CLASS GUIDELINE

DNVGL-CG-0137

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Strength analysis of hull structure in RO/RO vessels

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DNV GL AS

FOREWORD

DNV GL class guidelines contain methods, technical requirements, principles and acceptance criteria related to classed objects as referred to from the rules.

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

This is a new document.

CONTENTS

SECTION 1 INTRODUCTION

1 Definitions

1.1 Primary symbols and units

Reference is made to RU SHIP Pt.3 Ch.1 Sec.4 [1].

1.2 Abbreviations

The following abbreviations are used in this class guideline:

FLS	=	Fatigue Limit State
ULS	=	Ultimate Limit State
Bogie	=	A chassis or framework carrying wheels, attached to a vehicle, thus serving as a modular subassembly of wheels and axles.

2 General

The "Rules for Classification of Ships" (hereafter referred to as "the rules") RU SHIP Pt.5 Ch.3 give several requirements for structural analyses including loads and acceptance criteria to be applied for the hull structures of RO/RO ships and car carriers.

This class guideline describes an acceptable method required for such structural analyses. In case there are differences between the rules and this class guideline, the current rules prevail.

Any recognized calculation method or computer program for calculation of structural response may be applied, provided the effects of bending, shear and axial deformations are considered when relevant.

If the wave loads are calculated from a direct wave load analysis, it is required to use a recognised software.

Strength analysis carried out in accordance with the procedure outlined in this class guideline will normally be accepted as basis for class approval.

3 Objectives

The objective of this class guideline is:

— to give a guidance for the design and assessment of hull structures in RO/RO and car carriers in accordance with the rules
— to give a general description on how to carry out the required calculations and analyses
— to provide information on alternative methods for determining the racking response and fatigue damage of critical details
— to promote reliable designs through encouraging rational design and analysis procedures.

4 Vessel categorisation

4.1 RO/RO

RO/RO is a common abbreviation for a ship specially arranged for roll-on and roll-off cargo handling.

Typical RO/RO cargo is cars, trucks, dumpers, containers, road trailers and MAFI trailers. The vessel is loaded either by use of the cargo's own engine power or by use of special loading and un-loading vehicles.

In general RO/RO ships have deep transverse deck girders able to carry the deck load without pillar support. The racking moment of each transverse frame is normally carried by the frame alone. This means that a simplified structural analysis approach can be followed for the racking assessment of RO/RO ships with not more than two RO/RO decks above bulkhead deck.

The loading capacity of such ships is often given as lane metres.

4.2 RO/RO /Container

Several RO/RO ships are specially arranged also for transportation of containers. Such arrangement includes special fittings/lashing arrangement, and may also include special cargo handling vehicles onboard the ship.

4.3 Car carriers

4.3.1 General

Car carriers are specially made for transportation of cars or other vehicles. In general such vessel has one or two side ramps in addition to the stern ramp (quarter ramp).

From a structural point of view, a car carrier is similar to a RO/RO ship but has more decks (i.e. 'Multiple decks RO/RO carrier'). A car carrier usually has different load carrying capacity for the different decks. The upper most decks are commonly designed for a low uniform deck load corresponding to the weight of private cars, down to 150 kg/m^2 while some of the lower decks are designed for a higher load and are intended for buses, trucks, trailers or other heavier vehicles. Movable decks may in many cases be located above the decks with higher specified load. Movable decks are either liftable, meaning free panels lifted by scissor lift on board the vessel, or hoistable, meaning that the panels are equipped with internal jigger winch and wires for lifting. The load capacity of the movable deck is similar as for the upper decks. The decks may be supported by pillars and longitudinal girders are then usually connecting the pillars.

Due attention is to be paid to the racking response of the hull structure:

— for smaller car carriers, the racking moment on each frame may be carried by the frame alone
— smaller car carriers may also be designed assuming that the racking moment over a broader area (i.e. several web frame spacings) of the cargo space should be carried by the same broad area
— for larger car carriers, the structure may be designed so that the racking moment for each frame section is not fully carried by the frame itself. Thus, the racking moment is transferred through the decks to stronger racking constraining structure. Examples of such racking constraining structure are bow, stern, engine casings, partial bulkheads, engine bulkhead, deep webs and strengthened ventilation trunks.

The load capacity of car carriers is normally given as number of cars, or free deck area (m^2).

Car Carriers are normally denoted as PCTC or PCC.

PCTC/ LCTC: Pure/ Large Car and Truck Carriers are arranged for transportation of cars and vehicles including trucks, dumpers, containers, road trailers and MAFI trailers. One or several decks are specially strengthened to carry the heavier cargo.

PCC: Pure car carriers are arranged for transportation of light and heavier cars including SUV (Sport Utility Vehicles) and Land Cruisers. PCCs are normally designed for smaller draft compared to PCTCs.

4.3.2 Design concepts

There exist two different structural concepts for car carriers. These are the conventional rigid deck design and the hinged deck design. The hinged deck design is often referred to as the 'flexible' design. In this class guideline, the term hinged deck design will be used.

4.3.3 Conventional designs

A conventional Car Carrier design mean that the vertical side webs are in line with the deck transverses (see Figure 1). This means that transverse forces on the decks will induce bending of the deck transverses. Consequently, the frame section (vertical side and transverse deck girder) is rigid when exposed to transverse forces, compared to the hinged deck design. A considerable fraction of the racking moment created above the above the bulkhead deck (freeboard deck) is then mainly to be carried by the frame section itself.

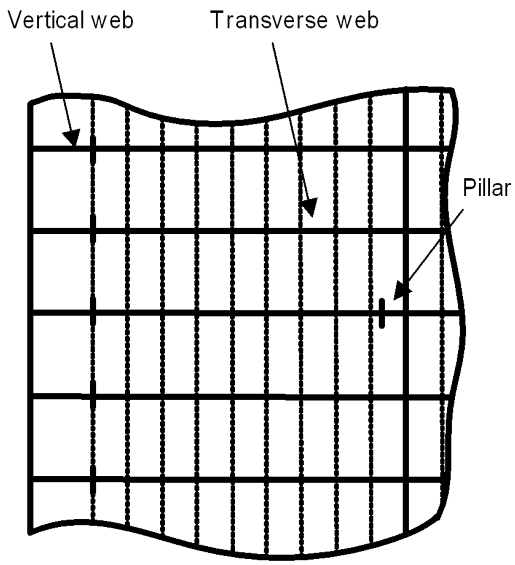


Figure 1 Typical deck plan for conventional (rigid deck design) car carrier

4.3.4 Hinged designs

A hinged deck car carrier design means that the vertical side frame is not in line with the deck transverse girder (see Figure 2). This means that no bending moment is induced in the transverse deck girder when the deck is exposed to transverse forces. The vertical side frame will then deform as a cantilever beam supported at the bulkhead deck and is only able to carry a reduced portion of the racking force on the transverse frame. The bow region and the stern are then activated and contribute as racking constraining structure together with other main structure such as engine- and stair casings, deep racking web(s) and strengthened ventilation trunks.

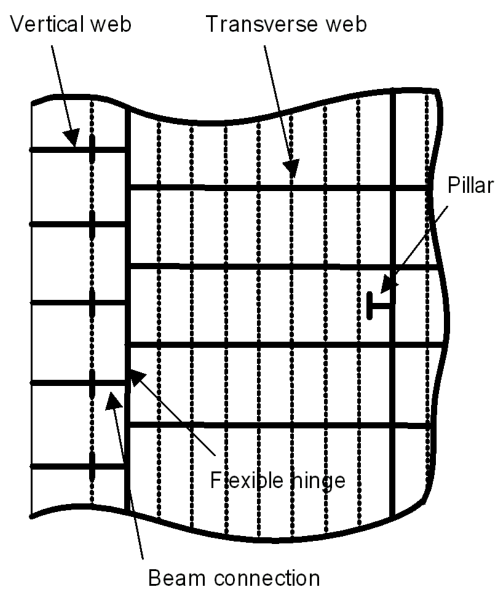


Figure 2 Typical deck plan for hinged deck design car carrier

An elastic hinge arrangement between the vertical web and the deck girders increases the ability of the ordinary side web frames to sustain transverse racking deformations of the upper hull. In consequence, the side webs are then normally more slender than for a conventional design. However, the main transverse racking constraining members have to be increased in strength to carry the racking moment.

With reference to Figure 2, the longitudinal flexible hinge should 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. Further, the flexible hinge is supported and will transfer the shear load to the side girders through short beams with sufficient web height considering local bending.

The total capacity of the racking constraining structures has, however, to be the same for a conventional (rigid deck) design as for a hinged deck design.

5 Operational considerations

Modern RO/RO ships are normally operated in regular routes between designated ports. Most of the charters are relatively long term. The weather and sea conditions may vary a lot depending on where the ship is trading. Change in loading will also affect the behaviour of the ship at sea, that may change the actual long term loads on the hull structure.

This class guideline will focus on typical loading conditions and load cases to ensure structural integrity during regular trade around the world. Ship owners/operators having specific knowledge about possible loading conditions/trading routes/intended GM-values during operation etc. should give such information to the designer/yard as early as possible when planning a new project.

6 Critical items and areas

6.1 Wheel loaded decks

In addition to the effect of longitudinal hull girder forces, the deck structures are subject to local loads from wheel print/axle loads and from container post loads where such arrangement is used. The rules have specific requirements for wheel loaded decks, with separate requirements depending on the direction of traffic relative to direction of deck plate stiffeners, see RU SHIP Pt.3 Ch.10 Sec.5. Areas where the traffic direction is perpendicular to the direction of deck plate stiffeners are more prone to local plate deformation. For areas where cargo handling vehicles are frequently operated, the effect of driving perpendicular to the stiffener direction should be specially considered.

6.2 Deflections in way of ramps

Deflections in way of ramps should be carefully taken into account. Satisfactory functionality and safe operation of ramps and movable decks depend on limited deflections of adjacent structure. Ramp openings may be closed by watertight ramps/ramp covers/doors or gas tight doors, and the designer should take into account possible deflections of loaded deck girders above ramp opening, allowing for realistic deflections during normal operation.

6.3 Transverse racking

Due to operational considerations, RO/RO ships have normally few racking constraining structural members that are effective with respect to support of transverse racking forces. The fatigue effect of racking forces due to the rolling of the ship in combination with vertical dynamic acceleration should be evaluated at an early stage of the design process.

6.4 Pillar structure

Pillars connecting two decks have to be designed to withstand the transverse relative deflection between the decks. Such connections may in particular be demanding when the deflections between the decks are high (for example as for the hinged deck car carrier design).

6.5 Fixed ramps

Fixed ramps between two decks have to be designed to withstand the transverse relative deflection between the decks. In particular this is important for decks above freeboard deck for the hinged deck car carrier design, where fixed ramps must be split in two parts or disconnected to one of the decks.

6.6 Ventilation ducts

Ventilation ducts connecting several decks with high relative deflection between the decks have to be designed with sufficient flexibility in order to avoid stress concentration.

6.7 Garage on upper deck

The connection between the garage and the upper deck has to be designed with sufficient flexibility to avoid stress concentration. The racking strength of the garage itself needs special attention.

6.8 Transverse bulkheads

For vessels with a reduced number of effective transverse bulkheads or transverse bulkheads with reduced vertical shear capacity due to openings or ramp penetrations, the effective vertical shear capacity is to be specially considered.

6.9 Bottom girders

Bottom longitudinal girders in the cargo area may be subject to large shear forces in way of their end supports. This typically applies in way of the engine room bulkhead, cargo space front bulkhead and connection to partial longitudinal bulkhead in way of internal ramps.

6.10 Floors

In cases where a rigid lower side structure provides end support of the bottom without allowing rotation, special attention should be paid to cut-outs in tank top since this will reduce the top plate flange. Local buckling in combination with the direction of stiffening has to be considered in way of support of the double bottom.

6.11 Internal ramps, stern- (quarter) and side ramps

Internal ramps, stern- (quarter) and side ramps are all subject to loads during cargo operations and from lashed vehicles. Deck plating and stiffeners subject to wheel loads must be dimensioned accordingly. Ramps forming part of the external side shell must also be dimensioned for relevant sea pressure. Stern ramps extending above upper deck are in addition subject to loads from seas on upper deck. Ramps should also be carefully assessed with respect to supporting and securing arrangement taking into account the actual inertia loads that apply. The flexibility of the surrounding structure to the ramp should be evaluated.

SECTION 2 HULL GIRDER STRENGTH

1 Hull girder bending strength

1.1 Wave bending moment

RO/RO and Car Carriers have moderate speed and large flare. Thus, the wave sagging moment according to the rules should be adjusted for the speed effect (C_{AV}) and the flare effect (C_{AF}) for buckling check of upper decks and ship side, see rules RU SHIP Pt.3 Ch.4 Sec.4 [3.1].

A similar correction should be made to the hogging moment and the corrected hogging moment is only to be used for buckling checks. The distance from summer load waterline to the deck line used to determine the factor C_{AF}, should be taken to the lowermost deck where water can be entrapped and give raise to an increased hogging moment. For designs with open mooring deck forward, the distance should be taken up to the mooring deck.

2 Hull girder shear strength

2.1 Ship side openings

Shear stress in way of large openings in the ship side should be specially considered. One way to analyse the shear stress is to determine the part of the total shear force which will distribute above and below the side opening based on the relative stiffness of the ship side above and below the opening.

