SLOVENSKI STANDARD
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Korozija kovin in zlitin - Ugotavljanje pokanja zaradi napetostne korozije - 10. del: Reverzna metoda "U-upognjenci" (ISO/DIS 7539-10:2019)

Corrosion of metals and alloys - Stress corrosion testing - Part 10: Reverse U-bend method (ISO/DIS 7539-10:2019)

Korrosion der Metalle und Legierungen - Prüfung der Spannungsrisskorrosion - Teil 10: Vorbereitung und Anwendung von reversierten Bügelproben (ISO/DIS 7539-10:2019)

Corrosion des métaux et alliages - Essais de corrosion sous contrainte - Partie 10: Méthode d'essai par cintrage en U inversé (ISO/DIS 7539-10:2019)

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Corrosion of metals and alloys — Stress corrosion testing —

Part 10: Reverse U-bend method

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

Partie 10: Méthode d'essai par cintrage en U inversé

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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.

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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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is 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: Method for the 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 for tests under constant load or constant displacement

— Part 7: Method for slow strain rate testing

— Part 8: Preparation and use of specimens to evaluate weldments

— Part9: Preparation and use of pre-cracked specimens for tests under rising load or rising displacement

— Part 10: Reverse U-bend test method

— Part 11: Guidelines for testing the resistance of metals and alloys to hydrogen embrittlement and hydrogen-assisted cracking

Corrosion of metals and alloys — Stress corrosion testing —

Part 10: Reverse U-bend method

WARNING — This International Standard may involve hazardous materials, operations, and equipment. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This part of ISO 7539 covers procedures for designing, preparing and using reversed U-bend (RUB) test specimens for investigating the susceptibility of the metal to stress corrosion cracking. The term “metal” as used in this standard includes alloys.

2 Normative reference

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 8407, *Corrosion of metals and alloys — Removal of corrosion products from corrosion test specimens*

ISO 3366, *Coated abrasives — Abrasive rolls*

ISO 21948, *Coated abrasives — Plain sheets*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7539-1 apply.

4 Principle

The RUB test is a particularly severe test for assessing susceptibility to stress corrosion cracking. The test is intended primarily for application to metals with high corrosion resistance, such as Ni-based alloys, with the advantage compared to methods such as the conventional U-bend test of having significantly less stress relaxation. It is used primarily as a screening test for tubing, piping, plate, bar and other products including welded materials. It may also be used as an acceptance test for performance in service subject to agreement between the parties.

The principle of the test is to introduce very severe stresses in a high corrosion resistance metal, with minimum relaxation, in order to enhance the likelihood of inducing stress corrosion cracking.

The test consists of exposing to the corroding medium a piece of metal of semi-circular section bent back on itself (i.e. reversed bent) into a U-shape and held in a manner which ensures that there are initial tensile stresses in excess of the yield strength over a large proportion of the inner surface. The test is accelerated by the presence of complex bi-axial stresses that may or may not exist in service. In the act of forming specimens, varying amounts of cold work may be introduced and this deformation may influence the stress corrosion cracking tendency as compared to that of the material in the original condition.

The test is normally performed in the laboratory by exposing the specimens to simulated service conditions.

A further objective of the test is to compare and evaluate the influence of different material parameters.

The principal advantages of the test are its simplicity and its ability to provide rapid screening: if conventional U-bend or C-ring specimens are used for screening tests in high temperature solution as 573 K or higher, marked stress relaxation occurs and a long testing time is needed for the evaluation. However, the stress relaxation in RUB specimens is smaller than that in conventional U-bend and C-ring specimens, due to the bi-axial stresses in RUB specimens. Therefore, screening tests can be done within a relatively short time through the use of RUB specimens.

A disadvantage is that the stress state is complicated and is difficult to quantify with accuracy. If an accurate stress state is desired an alternative method should be used.

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 from tubing of different dimensions or are subjected to different stressing procedures test results may be even more variable.

5 Specimens

5.1 General

RUB specimens are prepared from pieces of production tubing, piping and other hollow cylindrical products cut into half longitudinally or from plate, bar or other products formed into a semi-circular shape along the axial direction. The specimens should be cut by sawing or other such methods that do not affect material properties, and then they should be shaped into their dimensions by machining. The side face of the specimens should be deburred and then finished by sequentially coarse-to-fine grinding using abrasive papers or cloths to a surface finish such as P600 (ISO 3366 or ISO 21948) without increasing the temperature of the specimens.

Two-stage stressing consisting of bending and fastening with a loading bolt should be performed for RUB specimens. Elastic-stress relief should be avoided during fastening RUB specimens with a loading bolt.

5.2 Preparation of RUB specimens

5.2.1 Tubing and piping

A variety of tube dimensions and specimen size s can be employed. The tube is cut to selected specimen lengths and then sectioned axially to produce specimens with a semi-circular section.

The tubing shall retain its original surface finish.

If heat treatment is added, final heat treatment shall be performed before the reverse U-bending process (and pre-straining if this is adopted).

5.2.2 Other products

A variety of bar stock, plate and other forged or rolled material or welded material can be employed. These materials shall be machined into a plate after final heat treatment and pressed into a semi-circular shape between inner and other formers. The surface of the specimens shall be finished by sequentially coarse-to-fine grinding using abrasive papers or clothes up to a surface finish such as

P600 (ISO 3366 or ISO 21948) without increasing the temperature of the specimens before the pressing process. Specimen preparation from a plate is shown in Annexes A and B.

When testing welds, consideration shall be given to the orientation of the weld relative to the longitudinal axis of the specimen and this shall be noted. Tests may be conducted on the weld metal itself or on sections containing the weld metal and heat-affected zone.

