RULES FOR CLASSIFICATION

High speed and light craft

Edition December 2015

Part 3 Structures, equipment

Chapter 1 Design principles, design loads

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DNV GL AS

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.

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

CURRENT – CHANGES

This is a new document.

The rules enter into force 1 July 2016.

CONTENTS

SECTION 1 GENERAL

1 Rule application

1.1 General

1.1.1 This chapter contain design principles and design loads and is applicable for all high speed and light craft.

1.1.2 Structural requirements are defined in Chapters 2 – 4. Applicable chapter is dependent on building material of the craft.

Chapter.2 – Steel

Chapter.3 – Aluminum

Chapter.4 – Fibre composites and sandwich constructions

1.1.3 For craft being built in more than one material, compliance with more than one chapter may be required.

2 Documentation

2.1 Documentation requirements

2.1.1 The Builder shall submit the documentation required by Table 1. The documentation will be reviewed by the Society as a part of the class contract.

Table 1 Documentation requirements

Object	*Documentation type*	*Additional description*	*Info*
Vessel arrangement	Z010 – General arrangement plan		FI
Operation	Z222 – Vessel operation manual		FI
Ship hull structure	H030 – Tank and capacity plan		FI
	H050 – Structural drawing	Supporting structures for heavy or loaded objects, including towing force design loads and winch load footprint.	AP
	H052 – Midship section drawing	In addition to the information required in Pt.1 Ch.3 the following information shall be included on the drawing: — Length overall, L_{OA} — Beam waterline, B_{WL} — Full displacement, Δ — Deadrise at LCG, β_{cg} — Max. vertical acceleration, a_{cg} — Web frame spacing — Class notations — Operational profile	AP

Object	*Documentation type*	*Additional description*	*Info*
	H060 – Shell expansion drawing		AP
	H061 – Framing plan.		AP
	H062 – Longitudinal section drawing		AP
	H110 – Final loading manual		AP
	H120 – Docking arrangement plan		FI
Decks	H050 – Structural drawing	Including inner bottom. If applicable: — Cargo loads — Container stowage arrangements — Foundations for all deck fittings and equipment — Foundations for resilient mounts	AP
Longitudinal bulkheads	H050 – Structural drawing		AP
Transverse bulkheads	H050 – Structural drawing		AP
Bow	H050 – Structural drawing		AP
Transom	H050 – Structural drawing		AP
Sternframe	H050 – Structural drawing		AP
Moonpool	H050 – Structural drawing		AP
Sea water inlets	H050 – Structural drawing		AP
Cross structure	H050 – Structural drawing		AP
Internal hull structures other than bulkheads and decks	H050 – Structural drawing		AP
Superstructure	H050 – Structural drawing	If applicable: — Details of resilient mounts (type and technical specification including capacity) and the expected loads — Details of flexible skirts (material properties, longevity and durability)	AP
Deck houses	H050 – Structural drawing		AP
AP=For approval; FI=For information ACO=As carried out; L=Local handling; R=On request; TA=Covered by type approval; VS=Vessel specific			

2.1.2 For general requirements to documentation, including definition of the Info codes, see SHIP Pt.1 Ch.3 Sec.2.

2.1.3 For a full definition of the documentation types, see SHIP Pt.1 Ch.3 Sec.3.

3 Definitions

3.1 Symbols

3.1.1

L	=	length of the craft in m defined as the length on design waterline. Amidships is defined as the middle of L
FP	=	forward perpendicular is the perpendicular at the intersection of the fully loaded waterline (with the craft at rest) with the foreside of the stem
AP	=	after perpendicular is the perpendicular at the intersection of the fully loaded waterline (with the craft at rest) with the after side of sternpost or transom
B	=	greatest moulded breadth in m
D	=	moulded depth is the vertical distance in m from baseline to moulded deckline at the uppermost continuous deck measured amidships
T	=	fully loaded draught in m at L/2 with the craft floating at rest in calm water
Δ	=	fully loaded displacement in tonnes in salt water (density 1.025 t/m^3) on draught T
C_B	=	block coefficient, given by the formula:

$$\frac{\Delta}{1.025\ L\ B_{WL}\ T}$$

B_{WL}	=	greatest moulded breadth of the hull(s) in m at the fully loaded waterline (with the craft at rest). For multihull craft B_{WL} is the net sum of the waterline breadths
B_{WL2}	=	greatest moulded breadth of the hull(s) in m at the fully loaded waterline (with the craft at rest) measured at L/2. For multihull craft B_{WL2} is the net sum of the waterline breadths
V	=	maximum speed in knots
g_0	=	standard acceleration of gravity.9.81 m/s^2
a_{cg}	=	Design vertical acceleration in m/s^2 at longitudinal centre of gravitation.
LCG	=	longitudinal centre of gravity
WL	=	water line
H_s	=	Significant wave height in m. Significant wave height is the average of the 1/3 highest waves within a wave spectrum.

3.2 Terms

3.2.1 *Freeboard deck* is a deck above waterline, weathertight closed or protected, from which a freeboard is measured. For details see Load Line Convention of 1966, Regulation 3.

3.2.2 *Weather decks* are open decks or parts of decks which may be exposed to sea and weather loads.

3.2.3 *Bulkhead deck* is a deck to which the watertight bulkheads are carried.

3.2.4 *Superstructure* is defined as a decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 4% of the breadth (B).

3.2.5 *Deckhouse* is defined as a decked structure above the strength deck with the side plating being inboard of the shell plating more than 4% of the breadth (B).

3.2.6 *Weathertight* is used for external surfaces above freeboard (or bulkhead) deck and means that in any sea conditions water will not penetrate into the ship.

3.2.7 *Watertight* is related to the internal subdivision of the ship, and means that in a flooded condition water will not penetrate from one compartment into the other.

3.2.8 *Primary Structure* is a collective term for structural members, usually supporting stiffeners (part of secondary structure). Typical structural elements are:

— bottom and deck transverses
— bottom and deck girders
— floors (a bottom transverse)
— stringers (elements with a horizontal web on the side and/or bulkhead)
— web frames

3.2.9 *Stiffener* is a collective term for a secondary supporting member. Other terms used are:

— beam
— frame
— reversed frame (inner bottom transverse stiffeners)
— longitudinal.

3.2.10 *Flat cross structure (wet deck)* is a structure between the hulls having an exposed, down-facing, horizontal or near-horizontal surface above the waterline.

3.2.11 *Supporting structure.* Strengthening of the vessel structure, e.g. a deck, in order to accommodate loads and moments from a heavy or loaded object.

3.2.12 *Foundation*. A device transferring loads from a heavy or loaded object to the vessel structure.

SECTION 2 DESIGN PRINCIPLES

1 Subdivision and arrangement

1.1 General

1.1.1 The hull shall be subdivided into watertight compartments as required for the service and type notation requested.

1.2 Transverse watertight bulkheads

1.2.1 At least the following transverse watertight bulkheads shall be fitted:

— a collision bulkhead
— a bulkhead at each end of the machinery space(s).

1.2.2 The watertight bulkheads are in general to extend to the freeboard deck. Afterpeak bulkheads may, however, terminate at the first watertight deck above the waterline at draught T.

1.2.3 For craft with two continuous decks and a large freeboard to the uppermost deck, the following applies:

— when the draught is less than the depth to the lowest deck, only the collision bulkhead need extend to the uppermost continuous deck. The remaining bulkheads may terminate at the lower deck
— when the draught is greater than the depth to the lowest deck, the machinery bulkheads, with the exception of afterpeak bulkhead, shall extend watertight to the uppermost continuous deck.

1.2.4 In craft with a raised quarter deck, the watertight bulkheads within the quarter deck region shall extend to this deck.

