Rules for the Classification of Trimarans, January 2006, incorporating Notice No. 1

Volume 1 Ship Structures

Part 1 Classification of Trimarans

Chapter 1 Notations and Applications

Section 1 Rule philosophy

1.1 General

1.1.1. The Rules for the Classification of Trimarans (hereinafter referred to as the Trimaran Rules), are applicable to those type of craft which are defined in 3.1.

1.1.2. The Trimaran Rules are configured such that they are to be applied in conjunction with the following Lloyd's Register (hereinafter referred to as LR) Rules, as appropriate to the vessel type:

- *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships).
- *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).
- *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft).

The selected of these three LR Rules shall hereinafter be referred to as the Complementary Rules.

1.1.3. All Parts of the appropriate Complementary Rules are to be followed as listed in Table 1.1.1 except as otherwise noted in the Trimaran Rules. Those sections noted by '**Tri**' are given in the Trimaran Rules.

Table 1.1.1 Applicability of Complementary Rules

Volume/Part of Trimaran Rules	Section of Rules	Rules for Naval Ships	Rules for Ships	Rules for Special Service Craft
V1, P1	Regulations	Vol 1, Pt 1	Part 1	Vol 1, Pt 1
V1, P2	Materials	Vol 1, Pt 2	Part 2	Vol 2, Pt 2
V1, P3	Constructional Arrangements	Vol 1, Pt 3	Part 3	Vol 3, Pt 3
V1, P4	Military Design and Special Features/Ship Types/Additional Requirements for Yachts	Vol 1, Pt 4	Part 4	Vol 3, Pt 4
V1, P5	Environmental Loads	**Tri**	**Tri**	**Tri**
V1, P6	Scantling Determination	**Tri**	**Tri**	**Tri**
V2	Machinery	Vol 2, Pt 1–11	Part 5	Vol 7, Pt 9 –16
V2	Fire Protection	N/A	Part 6	Vol 18, Pt 17
V3	Additional Optional Requirements/Other Ship Types and Systems	Vol 3, Pt 1 and 2	Part 7	N/A
V4, P1	Direct Calculation Procedure	**Tri**	**Tri**	**Tri**

1.1.4. If the Complementary Rules are the Rules for Special Service Craft, the multi-hull requirements do not apply in the case of the Loads, Scantling Determination and Structural Design Assessment Parts but may apply to other Parts.

Section 2 Trimaran notation

2.1 Character symbols

2.1.1. All vessels in compliance with the Trimaran Rules according to the definition given in 3.1 are to be assigned the notation ’**TRI**’, in addition to any other notations approved by LR according to the Complementary Rules.

Section 3 Rule applicability

3.1 Vessel description

3.1.1. **Trimaran**. A trimaran is defined as a vessel with three hulls of displacement form, a main centre hull stabilised by two much smaller side hulls, with the displacement of each side hull not exceeding six per cent of the total vessel displacement. The Trimaran Rules may also apply to vessels with three hulls of planing or semi-planing form or to vessels with five hulls, described as pentamarans. In these cases, special arrangement must be made with LR.

3.1.2. **Vessel size**. The Trimaran Rules apply to vessels whose Rule length, L_R, as defined in 5.2.2, is between 70 m and 250 m. Vessels whose Rule Length is outside these limits will be specially considered.

3.1.3. **Material**. The material type applicable to vessels in compliance with the Trimaran Rules shall be steel and be in accordance with Part 2 of the Complementary Rules. The use of other materials will be specially considered.

3.1.4. **Service area**. The service area of the vessel is to be defined in accordance with the Complementary Rules. If the Complementary Rules are the Rules for Ships, unrestricted service is assumed.

3.1.5. **Vessel function**. The vessel may be of any type allowed in the Complementary Rules. All statutory requirements appropriate to the vessel must be complied with.

3.2 Corrosion margin

3.2.1. The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

3.2.2. If the Complementary Rules are the Rules for Naval Ships or the Rules for Special Service Craft, all requirements calculated according to the Complementary Rules are consistent with this 'net' scantling approach.

3.2.3. If the Complementary Rules are the Rules for Ships then the local scantling requirements calculated according to the Rules for Ships include a corrosion margin. This margin may be removed by reducing the Rules for Ships plating thickness requirements by 10 per cent and stiffener scantlings by five per cent.

3.2.4. Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require further consideration.

3.2.5. In the absence of a specific requirement from the Owner, the following corrosion margins are to be applied to net scantlings calculated by these Rules regardless of the type of corrosion protection fitted:

- +0,5 mm to all plating below a line 1,0 m above the design waterline;
- +2,0 mm to the keel plate.

3.2.6. Consideration should also be given to the addition of a corrosion margin to the following areas:

- Plating and stiffening at the lower edge of bulkheads bounding wet spaces.
- All tanks containing corrosive fluids and areas where spillage of corrosive fluids could occur.
- All uncoated structures.

3.2.7. If applicable, ships with a corrosion margin will be eligible for an enhanced scantling notation in accordance with the Complementary Rules.

Section 4 Constructional arrangement

4.1 Terminology

4.1.1. Fig. 1.4.1 shows the general terminology for the principal structural components of a trimaran.

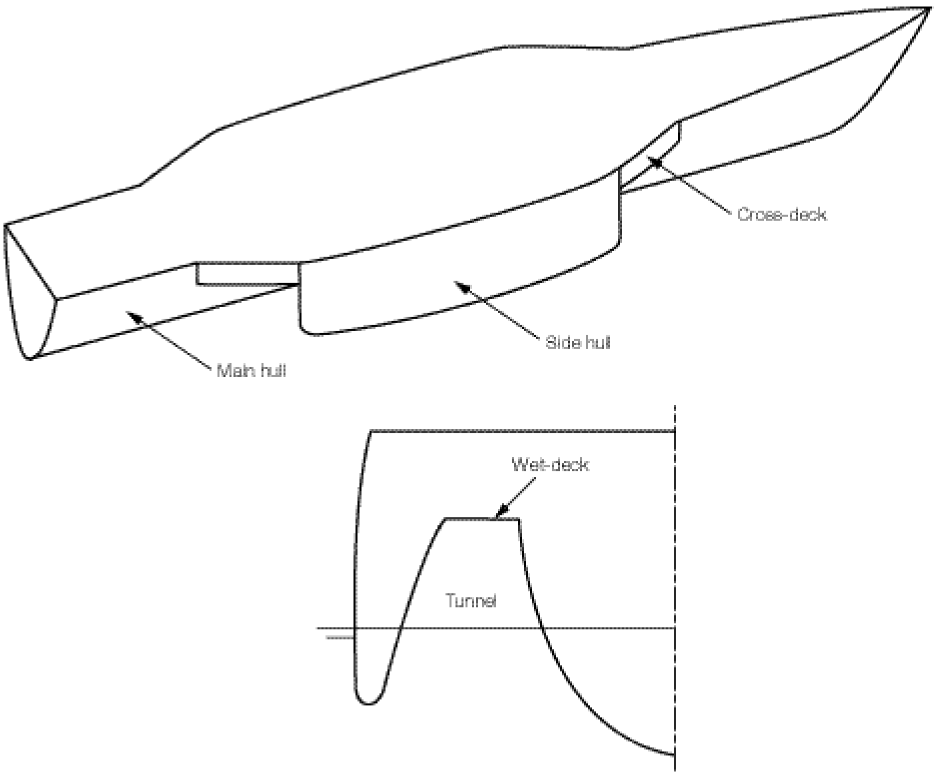

Fig. 1.4.1 Structural components of a trimaran

4.1.2. **Cross-deck**. The cross-deck is defined as a structure which connects the side hulls to the main hull, in general comprising an enclosed plated box structure bounded by the wet-deck, weather deck and forward and aft transitions.

4.1.3. **Wet-deck**. The wet-deck is defined as the lowest plating of the cross-deck structure potentially exposed to sea loads.

4.1.4. **Tunnel**. The tunnel is defined as the area beneath the wet-deck, bounded between the side and main hull.

4.1.5. **Shell envelope**. The shell envelope is defined as the bottom and side shell areas of the main and side hulls, excluding the wet-deck.

4.2 Structural design of cross-deck

4.2.1. Sufficient transverse strength is required in the cross-deck to support the side hulls.

4.2.2. Cross-deck length structural arrangements are to be sufficient to provide effective integration of the side hulls to the main hull.

4.2.3. The connection of the forward and aft ends of the cross-deck to the main hull are potential areas of high stress. Suitable arrangements should be provided to ensure effective integration at the point of intersection. The use of castings in these areas to eliminate welding is recommended.

4.2.4. The connections between the wet-deck and hulls are potential areas of high stress, *see* Fig. 1.4.2. The use of castings in these areas to eliminate welding is recommended.

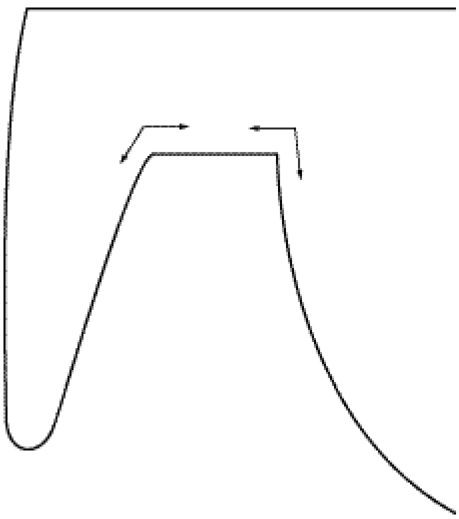

Fig.1.4.2 Region of potential high stress concentration

4.2.5. Increased plating thicknesses in the region depicted in Fig. 1.4.2 may be required and are to be evaluated in accordance with the Direct Calculation Procedure as described in Volume 4.

4.2.6. Continuity of transverse structural strength is to be maintained. All primary transverse members are to be continuous through the side hull and integrated into transverse bulkheads or other primary structure within the main hull.

4.2.7. Insufficient wet-deck clearance can result in severe slamming of the wet-deck. Impact loads due to slamming and the probability of occurrence of slams decrease with an increase in wet-deck clearance. The optimal clearance is a function of several parameters such as the length of the cross-deck, water level elevation, sea state and ship motions. Whilst the Rules give formulae for slamming loads, the determination of optimal clearance is outside the scope of these Rules.

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Section 5 Definitions

5.1 General

5.1.1. The following definitions apply. All principal particulars not explicitly defined in the Trimaran Rules are to be as defined in the Complementary Rules.

5.2 Principal particulars

5.2.1. Rule length, L_R, is the distance, in metres, on a waterline of the main hull, at the design draught from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on a waterline of the main hull at the design draught. In vessels without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on a waterline at the design draught. In vessels with unusual stem or stern arrangements, the Rule length will be specially considered.

5.2.2. Waterline length, L_{wl}, is the distance, in metres, measured on a waterline at the design draught, from the fore side of the stem to the after side of the stern or transom of the main hull.

5.2.3. Side hull length, L_{sh}, is the distance, in metres, measured on a waterline at the design draught, from the fore side of the stem to the after side of the stern or transom of the side hull. For stepped side hulls above the waterline, and where the side hull extends significantly forward of the stem, or aft of the stern or transom, the side hull length will be specially considered.

5.2.4. Side hull waterline length, L_{shwl}, is the distance, in metres, measured on a waterline at the design draught, from the fore side of the stem to the after side of the stern or transom of the side hull.

5.2.5. Breadth, *B*, is the greatest moulded breadth including the main hull, side hulls and cross-deck structure.

5.2.6. Waterline breadth, B_{wl}, is the total moulded breadth of the three hulls on a waterline at the design draught, excluding tunnels.

5.2.7. Total waterline breadth, B_{wltot}, is the total moulded breadth of the three hulls on a waterline at the design draught, including tunnels.

5.2.8. Side hull breadth, B_{sh}, is the greatest moulded breadth of a side hull measured from the lower point of intersection of the side hull and cross-deck structure as shown in Fig. 1.5.1 to the outermost point of the side hull. If the connection between the side hull and the cross deck structure is radiused, this point is to be taken as the point where the tangent line is at 45° from the horizontal.

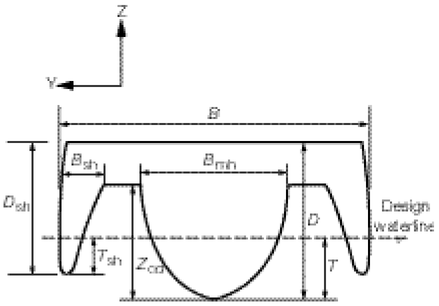

Fig. 1.5.1 Definitions

5.2.9. Main hull breadth, B_{mh}, is the greatest moulded breadth of the main hull measured from the lower point of intersection of the main hull and cross-deck structure as shown in Fig. 1.5.1. If the connection between the main hull and the cross deck structure is radiused, this point is to be taken as the point where the tangent line is at 45° from the horizontal.

5.2.10. Main hull waterline breadth, $B_{,mhwl}$ is the greatest moulded breadth of the main hull on a waterline at the design draught.

5.2.11. Side hull waterline breadth, B_{shwl}, is the greatest moulded breadth of a side hull on a waterline at the design draught.

5.2.12. Depth, *D*, is measured, in metres, at amidships, from the top of the main hull keel plate to the moulded deck line of the uppermost continuous deck, at the side of the side hull. This uppermost deck is to be a deck shared with the side hulls and cross-deck structure. *See* Fig. 1.5.1.

5.2.13. Side hull depth, D_{sh}, is measured, in metres, at amidships, from the top of the side hull keel plate to the moulded deck line at the side of the uppermost side hull continuous deck. This uppermost deck is to be a deck shared with the side hulls and cross-deck structure. *See* Fig. 1.5.1.

5.2.14. LCG is the longitudinal centre of gravity of the appropriate hull, in metres, measured from the aft end of the L_{wl} for the loading condition.

5.2.15. Draught, *T*, is the design draught, in metres, measured from the moulded baseline of the main hull.

5.2.16. Side hull draught, T_{sh}, is the design draught, in metres, measured from the moulded baseline of the side hull.

5.2.17. Displacement, Δ, is the total displacement of the side hull and the main hull in tonnes.

5.2.18. Displacement, Δ_{mh}, is the total displacement of the main hull in tonnes.

5.2.19. Displacement, Δ_{sh}, is the total displacement of one side hull in tonnes.

5.2.20. Block coefficient, C_b, is the block coefficient at draught *T* corresponding to the waterline at the design draught, based on Rule length L_R as follows:

$$C_b = \frac{\text{moulded displacement } (m^3) \text{ at draught } T}{L_R B_{mhwl} T + 2(L_{shwl} B_{shwl} T_{sh})}$$

5.3 Units system

5.3.1. Unless otherwise stated, the variables used in the Trimaran Rules are expressed in the following units. For calculations performed using the Complementary Rules, those units given in the Complementary Rules are to be used:

General	
Distances	m
Primary spacings	m
Secondary spacings	mm
Hull girder properties	
Dimensions	m
Area	m^2
Section modulus	m^3
Inertia	m^4
Moment of area	m^3
Stiffeners	
Area	cm^2
Dimensions	mm
Inertia	cm^4
Section modulus	cm^3
Length	m
Plating	
Breadth	mm
Length	m
Thickness	mm
Loads	
Pressures	kN/m^2
Loads	kN
Bending moment	kNm
Shear force	kN
Other items	
Stress/strength	N/mm^2
Deflections	mm
Modulus of elasticity	N/mm^2
Speed	knots

5.4 Co-ordinate system

5.4.1. Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.5.2. It is a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

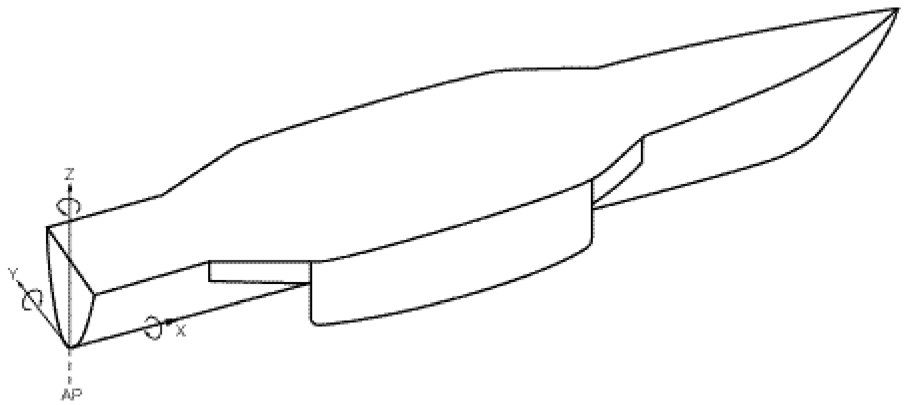

Fig.1.5.2 Co-ordinate system

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Part 5 Environmental Loads

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Chapter 1 Introduction

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Section 1 General

1.1 General

1.1.1. The global and local loads detailed in this Part are to be used in conjunction with the formulae given in Part 6 to determine the scantlings of Trimarans.

1.2 Theoretical analysis

1.2.1. An alternative method to derive loads through theoretical analysis is given in Vol 4, Pt 1, Ch 3,2.

1.3 Model experiments

1.3.1. An alternative method to derive loads through model experiments is given in Vol 4, Pt 1, Ch 3,3.

1.4 Symbols and definitions

1.4.1. The symbols and definitions for use throughout this Part are as follows:

a = projection of T_{CU} forward of the FP, in metres

a_{vmh} = the vertical acceleration at the centre of the main hull, in terms of g

a_{vsh} = the vertical acceleration at the centre of the side hull, in terms of g

b_0 = projection of T_{CU} waterline outboard of the design draught waterline at the FP, in metres, *see* Fig. 4.2.3 in Chapter 4

b_1 = projection of T_{CU} waterline outboard of the design draught waterline at 0,9L_R from the AP, in metres

b_2 = projection of T_{CU} waterline outboard of the design draught waterline at 0,8L_R from the AP, in metres

f_{roll} = factor for roll acceleration, *see* Ch 3,2.2.2

f_{serv} = factor for roll acceleration, *see* Ch 3,2.2.2

f_{serv} = service group factor, *see* Ch 4,2.4.1

f_{wv} = a wave height factor for service area or group, see Ch 3,2.2.1

g = acceleration due to gravity, is to be taken as 9,81 m/s^2

x_{sh} = the longitudinal distance, in metres, from midlength of the side hull to mid-length of the main hull where distance is positive for side hull mid-length aft of main hull mid-length

x_{shaft} = the longitudinal distance, in metres, from the aft end of L_R to the aft transition point on the main hull where the main deck extends towards the side hull

x_{shfwd} = the longitudinal distance, in metres, from the aft end of L_R to the fwd transition point on the main hull where the main deck connection from the side hull terminates

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of L_{wl} to the position or centre of gravity of the item being considered

y = transverse distance, in metres, from the centreline to the centre of gravity of the item being considered. y is positive to port and negative to starboard

y_{cs} = transverse distance from centreline to the centre of area of a cross-section A_{cs} taken at mid-length of the side hull, *see* Fig. 1.4.2

y_I = the distance between the centreline of the main hull and point I, as depicted in Fig. 4.3.1 in Chapter 4

y_{sh} = the distance, in metres between the centreline of the main hull and the transverse centre of area of the side hull, *see* Fig. 4.3.1 in Chapter 4

y_O = the distance between the centreline of the main hull and point O, as depicted in Fig. 4.3.1 in Chapter 4

z = vertical distance, in metres, from the baseline to the position or centre of gravity of the item under consideration. z is positive above the baseline

z_k = vertical distance from the baseline to the underside of the keel, *see* Fig. 1.4.1

z_{wl} = distance, in metres of the centroid of the area of plating or stiffener to the local design waterline

A_{BF} = bow flare area in m^2, *see* Ch 4,2.4.3

A_{LB} = half the water plane at the design draught in the bow region of the hull forward of 0,8L_R from the AP. The AP is to be taken at the aft end of the Rule length, L_R. The design draught is to be taken as T, as defined in Pt 1, Ch 1,5.2

A_{LS} = half the water plane area at a waterline T_{CL} of the stern region of the main hull from the aft end to 0,2L_R forward of the AP

A_{SF} = stern flare area in m^2, *see* Ch 4,2.4.4

A_{UB} = half the water plane area at a waterline T_{CU} of the bow region of the hull forward of 0,8 L_R from the AP

