods

5.4.1.1 Modes of loading

Figure 1 shows six methods of stressing specimens under nominally constant strain conditions. The two-point loaded, three-point loaded and four-point loaded specimens represent the three basic modes of loading used for bent-beam specimens. The double-beam specimen, fully supported specimen and lever-loaded specimen may be regarded as special cases of four-point loading.

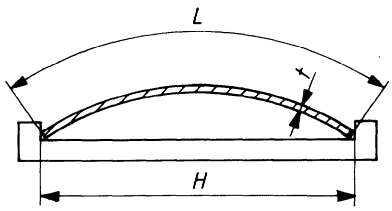
5.4.1.2 Two-point loading

5.4.1.2.1 The maximum stress in a two-point loaded specimen occurs at the mid-point of its convex surface and decreases to zero at the specimen ends.

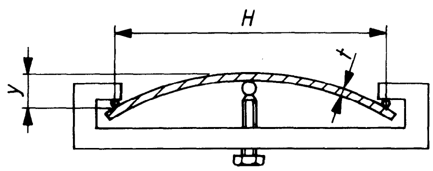
5.4.1.2.2 Flat two-point loaded specimens should be approximately 15 mm to 25 mm wide by 110 mm to 255 mm long as shown in figure 1a). The specimen thickness, t, exact length, L, and holder span, H, are selected to give the required stress calculated according to 5.4.1.2.4 and to give a value for $(L - H)/H$ between 0,01 and 0,50 to keep the error in calculating stress within acceptable limits. A specimen of thickness 0,8 mm to 1,8 mm with a holder span of 175 mm to 215 mm has proved convenient when working with very high strength steels and with aluminium alloys, with test stresses ranging from about 200 MN/m^2 for aluminium to 1 500 MN/m^2 for steel.

5.4.1.2.3 Care should be taken when fitting specimens into their holders to avoid overstressing, distortion or misalignment.