1.3 Position of collision bulkhead

1.3.1 The distance x_C from the forward perpendicular to the collision bulkhead shall be taken between the following limits:

$$x_C\ (minimum) = 0.05\ L\ (m)$$
$$x_C\ (maximum) = 3.0 + 0.05\ L\ (m)$$

An increase of the maximum distance given above may be acceptable upon consideration in each case, provided a floatability and stability calculation shows that, with the craft fully loaded to summer draught on even keel, flooding of the space forward of the collision bulkhead will not result in any other compartments being flooded, nor in an unacceptable loss of stability.

1.3.2 Steps or recesses in the collision bulkhead are accepted, provided the requirements to minimum and maximum distances from the forward perpendicular are complied with.

1.3.3 For craft having complete or long forward superstructures, the collision bulkhead shall extend to the next deck above freeboard deck. The extension need not be fitted directly over the bulkhead below, provided the requirements to distances from the forward perpendicular are complied with, and the part of the freeboard deck forming the step is made watertight.

1.3.4 For craft having particular high freeboard and long bow overhang, the position of the collision bulkhead above the freeboard deck may be specially considered.

1.4 Openings in watertight bulkheads

1.4.1 Openings may be accepted in watertight bulkheads, except in the part of the collision bulkhead which is situated below the freeboard deck. Openings situated in watertight bulkheads below the freeboard deck shall have watertight doors or hatches.

Requirements for watertight doors and hatches are stated in Pt.3 Ch.6 Sec.3.

1.4.2 Openings in the collision bulkhead above the freeboard deck shall have weathertight doors or an equivalent arrangement. The number of openings in the bulkhead shall be reduced to the minimum compatible with the design and normal operation of the craft.

1.5 Cofferdams

1.5.1 Fresh water tanks shall be separated from all other tanks with cofferdams.

1.6 Steering gear compartment

1.6.1 The steering gear compartment shall be readily accessible and, as far as practicable, separated from machinery spaces.

2 Principles

2.1 General

2.1.1 The rules specify design loads corresponding to the loads imposed by the sea and the containment of cargo, passengers, ballast and bunkers. The design loads are applicable in strength formulae and calculation methods where satisfactory strength level is represented by allowable stress and/or usage factors.

2.1.2 The structure shall be capable of withstanding the static and dynamic loads which can act on the craft under operating conditions, without such loading resulting in inadmissible deformation and loss of watertightness or interfering with the safe operation of the craft.

2.1.3 Cyclic loads, including those from vibrations which can occur on the craft, shall not:

- impair the integrity of structure during the anticipated service life of the craft
- hinder normal functioning of machinery and equipment
- impair the ability of the crew to carry out its duties.

2.2 Loading conditions

2.2.1 Static loads are derived from loading conditions submitted by the builder or standard conditions prescribed in the rules.

2.3 Resistance to slamming

2.3.1 Craft shall be strengthened to resist slamming. Requirements for minimum slamming loads and associated allowable stresses are given in Sec.3.

2.4 Local vibrations

2.4.1 The evaluation of structural response to vibrations caused by impulses from engine and propeller blades is not covered by the classification.

SECTION 3 DESIGN LOADS

1 General

1.1 Introduction

1.1.1 The effects of speed reduction in heavy weather are allowed for. Limiting sea state (significant wave height) to speed reduction shall be stipulated by the designer. Such restrictions will be stated in the appendix to classification certificate. A signboard giving the relationship between allowable speed and significant wave height as restricted shall be posted in the wheelhouse.

1.1.2 New design concepts may require tank tests, theoretical studies, or full scale measurements to establish seakeeping properties and design loads.

1.2 Definitions

1.2.1

Symbols:

p = design pressure in kN/m^2
ρ = density of liquid or stowage rate of dry cargo in t/m^3
C_W = wave coefficient.

For unrestricted service:

C_W = $0.08\ L$ for $L \leq 100m$
= $6 + 0.02\ L$ for $L > 100m$

Reduction of C_W for restricted service is given in Table 1.

Table 1 Reduction of Cw

Class notation	*Reduction*
R0	0 %
R1	10 %
R2	20 %
R3	30 %
R4	40 %
R5	50 %
R6	60 %

Restricted service class notations are defined in Pt.1 Ch.1 Sec.4.

Variation of wave coefficient C_W is shown in Figure 1.

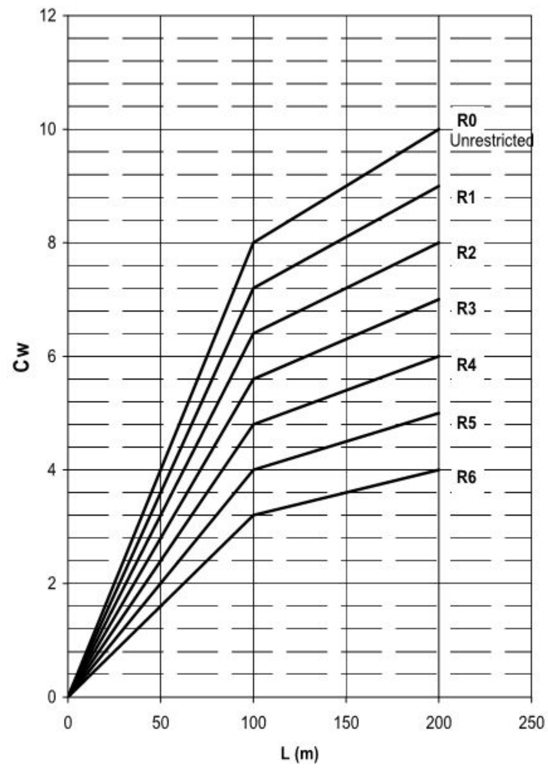

Figure 1 Wave coefficient

1.2.2 When applying the rule formulas for scantlings the load point where the design pressure shall be calculated is defined for various strength members as follows:

For stiffened panels of steel, aluminium or single skin FRP:

Horizontally stiffened:

— midpoint of plate.

Vertically stiffened:

— 50 % of stiffener spacing above the lower edge of the plate,
— when the plate thickness is changed within the plate, at the lower edge of the plate.

For FRP sandwich panels:

— the design load shall be equal to the mean pressure on the panel. For large panels the true pressure distribution shall be used if resulting in a higher stress level.

For stiffeners and girders:

— the larger of p_m and $(p_a+p_b)/2$ where p_m, p_a, and p_b are the pressures at the middle of the span and at each end of the stiffener respectively.

2 Operational conditions

2.1 Design operational conditions

2.1.1 The builder shall specify the craft's operational profile in terms of speed(s) in combination with significant wave height(s). When defining the operational profile of the craft, due attention must be given to the areas and sea conditions where the craft is intended to operate.

2.1.2 For ship with a speed and length ratio ($V/\sqrt{L} \geq 3$), the significant wave height shall not be chosen smaller than given in Table 2 for respective ship types.

Table 2 Minimum significant wave height Hs in m at maximum speed fully loaded

Type and service notation	*Hs(m)*
Passenger, car ferry, cargo craft, crew boats and small service crafts	0.25
Patrol boats, naval and naval support vessels	L < 20 m: 0.5 L > 30 m : 1.5 Linear interpolation for 20 m ≤L≤30 m

2.1.3 The craft's specified operational profile is to be used as basis for calculation of the vertical acceleration(s) a_{cgi}. The strength of the craft is to be checked for the combination of speed – sea states in the operational profile giving the highest a_{cgi}. The highest a_{cgi} will be the vertical design acceleration (a_{cg}) for the vessel.

2.1.4 The craft may from a structural point of view operate at a speed V up to the limiting significant wave height Hs. At wave heights in excess of this value, the operation of the craft has to be carefully adjusted, in terms of heading and reduced speed, to the wave pattern to prevent excessive loads on the hull.

Guidance note:

The specified operational profile will be stated in the Appendix to Classification Certificate for the craft.