A_{US} = half the water plane area at a waterline T_{CU} of the stern region of the main hull from the aft end to 0,2L_R forward of the AP

D_f = longitudinal distribution factor, *see* Ch 4,2.4.1

F_f = the hogging, F_{fh}, or sagging, F_{fs}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the after portion end of the ship above the waterline, *see* Ch 4,2.4.1

F_{fh} = the hogging correction factor

F_{fs} = the sagging correction factor

F_n = Froude number, *see* Ch 3,2.2.4

GM = metacentric height for the loading condition under consideration, in metres

H_{rm} = wave head due to relative vertical motion, in metres, *see* Ch 3,2.2.4

H_w = nominal wave height limit, in m, *see* Ch 5,2.3.4

IP_{bi} = bottom impact pressure due to slamming, in kN/m^2, *see* Ch 5,2.4

IP_{wi} = wave impact pressure above the waterline due to slamming, in kN/m^2, *see* Ch 5,2.5

K_f = the shear force distribution factor, *see* Ch 4,2.5.1

L_f = factor varying with length as defined in Ch 4,2.4.1 and Ch 4,2.6.1

M_h = horizontal wave bending moment, in kN-m, as defined in Ch 4,2.6.1

M_{lt} = longitudinal torsional moment, in kN-m, *see* Ch 4,2.7.1

M_o = a wave bending moment, in kN-m, as defined in Ch 4,2.4.1

M_{sph} = hogging splitting moment, in kN-m, *see* Ch 4,3.1

M_{sps} = sagging splitting moment, in kN-m, *see* Ch 4,3.1

M_{sw} = still water bending moment, in kN-m, *see* Ch 4,2.2

M_{tot} = total Rule vertical bending moment envelope, in kNm, *see* Ch 4,2.8.1

M_{tt} = transverse torsional moment, in kN-m, *see* Ch 4,3.3

M_w = vertical wave bending moment, in kN-m, *see* Ch 4,2.4.1

P_d = minimum design pressure for weather and exposed decks, in kN/m^2, *see* Ch 5,2.6

P_{des} = design pressure due to static and dynamic load components, in kN/m^2, *see* Ch 5, Sections 3, 4, 5 and 6

P_{hyd} = hydrodynamic wave pressure, in kN/m^2, *see* Ch 5,3

P_{hys} = hydrostatic pressure, in kN/m^2, *see* Ch 5,2.2

P_{pm} = hydrodynamic pressure due to pitching motion, in kN/m^2, *see* Ch 5,2.3.3

P_{rm} = hydrodynamic pressure due to relative motion, in kN/m^2, *see* Ch 5,2.3.2

Q_{sph} = splitting shear force, in kN, in the hogging condition, *see* Ch 4,3.2

Q_{sps} = splitting shear force, in kN, in the sagging condition, *see* Ch 4,3.2

Q_{tot} = total Rule shear force envelope, in kNm, *see* Ch 4,2.8.2

Q_w = wave shear force, in kN, *see* Ch 4,2.5

R_A = the area ratio factor for the combined stern and bow shape, *see* Ch 4,2.4.2

T_x = local draught to design waterline at longitudinal position under consideration, *see* Fig. 1.4.1

T_{CL} = the waterline taken L_f/2 below the design draught, *see* Ch 4,2.4.4

T_{CU} = the waterline taken L_f/2 above the design draught, *see* Ch 4,2.4.3

V_{cd} = the volume on the cross-deck structure, in m^3, on one side of the ship. The inside and outside boundaries of the cross-deck structure are to be taken as the vertical lines extending upward from points O and I, *see* Fig. 4.3.1 in Chapter 4

V_{cr} = two thirds the cruising speed, in knots

V_{mhs} = the volume of the main hull, in m^3, which extends the length of the side hull. The outside boundary of the main hull is to be taken as a vertical line extending upwards from point O, *see* Fig. 4.3.1 in Chapter 4

V_{sh} = the volume of one side hull, in m^3. The inside boundary of the side hull is to be taken as a vertical line extending upward from the point O, *see* Fig. 4.3.1 in Chapter 4

V_{sp} = the greater of the cruising speed or two thirds the sprint speed, in knots. For ships where it is not required to maintain high speeds in severe weather then the value of V_{sp} may be specially considered

W_{sh} = the total weight of one side hull, in tonnes, including lightship weight and deadweight. The inside boundary of the side hull is to be taken as a vertical line extending upward from the point O, *see* Fig. 4.3.1 in Chapter 4

α_p = buttock angle, in degrees, *see* Fig 5.2.1 in Chapter 5

β_p = deadrise or flare angle, in degrees, *see* Fig 5.2.1 in Chapter 5

γ_p = waterline angle, in degrees, *see* Fig 5.2.1 in Chapter 5

ρ = water density in t/m^3.

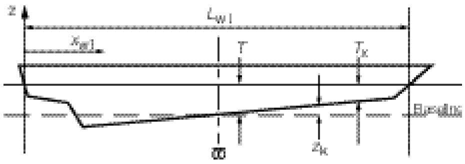

Fig. 1.4.1 Definition of draft *T* and baseline

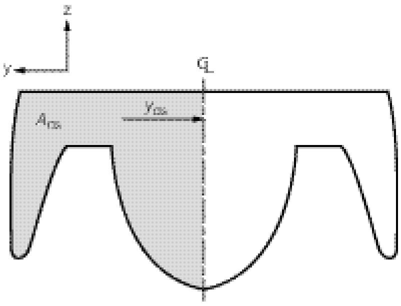

Fig. 1.4.2 Definition of y_{cs}

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Chapter 2 Environmental Conditions

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Section 1 General

1.1 Introduction

1.1.1. This Chapter contains information regarding the environmental conditions to be applied in the derivation of local and global loads.

1.1.2. Environmental conditions include natural phenomena such as wind, wave and currents and also ice and thermal conditions.

1.1.3. In general, the environmental conditions are to be taken as given in the Complementary Rules.

1.1.4. Alternative methods of establishing the environmental conditions will be specially considered, provided that they are based on hindcast data, long term measurements, global and local environmental theoretical models, or similar techniques. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

Section 2 Wave environment

2.1 General

2.1.1. Service requirements are to be categorised by the owner according to the notations permitted in the Complementary Rules.

2.1.2. The applicable service area notations are as described in 2.2.

2.2 Service areas and factors

2.2.1. All ships for which the Complementary Rules are the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are assumed to operate an unrestricted world-wide service.

2.2.2. All ships for which the Complementary Rules are the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) are to be assigned a specific service area in accordance with Vol 1, Pt 5, Ch 2 of the Rules for Naval Ships. Any such vessel shall be assigned a service area notation **SA** followed by a number or letter, e.g. **SA1**. A service area notation of **SA1** indicates unrestricted world-wide operation.

2.2.3. All ships for which the Complementary Rules are the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft) are to be assigned a specific service group in accordance with Vol 1, Pt 1, Ch 2,3 of the Rules for Special Service Craft. Any such vessel shall be assigned a service area restriction notation **G** followed by a number, e.g. **G1**. Craft classed under the Rules for Special Service Craft, for service groups **G1** to **G5**, are not suitable for unrestricted service except as noted in the service area restriction notation.

2.3 Wave environment

2.3.1. If the Complementary Rules are the Rules for Ships, the factors applied for unrestricted service are based upon wave conditions considered to be the most severe, corresponding to the North Atlantic.

2.3.2. If the Complementary Rules are the Rules for Naval Ships, the wave conditions relate to the service area and are given in Vol 1, Pt 5, Ch 2,2 of the Rules for Naval Ships.

2.3.3. If the Complementary Rules are the Rules for Special Service Craft, the wave conditions relate to the service group and are given in Vol 3, Pt 5, Ch 2 of the Rules for Special Service Craft.

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Section 3 Air environment

3.1 General

3.1.1. All ships for which the Complementary Rules are either the Rules for Ships or the Rules for Naval Ships are to comply with requirements for material selection in cold weather operation, if applicable. These requirements may apply even if the vessel is not assigned an ice class notation according to Section 4.

3.1.2. If the Complementary Rules are the Rules for Ships, the requirements of Pt 3, Ch 2 of the Rules for Ships are to be complied with.

3.1.3. If the Complementary Rules are the Rules for Naval Ships, the air environment is to be described as given in Vol 1, Pt 5, Ch 2,3 of the Rules for Naval Ships and appropriate material and welding requirements are to be applied in accordance with Vol 1, Pt 6, Ch 6 of the Rules for Naval Ships.

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Section 4 Ice environment

4.1 General

4.1.1. Ice class notations may be applied in accordance with the Complementary Rules. In addition to the structural requirements, all material and machinery requirements, for vessels assigned an ice class notation, are to be complied with in accordance with the Complementary Rules.

4.2 Ice conditions

4.2.1. All ships for which the Complementary Rules are the Rules for Ships may adopt an ice class notation as described in Pt 3, Ch 9, Sections 6, 7 and 8 of the Rules for Ships. These strengthening requirements for navigation in ice may be applicable to first-year ice conditions or multi-year ice conditions, as specified by the owner according to the service requirements of the vessel.

4.2.2. All ships for which the Complementary Rules are the Rules for Naval Ships may be assigned an ice class notation in accordance with Vol 1, Pt 5, Ch 2,4 of the Rules for Naval Ships.

4.2.3. All ships for which the Complementary Rules are the Rules for Special Service Craft may be assigned an ice class notation in accordance with Vol 4, Pt 6, Ch 5,7 of the Rules for Special Service Craft.

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Chapter 3 Motion Response

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Section 1 General

1.1 Introduction

1.1.1. The motions of the ship are to be considered in deriving the dynamic loads acting on the ship. The formulae given in this Section may be utilised. Alternatively, ship motion design values may be derived by model testing and be validated by direct calculation methods.

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Section 2 Design accelerations

2.1 General

2.1.1. The non-dimensional ship motion acceleration values given in this Section are to be used in the calculation of global and local loads. The equations given here are applicable to ships with trimaran hull forms operating in the displacement mode at their normal ship service speed or cruising speed. Any ships operating in the planing regime are to be specially considered.

2.2 Design accelerations

2.2.1. The heave acceleration, a_{heave}, is to be calculated in terms of g as follows:

$$a_{heave} = 0,8 f_{wv}\left(\frac{0,2V}{\sqrt{L_{wl}}} + \frac{34 - \left(\frac{600}{L_{wl}}\right)}{L_{wl}}\right)$$

where

f_{wv} is given in Table 3.2.1

V is an appropriate design speed, defined as follows:
= V_{cr} for determination of local and global loads
= V_{sp} for determination of impact pressures if the Complementary Rules are the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) f_{wv}, V_{cr} and V_{sp} are defined in Ch 1,1.4

L_{wl} is defined in Pt 1, Ch 1,5.2.

Table 3.2.1 Wave height factor, f_{wv}

Complementary Rules	Service Area/Group	f_{wv}
Ship	Unrestricted	1,0
NSR	SA1	1,0
	SA2	0,73
	SA3	0,65
	SA4	0,45
	SAR	To be specially considered
SSC	G1	0,15
	G2	0,25
	G3	0,5
	G4	1,0
	G5	1,0
	G6	1,0

2.2.2. The vertical acceleration due to roll, a_{rollz}, is to be calculated in terms of *g* as follows:

$$a_{rollz} = a_{heave} \frac{0,6\, y\, f_{roll}^{1,5}}{B_{wltot}}$$

where

$f_{roll} = \frac{13GM}{B_{wltot}}$ where f_{roll} should not be taken as less than 1

a_{heave} is defined in 2.2.1

GM and *y* are defined in Ch 1,1.4

B_{wltot} is defined in Vol 1, Pt 1, Ch 1,5.2.

2.2.3. The vertical acceleration, a_z, due to roll and heave, at a position *y*, is to be calculated as follows:

$$a_z = \sqrt{a_{heave}^2 + a_{rollz}^2}$$

y is defined in Ch 1,1.4.

2.2.4. The wave head due to relative vertical motion, H_{rm} is to be calculated as follows:

$$H_{rm} = H_{w1}\left[1 + \frac{f_{ld}}{(C_b + 0,2)}\left(\frac{x_{wl}}{L_{wl}} - x_{Fn}\right)^2\right] \text{m}$$

where

$H_{w1} = \frac{H_{w2}}{f_{Fn}} \sqrt{\frac{2,25}{f_{ld}}}$

$H_{w2} = f_{wv}\, 0,0771 L_{wl} (C_b + 0,2)^{0,3}\, e^{(-0,0044 L_{wl})}$

$f_{Fn} = 1 + \frac{f_{ld}(0,5 - x_{Fn})^2}{(C_b + 0,2)}$

f_{ld} varies according to the type of load being calculated as follows:
= 2,25 for the determination of pressure loads on shell in Ch 5,2.3.3
= 4,5 for the determination of impact loads on shell and cross-deck in Ch 5,2.4 and 2.5

x_{Fn} = 0,45 – 0,65F_n where x_{Fn} should not be taken as less than 0,2

$F_n = \frac{0{,}515\,V}{\sqrt{g L_{wl}}}$

V is defined in 2.2.1

x_{wl} and g are defined in Ch 1,1.4

L_{wl}, C_b is defined in Pt 1, Ch 1,5.2.

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Chapter 4 Global Design Loads

Section 1 General

1.1 Introduction

1.1.1. The global design loads in this Chapter are to be used in conjunction with Pt 6, Ch 3 to determine the global hull strength requirements. Unless otherwise stated, this Chapter is to be used exclusively for calculation of global loads for trimaran vessels and is to replace those global load calculations found in the Complementary Rules. For illustrations of global load cases, *see* Vol 4, Pt 1, Ch 2,3.

1.1.2. The global design load formulae in this Chapter are based on an x_{sh} range of between 0,22L_R and –0,06L_R. Loads for values of x_{sh} outside this range may need to be specially considered. x_{sh} is defined in Ch 1,1.4.

1.1.3. Loads may be calculated directly according to the Load Development Procedure, *see* Vol 4, Pt 1, Ch 3.

1.2 Information required

1.2.1. In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR’s standard format where appropriate:

(a). General arrangement and capacity plan or list showing details of the volume and position of the centre of gravity of all tanks, spaces and compartments.

(b). Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull together with lines plan and/or tables of offsets.

(c). Details of the calculated lightweight and its distribution.

(d). Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions.

(e). Calculated still water bending moments and shear forces and the proposed design envelopes. Calculated wave and dynamic bending moment shear force values.

1.2.2. It is recommended that this information be submitted in the form of a preliminary Loading Manual or Stability Information Book including: specification of operational requirements, hydrostatic data, details of loading conditions, etc. It may also be necessary to submit a summary of the damage stability analysis.

1.3 Direct calculation procedure

1.3.1. When utilising direct calculation procedures capable of deriving the wave induced loads on the ship, the ship's actual form and weight distribution is to be taken into account.

1.3.2. LR's direct calculation method of deriving the long term wave induced loads involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. This method is described in Vol 4, Pt 1, Ch 3. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.3.3. The long term response predictions are to be based on a probability of exceedance of 10^{-8}. The LR long term prediction method produces values which have a low statistical probability of occurring taking into account many factors. These factors include:

- The operating life of the vessel. Normally the operating life is taken as 20 years which is assumed to correspond to 10^8 wave encounters.
- The mission profile of the vessel.
- Different loading conditions.
- The effect of different wave headings on ship motions.

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Section 2 Global hull girder loads

2.1 Introduction

2.1.1. This section describes the calculation of global loads governing the design of the hull girder where all three hulls are to be considered a part of the hull girder. The structural effectiveness of the side hulls is described in Pt 6, Ch 3.

2.1.2. The still water bending moments and shear force distributions are to be derived using a suitable direct calculation method for a range of loading conditions which cover the operational envelope of the ship.

2.2 Still water bending moment

2.2.1. The still water bending moment, M_{sw}, is the maximum moment calculated from the loading conditions.

2.2.2. Still water bending moments are to be calculated along the vessel's length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of *L*. Hogging bending moments are positive.

2.2.3. If the vessel has low deadweight requirements and does not have a sag condition, then the maximum sagging bending moment may be taken as the minimum hogging bending moment.

2.3 Still water shear force

2.3.1. The still water shear force, Q_{sw}, at each transverse section along the vessel is to be taken as the maximum positive and negative value found from the longitudinal strength calculations.

2.3.2. Still water shear forces are to be calculated at each section along the vessel's length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L_R. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

2.4 Vertical wave bending moment

2.4.1. The vertical wave bending moment, M_w, at any position along the length of the vessel is given by the following:

$$M_w = F_f D_f M_o \text{ kNm}$$

where

D_f = 0 at aft end of L_R, *see* Fig. 4.2.1
= 1 from $\left(0,35 - \frac{x_{sh}}{4L_R}\right)L_R$ to $\left(0,6 - \frac{x_{sh}}{4L_R}\right)L_R$
= 0 at forward end of L_R

$M_o = 0,1 L_f f_{serv} L_R^{\ 2} B_{wl} (C_b + 0,7)$

$L_f = 0,0412 L_R + 4,0$ for $L_R \leq 90$ m
$= 10,75 - \left(\frac{300 - L_R}{100}\right)^{1,5}$ for $L_R > 90$ m

For unrestricted service:

$f_{serv} = 1$

For restricted service:

If the Complementary Rules are the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft)

$f_{serv} = G_f$, *see* Vol 3, Pt 5, Ch 5,3.2 of the Rules for Special Service Craft
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft

If the Complementary Rules are the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships)

$f_{serv} = f_s$, *see* Vol 1, Pt 5, Ch 2,2.4 of the Rules for Naval Ships

F_f = the hogging, F_{fh}, or sagging, F_{fs}, correction factor as follows:

$F_{fh} = \frac{1,9 C_b}{C_b + 0,7}$

$F_{fs} = 1,10 R_A^{\ 0,3}$ for values of $R_A \geq 1,0$

$F_{fs} = -1,10$ for values of $R_A < 1,0$

where

C_b is defined in Pt 1, Ch 1,5.2 but is not to be taken as less than 0,6

L_R and B_{wl} and are defined in Pt 1, Ch 1,5.2

D_f, x_{sh}, L_f, M_o, f_{serv}, F_f, F_{fh}, F_{fs} and R_A are defined in Ch 1,1.4.

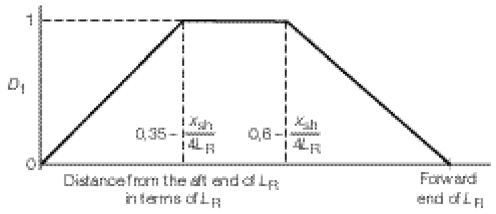

Fig. 4.2.1 Vertical bending moment distribution factor, D_f

2.4.2. The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30(A_{BF} - 0,5\,A_{SF})}{L_R B_{wl}}$$

where

A_{BF} and A_{SF} are defined in Ch 1,1.4

L_R and B_{wl} are defined in Pt 1, Ch 1,5.2.

2.4.3. The bow flare area, A_{BF}, is illustrated in Fig. 4.2.3 and may be derived as follows:

$$A_{BF} = A_{UB} - A_{LB}\ \mathrm{m}^2$$

Alternatively, the following formula may be used:

$$A_{BF} = 0,5\,L_R(b_0 + 2b_1 + b_2) + \frac{b_0 a}{2}\ \mathrm{m}^2$$

where

$$T_{CU} = T + \frac{L_f}{2}\ \mathrm{m}$$

For ships with large bow flare angles above the T_{CU} waterline, the bow flare area may need to be specially considered. If T_{CU} occurs above the level of the main deck, then the main deck is to be used.

A_{BF}, A_{UB}, A_{LB}, b_0, b_1, b_2, a and T_{CU} are defined in Ch 1,1.4.

L_f is defined in 2.4.1

T is defined in Pt 1, Ch 1,5.2.

2.4.4. The stern flare area, A_{SF}, is illustrated in Fig. 4.2.3 and may be derived as follows:

$$A_{SF} = A_{US} - A_{LS}\ \mathrm{m}^2$$

where

$$T_{CL} = T - \frac{L_f}{2}\ \mathrm{m}$$

If T_{CL} occurs below the baseline, then the baseline is to be taken as T_{CL}. This may result in a value of zero for the area A_{LS}

A_{SF}, A_{US}, A_{LS} and T_{CL} are defined in Ch 1,1.4

L_f is defined in 2.4.1

T is defined in Pt 1, Ch 1,5.2.

