



## CLASSIFICATION NOTES

No. 30.10

# EXTRA HIGH STRENGTH STEEL MATERIAL NV 47 FOR HULL STRUCTURAL APPLICATION IN CONTAINER SHIPS

MAY 2011

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DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

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### Background

This new document has been issued to manage risk of applying the extra high strength steel material NV 47. Over the last years, the container ships have grown significantly in size. In order to comply with requirements for hull girder strength, thicker and thicker plating has been applied in upper hull structure of container ships. As an industrial innovation, extra high strength steel material with specified minimum yield stress 460 N/mm<sup>2</sup> has been introduced in order to reduce the plating thickness of upper hull structure, especially hatch side coaming.

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## 1. General

This Classification Note describes the supplementary requirements for extra high strength steel material NV 47 with specified minimum yield stress  $460\text{N/mm}^2$  used for hull structural application in container ships. Unless otherwise stated in this Classification Note, DNV Rules for Classification of Ships/High Speed, Light Craft and Naval Surface Crafts shall be applied.

## 2. Application

The application of the extra high strength steel material NV 47 is limited to structural members of the upper hull structure of container ships with as-built plate thickness up to 100 mm in the purpose to satisfy the hull girder bending strength as specified in Rules Pt.3 Ch.1 Sec.5 C and the hull girder combined bending and torsion strength as specified in Rules Pt.5 Ch.2 Sec.6 B.

For ship types other than container ships, the application of this steel material shall be evaluated by and agreed with the Society on a case by case basis.

### 2.1 Material factor $f_1$

The material factor  $f_1 = 1.61$  shall be used for the extra high strength steel material NV 47 in the various formulae for scantlings and in expressions giving allowable stresses.

### 2.2 Material grade

The material grade for the extra high strength steel material NV 47 shall be in accordance with Rules Pt.3 Ch.1 Sec.2 Table B1 "Material classes" as for high strength steel material, with the following exceptions:

- The as-built plate thickness is limited to 100 mm as the maximum value.
- The material grade (as specified in the material certificate) is the minimum quality for thickness above 50 mm in any cases.

## 3. Fatigue

For the upper hull structure built with extra high strength steel material NV 47, special attention shall be paid to the fatigue strength as described below, in addition to relevant requirements in Rules Pt.5 Ch.2 Sec.6, Classification Note 31.7 "Strength Analysis of Hull Structures in Container Ships" (CN 31.7), and Classification Note 30.7 "Fatigue Assessment of Ship Structures" (CN 30.7).

### 3.1 Butt welded joints

The butt welded joints in the hatch side coaming top and side plates shall be shifted from the butt welded joints of upper deck structures by a minimum distance of 500 mm in ship's longitudinal direction.

The requirement for the shift may be waived for block joints, provided that the upper hull structure is inspected by NDT during construction stage according to Table 7-1, regardless of steel material grade and strength group applied in the upper hull structure. In this case the upper hull structure refers to structural members as followings:

- hatch side coaming
- upper deck
- sheer strake
- upper strake of longitudinal bulkhead.

The butt welded joints in the hatch side coaming and in the upper deck shall be kept away from hatch corners as far as practical. The distance between such a butt weld joint to the termination point of hatch corner curvature shall be at least 500 mm in the ship's longitudinal and transverse directions respectively.

Butt welded joints in the hatch side coaming top plate shall be analysed to show sufficient fatigue strength, at least 20 years of fatigue life in worldwide service, in accordance with CN 30.7. The hull girder loads due to vertical wave bending moment, horizontal wave bending moment and wave torsion moment shall be considered. The stress range shall be calculated in accordance with CN 31.7. The stress concentration factor shall be calculated according to CN 30.7 Appendix A, Table A-5.

In vicinity of the butt welded joints in the hatch side coaming and in the upper deck, between 500 mm aft and 500 mm forward in ship's longitudinal direction, the weld connection of hatch side coaming to upper deck and longitudinal bulkhead to upper deck shall be at least of partial penetration type with a maximum root face of  $1/3$  of the abutting plate gross thickness.

### 3.2 Hatch corner

Hatch corner in the hatch side coaming top plate and in the upper deck shall be analysed to show sufficient fatigue strength in accordance with CN 30.7. The stress range shall be calculated in accordance with CN 31.7. The hot spot stress at the hatch corner shall be obtained by finite element analysis according to the procedure required for Level 2 or Level 3 analysis as described in CN 31.7.

### 3.3 Grinding of Hatch side coaming top

The free edge of hatch side coaming top plate shall not have any defects such as notches.