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

2.2 Vertical acceleration

2.2.1 Vertical design accelerations a_{cgi} shall be estimated for simultaneous values of speed V_i and significant wave height Hs_i as given by the formulas below. Design vertical acceleration a_{cg} is the vertical acceleration at the craft's centre of gravity.

a_{cgi} shall be determined for at least one combination of V_i and Hs_i. The largest V_i shall be set equal to V.

2.2.2 When $V_i/\sqrt{L} \geq 3$

$$a_{cgi} = \frac{k_h g_0}{1650}\left(\frac{Hs_i}{B_{WL2}} + 0.084\right)(50 - \beta_{cg})\left(\frac{V_i}{\sqrt{L}}\right)^2 \frac{L\, B_{WL2}{}^2}{\Delta} \quad (m/s^2)$$

V_i = speed in knots

Hs_i = significant wave height in m

β_{cg} = dead rise angle at LCG in degrees
= minimum 10°
= maximum 30°

k_h = hull type factor given in Table 3.

The hull type factor k_h is an estimate for correction of the vertical acceleration depending on the different types of hull forms.

Table 3 Hull type factor

Hull type	k_h
Mono-hull, Catamaran	1.0
Wave Piercer	0.9
SES, ACV	0.8
Foil assisted hull (see [2.2.4])	0.7
SWATH (see [2.2.4])	0.7

a_{cg} shall be set to largest value of a_{cgi}. In case more than one operational envelope is determined, e.g. for other combinations of displacement and maximum speed at this displacement, a_{cg} shall be set to the largest value obtained including all operational envelopes.

The design vertical acceleration shall not be taken less than:

a_{cgi} = $1.0g_0$ for service restrictions R0-R4
a_{cgi} = $0.5g_0$ for service restrictions R5-R6

The design vertical acceleration a_{cgi} needs not be taken greater than $6.0g_0$.

2.2.3 When $V_i/\sqrt{L}<3$

$$a_{cgi} = 6\frac{Hs_i}{L}\left(0.85 + 0.35\frac{V_i}{\sqrt{L}}\right)g_0 \ \ (m/s^2)$$

2.2.4 Unless otherwise established, the design vertical acceleration at different positions along craft's length is not to be taken less than:

$$a_v = k_v a_{cg} \ \ (m/s^2)$$

k_v = longitudinal distribution factor taken from Figure 2.

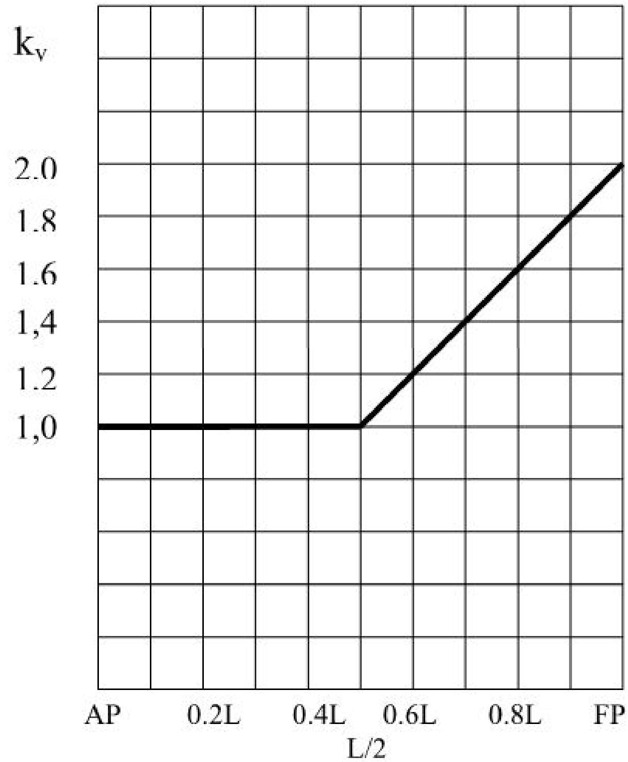

Figure 2 Longitudinal distribution factor for vertical design acceleration

2.2.5 Upon agreement, the vertical design acceleration may be documented by direct calculations, model tests or full scale measurements. For SWATH and craft with foil assisted hull, accelerations shall normally be determined in accordance with direct methods.

2.3 Horizontal accelerations

2.3.1 Longitudinal (surge) accelerations a_{li} shall be calculated as given below:

$$a_{li} = \frac{\mathrm{a_{cg}}}{6} (m/s^2)$$

a_{li} is intended for calculation of forward directed inertia forces and may have to be increased based on the overall impact possibilities in craft's front.

a_{li} shall not be taken less than $0.25g_0$.

The longitudinal acceleration a_{li}shall be applied simultaneous with downward vertical inertia in forebody.

2.3.2 Transverse acceleration from forced roll in bow seas shall be calculated as follows:

Period of forced roll to be taken:

$$T_R = \frac{\sqrt{L}}{1.05 + 0.175\frac{V}{\sqrt{L}}} \quad (s)$$

$V/\sqrt{L}$ need not to be taken greater than 4

Maximum roll inclination:

$$\Theta_r = \frac{\pi h_w}{2L} \quad (radians)$$

Resulting transverse acceleration:

$$a_t = \left(2\frac{\pi}{T_R}\right)^2 \Theta_r r_r \quad (m/s^2)$$

Static component $g_0 \sin \theta_r$ shall be added when above axis of roll.

h_w = maximum wave height in which 70% of maximum service speed will be maintained, minimum 0.6 Cw
r_r = height above axis of roll

Axis of roll to be taken:

— at waterline for twin hull craft
— at D/2 for mono-hull craft.

2.4 Combined accelerations

2.4.1 Accelerations in the craft's vertical, transverse and longitudinal axes are in general obtained by assuming the corresponding linear acceleration and relevant components of angular accelerations as statistically independent variables. The combined acceleration in each direction may be taken as:

$$a_c = \sqrt{a_v^2 + a_l^2 + a_t^2} \quad (m/s^2)$$

2.4.2 Transverse or longitudinal component of the angular acceleration considered in the above expression shall include the component of gravity acting simultaneously in the same direction.

3 Pressures and forces

3.1 General

3.1.1 Structural strength shall be based on the following external and internal pressures and forces:

— static and dynamic sea pressures
— static and dynamic pressures from liquids in a tank
— static and dynamic loads from dry cargoes, stores and equipment.

3.1.2 The internal pressures shall be applied irrespectively of possible simultaneous pressure from the opposite side.

3.1.3 The design sea pressures are assumed to be acting on the craft's outer panels at full draught.

3.2 Slamming pressure on bottom

3.2.1 The design slamming pressure on bottom of craft with speed $V/\sqrt{L} \geq 3$ shall be taken as:

$$p_{sl} = \frac{a_{CG} \cdot \Delta}{0.14 \cdot A_{ref}} \cdot K_{red} \cdot K_l \cdot K_\beta \ \ (kN/m^2)$$

A_{ref} = reference area from impact loads

$$A_{ref} = 0.7 \frac{\Delta}{T}$$

K_{red} = reduction factor for design load area

$$K_{red} = 0.445 - 0.35 \left(\frac{u^{0.75} - 1.7}{u^{0.75} + 1.7} \right)$$

$$u = 100 \cdot \frac{n \cdot A}{A_{ref}}$$

n = number of hulls, 1 for mono hull, 2 for catamaran, trimaran and other multi hulls will be specially considered

A = design load area for element considered in m^2

For plates, stiffeners and girders A shall be taken as spacing x span (sl)

For plates A shall not be taken greater than 2.5 s^2

K_l = longitudinal distribution factor from Figure 3

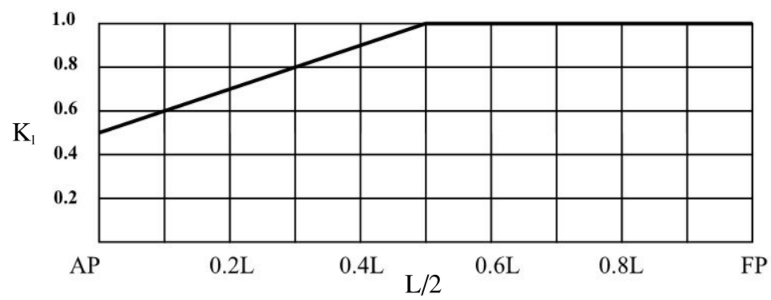

Figure 3 Longitudinal slamming pressure distribution factor for high speed mode slamming

K_β = correction factor for local deadrise angle

$$K_\beta = \frac{50 - \beta_x}{50 - \beta_{cg}}$$

β_x = deadrise angle in degrees at transverse section considered (minimum 10°, maximum 30 °), not to be taken less than β_{cg} aft of *LCG*.

