RECOMMENDED PRACTICE
DNV-RP-C101

ALLOWABLE THICKNESS DIMINUTION FOR HULL STRUCTURE OF OFFSHORE SHIPS

APRIL 2007

DET NORSKE VERITAS

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

DNV Offshore Codes consist of a three level hierarchy of documents:

— *Offshore Service Specifications.* Provide principles and procedures of DNV classification, certification, verification and consultancy services.
— *Offshore Standards.* Provide technical provisions and acceptance criteria for general use by the offshore industry as well as the technical basis for DNV offshore services.
— *Recommended Practices.* Provide proven technology and sound engineering practice as well as guidance for the higher level Offshore Service Specifications and Offshore Standards.

DNV Offshore Codes are offered within the following areas:

A) Qualification, Quality and Safety Methodology

B) Materials Technology

C) Structures

D) Systems

E) Special Facilities

F) Pipelines and Risers

G) Asset Operation

H) Marine Operations

J) Wind Turbines

Amendments and Corrections

This document is valid until superseded by a new revision. Minor amendments and corrections will be published in a separate document normally updated twice per year (April and October).

For a complete listing of the changes, see the "Amendments and Corrections" document located at: http://www.dnv.com/technologyservices/, "Offshore Rules & Standards", "Viewing Area".

The electronic web-versions of the DNV Offshore Codes will be regularly updated to include these amendments and corrections.

Introduction

The application of the principles for assessment of offshore ships in operation or for tankers candidates for conversions to FPSO/FSO has until now, not been described in any document.

It is thus a need for a document that clearly describes the principles and application for determining the allowable thickness diminution of the different elements in the hull structure.

CONTENTS

1. Introduction

The principles for determining the allowable thickness diminution of the different elements in the hull structure are developed under consideration of the following aspects:

— The principles are applicable to units in world wide service as well as in benign waters.
— The newbuilding may have been designed to comply with the main class requirements to hull girder section modulus.
— The newbuilding may have been designed for specific sites. In benign waters the section modulus will in such cases be lower than the main class requirements. In harsh environments the required section modulus will be higher than the main class requirements.
— The minimum thickness list shall, be as far as possible, be based on the same principles for structural assessment as newbuildings, without too complicated calculation procedure.
— Harmonised with the ship rules as far as possible.

2. Definitions

M_D = Design bending moment

M_S = Characteristic still water bending moment

M_W = Characteristic wave bending moment

Q_D = Design shear force

Q_S = Characteristic still water shear force

Q_W = Characteristic wave shear force

Z_{Act} = Section modulus based on as-measured thickness

Z_{New} = Section modulus based on as-build scantlings (gross)

t_k = Corrosion allowance according to the Ship Rules

Z_0 = Minimum section modulus according to main class requirements (based on gross thickness)
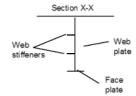
Z_{Org_Net} = Section modulus of stiffener based on as-build scantlings minus Z_k

t_{Org} = Plate thickness based on as-build scantlings (gross)

t_{Org_Net} = Plate thickness based on as-build scantlings minus t_k

t_{r_local} = Local net thickness rule requirements

t_{F-New} = The as-build plate flange thickness (gross) of transverse web frames where both flanges participate in the longitudinal strength. The smaller thickness of the two flanges to be used.

t_{F-Act} = The as-measured flange plate thickness of transverse web frames where one or both flanges participate in the longitudinal strength.
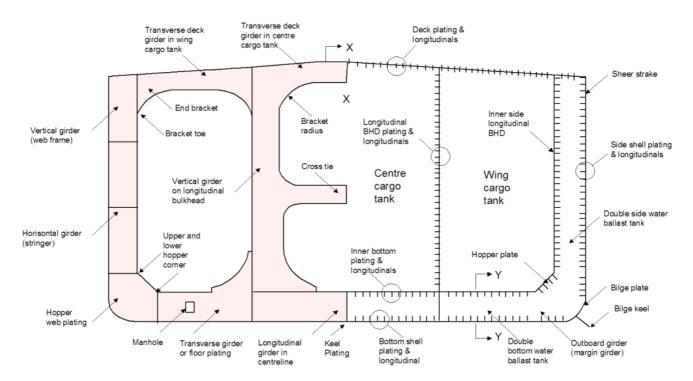
Figure 2-1
Typical midship section

3. Categories of Corrosion

Corrosion may be divided into the categories General, Pitting, Grooving and Edges.