SECTION 3 LOCAL STRENGTH

1 Hinged designs

With reference to Sec.1 [4.3.4], If longitudinal hinge member is not flat bar type, the local stresses in the flange can be estimated as:

$$\sigma = \frac{12Eb\delta h_d}{S^2 H_{dk}} \times 10^{-9}$$

Not to exceed:

$$\sigma_{all} = 200/k$$

where

E = module of elasticity
b = flange width of longitudinal hinge member in mm
δ = relative transverse deflection between actual deck and the deck below in mm, taken from the global ULS racking analysis according to RU SHIP Pt.5 Ch.3 Sec.2 [1.2]
h_d = web height of transverse deck web in mm
S = web frame spacing as defined in RU SHIP Pt.3 Ch.3 Sec.7 [1.2.2] in m
H_{dk} = height between actual deck and deck below in mm. See Figure 1.

The flexible hinge should have sufficient bending and shear strength against the vertical load.

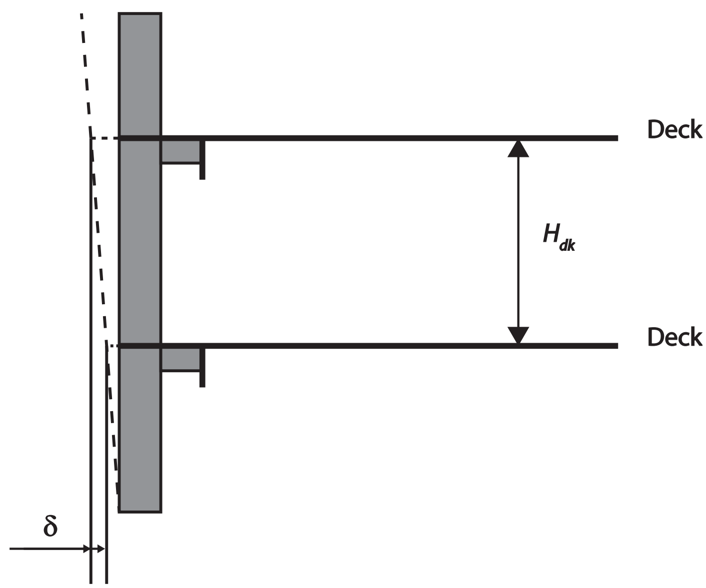


Figure 1 Hinged design - side web

SECTION 4 PRIMARY SUPPORTING MEMBER (PSM) ASSESSMENT

1 FE partial ship model

1.1 Application and objective

For multi deck RORO ships and Car carriers, the primary supporting members are often to be assessed from a FE partial ship model. This section describes special modelling issues and load application, not covered by RU SHIP Pt.3 Ch.7 and RU SHIP Pt.3 Ch.6 respectively.

1.2 Model extent

The analysis model should extend over minimum three (3) pillar spacings. The model should cover the full breadth of the ship in order to account for unsymmetrical load cases (LC4 and LC5, ref. RU SHIP Pt.5 Ch.3 Sec.2 Table 1).

The extent of the recommended model is visualised in Figure 1. Only half the model is shown.

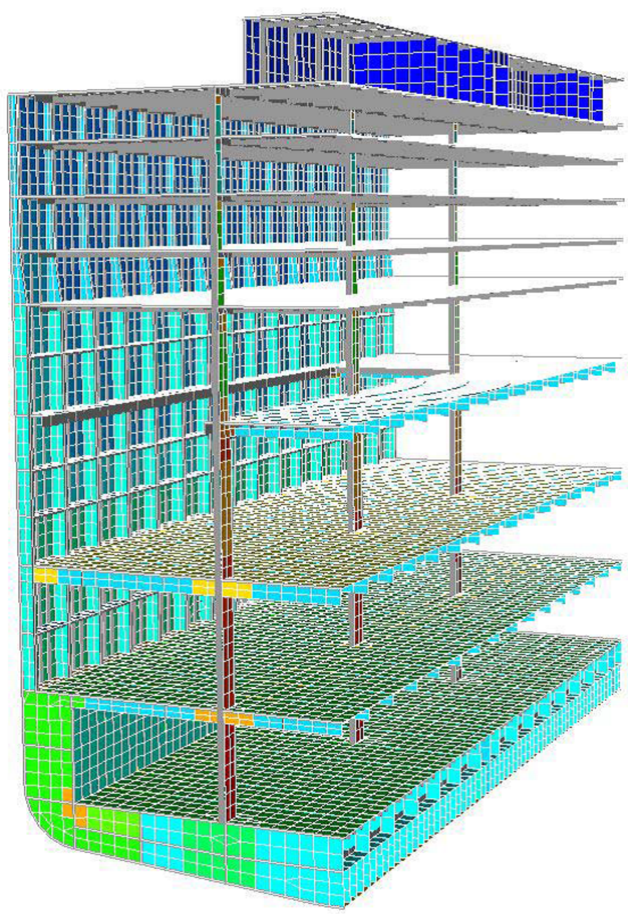


Figure 1 Example of partial ship model of a car carrier(shows only port side of the full breadth model)

1.3 FE Model

A general description of FE partial ship model including structural idealization, mesh, element size and boundary conditions, is given in RU SHIP Pt.3 Ch.7 Sec.3 and in supporting class guideline DNVGL CG 0127. A typical mesh arrangement on transverse web frame is shown in Figure 2.

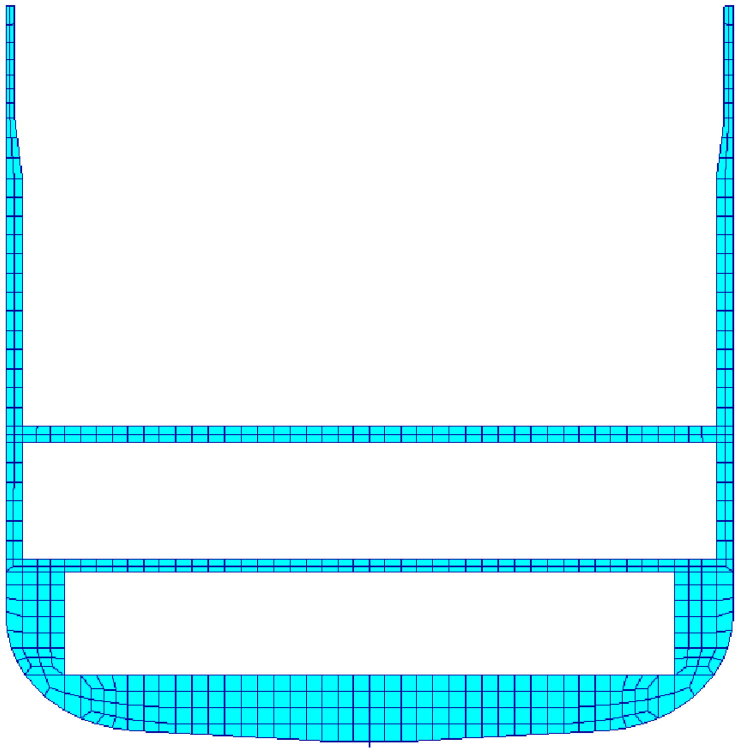


Figure 2 Typical mesh arrangement on transverse web of a car carrier

1.4 Structural idealisation

Non-continuous secondary structures such as web stiffeners on girders and floors may be included in the model as truss element when considered important, otherwise they may be ignored.

1.5 General load application

As given in RU SHIP Pt.5 Ch.3 Sec.2 [3.3] with a more detailed explanation of the different static load patterns in the following sub-sections.

1.6 LC1 Normal ballast draught with no cargo

The load case may be decisive for the double bottom.

Double bottom bunker tanks are to be considered empty. Ballast in double bottom tanks may be included as counteracting forces to the external pressure. The counteracting force corresponds to the gravity effect of the mass of water in the ballast tanks.

1.7 LC2 Maximum cargo load on lower decks

The load case may be decisive for the lower decks and pillars.

Note that the higher decks are also loaded, although not to its maximum load capacity, in order to achieve vertical balance at scantling draught.

1.8 LC3 Maximum cargo load on upper decks

The load case may be decisive for the double bottom, higher decks, pillars and longitudinal girders in the double bottom.

All cargo spaces, except the tank top, are normally to be considered loaded to maximum values.

1.9 LC4 and LC5 - Unsymmetrical static load patterns

This load case may be dimensioning for the transverse and longitudinal deck girders, respectively.

Unless specific limitations to the loading are given as a design basis, the marked area in Figure 3 and Figure 4 are to be loaded with maximum UDL and with no cargo load on the remaining deck part for LC4 and LC5, transversely- and longitudinally unsymmetrical load patterns.

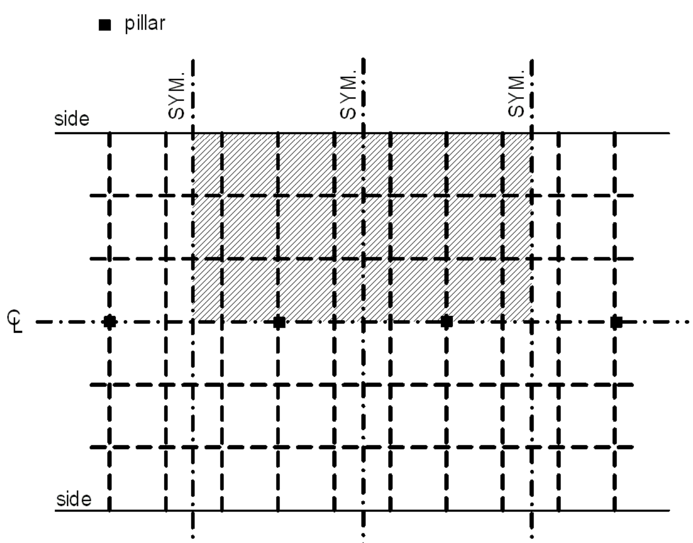


Figure 3 Load case LC4

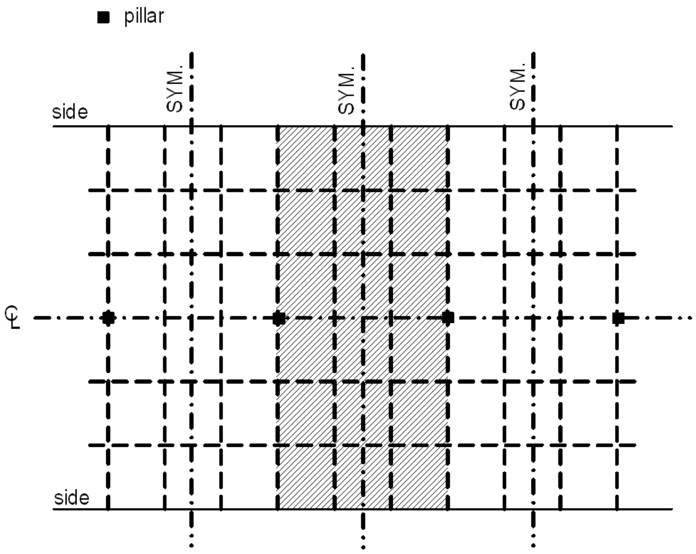


Figure 4 Load case LC5

For two-pillar system, the load between the pillars and the load outside the pillars need to be studied separately.

1.10 LC6 Heavy cargo unit on single girder

The load case may be decisive for transverse girders on heavy cargo decks, especially with respect to shear stress in girder webs towards pillar connections.

Maximum number of bogie loads, side by side, to be applied to one single girder according to stowage plan.

The following load patterns should be checked:

— Maximum bogie loads on the transverse girder in way of the pillars from side to side
— Maximum bogie loads on the transverse girder in way of the pillars, only between the pillars
— Maximum bogie loads on the transverse girder located in the middle between the pillars, from side to side.

1.11 LC7 Flooded condition

The load case is decisive for the watertight decks.

The watertight decks are to be loaded according to applicable final equilibrium waterline for the deck in question. No cargo to be applied on the watertight decks.

SECTION 5 GLOBAL RACKING STRENGTH ANALYSIS

1 Modelling

1.1 General

Reference is made to DNVGL CG 0127 Sec.2 for general description of objective, model extent, mesh arrangement, model idealisation, boundary conditions and analysis criteria. The following sub-sections give additional input concerning the global FE model.

1.2 Structure representation

All racking constraining structural members, i.e. external shell, decks, bulkheads, racking constraining girder structures, engine casing, deep webs, bow, stern bulkheads and partial bulkheads should be included in the model.

The deck panels including the deck stiffeners may be represented by plate elements and the girder structures by eccentric beam elements.

Gross scantlings to be applied.

1.3 Mesh size

A typical global coarse mesh models of a Car carrier is shown in Figure 1.