The upper and lower edges of the hatch side coaming top plate in way of the butt welded joints and the hatch corners shall be ground smooth with a radius of 2 ~ 5 mm. The grinding shall be to the minimum extent of 100 mm forward and aft of the butt welded joints. For hatch corners, the grinding shall be applied to whole hatch corner curvature and shall be extended to a point minimum 100 mm away from termination point of hatch corner curvature.

Remaining upper and lower edges of the hatch side coaming top plate shall be ground smooth, with a radius of 2 mm as minimum.

Butt welded joint edges at upper and lower sides of the hatch side coaming top plate shall be ground smooth.

For stiffeners on the hatch side coaming top plate, the grinding shall be carried out similarly as described above.

### 3.4 Outfitting details

For weld connections of smaller outfitting such as holders to hatch side coaming, if the welding is in a rectangular or polygonal or similar shape where good workmanship is difficult to achieve in the corners, circular doubling plates are required in order to achieve good workmanship. The doubling plate should be in a dimension and with a thickness as small as practical. The thickness shall be limited to 10 mm as a maximum value. The material grade of doubling plates shall be at least AH32.

For hatch cover pads welded to hatch coaming top plate, when the thickness of pads exceeds 25 mm, a taper not exceeding 1:3 shall be applied in order to reduce the stress concentration on hatch coaming top plate.

Welding for fixing outfitting items to the hatch coaming top plate shall be avoided in the area close to hatch corner to the extent 500 mm away from the termination point of hatch corner curvature, in the ship's longitudinal and transverse directions respectively. This may be achieved by applying flexible hatch cover pads without attachments to the hatch coaming top plate. However such a welding may be accepted, provided that the weld profile is ground smooth or treated in alternative equivalent means accepted by the Society.

## 4. Materials

### 4.1 Introduction

This section specifies requirements for hot rolled steel plates to be used in construction of hull structures. The requirements apply to plates of extra high strength steel material NV 47 not exceeding 100 mm in thickness.

Unless otherwise stated in this chapter, DNV Rules for Classification of Ships Pt.2 Ch.1 and Pt.2 Ch.2 Sec.1 A shall be applied.

### 4.2 Scope

Provision is made for the strength level with specified minimum yield stress 460 N/mm<sup>2</sup>. The strength level is further subdivided into two grades based on the specified impact toughness.

### 4.3 Manufacture

All materials shall be made at works approved by the Society for the grade of steel being supplied and for the relevant steel making and process route. The suitability for forming and welding is to be demonstrated during the initial approval tests at the steel works. Weldability test is to be carried out in accordance with Standard for Certification No.2.9, approval programme.

### 4.4 Condition of supply

The extra high strength steel material NV 47 may be supplied in N (normalised), TM (thermo-mechanical rolling) or QT (quenched and tempered) condition.

### 4.5 Chemical composition

#### 4.5.1 General

The chemical composition of each heat shall be determined on a sample taken preferably during the pouring of

the heat and shall be within the specified limits given in Table 4-1.

The chemical composition and deoxidation practice shall comply with the limits given in Table 4-1. The steel grades shall be killed and fine grain treated.

#### 4.5.2 Carbon equivalent value

The carbon equivalent value shall be calculated from the heat analysis using the formula below and is to meet the requirements given in Table 4-1:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\%)$$

#### 4.5.3 Cold cracking susceptibility

The cold cracking susceptibility shall be calculated by using the formula below and is to meet the requirements as given in Table 4-1:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B \quad (\%)$$

### 4.6 Mechanical properties

The mechanical properties shall comply with the limits given in Table 4-1.

### 4.7 Testing

#### 4.7.1 Test material and test pieces for mechanical testing

Test material shall be fully representative of the sample product and, where appropriate, shall not be cut from the sample product until heat treatment has been completed.

Test material shall be suitably marked to identify them with the products represented.

Test material and test pieces for mechanical testing shall comply with the relevant requirements of Pt.2 Ch.1 and Pt.2 Ch.2 Sec.1 A600.

For NV 47 material each piece shall be tensile and impact tested. A piece is understood to mean the rolled product from a single slab, billet or ingot if this is rolled directly into plates or sections.

#### 4.7.2 Tensile testing

The dimensions of the tensile test pieces shall be in accordance with Pt.2 Ch.1. Generally and unless otherwise agreed, flat test pieces of full product thickness shall be used.

Unless otherwise agreed, for each test unit presented, one tensile test shall be made from one sample product unless the weight of finished material is greater than 50 tonnes, in which case one extra test shall be made from a different sample product from each 50 tonnes or fraction thereof. Additional tests shall be made for every variation of 10 mm in the thickness of products from the same test unit.

