RULES FOR CLASSIFICATION

Ships

Edition October 2015

Part 5 Ship types

Chapter 3 RO/RO Ships
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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CHANGES – CURRENT

This is a new document.

The rules enter into force 1 January 2016.
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SECTION 1 GENERAL

1 Introduction

1.1 Introduction
These rules apply to vessels intended for loading and unloading the cargo by Roll on/ Roll off (RO/RO), i.e. with class notations Car carrier or RO/RO ship.

1.2 Scope
The rules in this chapter give requirements specific to RO/RO vessels.

1.3 Application

1.3.1 The requirements in this chapter are supplementary to the rules in Pt.2, Pt.3 and Pt.4 applicable for the assignment of the main class.

General reference is made to the Society's document DNVGL-CG-0137 Strength analysis of hull structure in RO/RO ships and car carriers for general ship type information, design concepts and a description of an acceptable approval procedure.

2 Class notations

2.1 Ship type notations

2.1.1 Vessels built in compliance with the requirements as specified in Table 1 will be assigned the class notations as follows:

Table 1 Ship type notations

<table>
<thead>
<tr>
<th>Class notation</th>
<th>Description</th>
<th>Design requirements, rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO/RO Ship</td>
<td>Vessels intended for loading and unloading the cargo by Roll on/ Roll off (RO/RO)</td>
<td>Sec.1 - General and Sec.2</td>
</tr>
<tr>
<td>Car Carrier</td>
<td>Vessels intended for carriage of vehicles</td>
<td>Sec.1 - General and Sec.2</td>
</tr>
</tbody>
</table>

2.2 Additional notations

2.2.1 The following additional notations, as specified in Table 2, are typically applied to RO/RO ships and car carriers:

Table 2 Additional notations

<table>
<thead>
<tr>
<th>Class notation</th>
<th>Description</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCDK</td>
<td>Requirements for movable car decks</td>
<td>All ships</td>
</tr>
</tbody>
</table>
3 Definitions

3.1 Terms

Table 3 Definitions

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RO/RO equipment</strong></td>
<td>Ramps, doors, hatch covers and movable decks and ramps for loading/off-loading of RO/RO cargo or acting as cargo decks at sea, designed to:</td>
</tr>
<tr>
<td></td>
<td>— load/off-load the ship’s cargo during port operations</td>
</tr>
<tr>
<td></td>
<td>— function as cargo deck space where applicable, i.e. movable decks, ramp covers/inner ramps</td>
</tr>
<tr>
<td></td>
<td>— function as watertight/weathertight boundary at sea where applicable, e.g. external doors/ramps, internal watertight hatches.</td>
</tr>
<tr>
<td><strong>Racking constraining structure</strong></td>
<td>The structure that will constrain deflections in transverse direction. Typical examples of racking constraining structures are engine room</td>
</tr>
<tr>
<td></td>
<td>bulkheads, collision bulkhead, engine- and stairway casings and partial racking bulkheads/deep vertical web structure.</td>
</tr>
<tr>
<td><strong>Uniformly distributed load (UDL)</strong></td>
<td>A defined distributed design load for cargo decks given in t/m², representing the maximum distributed load for a deck or part of a deck.</td>
</tr>
</tbody>
</table>

4 Documentation

4.1 Documentation requirements

General requirements for documentation, including definition of the Info codes, see Pt.1 Ch.3 Sec.1. For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.

Table 4 Documentation requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship hull structure</td>
<td>H081 - Global strength analysis</td>
<td>When required by Sec.2 [1.2]</td>
</tr>
<tr>
<td></td>
<td>H085 - Fatigue analysis</td>
<td>When required by Sec.2 [1.2]</td>
</tr>
<tr>
<td>Door frame connection</td>
<td>C030 – Detailed drawing</td>
<td>Connections between door frames and bulkheads in racking constraining structure.</td>
</tr>
<tr>
<td>Cargo securing arrangement</td>
<td>Z030 - Arrangement drawing</td>
<td>— securing points for lashing with data regarding position, type, design of fittings and Maximum Securing Load (MSL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— stowage and securing arrangement for all vehicles to be carried</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— maximum axle load and number of axles of vehicles.</td>
</tr>
</tbody>
</table>
5 Product certificates

5.1 Certification requirements

5.1.1 General
For products that shall be installed on board, the Builder shall request the Manufacturers to order certification as described in Table 5.