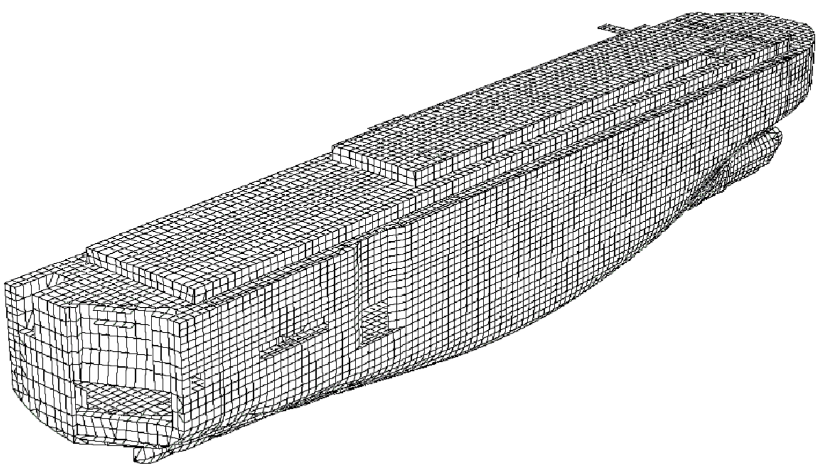


Figure 1 Global coarse mesh finite element model of a car carrier

1.4 Element type

By preference 6/8 node elements should be used. The use of 3/4 node elements will require half mesh size. Due attention should be given to the element shapes, in particular in case of 3/4 node-elements are used. Sharp corners, skewed elements and excessive use of triangle elements (3/6 nodes) may cause errors in the resulting deflection patterns in the model.

1.5 Boundary conditions

The boundary conditions should be specified only to prevent rigid body motions. Boundary example 3 in DNVGL CG 0127 Sec.2 Figure 11 should be applied. The reaction forces in the boundary nodes should be minimized.

2 Loads and load application

2.1 Loading condition

With reference to RU SHIP Pt.5 Ch.3 Sec.2, the loading conditions resulting in the highest racking moment about bulkhead deck, shall be chosen for the ULS racking analysis.

For FLS assessment, the most frequent loading condition should be the basis. To simplify the design process, the same loading conditions as for ULS may be applied for the FLS assessment, even if it could be somewhat conservative, depending on the design and loading manual.

2.2 Dynamic deck loads

With reference to RU SHIP Pt.5, the static deck loads and selfweight for the critical loading condition for racking from [2.1] are to be multiplied with the accelerations for BSR-1P/2P or BSR-1S/2S according to RU SHIP Pt.3 Ch.4 Sec.3 [3.3].

For ULS, the load combination factors are taken from RU SHIP Pt.3 Ch.4 Sec.2 Table 5.

For FLS, the load combination factors are taken from RU SHIP Pt.3 Ch.4 Sec.2 Table 11.

The dynamic deck loads may be applied as surface pressure in the global FE model.

2.3 Sea pressure

With reference to RU SHIP Pt.5, the sea pressure according to RU SHIP Pt.3 Ch.4 Sec.5, respectively, shall be added as surface pressure to the bottom and side structure.

3 Balancing of global FE model

It is of outmost importance that the global FE model is in balance with minimum reaction forces. This section focuses on such balancing for racking loadcase.

For cases were a direct wave load analysis is carried out and were these load are directly transferred to the FE model, the reaction forces will be small. For all other cases, when applying the rule loads according to [2], the FE model will not automatically be in balance. No adjustment of the racking moment itself will be accepted to achieve force and moment balance of the FE model.

Instead, the dynamic sea pressure can be adjusted following the below procedure:

1) Apply dynamic sea pressure as described herein. If sufficient balance is not possible when using the dynamic sea pressure, then a hydrostatic pressure will also be accepted.
2) Adjust the FE model vertically to achieve buoyancy force equal to the vertical loads (deck loads, self weight and tank content).
3) Rotate (roll) the model until balance of the transverse force is achieved or use the fraction of the sea pressure in heeled condition.
4) Re-check vertical force balance and adjust the pressure if necessary.
5) Re-check transverse force balance and adjust by rotation (roll) if necessary.
6) Balance the racking moment M_{xx} by a force pair distribution (i.e. line load expressed in N/m) along the intersection line between the freeboard deck and the ship side. The racking moment M_{xx} is then calculated about the axis defined as the intersection line between the freeboard deck and the centre line. The force pair distribution can either be constant or have a proper variation in the longitudinal

direction. One option is to scale the force pair distribution with the height of the parallel ship side below the freeboard deck. Another option is to scale the force pair with the width of the hull in the waterline.

The following steps describe a possible balancing procedure more in detail, in line with the above principle:

1) Apply the dynamic racking dynamic load case BSR according to [2].
2) Add a transverse horizontal unit load, LC_{Fy}, in bottom to cancel F_y according to Figure 2.
3) Add a vertical unit force couple, LC_{Mxx}, in order to cancel M_{xx} according to Figure 2.
4) Required unit loads for LC_{Fy} and LC_{Mxx} may then be calculated as follows:

   Step 1) Final transverse horizontal load F_y for $LC_{Fy} = F_y(\text{BSR})/F_y(LC_{Fy})$

   Step 2) M_{xx} created by LC_{Fy},$M_{xx}(LC1_{Fy}) = M_{xx}(LC_{Fy})) * F_y(LC_{Fy})/F_y(\text{BSR})$

   Step 3) Final vertical force couple for $LC_{Mxx} = \{M_{xx}(\text{BSR}) - M_{xx}(LC_{Fy})\}/M_{xx}(LC_{\text{Mxx}})$

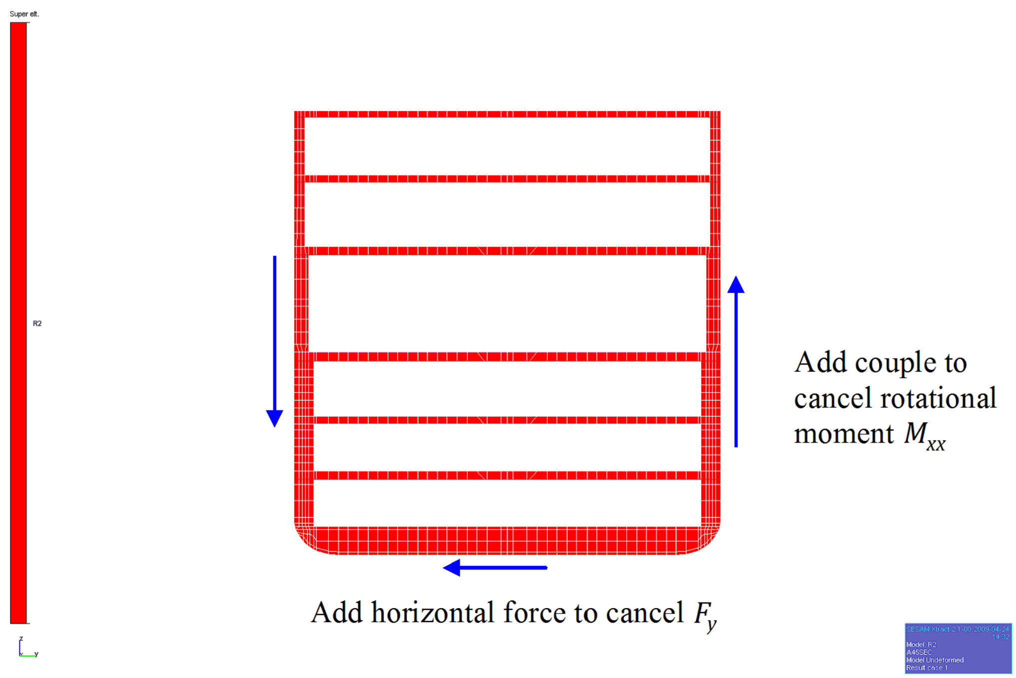


Figure 2 Balancing loads for rotational moment

SECTION 6 DOCKING ANALYSIS

1 Modelling and load application

When required, a separate docking load case should be applied to the global FE model based on the lightship weight and the docking plan.

Spring elements should be added as boundary conditions to model the docking blocks.

2 Critical structure

This loading condition will often be decisive for the dimensioning of the following structural areas:

— Capacity of double bottom structure and support
— Shear buckling of floors and girders in the double bottom.

3 Aft structure

For vessels with extended flat bottom design in the aft structure, the docking analysis will provide a good overview of the vertical deflections. It may be necessary to add supporting pillars/docking blocks under the flat bottom during docking if the analysis shows significant deflections.

SECTION 7 LOCAL FE MODELS

1 General

Reference is made to RU SHIP Pt.3 Ch.7 Sec.4 and DNVGL CG 0127, *Finite element analysis*, for local FE model procedures.

With reference to RU SHIP Pt.5 Ch.3 Sec.2 [8], finite element modelling of local structures will be required for special structure with special focus on fatigue. For vessels with required FLS scope, required local FE models will depend on the nominal stress screening process for the ULS global racking analysis. Typical critical structures are the main transverse racking constraining members of the hull such as bow, stern, partial transverse bulkhead, the machinery bulkhead, engine casing front wall, shell, and deck structures in way of racking bulkheads and deep webs and typical pillar and web frame connections to lower decks.

2 Sub-modelling

The local FE model may be developed separately from the global FE model by using a sub-modelling technique. Alternatively, the local model may be inserted into the global FE model. In case a sub-modelling technique is used, the loads on the local FE model should be applied as forced deformation or nodal forces in the boundary nodes.

The consistency between the global and the local model with respect to boundary forces and nodal deformations has to be documented.

SECTION 8 FATIGUE ASSESSMENT

1 Fatigue capacity and strength representation

1.1 General

Reference is made to RU SHIP Pt.5 Ch.3 Sec.2 [8], RU SHIP Pt.3 Ch.9 and DNVGL CG 0129 Sec.2 and DNVGL CG 0129 Sec.3.

1.2 Scantling approach factor, f_c

When the global FE model and the local FE model are based on t_{gr} , the f_c should be taken as 1.0. See DNVGL CG 0129 Sec.3 [2.2].

1.3 Environmental factor, f_e

For world wide operation, f_e = 0.8, should be applied.

1.4 Mean stress, f_{mean}

A mean stress factor, f_{mean} = 0.9 for welded details and 0.8 for free plate edges may be applied for structural details where the static stress is zero in racking condition. The calculated dynamic stresses are reduced accordingly by multiplication with f_{mean}. Examples of such structure with negligible static stresses are a partial racking bulkheads and engine-/ stairway casing bulkheads.

For structural details where the total stress is a combined effect due to roll and vertical accelerations, the static stress will not be zero. Typical examples of such structure are transverse deck girders, pillar structure and vertical web frame structure. Reference is made to DNVGL CG 0129 Sec.2 [4] for the mean stress correction factor.

1.5 Fatigue stress range

The fatigue stress range $\Delta\sigma_{FS}$ in N/mm^2 to be used in the assessment is based on the calculated stress range $\Delta\sigma$ multiplied by the corrections for mean stress effect, thickness effect, material factor, post-weld treatment factor, scantlings approach factor, the environmental factor, and the misalignment factor:

$$\Delta\sigma_{FS} = f_{mean} \cdot f_{thick} \cdot f_{material} \cdot f_w \cdot f_c \cdot f_e \cdot K_m \cdot \Delta\sigma$$

$\Delta\sigma$ to be taken as defined in RU SHIP Pt.5 Ch.3 Sec.2 [8.4.2].

With reference to DNVGL CG 0129 Sec.6 [5], σ_{HS} to be calculated as:

$$\sigma_{HS} = 1.12\sigma_{shift}$$

when the stress is constant, or close to constant, over the flange breadth. In Figure 1, this applies to the hot spot in the vertical web flange, which is continuous through the deck.

If the nominal stresses in the flange or plate is not constant over the breadth and local peak stresses occurs in way of the webs, σ_{HS} should be calculated as:

$$\sigma_{shift} = (\sigma_{membrane}(x_{shift}) + 0.6 \cdot \sigma_{bending}(x_{shift})) \cdot \beta$$

$$\sigma_{bending}(x_{shift}) = \sigma_{surface}(x_{shift}) - \sigma_{membrane}(x_{shift})$$

In Figure 1, this applies to the hot spot in the deck plating in way of the vertical web frame flange.

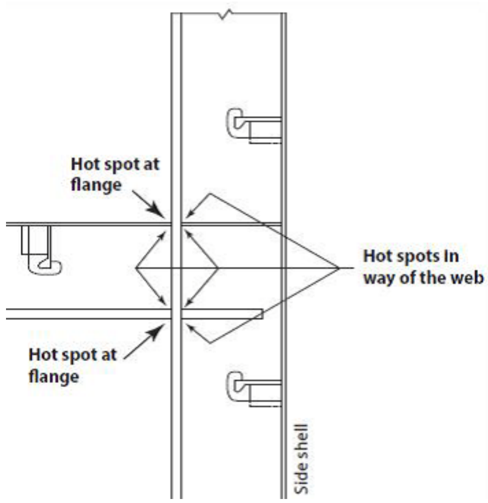


Figure 1 Example of continuous vertical web frame flange

1.6 Fatigue damage

Annual fatigue damage should be calculated according to DNVGL CG 0129 Sec.3 [3.3], applying:

$$N_D = 31.557 \cdot 10^6 \cdot v_{0,r}$$

where:

$v_{0,r}$ = $\frac{\sqrt{GM}}{2.3k_r}$ as specified in RU SHIP Pt.5 Ch.3 Sec.2 [8.4].

The combined fatigue damage is then to be calculated according to DNVGL CG 0129 Sec.3 [3.4] with $T_{C,25}$ equal to zero for all details in dry space.

CHANGES – HISTORIC

There are currently no historical changes for this document.