#### 4.7.3 Impact testing

The impact test pieces shall be of the Charpy V-notch type cut with their longitudinal axes transverse to the final direction of rolling of the material.

The notch shall be cut in a face of the test pieces which was originally perpendicular to the rolled surface. The position of the notch shall not be nearer than 25 mm to a flame cut or sheared edge.

For thicknesses equal to or below 50 mm, the impact test pieces shall be taken not less than 2 mm below the surface. For plate thicknesses exceeding 50 mm, impact test pieces shall be situated so that the distance between the centre-line of the test piece and the plate surface is not less than 1/4 of the plate thickness.

The average energy value from each set of three impact tests and the single values shall comply with the appropriate requirements of Table 4-1 for extra high strength steel material NV 47. Further, only one individual value within each set may be below the specified minimum average value, but not lower than 70% of this value.

#### 4.7.4 Steel grades with specified through thickness properties

Supplementary requirements for steel grades with specified through thickness properties – “Z” grade steel shall refer to DNV Rules for Classification of Ships Pt.2 Ch.2 Sec.1 E.

Table 4-1 Requirements for extra high strength steel material NV 47	
Grade	NV D47 NV E47
Deoxidation	Killed and fine grain treated
<i>Chemical composition (ladle analysis, maximum weight% unless range stated)</i>	
C	0.12
Si	0.10 to 0.50
Mn	1.65
P	0.020
S	0.008
Cu	0.50
Cr	0.25
Ni	1.00
Mo	0.25
Al (total) <sup>2)</sup>	0.06
Nb <sup>3)4)</sup>	0.04
V <sup>3)4)</sup>	0.08
Ti <sup>4)</sup>	0.05
N	0.010
B <sup>5)</sup>	0.0005
C <sub>eq</sub> (t ≤ 50)	0.46
C <sub>eq</sub> (50 < t ≤ 100)	0.49
P <sub>cm</sub>	0.22
<i>Tensile Test</i>	
Tensile strength(N/mm <sup>2</sup> )	570 to 720
Yield stress (N/mm <sup>2</sup> )	460
Elongation, A <sub>5</sub> (%)	19
<i>Impact test, Charpy V-notch</i>	
Test temperature (°C)	
Grade NV D47	-20
Grade NV E47	-40
Minimum average energy (J) Longitudinal	60
Minimum average energy (J) Transverse	42
Minimum average through thickness ductility Z <sub>z</sub> (%)	35
1) When scrap material is being used in steel production, the amount of the following residual elements shall be determined and reported and the levels shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca. 2) Al:N ≥ 2:1 (not applicable for titanium killed steel). 3) (Nb+V) <sub>max</sub> : 0.09%. 4) (Nb+V+Ti) <sub>max</sub> : 0.13%. 5) Boron (maximum 30 ppm) may be added subject to agreement.	

#### 4.8 Fracture mechanics (FM) testing

The material toughness of NV47 material shall be evaluated by fracture mechanics testing for thickness' exceeding 50 mm. The crack tip opening displacement, CTOD, technique shall be used. Both base material, heat affected zone and weld material are to be tested. The requirements for FM are defined in Offshore Standard DNV-OS-C401 Ch.2 Sec.1 C900.

## 4.9 Inspection, tolerances, repair, identification and certification of materials

The requirement to inspection, tolerances, repair, identification and certification of materials are defined in Pt.2 Ch.2 Sec.1.

## 5. Welding

### 5.1 Introduction

The requirements in this chapter are applicable to the extra high strength steel material NV 47 with a thickness not exceeding 100mm.

Unless otherwise stated in this chapter, DNV Rules for Classification of Ships Pt.2 Ch.3 shall be applied.

### 5.2 Basic requirements

Welding shall be carried out by certified welders, with approved welding procedures and type approved welding consumables, and at builders as outlined in Pt. 2 Ch.3. Welders and welding procedures approved for the type of connection and parent material in question as given in Sec.3 and Sec.5, respectively, shall be used.

Wherever possible, multi-pass welding shall be applied.

### 5.3 Welding consumables

Welding consumables shall be type approved in accordance with Standard for Certification No.2.9, Type approval programme.

All welding consumables shall have identifiable marking.

Covered electrodes for welding of NV 47 material shall satisfy a hydrogen test requirement for the suffix H5, i.e.  $H_{DM} \leq 5$  ml/100 g in weld metal.

Table 5-1 shows welding consumables that can be applied for NV 47 material.