General:

Where uniform reductions of material are found. Criteria for minimum thickness of hull structural elements may be applied in order to determine average diminution values. Typically, repairs will include steel replacement to original scantlings and/or reinforcement upon special consideration.

Pitting:

Random scattered corrosion spots/areas with local material reductions. The intensity of the pitting must first be estimated before applying criteria. Typically, repairs will include renewal of plates, building up pits by welding.

Grooving:

Local line material loss normally adjacent to welding joints along abutting stiffeners and at stiffener or plate butts or seams. Due to the complexity and effects of groove corrosion, diminution criteria are limited and special repair considerations are required.

Edges:

Local material wastage at the free edges of plates and stiffeners. Typically, if not renewed, repairs may be carried out by means of edge stiffeners/doublers.

For each of the corrosion categories separate assumptions, criteria and typical repairs should be applied as given in relevant chapters.

4. Principles

Offshore ships are designed for site specific environments. Therefore the minimum thickness list is only valid for the geographical areas with environments less or equal to the design basis. New minimum thickness may be calculated for ships intended to operate in new locations with less severe environments. If the environment at the new location is more severe, new minimum thicknesses are required. The aim of the procedure described below is to ensure the same probability of failure throughout the entire life.
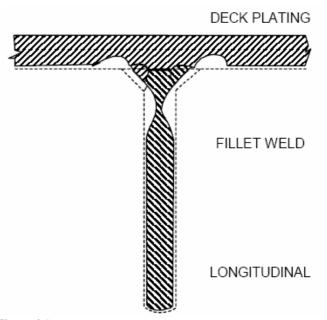
Figure 4-1
Typical grooving corrosion in stiffener connection

In principle the minimum thickness can be determined based on the actual hull girder ULS capacities and local structural element requirements employing scantlings expected at the next survey. However, this may be a rather time consuming process as the measured thickness may vary considerable over the length and breadth of the ship implying that global stress and local capacities changes. A more easy-to-use procedure is therefore outlined in this Recommended Practice.

Hull girder bending moment, shear and local structural capacities are checked.

The ULS loads applied are determined according to DNV-OS-C102 Ch.1.

Units operating only in benign waters and also comply with the main class requirements to section modulus, may alternatively be assessed according to Classification Notes 72.1. In such cases the Ship Rules Pt.3. Ch.1 or Ch.2 regarding wave bending moments and shear forces are to be applied.

The minimum thickness within 0.4L amidships are determined according to the following flow:

Figure 4-2
Flow diagram for bending moment and shear capacity checks

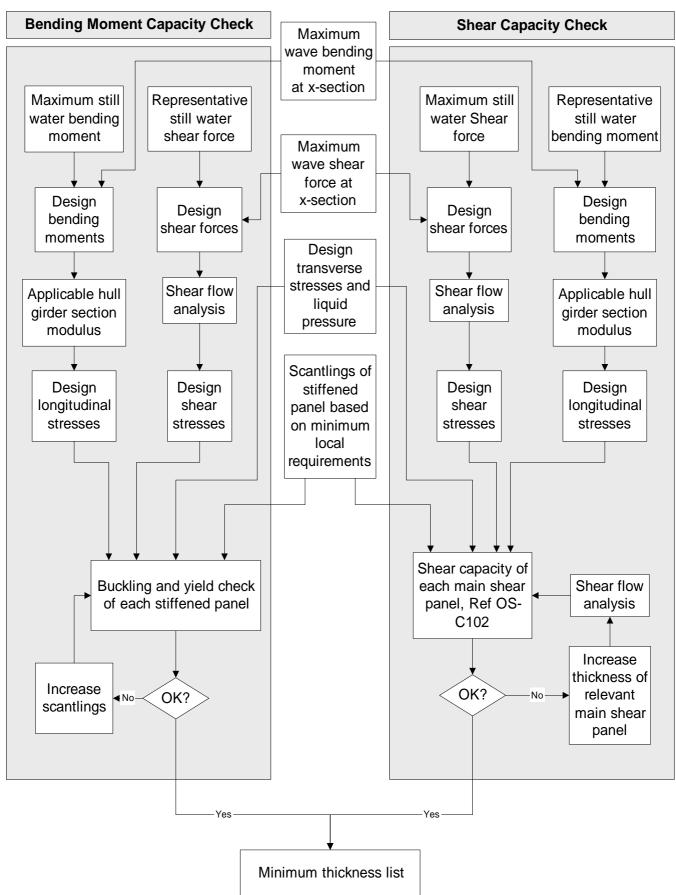# 5. Structure within 0.4L Amidships

5.1 Hull girder longitudinal elements (contributing to hull girder section modulus)

5.1.1 Loads

The design bending moments and shear forces are calculated according to DNV-OS-C102 Ch.1.