β_{cg} = deadrise angle in degrees at *LCG* (minimum 10°, maximum 30°).

For transverse sections with no pronounced dead-rise angle, β_{cg} shall be determined as shown in Figure 4 a) to c).

3.2.2 The bottom slamming pressure need not be applied to craft with no significant hydrodynamic or air cushion lift in normal operating condition; i.e. SWATH hull forms

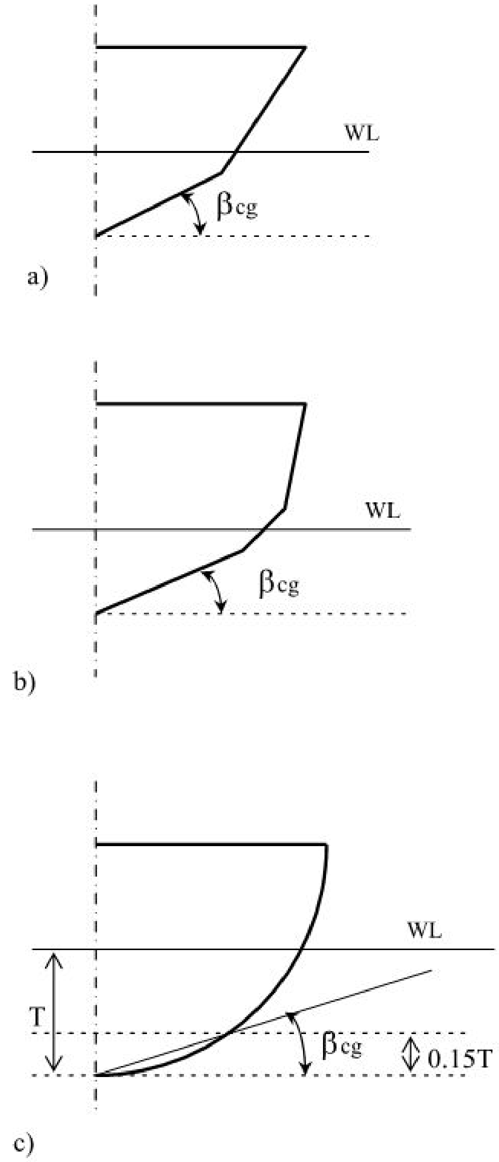

Figure 4 Dead-rise angle β_{cg}

3.2.3 β_x shall be determined as the angle of the tangent of the hull shell at the centre of the loaded element as shown in Figure 5 a) to b).

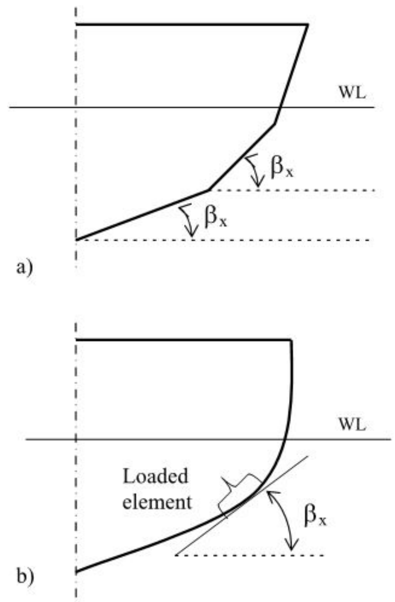

Figure 5 Panel angle β_x

3.2.4 Bottom slamming pressure shall be applied on elements within the area extending form the keel line to the chine or upper turn of bilge.

For V-shaped hull sections without pronounced chine or turn of bilge the slamming pressure shall be applied to elements within the area extending from the keel line to the design water line. The pressure on the hull side shall be reduced linearly from the design water line to the design hull side pressure at the weather deck, as shown in Figure. 6.

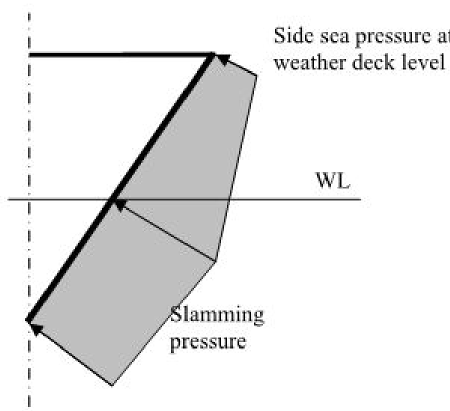

Figure 6 Bottom slamming on V-shaped section

3.2.5 All craft shall be designed for a pitching slamming pressure on bottom as given below:

$$p_{sl} = \frac{21}{tan(\beta_x)} k_a k_b C_W \left(1 - \frac{20 T_{FP}}{L}\right)\left(\frac{0.3}{A}\right)^{0.3} \quad (kN/m^2)$$

β_x = as in [3.2.2]
k_a = 1 for plating
= 1.1 – 20 l_A/L; maximum 1.0, minimum 0.35 for stiffeners and girders
l_A = longitudinal extent in m of load area
k_b = 1 for plating and longitudinal stiffeners and girders
= $L/40\, l$ + 0.5 (maximum 1.0) for transverse stiffeners and girders (l = span in m of stiffener or girder)
T_{FP} = as given in Figure 7
A = A need not for any structure be taken less than 0.002 Δ/T, otherwise as in [3.2.1].

Above pressure shall extend within a length from FP:

$$\left(0.1 + 0.15\frac{V}{\sqrt{L}}\right) L$$

$V/\sqrt{L}$ need not to be taken greater than 3. p_{sl} may be gradually reduced to zero at 0.175 L aft of the above length. Pitching slamming pressure shall be exposed on elements within the area extending from the keel line to chine, upper turn of bilge or pronounced sprayrail.

3.2.6 Pressure on bottom structure shall not be less than given in [3.5].

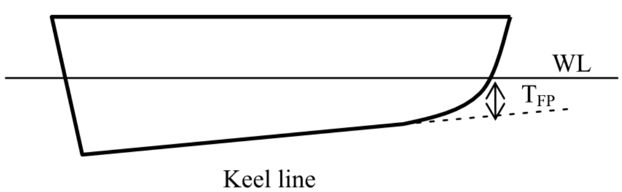

Figure 7 Definition of T_{FP}

3.3 Forebody side and bow impact pressure

3.3.1 Forebody side and bow impact pressure shall be taken as:

$$p_{sl} = \frac{0.7 L C_L C_H}{A^{0.3}}\left(0.6 + 0.4\frac{V}{\sqrt{L}}\sin\gamma\cos(90^\circ - \alpha) + \frac{2.1 a_0}{C_B}\sin(90^\circ - \alpha)\left(\frac{x}{L} - 0.4\right)\sqrt{0.4\frac{V}{\sqrt{L}} + 0.6}\right)^2 \quad (\mathrm{kN/m^2})$$

$V/\sqrt{L}$ need not be taken greater than 3.