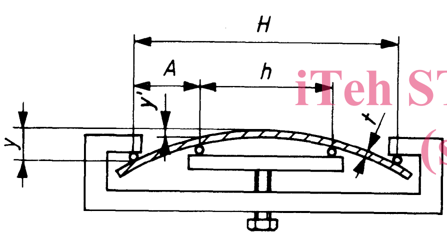
Dimensions in millimetres



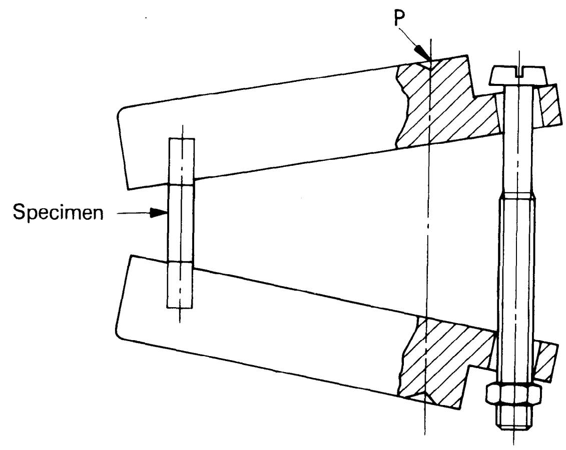
a) Two-point loaded specimen



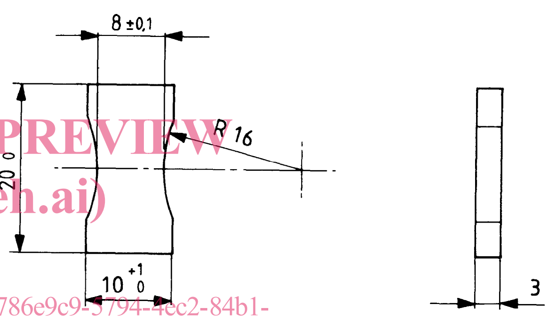
b) Three-point loaded specimen



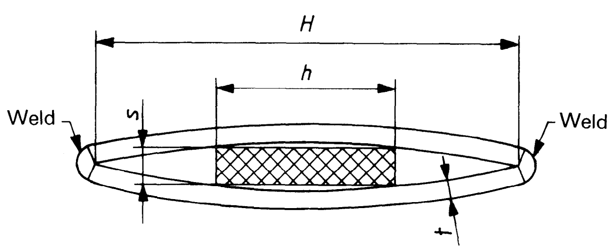
c) Four-point loaded specimen



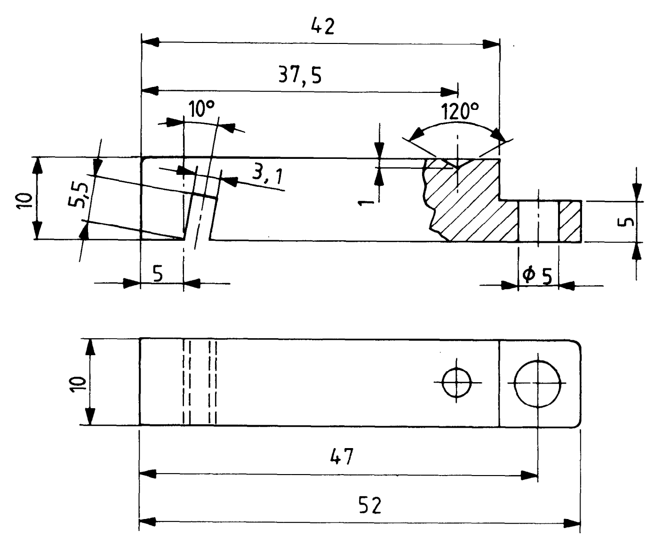
(i) Assembly



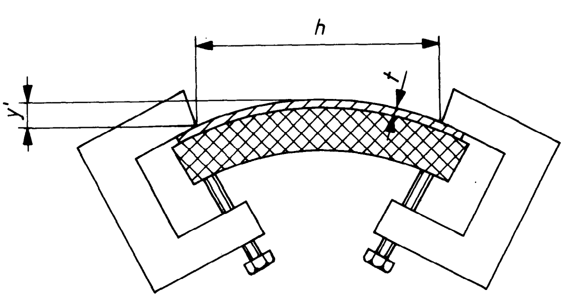
(ii) Specimen



d) Double-beam specimen



(iii) Lever



e) Fully supported specimen

f) Lever-loaded specimen

Figure 1 — Constant strain loading test specimens

5.4.1.2.4 The approximate elastic stress at the mid-point of the convex surface is calculated from the relationship

$$L = (ktE/\sigma) \sin^{-1} (H\sigma/ktE)$$

where

L is the specimen length in metres;

σ is the maximum stress in newtons per square metre;

E is the modulus of elasticity in newtons per square metre;

H is the holder span in metres;

t is the thickness of specimen in metres;

$k = 1{,}280$, an empirical constant.

The equation should be used only with

$$H\sigma/ktE = 1{,}0$$

This equation can be solved by computer, by trial and error, or by using a series expansion of the sine function.

5.4.1.2.5 A more rigorous calculation of stress may be based on a theoretically exact large deflection analysis.

Calculation of stresses above the limit of elasticity may be carried out on the basis of an elastic-plastic analysis.

5.4.1.3 Three-point loading

5.4.1.3.1 The maximum tensile stress in a three-point loaded specimen occurs at the mid-point of its convex surface and decreases linearly to zero at the outer supports. A disadvantage of three-point loaded specimens is the possiblity of crevice corrosion occurring at the central support close to the region of maximum tensile stress. The pressure of the central support also introduces unknown bi-axial stresses in the region of maximum calculated longitudinal tensile stress.

5.4.1.3.2 Three-point loaded specimens are usually flat strips 15 mm to 50 mm wide and 110 mm to 250 mm long. The thickness of the specimen is usually dictated by the mechanical properties of the material and the product form available. Specimen dimensions can be modified to suit specific needs but the approximate dimensional proportions should be preserved.

5.4.1.3.3 The specimen is supported near the ends and bent by forcing a ball-ended screw against it at its mid-point as shown in figure 1b).

5.4.1.3.4 The elastic stress at the mid-point of the convex surface is calculated from the relationship

$$\sigma = 6Ety/H^2$$

where

σ is the maximum tensile stress in newtons per square metre;

E is the modulus of elasticity in newtons per square metre;

t is the thickness of specimen in metres;

y is the maximum deflection in metres;

H is the distance between outer supports in metres.

5.4.1.4 Four-point loading

5.4.1.4.1 Four-point loading gives a uniform longitudinal tensile stress in the convex surface of the part of the specimen between the inner supports.

The stress decreases linearly to zero from the inner supports to the outer supports. The relatively large area of uniformly stressed material makes four-point loaded specimens generally preferable to two or three-point loaded specimens and particularly suitable for tests of welded material and for studies of protection by sprayed metal or organic coatings.

5.4.1.4.2 Four-point loaded specimens are commonly flat strips 15 mm to 50 mm wide and 110 mm to 250 mm long. The thickness of the specimen is usually dictated by the mechanical properties of the material and the product form available. Specimen dimensions can be modified to suit specific needs but the approximate dimensional proportions should be preserved.

5.4.1.4.3 The specimen is supported near the ends and bent by forcing the two inner supports against it in the manner shown in figure 1c). The two inner supports must be located symmetrically about the line midway between the outer supports.

