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Test Method for Weldability of Ocean Engineering Structural Steel

海洋工程结构钢可焊性试验方法

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1 Scope

This Document specifies the general requirements, butt welding tests, cladding tests, controlled thermal strength tests (CTS), and the like requirements for weldability tests of ocean engineering structural steel

This Document is applicable to weldability tests of ocean engineering structural steel such as steel plates with a thickness not exceeding 150mm and hot-rolled H-shaped steel with a thickness not exceeding 63mm.

2 Normative References

The provisions in following documents become the essential provisions of this Document through reference in this Document. For the dated documents, only the versions with the dates indicated are applicable to this Document; for the undated documents, only the latest version (including all the amendments) is applicable to this Document.

GB/T 229 Metallic materials - Charpy pendulum impact test method

GB/T 2651 Method of tensile test for welded joint

GB/T 2653 Bend test methods on welded joints

GB/T 3375 Welding terminology

GB/T 4340.1 Metallic materials - Vickers hardness test - Part 1: Test method

GB/T 5185 Welding and allied processes - Nomenclature of processes and reference numbers

GB/T 16672 Welds - Working positions - Definitions of angles of slope and rotation

GB/T 17505 Steel and steel products General technical delivery requirements

GB/T 19869.1 Welding Procedure Qualification Test for Steels, Nickel and Nickel Alloys

GB/T 21143 Metallic materials - Unified method of test for determination of quasistatic fracture toughness

GB/T 28896 Metallic materials - Method of test for the determination of quasistatic

a) The heating rate shall not exceed (5500/*t*)℃/h or 55℃/h, whichever is larger; where *t* is the thickness of the test plate in mm;

b) The welded specimen shall be cooled to 400℃ at a cooling rate not exceeding (6875/*t*)℃/h or 55℃/h, whichever is larger; where *t* is the thickness of the test plate in mm;

c) Air-cool to room temperature below 400℃.

5.3.6.2 For steel sheets with steel grades of Q420, Q460, Q500, Q550, Q620 and Q690 quenched and tempered (QT), the heat treatment temperature during post-weld heat treatment shall be between 550℃ and 620℃; and the maximum temperature shall be 25℃ lower than the tempering temperature specified in the quality assurance certificate. The heat treatment time shall be no less than the time calculated by 1h for every 25mm thickness of the steel or 4h. The heating rate and cooling rate shall comply with the following provisions:

a) The heating rate shall not exceed (5500/*t*)℃/h or 55℃/h, whichever is larger; where *t* is the thickness of the test plate in mm;

b) The welding specimen shall be cooled to 400℃ at a cooling rate not exceeding (6875/*t*)℃/h or 55℃/h, whichever is larger; where *t* is the thickness of the test plate in mm;

c) Air-cool to room temperature below 400℃.

5.3.7 Dehydrogenation treatment of specimen

Under necessary conditions, low-temperature dehydrogenation treatment shall be carried out on the welded specimens before the fracture mechanics test. The specific process shall be noted in the dehydrogenation treatment report.

The recommended dehydrogenation treatment process is 150℃ heat-insulation for 48h; and the dehydrogenation treatment process parameters shall be noted in the fracture mechanics test report.

In special cases, such as ultra-thick specimens, the dehydrogenation treatment process can be adjusted to reduce the hydrogen content in the specimen after consultation between the supplier and the purchaser. In this case, the dehydrogenation treatment process can increase the temperature and extend the treatment time, but the heat-insulation temperature shall not exceed 250℃.

5.4 Butt welding mechanical test

5.4.1 General requirements

Butt welding mechanical test shall comply with the provisions of Tables 5 and 6.

For hot-rolled H-shaped steel, longitudinal or transverse butt weld mechanical tests shall be carried out, as shown in Figure 1. The specimen shall be taken from 1/6 of the flange width. When the weldability test involves weld metal properties [e.g., weld metal fracture mechanics and Charpy V-notch impact toughness (*FL*-2)], the sampling position of the specimen can be determined by the supplier.

For hot-rolled H-shaped steel with flange thickness exceeding 16 mm, fracture mechanics tests can be carried out after consultation between the supplier and the purchaser.

Butt welding joint shall comply with the following mechanical test requirements:

a) Charpy V-notch impact test

The sampling position, sampling direction and impact test results of steel sheets and hot-rolled H-shaped steel impact specimens shall comply with the provisions of Tables 5 and 6, respectively. Re-inspection shall comply with the provisions of GB/T 17505.

b) Fracture mechanics test

The test shall be carried out at an ambient temperature of -10℃, and the test results shall meet the requirements of the purchaser.

c) Hardness test

In accordance with the provisions of 5.4.4, the hardness test shall be carried out on the cross section of the welded joint. The test results shall meet the requirements of Tables 5 and 6, respectively.

d) Tensile test of welded joints

The tensile test of welded joints shall meet the requirements of Tables 5 and 6. Only the tensile strength R_m shall be tested, and the test results shall be no less than the minimum tensile strength specified for the parent material.

e) Bending test of welded joints

The bending test of welded joints shall meet the requirements of Tables 5 and 6; and the length of the surface defect of the weld of the bending specimen shall not exceed 3mm.

9 – Parent material;

10 - Unchanged [b] fine grained heat affected zone (FGHAZ);

11 - Unchanged [b] coarse grained heat affected zone (GCHAZ) [Translator Note: Here it shall be (CGHAZ)];

12 – Fusion line.

[a] The area formed by multi-pass welding.

[b] The area formed by single-pass welding.