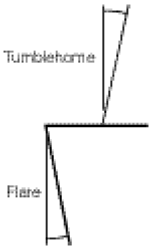

Fig. 4.2.2 Tumblehome

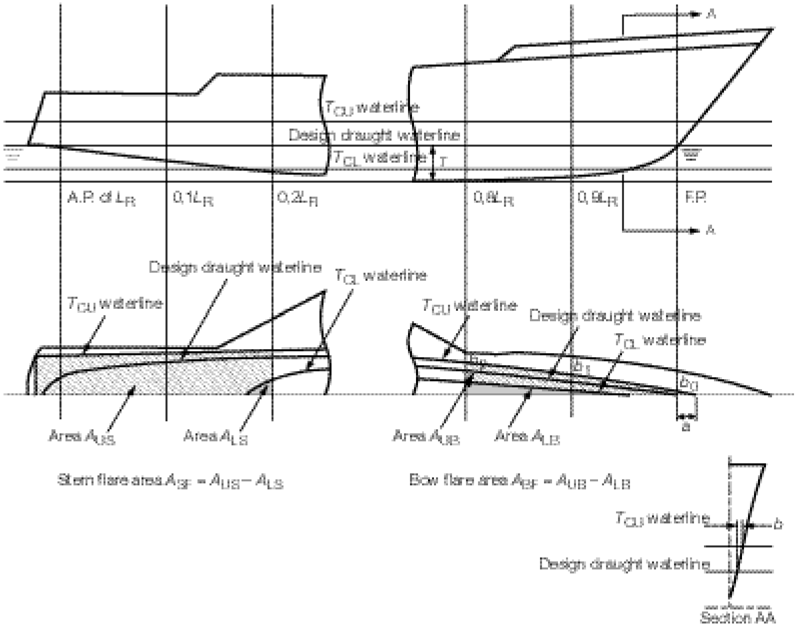

Fig. 4.2.3 Derivation of bow and stern flare areas

2.4.5. For ships with tumblehome in the stern region, *see* Fig. 4.2.2, the maximum breadth at any waterline less than T_{CU} is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.4.6. Direct calculation methods may be used to derive the vertical wave bending moments, *see* 1.3.

2.5 Vertical wave shear force

2.5.1. The wave shear force, Q_w, at any position along the ship is given by:

$$Q_w = \frac{3 K_f M_o}{L_R} \text{ kN}$$

where K_f is illustrated in Fig. 4.2.4 and is to be taken as follows:

(a). Positive shear force:

K_f = 0 at aft end of L_R

= +0,836F_{fH} between $\left(0,15 - \frac{X_{sh}}{4L_R}\right) L_R$ and $\left(0,25 - \frac{X_{sh}}{4L_R}\right) L_R$

= +0,65F_{fH} between $\left(0,35 - \frac{X_{sh}}{4L_R}\right) L_R$ and $\left(0,45 - \frac{X_{sh}}{4L_R}\right) L_R$

= –0,65F_{fS} between $\left(0,45 - \frac{X_{rh}}{4L_R}\right)L_R$ and $\left(0,55 - \frac{X_{rh}}{4L_R}\right)L_R$

= –0,91F_{fS} between $\left(0,65 - \frac{X_{rh}}{4L_R}\right)L_R$ and $\left(0,80 - \frac{X_{rh}}{4L_R}\right)L_R$

= 0 at the aft end of L_R

(b). Negative shear force:

K_f = 0 at aft end of L_R

= +0,836F_{fS} between $\left(0,15 - \frac{X_{rh}}{4L_R}\right)L_R$ and $\left(0,25 - \frac{X_{rh}}{4L_R}\right)L_R$

= +0,65F_{fS} between $\left(0,35 - \frac{X_{rh}}{4L_R}\right)L_R$ and $\left(0,45 - \frac{X_{rh}}{4L_R}\right)L_R$

= –0,65F_{fH} between $\left(0,45 - \frac{X_{rh}}{4L_R}\right)L_R$ and $\left(0,55 - \frac{X_{rh}}{4L_R}\right)L_R$

= –0,91F_{fH} between $\left(0,65 - \frac{X_{rh}}{4L_R}\right)L_R$ and $\left(0,80 - \frac{X_{rh}}{4L_R}\right)L_R$

= 0 at the aft end of L_R

Intermediate values are to be determined by linear interpolation.

M_o,F_{fh} and F_{fs} are defined in 2.4.1.

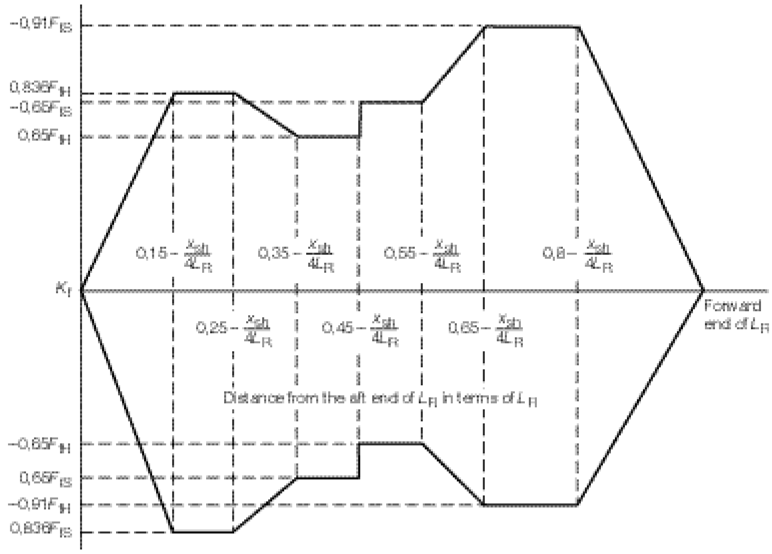

Fig 4.2.4 Shear force distribution factor, K_f

2.5.2. The direct calculation method used to derive the vertical bending moments may also be used to derive the vertical shear forces, *see* 1.3.

2.6 Horizontal bending moment

2.6.1. The horizontal bending moment, M_h, is to be calculated as follows:

$$M_h = D_f L_f f_{serv} L^2 D (C_b + 0,7) \text{ kNm}$$

where

$$L_f = \left(-70\left(\frac{L_R}{100}\right)^2 + 5L_R\right)10^{-3}$$

D_f and f_{serv} are defined in 2.4.1.

L_R, D and C_b are defined in Pt 1, Ch 1,5.2.

2.7 Longitudinal torsional moment

2.7.1. The longitudinal torsional moment, M_{lt}, illustrated in Fig. 4.2.5 is to be calculated as follows:

$$M_{lt} = 7{,}5 T_f f_{serv} \rho V_{sh} + V_{cd} + \frac{V_{mhs}}{2} y_{cs} a_{heave} \text{ kNm}$$

where

T_f is defined in Fig. 4.2.6.

x_{shaft}, x_{shfwd}, ρ, V_{sh}, V_{cd}, V_{mhs} and y_{cs} are defined in Ch 1,1.4.

a_{heave} is defined in Ch 3,2.2.

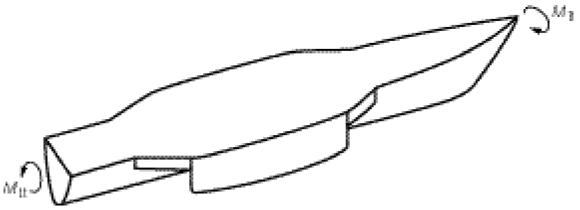

Fig. 4.2.5 Longitudinal torsional moment

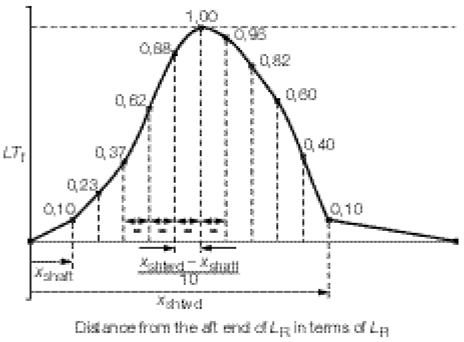

Fig. 4.2.6 Longitudinal torsional moment distribution factor, T_f

2.8 Longitudinal hull girder design loads

2.8.1. The total Rule vertical bending moment envelope, M_{tot}, is to be taken as follows:

$$M_{tot} = M_{sw} + M_w$$

where M_{sw} and M_w are defined in 2.2 and 2.4, respectively, and are to take into account the hogging and sagging conditions.

2.8.2. The total Rule shear force envelope, Q_{tot}, is to be taken as follows:

$$Q_{tot} = Q_{sw} + Q_w$$

where Q_{sw} and Q_w are defined in 2.3 and 2.5, respectively, and are to take into account the hogging and sagging conditions.

Section 3 Global cross-deck loads

3.1 Splitting moment

3.1.1. The splitting moments, for hog, M_{sph}, and for sag, M_{sps}, illustrated in Fig. 4.3.1 are to be given by the following:

$$M_{sph} = 9{,}81 f_{serv} W_{sh} (1 + a_z)\left(y_{sh} - \frac{B_{mh}}{2} \right) \text{ at point I, kNm}$$

$$M_{sph} = 9{,}81 f_{serv} W_{sh} (1 + a_z)(y_{sh} - y_o) \text{ at point O, kNm}$$

$$M_{sps} = 9{,}81 f_{serv} \frac{(\Delta - 2\Delta_{sh})}{2} a_z \left(y_{sh} - \frac{B_{mh}}{2} \right) \text{ at point I, kNm}$$

$$M_{sps} = 9{,}81 f_{serv} \frac{(\Delta - 2\Delta_{sh})}{2} a_z (y_{sh} - y_o) \text{ at point O, kNm}$$

where

Points I and O are given in Fig. 4.3.2. Moment values at locations on the cross-deck between I and O are to be linearly interpolated. If the cross-deck structure is radiused, points I and O are to be taken as the points where the tangents lines are at 45° from the horizontal.

W_{hs} = the total weight of one side hull, in tonnes, including lightship weight and deadweight, *see* Ch 1,1.4. For preliminary design purposes, this value may be estimated as a proportion of the total displacement according to the ratio of the side hull volume to the total volume. This weight is to be calculated according to the actual weight distribution before final submission to LR

f_{serv} is defined in 2.4.1

a_z is defined in Ch 3,2.2. The a_{rollz} component of a_z is to be calculated at a position $y = y_{sh}$

B_{mh}, B_{sh}, Δ and Δ_{mh} are defined in Pt 1, Ch 1,5.2.

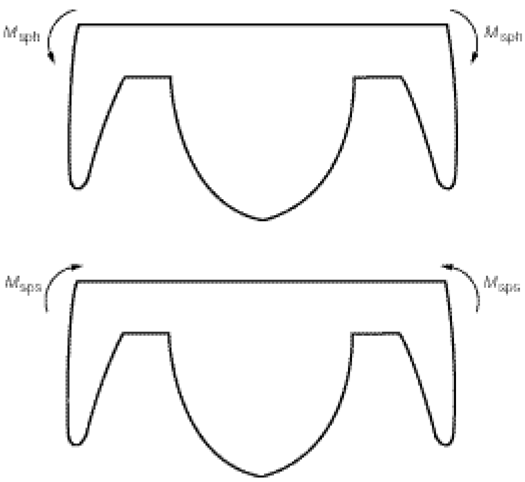

Fig. 4.3.1 Splitting moment

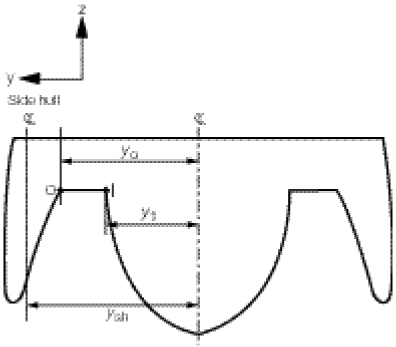

Fig.4.3.2 Distances and locations for splitting loads

3.2 Splitting shear force

3.2.1. The splitting shear force, Q_{sph}, corresponding to the hogging condition and Q_{sps}, corresponding to the sagging condition are uniform along the breadth of the cross-deck structure and are to be calculated as follows:

$$Q_{sph} = 9,81 f_{serv} W_{sh} (1 + a_z) \text{ kN}$$

$$Q_{sps} = \frac{9,81 f_{serv} (\Delta - 2\Delta_{sh}) a_z}{2} \text{ kN}$$

where

W_{sh} is defined in 3.1

f_{serv} is defined in 2.4.1

Δ is defined in Pt 1, Ch 1,5.2

a_z is defined in Ch 3,2.2. The a_{rollz} component of a_z is to be calculated at a position $y = y_{sh}$.

3.3 Transverse torsional moment

3.3.1. The transverse torsional moment, M_{tt}, as illustrated in Fig. 4.3.3 is uniform along the breadth of the cross-deck structure and is to be given by the following:

$$M_{tt} = 3,75 f_{serv} \rho (V_{sh} + V_{cd}) L_{sh} a_{heave} \text{ kN m}$$

where

L_{sh} is defined in Pt 1, Ch 1,5.2

ρ, V_{sh} and V_{cd} are defined in Ch 1,1.4

a_{heave} is defined in Ch 3,2.2

f_{serv} is defined in 2.4.1.

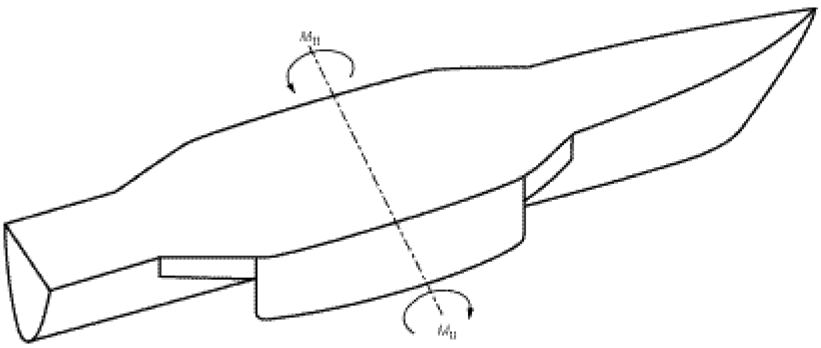

Fig. 4.3.3 Transverse torsional moment

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Chapter 5 Local Design Loads

Section 1 General

1.1 Introduction

1.1.1. This Chapter contains information regarding the derivation of local design loads that are to be used for the assessment of scantlings given in Pt 6, Ch 4.

1.2 Application

1.2.1. The environmental conditions used for the determination of the local loads are to be based on the environmental design criteria specified in Chapter 2.

1.2.2. The formulae for ship motion loads given in this Chapter are suitable for all trimarans that operate in displacement mode. Ship motion loads for ships that operate in the fully planing mode are to be specially considered.

1.2.3. Design pressures consisting of a hydrostatic and a hydrodynamic component are to be calculated for the shell envelope, wet-deck, weather deck and inner bottom structures. Additionally, design impact pressures are to be calculated for portions of the shell envelope and wet-deck. These design pressures, calculated according to Sections 3 to 6, are comprised of the pressure components described in Section 2.

1.2.4. All remaining local structural requirements, described in Sections 7 to 11, are to be calculated according to the appropriate Complementary Rules.

Section 2 Pressure components

2.1 General

2.1.1. This Section includes requirements for calculation of hydrostatic, hydrodynamic and impact pressures.

2.1.2. The calculation of the impact pressures is based on the Ochi-Motter slamming approach and is equivalent to the standard direct calculation procedure. The values of m_0, variance of the relative vertical motion, and m_1, variance of the relative vertical velocity, may be derived using direct calculations. In this case the variances are to be based on sea states as defined by the normal design assessment environmental criteria, *see* Chapter 2.

2.2 Hydrostatic pressure

2.2.1. The hydrostatic pressure P_{hys} is to be taken as:

$$P_{hys} = 10(T_x - (z - z_K))\ \mathrm{kN/m^2}$$

where

T_x, z and z_k are defined in Ch 1,1.4.

2.3 Hydrodynamic wave pressure

2.3.1. The hydrodynamic wave pressure P_{hyd} is to be taken as the greater of the pressure due to relative motion,

P_{rm}, and the pressure due to the pitching motion, P_{pm}

P_{rm} is defined in 2.3.2

P_{pm} is defined in 2.3.3.

2.3.2. Hydrodynamic pressure due to relative motion P_{rm} is to be taken as:

$$P_{rm} = f_{type}\, 10\, f_z\, H_{rm}\ \mathrm{kN/m^2}$$

where

f_{type} is a service type factor to be taken as:

1,05 for passenger ships
1,16 for cargo ships
1,26 for naval ships
1,31 for workboat ships

f_z = the vertical distribution factor
$= k_z + (1 - k_z)\frac{(z - z_k)}{T_x}$

$k_z = e^{-u}$

$u = \frac{2\pi T_x}{L_{wl}}$

H_{rm} is defined in Ch 3,2.2.4

z, z_k and T_x are defined in Ch 1,1.4

L_{wl} is defined in Pt 1, Ch 1,5.2.

2.3.3. The distribution of hydrodynamic pressure due to pitching motion P_{pm} is to be taken as:

$$P_{pm} = f_{type} 10 H_{pm} \text{ kN/m}^2$$

where

$H_{pm} = 1,1\left(f_w \frac{2x_{wl}}{L_{wl}} - 1\right)\sqrt{L_P}$

but not less than $0,3 f_{wv} \sqrt{L_P}$

$L_p = L_{wl}$ but ≤ 150 m

f_{wv} and x_{wl} are defined in Ch 1,1.4

f_{type} is defined in 2.3.2

L_{wl} is defined in Pt 1, Ch 1,5.2.

2.3.4. The nominal wave height limit, H_w, above the design draft T_x is to be taken as:

$$H_w = 2H_{rm}$$

where

H_{rm} is defined in Ch 3,2.2.4.

2.4 Bottom impact pressure

2.4.1. If the Complementary Rules are the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as Rules for Naval Ships) then the bottom impact pressure due to slamming, IP_{bi} is to be derived using the method given below. This method will produce impact pressures over the whole of the underwater plating region:

$$IP_{bi} = 0{,}5 k_{sl} V_{bs}^2 \ \mathrm{kN/m^2}$$

where

k_{sl} = hull form coefficient
$= \frac{\pi}{\mathrm{Tan}\beta_\rho}$ for $\beta_\rho \geq 10$
= 28 (1–Tan ($2\beta_\rho$) for $\beta_\rho < 10$

V_{bs} = slamming velocity, in m/s, and is given by
$= \sqrt{V_{th}^2 + 2 m_1 ln(N_{sl})}$ for $N_{sl} \geq 1$
= 0 for $N_{sl} < 1$

V_{th} = threshold velocity for slamming, in m/s
$= \sqrt{10}$

N_{sl} = number of slams in a 3 hour period
$= 1720 PR_{sl} \sqrt{\frac{m_1}{m_0}}$

PR_{sl} = probability of a slam
$= e^{-u}$

$u = \frac{z_{wl}^2}{2m_0} + \frac{V_{th}^2}{2m_1}$

z_{wl} = distance of the centroid of the area of plating or stiffener to the local design waterline
$= z - (T_x + z_k)$

m_1 = variance of the relative vertical velocity
$= 0{,}25\,(\omega_e f_{sl} H_{rm})^2$

m_0 = variance of the relative vertical velocity
$= 0{,}25\,(f_{sl} H_{rm})^2$

ω = effective wave frequency based on 80 per cent ship length
$= \sqrt{\frac{2\pi g}{0{,}8 L_{wl}}}$

ω_e = effective encounter wave frequency
$= \omega \left(1 + \frac{0.2\omega V_{sp}}{g}\right)$

f_{sl} = probability level correction factor for relative vertical motion
= 1,0

β_p = deadrise angle, in degrees, *see* Fig. 5.2.1

z, z_k, z_{wl}, T_x, g, V_{sp} and H_{rm} are defined in Ch 1,1.4

L_{wl} is defined in Pt 1, Ch 1,5.2.