5.2.3 Reverse U-bending process

During bending, deformation of the tube half may be constrained by the forming jig to force it to maintain its semi-circular cross-section or its sides may be allowed to deform freely in which case it may tend to flatten at the apex. Both methods may be used. The latter procedure results in lower stresses, but has the advantage of avoiding cracking at the edges. The former type specimen is named as “Half tube RUB specimen”, and the latter type specimen is named as “RUB specimen with a gauge section”, in this standard.

When testing RUB specimens with a gauge section (in which the stresses generated during reverse U-bending are lower because of reduced constraint), pre-straining can be used to achieve the desired stress level.

Examples of preparation of non-pre-strained half tube RUB specimens are shown in Annex A. Examples of preparation of non-pre-strained and pre-strained RUB specimens with a gauge section are shown in Annex B.

The apex of the pressing template has a concave curve whose curvature is suited to the external diameter of the tube half, while the rolls have a convex curve whose curvature is suited to the internal diameter of the tube half.

Only RUB specimens that do not crack at the apex when bent should be adopted.

5.3 Fastening RUB specimens with a loading bolt

When fastening specimens with a loading bolt after a bending operation, care shall be taken to ensure that the deflection is restored beyond that pertaining at the end of the bending operation. RUB specimens should be stressed using a vice bench as the final stage of the bending operation before fastening the specimen to align specimen’s legs by attaching them with bolts and nuts. The final distance between the specimen legs at the loading bolt shall be approximately 1 mm less than the minimum distance during the bending operation. The final distance should be the same for all specimens in a given series; loosening after loading should be avoided. To obtain consistency a micrometer measuring device should be used.

The bolting material should have a similar (or lower) coefficient of thermal expansion to that of the specimen. Washers with a curved surface should be used to avoid non-uniform loading on the specimen during screwing of the bolt. The washers help to keep the same contact point on the bolt-holes of a specimen. In addition, the use of double nuts to reduce the likelihood of loosening of the bolts is recommended.

Bolting material that avoids galvanic corrosion with RUB specimens and is resistant to corrosion in the environment should be selected. In a high-pH environment, the same material as RUB specimens can be adopted, but zirconia should not be adopted. In high-temperature water, the use of oxidized zircaloy washers for insulation is recommended.

6 Experimental procedure

If more than one metal is present in a system, electrical insulation of the specimen may be necessary to avoid galvanic corrosion, depending on the test environment. Where insulation is used, the insulating material shall not deform during the test. Ceramic insulating materials are suitable provided that they are compatible with the test conditions.

Specimens shall be degreased using a solvent such as acetone, then they shall be rinsed with distilled water or ethanol and dried prior to testing. They should be handled with care thereafter.

Specimens shall be examined, after forming, for cracks that may have developed before exposure to the test environment. It may also be desirable to prepare additional specimens, which are stressed but not exposed to the test environment for use as controls for later comparison.

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

As soon as possible after degreasing, stressing and inspection, the specimens should be put on test.

Multiple specimens shall be tested for one condition in order to chart damage development over time. Typically, two methods shall be applied. One is a multiple immersion test with different periods and the other is a serial immersion test.

In the multiple immersion test, multiple sets of specimens are tested for different exposure periods. Cracks are detected by inspection after the immersion test. It can be useful to test a sufficient number of identical specimens for statistical evaluation at each exposure time. On test completion the specimens shall be rinsed with distilled water or ethanol and dried. Destructive inspection can be applied to detect cracks. If required, a suitable cleaning method (ISO 8407) shall then be used to allow observation of possible cracks.

In the serial immersion test, specimens are repeatedly observed by non-destructive inspection after lapses of certain times until a crack is detected in the test. Before the inspection, the specimens shall be rinsed with distilled water or ethanol and then dried. The test time for a specimen is defined as the accumulated period over which the specimen is tested in a test environment. It can be useful to test a sufficient number of identical specimens for statistical evaluation. The serial immersion test is a more effective evaluation of the inspection time for crack detection with limited specimens than the multiple immersion test.

Generally, it takes time for corrosion potential of specimens to return back to the previous potential in the environment after restarting immersion test because oxide film on the specimens is transformed in the atmosphere. This might result in crack-initiation time different from the immersion test without intermediate inspections. When the time to return back to the previous potential is so short that it can be negligible compared with the immersion test time, the serial immersion test can be carried out without considering effect of intermediate inspections. Thin solid oxide film formed on surface of high corrosion resistant alloys such as Alloys 600 and 690 is hardly transformed in the atmosphere after taking out from the environment. Additionally, the corrosion potential returns back to the previous potential after several hours in the environment such as simulated PWR primary water environment.

7 Post-exposure evaluation

Before specimens are examined it is necessary to check that failure or loosening of the loading bolt has not invalidated the test.

Preliminary examination of specimens for evidence of cracks is by predetermined non-destructive observation methods such as generally visual inspection or 10-40 fold magnification optical microscopy without loosening the loading bolt after rinsing the specimen with distilled water or ethanol and drying it.

If specimens are returned to the test environment in the serial immersion test, loosening of the loading bolt and destructive inspection should be avoided. Removal of corrosion products and the electric charging of the surface by electron microscopy change the conditions of corrosion phenomena.

High-magnification observation by scanning electron microscopy or optical microscopy on metallographically prepared cross-sections may be useful in checking to confirm that a specimen does not contain any cracks.

Any cracking observed, unless positively proved to have occurred for some reason other than stress corrosion cracking, should be considered as indicative of failure.