a) load combination

$$M_D = 1.2\, M_S + 0.7\, M_W$$
$$Q_D = 1.2\, Q_S + 0.7\, Q_W$$

b) load combination

$$M_D = 1.0\, M_S + 1.15\, M_W$$
$$Q_D = 1.0\, Q_S + 1.15\, Q_W$$

5.1.2 Hull girder longitudinal stress

The longitudinal stress applied in the global capacity assessment are determined according to:

$$\sigma_l = \frac{M_D}{0.9\, Z_{New}}$$

or

$$\sigma_l = \frac{M_D}{0.95\, Z_{Act}}$$

if relevant thickness measurements exists.

The section modulus shall not be taken less than $0.75 \cdot Z_0$.

5.1.3 Hull girder transverse stress

The transverse stress are mainly due to bending of the transverse web frames. For web frames where one or both flanges participate in the longitudinal strength, the stress applied in the capacity checks may be determined according to:

$$\sigma_l = 1.25\, \sigma_{t\_new}$$

or

$$\sigma_l = \frac{t_{F-New}}{t_{F-Act}}\, \sigma_{t\_new}$$

if relevant thickness measurements exists.

t_{F-Act} to be take as the smaller thickness of the two flanges.

5.1.4 Hull girder shear stress

The hull girder shear stress in is to be determined by means of shear flow analysis where the scantlings of the main shear panels like side, inner side and longitudinal bulkheads are based on local minimum requirements. If relevant thickness measurements exist, the shear flow and shear stress may be are based on actual thickness minus corrosion margin 'm' unto next hull survey.

5.1.5 Buckling and yield capacity control of each stiffened panels

Each stiffened panel in the cross section shall be checked for buckling and yield capacities subjected to global longitudinal, transverse and shear stress as well as lateral pressures in the

same manner as for the newbuilding. Buckling are to be assessed according to DNV-RP-C201 *Buckling Strength of Plated Structures* or equivalent. Both global and local buckling modes shall be controlled.

The stresses used are determined according to 5.1.2, 5.1.3 and 5.1.4.

The thickness of plates and stiffeners (webs and plate flanges) is not to be less than:

$$t_{min} = k \cdot t_{r\_local} + m$$

where

k	= Diminution coefficient from Table 5-1 and Table 5-2
m*	= Corrosion margin until next hull survey
	= 0.5 in general
	= 0 for t_k less or equal to 1.0 mm

* The value of m shall be specially considered if the unit is not following normal Class survey periods.

In addition, the load independent rule minimum thickness requirements, multiplied by 0.9, given for the different structural members are to be complied with. (e.g. for keel plate the thickness is not to be less than:

$$0.9\left(7.0 + \frac{0.05 \cdot L_1}{\sqrt{f_1}} + t_k\right)$$

Table 5-1 Longitudinal members

Structural component	Diminution coefficients "k"
Plating	0.80
Stiffeners	0.75
Girders and stringers	0.80

5.2 Transverse elements

The minimum thickness for transverse elements are determined according to Table 5-2.

Table 5-2 Transverse members

Structural component		Diminution coefficients "k"
Transverse bulkheads		
Plating		0.80
Frames / stiffeners	Web	0.8
	Flange	0.8
Web frames / Floors / Girders and stringers 1)	Web	0.8
	Flange	0.8
Cross ties web and flange		0.85
Hatch covers / coamings	Plate	0.8
	Stiffener	0.8
1) Flanges on transverse members contributing to hull girder section modulus are considered according to Table 5-1		

6. Structure outside 0.4L Amidship

6.1 Hull girder longitudinal elements (contributing to hull girder section modulus)

The principles and procedure given in 5.1 apply. The bending moment capacity check may be omitted provided the following requirements are complied with:

Deck and bottom plating:

Minimum thickness at 0.1 L from perpendiculars is:

$$t_{min} = k \cdot t_{Org\_Net}$$
where k = 0.8

Linear interpolation should be applied between 0.4 L midship area t_{min} requirements and the t_{min} requirements at 0.1 L from perpendiculars.