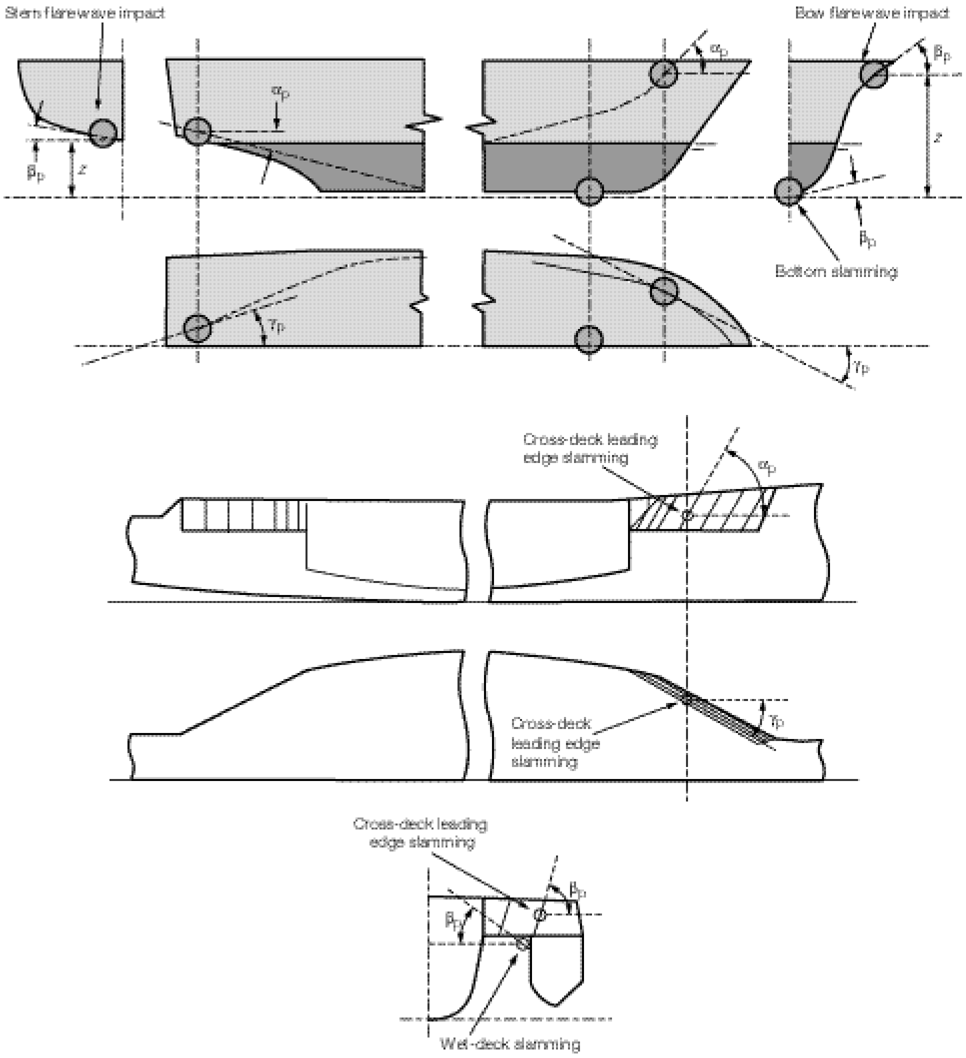

Fig. 5.2.1 Impact angles for slamming loads

2.4.2. If the Complementary Rules are the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as Rules for Special Service Craft) then the bottom impact pressure due to slamming, IP_{bi}, is to be derived using the method given below. This method will produce impact pressures forward of 0,8*L* from the aft end over the underwater plating region:

$$IP_{bi} = f_{bi}\left(19 - 2720\left(\frac{T_x}{L_{w1}}\right)^2\right)\sqrt{L_{w1}V_{sp}}\ \mathrm{kN/m^2}$$

where

f_{bi} = 0,09 at fwd end of L_R

f_{bi} = 0,18 at 0,9L_R

f_{bi} = 0,18 at 0,8 L_R

V_{sp} is defined in Ch 1,1.4.

2.5 Wave impact pressure above waterline

2.5.1. If the Complementary Rules are the Rules for Ships or the Rules for Naval Ships then the wave impact pressure above the waterline due to slamming, IP_{wi}, is to be derived using the method given below. This method will produce impact pressures for the following areas:

- Over the fore end side and bow structure above the waterline up to the deck at side
- Over the wet-deck structure of the cross-deck
- Over the leading edge structure of the cross deck
- Over the after body in way of a flat counter stern which is close to the waterline

$$IP_{wi} = 0,5\left(k_{wi}V_{wi}^2 + k_{rv}H_{rv}V_{rv}^2\right) \text{ kN/m}^2$$

where

k_{wi} = hull form coefficient
= $\frac{\pi}{\tan\beta_p}$ for $\beta_p \geq 10$
= 28 (1 – Tan ($2\beta_p$) for $\beta_p < 10$

V_{wi} = slamming velocity, in m/s and is given by
= $\sqrt{V_{thwi}^2 + 2m_1 ln(N_{wi})}$ for $N_{wi} \geq 1$
= 0 for $N_{wi} < 1$

V_{thwi} = threshold velocity for slamming, in m/s
= $\frac{\sqrt{10}}{\cos\alpha_p}$

N_{wi} = Number of slams in a three hour period
= $1720 PR_{wi}\sqrt{\frac{m_1}{m_0}}$

PR_{wi} = probability of a slam and is given by
= e^{-u}

$u = \frac{z_{wl}^2}{2m_0} + \frac{V_{thwi}^2}{2m_1}$

k_{rv} = hull form shape coefficient for impact due to forward speed
= $\frac{\pi}{\tan(90-\alpha_p)}$ for $\alpha_p \leq 80$
= 28 [1 – tan (2 (90 – α_p))] for $\alpha_p > 80$

H_{rv} = relative wave heading coefficient
= 1,0 for $\gamma_p \geq 45$
= cos (45 – γ_p) for $\gamma_p < 45$ and ≥ 0
= 0 for $\gamma_p < 0$

V_{rv} = relative forward speed, in m/s
= $0,515V_{sp}\sin(\gamma_p)$

α_p = buttock angle, in degrees, *see* Fig. 5.2.1

β_p = flare angle, in degrees, *see* Fig. 5.2.1

γ_p = waterline angle, in degrees, *see* Fig. 5.2.1

m_1 and m_0 are defined in 2.4.1

z_{wl} and V_{sp} are defined in Ch 1,1.4.

2.5.2. The flare angle, β_p, is to be decreased by 10° to allow for the effects of roll motion on the above waterline impact pressures.

2.5.3. Where only two angles are known, then the third may be obtained by the following expression:

$$\alpha = \mathrm{Tan}^{-1}(\mathrm{Tan}\beta\ \mathrm{Tan}\gamma)$$

2.5.4. If the area of plating under consideration has a waterline angle which is re-entrant or decreasing, e.g. in the stern region, then the relative wave heading coefficient, H_{rv} and the speed V_{sp} used in the derivation of H_{rm} are to be taken as zero.

2.5.5. If the Complementary Rules are the Rules for Special Service Craft then the impact pressure above the waterline, IP_{wi}, is to be derived using the methods given below:

For bow flare slamming:

$$IP_{wi} = L_{wl}(0,8 + 0,15\Gamma)^2 \ \mathrm{kN/m^2}$$

where

$$\Gamma = \frac{V}{\sqrt{L_{wl}}}$$

$$IP_{wi} = 0,18\left(19 - 2720\left(\frac{T_x}{L_{wl}}\right)^2\right)\sqrt{L_{wl}}V \text{ at } 0,9L_R$$

$IP_{wi} = P_{des}$ at $0,8L_R$

These formulae give pressures to be applied at the design waterline. At the weather deck the pressure is to be taken as $0,4IP_{wi}$ and intermediate values determined by interpolation.

For wet-deck slamming:

$$IP_{wi} = f_{imp}\,k_f V_R\, V_{sp}\left(1 - \frac{G_A}{1,29H}\right)$$

where

f_{imp} = 1/3 for the leading edge of the wet-deck
= 1/6 for the underside of the wet-deck

k_f is a longitudinal distribution factor
= 2,0 for the forward quarter of the wet-deck
= 1,0 elsewhere

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H}{\sqrt{L_{wl}}} + 2 \text{ knots}$$

G_A = Air Gap between underside of wet-deck and design waterline

H is minimum significant waveheight

For G1 ships H = 0,6

For G2 ships H = 1,0

For G3 ships H = 2,0

For G4, G5 and G6 ships H = 4,0

V_{sp} is as defined in Ch 1,1.4

V is maximum service speed, in knots

P_{des} is given in 3.2.

2.6 Minimum weather deck pressure

2.6.1. The minimum weather deck pressure, P_d, is to be taken as:

$$P_d = 6 + 6 f_L f_{wv} \text{ kN/m}^2$$

where

f_L is a location factor

$$= 1 + 4\left(\frac{x_{w1}}{L_{w1}} - 0{,}75\right)$$

but not less than 1,0

f_{wv} and x_{w1} are defined in Ch 1,1.4

L_{w1} is defined in Pt 1, Ch 1,5.2.

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Section 3 Shell envelope

3.1 General

3.1.1. Two design pressures are to be calculated for each item on the shell envelope; a combined pressure and an impact pressure.

3.1.2. In determining the vertical distance, z, as defined in Ch 1,1.4, the following applies:

- For a longitudinally framed plate panel, is to be taken at the panel centre.
- For a transversely framed plate panel, is to be taken at two thirds of the panel height.
- For short stiffener members: z is to be taken at the stiffener mid position.
- For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length.

3.2 Combined pressure

3.2.1. The distribution of design pressures acting on the shell envelope due to static and dynamic load components, P_{des}, is illustrated in Fig. 5.3.1 and taken as specified in Table 5.3.1.

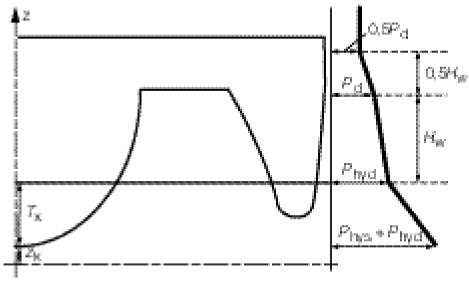

Fig 5.3.1 Combined hydrostatic and hydrodynamic pressure distribution

Table 5.3.1

Vertical location	P_{des} kN/m^2
At z ≤ $T_x + z_k$	$P_{hyd} + P_{hys}$
At $z = T_x + z_k$	P_{hyd}
At $z = T_x + z_k + H_w$	P_d
At $z = T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
P_{hyd}, P_{hys} and P_d are to be calculated according to Section 2 z, T_x, z_k and H_w are defined in Ch 1,1.4	
NOTE Pressure values at other *z* values to be determined by linear interpolation.	

3.3 Impact pressure

3.3.1. The design impact pressure is to be taken as IP_{bi} or IP_{wi}, according to 2.4 or 2.5, depending on the vertical location of the shell item.

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Section 4 Wet-deck

4.1 General

4.1.1. Two design pressures are to be calculated for each item on the wet-deck; a combined pressure and an impact pressure.

4.2 Combined pressure

4.2.1. The distribution of pressure acting on the wet-deck due to static and dynamic load components is to be taken as P_{des}, where *z* corresponds to the height of the underside of the wet-deck, as described in Table 5.3.1.

4.3 Impact pressure

4.3.1. The design impact pressure is to be taken as IP_{wi}, calculated according to 2.5.

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Section 5 Weather decks

5.1 Weather and exposed deck pressure

5.1.1. The design pressure acting on weather decks, exposed decks or decks designed for prolonged immersion, P_{des}, is to be taken as specified in Table 5.5.1 and illustrated in Fig. 5.5.1.

Table 5.5.1 Weather and exposed deck pressure distribution

Vertical location, i.e. *z* value	P_{des} kN/m^2

At $z = T_x + z_k$	P_{hyd}
At $z = T_x + z_k + 0{,}5H_w$	P_d
At $z = T_x + z_k + H_w$	P_d
At $z = T_x + z_k + 1{,}5H_w$	P_d
NOTE Pressure values at other z values to be determined by linear interpolation.	

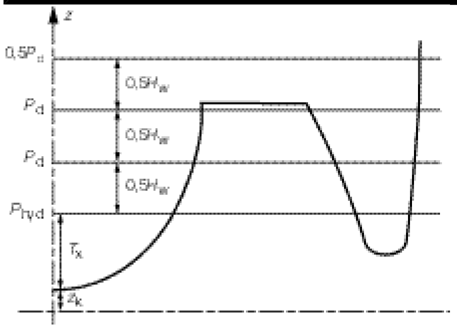

Fig 5.5.1 Weather and exposed deck pressure variation with height

5.1.2. If the Complementary Rules are the Rules for Naval Ships types NS2 and NS3, then for weather and exposed decks designed to carry cargo or heavy equipment, the design pressure is to be taken as the greater of that specified in Table 5.5.1 and Vol 1, Pt 5, Ch 3,5.4 of the Rules for Naval Ships.

5.1.3. If the Complementary Rules are the Rules for Special Service Craft, then for weather and exposed decks designed to carry cargo or heavy equipment, the design pressure is to be taken as the greater of that specified in Table 5.5.1 and Pt 6, Ch 3,8 of the Rules for Special Service Craft.

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Section 6 Inner bottom

6.1 Pressure on inner bottom

6.1.1. If the Complementary Rules are the Rules for Naval Ships then the design pressure on the inner bottom is not to be less than the following:

$$P_{des} = P_{hys} + \frac{P_{hyd}}{1{,}85}$$

where

P_{hys} is defined in 2.2.1

P_{hyd} is defined in 2.3.1

For calculation of P_{hys} and P_{hyd}; T_x, z and z_k are to be taken at an appropriate damaged waterline.

6.1.2. If the Complementary Rules are the Rules for Special Service Craft then the design pressure, P_{des}, is not to be less than that given in Pt 6, Ch 4,6 of the Rules for Special Service Craft.

6.1.3. If the Complementary Rules are the Rules for Ships, then the local pressures are not explicitly calculated. Local scantlings for the inner bottom are to be calculated according to Pt 6, Ch 4,6 of the Trimaran Rules.

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Section 7 Internal decks

7.1 Pressure on internal decks

7.1.1. This Section contains requirements for internal or lower decks.

7.1.2. If the Complementary Rules are the Rules for Naval Ships:

- For ship types NS2 and NS3, the design pressures are to be calculated in accordance with Vol 1, Pt 5, Ch 3,5.3 of the Rules for Naval Ships, where a_z is to be calculated according to Ch 3,2.2.3 of the Trimaran Rules.
- For ship type NS1, the pressures are not explicitly calculated and the scantling requirements for internal decks

are to be calculated according to Pt 6, Ch 4,7 of the Trimaran Rules.

7.1.3. If the Complementary Rules are the Rules for Special Service Craft then the design pressures are to be in accordance with those given in Pt 5, Ch 4 of the Rules for Special Service Craft.

7.1.4. If the Complementary Rules are the Rules for Ships then the local pressures are not explicitly calculated. Local scantlings for the internal decks are to be calculated according to Pt 6, Ch 4,7 of the Trimaran Rules.

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Section 8 Bulkheads and deep tanks

8.1 Pressure on bulkheads and deep tanks

8.1.1. This Section contains requirements for deep tank, watertight and collision bulkheads.

8.1.2. If the Complementary Rules are the Rules for Naval Ships:

- For ship types NS2 and NS3, the design pressures are to be calculated in accordance with Vol. 1, Pt 5, Ch 3,5.6 to 5.9 of the Rules for Naval Ships.
- For ship type NS1, the pressures are not explicitly calculated and the scantling requirements for bulkheads and

deep tanks are to be calculated according to Pt 6, Ch 4,8 of the Trimaran Rules.

8.1.3. If the Complementary Rules are the Rules for Special Service Craft then the design pressures are to be in accordance with those given in Pt 5, Ch 4 of the Rules for Special Service Craft.

8.1.4. If the Complementary Rules are the Rules for Ships then the local pressures are not explicitly calculated. Local scantlings for the bulkheads and deep tanks are to be calculated according to Pt 6, Ch 4,8 of the Trimaran Rules.

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Section 9 Deckhouses, bulwarks and superstructures

9.1 Pressure on deckhouses, bulwarks and superstructures

9.1.1. This Section contains requirements for deckhouses, bulwarks and superstructures.

9.1.2. If the Complementary Rules are the Rules for Naval Ships:

- For ship types NS2 and NS3, the design pressures are to be calculated in accordance with Vol 1, Pt 5, Ch 3,5.5 of the Rules for Naval Ships.
- For ship type NS1, the pressures are not explicitly calculated and the scantling requirements for deckhouses,

bulwarks and superstructures are to be calculated according to Pt 6, Ch 4,9 of the Trimaran Rules.

9.1.3. If the Complementary Rules are the Rules for Special Service Craft then the design pressures are to be in accordance with those given in Pt 5, Ch 4 of the Rules for Special Service Craft.

9.1.4. If the Complementary Rules are the Rules for Ships then the local pressures are not explicitly calculated. Local scantlings for deckhouses, bulwarks and superstructures are to be calculated according to Pt 6, Ch 4,9 of the Trimaran Rules.

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Section 10 Other local loads

10.1 Pressure on other local structure

10.1.1. If the Complementary Rules are the Rules for Naval Ships:

- For ship types NS2 and NS3, the design pressures are to be calculated in accordance with Vol 1, Pt 5, Ch 3,6 of the Rules for Naval Ships.
- For ship type NS1, the pressures are not explicitly calculated and the scantling requirements for other local structure are to be calculated according to Pt 6, Ch 4,10 of the Trimaran Rules.

10.1.2. If the Complementary Rules are the Rules for Special Service Craft then the design pressures are to be calculated in accordance with those given in Pt 6, Ch 4,8 of the Rules for Special Service Craft.

10.1.3. If the Complementary Rules are the Rules for Ships then the local pressures are not explicitly calculated. Local scantlings for other structure is to be calculated according to Pt 6, Ch 4,10 of the Trimaran Rules.

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Section 11 Ice loads

11.1 Loads due to ice conditions

11.1.1. If the Complementary Rules are the Rules for Naval Ships:

- For ship types NS2 and NS3, the design pressures are to be calculated in accordance with Vol. 1, Pt 5, Ch 3,7 of the Rules for Naval Ships.
- For ship type NS1, the pressures are not explicitly calculated and the scantling requirements due to ice loads are to be calculated according to Pt 6, Ch 4,11 of the Trimaran Rules.

11.1.2. If the Complementary Rules are the Rules for Special Service Craft then the local pressures are not explicitly calculated. Local scantlings due to ice loads are to be calculated according to Pt 6, Ch 4,11 of the Trimaran Rules.

11.1.3. If the Complementary Rules are the Rules for Ships then the local pressures are not explicitly calculated. Local scantlings due to ice loads are to be calculated according to Pt 6, Ch 4,11 of the Trimaran Rules.

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Part 6 Scantling Determination

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Chapter 1 Introduction

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Section 1 Application

1.1 General

1.1.1. This Part of the Rules provides global strength requirements and local scantling requirements according to the loads calculated in Part 5.

1.1.2. In addition to the requirements of this Part mandatory structural strength analysis and verification is to be carried out for all Trimarans, *see* Vol 4, Pt 1, Ch 2.

1.2 Equivalents

1.2.1. Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration.

