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**Stress corrosion cracking testing of
metals and alloys using reverse U-bend
test method**

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Society of Corrosion Engineering (JSCE)/Japanese Standard Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently, **JIS G 0511 : 2006** is replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, applications for a patent after opening to the public or utility model rights. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, applications for a patent after opening to the public or utility model rights.

Stress corrosion cracking testing of metals and alloys using reverse U-bend test method

Introduction

This Japanese Industrial Standard has been prepared based on the first edition of **ISO 7539-10** published in 2013 with some modifications of the technical contents.

The portions given sidelines or dotted underlines are the matters in which the contents of the corresponding International Standard have been modified. A list of modifications with the explanations is given in Annex JC. Matters contained in Annex JA and Annex JB are unique contents of **JIS** that are not given in the corresponding International Standard.

1 Scope

This Standard specifies the methods of evaluating susceptibility mainly of Fe-based alloy and Ni-based alloy of austenitic materials to stress corrosion cracking in the environment of high temperature and high pressure water using reverse U-bend (hereafter abbreviated as “RUB”) specimens.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 7539-10 : 2013 *Corrosion of metals and alloys — Stress corrosion testing — Part 10 : Reverse U-bend method* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standards and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

WARNING Persons carrying out tests based on this Standard should be familiar with normal laboratory practice. This Standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this Standard to establish appropriate safety and health practices.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) listed below shall be applied.

JIS R 6251 *Abrasive cloths*

JIS R 6252 *Abrasive papers*

JIS R 6253 *Waterproof abrasive papers*

JIS Z 2241 *Metallic materials — Tensile testing — Method of test at room temperature*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions apply.

3.1 stress corrosion cracking

metal cracking that occurs and develops due to a simultaneous effect of the corrosion environment and the static tensile stress

It often severely deteriorates the load bearing characteristics of the metal structures.

3.2 test environment

either a service environment, or an environment produced in the laboratory, to which the specimen is exposed

Whether the test environment is maintained constant or varied depends on the previous agreement.

3.3 start of test

time when the specimen is exposed to the test environment

3.4 crack detection time

period from the start of a test to the time when a crack exceeding a limit value is detectable

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 tubes obtained from piping or heat transfer tubes, 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 purchaser and the supplier.

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 test corroding solution a piece of metal of semi-circular section bent back on itself (i.e. reversed bent) along its longitudinal axis 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 com-

pared 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 (300 °C) 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 piping, heat transfer tubes, and other hollow cylindrical products cut into half longitudinally or from plate, bar or other products formed into a semicircular shape along the axial direction, by forming them into a U-shape by reverse bending.

Specimen is cut out by saw cutting or the like which hardly affects the material quality, and then sheared to the intended specimen shape. Burrs on the side surfaces shall be removed, and the surfaces polished with abrasive cloths specified in JIS R 6251 or abrasive papers specified in JIS R 6252 or JIS R 6253 successively to grain size P600 while taking care to avoid the temperature rise of the specimen.

5.2 Preparation of RUB specimen

5.2.1 Tubes cut out from piping or heat transfer tubes

For tubes cut out from piping or heat transfer tubes, since their inner surface constitutes the test surface, the original surface finish of the tube should be retained with no surface treatment performed, unless there is a special test purpose. Final heat treatment, if heat treatment is to be given, shall be performed before bending (and pre-straining if this is adopted). Preparation of RUB specimens from tubes is shown in Annex A and Annex B. The types of RUB specimens shall be No. 1 specimen, No. 2 specimen and No. 3 specimen, as specified in Annex JA.

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 strip after final heat treatment and pressed into a semicircular shape by using forming jigs. The surface of the flat plate which is eventually to be the curved inner surface to be tested shall be polished with abrasive cloths specified in JIS R 6251 or abrasive papers specified in JIS R 6252 or JIS R 6253 successively to grain size P600 before being formed into a half tube. Preparation of RUB specimen from a plate is shown in Annex A and Annex B. The types of RUB specimens shall be No. 1 specimen, No. 4 specimen and No. 5 specimen, as specified in Annex JA.

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 in the report. Tests may be conducted on the weld metal itself or on sections containing the weld metal and heat-affected zone.

5.3 Reverse U-bending process

Reverse bending shall be performed to obtain a smooth U-shape using a special forming jig (see figures A.1 and B.1) to a reverse U-bend radius (R_{RUB}) agreed between the purchaser and the supplier. For half tube RUB specimens (No. 1 specimens), half-rod (supporting tool) of austenitic stainless steel shall be used to prevent the bending of the U-bend top part. On the other hand, for RUB specimens with a gauge section [non-pre-strained or pre-strained specimens machined to be in accordance with 14B tensile specimen specified in JIS Z 2241 (No. 2 to No. 5 specimens)], bending shall be performed directly without any supporting tool. The pressing end of the forming jig shall have a concave curvature matching that of the outer diameter of the tube, and the roll which receives the pressing jig shall have a convex curvature matching that of the inner diameter of the tube. RUB specimens shall be applied as far as reverse U-bending does not cause generation of cracks on top part of the bend. Specimens with cracks shall be discarded without being supplied for the test.