Table 5 Certification requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo securing devices, fixed</td>
<td>PC</td>
<td>Society</td>
<td>Standard for Certification No. 2.23</td>
<td>If certification by the Society, Standard for Certification No. 2.23, shall be applied.</td>
</tr>
<tr>
<td>Cargo securing devices, portable</td>
<td>PC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For general certification requirements, see Pt.1 Ch.3 Sec.4.
For a definition of the certificate types, see Pt.1 Ch.3 Sec.5.
SECTION 2 HULL

1 Racking

1.1 General
A racking strength assessment shall be carried out following the requirements given in this sub-section. Special attention shall be given to the connections between transverse structural members to the bulkhead deck or the uppermost deck level with high racking rigidity. Intersections between horizontal and transverse members shall be assessed in areas subjected to high racking deformations, i.e. response caused by roll motion acting on the cargo at multiple decks combined with selfweight of structure and equipment.

1.2 Calculation scope for racking

1.2.1 General
The transverse strength shall be checked against:
1) the ultimate limit state (ULS) under extreme loading as described in [3.2]
2) the fatigue limit state (FLS) under variable cyclic loading as described in [6].

The extent of the calculation scope depends on the vessel's arrangement and complexity. Two categories, based on structural configuration, are used to group the scope and the calculation requirements for ULS and FLS:

Category I, ref. [1.2.2]:
— designs with not more than two RO/RO decks above bulkhead deck
— designs with evenly distributed self-supporting side web frames, e.g. frames able to restrain the racking response from all decks based on given frame spacing.

Category II, ref. [1.2.3]:
— designs with multiple decks and few effective transverse strength members such as engine casing box, stair casing box and deep racking frames/bulkheads.

1.2.2 Scope of racking calculations for category I vessels
Transverse strength is provided by deep vertical web frames in the ship's side and/or transverse bulkheads in the accommodation area. A simplified racking assessment model using beam elements will be accepted for the evaluation of the adequacy of the transverse strength for the ULS scope. Acceptable calculation and modelling methods and criteria are given in Pt.3 Ch.7.
A simplified FLS assessment for racking will be required on a case by case basis depending on the nominal stress.

1.2.3 Scope of racking calculations for category II vessels
A global FE strength analysis is required to document the racking response and to demonstrate that the stresses are acceptable under ULS load conditions. Acceptable calculation methods and criteria are given in Ch.7 Sec.3 and [4.3]. Supporting documentation for the direct strength analysis is described in the Society's document DNVGL-CG-0127, Finite element analysis, [2]. A separate FLS analysis shall be carried out according to [6].
For vessels with length \( L < 120 \) m, a reduced calculation scope according to [1.2.2] may be accepted on a case-by-case basis.
2 Docking

For large RO/RO ships and car carriers that may have large docking weight, special strength calculation of the bottom structure in way of the docking blocks. Reference is made to the rules Pt.3 Ch.3 Sec.5 [3.4] regarding requirements for docking.

For direct docking analysis, reference is made to:
— beam analysis: Pt.3 Ch.6 Sec.6 [2.3.2], AC-I
— FE analysis: Pt.3 Ch.7 Sec.3 Table 1, AC-I.

3 Loads

3.1 Design still water bending moments

The still water bending moment limits shall be based on an extreme non-homogenous loading condition. For the hogging limit, an increased load density shall be assumed in the aft ship and fore ship area.

Guidance note:
Based on a homogeneous loading condition on scantling draught, 25% of the load within 0.4L should be redistributed equally to the load area aft of 0.3L and forward of 0.7L, without exceeding the maximum specified uniformed distributed load (UDL) for the heavy RO/RO decks.

---end---of---guide-note---

A sagging still water bending moment limit value lower than the minimum rule sagging moment may be accepted, provided this can be documented. A negative still water sagging limit (i.e. minimum hogging) may be accepted provided that it can be demonstrated that the vessel will not experience static sagging. In such case, an extreme but realistic still water sagging condition with increased load density within 0.4L and decreased load density outside 0.4L, shall be taken into account.