1.3 Symbols and definitions

1.3.1. The symbols and definitions for use throughout this Part are as follows:

b = actual breadth of plating, in mm, of the load bearing plating which is defined as one-half the sum of the spacings between parallel adjacent members or equivalent supports

b_e = effective breadth of attached plating, *see* Ch 2,2.2

c_I = inertia coefficient dependent on the loading model assumption, *see* Fig 4.2.1

c_A = web area coefficient dependent on the loading model assumption, *see* Fig 4.2.1

c_Z = section modulus coefficient dependent on the loading model assumption, *see* Fig 4.2.1

d_{cd} = depth of cross-deck structure, in metres, *see* Ch 3,3.2

d_{ch} = the distance, in mm, measured perpendicularly from the chord length, l_{ch}, (i.e. spacing in mm) to the highest point of the curved plating arc between the two supports, *see* Ch 2,2.4

f_{ar} = panel aspect ratio correction factor as defined in Ch 2,2.5

f_{curv} = convex curvature correction factor as defined in Ch 2,2.4.1

f_{hts} = high tensile steel factor, defined in Ch 2,1.4

f_σ = limiting stress coefficient for local plate bending for the plating area under consideration given in Table 4.2.2 in Chapter 4

$f_{\sigma hg}$ = limiting hull bending stress coefficient, *see* Ch 3,2.4

$f_{\sigma ws}$ = limiting working stress coefficient, *see* Ch 3,2.5

k_l = higher tensile steel factor for local loads, *see* Ch 2,1.4

k_g = higher tensile steel factor for global loads, *see* Ch 2,1.4

l = overall length of stiffener or primary member, in metres

l_{ch} = chord length between stiffeners in mm, *see* Ch 2,2.4

l_e = effective span length, in metres

n_{bhd} = number of transverse bulkheads in the longitudinal cross-deck section

s = secondary stiffener spacing, in mm

t_{bhd} = cross-deck structure transverse bulkhead plating thickness, in mm

t_{dk} = deck plating thickness in way of cross-deck structure, in mm

t_p = plating thickness, in mm

x = longitudinal distance, in metres, measured forwards from the aft end of L_R to the position or centre of gravity of the item being considered

z = vertical distance, in metres, from the hull transverse neutral axis to a position under consideration

z_i = section modulus of cross-deck beam, in cm^3, *see* Ch 3,3.2

z_m = vertical distance, in metres, from the hull transverse neutral axis to the minimum limit of higher tensile steel, above or below the neutral axis as appropriate

z_B = the vertical distance, in metres, from the transverse neutral axis of the total hull cross-section to the top of the keel

z_D = the vertical distance, in metres, from the transverse neutral axis of the total hull cross-section to the uppermost continuous longitudinally effective material

A_{cd} = total vertical shear area of a longitudinal cross section of the cross-deck structure, extending only the length of the side hull, in cm^2. Initially only transverse bulkheads with breadth including the main hull, side hulls and cross-deck structure will be considered effective in shear

A_{wi} = shear area of cross deck beam web, in cm^2, *see* Ch 3,3.2

A_R = panel aspect ratio
= panel length/panel breadth

A_T = effective shear area of transverse section, in m^2, to be taken as the net effective sectional area of the side shell plating and the longitudinal bulkheads after deductions for openings

E = modulus of elasticity, in N/mm^2

F_B = local scantling reduction factor for hull members below the neutral axis, *see* Ch 3,2.3.2

F_D = local scantling reduction factor for hull members above the neutral axis, *see* Ch 3,2.3.2

I = moment of inertia, in cm^4

I_i = moment of inertia of cross deck beam, in cm^4, *see* Ch 3,3.2

I_{cd} = total inertia of a longitudinal cross section of the cross-deck structure, extending only the length of the side hull, in cm^4

M_{tot} = total Rule bending moment, in kNm, given in Pt 5, Ch 4,2.8

M_{wHog} = hogging value of M_w, in kNm, given in Pt 5, Ch 4,2.4

M_{wSag} = sagging value of M_w, in kNm, given in Pt 5, Ch 4,2.4

P_{des} = design pressure, in kN/m^2, for structural item under consideration, as calculated according to Pt 5, Ch 5

S = primary stiffener spacing, in metres

S_{bhd} = spacing of transverse bulkheads in the cross-deck structure, in metres

Z_{cdb} = section modulus at the bottom, or wet deck, of a longitudinal section of the cross-deck structure, extending only the length of the side hull, in cm^3

Z_{cdt} = section modulus at the top, typically the main deck, of a longitudinal section of the cross-deck structure, extending only the length of the side hull, in cm^3

Z_{curv} = section modulus, in cm^3, of transverse main and 'tween deck frames, corrected for convex curvature

Z_i = actual section modulus at structural element being considered, in cm^3

Z_i = section modulus of general stiffening member, in cm^3

σ_B = maximum hull vertical bending stress at keel in N/mm^2, *see* Table 3.2.1 in Chapter 3

σ_D = maximum hull vertical bending stress at strength deck in N/mm^2, *see* Table 3.2.1 in Chapter 3

σ_p = permissible combined stress in N/mm^2, *see* Ch 3,2.4.3

σ_{sph} = direct stress on transverse primary member due to hog splitting load, in N/mm^2

σ_{sps} = direct stress on transverse primary member due to sag splitting load, in N/mm^2

σ_{tt} = direct stress on transverse primary member due to transverse torsional moment, in N/mm^2

σ_{yd} = guaranteed minimum yield strength of the material in N/mm^2

σ_{ydMild} = minimum yield strength of mild steel in N/mm^2

σ_u = ultimate tensile strength of the material in N/mm^2

σ_{ws} = hull girder bending stress range in N/mm^2, *see* Ch 3,2.4

τ_{sp} = shear stress induced by the splitting shear force, in N/mm^2

τ_{tt} = shear stress induced by the transverse torsional moment, in N/mm^2

τ_{yd} = shear strength of the material in N/mm^2
$= \frac{\sigma_{yd}}{\sqrt{3}}$

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Section 2 General requirements

2.1 General

2.1.1. Limitations with regard to the application of this Part are indicated in the individual Chapters.

2.2 Plans to be submitted

2.2.1. Plans are to be of sufficient detail for plan approval purposes. For all areas of structure listed below the submitted plans are to show all plating thickness, stiffeners sizes and spacings, bracket arrangements and connections. Where appropriate, the plans should clearly show the allowance for corrosion margin or Owner's extra. Welding, constructional arrangements and tolerances are also to be submitted and this may be in the form of a booklet.

2.2.2. In general all items of steel structure are to be shown except where they are ineffective in supporting hull girder and local loads and do not impinge on such structure.

2.2.3. Equipment seating and supports are to be shown where they require additional stiffening and support to be incorporated in items of hull structure. In such cases the loading on the seating is also to be supplied. Generally total combined equipment weights on seating less than 0,5 tonnes need not be considered.

2.2.4. Normally the plans for each item will be able to be contained on a few sheets. Unit or production drawings will not be accepted.

2.2.5. Plans and calculations are to be submitted as required in the Complementary Rules and are to include all appropriate structure in the side hulls, centre hull and cross deck structure.

2.2.6. The details of the cross deck structure connections, forward and aft, to the main and centre hulls must either be included within the required plans or be provided as a separate plan.

2.2.7. Plans are to be supplied to the ship as required in the Complementary Rules.

2.3 Enhanced scantlings

2.3.1. An enhanced scantling notation may be applied as described in the Complementary Rules.

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Chapter 2 Design Tools

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Section 1 General

1.1 General

1.1.1. The guidance notes, information and formulae contained within this Chapter are to be used when calculating the global strength requirements (Chapter 3) and the required scantlings due to local loads (Chapter 4).

1.2 Rounding policy for Rule plating thickness

1.2.1. Where plating thicknesses as determined by the Rules require to be rounded then this is to be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.3 Material properties

1.3.1. The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

(a). Yield strength (minimum), σ_{yd} = 235 N/mm^2

(b). Tensile strength, σ_u = 400 – 490 N/mm^2

(c). Modulus of elasticity, E = 200 x 10^3 N/mm^2.

1.4 Higher tensile steel

1.4.1. Steels having a yield stress not less than 265 N/mm^2 are to be regarded as higher tensile steels.

1.4.2. Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, stiffener section modulus, inertia and cross-sectional area by the use of higher tensile steel correction factors k_l and k_g or f_{hts}

where

$$k_l = \frac{235}{\sigma_{yd}}$$

$$k_g = \frac{235}{\sigma_{yd}\, f_{hts}}$$

f_{hts} is as follows:

σ_{yd}	f_{hts}
235	1,00
265	0,964
315	0,956
355	0,919
>390	$0{,}886\frac{390}{\sigma_{yd}}$

1.4.3. Normally, this allowance is included in the appropriate scantling requirements. Where this is not the case, the following correction factors may be applied:

(a). Plating thickness factor $= \sqrt{k_1}$ for local loads $= \sqrt{k_g}$ for global loads

(b). Plating thickness factorSection modulus and cross sectional area factor = k_l.

1.4.4. The designer should note that there is no increase in fatigue performance with the use of higher tensile steels.

1.4.5. Local scantlings which are to be calculated according to the Complementary Rules are to use the high tensile steel factor as defined in the Complementary Rules. This local factor, having the same values as in the Trimaran Rules, is named as follows in the Complementary Rules:

k_l = k_s *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships)
= k_s *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the

Rules for Special Service Craft)
= *k Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

Section 2 Structural design

2.1 General

2.1.1. This Section gives the basic principles to be adopted in determining the Rule structural requirements given in Chapter 3 and Chapter 4.

2.1.2. For derivation of scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated distributed load.

2.1.3. The stiffener, beam or girder strength is defined by a section modulus and moments of inertia requirements. In addition there are local requirements for web thickness and flange thickness.

2.2 Effective width of attached plating

2.2.1. For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness, t_p, in mm and an effective breadth, t_p in mm.

2.2.2. The effective breadth of attached plating to secondary stiffener members b_e, in mm, is to be taken as the lesser of:

(a). The actual spacing of the stiffeners, *b*, and

(b). The greater of $40t_p$ and 600 mm

(c). The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) is to be taken as follows:

$$b_e = 300 S \left(\frac{l}{S}\right)^{2/3} \text{ mm}$$

but is not to exceed *S*

S and *l* are defined in Ch 1,1.3.

2.3 Section properties

2.3.1. The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

2.3.2. If applicable, idealised section properties may be calculated as described in the Complementary Rules.

2.4 Convex curvature correction

2.4.1. The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

$$f_{curv} = 1 - \frac{d_{ch}}{l_{ch}}$$

see Fig. 2.2.1

where

f_{curv}, d_{ch} and l_{ch} are defined in Ch 1,1.3.

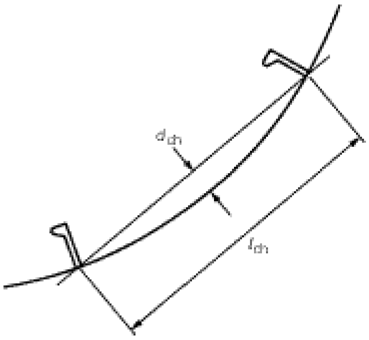

Fig. 2.2.1 Convex curvature

2.4.2. The required section modulus of transverse main and ‘tween deck frames, which have reasonably constant convex curvature over their entire length, may be corrected for curvature as follows:

$$Z_{curv} = Z \frac{1}{\cosh \frac{2\pi d_{ch}}{l_{ch}}} \text{cm}^3$$

where

Z_{curv}, Z, d_{ch} and l_{ch} are defined in Ch 1,1.3.

2.5 Aspect ratio correction

2.5.1. The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

$$f_{AR} = A_R(1 - 0,25 A_R) \text{ for } A_R \leq 2$$
$$= 1 \text{ for } A_R > 2$$

where

f_{AR} and A_R are defined in Ch 1,1.3.

2.6 Determination of span length

2.6.1. The effective length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured are to be determined as follows:

(a). **For rolled or built secondary stiffening members:** The span point is to be taken at the point where the depth of the end bracket, measured from the face of the member, is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs. For double bottom construction the span may be reduced by the depth of primary member web stiffener, *see* Fig. 2.2.2.

(b). **For primary support members:** The span point is to be taken at a point distant from the end of the member,

where

$b_e = b_b \left(1 - \frac{d_w}{d_b}\right)$, *see* Fig. 2.2.2

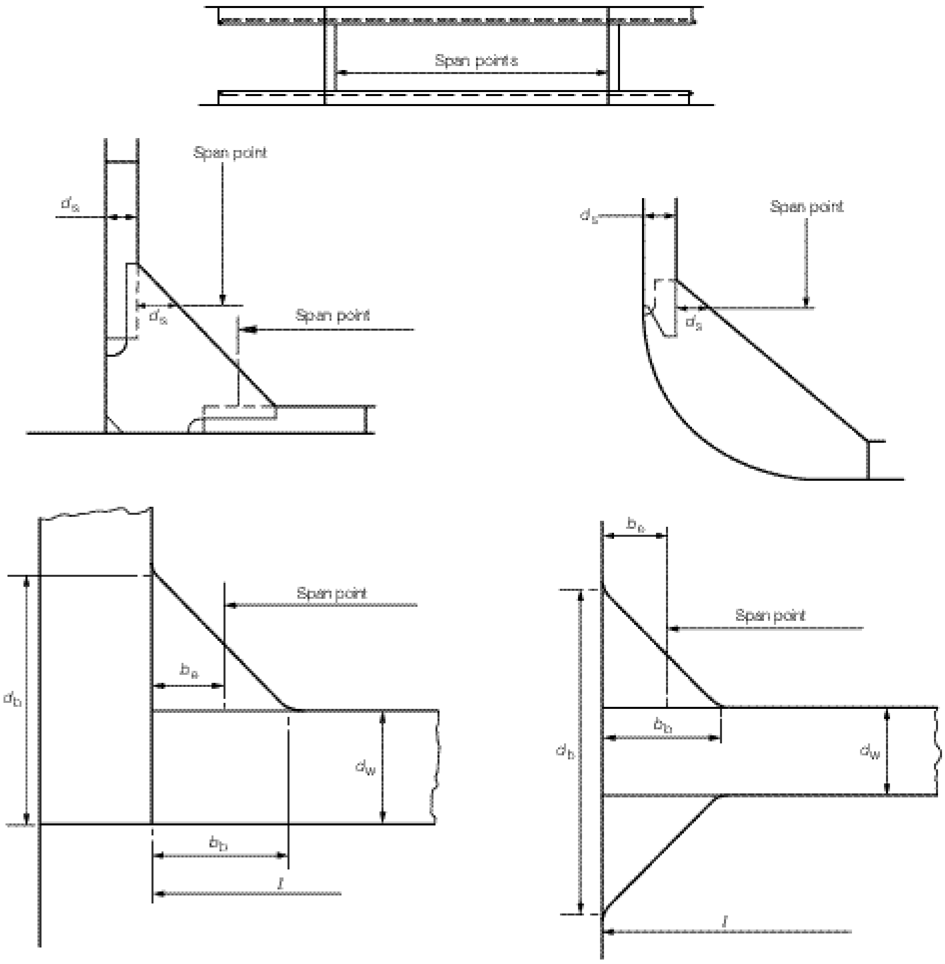

Fig. 2.2.2 Definition of span points

2.7 Proportions of stiffener sections

2.7.1. Requirements for the proportions of stiffener sections are to be calculated according to the following sections of the Complementary Rules:

. Vol 1, Pt 6, Ch 2,2.9 of the Rules for Naval Ships

. Pt 6, Ch 3,1.18 of the Rules for Special Service Craft

. Pt 3, Ch 10,4.5 of the Rules for Ships.

2.8 Grillage structures

2.8.1. For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

2.8.2. General or special purpose computer programs or other analytical techniques may be used provided that the effects of bending, shear, axial load and torsion are properly accounted for and the theory and idealisation used can be justified.

2.8.3. In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption in not applicable, finite element analysis or equivalent methods may have to be used.

2.9 Detail design

2.9.1. Items such as details of end connections and scantlings of end brackets are to be in compliance with the Complementary Rules.

Section 3 Buckling

3.1 General

3.1.1. In general, all areas of the structure are to meet the buckling requirements for the design stresses calculated according to Pt 5, Ch 3.

3.2 Buckling requirements

3.2.1. Requirements for buckling are to be calculated according to the following Sections of the Complementary Rules:

. Vol 1, Pt 6, Ch 2,4 of the Rules for Naval Ships

. Vol 1, Pt 6, Ch 5,3 of the Rules for Naval Ships

. Pt 6, Ch 7,4 of the Rules for Special Service Craft

. Pt 3, Ch 4,7 of the Rules for Ships

. Additional requirements for specific ship types are also to be complied with.

Section 4 Fatigue

4.1 General

4.1.1. For guidance on evaluation of structural models for fatigue aspects, *see* the *Fatigue Design Assessment (FDA) – Structural Detail Design Guide*.

Chapter 3 Global Strength Requirements

Section 1 General

1.1 Introduction

1.1.1. This Chapter contains information regarding the derivation of global strength requirements that are to be used in conjunction with the global design loads calculated according to Pt 5, Ch 4.

1.2 Application

1.2.1. The requirements for longitudinal and transverse global strength are contained within this Chapter.

1.2.2. The requirements of this Chapter are to be applied *in lieu* of the corresponding requirements of the Complementary Rules.

Section 2 Hull girder strength

2.1 Application

2.1.1. The requirements for longitudinal strength of trimarans are contained within this Section.

2.1.2. Longitudinal strength calculations are to be carried out for all vessels, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.2 Section modulus calculation

2.2.1. In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of the midship section modulus.

2.2.2. Initially, the side hulls and deck structure extending outside the breadth of the main hull may only be considered effective if the cross-deck length is greater than 0,4*L*. Additional structure may be incorporated into the section modulus calculations if proven effective by a global finite element analysis. This analysis must be submitted to and approved by LR.

2.2.3. In general, sections are to be evaluated along the length of the ship to adequately represent structural transitions. If portions of the side hull and decks outside the breadth of the main hull are considered longitudinally effective according to 2.2.2, additional sections are to be calculated at amidships of the side hull, at side hull terminations, and at any other appropriate sections to capture the transitions of the side hulls.

2.2.4. In addition to meeting the requirement of 2.2.2, in order for the full breadth of the deck structure to be effective in longitudinal bending, the taper ratio, as depicted in Fig. 3.2.1, is to be 3:1 or greater

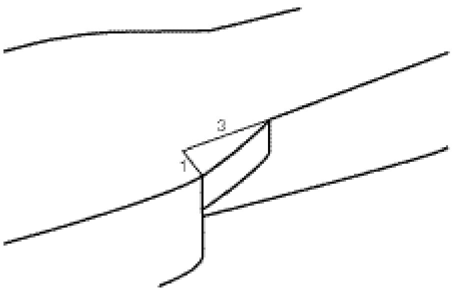

Fig. 3.2.1 Taper ratio of cross-deck connecting main hull to side hull

2.2.5. Deck and side hull plating located forward of the position on the side hull corresponding to the 3:1 taper ratio is to be considered ineffective, *see* Fig. 3.2.2.

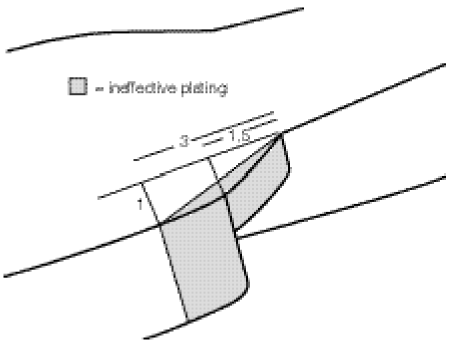

Fig. 3.2.2 Ineffective plating for lower taper ratios

2.2.6. Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of opening which may affect their structural performance.

2.2.7. In general, short superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the ship. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations.

2.2.8. Where continuous deck longitudinal or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus.

2.2.9. Adequate transition arrangements are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

2.2.10. Structural material which is longitudinally continuous but which is not considered to be fully effective for longitudinal strength purposes will need to be specially considered. The global longitudinal strength assessment must take into account the presence of such material when it can be considered effective. The consequences of failure of such structural material and subsequent redistribution of stresses into or additional loads imposed on the remaining structure must be considered.

2.2.11. In particular, all longitudinally continuous material will be fully effective in tension whereas this may not be so in compression due to a low buckling capability. In this case, it may be necessary to derive and apply different hull girder section moduli to the hogging and sagging bending moment cases.

2.2.12. Openings in decks, longitudinal bulkheads and other longitudinal effective material having a length in the fore and aft directions exceeding 0,1*B* m or 2,5 m or a breadth exceeding 1,2 m or 0,04*B* m whichever is the lesser, are in all cases to be deducted from the sectional areas used in the section modulus calculation. *B* is as defined in Pt 1, Ch 1,5.2.

2.2.13. Openings smaller than stated in 2.2.9, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths, ***see*** 2.2.14, in one transverse section does reduce the section modulus at deck or bottom by more than 3 per cent.

2.2.14. The expression 0,06 ($B_1 - b_1$), where B_1 equals the breadth of the ship at the section considered and equals the sum of the breadths of deductible openings, may be used for deck openings in lieu of the 3 per cent limitation of reduction of section modulus in 2.2.13.

2.2.15. Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 3.2.3. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.