A = design load area for element considered in m^2

For plating A shall not be taken greater than = 2.5 s^2 (m^2)

For stiffeners and girders A need not be taken smaller than e^2 (m^2)

In general A need not be taken smaller than $LB_{wl}/1000$ (m^2)

e = vertical extent of load area, measured along shell perpendicular to the waterline
x = distance in m from AP to position considered
C_L = correction factor for length of craft

$$C_L = \frac{250L - L^2}{15000}$$

C_H = correction factor for height above waterline to load point

$$C_H = 1 - \frac{0.5}{C_W} h_0$$

C_w may be reduced according to [1.2.1]

h_0 = vertical distance in m from the waterline at draught T to the load point
α = flare angle taken as the angle between the side plating and a horizontal line, measured at the point considered. See Figure 8
γ = angle between the waterline and a longitudinal line measured at the point considered. See Figure 9
a_0 = acceleration parameter:

$$a_0 = 3\frac{C_W}{L} + C_V \frac{V}{\sqrt{L}}$$

$$C_V = \frac{\sqrt{L}}{50}, maximum\ 0.2$$

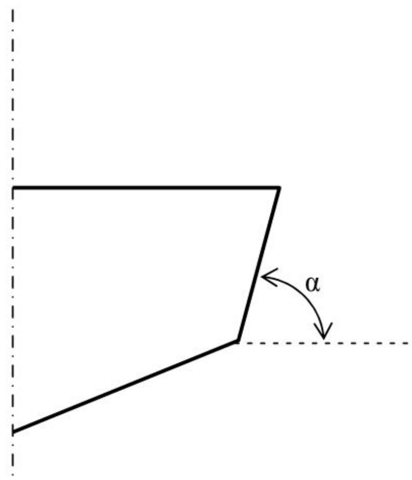

Figure 8 Flare angle α

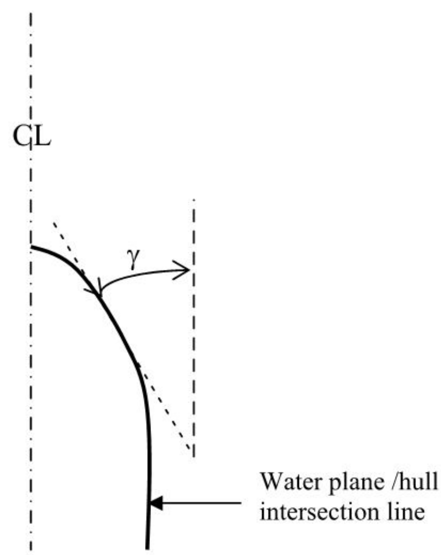

Figure 9 Waterline angle γ

3.3.2 Forebody side and bow pressure shall not be taken less than according to [3.5].

3.3.3 The impact pressure according to [3.3.1] shall be calculated for longitudinal positions between 0.4 L from AP and bow.

3.3.4 In vertical direction the impact pressure shall extend from bottom chine or upper turn of bilge to main deck or vertical part of craft side.

Upper turn of bilge shall be taken at a position where deadrise angle reaches 70°, but not higher than the waterline.

If no pronounced bottom chine or upper turn of bilge is given (V-shape), the impact pressure shall extend from keel to main deck or vertical part of craft side.

3.4 Slamming pressure on flat cross structures

3.4.1 The design slamming pressure on flat cross structures (catamaran wet deck, etc.), shall be taken as:

$$p_{sl} = 2.6 k_t \left(\frac{\Delta}{A}\right)^{0.3} a_{cg} \left(1 - \frac{H_C}{H_L}\right) \ (\mathrm{kN/m^2})$$

In no case shall p_{sl} be taken less than that given by Figure 10

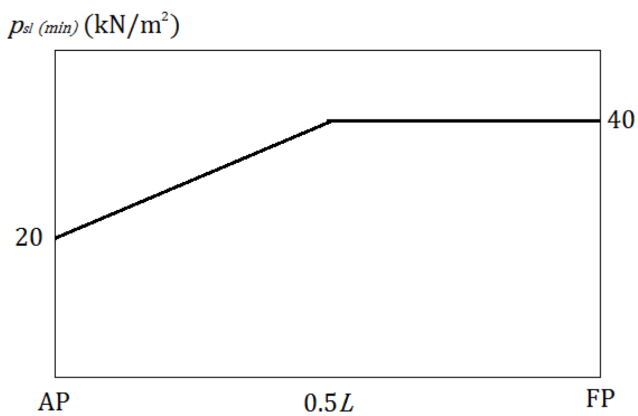

Figure 10 Minimum slamming pressure on flat cross structures p_{sl}

A = design load area for element considered. See [3.2.1]
H_C = minimum vertical distance in m from WL to load point in operating condition
k_t = longitudinal pressure distribution factor according to Figure 12
H_L = necessary vertical clearance in m from WL to load point to avoid slamming
= $0.22\, L\, k_w \left(\mathrm{k}_c - \frac{0.8}{1000} L\right)$

k_w = height coefficient according to Figure 13
k_c = hull type clearance factor
= 0.3 for catamaran, wave piercer
= 0.3 for SES, ACV
= 0.3 for hydrofoil, foilcatamaran
= 0.5 for SWATH.

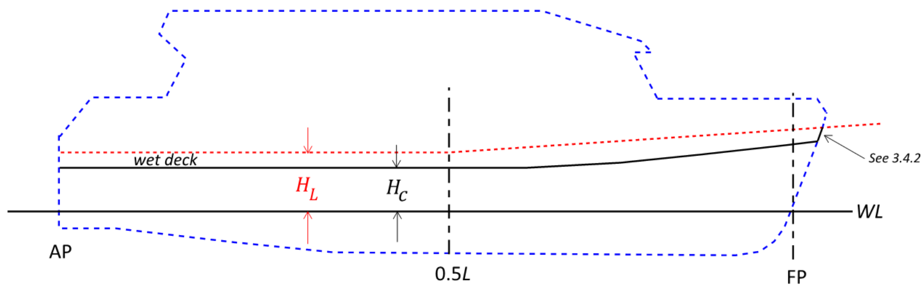

Figure 11 Flat cross structure (wet deck) subject to slamming

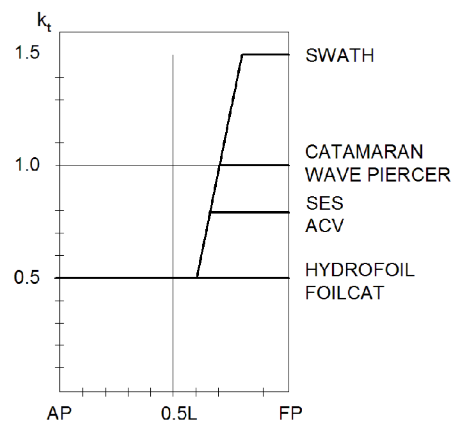

Figure 12 Flat cross structure slamming distribution factor k_t

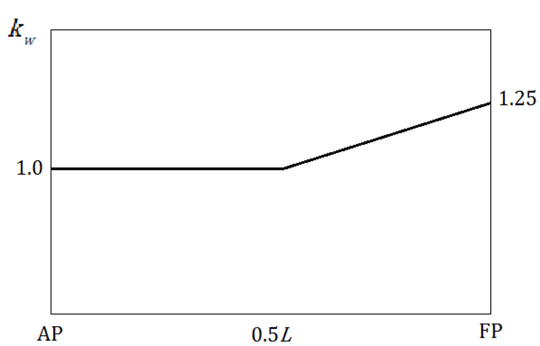

Figure 13 Flat cross structure height coefficient k_w

Forward of *FP*, $k_w$shall be extended linearly

3.4.2 The slamming pressure given in [3.4.1] is intended for horizontal or near-horizontal surfaces only. As very high impact pressures may be expected for forward-facing surfaces, these shall be avoided wherever possible in the slamming area. Where it is not possible to avoid such surfaces, they shall be specially considered.