SECTION 5 EXTERNAL LOADS

Symbols

For symbols not defined in this section, refer to Ch.1 Sec.4.

λ = wave length, in m

B_x = moulded breadth at the waterline, in m, at the considered cross section

x, y, z = X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Sec.1 [1.2.1]

f_{xL} = ratio as defined in Sec.2

f_{yB} = ratio between Y-coordinate of the load point and B_x, to be taken as:

$$f_{yB} = \frac{|2y|}{B_x} \quad \text{but not greater than 1.0}$$

$f_{yB} = 0$ when $B_x = 0$

f_{yB1} = ratio between Y-coordinate of the load point and B, to be taken as:

$$f_{yB1} = \frac{|2y|}{B} \quad \text{but not greater than 1.0}$$

C_w = wave coefficient defined in Sec.4

f_T = ratio as defined in Sec.3

$P_{W,WL}$ = wave pressure at the waterline, kN/m^2, for the considered dynamic load case

$$P_{W,WL} = P_W \quad \text{for } z = T_{LC} \quad \begin{array}{l} y = B_x/2 \text{ when } y \geq 0 \\ y = -B_x/2, \text{ when } y < 0 \end{array}$$

h_W = water head equivalent to the pressure at waterline, in m, to be taken as:

$$h_W = \frac{P_{W,WL}}{\rho g}$$

f_{ps} = coefficient for strength assessment, as defined in Sec.3

θ = roll angle, in deg, as defined in Sec.3 [2.1.1]

T_θ = roll period, in s, as defined in Sec.3 [2.1.1]

f_R = factor related to the operational profile, as defined in Ch.9 Sec.4 [4.3]

f_β = coefficient defined in Sec.4.

1 Sea pressure

1.1 Total pressure

1.1.1 The external pressure P_{ex} at any load point of the hull, in kN/m^2, for the static (S) design load scenarios, given in Sec.7, shall be taken as:

$$P_{ex} = P_S \quad \text{but not less than 0.}$$

The total pressure P_{ex} at any load point of the hull for the static plus dynamic (S + D) design load scenarios, given in Sec.7, shall be derived from each dynamic load case and shall be taken as:

$$P_{ex} = P_S + P_W \text{ but not less than 0.}$$

where:

P_S = hydrostatic pressure, in kN/m^2, is defined in [1.2]
P_W = wave pressure, in kN/m^2, is defined in [1.3].

1.2 Hydrostatic pressure

1.2.1 The hydrostatic pressure, P_S at any load point, in kN/m^2, is obtained from Table 1. See also Figure 1.

Table 1 Hydrostatic pressure, PS

Location	*Hydrostatic pressure, P_S, in kN/m^2*
$z \leq T_{LC}$	$\rho g \, (T_{LC} - z)$
$z > T_{LC}$	0

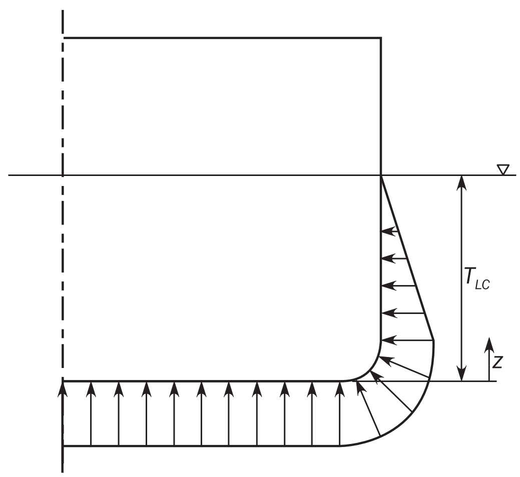


Figure 1 Transverse distribution of hydrostatic pressure Ps

1.3 External dynamic pressures for strength assessment

1.3.1 General

The hydrodynamic pressures for each dynamic load case defined in Sec.2 [2] are defined in [1.3.2] to [1.3.8].

1.3.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, P_W, for HSM-1 and HSM-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 2. See also Figure 2 and Figure 3.

Table 2 Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max\{-P_{HS}; \rho g(z - T_{LC})\}$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_W = \max\{P_{HS}; \rho g(z - T_{LC})\}$		

where:

$$P_{HS} = C_{f_T} f_{ps} f_{n\ell} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

C_{fT} = $f_T + 0.5 - (0.7 f_T - 0.2) C_B$

$f_{n\ell}$ = coefficient considering non-linear effects, to be taken as:

for extreme sea loads design load scenario:

$f_{n\ell} = 0.7$ at $f_{xL} = 0$

$f_{n\ell} = 0.9$ at $f_{xL} = 0.3$

$f_{n\ell} = 0.9$ at $f_{xL} = 0.7$

$f_{n\ell} = 0.6$ at $f_{xL} = 1$

for ballast water exchange design load scenario:

$f_{n\ell} = 0.85$ at $f_{xL} = 0$

$f_{n\ell} = 0.95$ at $f_{xL} = 0.3$

$f_{n\ell} = 0.95$ at $f_{xL} = 0.7$

$f_{n\ell} = 0.80$ at $f_{xL} = 1$

Intermediate values are obtained by linear interpolation

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = C_x \cdot \frac{z}{T_{LC}} + \left(2 - C_x\right) f_{yB} + 1$$

C_x = coefficient to be taken as:

$$C_x = 1.5 - \frac{|x - 0.5L|}{L}$$

f_h = coefficient to be taken as:

$$f_h = 3.0\left(1.21 - 0.66 f_T\right)$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = \left(0.5 + f_T\right)\left[\left(3 - 2\sqrt{f_{yB}}\right) - \frac{20}{9} f_{xL}\left(7 - 6\sqrt{f_{yB}}\right)\right] + \frac{2}{3}\left(1 - f_T\right) \quad \text{for } f_{xL} < 0.15$$

$$k_a = 1.0 \quad \text{for } 0.15 \le f_{xL} < 0.7$$

$$k_a = 1 + \left(f_{xL} - 0.7\right)\left\{\left(\frac{40}{3} f_T - 5\right) + 2\left(1 - f_{yB}\right)\left[\frac{18}{C_B} f_T\left(f_{xL} - 0.7\right) - 0.25\left(2 - f_T\right)\right]\right\} \quad \text{for } f_{xL} \ge 0.7$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + f_T)L$

k_p = phase coefficient to be obtained from Table 3. Intermediate values shall be interpolated.

Table 3 Definition of phase coefficient K_p

f_{xL}	0	$0.3 - 0.1\ f_T$	$0.35 - 0.1\ f_T$	$0.8 - 0.2\ f_T$	$0.9 - 0.2\ f_T$	1.0
k_p	$-0.25\ f_T(1 + f_{yB})$	−1	1	1	−1	−1

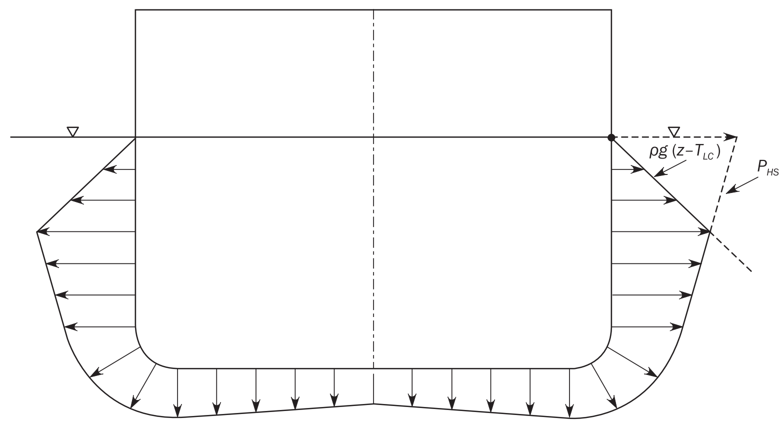


Figure 2 Transverse distribution amidships of dynamic pressure for HSM-1, HSA-1 and FSM-1 load cases

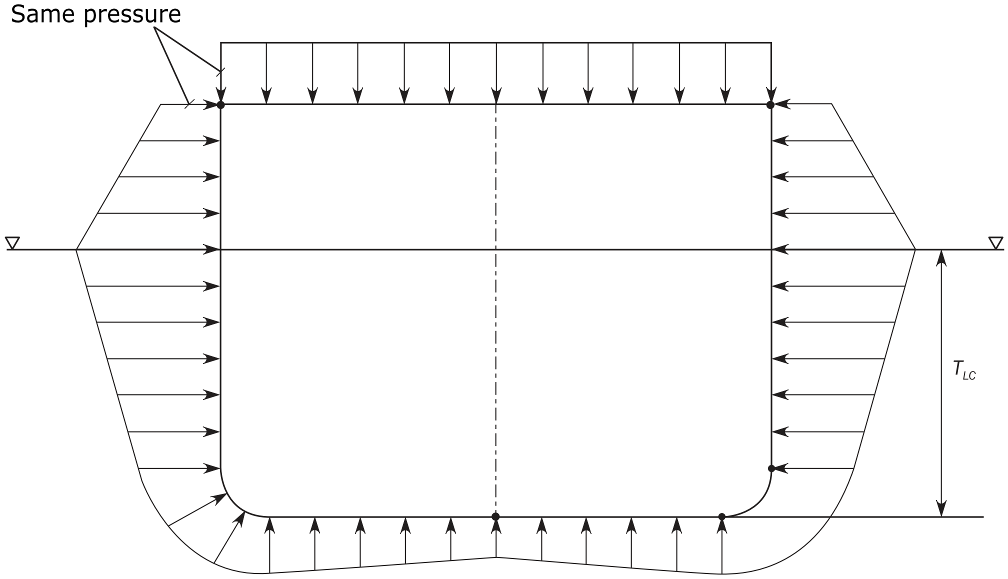


Figure 3 Transverse distribution amidships of dynamic pressure for HSM-2, HSA-2 and FSM-2 load cases

1.3.3 Hydrodynamic pressures for HSA load cases

The hydrodynamic pressures, P_W, for HSA-1 and HSA-2 load cases at any load point, in kN/m^2, shall be obtained from Table 4. See also Figure 2 and Figure 3.

Table 4 Hydrodynamic pressures for HSA load cases

	Wave pressure, in kN/m²		
Load case	$z \leq T_{LC}$	$T_{LC} < z \leq h_W + T_{LC}$	$z > h_W + T_{LC}$
HSA-1	$P_W = \max\{-P_{HS}; \rho g(z - T_{LC})\}$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSA-2	$P_W = \max\{P_{HS}; \rho g(z - T_{LC})\}$		

where:

P_{HS} = as defined in [1.3.2]
$f_{n\ell}$ = coefficient considering non-linear effects, to be taken as defined in [1.3.2]
f_{yz} = girth distribution coefficient as defined in [1.3.2]
f_h = coefficient to be taken as:

$$f_h = 2.4(1.21 - 0.66\, f_T)$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as defined in [1.3.2]
λ = wave length of the dynamic load case, in m, as defined in [1.3.2]
k_p = phase coefficient to be obtained from Table 5. Intermediate values shall be interpolated.

Table 5 Definition of phase coefficient k_p

f_{xL}	*0*	*0.3 − 0.1 f_T*	*0.5 − 0.2 f_T*	*0.8 − 0.2 f_T*	*0.9 − 0.2 f_T*	*1.0*
k_p	$1.5 - f_T - 0.5\, f_{yB}$	−1	1	1	−1	−1

1.3.4 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m², shall be obtained from Table 6. See also Figure 2 and Figure 3.

Table 6 Hydrodynamic pressures for FSM load cases

	Wave pressure, in kN/m²		
Load case	$z \leq T_{LC}$	$T_{LC} < z \leq h_W + T_{LC}$	$z > h_W + T_{LC}$
FSM-1	$P_W = \max\{-P_{FS}; \rho g(z - T_{LC})\}$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
FSM-2	$P_W = \max\{P_{FS}; \rho g(z - T_{LC})\}$		

where:

$$P_{FS} = C_{f_T} f_{ps} f_{n\ell} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

C_{fT} = coefficient to be taken as:

$$C_{f_T} = \left[1.0 + \left(1.5 - f_T\right)\left(C_B - 1.0\right)\right] \cdot \left(0.6 - 0.55\frac{L - 400}{300}\right)$$

$f_{n\ell}$ = coefficient considering non-linear effects, to be taken as:
$f_{n\ell}$ = 0.9 for extreme sea loads design load scenario
$f_{n\ell}$ = 0.95 for ballast water exchange design load scenarios

f_{yz} = girth distribution coefficient to be taken as:

$$f_{yz} = \left(C_x - 0.2\right)\frac{z}{T_{LC}} + \left(2 - C_x\right)f_{yB} + 1.2$$

C_x = coefficient to be taken as:

$$C_x = 1.5 - \frac{|x - 0.5L|}{L}$$

f_h = coefficient to be taken as: f_h = 2.6

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = 1 + \left(3.75 - 2f_T\right)\left(1 - 5f_{xL}\right)\left(1 - f_{yB}\right) \quad \text{for} \quad f_{xL} < 0.2$$

$$k_a = 1.0 \quad \text{for} \quad 0.2 \le f_{xL} < 0.9$$

$$k_a = 1 + 20\left(1 - f_{yB}\right)\left(f_{xL} - 0.9\right) \quad \text{for} \quad f_{xL} \ge 0.9$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + 2/3\ f_T)L$

k_p = phase coefficient to be obtained from Table 7. Intermediate values shall be interpolated.