<b>Table 5-1 Grade of welding consumables for NV 47 material</b>	
<i>Grade of welding consumables</i>	<i>As-built thickness <math>t</math> in mm for NV 47 material</i>
4/IV Y46	$t \leq 50$
5/V Y46	$50 < t \leq 100$

### 5.4 Welding procedures

#### 5.4.1 General

Welding procedures specifications, WPS, with supporting welding procedure qualification tests record WPQR, for extra high strength steel material NV 47 shall be approved by the Society. Preparation and welding of test pieces shall be carried out in accordance with the WPS and under the general condition of production welding which it represents.

#### 5.4.2 Transverse tensile test

The tensile strength shall not be below the specified minimum tensile strength for the steel grade in question, i.e. 570 N/mm<sup>2</sup>.

#### 5.4.3 Bend test

The test specimens shall be bent on a mandrel with diameter  $4xt$ , where  $t$  is the thickness of the specimen. The bending angle shall be at least 180°.

#### 5.4.4 Macro section and hardness testing

The hardness testing shall be in accordance with ISO 6507/1 or equivalent. Normally, the Vickers method (HV10) is used.

For NV 47 material a maximum hardness limit of 380 HV10 shall be met.

#### 5.4.5 Impact testing

For NV 47 material the Charpy V-notch test temperature and the average value for absorbed energy in weld metal, fusion line and HAZ shall be the same as required for the NV 47 material in transverse direction as specified in Table 4-1.

## 6. Fabrication

### 6.1 General

Unless otherwise stated in this chapter, DNV Rules for Classification of Ships Pt.2 Ch.3 Sec.6 shall be applied.

### 6.2 Assembly, welding, repairs, inspection and tolerances

If applicable, pre-heating shall be applied prior to any welding, including tack welding, in accordance with agreed procedures. The pre-heating temperature shall be measured at a distance of minimum 75 mm from the edges of the groove at the opposite side of the heating source when practically possible.

Preheating shall preferably be performed with electric heating elements.

All fabrication welding shall be performed within the limits of essential variables of the qualified welding procedure. This also includes tack welding, seal welding, welding of lifting lugs and attachment welds as well as repair welding.

Verification of the WPS during welding shall be carried out and recorded.

Gouging shall be followed by grinding to remove any carburised layer. In doubtful cases proof of satisfactory performance of gouging may be required. Arc strikes shall be repaired by mechanical removal of affected base material followed by Magnetic particle testing, MT, to verify absence of cracks.

When deemed necessary, welding production tests (WPT) shall be made during fabrication of welds to verify that the produced welds are of acceptable quality.

## 7. Non-destructive testing of welds

### 7.1 Introduction

The requirements in this chapter are applicable to welded joints for structural members of the upper hull of container ships made from extra high strength steel material NV 47 with a thickness not exceeding 100mm.

Unless otherwise stated in this chapter, DNV Rules for Classification of Ships Pt.2 Ch.3 Sec.7 and Classification Notes No.7 shall be applied.

Final inspection and NDT shall not be carried out before 48 hours after completion.

NDT procedures for testing of welded joints during periodical surveys have to reflect the surface condition. If the specified sensitivity requirements can not be obtained, the painting has to be removed. Normally ultrasonic testing, UT, can be performed on painted surfaces.. The loss of sensitivity has to be compensated by performing transfer correction.

Magnetic particle testing, MT, may be replaced by eddy current, ET.

### 7.2 Extent of NDT

#### 7.2.1 Extent of NDT during construction stage

During construction stage, extent of NDT on welds of NV 47 material shall be at least as specified in Table 7-1.

<i>Testing method</i>	<i>Type of connection</i>	<i>Extent</i>
Visual Inspection, VT	All weld joints	100%
Magnetic particle testing, MT	Transversely or vertically orientated butt and T-joints, (full penetration, partial penetration and fillet welds) Longitudinally orientated joints	100% 20%
Ultrasonic testing, UT	Butt- and T-Joints of full penetration	100%

#### 7.2.2 Extent of NDT during Ship in Operation stage

During Ship in Operation stage, in the first periodical surveys after 10 years of delivery and then in the periodical surveys every 5 years, extent of NDT on welds of NV 47 material shall be at least as specified in Table 7-2. Based on the results of VT and MT, UT may be required at additional locations selected by the Society.

<i>Testing method</i>	<i>Type of connection</i>	<i>Extent</i>
Visual Inspection, VT	All weld joints	100%
Magnetic particle testing, MT	Transversely or vertically orientated joints	100%
Ultrasonic testing, UT	Butt-joints of full penetration of hatch side coaming top at the location of block joints	100% <sup>1)</sup>

1) only required if there is access from one side only.