When testing RUB specimens with a gauge section (No. 2 to No. 5 specimens) (in which the stresses generated during reverse bending are lower because of reduced strain), pre-straining can be used to achieve the desired stress level (No. 3 or No. 5 specimens).

Preparation of half tube RUB specimens (No. 1 specimens) is shown in Annex A. Preparation of RUB specimens with a gauge section (No. 2 to No. 5 specimens) is shown in Annex B.

5.4 Loading with loading bolt and nut

When stressing specimens with loading bolt and nut after forming, care shall be taken to ensure that the deflection is restored beyond that at the end of the forming operation. The final form of RUB specimen tightened with loading bolt and nut shall be such that the distance between the specimen legs (L) at the loading bolt and nut is about 1 mm less than twice the reverse U-bend radius (R_{RUB}) as shown in figure 1. The final tightening shall be 2 mm at the maximum. Overloaded RUB specimens shall be discarded and loosening of the bolt and nut for readjustment shall not be performed.

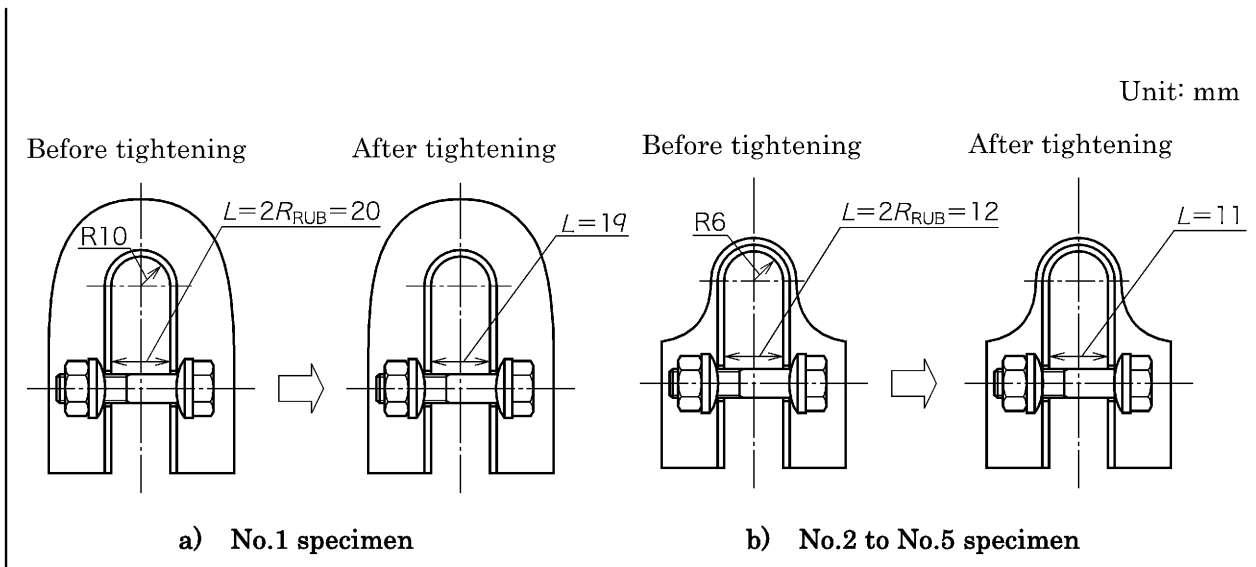


Figure 1 Example of tightening of RUB specimen and distance between specimen legs (L)

The loading bolt and nut used shall have a hog-backed or hemispherical washer. The bolting material should have a similar or lower coefficient of thermal expansion to that of the RUB specimen. In addition, the use of double nuts to reduce the likelihood of loosening of the bolts is recommended.

In a reducing or sodium hydroxide aqueous solution environment, washers of the same material as that of the RUB specimen may be used, but insulating washer made of oxidatively-treated zircalloy shall not be used in a sodium hydroxide aqueous solution environment. On the other hand, in an oxidizing high-temperature and high-pressure water environment, the RUB specimens should be tightened with loading bolts and nuts in combination with oxidatively-treated zircalloy insulating washers for enhancing the insulation quality.

6 Test procedure

The test procedure shall be as follows.

- a) **Number of specimens** A series of specimens shall be prepared to enable multiple testing under the same conditions. In order to chart the development of damage with time, examine the presence of cracks on specimens after different exposure periods. It can be useful to test a sufficient number of identical specimens for statistical evaluation at each exposure time.
- b) **Preparation of RUB specimens** The RUB specimens shall be degreased with acetone or other liquid and rinsed with ion-exchange water or ethanol and dried prior to testing. They shall be handled with care thereafter so as to be free from any contamination.

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 addi-