Materials and Qualification Procedures for Ships

Procedure 0-3
Guidelines for Weldability Tests

1 Introduction

1.1 Scope

1.1.1 The weldability tests set out in this document are to be made when required by other Material Qualification Procedures. The tests are:

(a) Bead-on-plate tests for hardness assessment.
(b) Butt weld tests.

1.2 Related Rules

1.2.1 Reference is made in these guidelines to LR's Rules and Regulations for the Classification of Ships (hereinafter referred to as the Rules for Ships).

1.2.2 LR's Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as the Rules for Materials).

2 Information required for approval

2.1 General

2.1.1 The following details are required for each cast of steel:

(a) Steelmaking process, including de-oxidation procedure, degassing and desulphurisation procedures, etc.
(b) Ladle chemical analysis, including residual elements.
(c) Method of casting, including slab or ingot and discard dimensions.
(d) Dimensions of finished plate.
(e) Heat treatment and rolling procedure.

2.1.2 The approved composition range is to be stated, and is to include full details of the grain refining elements in the steel.
3 Test procedures

3.1 General

3.1.1 At least two plates, tubes or sections from different casts are to be submitted for test. They are to have chemical compositions, mechanical properties and manufacturing routes typical for the material the manufacturer intends to supply in production.

3.1.2 The material for the weldability evaluation is to be selected from products with carbon equivalent values within 0.025 per cent of the maximum permitted by the specification and are to be in the specified condition of heat treatment.

3.1.3 At least one test sample is to be cut from each end of the product submitted for evaluation.

3.1.4 Weldability is to be assessed by means of both of the tests listed in 1.1.1.

3.2 Bead-on-plate test

3.2.1 The tests are to be carried out on plate representing the maximum thickness for which approval is required.

3.2.2 Each test sample is to have a minimum length of 300 mm and a minimum width of 150 mm.

3.2.3 The bead-on-plate weld is to be made using an automatic autogenous GTAW welding procedure which includes the following conditions:

   (a) Welding position Flat
   (b) Electrode diameter 2.4 mm
   (c) Arc voltage 10 ± 0.5 V
   (d) Polarity DCEN (Straight)
   (e) Current 200 ± 5 A
   (f) Travel speed 120 ± 5 mm/min
   (g) Maximum preheat 125°C

3.2.4 All testing is to be carried out on the welded samples in the as welded condition.

3.2.5 Cross-sections are to be cut through the weld at 100 mm from each of its ends, as shown in Fig. 0-3.3.1(a). The sections are to be polished and etched to allow the hardness test machine operator to identify the fusion line, the heat affected zone (HAZ), and the grain coarsened region of the heat affected zone (GCHAZ). Vickers hardness indentations are to be made using a maximum of 10 kg indenting load. The load actually used to make valid indentations shall be chosen so that the diagonal measurement of the indentation does not exceed 0.25 mm (normally an ocular reading of 250). Valid indentations will also be located entirely within the 0.5 mm wide GCHAZ adjacent to the fusion line as indicated in Fig. 0-3.3.1(b).

3.2.6 A minimum of five valid hardness indentations are to be reported for each cross-section. The report is to show the indentation sizes, the indenting load and the interpreted hardness value (HV) for each identified section. For each section, the average of the three highest values is also to be reported.

3.2.7 For steels with a specified minimum yield strength not exceeding 355 N/mm², or a tensile strength not exceeding 520 N/mm², and for normalized or thermomechanically treated
fine grain steels with a specified minimum yield strength in excess of 355 N/mm², the reported average hardness values are not to exceed 380 HV.