Guidance note:
Based on a homogeneous loading condition on scantling draught, load density within 0.4L should be increased with 25%, without exceeding the maximum specified uniformed distributed load (UDL) for the heavy RO/RO decks. Increased load density within 0.4L shall be compensated by reduction of load density aft of 0.3L and fwd of 0.7L to obtain the same cargo deadweight.

---end---of---guide-note---

3.2 Loads for global racking strength assessment

3.2.1 Loading condition for racking

The loading condition, which in combination with relevant dynamic load cases defined in [3.2.3] results in the maximum racking moment about the bulkhead deck, shall be chosen for the ULS transverse strength analysis. The racking moment shall be calculated according to [3.2.2].

The actual GM value for this design load case shall be determined and applied since it has a significant influence on the dynamic load cases. In no case shall the GM value for the design still water loading condition be smaller than 0.058.

3.2.2 Racking moment calculation

The racking moment is calculated using both cargo weight \(m_c\) and the self weight \(m_s\) to obtain the total mass. An average minimum distributed load equal to 0.2 t/m² shall be applied for the accommodation decks, in addition to the self weight. For unloaded weather decks, it is sufficient to include the load corresponding to the self-weight if no deadweight is specified. The transverse force on each deck level is obtained as the total mass times the transverse acceleration corresponding to the relevant equivalent design wave (EDW) given in [3.2.3]. Thus, the racking moment, \(M_R\), may be estimated as:
\[ M_R = \sum_i (m_{c,i} + m_{s,i}) \cdot a_{t,i} \cdot (z_i - z_{main}) \]

- \( m_{c,i} \) = mass on deck number i.
- \( m_{s,i} \) = self weight of deck number i
- \( a_{t,i} \) = transverse acceleration at deck number i
- \( z_i \) = vertical distance above base line for deck number i
- \( z_{main} \) = vertical position above base line for bulkhead deck.

If the maximum allowable cargo mass has been assumed for the heavy cargo decks, movable cargo decks installed directly above such decks should be assumed empty, and in the stowed position.

Lower decks shall be assumed loaded until the design draught is reached.

**Guidance note:**
A high racking moment is achieved if the load is located on the upper decks. However this results in lower GM values and thus also lower transverse accelerations which will reduce the racking moment. Usually, several loading conditions for racking analysis should be reviewed using the simplified racking moment calculation described in this paragraph.

---end---of---g-u-i-d-a-n-c-e---n-o-t-e---

### 3.2.3 Dynamic load cases
The design wave load cases which shall be used to evaluate the transverse strength of the ship structure are the beam sea load cases, BSR (1P/2P) and/or BSR (1S/2S), as defined in Pt.3 Ch.4 Sec.2 [1.1.1]. For ship structures with symmetrical arrangement of racking constraining elements, only BSR(1P/2P) or BSR(1S/2S) needs to be examined.

### 3.2.4 Load combinations for ULS
The loading condition from [3.2.1] shall be combined with the dynamic load cases as described in [3.2.3]. The external sea pressure shall be applied according to Pt.3 Ch.4 Sec.5 Table 8. Load combination factors for hull girder loads and accelerations shall be applied according to Pt.3 Ch.4 Sec.2 Table 3 with the internal cargo, equipment and steel weight loads.

### 3.2.5 FE load application
The deck load may generally be applied as distributed vertical and transverse loads based on load combination as described in [3.2.4].

Self-mass of the upper light car decks including accommodation- and garage decks must be included. Movable car decks shall be included as point loads in way of support positions.

### 3.3 Loads for primary supporting members

#### 3.3.1 Design load sets for prescriptive rule check
Design load sets and load combinations of static and dynamic loads for tank and watertight boundary structure, external shell envelope structure e.g. bottom structure, side shell primary members and deck structure is given in Pt.3 Ch.6 Sec.2 Table 2.

