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Corrosion of metals and alloys — Stress corrosion testing —

Part 4: Preparation and use of uniaxially loaded tension specimens

Corrosion des métaux et alliages — Essais de corrosion sous contrainte —
Partie 4: Préparation et utilisation des éprouvettes pour essais en traction uniaxiale

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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 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 7539-4 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 4: Preparation and use of uniaxially loaded tension specimens

1 Scope

1.1 This part of ISO 7539 covers procedures for designing, preparing and using uniaxially loaded tension 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 Tension test specimens are adaptable for testing a wide variety of product forms, including plate, rod, wire, sheet and tubes, as well as parts joined by welding, riveting, or other methods. Notched specimens may also be used (see 5.1.3).

1.3 Uniaxially loaded tensile specimens may be stressed quantitatively with equipment for application of either a constant load, a constant strain or an increasing load or strain.

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 6892 : 1984, *Metallic materials — Tensile testing.*

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

ISO 7539-6 : 1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked 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 in subjecting a specimen to constant load, constant strain or increasing load or strain with a view to determining stress corrosion susceptibility by reference to one or more of the parameters enumerated in clause 7.

4.2 Corrosive environments may cause a deterioration of the properties of stressed materials beyond those observed with the same combination of environment and material when the latter is not subjected to stress. This enhanced deterioration may be expressed in a number of different ways for the purpose of assessing stress corrosion susceptibility.

4.3 The commonest form of deterioration due to stress corrosion involves the initiation and growth of cracks, one or more of which may eventually lead to total failure of a specimen if the test is conducted for an appropriate time. In the absence of total failure, the mechanical properties of the specimens will be impaired by an amount depending upon the extent of crack development or the growth of pits or fissures.

4.4 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. If specimens are prepared to different sizes or orientations or are subjected to different stressing pressures, test results may be even more variable.

5 Specimens

5.1 General

5.1.1 Specimens of constant cross-section may be circular, square, rectangular, annular or, in special cases, of other forms.

5.1.2 Specimens having tapered gauge lengths may be employed for the purpose of obtaining a range of initial stresses.

5.1.3 Tension specimens containing a machined notch or in which a mechanical pre-crack has been started may also be used. In the case of notched specimens, a triaxial stress state is present in the vicinity of the notch. In addition, the axial stress at the root of the notch will be greater than the nominal stress derived using the minimum cross-sectional area at the root of the notch. The maximum stress at the notch can be calculated from the product of this nominal stres and the stress concentration factor K_T for the specific notch. Pre-cracked specimens are dealt with separately in ISO 7539-6.

5.1.4 Finished products may be tested in the manufactured condition by agreement between the parties.

5.1.5 The proportionality of machined specimens used for tensile testing in general is less important in stress corrosion testing, but for purposes of comparison it is desirable to use specimens as used for tensile tests complying with ISO 6892.

5.1.6 To minimize stress concentration, whereby crack initiation may be facilitated, machined specimens should incorporate a transition radius between the gripped end and the parallel length, if these are of different dimensions. The value of this transition radius is at least as important in stress corrosion testing as in tensile testing in general and, unless otherwise specified, should conform to the requirements of the appropriate International Standard. Crack initiation may also be facilitated at sharp corners in specimens having such cross-sections as square or rectangular if such corners are not appropriately rounded.

5.1.7 The gripped ends may be of any shape to suit the holders of the testing machine. Problems may arise unless the gripped portion of the specimen is isolated from the corrosive test environment (see 6.3).

5.1.8 A wide range of sizes of specimens is possible, depending primarily upon the dimensions of the product to be tested. Because the expression of the results from stress corrosion tests can be markedly influenced by the cross-sectional area of the specimen, this factor should be given careful consideration with regard to the object of the investigation.

5.1.9 The number of constant load test machines can be minimized by testing chains of specimens. These may be connected by loading links which are designed to prevent unloading on the failure of specimens.

5.1.10 Small cross-section specimens may be used because they

a) are directly related to product form;

b) permit greater convenience in testing;

c) usually give test results more quickly;

d) usually have a greater sensitivity to the presence of small stress corrosion cracks.

On the other hand, small cross-section specimens are more difficult to machine and their performance is more likely to be influenced by extraneous stress concentrations resulting from non-axial loading, corrosion pits or other forms of attack, for example general corrosion. In the case of machined specimens, dimensions greater than 10 mm in gauge length and 3,0 mm in section are preferred.

5.2 Preparation of specimens

5.2.1 The pronounced effect of surface conditions on the time required to initiate stress corrosion cracking in certain combinations of metal and environment is well established. Of particular importance is the avoidance of stress concentrations, machining damage and chemical contamination. Unless it is desired to evaluate the as-supplied or as-fabricated surface, the final preparation usually preferred is a mechanical process followed by degreasing. Stress intensification at surface irregularities is usually more important in the initiation of stress corrosion cracks in high strength alloys than in lower strength, ductile alloys, but a surface quality of 1 µm root mean square or better should always be the aim.