Deck and bottom longitudinals:

The minimum thickness 0.1 L from the perpendiculars:

$$t_{min} = k \cdot t_{Org\_Net}$$
where k = 0.75

Linear interpolation should be applied between 0.4 L midship area t_{min} requirements and the t_{min} requirements at 0.1 L from perpendiculars.

The web height/thickness ratio should not exceed 20 for flat bar stiffeners and 80 for angle and T-bar profiles.

The hull girder shear capacity checks are to be carried out according to DNV-OS-C102 Ch.1.

6.2 Transverse strength elements

Minimum thickness calculations of transverse strength members are in general to follow the procedures of 5.2.

7. Pitting, Groove and Edge Corrosion

7.1 Pitting

7.1.1 Assumptions

The following assumptions apply:

— Pitting repaired by plastic compound filler material is only considered as a method to prevent further corrosion and does not contribute to the strength.
— Hard coatings are normally to be applied after repair.

7.1.2 Minimum acceptable remaining thickness without repair

General

The average thickness in worst cross section through pitting in a plate field is to be more or equal to $0.8 t_{org}$.

a) Internal pitting of plates with intensity less than 20%

The minimum remaining thickness in pitting is to be at least:

$$t_{min} = 0.6 \, t_{Org}$$
but, not less than 6 mm.

b) Internal pitting of plates with 100% intensity (i.e. general corrosion)

The average remaining thickness, in the worst cross section through the pitting in a plate field should not be less than minimum thickness for general corrosion given in 5.1.5.

c) Intermediate pitting intensities

For intermediate pitting intensities, the acceptance of average remaining thickness may be decided based on linear interpolation between a) and b).

d) External pitting of plates

The criteria for acceptance of internal pitting are based on the assumption that there is no external pitting. In case of external pitting, the required remaining thickness in pitting to be the worst of the following requirements:

— In case of no internal pitting,

$$t_{min} = 0.6 \, t_{Org}$$
but, not less than 6 mm.

— In case of internal pitting,

Maximum permissible external pitting depth is
$$t_{Org} - t_{min} - 0.2 t_{Org}$$
where t_{min} is determined from a), b) or c) above, but need not to more than 4mm.

7.1.3 Average remaining thickness for pitted areas

As a rough guide for estimating the average remaining thickness for pitted areas the following may be applied:

$$t_{act} = t_{plate} (1-Int/100) + t_{pit} \, Int/100$$
where:

t_{act} = corrected average remaining thickness
t_{plate} = average remaining thickness outside pitting
t_{pit} = average remaining thickness in pitting
Int = estimated pitting intensity in %

Further, in order to assist in the assessment of estimated pitting intensity, see Figure 7-1.

7.1.4 Repair

For widely scattered pitting, i.e. intensity < 5%:

Provided the remaining thickness in pitting is not less than 6 mm, the following may apply:

a) The use of filler material/plastic compound of a suitable elastic type according to the manufacturers instructions and including the following:

— pitting to be thoroughly cleaned (sand/grit blasted) and dried prior to application
— pitting to be completely filled
— a top layer of coating to be applied.

b) Welding, may be carried out afloat, in accordance with the following:

— pitting is to be thoroughly cleaned, ground and dried prior to welding
— low hydrogen electrodes approved for the material in question are to be used. Weld to start outside pitting and direction reversed for each layer.

For high intensity pitting and/or where the remaining thickness is below the acceptable limits:

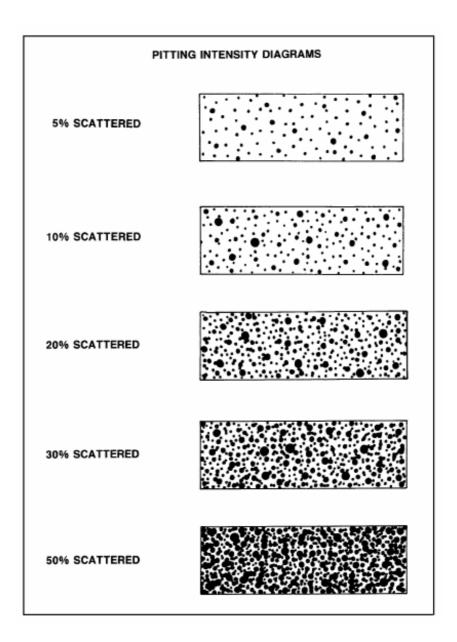The plates and/or stiffeners are to be renewed by inserts.

Figure 7-1
Pitting Intensity Diagrams