3.3 Tests on butt welds

3.3.1 Butt weld assemblies are to be welded with the following welding parameters:

(a) A fully mechanised (automatic) multi-run weld using welding conditions to give a calculated heat input rate (sometimes referred to as the `Arc Energy') of 1.5 kJ/mm ± 0.1 kJ/mm,

(b) A full mechanised (automatic) multi-run weld with welding conditions to give a calculated heat input rate of 5.0 kJ/mm ± 0.2 kJ/mm,

and where a steel is to be approved for heat input in excess of 5.0 kJ/mm

(c) A full mechanised (automatic) weld with welding conditions to give a calculated heat input rate equal to the maximum to be approved.

The heat input rate, E, is to be calculated using the following formula:

\[ E = \left( \frac{VI}{W} \right) \times 10^{-3} \text{ kJ/mm} \]

where

\[ V = \text{arc voltage, in volts} \]
\[ I = \text{welding current, in amperes} \]
\[ W = \text{welding travel speed, in mm/s} \]

Weld procedures are to be submitted for review.

3.3.2 The welds are to be made in accordance with normal fabrication practices, but a square edge preparation is to be used for one side of the joint preparation. The individual beads are to be carefully placed so as to create a sequence of overlapping heat affected zones in which not less than 15 per cent of the total grain coarsened area along the square edge side of the joint consists of un-reheated (non-tempered) microstructure.

3.3.3 The test welds are to be made on the thickest plate for which approval is required. Separate approvals are required for the Ingot and Concast manufacturing routes.

3.3.4 If the product is intended to be weldable in both the as welded and post-weld stress relief heat treated (PWSRHT) conditions, test weld sets are to be made and tested in both conditions.

3.3.5 The butt weld tests are to include at least one cross weld tensile, a set of Charpy V-notch impact tests (located at the fusion line, fusion line plus 2 mm, fusion line plus 5 mm and fusion line plus 20 mm), hardness tests HV5 and photomacrographs of the weld cross section representing each assembly.

3.3.6 The test sample locations of Charpy V-notch specimens for each welded assembly are to be as shown in Fig. 0-3.3.2. The cutting of each assembly to prepare the individual test specimens can use any technique, provided that any thermal cutting is at least 20 mm from the position of any finished specimen.
3.3.7 The hardness survey on each sample is to follow the requirements of 3.2.5 and 3.2.6 except in respect of the location and number of indentations to be made, and their reporting. Fig 0-3.3.3 shows how the indentations are to be placed adjacent to the weld beads at the toes of the butt welds. For each butt weld cross-section, there are to be at least three valid indentations in the GCHAZ adjacent to each of the four toe positions. The results for each toe position are to be grouped, and the highest value in each group is to be highlighted. The location of each group reported is to be identified.

3.3.8 The highlighted values are not to exceed the values specified in Ch 12 of the Rules for Materials.

3.3.9 The detailed positions of the Charpy V-notch impact test specimens are shown in Fig. 0-3.3.2. Each of the 18 positions indicated represents a set of three specimens, which are to be tested at a temperature 20°C higher than that corresponding to the approval grade of the respective steel product. See Ch 3 of the Rules for Materials.

3.3.10 The Charpy V-notch test results are to be not less than those specified Ch 3 of the Rules for Materials for the corresponding parent steel grade.

3.3.11 Where CTOD tests are required, specimens are to be prepared from the positions shown in Fig. 0-3.3.2, but only in respect of the square edge side of the joint, i.e. a total of three positions for each welded assembly. Three specimens are to be prepared from each position.

3.3.12 Each CTOD specimen is to be tested at 0°C using the procedure given in Ch 2,6 of the Rules for Materials. The results are to be reported in detail, showing all specimen and test measurements. Individual calculated CTOD values reported are to be not less than 0,15 mm.
Fig. 0-3.3.1(b)
Example showing location of hardness indentations on bead-on-plate welds

Fig. 0-3.3.2
Location of Charpy V-notch impact and CTOD specimens

Where \( t \) is the plate thickness and \( D \), the specimen size = 10 mm and FL is the Fusion Line.
Fig. 0-3.3.3
Example showing locations of hardness testing in the weld, heat affected zone and parent metal of a butt weld