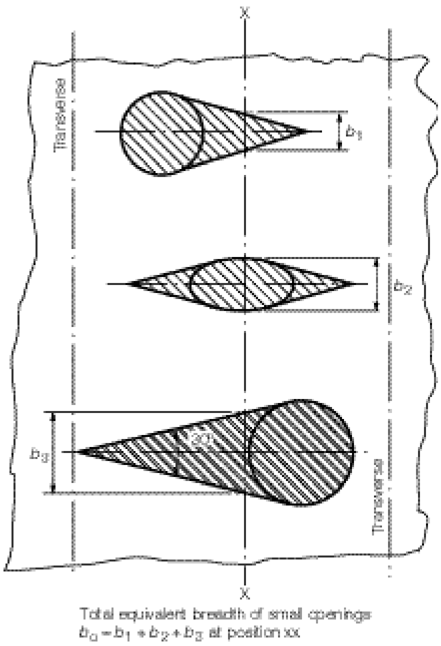

Fig. 3.2.3 Isolated openings

2.2.16. Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

2.2.17. Openings are considered isolated if they are spaced more than 1 m apart.

2.2.18. A reduction for drainage holes and scallops in beams and girder, etc., is not necessary so long as the global section modulus at deck or keel is reduced by no more than 0,5 per cent.

2.3 Higher tensile steel

2.3.1. Higher tensile steel may be used for both deck and bottom structures or deck structure only. Where fitted for global strength purposes, it is to be used for the whole of the longitudinally continuous material for the following vertical distances:

(a). z_{htd} below the line of deck at side

$$z_{htd} = 1 - \frac{k_g}{F_D} z_D$$

(b). z_{htb} above the top of keel

$$z_{htb} = 1 - \frac{k_g}{F_B} z_B$$

where

F_D and F_B are not to be taken as less than k_g and are defined in 2.3.2

z_D, z_B and k_g and are defined in Ch 1,1.3.

2.3.2. Where the maximum hull vertical bending stress at the deck or keel is less than the permissible combined stress, σp, reductions in local scantlings within to 0,3L_R to 0,7L_R may be permitted. The reduction factors are defined as follows:

(a). For hull members above the neutral axis

$$F_D = \frac{\sigma_D}{\sigma_P}$$

(b). For hull member below the neutral axis

$$F_D = \frac{\sigma_B}{\sigma_P}$$

where

σ_D, σ_B and σ_{ws} are defined in Ch 1,1.3.1.

2.3.3. In general, the values of σ_D and σ_B to be used are the greater of the sagging or hogging stresses. F_D and F_B are not to be taken as less than 0,67 for plating and 0,75 for longitudinal stiffeners.

2.3.4. Where higher tensile steel is used in the hull structure, the values of F_D and F_B for the mild steel part are to be taken as not less than z/z_m

where

z and z_m are defined in Ch 1,1.3.1.

2.4 Longitudinal bending strength

2.4.1. The effective geometric properties of all critical sections along the length of the ship are to be calculated directly from the dimensions of the section using only effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction, *see* 2.2.

2.4.2. Where higher tensile steel is fitted to satisfy global strength requirements, the extent of higher tensile steel is to be as specified in 2.3. Where a mix of steel grades is used for plating and associated stiffeners, then the lower of the steel grades is to be used for the derivation of permissible stresses.

2.4.3. The longitudinal strength of the ship is to satisfy the following criteria for the hogging and sagging conditions:

$$\sigma_B < \sigma_P$$

$$\sigma_D < \sigma_P$$

$$\sigma_{ws} < f_{\sigma ws}\,\sigma_{ydMild}$$

where

$\sigma_p = f_{\sigma hg} f_{hts}\, \sigma_{yd}$

$f_{\sigma hg}$ = 0,75 from 0,3L to 0,7L

$= 0{,}319 + 2{,}311\frac{X}{L} - 2{,}974\left(\frac{X}{L}\right)^2$ for continuous structural members aft of 0,3L and forward of 0,7L

$f_{\sigma ws}$ = limiting working stress coefficient
= 1,2

Note that the σ_{ws} criteria may be relaxed if it can be demonstrated that either:

- A continuous fatigue monitoring system is to be adopted for the in-service life of the ship, or
- A fatigue design assessment procedure is applied which demonstrates that a higher limiting working stress coefficient, $f_{\sigma ws}$, may be applied.

σ_B, σ_D and σ_p are given in Table 3.2.1

f_{hts}, $f_{\sigma hg}$, $f_{\sigma ws}$, M_{wHog}, M_{wSag}, M_{tot}, σ_{yd}, σ_{ydMild} and x are defined in Ch 1,1.3.

L is defined in Pt 1, Ch 1,5.2.

Component stress type	Nominal stress, N/mm^2
Hull girder bending stress at strength deck, *see* Note 1	$\sigma_D = \dfrac{M_{tot}}{1000\, Z_D}$
Hull girder bending stress at keel, *see* Note 1	$\sigma_B = \dfrac{M_{tot}}{1000\, Z_B}$
Hull girder bending stress range, *see* Note 2	$\sigma_{ws} = \dfrac{M_{wHog} - M_{wSag}}{1000\, Z_D}$
NOTES *1.* The hogging and bending moments are to be considered. *2.* The stress range at the keel or other longitudinally effective material should be used if it is greater than the stress range at the strength deck.	

2.4.4. The design stress due to hull girder bending, σ_{hg}, for each structural member is given by:

$$\sigma_{hg} = \frac{M_{tot}}{1000\, Z_i} \text{ N/mm}^2$$

where

M_{tot} is defined in Pt 5, Ch 1,1.4

Z_i is defined in Ch 1,1.3.

2.4.5. Where different grades of steel are used then it should be ensured that the design stress in each structural member is less than the permissible hull vertical bending stress, i.e.

$$\sigma_{hg} < \sigma_p \text{ N/mm}^2$$

where

σ_{hg} and σ_p are defined in Ch 1,1.3.

2.5 Minimum hull section modulus

2.5.1. The hull midship section modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = 0{,}95\, k_g M_o \text{ x } 10^{-5} \text{ m}^3$$

where

k_g is defined in Ch 1,1.3

M_o is defined in Pt 5, Ch 4,2.4.1.

2.6 Minimum hull moment of inertia

2.6.1. The hull midship section moment of inertia about the transverse neutral axis is to be not less than the following using the maximum total bending moment, sagging or hogging:

$$I_{min} = \frac{3{,}0\, L\, M_{tot}}{175} \text{ x } 10^{-5} \text{ m}^4$$

where

M_{tot} is defined in Pt 5, Ch 1,1.4.1

L is defined in Pt 1, Ch 1,5.2.

2.7 Shear strength

2.7.1. The shear strength of the vessel at any position along its length is to satisfy the following criteria:

$$\frac{Q_{tot}}{A_{\tau}} 10^{-3} \leq \tau_p$$

where

Q_{tot} is defined in Pt 5, Ch 1,1.4

A_{τ} is defined in Ch 1,1.3

$\tau_p = 0{,}72\tau_{yd}$

τ_{yd} is defined in Ch 1,1.3.

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Section 3 Cross-deck strength

3.1 Application

3.1.1. The requirements for transverse strength of trimarans are contained within this Section.

3.1.2. Transverse strength calculations are to be carried out for all vessels. If the vessel's transverse deadweight distribution varies significantly over the range of load and ballast conditions proposed, then transverse hog and sag still water conditions must be specified to be applied in conjunction with the hogging and sagging wave splitting moments. If the transverse deadweight distribution remains fairly constant, one transverse still water distribution may be used.

3.2 Cross-deck component stresses

3.2.1. The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria in Table 3.3.1.

Table 3.3.1 Cross-deck component stresses

Component stress type	Nominal stress (N/mm^2)
Direct stress induced by the sag splitting moment, M_{sps}, and the hog splitting moment M_{sph}, as defined in Pt 5, Ch 4,3.1	$\sigma_{sps} = \frac{M_{sps}}{Z_{cd}} 10^3$ $\sigma_{sph} = \frac{M_{sph}}{Z_{cd}} 10^3$
Shear stress induced by the splitting shear force, Q_{sps} and Q_{sph}, as defined in Pt 5, Ch 4,3.2	$\tau_{sps} = \frac{5\,Q_{sps}}{A_{cd}}$

	$\tau_{sph} = \dfrac{5\,Q_{sph}}{A_{cd}}$
Bending stress induced by the transverse torsional moment, M_{tt}, as defined in Pt 5, Ch 4,3.3	$\sigma_{tt} = \dfrac{3000(y_o - y_I)M_{tt}}{S_{bhd}\,n_{bhd}(n_{bhd} + 1)z_i}$
Shear stress induced by the transverse torsional moment, M_{tt}, as defined in Pt 5, Ch 4,3.3	$\tau_{tt} = \dfrac{60\,M_{tt}}{S_{bhd}\,n_{bhd}(n_{bhd} + 1)} + \dfrac{38\,k\,M_{tt}(y_o - y_I)^2}{2\,S_{bhd}\,n_{bhd}(n_{bhd}^2 - 1)\,I_i}$
$k = \dfrac{K}{R}$ where $K = \dfrac{2\,t_{dk}\,t_{bhd}\,S_{bhd}^2\,d_{cd}^2}{S_{bhd}\,t_{bhd} + d_{cd}\,t_{dk}}$ $R = 2t_{dk}S_{bhd}d_{cd}$ for the deck $R = 2t_{bhd}\,S_{bhd}d_{cd}$ for the transverse bulkhead Z_{cd} = is to be taken as the lesser of Z_{cdb} and Z_{cdt} σ_{sps}, σ_{sph}, Z_{cdb}, Z_{cdt}, σ_{tt}, n_{bhd}, S_p, τ_{sps}, τ_{sph}, A_{cd}, τ_{tt}, d_{cd}, A_{wi}, z_i, I_i, t_{dk} and t_{bhd} are defined in Ch 1,1.3 M_{sps}, M_{sph}, M_{tt}, y_o, y_I, Q_{sps} and Q_{sph} are defined in Pt 5, Ch 1,1.4.	

3.2.2. When calculating the stresses due to the transverse torsional moment M_{tt} the following is assumed:

(a). The cross-deck structure is a series of 'beams' formed by transverse bulkheads and decks.

(b). Transverse bulkheads are equally spaced.

(c). The beams are treated as built-in at each hull, i.e. the hulls have much greater stiffness than the cross-deck.

(d). The cross-deck is symmetrical forward and aft of a transverse axis at its mid-length.

(e). The hulls move vertically only, rotating about their pitch axis, but do not rotate about their own longitudinal axis.

3.2.3. Cross-deck designs other than those described in 3.2.2 may require an alternative analysis to demonstrate compliance with the combined stress criteria.

3.2.4. Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 2,2.2.

3.2.5. Z_{cdt}, Z_{cdb} and A_{cd}, defined in Ch 1,1.3, are to be calculated using the effective section at the appropriate load calculation point, *see* Fig. 3.3.1.

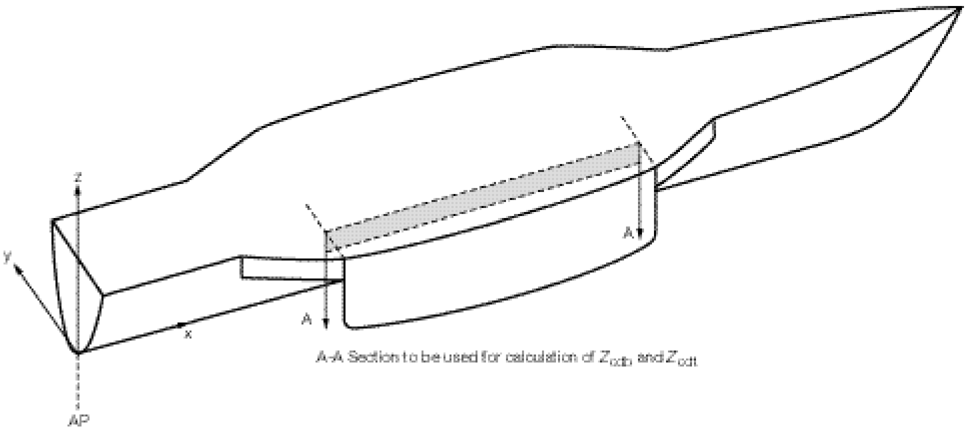

Fig. 3.3.1 Cross-deck section

3.3 Combined stress criteria

3.3.1. The total stresses are to be evaluated for four different load cases (a) to (d) as given in Table 3.3.2.

Table 3.3.2 Cross-deck primary member stress criteria

Stress type	Component stresses	Allowable stress level, N/mm^2
Total direct stress, σ_{cd}	*(a)* σ_{sps} *(b)* σ_{sph} *(c)* $\sigma_{tt} + 0{,}6\sigma_{sps}$ *(d)* $\sigma_{tt} + 0{,}6\sigma_{sph}$	$0{,}72 f_{hts}\ \sigma_{yd}$
Total shear stress, τ_{cd}	*(a)* τ_{sps} *(b)* τ_{sph} *(c)* $\tau_{tt} + 0{,}6\tau_{sps}$ *(d)* $\tau_{tt} + 0{,}6\tau_{sph}$	$0{,}72 f_{hts}\ \tau_{yd}$
Equivalent stress, σ_{eq} (*see* Note 1)	$\sqrt{\sigma_{cd} + 3^2 \tau_{cd}}$	$0{,}90 f_{hts}\ \sigma_{yd}$

NOTES

1. When calculating equivalent stress, the component stresses for direct and shear stress are to correspond to the load case considered, i.e. for load case (a) $\sigma_{eq} = \sqrt{\sigma_{sps}^2 + 3\tau_{sps}^2}$

2. f_{hts} is defined in Ch 2,1.4.

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Chapter 4 Local Scantling Requirements

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Section 1 General

1.1 Introduction

1.1.1. This Chapter contains local scantling requirements for the structural elements of a trimaran.

1.1.2. Where plating or stiffening contributes to the global strength of the ship, the scantlings are not to be less than that required to satisfy the global strength requirements detailed in Chapter 3.

1.2 Corrosion margin

1.2.1. The local scantling requirements are calculated in the Rules using a ‘net’ scantling approach, *see* Vol 1, Pt 1, Ch 1,3.2.

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Section 2 Minimum structural requirements

2.1 General

2.1.1. This Section gives the basic principles to be adopted in determining the Rule structural requirements.

2.1.2. The equations given in this Section are to be used to determine the scantling requirements for shell envelope, wet-deck, weather deck and inner bottom, *see* Sections 4 to 7.

2.1.3. The remaining scantlings not listed in 2.1.2 and 2.1.3 are to be determined directly from the Complementary Rules as defined in Sections 7 to 11.

2.2 Plate thickness

2.2.1. The requirements for the thickness of plating, t_p, is in general to be in accordance with the following:

$$t_p = 22{,}4 s f_{curv} f_{ar} \sqrt{\frac{P_{des}}{f_\sigma \sigma_{yd}}} \times 10^{-3}\ \text{mm}$$

where

f_σ is defined in Table 4.2.2

s, f_{curv}, f_{ar}, P_{des} and σ_{yd} are defined in Ch 1,1.3.1.

2.3 Stiffener properties

2.3.1. **Primary stiffening members.** The requirements for section modulus, inertia and web area of primary stiffening members subjected to pressure loads are, in general, to be in accordance with the following: Section Modulus:

$$Z = \frac{c_z \delta_f P_{des} S l_e^2}{f_\sigma \sigma_{yd}} 10^3 \text{ cm}^3$$

Inertia:

$$I = \frac{c_I \delta_f P_{des} S l_e^2}{f_\sigma E} 10^5 \text{ cm}^4$$

Web area:

$$A_w = \frac{10 c_A \delta_f P_{des} S l_e}{f_\tau \tau_{yd}} \text{cm}^2$$

where

f_σ is a structural element type factor and is 0,5 in general, for primary stiffening members

f_σ factors are listed for specific structural items in Table 4.2.1

c_A, c_Z and c_I are coefficients defined in Fig. 4.2.1

f_σ, f_τ, f_δ are defined in Table 4.2.2

P_{des}, S, l_e, σ_{yd}, τ_{yd} and E are defined in Ch 1,1.3.1.

2.3.2. **Secondary stiffening members.** The requirements for section modulus, inertia and web area of secondary stiffening members subjected to pressure loads are, in general, to be in accordance with the following: Section Modulus:

$$Z = \frac{c_Z \delta_f P_{des} s l_e^2}{f_\sigma \sigma_{yd}} \text{ cm}^3$$

Inertia:

$$I = \frac{100 c_I \delta_f P_{des} s l_e^2}{f_\sigma E} \text{ cm}^4$$

Web area:

$$A_w = \frac{c_A \delta_f P_{des} s l_e}{100 f_\tau \tau_o} \text{ cm}^2$$

where

δ_f is a structural element type factor and is 0,8 in general, for secondary stiffening members

δ_f factors are listed for specific structural items in Table 4.2.1

c_A, c_Z and c_I are coefficients defined in Fig. 4.2.1

f_σ, f_λ and f_δ are defined in Table 4.2.2

P_{des}, s, l_e ,σ_{yd}, τ_o and E are defined in Ch 1,1.3.1.

Fig. 4.2.1 Section modulus, inertia and web area coefficients for different load models

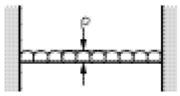
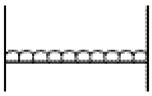
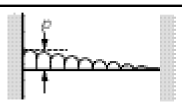
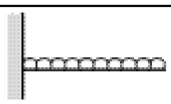
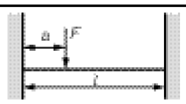
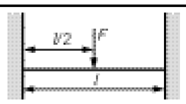
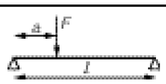
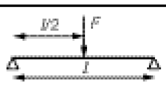
Load Model	Position (i): 1 End, 2 Midspan, 3 End	(i)	Web area coefficient C_A	Section modulus coefficient C_Z	Inertia coefficient C_I	Application
(A)		1	1/2	1/2	—	Primary and other members where the end fixity is considered encastre and the pressure is uniformly distributed
		2	—	- 1/24	1/384	
		3	1/2	1/12	—	
(B)		1	1/2	1/10	—	Local, secondary and other members where the end fixity is considered to be partial and the pressure is uniformly distributed
		2	—	- 1/10	1/288	
		3	1/2	1/10	—	
(C)		1	7/20	1/20	—	Fully fixed and the pressure is a linearly varying distribution
		2	—	—	1/764	
		3	3/20	1/30	—	
(D)		1	1	1/2	1/8	Cantilever and uniformly distributed pressure
		2	—	—	—	
		3	—	—	—	
(E)		1	1/2	—	—	Simply supported and uniformly distributed pressure
		2	—	- 1/10	5/384	
		3	1/2	—	—	
(F)		1	$\frac{(l-a)^2(l+2a)}{l^3}$	$\frac{a(l-a)^2}{l^3}$	—	Fully fixed and a single point load anywhere on the span
		2	—	$\frac{2a^2(l-a)^2}{l^4}$	$\frac{2a^3(l-a)^2}{3l^3(l+2a)^2}$	
		3	$\frac{a^2(3l-2a)}{l^3}$	$\frac{a^2(l-a)^2}{l^3}$	—	
(G)		1	1/2	1/8	—	Fully fixed and a single point load at the centre of the span
		2	—	- 1/8	1/192	
		3	1/2	1/8	—	
(H)		1	$\frac{(l-a)}{l}$	—	—	Simply supported and a single point load anywhere on the span
		2		$\frac{-a(l-a)^2}{l^2}$	$\frac{a}{3l^4}\left(\frac{l^2-a^2}{3}\right)^{3/2}$	
		3	$\frac{a}{l}$	—	—	
(J)		1	1/2	—	—	Simply supported and a single point load at the centre of the span
		2	—	- 1/4	1/48	
		3	1/2	—	—	

Table. 4.2.1 Stiffening type factors

Structural element	δ_f
Shell envelope	
Main hull bottom and bilge longitudinals Main hull side longitudinals Side hull bottom and bilge longitudinals Side hull side longitudinals	0,8
Main hull bottom transverse frames Main hull side frames Side hull bottom transverse frames Side hull side frames	0,8
Bottom girders Side stringers Floors Bottom transverse web frames Side transverse web frames	0,5
Wet deck	
Wet-deck longitudinals Wet deck transverse frames	0,8
Wet-deck transverse web frames Wet-deck girders	0,5
Weather and exposed decks	
Deck longitudinals Deck beams	0,8
Deck girders Deck transverses Deck deep beams	0,5
Inner bottom	
Inner bottom longitudinals	0,8
Inner bottom transverse frames	0,5