Table 7 Definition of phase coefficient k_p

f_{xL}	0	$0.35 - 0.1f_T$	$0.5 - 0.2f_T$	0.75	0.8	1.0
k_p	$-0.75 - 0.25f_{yB}$	-1	1	1	-1	$-0.75 - 0.25f_{yB}$

1.3.5 Hydrodynamic pressures for BSR load cases

The wave pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 8. See also Figure 4 and Figure 5.

Table 8 Hydrodynamic pressures for BSR load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
BSR-1P	$P_W = \max(P_{BSR}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
BSR-2P	$P_W = \max(-P_{BSR}, \rho g(z - T_{LC}))$		
BSR-1S	$P_W = \max(P_{BSR}, \rho g(z - T_{LC}))$		
BSR-2S	$P_W = \max(-P_{BSR}, \rho g(z - T_{LC}))$		

where:

$$P_{BSR} = f_\beta f_{nl}\left[10y\sin\theta_1 + 0.88f_{ps}C_W\sqrt{\frac{L_0 + \lambda - 125}{L_0}}\left(f_{yB1} + 1\right)\right]$$

for BSR-1P and BSR-2P load cases.

$$P_{BSR} = f_{\beta} f_{nl}\left[-10y\sin\theta_1 + 0.88 f_{ps} C_w \sqrt{\frac{L_0+\lambda-125}{L_0}}\left(f_{yB1}+1\right)\right]$$

for BSR-1S and BSR-2S load cases.

$f_{n\ell}$ = coefficient considering non-linear effect, to be taken as:

$f_{n\ell}$ = 1 for extreme sea loads design load scenario

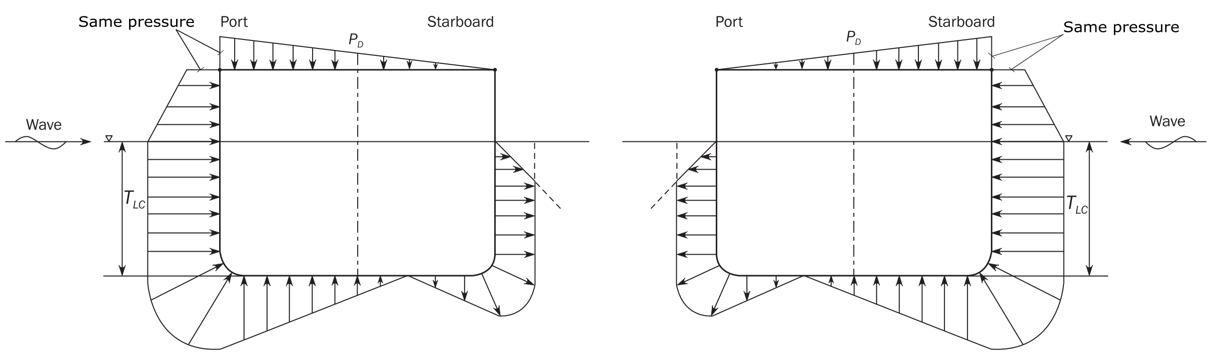
$f_{n\ell}$ = 1 for ballast water exchange design load scenarios

λ = wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi} T_{\theta}^2$$

θ_1 =

$$\theta_1 = \frac{9000\left(1.4 - 0,035 T_{\theta}\right)}{(1.15B + 55)\pi}$$



P_D = green sea pressure on exposed deck as defined in [2.2].

Figure 4 Transverse distribution of dynamic pressure for BSR-1P (left) and BSR-1S (right) load cases

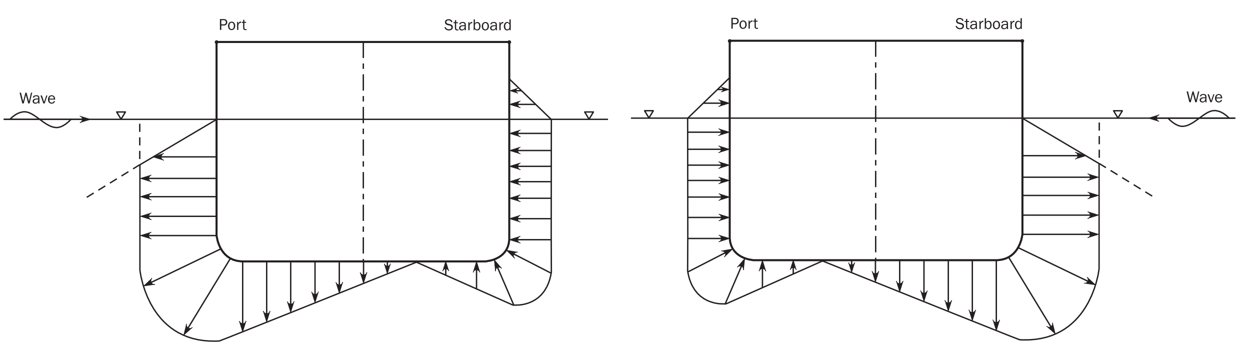


Figure 5 Transverse distribution of dynamic pressure for BSR-2P (left) and BSR-2S (right) load cases

1.3.6 Hydrodynamic pressures for BSP load cases

The wave pressures, P_W, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 9. See also Figure 6 and Figure 7.

Table 9 Hydrodynamic pressures for BSP load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
BSP-1P	$P_W = \max(P_{BSP}, \rho g (z - T_{LC}))$	$P_W = P_{W,WL} - \rho g (z - T_{LC})$	$P_W = 0.0$
BSP-2P	$P_W = \max(-P_{BSP}, \rho g (z - T_{LC}))$		
BSP-1S	$P_W = \max(P_{BSP}, \rho g (z - T_{LC}))$		
BSP-2S	$P_W = \max(-P_{BSP}, \rho g (z - T_{LC}))$		

where:

$$P_{BSP} = 4.5 f_{corr1} f_{corr2} f_\beta f_{ps} f_{n\ell} f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L_0}}$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.2(1 + 2f_T)L_0$

f_{yz} = girth distribution coefficient, to be obtained from Table 10

Table 10 Definition of girth distribution coefficient f_{yz}

Transverse position	BSP-1P - BSP-2P	BSP-1S - BSP-2S
$y \ge 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB1} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB1} + 0.5$
$y < 0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB1} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB1} + 0.5$

$f_{n\ell}$ = coefficient considering non-linear effect, to be taken as:

for extreme sea loads design load scenario:

$f_{n\ell} = 0.6$ at $f_{xL} = 0$

$f_{n\ell} = 0.8$ at $f_{xL} = 0.3$

$f_{n\ell} = 0.8$ at $f_{xL} = 0.7$

$f_{n\ell} = 0.6$ at $f_{xL} = 1$

for ballast water exchange design load scenario:

$f_{n\ell} = 0.6$ at $f_{xL} = 0$

$f_{n\ell} = 0.8$ at $f_{xL} = 0.3$

$f_{n\ell} = 0.8$ at $f_{xL} = 0.7$

$f_{n\ell} = 0.6$ at $f_{xL} = 1$

intermediate values are obtained by linear interpolation

f_{corr1} = fullness and draft correction factor, to be taken as:

$$= \left[0.9 + \left(\frac{2T_{LC}}{T_{SC}} - 1.05\right)\left(\frac{C_B}{0.85} - 0.85\right)\right] \cdot \left(1.03 - 0.16 f_T\right)$$

f_{corr2} = ship length correction factor, to be taken as:

$$f_{corr2} = 1 + 0.25\frac{110}{L}$$ for $L < 110$

$$f_{corr2} = 1.25 - 0.25\frac{L-110}{40}$$ for $110 < L < 150$

$$f_{corr2} = 1$$ for $150 < L$

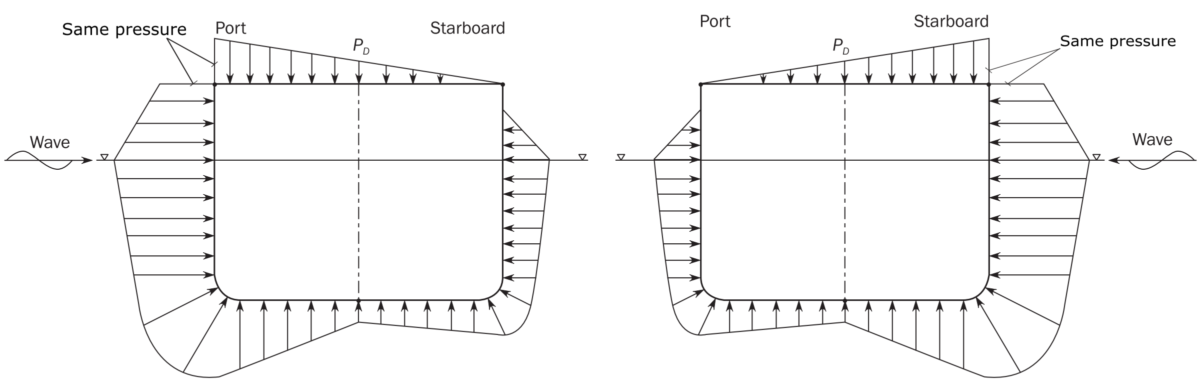


Figure 6 Transverse distribution of dynamic pressure for BSP-1P (left) and BSP-1S (right) load cases

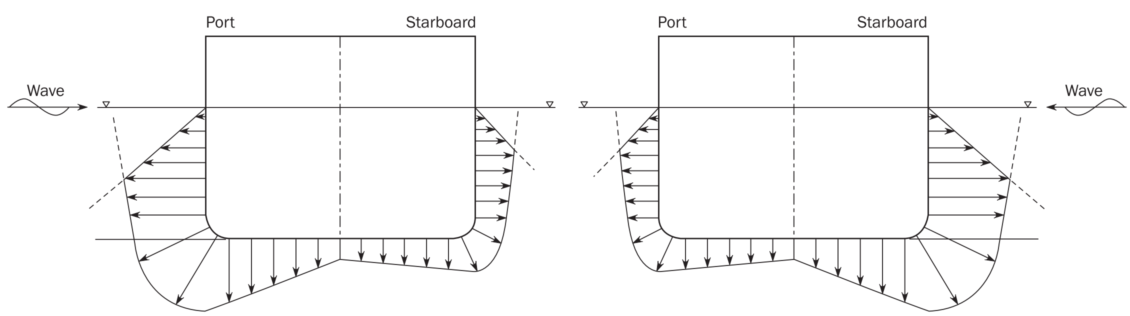


Figure 7 Transverse distribution of dynamic pressure for BSP-2P (left) and BSP-2S (right) load cases

1.3.7 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point shall be obtained, in kN/m^2, from Table 11. See also Figure 8 and Figure 9.

Table 11 Hydrodynamic pressures for OST load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
OST-1P	$P_W = \max(P_{OST}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
OST-2P	$P_W = \max(-P_{OST}, \rho g(z - T_{LC}))$		
OST-1S	$P_W = \max(P_{OST}, \rho g(z - T_{LC}))$		
OST-2S	$P_W = \max(-P_{OST}, \rho g(z - T_{LC}))$		

where:

$$P_{OST} = 1.38 f_{corr} f_{ps} f_{nl} k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} = girth distribution coefficient, to be obtained from Table 12

$f_{n\ell}$ = coefficient considering non-linear effect, to be taken as:

$f_{n\ell} = 0.8$ for extreme sea loads design load scenario

$f_{n\ell} = 0.9$ for ballast water exchange design load scenarios

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.45\ L$

f_{corr} = coefficient, to be taken as:

$$f_{corr} = \begin{cases} (1.15 - 0.3 f_T)\left[1 + (f_T + 0.55)\dfrac{150 - L_0}{80}\right] & \text{for } L \le 150 \\ 1.15 - 0.3 f_T & \text{for } L > 150 \end{cases}$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 13

k_p = phase coefficient to be obtained from Table 14. Intermediate values shall be interpolated.