3.5 Sea pressure

3.5.1 Pressure acting on the craft's bottom, side, superstructure side, deckhouse side and weather decks shall be taken as:

— for load point below design waterline:

$$p = a\left(10h_0 + \left(k_s - 1.5\frac{h_0}{T}\right)C_w\right)\ \ (kN/m^2)$$

— for load point above design waterline:

$$p = a\,k_s\,(C_w - 0.67\,h_0)\ \ (kN/m^2)$$

h_0 = vertical distance in m from the waterline at draught T to the load point. Always to be given a positive value.
k_s = *7.5* aft of amidships
= $5/C_B$ forward of *FP*.

Between specified areas k_s shall be varied linearly, see Figure 11

a = load intensity factor according to Table 4.
C_w = wave coefficient according to [1.2].

Table 4 Load intensity factors (a) for weather exposed areas *)

Location		*General (all types of crafts)*
Bottom, side and transom		1.0
Deck	Weather deck	1.0
	Weather deck higher than 0.1 L above WL	0.8
Deckhouse side		0.8
Front bulkhead	1st tier	2.0
	Other fronts	0.8
End bulkhead		0.8
*) See also Pt.5 Pt.5 Ch.1 for possible individual consideration for each special service and type of ship.		

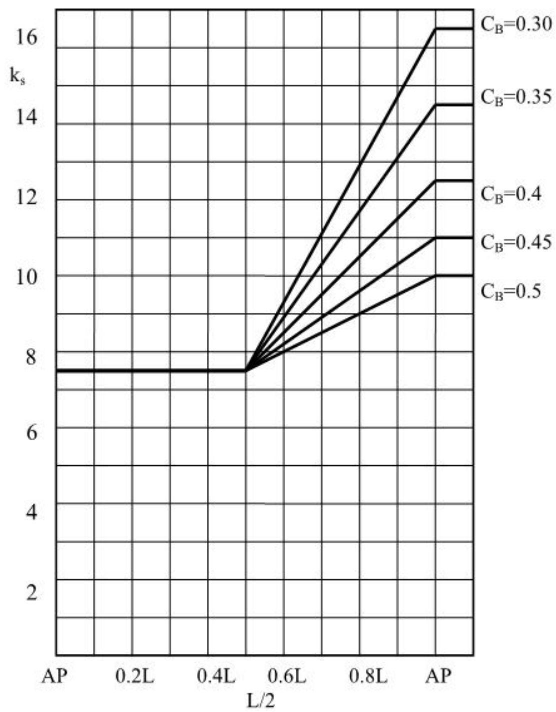

Figure 14 Sea load distribution factor

3.5.2 The design pressure shall not be taken less than according to Table 5.

Table 5 Minimum sea pressures (kN/m^2)

Location		*Service restriction notation*		
		Unrestricted – R0	*R1 – R3*	*R4 – R6*
Bottom, side and transom		6.5	5.0	3.0
Deck	Weather deck	5.0	4.0	3.0
	Weather deck higher than 0.1 L above WL	3.0	3.0	3.0
Deckhouse side		5.0	4.0	3.0
Front bulkhead	1st tier	$5 + (5 + 0.05L) \sin \alpha$		5.0
	Other fronts	$5 + 0.025L \sin \alpha$		5.0
End bulkheads		5.0	4.0	3.0
Where α is the angle between the bulkhead and the deck.				

3.5.3 The design pressure on watertight bulkheads (compartment flooded) shall be taken as:

$$p = 10h_b \text{ (kN/m}^2\text{)}$$

h_b = vertical distance in m from the load point to the top of bulkhead or to flooded waterline, if deeper.

3.5.4 The design pressure on deck or inner bottom forming part of watertight bulkhead shall not be less than for the bulkhead at same level.

3.6 Liquids

3.6.1 Tanks for bunkers and tank bulkheads shall normally be designed for liquids of density equal to that of sea water, taken as $\rho = 1.025 \ \mathrm{t/m^3}$ (i.e. $\rho g_0 \cong 10$).

3.6.2 The pressure in tanks shall be taken as the greater of:

— $p = \rho (g_0 + 0.5 a_v) h_s$ (kN/m^2)
— $p = 0.67 \rho g_0 h_p$ (kN/m^2)
— $p = \rho g_0 h_s + 10$ (kN/m^2) for $L \leq 50m$
— $p = \rho g_0 h_s + 0.3 L - 5$ (kN/m^2) for $L > 50m$

a_v = as given in [2.2]
h_s = vertical distance in m from the load point to the top of tank
h_p = vertical distance in m from the load point to the top of air pipe or filling station.

For tanks which may be filled to top of air pipe or filling station and subsequently subjected to accelerations, the pressure shall be modified accordingly.

3.6.3 The design pressure on wash bulkheads is given by:

$$p = 3.5 \, l_t \ (\mathrm{kN/m^2})$$

l_t = the greater distance in m to the next bulkhead forward or aft.

For wash bulkhead plating, requirement to thicknesses may have to be based on the reaction forces imposed on the bulkhead by boundary structures.

3.7 Dry cargo, stores and equipment

3.7.1 The pressure on inner bottom, decks or hatch covers shall be taken as:

$$p = \rho H (g_0 + 0.5 a_v) \ (\mathrm{kN/m^2})$$

a_v = as given in [2.2]
H = stowage height in m.

Standard values of ρ and H are given in Table 6.

3.7.2 When weather decks are intended to carry deck cargo the pressure is in general to be taken as the greater of p according to [3.5] and [3.7].

Table 6 Minimum deck cargo load

Decks	*Minimum load*
Decks intended for cargo	$q=1.0\ t/m^3$
Accommodation decks	$q=0.25\ t/m^3$

3.8 Heavy units

3.8.1 The vertical force acting on supporting structures from rigid units of cargo, equipment or other structural components shall normally be taken as:

$$P_v = (g_0+0.5\ a_v)M\ (kN)$$

M = mass of unit in tonnes
a_v = as given in [2.2].

SECTION 4 HULL GIRDER LOADS

1 Longitudinal bending, shearing and axial loads

1.1 General

1.1.1 Longitudinal hull girder loads shall be calculated for high speed mode cases caused by bottom slamming at speed exceeding $3/\sqrt{L}$ and displacement mode cases caused by vessel's motion in a seaway.

High speed mode conditions are crest landing and hollow landing arising from bottom slamming around midship area and fore and aft areas respectively.

1.2 High speed mode – crest landing

1.2.1 For craft with $V/\sqrt{L} \geq 3$ a slamming pressure is acting on an area equal to the reference area, A_R, given below. The area shall be situated with centroid at *LCG* of the craft.

$$A_R = 0.7\Delta \frac{\left(1 + 0.2\frac{a_{cg}}{g_0}\right)}{T} \ (m^2)$$

1.2.2 The load combination which is illustrated in Figure 1 may be required analysed with actual weight distribution along the hull beam.

1.2.3 The longitudinal midship bending moment shall be taken equal to:

$$M_B = \frac{\Delta}{2}\left(g_0 + a_{cg}\right)\left(e_w - \frac{l_s}{4}\right) \ (kNm)$$

e_W = half of the distance from *LCG* of the fore half body to the *LCG* of the aft half body of the vessel, in m.
= 0.25 *L* if not known

l_s = longitudinal extension of slamming reference area:

$$l_s = \frac{A_R}{b_s}$$

where b_s is the breadth of the slamming reference area. See Figure 2.

(e_W - l_s/4) shall not be taken less than 0.04 *L*.