#### 3.3.2 Load sets and load combinations for direct analysis
The static load pattern described in Table 1 below shall be assessed to ensure that the primary support members have sufficient strength.
### Table 1 Load pattern

<table>
<thead>
<tr>
<th>Load pattern</th>
<th>Description(^1)</th>
<th>Draught</th>
<th>Strength members</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC 1</td>
<td>Normal ballast draught with no cargo</td>
<td>(T_{\text{BAL}})</td>
<td>Bottom structure</td>
</tr>
<tr>
<td>LC 2</td>
<td>Maximum uniform cargo on lower decks until (T_{\text{SC}}) is reached</td>
<td>(T_{\text{SC}})</td>
<td>Lower cargo decks</td>
</tr>
<tr>
<td>LC 3</td>
<td>Maximum uniform cargo on upper decks until (T_{\text{SC}}) is reached</td>
<td>(T_{\text{SC}})</td>
<td>Upper cargo decks</td>
</tr>
<tr>
<td>LC 4</td>
<td>Transversely unsymmetrical deck loads</td>
<td>(T_{\text{SC}})</td>
<td>Transverse deck girders</td>
</tr>
<tr>
<td>LC 5</td>
<td>Longitudinally unsymmetrical deck loads</td>
<td>(T_{\text{SC}})</td>
<td>Longitudinal deck girders</td>
</tr>
<tr>
<td>LC 6(^2)</td>
<td>Heavy cargo unit (e.g. MAFI) on single girder</td>
<td>(T_{\text{SC}})</td>
<td>Transverse and longitudinal girders</td>
</tr>
<tr>
<td>LC 7(^3)</td>
<td>Flooded condition</td>
<td>(T_{\text{DAM}})</td>
<td>Transverse and longitudinal girders</td>
</tr>
</tbody>
</table>

1) Self weight shall be included.  
2) Special load case to evaluate strength of individual strength members under heavy cargo units. Load distribution/comination must be based on information from a cargo stowage plan, see the Society’s document DNVGL-CG-0137 *Strength analysis of hull structure in RO/RO ships and car carriers*.  
3) No cargo load on the watertight deck shall be applied, only selfweight.

The given static load pattern shall be combined with the dynamic load cases according to Pt.3 Ch.4 Sec.2.

### 3.3.3 Cargo loading

In addition to the uniform design load as given by the designer, the deck girder structure shall be checked for the most severe combination of axle(s) positioning of cargo handling vehicles in harbour and for vehicles as cargo in sea-going conditions.

#### 3.3.4 Non cargo decks

A minimum static load for accommodation decks and wheelhouse deck equal to 1.5 kN/m\(^2\), excluding self weight, shall be applied.  
For exposed weather decks, only self weight shall be applied.

### 3.4 Loads for FE fine mesh fatigue

#### 3.4.1 Loading condition

The loading condition resulting in the highest transverse racking moment according to [3.2.2] should normally be selected as basis for the fatigue analysis. In addition it should represent the most frequently used loading condition, as the load case with all decks loaded with personal cars. The \(GM\) to be used in the analysis shall be the actual \(GM\) of the load case, but not less than 0.035\(B\).

**Guidance note:**  
It should be noted that using a lower \(GM\) value means that the predicted fatigue life will be increased. The \(GM\) value representative for the departure condition should therefore be used as basis for the fatigue analysis.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

#### 3.4.2 Dynamic load cases

For the fatigue analysis of local connections of transverse elements, the dynamic load cases that induce the highest transverse accelerations in the hull girder, shall be considered. If more than one dynamic load case is selected, the fraction for each one shall be provided and accounted for in the fatigue analysis. As a minimum requirement, BSR (1P/2P) and/or BSR (1S/2S) as given in Pt.3 Ch.4 Sec.2 Table 8, shall be applied. For ship
designs with symmetrical arrangement of racking constraining elements, only BSR(1P/2P) or BSR(1S/2S) needs to be examined.

**3.4.3 Load combinations for FLS**
The loading condition from [3.4.1] shall be combined with the dynamic load cases in [3.4.2]. External sea pressure shall be applied according to Pt.3 Ch.4 Sec.5 Table 23. Load combination factors for hull girder loads and accelerations shall be applied according to Pt.3 Ch.4 Sec.2 Table 9 with the internal cargo, equipment and steel weight loads.

**4 Hull local scantling**

**4.1 Primary supporting members**

**4.1.1 General**
The strength of primary structural members that form part of a grillage system, such as deck girders, side web frames, pillars, floors and girders in double bottom shall be determined by direct strength analysis either by the use of a beam- or FE part ship model.

Beam analysis should in general only be applied for 2-dimensional grillage structures, such as in decks, side structure or ramps.