Table 12 Definition of girth distribution coefficient f_{yz}

Transverse position	*OST-1P - OST-2P*	*OST-1S - OST-2S*
$y \ge 0$	$5\frac{z}{T_{LC}} + 3.5 f_{yB} + 1.5$	$1.5\frac{z}{T_{LC}} + 1.5$
$y < 0$	$1.5\frac{z}{T_{LC}} + 1.5$	$5\frac{z}{T_{LC}} + 3.5 f_{yB} + 1.5$

Table 13 Definition of amplitude coefficient K_a

Transverse position	*Longitudinal position*	*OST-1P - OST-2P*	*OST-1S - OST-2S*
$y \ge 0$	$f_{xL} \le 0.2$	$1 + 3.5(1 - f_{yB})(1 - 5 f_{xL})$	$1 + [3.5 - (4 f_T - 0.5) f_{yB}](1 - 5 f_{xL})$

Transverse position	Longitudinal position	OST-1P - OST-2P	OST-1S - OST-2S
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1 + 4\left(1 - f_T\right)\left(5f_{xL} - 4\right)f_{yB}$
$y < 0$	$f_{xL} \leq 0.2$	$1 + \left[3.5 - \left(4f_T - 0.5\right)f_{yB}\right]\left(1 - 5f_{xL}\right)$	$1 + 3.5\left(1 - f_{yB}\right)\left(1 - 5f_{xL}\right)$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1 + 4\left(1 - f_T\right)\left(5f_{xL} - 4\right)f_{yB}$	1.0

Table 14 Definition of phase coefficient K_p

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	0.0	1.0	1.0
	0.2	1.0	$1 + \left(0.75 - 1.5f_T\right)f_{yB}$
	0.4	-1.0	$-1 + \left(1.75 - 0.5f_T\right)f_{yB}$
	0.5	-1.0	$-1 + \left(1.75 - 0.5f_T\right)f_{yB}$
	0.7	$-0.1 + \left(1.6f_T - 1.5\right)f_{yB}$	$-0.1 + \left(0.25 - 0.3f_T\right)f_{yB}$
	0.9	$0.8 + 0.2f_{yB}$	$0.8 - \left(0.9f_T + 0.85\right)f_{yB}$
	1.0	$-1 + f_{yB}$	$-1 + \left(0.5 - 0.5f_T\right)f_{yB}$
$y < 0$	0.0	1.0	1.0
	0.2	$1 + \left(0.75 - 1.5f_T\right)f_{yB}$	1.0
	0.4	$-1 + \left(1.75 - 0.5f_T\right)f_{yB}$	-1.0
	0.5	$-1 + \left(1.75 - 0.5f_T\right)f_{yB}$	-1.0
	0.7	$-0.1 + \left(0.25 - 0.3f_T\right)f_{yB}$	$-0.1 + \left(1.6f_T - 1.5\right)f_{yB}$
	0.9	$0.8 - \left(0.9f_T + 0.85\right)f_{yB}$	$0.8 + 0.2f_{yB}$
	1.0	$-1 + \left(0.5 - 0.5f_T\right)f_{yB}$	$-1 + f_{yB}$

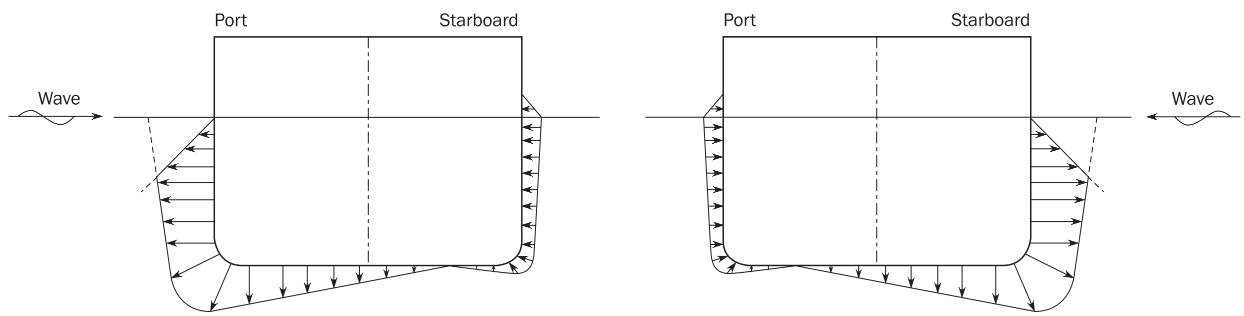


Figure 8 Transverse distribution of dynamic pressure amidships for OST-1P (left) and OST-1S (right) load cases

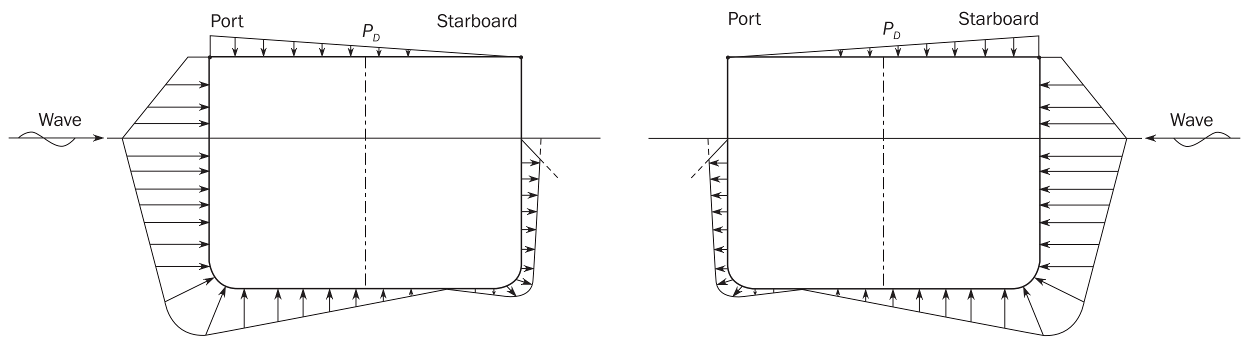


Figure 9 Transverse distribution of dynamic pressure amidships for OST-2P (left) and OST-2S (right) load cases

1.3.8 Hydrodynamic pressures for OSA load cases

The wave pressures, P_W, for OSA-1 and OSA-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 15. See also Figure 10 and Figure 11.

Table 15 Hydrodynamic pressures for OSA load cases

	Wave pressure, in kN/m²		
Load case	$z \leq T_{LC}$	$T_{LC} < z \leq h_W + T_{LC}$	$z > h_W + T_{LC}$
OSA-1P	$P_W = \max\left(P_{OSA}, \rho g\,(z - T_{LC})\right)$	$P_W = P_{W,WL} - \rho g\,(z - T_{LC})$	$P_W = 0.0$
OSA-2P	$P_W = \max\left(-P_{OSA}, \rho g\,(z - T_{LC})\right)$		
OSA-1S	$P_W = \max\left(P_{OSA}, \rho g\,(z - T_{LC})\right)$		
OSA-2S	$P_W = \max\left(-P_{OSA}, \rho g\,(z - T_{LC})\right)$		

where:

$$P_{OSA} = 0.81 f_{corr} f_{ps} f_{nl} k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}\left(1 + 0.5 f_T\right)$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.7\ L$

f_{corr} = fullness and draft correction factor, to be taken as:

$$f_{corr} = (1.08 - 0.18 f_T)[1.25 + \ln(C_B)] \quad \text{for } L < 80$$

$$f_{corr} = (1.08 - 0.18 f_T)[1.25 + \ln(C_B)]\left[1 - \left(\frac{L}{20} - 4\right)\left(1 - \sin\left(\frac{25 T_{LC}}{L}\right)\right)\right] \quad \text{for } 80 \le L < 100$$

$$f_{corr} = (1.08 - 0.18 f_T)[1.25 + \ln(C_B)]\sin\left(\frac{25 T_{LC}}{L}\right) \quad \text{for } L \ge 100$$

$f_{n\ell}$ = coefficient considering non-linear effect, to be taken as:

for extreme sea loads design load scenario:

$f_{n\ell} = 0.5$ at $f_{xL} = 0$

$f_{n\ell} = 0.8$ at $f_{xL} = 0.3$

$f_{n\ell} = 0.8$ at $f_{xL} = 0.7$

$f_{n\ell} = 0.6$ at $f_{xL} = 1$

for ballast water exchange design load scenario:

$f_{n\ell} = 0.75$ at $f_{xL} = 0$

$f_{n\ell} = 0.9$ at $f_{xL} = 0.3$

$f_{n\ell} = 0.9$ at $f_{xL} = 0.7$

$f_{n\ell} = 0.8$ at $f_{xL} = 1$

intermediate values are obtained by linear interpolation

f_{yz} = girth distribution coefficient, to be obtained from Table 16

k_a = amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 17

k_p = phase coefficient to be obtained from Table 18. Intermediate values shall be interpolated.

Table 16 Definition of girth distribution coefficient f_{yz}

Transverse position	*OSA-1P - OSA-2P*	*OSA-1S - OSA-2S*
$y \ge 0$	$5.5\frac{z}{T_{LC}} + 5.3 f_{yB} + 2.2$	$0.9\frac{z}{T_{LC}} + 0.4 f_{yB} + 2.2$
$y < 0$	$0.9\frac{z}{T_{LC}} + 0.4 f_{yB} + 2.2$	$5.5\frac{z}{T_{LC}} + 5.3 f_{yB} + 2.2$

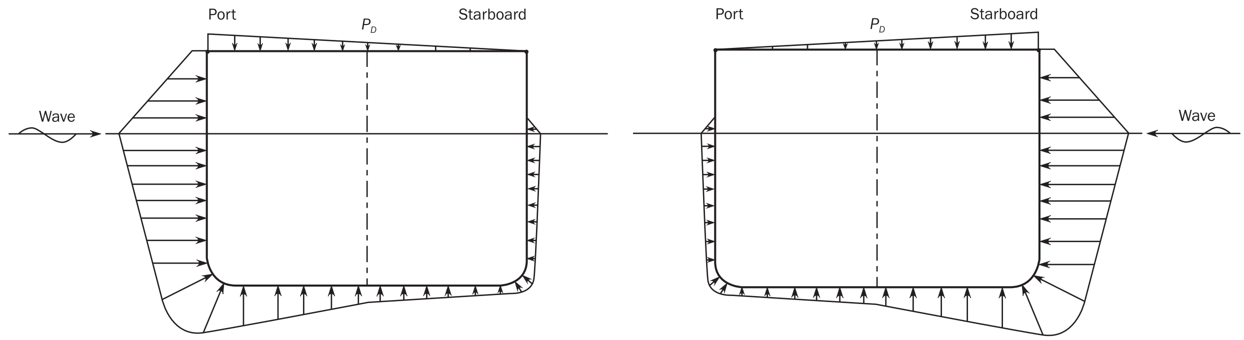


Figure 10 Transverse distribution of dynamic pressure amidships for OSA-1P (left) and OSA-1S (right) load cases

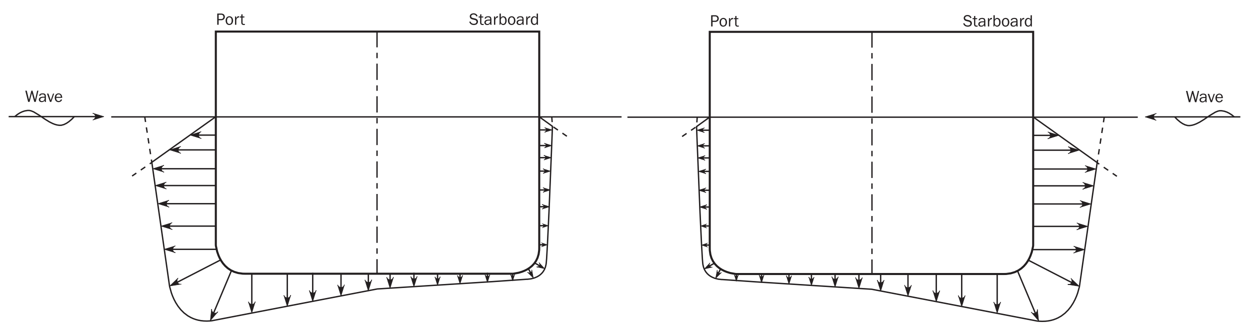


Figure 11 Transverse distribution of dynamic pressure amidships for OSA-2P (left) and OSA-2S (right) load cases

Table 17 Definition of amplitude coefficient K_a

Transverse position	*Longitudinal position*	*OSA-1P - OSA-2P*	*Longitudinal position*	*OSA-1S - OSA-2S*
$y \geq 0$	$f_{xL} < 0.275$	$\min\{k_{a3};\ 1.05\}$	$f_{xL} < 0.35$	$1 + 4(f_T - 0.75)f_{yB}$ $+1.2f_{yB}\cos[90(5f_{xL} - 0.75)]$
	$0.275 < f_{xL} \leq 0.7$	$\min\{k_{a1};\ 1.05\}$	$0.35 < f_{xL} \leq 0.65$	k_{a2}
	$f_{xL} > 0.7$	$k_{a1} + (1.9f_T - 2.05)f_{yB}$ $\cos\left[\frac{180(f_{xL} - 0.4)}{0.6}\right]$	$f_{xL} > 0.65$	$k_{a2} + 36(f_{xL} - 0.65)^2 f_{yB}$
$y < 0$	$f_{xL} < 0.35$	$1 + 4(f_T - 0.75)f_{yB}$ $+1.2f_{yB}\cos[90(5f_{xL} - 0.75)]$	$f_{xL} < 0.275$	$\min\{k_{a3};\ 1.05\}$
	$0.35 < f_{xL} \leq 0.65$	k_{a2}	$0.275 < f_{xL} \leq 0.7$	$\min\{k_{a1};\ 1.05\}$
	$f_{xL} > 0.65$	$k_{a2} + 36(f_{xL} - 0.65)^2 f_{yB}$	$f_{xL} > 0.7$	$k_{a1} + (1.9f_T - 2.05)f_{yB}$ $\cos\left[\frac{180(f_{xL} - 0.4)}{0.6}\right]$

where:

$$k_{a1} = 1 + 0.2(2 - f_T)f_{yB}\left\{\sin\left[180\left(0.5 + \frac{f_{xL} - 0.275}{0.425}\right)\right] + 0.09\right\}$$

$$k_{a2} = 1 - 2(f_T - 0.75)f_{yB}(3.75 - 5f_{xL})\sin[60(10f_{xL} - 5)]$$

$$k_{a3} = k_{a1} + (0.3f_T - 1.15)f_{yB}\cos\left[\frac{180(f_{xL} - 0.05)}{0.45}\right]$$