Figure 4 -- Heat affected zone of single-groove and multi-pass welding

5.4.3.3 Test requirements

Three fracture mechanics tests shall be conducted on each of the following zones:

--- Coarse grained heat affected zone (GCHAZ) [Translator Note: Here it shall be (CGHAZ)];

--- Boundary areas of subcritical heat affected zone (SCHAZ)/incomplete crystallization heat affected zone (ICHAZ);

--- When required by the purchaser, fracture mechanics tests shall be conducted on the weld metal (2mm from the fusion line).

Fracture mechanics tests shall be conducted preferentially using the displacement control method according to GB/T 21143 and/or GB/T 28896. The specimen shall be notched in the thickness direction. When the thickness of steel sheet is <75mm, a rectangular cross-section bending specimen shall be used; when the thickness of steel sheet is ≥75mm, a square cross-section bending specimen shall be used.

The specimens shall be checked for validity, and invalid specimens shall be removed and re-made. In addition to meeting the requirements of GB/T 28896, the validity of the specimens shall comply with the following provisions.

--- Coarse grained heat affected zone. For a valid test, the fatigue crack shall penetrate the coarse grained zone to the maximum extent and be within 0.5mm of the fusion line; and 75% or more of the thickness of the fractured specimen shall be the coarse grained area. The proportion of the coarse grained zone shall be noted in the test results.

--- The boundary area of subcritical heat affected zone (SCHAZ)/incomplete crystallization heat affected zone (ICHAZ). For a valid test, the fatigue crack shall penetrate the boundary area of subcritical heat affected zone (SCHAZ)/incomplete crystallization heat affected zone (ICHAZ).

5.4.4 Hardness test

Prepare two macro specimens at the positions shown in Figure 3, and conduct hardness tests on the heat affected zone and parent material at the top and root of both sides of the weld. Measure 7 points at each position, as shown in Figure 3.

The hardness indentation shall be separated from the fusion line; and its center shall be within 0.4mm from the fusion line. During the hardness test, the spacing between indentation points shall be no less than 1mm (from indentation center to indentation center); in addition to this spacing requirement, it shall also comply with the provisions of GB/T 4340.1.

All hardness tests use a test force of 98.07 N.

When requested by the purchaser, several more rows of hardness can be measured in parallel according to the spacing requirements, parallel to the previous row and separated by 1.0mm~1.5mm. The hardness indentations are staggered.

5.4.5 Tensile test of welded joint

Carry out two tensile tests of butt welded joint according to the provisions of GB/T 2651.

5.4.6 Bending test of welded joint

Carry out two transverse positive bending tests and transverse reverse bending tests of butt welded joints according to the provisions of GB/T 2653.

6 Overlay Welding Test

6.1 General requirements

The supplier shall carry out overlay welding test on steel sheets and hot-rolled H-shaped steel and measure the hardness of the heat-affected zone, and the test results can be used as:

a) Reference for classification of steel grade;

b) Evaluation of the effect of single heat input on material hardness during welding.

The purchaser shall specify the scope of application.

When used as a reference for classification of steel grade, the test specimen billet shall be taken from the same steel (the same designation, the same thickness) as the butt welding test specified in this Document. When evaluating the effect of single heat input on material hardness during welding, the test specimen billet shall be taken from the thickest steel produced in each furnace.

6.2 Test material size

The weld deposition shall not produce hydrogen-induced cracks. If necessary, preheating, inter-pass temperature control and post-heating measures may be adopted.

The welding materials for welding constrained welds shall be dried according to the material instructions to control the hydrogen content as low as possible. The welding materials and drying conditions shall be recorded in detail.

Check the bolt torque on the test device according to Table 8 and tighten as required. The test device shall be placed for 12h before the welding test.

7.3.2 Test welds

Two welds shall be made on the steel sheet of the test device, as shown in Figure 8; and welding materials with the same or higher yield strength than the test steel plate shall be used. The test device shall be preheated in a suitable furnace before welding. The surface temperature of the weldment shall be measured before welding; and the temperature difference between the upper and the lower sheets shall not exceed 5°C.

According to the provisions of GB/T 5185, the test weld shall be horizontally welded by electrode arc welding (111), self-shielded flux-cored arc welding (114) or gas metal arc welding (13). The welding device shall be at an angle of 45° to the horizontal direction, as shown in Figure 9. The heat input of the test weld is 1 kJ/mm. The welding material shall be dried according to the instructions to ensure that the hydrogen content of the welding material deposition metal is controlled within 3 mL/100g~5mL/100g or 10mL/100g~15mL/100g. The supplier shall select any hydrogen content level and weld under the selected hydrogen content level. During welding, welding parameters such as voltage, current, welding speed and drying conditions of welding materials shall be recorded.

After the first test weld is deposited, the unwelded side of the test shall be immediately placed vertically in flowing cold water at a depth of (60±5) mm, as shown in Figure 10; and taken out after cooling to room temperature. The same process shall be adopted for the second test weld.

There shall be at least 72 h intervals between the second test weld and the first test weld, and between the second test weld and the time of cutting the sample.

7.4 Evaluation of weld

Cut the test weld and observe the cross section metallographically, as shown in Figure 11. Prepare 6 specimens, polish the surface, and observe the metallographic structure after etching. Observe whether there are cracks in the heat-affected zone and weld metal at least at 50 times. If no cracks are observed, magnify it to 200 times for further confirmation.

First, take the middle specimen for observation.

If cracks are found, the length of the crack shall be measured according to GB/T 28896. If the length of a single crack is less than 5% of the weld leg size (see Figure 12), it can be judged as

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