For transverse members and longitudinal members with hull girder stresses not exceeding $0.15 \times R_{eff}$, Pt.3 Ch.6 Sec.6 [2.2] applies. For other cases, advanced calculation method described in Pt.3 Ch.6 Sec.6 [2.3] applies.

**4.1.2 Beam analysis**
Beam analysis may be accepted in order to evaluate bending and shear stresses in webs and flanges of grillage structure under lateral loads such as decks, double bottom and side structure under cargo or liquid pressure (e.g. sea pressure, tank pressure etc.). The effective plate breadth in bending of the primary strength members shall be calculated according to Pt.3 Ch.3 Sec.7 [1.3].

Acceptance criteria for yield and buckling are given in Pt.3 Ch.6 Sec.6 [2.2.2] and Pt.3 Ch.6 Sec.6 [2.2.3], respectively.

**4.1.3 FE analysis**
FE analysis will be required to determine the actual stress distribution in stiffened panel structures having discontinuities or geometric irregularities such as openings in deck/bulkhead/side shell plating, holes in girder web/floors, in association with a yield or buckling check then a direct model based on shell finite elements is required.

FE Partial ship structural analysis shall be carried out in accordance with Pt.3 Ch.7 Sec.1 and Pt.3 Ch.7 Sec.3 using detailed requirements given in the following sub-sections.

Acceptance criteria for yield and buckling are given in Pt.3 Ch.7 Sec.3 [4]

**4.2 Securing points for lashing**

**4.2.1 General**
Decks intended for carriage of vehicles shall be equipped with a satisfactory number of securing points (cargo securing device) for lashing of the vehicles. The arrangement of securing is left to the discretion of the owner, provided the minimum requirements in [4.2.2] through [4.2.6] are satisfied.

**4.2.2 Scantling**
Stiffeners and girders are subject to direct analysis according to Pt.3 Ch.6 Sec.5 [1.2] and Pt.3 Ch.6 Sec.6 [2.2], respectively, applying the maximum securing load defined in [4.2.3] to [4.2.6].

$\beta_s \alpha_s$ and $C_s$-max may be taken as for acceptance criteria AC-II.
4.2.3 Maximum securing load
Unless otherwise specified, each lashing point shall have a Maximum Securing Load (MSL) of not less than:

\[
MSL = kQg_0 \\
\text{max, } 0.5P_m \\
\text{min, } 100 \text{ kN in decks for heavy cargo, e.g buses, road- and MAFI trailers} \\
\text{min, } 15 \text{ kN in decks for cars only}
\]

\[
k = n/r \\
P_m = \text{minimum breaking load of the considered cargo securing device.} \\
r = \text{number of effective lashing points at each side of the vehicle for the number } n \text{ of axles in group.}
\]

If \( r \) is different from 1, \( k \) shall be increased by 10%.

\( Q = \) the maximum axle load given in tons.

For MAFI road trailers, \( Q \) can be calculated as the total weight with \( n = 1 \) and \( r = \) the total number of lashings at each side.

4.2.4 More than one lashing
If the securing point is designed to accommodate more than one lashing, the magnitude and direction of the lashing loads shall be taken into account when determining the total MSL of the securing point.

4.2.5 MSL less or equal to 15 kN
Lashing points intended for a maximum working load of 15 kN can normally be arranged without any strengthening of the deck plating.

4.2.6 MSL more than 15 kN
The strength of lashing points intended for a maximum working load of more than 15 kN shall be documented by either structural analysis or mock-up tests.

4.3 Special strength considerations

4.3.1 Pillars
Strength of pillars shall be assessed assuming summation of the maximum design loads of all the decks above.

The pillars shall be fitted in the same vertical line, from bottom to upper most deck. If not possible, the pillars shall be effectively supported by box girder or bulkhead structures, and direct strength analysis will be required.

4.3.2 Double bottom structure in way of pillars
The double bottom structure in way of pillar endings, in ships with multiple cargo decks supported by pillars, shall be investigated for all relevant seagoing conditions and maximum ballast draught with no cargo loads on decks above, \( T_B(\text{min}) = 0.6T_{sc} \). Counteracting forces due to ballast in double bottom may be taken into account in the analysis.