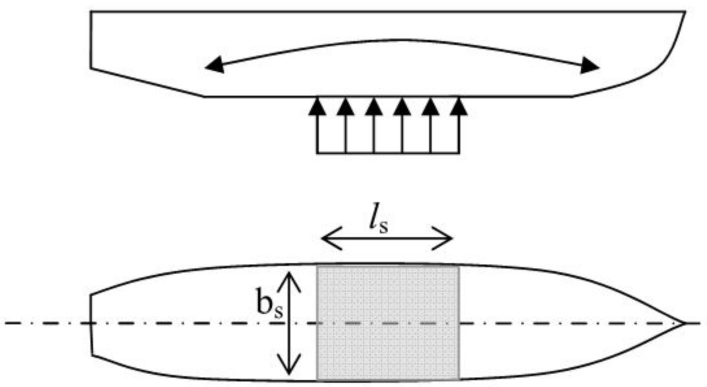

Figure 1 Crest landing

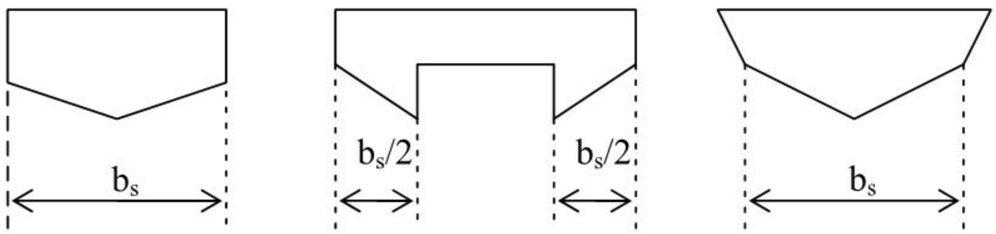

Figure 2 Breadth of midship slamming reference area

1.3 High speed mode – hollow landing

1.3.1 Hollow landing is similar to crest landing except that the reference area A_R as defined below is situated with half the area towards *AP* and half the area towards *FP* as shown in Figure 3.

$$A_R = 0.6\Delta \frac{\left(1 + 0.2\frac{a_{cg}}{g_0}\right)}{T} \ (m^2)$$

1.3.2 The load combination may be required analysed with actual weight distribution along the hull girder beam.

1.3.3 The longitudinal midship bending moment shall be taken equal to:

$$M_B = \frac{\Delta}{2}(g_0 + a_{cg})(e_r - e_w) \ (kNm)$$

e_r = mean distance from the centre of the $A_R/^2$ end areas to the vessels *LCG* in m.
e_W= half of the distance from *LCG* of the fore half body to the *LCG* of the aft half body of the vessel, in m.
= 0.25 L if not known

$(e_r - e_w)$ shall not be taken less than 0.04 L

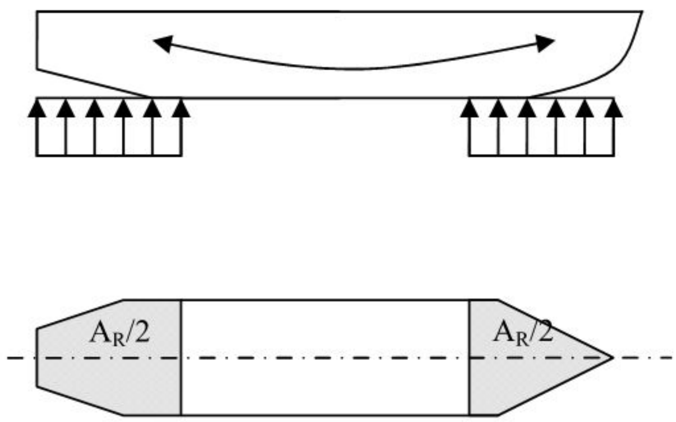

Figure 3 Hollow landing

1.4 High speed mode - hydrofoils

1.4.1 The calculation of longitudinal strength of hydrofoils shall be carried out for the most severe condition. Normally this will be considering the craft sustained above the water surface by the foils and supposing it to be stationary in the navigation condition, taking into account vertical acceleration as well as the vertical components of the hydrodynamic action of the water on the foils.

1.5 Hogging and sagging bending moments

1.5.1 Longitudinal hull bending moments (still water + wave) shall not be taken smaller than:

$$M_{tot} = M_{SW}+M_W\ (kNm)$$

M_{sw} = still water bending moment in the most unfavourable loading condition in *kNm*
M_w = wave bending moment amidships in *kNm*

The most unfavourable still water conditions shall be given.

If the still water moment is a hogging moment, 50% of this moment can be deducted where the design sagging moment is calculated.

Additional correction may be required added to the wave sagging moment for craft with large flare in the fore ship.

For monohull craft:

M_{sw} = 0.11 $C_w L^2 B C_B$ (*kNm*) in hogging if not known

= 0 in sagging if not known.

M_w = $0.19\ C_w L_2^2 B C_B$ (kNm)in hogging

= $0.14\ C_w L^2 B\ (C_B + 0.7)$ (kNm)in sagging

For twin hull craft:

M_{sw} = $0.5\ \Delta\ L$ (kNm)in hogging if not known

= 0 in sagging if not known.

M_w = $0.19\ C_W L^2\ (B_{WL2} + k_2 B_{tn})\ C_B$ (kNm) in hogging

$0.14\ C_W L^2\ (B_{WL2} + k_3 B_{tn})(C_B + 0.7)$ (kNm) in sagging

B_{tn} = breadth in m of cross structures (tunnel breadth)

k_2, k_3 empirical factors for the effect of cross structure immersion in hogging and sagging waves. If no other value available:

$$k_2 = 1 - \frac{z - 0.5\,T}{0.5\,T + 2\,C_W}, minimum\ 0$$

$$k_3 = 1 - \frac{z - 0.5\,T}{0.5\,T + 2.5\,C_W}, minimum\ 0$$

z = height in m from base line to wet deck (top of tunnel).

1.5.2 Bending moments at arbitrary positions along the length of the ship are normally shall not be taken less than:

M = $k_m M_{tot}$ (kNm)

M_{tot} = design bending moment (stillwater + bending)

k_m = distribution factor, see Figure 4

Vessels with concentrated loads from cargo or equipment are to be specially considered

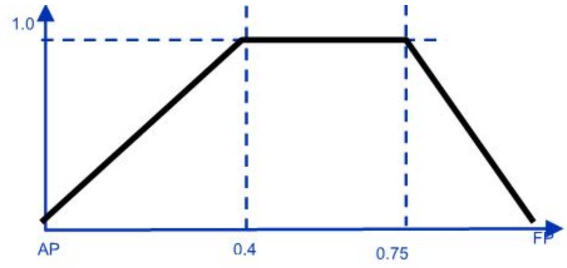

Figure 4 Distribution of bending moment factor k_m along hull girder.

1.6 Shear forces from longitudinal bending

1.6.1 A vertical hull girder shear force shall be calculated from the hull girder bending moments from [1.2], [1.3], and [1.5] as follows:

$$Q_b = \frac{M_b}{0.25\,L} \ (kN)$$

M_b= bending moment in *kNm*

1.6.2
The distribution of shear forces along the hull girder shall not to be taken less than:

$$Q_x = k_q Q_b \ (kN)$$

k_q = distribution factor for shear force, see Figure 5.

Vessels with concentrated loads from cargo or equipment shall be specially considered.

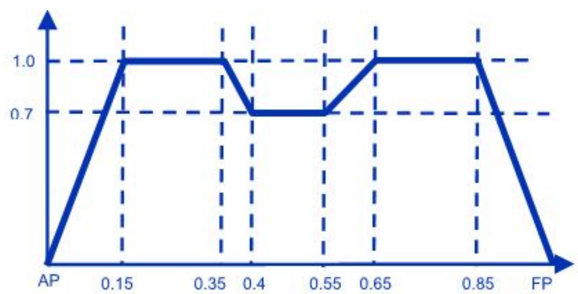

Figure 5 Shear force distribution factor k_q.