Table 4.2.2 Acceptance criteria

Structural item	Limiting criteria			
Longitudinally effective structure	Bending stress	Stiffener web shear stress	Stiffener deflection ratio	Buckling factor, Compressive stresses *See* Note 3
Stress descriptor	f_σ	f_τ	f_δ	λ_σ
Plating	*See* Note 5		*See* Note 1	
Main hull bottom shell	f_2	—	0,00125	1,0
Main hull side shell	f_2	—	0,00125	1,0
Side hull bottom shell	$0,9f_2$	—	0,00125	1,0
Side hull side shell	$0,9f_2$	—	0,00125	1,0
Wet-deck	$0,9f_2$	—	0,00125	1,0
Weather deck, outboard the line of openings	f_2	—	0,00100	1,0
Inner bottom	$1,4f_2$	—	0,00125	1,0
Secondary stiffeners			*See* Note 1	1,1
Main hull bottom and bilge	f_2	0,65	0,00125	1,1

longitudinals				
Main hull side longitudinals	f_2	0,65	0,00125	1,1
Side hull bottom and bilge longitudinals	f_2	0,65	0,00125	1,1
Side hull side longitudinals	f_2	0,65	0,00125	1,1
Wet-deck longitudinals	f_2	0,65	0,00125	1,1
Main hull bottom transverse frames	0,65	0,65	0,00125	1,1
Main hull side frames	0,65	0,65	0,00125	1,1
Side hull bottom transverse frames	0,65	0,65	0,00125	1,1
Side hull side frames	0,65	0,65	0,00125	1,1
Wet-deck transverse frames	0,65	0,65	0,00125	1,1
Weather deck longitudinals	f_2	0,65	0,00100	1,1
Weather deck beams	0,65	0,65	0,00100	1,1
Inner bottom longitudinals	f_2	0,65	0,00125	1,1
Primary stiffeners			*See* Note 2	
Single bottom girders	0,75	0,65	0,00100	1,0
Double bottom girders	0,75	0,80	0,00100	1,0
Side stringers	0,75	0,65	0,00100	1,0
Floors	0,75	0,65	0,00100	1,0
Bottom transverse web frames	0,65	0,65	0,00100	1,0
Side transverse web frames	0,65	0,65	0,00100	1,0
Wet-deck transverse web frames	0,65	0,65	0,00100	1,0
Wet-deck girders	0,75	0,65	0,00100	1,0
Deck transverses	0,75	0,65	0,00100	1,0
Deck deep beams	0,65	0,65	0,00100	1,0
Wet-deck transverse frames	0,65	0,65	0,00100	1,0
Weather deck girders	0,75	0,65	0,00100	1,0
Weather deck transverses	0,65	0,65	0,00100	1,0
Weather deck deep beams	0,65	0,65	0,00100	1,0

Symbols

f_2 is applicable to stiffeners and plating subjected to global hull girder bending stresses and local bending stresses and is to be taken as follows:

$$f_2 = 0,9\left(183 - \frac{\sigma_{hg}}{\sigma_a}\right)$$

but not greater than 0,95. Note that for initial design assessment f_2 may be taken as 0,75.

where

σ_{hg} is the stress due to hull girder bending in the appropriate structural item, *see* Ch 3,2.4.4

σ_a is the lower of

- allowable hull girder stress, σ_p, given in Ch 3,2.4.3
- $\frac{\sigma_{cr}}{\lambda_\sigma}$

λ_σ is the buckling factor for this item

σ_{cr} is the critical buckling stress, *see* Note 4.
NOTES *1.* Deflection ratio for secondary stiffeners, expressed as a ratio of the stiffener's span, i.e. $\delta \leq f_\delta$ x span where ☼ is the deflection *2.* Deflection ratio for secondary stiffeners, expressed as a ratio of the stiffener's span, i.e. $\delta \leq f_\delta$ x span where ☼ is the deflection *3.* Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses *4.* If the Complementary Rules are the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) then *see* Vol 1, Pt 6, Ch 2,4 of the Rules for Naval Ships. If the Complementary Rules are the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) then *see* Pt 3, Ch 4,7 of the Rules for Ships. If the Complementary *Rules are the Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft) then *see* Pt 6, Ch 7,4 of the Rules for Special Service Craft. *5.* If the Complementary Rules are the *Rules for Special Service Craft* then for bottom, bow and wet-deck slamming f_2 is to be taken as 0,85.

Section 3 Shell envelope

3.1 General

3.1.1. This Section contains local scantling requirements applicable to the shell envelope. Each applicable sub-Section is to be evaluated to determine the governing scantling requirement as follows:

- All shell envelope structure over the length of the ship is to be evaluated according to 3.2 and 3.3.
- All bottom structure in way of a single bottom is to be evaluated against the requirements of 3.4.
- All bottom structure in way of a double bottom is to be evaluated against the requirements of 3.5.
- Where applicable, bottom and side shell structure below the waterline is to be evaluated against the slamming requirements in 3.6.
- Side shell above the waterline is to be evaluated against the requirements of 3.7.

3.2 Requirements due to design pressures

3.2.1. The scantlings of plating and stiffeners on the shell envelope are to be determined from the general equations given in Section 2, using the design pressures calculated according to Pt 5, Ch 5,3.

3.3 Additional minimum requirements

3.3.1. In addition to complying with 3.1.1, scantling requirements are to be assessed according to 3.3.2 to 3.3.4.

3.3.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in:

- Pt 3, Ch 5 and Ch 6 of the Rules for Ships.
- Pt 4, Ch 1 of the Rules for Ships and the appropriate Chapter for the particular ship type.

3.3.3. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Vol 1, Pt 6, Ch 3 of the Rules for Naval Ships.

3.3.4. If the Complementary Rules are the Rules for Special Service Crafts then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Vol 1, Pt 6, Ch 3 of the Rules for Special Service Craft.

3.4 Single bottom

3.4.1. The requirements of this sub-Section are applicable to the bottom structure of vessels having a single bottom.

3.4.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in:

- Pt 3, Ch 5 and Ch 6 of the Rules for Ships,
- Pt 4, Ch 1 of the Rules for Ships and the Chapter appropriate for the ship type.

3.4.3. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 3, Ch 2,3.5 of the Rules for Naval Ships.

3.4.4. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Pt 6, Ch 4,5 of the Rules for Special Service Craft.

3.5 Double bottom

3.5.1. The requirements of this sub-Section are applicable to the bottom structure of vessels having a double bottom.

3.5.2. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 3, Ch 2,3.6 of the Rules for Naval Ships.

3.5.3. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in:

- Pt 3, Ch 5 and Ch 6 of the Rules for Ships.
- Pt 4, Ch 1 of the Rules for Ships and the Chapter appropriate for the ship type.

3.5.4. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Pt 6, Ch 4,6 of the Rules for Special Service Craft.

3.6 Strengthening due to bottom slamming

3.6.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 6, Ch 3,14 of the Rules for Naval Ships using the pressure, IP_{bi}, calculated according to Pt 5, Ch 5,2.4. Note that for calculation of h_s according to Vol 1, Pt 6, Ch 3,14.2.8 of the Rules for Naval Ships:

$$h_s = 0{,}1 f_{DLF}\, IP_{bi} \text{ m}$$

where

f_{DLF} is to be taken as 1,0.

3.6.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in Pt 3, Ch 5,1.5 of the Rules for Ships.

3.6.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are to be determined from the general equations given in Section 2, using the design pressures calculated according to Pt 5, Ch 5,2.5.

3.7 Slamming above the waterline

3.7.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 6, Ch 3,15 of the Rules for Naval Ships using the pressure, IP_{wi}, calculated according to Pt 5, Ch 5,2.5. Note that for calculation of h_s according to Vol 1, Pt 6, Ch 3,15.2.2 of the Rules for Naval Ships:

$$h_s = 0,1 f_{DLF} IP_{wi} \text{ m}$$

where

f_{DLF} is to be taken as 1,0.

3.7.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in Pt 3, Ch 5,1.6, Pt 4, Ch 2 and Pt 4, Ch 8 of the Rules for Ships, depending on the particular ship type, using the pressure, IP_{wi}, calculated according to Pt 5, Ch 5,2.5. Note that for calculation of h_s according to Pt 4, Ch 2 of the Rules for Ships:

$$h_s = 0,1 IP_{wi} \text{ m}$$

3.7.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are to be determined from the general equations given in Section 2, using the design pressures calculated according to Pt 5, Ch 5,2.5.

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Section 4 Wet-deck

4.1 General

4.1.1. This Section contains local scantling requirements applicable to the wet-deck. Each applicable sub-Section is to be evaluated to determine the governing scantling requirement as follows:

- All wet-deck structure is to be evaluated according to 4.2 and 4.3.
- Where applicable, wet-deck structure above the waterline is to be evaluated against the requirements of 4.4.

4.2 Requirements due to design pressures

4.2.1. The scantlings of plating and stiffeners on the wet-deck are to be determined from the general equations given in Section 2, using the design pressures calculated according to Pt 5, Ch 5,4.

4.3 Additional minimum requirements

4.3.1. The scantlings of plating and stiffeners are not to be less than those required for the main hull side shell, as in 3.3.

4.4 Slamming above the waterline

4.4.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 6, Ch 3,15 of the Rules for Naval Ships using the pressure, IP_{wi}, calculated according to Pt 5, Ch 5,4.3. Note that for calculation of h_s according to Vol 1, Pt 6, Ch 3,15.2.2 of the Rules for Naval Ships, f_{DLF} is to be taken as 1,0.

4.4.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in Pt 3, Ch 5,1.6, Pt 4, Ch 2 and Pt 4, Ch 8 of the Rules for Ships depending on the particular ship type, using the pressure, IP_{wi}, calculated according to Pt 5, Ch 5,2.5.

4.4.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Section 2 using the pressure calculated according to Pt 5, Ch 5,2.5.

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Section 5 Weather deck

5.1 General

5.1.1. This Section contains local scantling requirements applicable to the weather-deck. All weather deck structure is to be evaluated according to 5.2 and 5.3.

5.2 Requirements due to design pressures

5.2.1. The scantlings of plating and stiffeners on the weather deck are to be determined from the general equations given in Section 2, using the design pressures calculated according to Pt 5, Ch 5,5.1.

5.3 Additional minimum requirements

5.3.1. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in

- Pt 3, Ch 5 and Ch 6 of the Rules for Ships.
- Pt 4, Ch 1 of the Rules for Ships and the appropriate Chapter for the particular ship type.

5.3.2. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Vol. 1, Pt 6, Ch 3, of the Rules for Naval Ships.

5.3.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Pt 6, Ch 3 of the Rules for Special Service Craft.

Section 6 Inner bottom

6.1 General

6.1.1. This Section contains local scantling requirements applicable to the inner bottom. All inner bottom structure is to be evaluated according to 6.2 and 6.3.

6.2 Scantlings

6.2.1. The scantlings of plating and stiffeners on the inner bottom are to be determined from the general equations given in Section 2, using the design pressures calculated according to Pt 5, Ch 5,6.1.

6.3 Additional minimum requirements

6.3.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Vol 1, Pt 6, Ch 3 of the Rules for Naval Ships.

6.3.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in:

- Pt 3, Ch 5 and Ch 6 of the Rules for Ships
- Pt 4, Ch 1 of the Rules for Ships and the appropriate Chapter for the particular ship type.

6.3.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Pt 6, Ch 3 of the Rules for Special Service Craft.

Section 7 Internal decks

7.1 General

7.1.1. This Section contains local scantling requirements applicable to the internal decks. All internal decks are to be evaluated according to 7.2.

7.2 Minimum requirements

7.2.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are to be in accordance with Vol 1, Pt 3, Ch 2,3.7 of the Rules for Naval Ships.

7.2.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are to be in accordance with Pt 4, Ch 1,9 of the Rules for Ships.

7.2.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are to be in accordance with Pt 4, Ch 1,9 of the Rules for Ships.

Section 8 Bulkheads and deep tanks

8.1 General

8.1.1. This Section contains local scantling requirements applicable to bulkheads and deep tanks. All bulkheads and deep tanks are to be evaluated according to 8.2.

8.2 Minimum requirements

8.2.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are to be in accordance with Vol 1, Pt 3, Ch 2,4.1 of the Rules for Naval Ships.

8.2.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are to be in accordance with Pt 4, Ch 1,9 of the Rules for Ships.

8.2.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are to be in accordance with Pt 6, Ch 3,7 of the Rules for Special Service Craft.

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Section 9 Deckhouses, bulwarks and superstructures

9.1 General

9.1.1. This Section contains local scantling requirements applicable to deckhouses, bulwarks and superstructures. All deckhouses, bulwarks and superstructures are to be evaluated according to 9.2.

9.2 Minimum requirements

9.2.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 3, Ch 2,7 of the Rules for Naval Ships.

9.2.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in Pt 3, Ch 8 of the Rules for Ships.

9.2.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Table 3.2.1 in Pt 6, Ch 3 of the Rules for Special Service Craft.

Section 10 Other structure

10.1 General

10.1.1. This Section contains local scantling requirements applicable to other local structure as given in 10.2 and 10.3.

10.2 Pillars and pillar bulkheads

10.2.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of pillars are to be in accordance with the requirements of Vol 1, Pt 3, Ch 2,8 of the Rules for Naval Ships.

10.2.2. If the Complementary Rules are the Rules for Ships then the scantlings of pillars are to be in accordance with the requirements of Pt 4, Ch 1,4.4 of the Rules for Ships and the appropriate Chapter for the particular ship type.

10.2.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of pillars are to be in accordance with the requirements of Pt 6, Ch 4,9 of the Rules for Special Service Craft.

10.3 Machinery and raft seating

10.3.1. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 3, Ch 2,6 of the Rules for Naval Ships.

10.3.2. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in Pt 3, Ch 7 of the Rules for Ships.

10.3.3. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Pt 6, Ch 4,5 of the Rules for Special Service Craft.

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Section 11 Ice strengthening

11.1 General

11.1.1. This Section contains local scantling requirements for ice strengthening.

11.1.2. If the Complementary Rules are the Rules for Naval Ships then the scantlings of plating and stiffeners are not to be less than those given in Vol 1, Pt 5, Ch 3,7 of the Rules for Naval Ships.

11.1.3. If the Complementary Rules are the Rules for Ships then the scantlings of plating and stiffeners are not to be less than those given in Pt 3, Ch 9 of the Rules for Ships.

11.1.4. If the Complementary Rules are the Rules for Special Service Craft then the scantlings of plating and stiffeners are not to be less than those given in Pt 6, Ch 5,7 of the Rules for Special Service Craft.

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Volume 2 Machinery and Engineering Systems

Part 1 Direct Calculation Procedure

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Chapter 1 Introduction

Section 1 General

1.1 Contents

1.1.1. This part of the Rules contains the following:

- Structural strength analysis and verification, *see*Chapter 2.
- Load development procedure, *see* Chapter 3.

1.1.2. Chapter 2 provides techniques for applying the global loads which are specified in previous Parts of the Rules. Chapter 2 also describes appropriate boundary conditions and specifies acceptance criteria by which the analysis is to be assessed.

1.1.3. After identifying high stress local areas in the global analysis, Chapter 2 then provides information on modelling, loading and analysis of local details.

1.1.4. Chapter 3 provides an alternative procedure for developing loads to that of the Rule loads. The load development procedure can be based on either theoretical analysis or experimental techniques using model experiments.

(a). Theoretical analysis involves derivation of response to regular waves using a hydrodynamic program, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states.

(b). Experimental techniques involve conduct of model experiments in a hydrodynamic test facility to arrive at long-term response predictions using statistical distributions of seastates.

1.1.5. Analysis according to the procedure outlined in Chapter 3 will result in a pressure distribution and inertial loads being calculated for each global load case.

1.1.6. The flow diagram depicted in Fig. 1.1.1 gives an overview of the Direct Calculation Procedure.

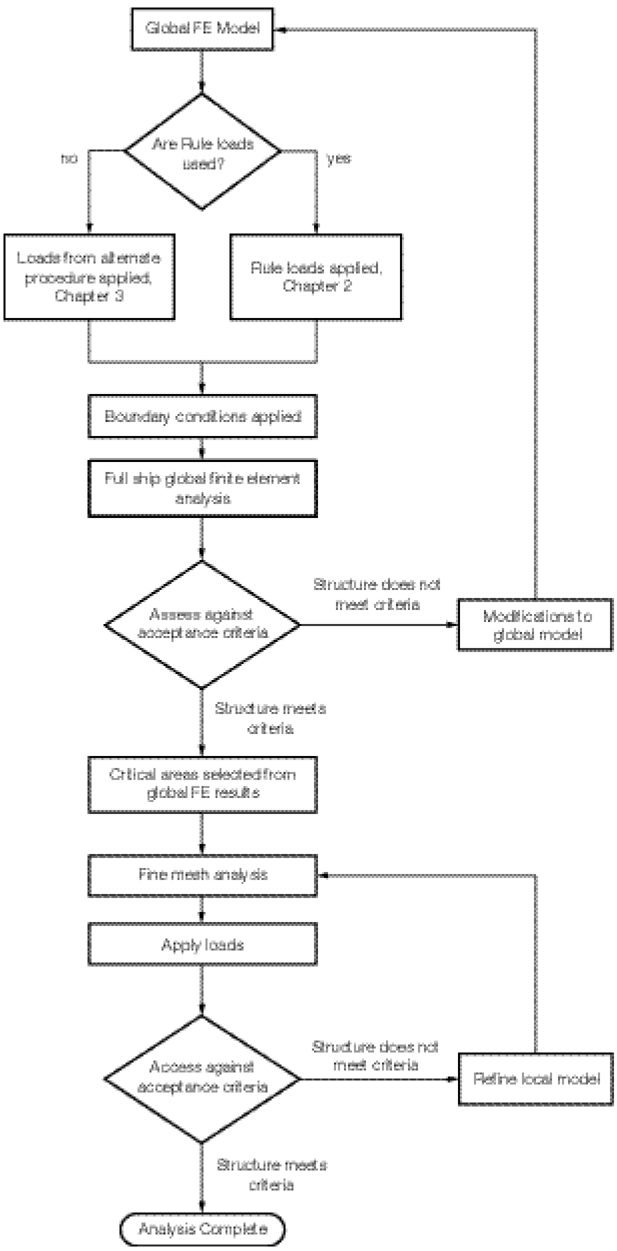

Fig. 1.1.1 Direct Calculation Procedure flow diagram

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Section 2 Application

2.1 General

2.1.1. The Structural Strength Analysis and Verification procedure given in Chapter 2 is mandatory for all Trimarans. This procedure requires the following:

- A detailed analysis of the ship's structural response to specified load scenarios using finite element analysis.
- Other direct calculations as applicable.

2.1.2. The loads developed according to the procedure in Chapter 3 may be used instead of the global Rule loads given in Chapter 2.

2.1.3. Full details of the procedures to be adopted are to be submitted and agreed with LR, prior to commencement of any analysis.

2.1.4. The responsibility for error free specification and input of program data and the subsequent correct interpretation of output rests with the Designer/Builder.

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Section 3 List of symbols

3.1 Symbols

3.1.1. The following symbols are to be used in this Part of the Rules:

M_h = horizontal wave bending moment, in kN-m

M_{lt} = longitudinal torsional moment, in kN-m

M_{sph} = splitting moment in hog, in kN-m

M_{sps} = splitting moment in sag, in kN-m

M_{swh} = still water bending moment in hog, in kN-m

M_{sws} = still water bending moment in sag, in kN-m

M_{tt} = transverse torsional moment, in kN-m

M_{wh} = vertical wave bending moment in hog, in kN-m

M_{ws} = vertical wave bending moment in sag, in kN-m

V_{cr} = cruising speed, in knots

δ_x = displacement in the x-direction, in metres

δ_y = displacement in the y-direction, in metres

δ_z = displacement in the z-direction, in metres

θ_{max} = maximum roll angle, in degrees

σ = direct longitudinal stress, in N/mm^2

σ_{cr} = elastic critical buckling stress, in N/mm^2

σ_{crp} = critical buckling stress corrected for plasticity effects, in N/mm^2

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

σ_{vm} = Von Mises stress, in N/mm^2

τ = shear stress, in N/mm^2.

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Chapter 2 Structural Strength Analysis and Verification

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Section 1 General

1.1 Application

1.1.1. The direct calculation of the ship's structural response is to be based on a three-dimensional (3-D) plate finite element analysis carried out in accordance with this Chapter. Where alternate procedures are proposed, these are to be agreed with LR before commencement.