4.3.3 2-stack MAFI trailers
Strength of decks intended for carrying MAFI trailers or other vehicles carrying more than one tier of containers must be checked for possible tension loads and increased vertical compression load due to rolling. Additional loadcases shall be included in beam- or FE analysis.

4.3.4 Door openings in racking constraining structure
In case of door openings in racking constraining structure, especially transverse structure, it is important to provide radius in the corners to obtain acceptable local stresses in the corners. Rectangular door frames
without radius shall not be welded directly to the bulkhead plate. It is recommended to introduce recess structure in order to avoid unnecessary stress concentrations in way of the door frame.

4.3.5 Deck openings in way of ramps/ ramp covers
Special consideration is required for girder structure forming the framing around deck ramp openings. Direct strength analysis shall be used to demonstrate that rule requirements are satisfied.

4.3.6 Watertight integrity of trunks
Where a ventilation trunk passing through a structure penetrates the bulkhead deck, the trunk shall be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heel angle allowable during intermediate stages of flooding, in accordance with SOLAS Ch. II-1/8.5.
Where all or part of the penetration of the bulkhead deck is on the main ro-ro deck, the trunk shall be capable of withstanding impact pressure due to internal water motions (sloshing) of water trapped on the ro-ro deck.

4.3.7 Flexible hinge member
The longitudinal flexible hinge in the hinged deck design Car carriers shall have low torsional stiffness (i.e. flat bar is preferred) and the distance between the flexible hinge and the face plate of the side girder should be made as small as possible, see the Society's document DNVGL-CG-0137, Strength analysis of hull structure in RO/RO ships and car carriers, Figure 1-2.

4.3.8 Slenderness of primary support members
Where a primary structure member is intended mainly for interfacing structure of RO/RO equipment and not contributing to major structural strength, e.g. a stringer in superstructure side for movable car deck, a slenderness coefficient \( C_w = 125 \) to be applied for the web plate requirement given in Pt.3 Ch.8 Sec.2 [4.1.1].

5 FE analysis

5.1 General
Reference is made to Pt.3 Ch.7 Sec.4, supporting the Society's document DNVGL-CG-0127, Finite element analysis and the Society's document DNVGL-CG-0137, Strength analysis of hull structure in RO/RO ships and car carriers, for FE model procedures.

5.2 ULS racking acceptance criteria
Stresses in plating of transverse racking constraining structure shall not exceed the permissible values as given in :

<table>
<thead>
<tr>
<th>Table 2 Permissible stresses for global finite element analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permissible axial &amp; principal stress</td>
</tr>
<tr>
<td>200/k</td>
</tr>
</tbody>
</table>
6 Fatigue strength

6.1 Application
A prescriptive fatigue check according to [6.2] is mandatory for all vessels with \( L > 150 \) m.
Fatigue assessment by hot spot models according to [6.3] is mandatory for category II vessels, defined in [1.2.1] and will be required on a case by case basis for category I vessels.

6.2 Prescriptive fatigue
Local structure that shall be assessed by the prescriptive fatigue method, according to Pt.3 Ch.9 are the end connections of longitudinal stiffeners subjected to lateral and/or variable longitudinal loading in outer shell below freeboard deck. Relative deflections may be ignored.

6.3 FE analysis

6.3.1 Application
With reference to Pt.3 Ch.9 Sec.3 [4], standard critical details, defined in [6.3.2], shall be assessed by hot spot fatigue analysis. Local models shall be made according to Pt.3 Ch.7 Sec.4.
Fatigue assessment for other details will be required on a case by case basis, determined based on the nominal stress level from the global ULS analysis. Such details are given in [6.3.3].

6.3.2 Standard critical details
Connection of main racking constraining structure to bulkhead deck, typically:
— engine room casing
— stairway/lift casings, if continuous up to weather deck
— deep racking frames
— partial bulkheads.

6.3.3 Other critical areas
— typical connection between transverse deck girders and racking constraining structure such as casings and/or racking boxes
— typical connections of vertical web frames to bulkhead deck
— typical connection between vertical side frames and transverse deck girders
— typical connection between pillars and transverse deck girders
— typical pillar connection to top deck and inner bottom
— other rigid structure, such as staircase or ventilation ducts and their connection to PSM's
— vertical side frames connection to collision bulkhead.