5.2.2 Care should be taken to avoid over-heating or excessive pressure during the final preparation, which may otherwise induce residual stresses or metallurgical changes in the surface. Post-preparation heat treatment, chemical polishing or electropolishing may be appropriate to overcome such effects in some cases. Care should also be taken to minimize contamination of the surface by polishing residues.

5.2.3 It should not be assumed that electropolishing will invariably give the correct results, i.e. devoid of the problems mentioned above deriving from mechanical preparation of surfaces.

5.2.4 If the final surface preparation involves a chemical treatment, 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.

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

5.2.6 Where it is necessary to mark the specimen for purposes of identification, the methods given in ISO 7539-1 should be followed.

6 Procedure

6.1 The environmental testing conditions selected depend upon the purpose of the test but, ideally, should be the same as those prevailing for the intended use of the alloy or comparable to the anticipated service condition. In practice, a number of standard environments are used for ranking purposes, but the results obtained require cautious interpretation in relation to the anticipated service conditions.

6.2 If practical, it is recommended that the specimens be stressed after being brought into contact with the test environment. Otherwise, the stressed specimens should be exposed to the test environment as soon as possible after stressing.

6.3 It is recommended that wherever possible the gripped portions should be excluded from contact with the corrosive environment. If this is not possible, the problems that may arise include the following:

a) galvanic effects may influence results if the grips are made from a different material from that of the test piece and electrical insulation is then necessary;

b) crevice corrosion may occur within the confines of the restricted spaces between grips and test pieces and stress discontinuities can lead to premature stress corrosion failure in such regions;

c) crevice problems may also arise where the test piece emerges from the test cell and these should be avoided by appropriate design of the cell, by the use of protective coatings at such positions or by enlargement of the cross-sectional area of the test piece beyond the parallel portion.

6.4 It is recommended that specimens without applied stress should be exposed to the same conditions and for the same time as stressed specimens, so that a comparative assessment of the results will allow the effect of applied stress to be identified. In the testing of thin sheet and specimens prepared from fabricated joints, e.g. by welding, residual stresses may be sufficiently high to promote stress corrosion failure in the absence of applied stress, or at relatively small values of the latter as compared to those necessary in the absence of residual stresses. Metals may also suffer a deterioration in mechanical properties by contact with corrosive environments even in the absence of applied stress, e.g. by pitting, intergranular corrosion, etc., and the effect of applied stress can only be assessed by comparison with the behaviour of unstressed specimens.

6.5 It is recommended, especially if tests involve increasing load or strain and specimens are taken to the point of total failure, that specimens should be tested in an inert environment as well as in the corrosive test environment. This allows a comparative assessment of the effects of the corrosive environment, by providing baseline data relating to inert conditions. For some materials, including high strength aluminium alloys and steels, it may not be sufficient to assume that a test in air constitutes a test in an inert environment.

6.6 If it is required to minimize the number of specimens used, a binary search procedure may be employed to determine the threshold stress. For example, the first test should be conducted at an initial stress equal to half the tensile strength of the material involved, with subsequent tests at other fractions of the tensile strength according to the schedule shown in the figure of ISO 7539-1, depending on whether or not failure occurred in preceding tests.

7 Assessment of results

7.1 The most frequently used parameter for assessing cracking susceptibility is the time to total failure, which is usually easy to measure with reasonable accuracy. Since the time to failure is dependent upon the initial applied stress, among other things, and the nature of this dependency is not the same for all materials in all environments, a comparison of times to failure at a particular initial applied stress can be misleading. Rather than conduct a large number of replicate tests at the same stress level to assess scatter, it is recommended that specimens should be exposed at different initial stresses to define the threshold stress below which total failure does not occur, with fewer replicate tests at each particular initial stress.

7.2 It is usual to terminate tests after some arbitrarily chosen time if total failure has not occurred. Such specimens may contain cracks, even though these have not propagated to the point where total failure can occur. All specimens that have not progressed to total failure should be examined for cracks, after removal of corrosion products if need be.

7.3 The number of cracks per unit length of specimen can be used for a comparative assessment of susceptibility, especially to the initiation of stress corrosion cracks. If such a method is used, the technique employed in determining the number of cracks should be specified because metallographic examination of sectioned specimens, for example, is likely to reveal small cracks not visible to the naked eye.

7.4 An average crack velocity may be determined from the length of the longest crack, measured on the fracture surfaces of specimens that have failed completely or on sections through specimens that have not proceeded to total failure, divided by the time of testing. Although this parameter assumes that cracking is initiated at the start of the test, which is not always the case, nevertheless such a measurement is frequently found to be in reasonable agreement with those made more precisely.

7.5 Specimens that have not progressed to total failure may be assessed by mechanical tests at the conclusion of the period of exposure. The parameters most likely to reflect readily the presence of cracks are the tensile strength and those concerned with ductility, such as the percentage reduction of area.

8 Test report

The test report should include the following information:

a) full description of the test material, including composition and structural conditions, type of product and section thickness from which specimens were taken;

b) orientation, type and size of test specimens and their surface preparation;

c) stressing procedure;

d) the environment and period of exposure;

e) methods used in assessing test results (time to total failure, number and location of cracks, average crack velocity, remnant strength and ductility).

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