Table 18 Definition of phase coefficient K_p

Transverse position	f_{xL} = *x/L*	*OSA-1P and OSA-2P*	*OSA-1S and OSA-2S*[1)]
y ≥ 0	0.0	$0.75 - 0.5f_{yB}$	0.75
	0.1	$f_T - 0.25 + (1.25 - f_T)f_{yB}$	$f_T - 0.25 + (0.35f_T - 0.47)f_{yB}$
	0.35	1.0	$1 + (2.7f_T - 3.2)f_{yB}$
	0.4	$1.25 - 0.5f_T + (0.5f_T - 0.25)f_{yB}$	$1.25 - 0.5f_T + (2.7f_T - 3.2)f_{yB}$
	0.55	$1.5 - f_T + (f_T - 1.07)f_{yB}$	$1.5 - f_T + (2.7f_T - 3.2)f_{yB}$
	0.85	$0.5f_T - 1.25 + (0.25 - 0.5f_T)f_{yB}$	$0.5f_T - 1.25 + (0.2 - 0.1f_T)f_{yB}$
	1.0	$0.5f_T - 1.25 + (0.25 - 0.5f_T)f_{yB}$	$0.5f_T - 1.25 + (0.2 - 0.1f_T)f_{yB}$
y < 0	0.0	0.75	$0.75 - 0.5f_{yB}$
	0.1	$f_T - 0.25 + (0.35f_T - 0.47)f_{yB}$	$f_T - 0.25 + (1.25 - f_T)f_{yB}$
	0.35	$1 + (2.7f_T - 3.2)f_{yB}$	1.0
	0.4	$1.25 - 0.5f_T + (2.7f_T - 3.2)f_{yB}$	$1.25 - 0.5f_T + (0.5f_T - 0.25)f_{yB}$
	0.55	$1.5 - f_T + (2.7f_T - 3.2)f_{yB}$	$1.5 - f_T + (f_T - 1.07)f_{yB}$
	0.85	$0.5f_T - 1.25 + (0.2 - 0.1f_T)f_{yB}$	$0.5f_T - 1.25 + (0.25 - 0.5f_T)f_{yB}$
	1.0	$0.5f_T - 1.25 + (0.2 - 0.1f_T)f_{yB}$	$0.5f_T - 1.25 + (0.25 - 0.5f_T)f_{yB}$
1) k_p shall not be taken less than −1.0 or greater than 1.0.			

k_p for other f_{xL} shall be linearly interpolated.

1.3.9 Envelope pressure

The envelope of wave pressure at any point, $P_{w\text{-}max}$, shall be taken as the greatest pressure obtained from any of the load cases determined by [1.3.2] to [1.3.8]. For ships with L=<90 m the envelope wave pressure, P_w, as obtained from Table 19 may be used in lieu of the pressures defined in [1.3.2] to [1.3.8].

Table 19 Wave pressure in kN/m², for ships with length ≤ 90 m

	Wave pressure in kN/m², for ships with length 90 m or less		
Load case	$z \le T_{SC}$	$T_{SC} < z \le h_w + T_{SC}$	$z > h_w + T_{SC}$
ENV	$P_W = P_{ENV}$	$P_W = P_{W,\,WL} - pq(z - T_{SC})$	$P_W = 0$

P_{ENV}, shall be taken as the maximum of $P_{ENV\text{-}BS}$ and $P_{ENV\text{-}HS}$ where:

$$P_{ENV-BS} = f_r f_3 \left(2 + \frac{55}{L}\right) f_{yz} C_w$$

$$P_{ENV-HS} = 5 f_r f_4 f_5 \left(1 - \frac{C_B}{3}\right) C_w \sqrt{\frac{1.2L - 15}{L}}$$

where:

f_3 = shall be taken as the greater of:

= 0.60
= 0.05+CB
= 1.1-0.1 L/B

f_4 = 2.0 when f_{xl}= 0
= 1.0 when f_{xl}= 0.2 to 0.6
= 3.0 when f_{xl}=1.0 and intermediate values to be obtained by linear interpolation

f_{yz} = 0.5 z/T+2.5 f_{yB}+2

1.4 External dynamic pressures for fatigue assessments

1.4.1 General

The external pressure P_{ex} at any load point of the hull for the fatigue static plus dynamic (F:S + D) design load scenario, shall be derived for each fatigue dynamic load case and shall be taken as:

$$P_{ex} = P_S + P_W \text{ but not less than } 0.$$

where:

P_S = hydrostatic pressure, in kN/m^2, defined in [1.2]
P_W = hydrodynamic pressure, in kN/m^2, defined in [1.4.2] to [1.4.6].

1.4.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, P_W, for load cases HSM-1 and HSM-2, at any load point, in kN/m^2, shall be obtained from Table 20.

Table 20 Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
HSM-1	$P_w = \max\{-P_{HS}, \rho g(z - T_{LC})\}$	$P_w = P_{w,wL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_w = 0.0$
HSM-2	$P_w = \max\{P_{HS}, \rho g(z - T_{LC})\}$		

where:

$$P_{HS} = f_p f_h k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h = coefficient to be taken as: f_h = 2.75(1.21 – 0.66f_T)

f_p = coefficient to be taken as:

$$f_p = f_R\left[\left(0.21 + 0.02f_T\right) + \left(6 - 4f_T\right)L \cdot 10^{-5}\right]$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = 1 + 3f_T - (1 + f_T)f_{yB} + \left[5(1 + f_T)f_{yB} - 15f_T\right]f_{xL} \quad \text{for } f_{xL} < 0.2$$

$$k_a = 1.0 \quad \text{for } 0.2 \le f_{xL} < 0.6$$

$$k_a = 1 + (f_{xL} - 0.6)\left[(13.5 - 3.5f_T)f_{yB} + (14.5f_T - 17) + 40(1 - f_{yB})(f_{xL} - .06)\right] \quad \text{for } f_{xL} \ge 0.6$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + f_T)L$

k_p = phase coefficient to be obtained from Table 21. Intermediate values shall be interpolated.

Table 21 Definition of phase coefficient K_p

f_{xL}	k_P
0	$(1 - f_T) + (0.5 - f_T)f_{yB}$
$0.3 - 0.1\,f_T$	-1
$0.5 - 0.2\,f_T$	1
$0.9 - 0.4\,f_T$	1
$0.9 - 0.2\,f_T$	-1
1.0	-1

1.4.3 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 22.

Table 22 Hydrodynamic pressures for FSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
FSM-1	$P_w = \max\{-P_{FS}, \rho g(z - T_{LC})\}$	$P_w = P_{w,wL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_w = 0.0$
FSM-2	$P_w = \max\{P_{FS}, \rho g(z - T_{LC})\}$		

where:

$$P_{FS} = f_p f_h k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h = coefficient to be taken as: $f_h = 2.6$

f_p = coefficient to be taken as: $f_p = f_R[(0.21 + 0.02\,f_T + (6 - 4\,f_T)L \cdot 10^{-5}]$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$k_a = 1 + (3.5 - 2f_T)(1 - 5f_{xL})(1 - f_{yB})$ for $f_{xL} < 0.2$

$k_a = 1.0$ for $0.2 \le f_{xL} < 0.9$

$k_a = 1 + 15(1 - f_{yB})(f_{xL} - 0.9)$ for $f_{xL} \ge 0.9$

λ = wave length of the dynamic load case, in m, to be taken as:

$\lambda = 0.6\left(1 + \frac{2}{3}f_T\right)L$

k_p = phase coefficient to be obtained from Table 23. Intermediate values shall be interpolated.

Table 23 Definition of phase coefficient K_p

f_{xL}	k_P
0	$-0.75 - 0.25\,f_{yB}$
$0.35 - 0.1\,f_T$	-1
$0.5 - 0.2\,f_T$	1
0.75	1
$0.9 - 0.1\,f_T$	-1
1.0	$-0.5 - 0.5\,f_{yB}$

1.4.4 Hydrodynamic pressures for BSR load cases

The hydrodynamic pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 24.

Table 24 Hydrodynamic pressures for BSR load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
BSR-1P	$P_w = \max\{P_{BSR}, \rho g(z - T_{LC})\}$	$P_w = P_{w,wL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_w = 0.0$
BSR-2P	$P_w = \max\{-P_{BSR}, \rho g(z - T_{LC})\}$		
BSR-1S	$P_w = \max\{P_{BSR}, \rho g(z - T_{LC})\}$		
BSR-2S	$P_w = \max\{-P_{BSR}, \rho g(z - T_{LC})\}$		

where:

$$P_{BSR} = 10y\sin\theta + 0.88 f_p C_W \sqrt{\frac{L_0 + \lambda - 125}{L_0}}\left(f_{yB1} + 1\right)$$

for BSR-1P and BSR-2P load cases.

$$P_{BSR} = -10y\sin\theta + 0.88 f_p C_w \sqrt{\frac{L_0 + \lambda - 125}{L_0}}\left(f_{yB1} + 1\right)$$

for BSR-1S and BSR-2S load cases.

f_p = coefficient to be taken as: $f_p = f_R[(0.21 + 0.04\, f_T) - (12\, f_T - 2)\, B \cdot 10^{-4}]$

λ = wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi} T_\theta^2$$

1.4.5 Hydrodynamic pressures for BSP load cases

The wave pressures, P_W, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 25.

Table 25 Hydrodynamic pressures for BSP load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
BSP-1P	$P_w = \max\{P_{BSP}, \rho g(z - T_{LC})\}$	$P_w = P_{w,wL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_w = 0.0$
BSP-2P	$P_w = \max\{-P_{BSP}, \rho g(z - T_{LC})\}$		
BSP-1S	$P_w = \max\{P_{BSP}, \rho g(z - T_{LC})\}$		
BSP-2S	$P_w = \max\{-P_{BSP}, \rho g(z - T_{LC})\}$		

where:

$$P_{BSP} = 4.5 f_{corr1} f_{corr2} f_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L_0}}$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.2(1 + 2\, f_T)L_0$

f_{corr1} = fullness and draft correction factor, to be taken as:

$$f_{corr1} = \left[0.9 + \left(\frac{2T_{LC}}{T_{SC}} - 1.05\right)\left(\frac{C_B}{0.85} - 0.85\right)\right]\left(1.03 - 0.16 f_T\right)$$

f_{corr2} = ship length correction factor, to be taken as:

$f_{corr2} = 1 + 0.25\frac{110}{L}$ for $L < 110$

$f_{corr2} = 1.25 - 0.25\frac{L - 110}{40}$ for $110 \le L < 150$

$f_{corr2} = 1$ for $150 \le L$

f_p = coefficient to be taken as:

$$f_p = f_R\left[0.2 + \left(8 + 16 f_T\right) \cdot 10^{-3}\right]$$

f_{yz} = girth distribution coefficient, to be obtained from Table 26.

Table 26 Definition of girth distribution coefficient f_{yz}

Transverse position	BSP-1P; BSP-2P	BSP-1S; BSP-2S
y ≥ 0	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5f_{yB1} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2}f_{yB1} + 0.5$
y < 0	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2}f_{yB1} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5f_{yB1} + 0.5$

1.4.6 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point, in kN/m^2, shall be obtained from Table 27.

Table 27 Hydrodynamic pressures for OST load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
OST-1P	$P_w = \max\{P_{OST}, \rho g(z - T_{LC})\}$	$P_w = P_{w,wL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_w = 0.0$
OST-2P	$P_w = \max\{-P_{OST}, \rho g(z - T_{LC})\}$		
OST-1S	$P_w = \max\{P_{OST}, \rho g(z - T_{LC})\}$		
OST-2S	$P_w = \max\{-P_{OST}, \rho g(z - T_{LC})\}$		

where:

$$P_{OST} = 1.38(1.15 - 0.3f_T)f_p k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} = girth distribution coefficient, to be obtained from Table 28

Table 28 Definition of girth distribution coefficient f_{yz}

Transverse position	OST-1P; OST-2P	OST-1S; OST-2S
y ≥ 0	$5\frac{z}{T_{LC}} + 3.3f_{yB} + 1.7$	$\frac{z}{T_{LC}} + 0.3f_{yB} + 1.7$
y < 0	$\frac{z}{T_{LC}} + 0.3f_{yB} + 1.7$	$5\frac{z}{T_{LC}} + 3.3f_{yB} + 1.7$

f_p = coefficient to be taken as: $f_p = f_R(0.28C_B + 0.01)$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.45\ L$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 29

k_p = phase coefficient to be obtained from Table 30. Intermediate values shall be interpolated.