6.4 Fatigue damage calculations

6.4.1 Zero-crossing frequency
The zero-crossing frequency for the roll response shall be taken as:

\[
\nu_{0,r} = \frac{\sqrt{GM}}{2.3k_r}
\]
when calculating the fatigue damage accumulation according to the Society's document DNVGL-CG-0129, *Fatigue assessment of ship structure*, [3].

### 6.4.2 Stress range

With reference to the Society's document DNVGL-CG-0129, *Fatigue assessment of ship structure*, [3.2.5], the stress range $\Delta \sigma$ needed for the fatigue damage evaluation shall be calculated as:

$$
\Delta \sigma = \Delta \sigma_p = \left| \sigma_{HS-2P} - \sigma_{HS-1P} \right|
$$

for symmetric designs, where,

- $\Delta \sigma_p$ = Hot spot stress range for BSR-P
- $\sigma_{HS-1P}$ = Hot spot stress for BSR-1P
- $\sigma_{HS-2P}$ = Hot spot stress for BSR-2P

For un-symmetric designs, also stress range for BSR-1S and BSR-2S must be calculated as:

$$
\Delta \sigma = \Delta \sigma_s = \left| \sigma_{HS-2S} - \sigma_{HS-1S} \right|
$$

where,

- $\Delta \sigma_s$ = Hot spot stress range for BSR-S
- $\sigma_{HS-1S}$ = Hot spot stress for BSR-1S
- $\sigma_{HS-2S}$ = Hot spot stress for BSR-2S

For un-symmetrical design, the fatigue damage shall be calculated based on:

$$
\Delta \sigma = \text{Max}(\Delta \sigma_p, \Delta \sigma_s)
$$

### 7 RO/RO equipment

#### 7.1 General

**7.1.1 Introduction**

RO/RO equipment shall satisfy the requirements in this section in addition to general requirements for shell doors and ramps given in Pt.3 Ch.12 Sec.4 and internal doors as given in Pt.3 Ch.12 Sec.2.

**7.1.2 Local scantling**

Requirements for plate and stiffener are given in Pt.3 Ch.6 Sec.4 and Pt.3 Ch.6 Sec.5, respectively.

Decks and ramps subject to wheel loading shall comply with requirements in Pt.3 Ch.10 Sec.5 under port operations and at sea.

Minimum thicknesses are given in Pt.3 Ch.6 Sec.3.

**Guidance note:**

It is particularly important that all vehicle information is available, together with footprint data and axle arrangements since these are the main parameters to determine the design loads for the plating and stiffeners.
Scantlings of decks, ramps, lifts etc. for railway carriages will be specially considered in each case.

7.1.3 Damage condition
The maximum deflection of the ramp/ramp cover edge under damage condition shall be carefully examined and documented, in order to ensure watertightness.

7.2 External vehicle ramps/ doors

7.2.1 General
Requirements for side- or stern doors and bow doors are given in Pt.3 Ch.12 Sec.5 [1] and Pt.3 Ch.12 Sec.5 [2], respectively.

7.3 Hoistable internal vehicle ramps/ ramp covers

7.3.1 General
For internal ramp covers, requirements in Pt.3 Ch.12 Sec.4 applies.

7.3.2 Loads at sea
If the ramp/ramp cover is acting as a watertight deck opening cover, it shall be designed against the deepest damage waterline according to Pt.3 Ch.12 Sec.3 [2].

7.3.3 Girders
A direct strength analysis is generally required to analyse and check the strength of the primary girder system.

7.4 Movable car deck panels

7.4.1 General
Ships arranged with movable car decks or deck pontoons shall be built in compliance with relevant requirements given in Pt.6 Ch.4 Sec.6.

7.4.2 Additional class notation
Upon compliance with requirements given in Pt.6 Ch.4 Sec.6, additional class notation MCDK may be given.

7.5 Function test of RO/RO equipment
Every RO/RO equipment item shall be function tested to demonstrate that all expected operations are functioning properly.
Load testing as part of function testing is required for RO/RO equipment which is lifted with cargo. The test load shall be the maximum design load of the equipment.
Testing and certification requirements according to 2.21 Lifting Appliance Standard is required if the ILO 152 certificate shall be issued by the Society.
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