1.7 Longitudinal loads

1.7.1 The following longitudinal loads shall be considered:

— inertia due to surge acceleration a_l
— thrust
— sea end pressures

a_l = maximum surge acceleration as defined in Sec.3 [2.3.1], shall not be taken less than:

$$a_l = 0.4\,g_0 \ for \ \frac{V}{\sqrt{L}} \geq 5$$

$$a_l = 0.2\, g_0\, for\ \frac{V}{\sqrt{L}} \leq 3$$

with linear interpolation for intermediate values of $V/\sqrt{L}$

1.8 Transverse loads

1.8.1 Transverse loads from inertia due to transverse acceleration at shall be considered.

a_t = maximum transverse acceleration as defined in Sec.3 [2.3.2]

2 Twin Hull Loads

2.1 General

2.1.1 The transverse strength of twin hull connecting structure shall be analysed for moments and forces specified below.

2.1.2 Design forces and moments given in [2.2], [2.3] and [2.4] shall be used unless other values are verified by model tests or full scale measurements or if similar structures have proved to be satisfactory in service.

2.2 Vertical bending moment and shear force

2.2.1 For craft with ($V/\sqrt{L} \geq 3$) and L < 50 m, the twin hull transverse bending moment may be assumed to be:

$$M_s = \frac{\Delta\, a_{cg}\, b}{s}\ (kNm)$$

b = transverse distance between the centrelines of the two hulls
s = factor given in Table 1.

Table 1 Factors s and q

Service restriction	*s*	*q*
R4 – R6	8.0	6.0
R3	7.5	5.5
R2	6.5	5.0
R1	5.5	4.0
R0	4.0	3.0

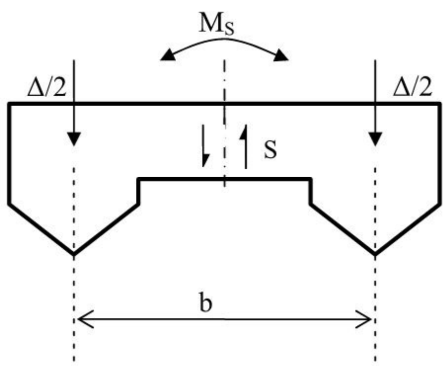

Figure 6 Transverse vertical bending moment and shear force

2.2.2 For all SWATH and other crafts with $L \geq 50$ m the twin hull transverse bending moment shall be assumed to be the greater of:

$$M_S = M_{S0}\left(1 + \frac{a_{cg}}{g_0}\right) \ (kNm)$$

$$M_S = M_{S0} + F_y\,(z - 0.5T)\ (kNm)$$

M_{SO} = still water transverse bending moment in *kNm*
F_Y = horizontal split force on immersed hull

$$F_y = 3.25\left(1 + 0.0172\frac{V}{\sqrt{L}}\right) L^{1.05} T^{1.30} (0.5B_{WL})^{0.146} \left[1 - \frac{L_{BMAX}}{L} + \frac{L_{BMAX}}{L}\left(\frac{B_{MAX}}{B_{WL}}\right)^{2.10}\right] H_1 \ (kN)$$

H_1 = Minimum of 0.143B and $H_{(S,MAX)}$
B_{WL} = maximum width (m) in water line (sum of both hulls)
B_{MAX} = maximum width (m) of submerged part (sum of both hulls)
L_{BMAX} = length in metres where $B_{MAX}/B_{WL}>1$
$H_{(S,MAX)}$ = maximum significant wave height in which the vessel is allowed to operate (m)
B = beam over all (m)
z = height from base line to neutral axis of cross structure (m).

$\frac{V}{\sqrt{L}}$ need not to be taken greater than 3

See Figure 7 for explanation of symbols. The expression should not be used for Surface Effect Ships (SES) on cushion, but shall be applied to SES in a survival condition with cushion air pressure equal to zero. A reduction factor of 0.8 is then to be applied to the dynamic split moment.

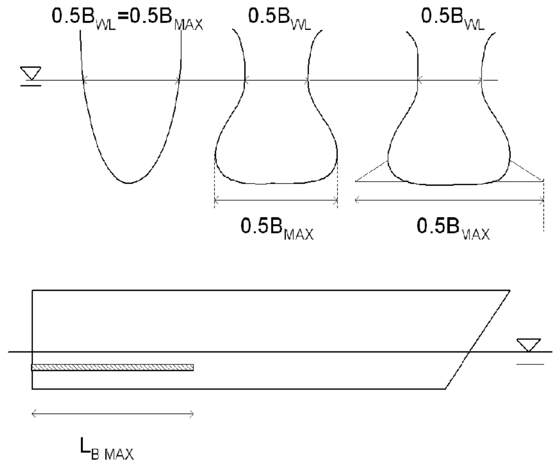

Figure 7 Definition of parameters in case of different sectional shapes

2.2.3 The vertical shear force in centreline between twin hulls shall be taken equal to:

$$S = \frac{\Delta\, a_{cg}}{q} \quad (kN)$$

q = factor given in Table 1.

2.2.4 For craft with length $L \geq 50$ m the twin hull still water transverse bending moment shall be assumed to be:

$$M_{S0} = 4.91\Delta\, (y_b - 0.4\, B^{0.88})\ (kNm)$$

M_{S0} = still water transverse bending moment
D = displacement in tonnes
y_b = distance in m from centre line to local centre line of one hull (see Figure 8 for definition)
B = width over all in m.

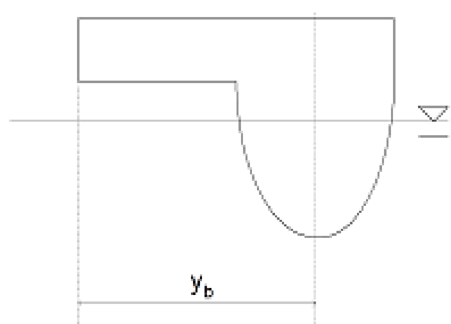

Figure 8 Definition of local geometry for one hull on twin hull craft

The expression shall not be used for surface effect ships (SES) or for twin hulls with significant weight along the centre line.

2.3 Pitch connecting moment

2.3.1 The twin hull pitch connection moment (see Figure 9) shall be taken as:

$$M_P = \frac{\Delta\, a_{cg}\, L}{8} \quad (kNm)$$

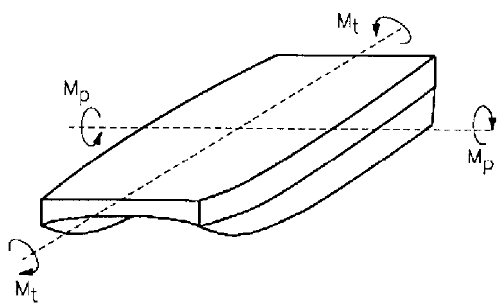

Figure 9 Pitch connecting moment and torsional moment on twin hull connection

2.4 Twin hull torsional moment

2.4.1 Hull torsional moment of twin hull shall be taken as:

$$M_t = \frac{\Delta\, a_{cg}\, b}{4} \quad (kNm)$$

b = distance in m between the two hull centrelines.

2.5 Combination of hull girder loads

2.5.1 The hull girder loads vertical bending, vertical shear and torsion ([2.4]) shall be calculated according to the following combinations:

80% longitudinal bending and shear + 60% torsion

60% longitudinal bending and shear + 80% torsion

2.5.2 The hull girder loads transverse vertical bending moment ([2.2]) and pitch connecting moment ([2.3]) shall be calculated according to the following combinations:

70% transverse bending + 100% pitch connecting

100% transverse bending + 70% pitch connecting

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