Table 29 Definition of amplitude coefficient K_a

Transverse position	*Longitudinal position*	*OST-1P; OST-2P*	*OST-1S; OST-2S*
y ≥ 0	$f_{xL} \leq 0.2$	$1 + \left[(3.5 - 2f_T) + (10f_T - 17.5)f_{xL}\right](1 - f_{yB})$	$1 + (3.5 - 2f_T - 1.5f_{yB})$ $+(10f_T - 17.5 + 7.5f_{yB})f_{xL}$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1 + 2(1 - f_T)(5f_{xL} - 4)f_{yB}$
y < 0	$f_{xL} \leq 0.2$	$1 + (3.5 - 2f_T - 1.5f_{yB})$ $+(10f_T - 17.5 + 7.5f_{yB})f_{xL}$	$1 + \left[(3.5 - 2f_T)\right.$ $\left.+(10f_T - 17.5)f_{xL}\right](1 - f_{yB})$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1 + 2(1 - f_T)(5f_{xL} - 4)f_{yB}$	1.0

Table 30 Definition of phase coefficient K_p

Transverse position	f_{xL}	*OST-1P - OST-2P*	*OST-1S - OST-2S*
y ≥ 0	0.0	1.0	$1 + (0.5 - f_T)f_{yB}$
	0.2	1.0	$1 + 3(0.5 - f_T)f_{yB}$
	0.4	−1.0	$(2.7 - 2.4f_T)f_{yB} - 1$
	0.5	−1.0	$(2.8 - 2.6f_T)f_{yB} - 1$
	0.7	$(f_T - 0.62)f_{yB} - 0.38$	$(2.38 - 3f_T)f_{yB} - 0.38$
	0.9	$0.24 + 0.76f_{yB}$	$0.24 - (0.24 + f_T)f_{yB}$
	1.0	$-1 + 0.5f_{yB}$	−1.0
y < 0	0.0	$1 + (0.5 - f_T)f_{yB}$	1.0
	0.2	$1 + 3(0.5 - f_T)f_{yB}$	1.0
	0.4	$(2.7 - 2.4f_T)f_{yB} - 1$	−1.0
	0.5	$(2.8 - 2.6f_T)f_{yB} - 1$	−1.0
	0.7	$(2.38 - 3f_T)f_{yB} - 0.38$	$(f_T - 0.62)f_{yB} - 0.38$
	0.9	$0.24 - (0.24 + f_T)f_{yB}$	$0.24 + 0.76f_{yB}$

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
	1.0	−1.0	$-1+0.5f_{yB}$

2 Loads on exposed decks

2.1 Application

2.1.1 Pressures and forces on exposed decks shall only be applied for strength assessment, i.e. yield and buckling assessment.

2.1.2 The green sea pressures defined in [2.2] for exposed decks shall be considered independently of the pressures due to distributed cargo or other equipment loads and any concentrated forces due to cargo or other unit equipment loads, defined in [2.3.1] and [2.3.2] respectively.

2.2 Green sea loads

2.2.1 Pressure on exposed deck

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck, in kN/m^2, for the static plus dynamic (S + D) design load scenarios shall be derived for each dynamic load case and shall be taken as defined in [2.2.3] to [2.2.4].

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck for the static (S) design load scenarios is zero.

2.2.2 If a wave breaker is fitted on the exposed deck, no reduction in the green sea pressure is allowed for the area of the exposed deck located aft of the wave breaker.

2.2.3 HSM, HSA and FSM load cases

The external pressure, P_D, for HSM, HSA and FSM load cases, at any load point of an exposed deck shall be obtained, in kN/m^2, from the following formula, see Figure 2 and Figure 3:

$$P_D = \max(\chi P_{D\text{-}min},\ P_{W,D} - \rho g\,(z - z_{dk})),\ \text{but not to be taken less than 0}$$

where:

$P_{W,D}$ = pressure in kN/m^2 obtained at ship's side, at vertical coordinate equal to z_{dk} for HSM, HSA and FSM load cases as defined in [1.3]

$P_{D\text{-}min}$ = minimum pressure on exposed freeboard deck, in kN/m^2, to be taken as:

for cargo hold analysis or PSM grillage according to Ch.7: $P_{D\text{-}min} = 0$

for other cases: $P_{D\text{-}min}$ as defined in Table 31

χ = reduction factor for pressure on exposed deck above freeboard deck:

$\chi = 0.75^C$, when $C < 3$

$\chi = 2.5 / P_{D\text{-}min}$, when $C \geq 3$

$\chi = 0$, when $P_{D\text{-}min} = 0$

$\chi = 1.0$ for freeboard deck

C = $(z_{dk} - z_{fdk})/2.3$

z_{fdk} = distance from baseline to freeboard deck considered at side, in m

z_{dk} = distance from baseline to lowest point of the exposed deck considered, in m
z = distance from baseline to load point, in m.

If a recess without coaming is arranged in the weather deck, P_D shall be tapered linearly down to the edge of the recess, but not to be taken less than $\chi P_{D\text{-}min}$, see Figure 12. Forward and aft of the recess the pressure may be tapered linearly down to the line as shown in Figure 12. The minimum pressure $\chi P_{D\text{-}min}$ for the weather deck shall be applied to the exposed deck in way of the recess.

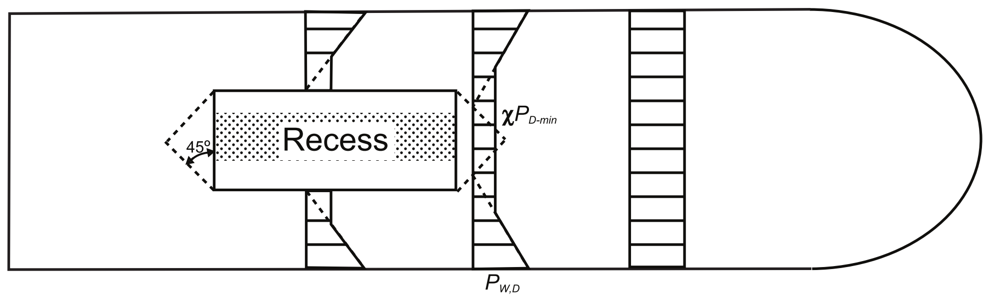


Figure 12 Transverse distribution of green sea pressure head sea

Table 31 Minimum pressures on exposed decks for HSM, HSA, FSM load cases

Location	*Minimum pressure on exposed freeboard deck, $P_{D\text{-}min}$, in kN/m²*	
	$L_{LL} \geq 100$ m	*$L_{LL} < 100$ m*
$\frac{x_{LL}}{L_{LL}} \leq 0.75$	34.3	14.9 + 0.195 L_{LL}
$\frac{x_{LL}}{L_{LL}} > 0.75$	$34.3 + \left[14.8 + a\left(L_{LL} - 100\right)\right]\left(4\frac{x_{LL}}{L_{LL}} - 3\right)$	$12.2 + \frac{L_{LL}}{9}\left(5\frac{x_{LL}}{L_{LL}} - 2\right) + 3.6\frac{x_{LL}}{L_{LL}}$

where:
a = coefficient taken equal to:
a = 0.356 for type A, type B-60 and type B-100 freeboard ships
a = 0.0726 for type B freeboard ships
x_{LL} = *X*-coordinate of the load point measured from the aft end of the freeboard length L_{LL}.

2.2.4 BSR, BSP, OST and OSA load cases

The external pressure, P_D, for BSR, BSP, OST and OSA load cases at any load point of an exposed deck shall be obtained, in kN/m², by linear interpolation between the pressures at the port and starboard deck edges (see also Figure 4, [1.3.6], Figure 9 and Figure 10):

$$P_D = P_{W,D\text{-}int} - \rho g\,(z - z_{dk}) \text{ but not to be taken less than } 0$$

where:

$P_{W,D\text{-}int}$ = pressure obtained by linear interpolation in transverse direction to the transverse coordinate of the load point between $P_{W,D\text{-}stb}$ and $P_{W,D\text{-}pt}$

$P_{W,D\text{-}stb}$ = pressure obtained at ship's starboard side, at vertical coordinate equal to z_{dk} for BSR, BSP, OST or OSA load cases as defined in [1.3], as appropriate

$P_{W,D\text{-}pt}$ = pressure obtained at ship's port side, at vertical coordinate equal to z_{dk} for BSR, BSP, OST and OSA load cases as defined in [1.3], as appropriate

z = as defined in [2.2.3]

z_{dk} = as defined in [2.2.3]

If a recess without coaming is arranged in the weather deck, P_D shall be tapered linearly down to 0 at the outer edge of the recess on the heeled side of the weather deck, see Figure 13. Forward and aft of the recess the pressure may be tapered linearly down to 0 at a line as shown in Figure 13.

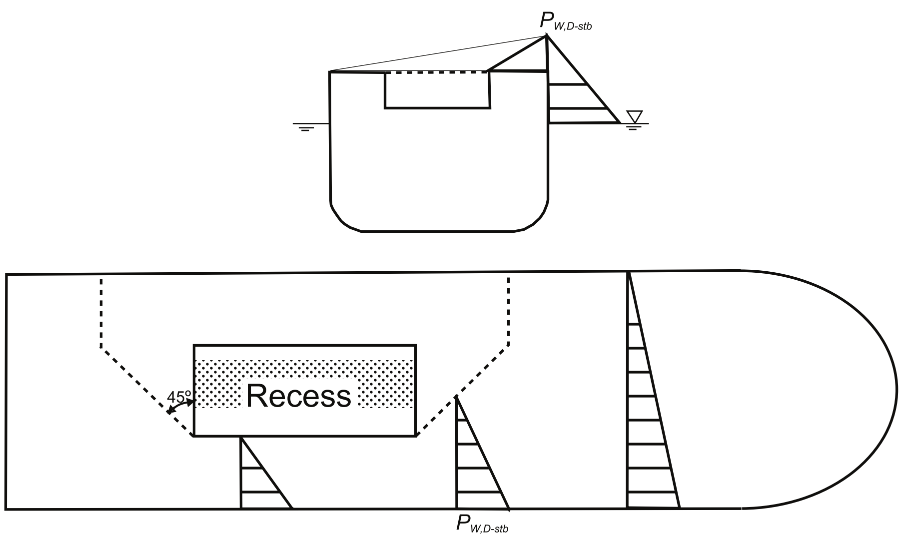


Figure 13 Transverse distribution of green sea pressure in beam sea

2.2.5 Envelope of dynamic pressures on exposed deck

The envelope of dynamic pressure at any point of an exposed deck, $P_{D\text{-}max}$, shall be taken as the greatest pressure obtained from any of the load cases determined by [2.2.3] and [2.2.4].

2.3 Load carried on decks and platforms

2.3.1 Pressure due to distributed load

If a distributed load is carried on a deck or platform, for example deck cargo or other equipment, the static and dynamic pressures due to this distributed load shall be considered.

The total pressure, in kN/m^2, due to this distributed load for the static (S) design load scenario shall be taken as:

$$P_{dl} = P_{dl-s}$$

The pressure, in kN/m^2, due to this distributed load for the static plus dynamic (S + D) design load scenario shall be derived for each dynamic load case and shall be taken as:

$$P_{dl} = P_{dl-s} + P_{dl-d}$$

where:

$P_{dl\text{-}s}$ = static pressure, in kN/m^2, due to the distributed load, to be defined by the designer

$P_{dl\text{-}d}$ = dynamic pressure, in kN/m^2, due to the distributed load

= $P_{dl\text{-}s} \cdot a_z/g$

a_Z = vertical envelope acceleration, in m/s^2, as defined in Sec.3 [3.3.3]. Optionally, the acceleration for the considered dynamic load case, according to Sec.3 [3.2.3], may be applied.

2.3.2 Concentrated force due to unit load

If a unit load, for example deck cargo, is carried on a deck or platform, the static and dynamic forces due to the unit load carried shall be considered.

The force, in kN, due to this concentrated load for the static (S) design load scenarios, shall be taken as:

$$F_U = F_{U-s}$$

The longitudinal force $F_{U\text{-}x}$, transverse force $F_{U\text{-}y}$ and vertical force $F_{U\text{-}z}$, in kN, due to this concentrated load for the static plus dynamic (S + D) design load scenarios shall be taken as:

$$F_{U\text{-}x} = m_U\, a_{x\text{-}U}$$

$$F_{U\text{-}y} = m_U\, a_{y\text{-}U}$$

$$F_{U\text{-}z} = F_{U\text{-}s} + m_U\, a_{z\text{-}U}$$

$F_{U\text{-}s}$ = static force, in kN, due to the unit load to be taken equal to:

= $m_U\, g$

m_U = mass of the unit load carried, in t

$a_{x\text{-}U}$, $a_{y\text{-}U}$ and $a_{z\text{-}U}$ = envelope accelerations, in m/s^2, as defined in Sec.3 [3.3.4].

Guidance note:

1) For heavy units with centre of gravity (COG) less than 0.25 b_c or 0.25 ℓ_c above the deck it is attached to, where b_c and ℓ_c are the breadth and length of the unit in m, the horizontal accelerations, $a_{x\text{-}U}$ and $a_{y\text{-}U}$, may be neglected.

2) The longitudinal force $F_{U\text{-}x}$, transverse force $F_{U\text{-}y}$ and vertical force $F_{U\text{-}z}$ in kN, due to this concentrated load for the static plus dynamic (S + D) design load scenarios may be derived for each dynamic load case when these forces are considered in combination with hull girder loads.

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

3 External pressures on superstructure and deckhouses

3.1 Application

3.1.1 The external pressures on superstructure and deckhouses shall only be applied for strength assessment.

These pressures shall be considered as dynamic pressures and shall be applied to the appropriate structure without any static pressure load component.

3.1.2 The pressure defined in [3.4] are only applicable to the requirements given in Ch.6 Sec.8.