5.4.1.4.4 The elastic stress in the convex surface of the part of the specimen between the inner supports is calculated from the relationship

$$\sigma = 12Ety/(3H^2 - 4A^2)$$

where

σ is the maximum tensile stress in newtons per square metre;

E is the modulus of elasticity in newtons per square metre;

t is the thickness of specimen in metres;

y is the maximum deflection between outer supports in metres;

H is the distance between outer supports in metres;

A is the distance between inner and outer supports in metres.

The dimensions are often chosen so that $A = H/4$.

5.4.1.4.5 An alternative method of calculating the elastic stress between the inner supports is to use the relationship

$$\sigma = 4Ety'/h^2$$

where

h is the distance between inner supports in metres;

y' is the deflection between inner supports in metres.

NOTE — This equation is a special case of the equation in 5.4.1.4.4 when $A = 0$.

5.4.1.4.6 The above relationships are based on small deflections (y/H or $y'/h < 0{,}1$). In light gauge specimens the deflections may be larger than this and the relationships are then only approximate. More accurate stress values may be obtained by attaching strain gauges to a specimen of the same material and the same dimensions as the stress corrosion specimens and stressed in the same way.

5.4.1.5 Double-beam specimens

5.4.1.5.1 In double-beam specimens there is a uniform longitudinal tensile stress in the convex surface between the lines of contact with the spacer. From these lines the stress decreases linearly towards zero at the ends of the specimens. Double-beam specimens are usually employed for thicker material than can conveniently be handled by a four-point loading jig.

5.4.1.5.2 Double-beam specimens usually comprise two flat strips 25 mm to 50 mm wide and 125 mm to 250 mm long. The thickness of the specimens is dictated by the mechanical properties of the material and the product form available.

5.4.1.5.3 The two strips are bent against each other over a centrally located spacer until both ends of the specimens touch. They are held in this position by welding as shown in figure 1 d) or by bolting.

5.4.1.5.4 The elastic stress in the convex surface of the portions of the specimens between the lines of contact with the spacer is calculated from the relationship

$$\sigma = \frac{3Ets}{H^2 [1 - (h/H)] [1 + (2h/H)]}$$

where

σ is the maximum tensile stress in newtons per square metre;

E is the modulus of elasticity in newtons per square metre;

t is the thickness of the specimen strip in metres;

s is the thickness of the spacer in metres;

H is the length of the specimen in metres;

h is the length of the spacer in metres.

5.4.1.5.5 If the length of the spacer, h, is chosen so that $H = 2h$ the equation in 5.4.1.5.4 is simplified to

$$\sigma = 3Ets/H^2$$

5.4.1.5.6 The above relationships are based on small deflections ($s/H < 0{,}2$). For light gauge specimens the deflections may be larger and the relationships are then only approximate. More accurate stress values may be obtained by attaching strain gauges to specimens of the same material and the same dimensions as the stress corrosion specimens and stressed in the same way.

5.4.1.6 Fully supported specimens

5.4.1.6.1 In fully supported specimens there is a uniform longitudinal tensile stress in the convex surface between the clamping points. Fully supported specimens may be used when the dimensions of the material are too small for normal four-point loading — for example, when specimens are taken in the short transverse direction from rolled plate.

5.4.1.6.2 The dimensions of fully supported specimens are largely dictated by the product from which they are prepared. Specimens of high strength aluminium alloy 32 mm × 10 mm and 1 mm thick have given satisfactory results and indicate the approximate dimensional proportions to be employed.

5.4.1.6.3 The outer diameter of the supporting block is selected to produce a radius of curvature in the convex surface of the specimen which will impose the desired stress. The specimen is clamped at one end to the supporting block, pressed down against the surface of the block and then clamped at the opposite end, as shown in figure 1 e).

5.4.1.6.4 The elastic stress in the convex surface of the specimen between the clamping point is calculated using the relationship given in 5.4.1.4.5, h then being the distance between the inner edges of the clamps.

5.4.1.7 Lever loading

5.4.1.7.1 In lever-loaded specimens of the type shown in figure 1 f) (ii) the maximum tensile stress in the convex face is across the centre line. Lever-loaded specimens may be used when the dimensions of the material are too small for normal four-point loading — for example, when specimens are taken in the short transverse direction from rolled plate.

5.4.1.7.2 The recommended dimensions for lever-loaded specimens and for test jigs are given in figure 1 f) (i) to (iii).

5.4.1.7.3 To load the specimen it is fitted into the slots in the upper and lower levers and stressed by applying a known load at the point P. This may be done using a tensile testing machine or by dead loading. The clamping nut is then tightened sufficiently to retain the specimen and levers in the same relative positions when the load is removed.

5.4.1.7.4 The elastic stress across the centre line of the specimen is calculated fom the modulus of elasticity and dimensions of the specimen, and the magnitude of the load applied at P.