1.1.2. A detailed report of the calculations is to be submitted and must include the information listed in 1.2. The report must demonstrate compliance with this procedure.

1.1.3. LR may, in certain circumstances, require the submission of computer input and output to further verify the adequacy of the calculations carried out.

1.1.4. It is recommended that the designer discuss the requirements with LR at an early stage of the design phase.

1.2 Global strength analysis and verification report

1.2.1. A report is to be submitted to LR for approval of the global hull structure of the ship and is to contain:

(a). Lists of plans used, including dates and versions;

(b). Detailed descriptions of structural model, including all modelling assumptions;

(c). Plots to demonstrate correct structural modelling and assigned properties;

(d). Details of material properties used;

(e). Details of all boundary conditions;

(f). Details of all loading conditions applied including calculated still water shear force (SF) and bending moment (BM) distributions, *see* also 3.3;

(g). Details of applied loadings and confirmation that individual and total applied loads are correct;

(h). Details of boundary support forces and moments;

(j). Plots and results that demonstrate the correct behaviour of the ship structural models to the applied loads;

(k). Summaries and sufficient plots of global and local deflections;

(l). Summaries and sufficient plots of von Mises, directional and shear stresses to demonstrate that the design criteria contained in this procedure has not been exceeded in any member and to demonstrate that the model behaviour is correct;

(m). Plate buckling analysis and results;

(n). Pillar buckling analysis and results, if applicable;

(o). Tabulated results showing compliance, or otherwise, with the design criteria; and

(p). Proposed amendments to structure where necessary, including revised assessment of stresses and buckling capabilities.

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Section 2 Structural modelling

2.1 Global model

2.1.1. A 3-D plate element model of the ship is to be used. This model should extend over the full length, breadth and depth of the ship. In some cases, a half breadth model may be used with the appropriate symmetrical boundary conditions. However, to simplify the loading and boundary conditions, it is recommended that a full breadth model be used.

2.1.2. The scantlings to be modelled are to be in accordance with those required by the Rules, as well as those required by the Complementary Rules. If the Complementary Rules are the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) or the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft), then these scantlings are 'net' scantlings. If the Complementary Rules are the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), the required scantlings are 'gross' scantlings. Any additional thicknesses added due to the Enhanced Scantlings notation are not to be modelled.

2.1.3. The model should represent, with reasonable accuracy, the actual geometric shape of the hull. All effective longitudinal material is to be included. Similarly, all transverse primary structure, i.e. web frames, watertight and fire divisional bulkheads are to be represented in the model. The superstructure should also be included in the model.

2.1.4. The FE model is to be represented using a right handed Cartesian co-ordinate system, depicted in Fig. 2.3.1, where:

(a). x is measured in the longitudinal direction, positive forward from the aft perpendicular

(b). y is measured in the transverse direction, positive to port from the centreline

(c). z is measured in the vertical direction, positive upward from the baseline

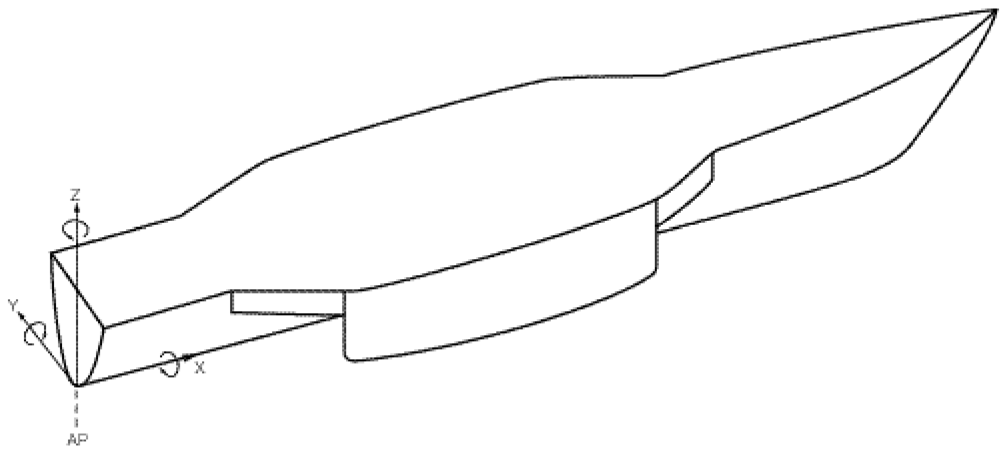

Fig. 2.3.1 FE Co-ordinate system

2.1.5. The size and type of plate elements selected are to provide a satisfactory representation of the deflection and stress distribution within the ship's structure. In general, the plate element mesh is to follow the primary stiffening. Typically, the following guidelines are applicable:

(a). Longitudinally, one element between web frames or intermediate floors, if applicable;

(b). Vertically, two elements between decks, stringers, or every second or third stiffener, whichever is the smaller distance;

(c). Transversely, at least two elements spanning the cross-deck structure and elsewhere, sufficient elements to maintain a satisfactory panel aspect ratio.

2.1.6. Plate elements are to have an aspect ratio less than 3, particularly in areas of interest in the model.

2.1.7. All primary structure, such as deck plating, bottom and side shell plating, longitudinal and transverse bulkhead plating, transverse floors, superstructure blocks, deckhouse blocks and internal structural walls are to be represented by plate elements. Primary girders, deep beams, web frames, etc. are to be represented by at least three elements through the depth of the member in areas of interest.

2.1.8. In areas where local fine mesh analysis is potentially required, as specified in 2.2.1, the structure in way of this area is to be adequately represented.

2.1.9. Secondary stiffening members may be modelled using line elements having axial and bending stiffness (bars).

These elements may be grouped as necessary at the plate boundaries.

2.1.10. Pillars are to be represented by line elements having axial and bending stiffness.

2.1.11. Shell openings, deck openings, door openings and window openings of a significant size are to be represented in the model such that the deformation pattern under hull torsion, shear and bending loads is adequately represented in way of critical areas.

2.1.12. The model is to accurately reflect shell and superstructure side recesses, sweep brackets and superstructure breaks. The basic mesh, as described in 2.1.5 may need to be further refined in order to include these features.

2.2 Local models

2.2.1. In general, detailed stress analysis is to be carried out in the following locations, *see* also 1.1.4:

(a). The connections of the side hull to the ends of the cross-deck structure.

(b). The connections of the centre hull to the ends of the cross-deck structure.

(c). The transverse bulkhead where the highest shear stresses has been identified from the global load cases.

(d). Areas with discontinuities in structure such as in way of openings or at the termination points of major structure.

(e). After reviewing the results from the global load cases, areas in way of high stress gradients and areas exceeding the stress criteria specified in Table 2.5.1.

Table 2.5.1 Stress acceptance criteria permissible stresses

	Permissible stresses		
	σ_{vm}	σ	τ
Global model, coarse mesh	$0{,}9\sigma_{yd}$	$0{,}75\sigma_{yd}$	$0{,}35_{\sigma yd}$
Fine mesh models, individual element stresses	$1{,}2\sigma_{yd}$	—	—
Fine mesh models, average stress	1,0σyd	—	—

NOTES

1. σ_{vm}, σ, τ and σ_{yd} are defined in Ch 1,3.1.

2. σ, τ, are to be taken as membrane stresses.

3. σ_{vm} is to be calculated based on the membrane shear and direct stresses of the plate element.

4. Average von Mises stress is to be calculated as the average of the von Mises stresses from the element being assessed and the elements connected to its boundary nodes. Averaging is not to be carried across structural discontinuity and abutting structure.

2.2.2. Evaluation of detailed stresses requires the use of refined finite element mesh density in way of areas of high stress.

2.2.3. The extent of the local finite element model is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to coincide with main supporting structural members.

2.2.4. The mesh size in the fine mesh regions is not to be greater than 100 mm x 100 mm. A finer mesh size, such as 50 mm x 50 mm, may be required dependent on vessel size and the detail being considered. The extent of the fine mesh region is to be in general not less than 10 elements in all directions from the area under investigation. A smooth transition of mesh density is to be maintained.

2.2.5. The structural geometry, particularly in areas of concern is to be accurately represented.

Section 3 Load cases

3.1 General

3.1.1. The standard load cases, given in Table 2.3.1, are to be considered. The purpose of these load cases is to ensure that the longitudinal, transverse and shear strength of the hull structure complies with the acceptance criteria given in Section 5.

Table 2.3.1 Load combinations

Wave direction	Load cases	Load components (*see* Note 1)									
		A. M_{swh}	B. M_{sws}	C. M_{wh}	D. M_{ws}	E. M_{h}	F. M_{sph}	G. M_{sps}	H. M_{lt}	I. M_{tt}	J. θ_{max}
	(1)	1,0	—	1,0	—	—	0,3	—	—	- 0,2	—
Head Seas	(2)	—	1,0	—	1,0	—	—	0,3	—	- 0,2	—
	(3)	1,0	—	0,1	—	—	1,0	—	0,2	—	—
Beam Seas	(4)	—	1,0	—	0,1	—	—	1,0	0,2	—	—
Oblique Seas	(5)	(see Note 2)		—	—	- 0,3	0,4	—	1,0	0,3	—
	(6)	(see Note 2)		—	—	1,0	0,4	—	—	0.2	—
	(7)	1,0	—	—	0,2	- 0,2	0,6	—	—	1,0	—
	(8)	—	1,0	—	—	—	—	—	—	—	1,0

NOTES

1. For each load case the load components give the proportion of the Rule moments to be applied. All moments should be positive.

2. The still water bending moment to be used is that which results in the highest stress for the load case under consideration.

3.1.2. Loads are to be applied as described in this Section or alternatively, as derived according to Chapter 3.

3.2 Load cases – Global model

3.2.1. The load cases, 1–8, as described in Table 2.3.1, are to be comprised of the proportion of global load components as indicated. In each load case, one of the load components is maximised. The load components may be combined by superposition.

3.2.2. The load cases in Table 2.3.1 are applicable only if the Rule loads are being used. If the loads are derived based on a 'first principle' approach, then the load cases described in Chapter 3 are to be used.

3.3 Load cases – Local model

3.3.1. In general, all load cases specified in Table 2.3.1 are to be investigated to identify areas that require local fine mesh analysis.

3.3.2. The fine mesh analysis can be carried out by means of separate local finite element models, in conjunction with the boundary conditions obtained from the global coarse mesh model. Alternatively, fine mesh zones may be incorporated into the global coarse mesh model.

3.3.3. Where appropriate, secondary loads such as pressure loads are to be applied in conjunction with the boundary displacements obtained from the global model.

3.4 Component A – Still water loads, hog - Component B – Still water loads, sag

3.4.1. The still water loads are to be applied to the global finite element model regardless of whether Rule loads are being applied or loads calculated by direct calculation.

3.4.2. Hog and sag still water load cases are to be analysed fulfilling the following criteria:

(a). Ship upright and at or near to the maximum draught.

(b). The still water bending moment cases are to approximate, as far as is possible, the assigned, or specified, permissible still water bending moment condition distributions. It may only be necessary to include one loading condition; if there is not a large variation in the deadweight distribution.

3.4.3. The following still water loads are to be included:

(a). **Self weight** – as generated from the modelled hull structure, suitably factored to achieve the specified steel weight, including the position of the LCG. In this respect, it may be useful to divide the model longitudinally into a number of material zones, each of which can have a separate factored value for the steel density.

(b). **Machinery, outfit and other equipment** – all major items to be applied as point loads or pressure loads at the correct locations. Minor or unknown items may be included in the steel weight.

(c). **Buoyancy loads** – to be applied as pressure loads , ρ_{gh}, on wetted shell elements, where *h* is the distance of the element centroid below the still waterline.

(d). **Ballast and fuel oil** – to be applied as pressure loads on tank boundaries, based on the actual liquid head and density.

(e). **Containers** – vertical point loads to be applied at each corner of the stack base, whether above or below deck.

(f). **Cargo, payload, passengers or vehicles** – as point loads, uniformly distributed loads or pressure loads at the correct locations.

3.5 Component C – Vertical wave bending moment, hog - Component D – Vertical wave bending moment, sag

3.5.1. The vertical wave bending moment load cases are to be applied by using a static wave balance program. Separate cases are required for the hog and sag conditions. Each case is comprised of a wave with the following properties:

(a). A wavelength equal to LBP

(b). A wave crest amidships for the hogging condition and a wave trough amidships for the sagging condition

(c). A sinusoidal wave profile

(d). A wave height sufficient to induce the Rule hogging or sagging design vertical wave bending moment (VWBM) amidships, as given in Pt 5, Ch 4,2.4.

3.5.2. The wave height required to induce the required bending moment will need to be derived by trial and error using a suitable longitudinal strength program. The ship is to be balanced on the wave and the resulting draught, trim and wave parameters are to be used for determination of external pressure distribution. This wave is to be determined for both the hog and sag condition.

3.5.3. The pressure values to be applied should not include the pressure component or buoyancy loads due to the still water condition.

3.6 Component E – Horizontal wave bending moment

3.6.1. The Rule horizontal bending moment distribution, as described in Fig. 2.3.4, is to be modelled by applying longitudinal force pairs at each transverse bulkhead position in the plane of the side shell. These loads are to be distributed longitudinally along the depth of the side hull structure or of the centre hull structure at the forward and aft ends where the side hull structure has terminated. When integrated along the ship length, the incremental moment couples are to generate the Rule horizontal wave bending moment distribution specified in Vol 1, Pt 5, Ch 4,2.6.

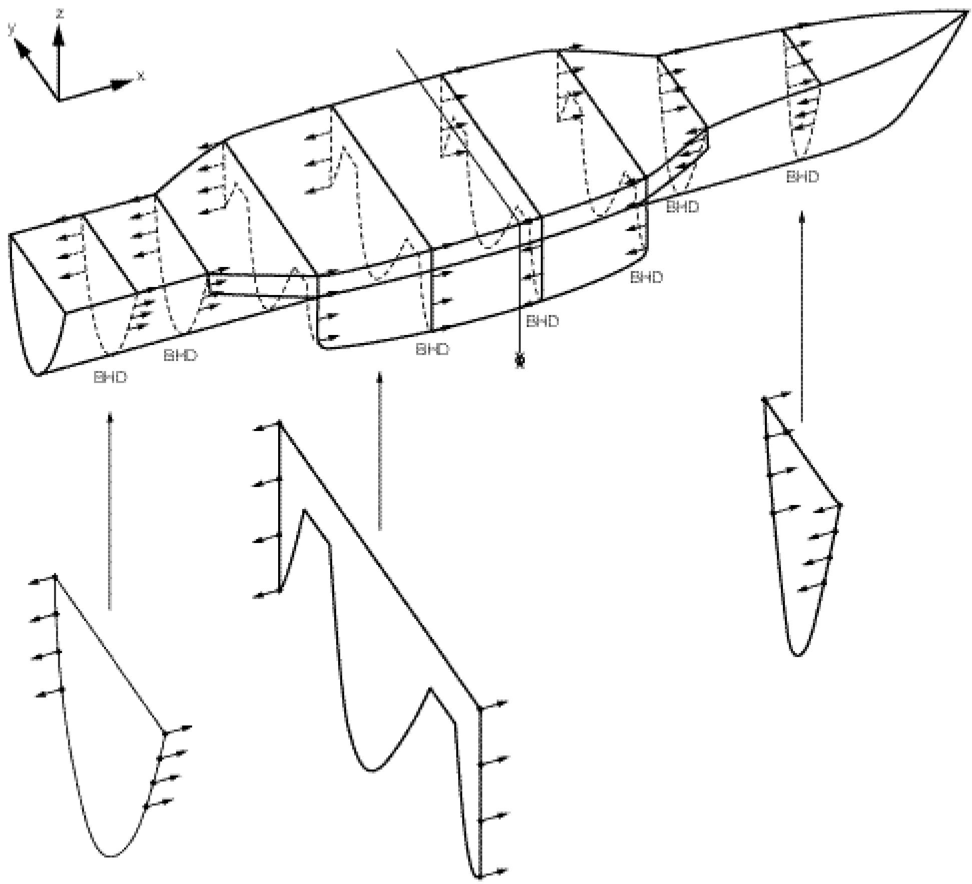

Fig.2.3.4 Horizontal wave moment distribution

3.6.2. The horizontal bending moment couples are to be calculated in the same manner as described in 3.8.3 for the longitudinal torsional moment.

3.7 Component F – Splitting moment, hog - Component G – Splitting moment sag

3.7.1. The splitting moment occurs when the waves force the side hulls away from (sag) or towards (hog) the centre hull, resulting in stresses in the cross-deck structure.

3.7.2. The splitting moment may be achieved by applying simplified line loads, in the directions depicted in Fig. 2.3.2 for hog and Fig. 2.3.3 for sag, at the following locations:

(a). A line load is to be applied vertically on the length of the keel of each of the side hulls.

(b). A line load is also to be applied transversely, near the keel in way of supporting structure, along the length of the outboard side of both side hulls.

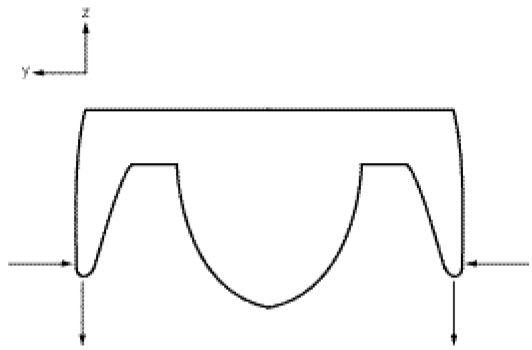

Fig. 2.3.2 Splitting moment, hog

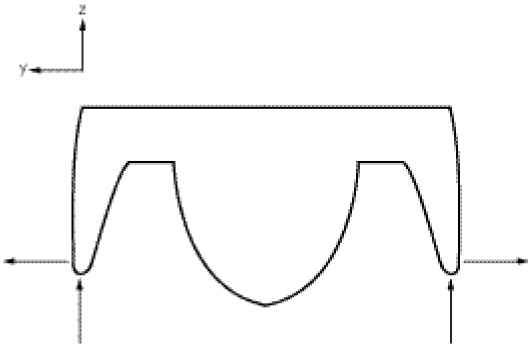

Fig. 2.3.3 Splitting moment, sag

3.7.3. The magnitude of the distributed loads should be determined so that the resulting splitting moment distribution along the cross-deck is equal to that specified in Vol 1, Pt 5, Ch 4,3.1.

3.7.4. Alternatively, uniformly distributed loads may be applied to the side hulls in order to achieve the Rule splitting moment distribution. In the sag case, these loads would act on the inside of the side hulls and in the case of the hog would act on the outside of the side hulls. The loads would consist of a hydrostatic head, as well as a dynamic component sufficient to generate the Rule splitting moment value.

3.8 Component H – Longitudinal torsional moment

3.8.1. The Rule torsional moment distribution, as specified in Vol 1, Pt 5, Ch 4,2.7, is to be applied as depicted in Fig. 2.3.5 and is to be modelled by applying a torsional moment at each transverse bulkhead position. This results in a stepwise torsional distribution, as depicted in Fig. 2.3.7.

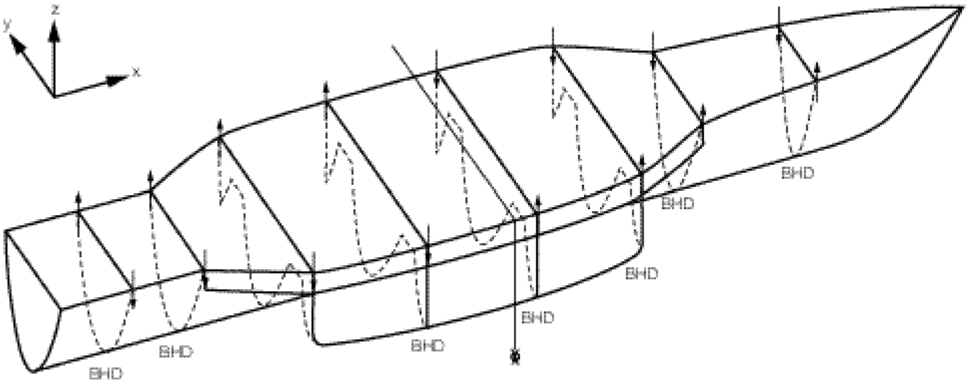

Fig. 2.3.5 Longitudinal torsional moment distribution

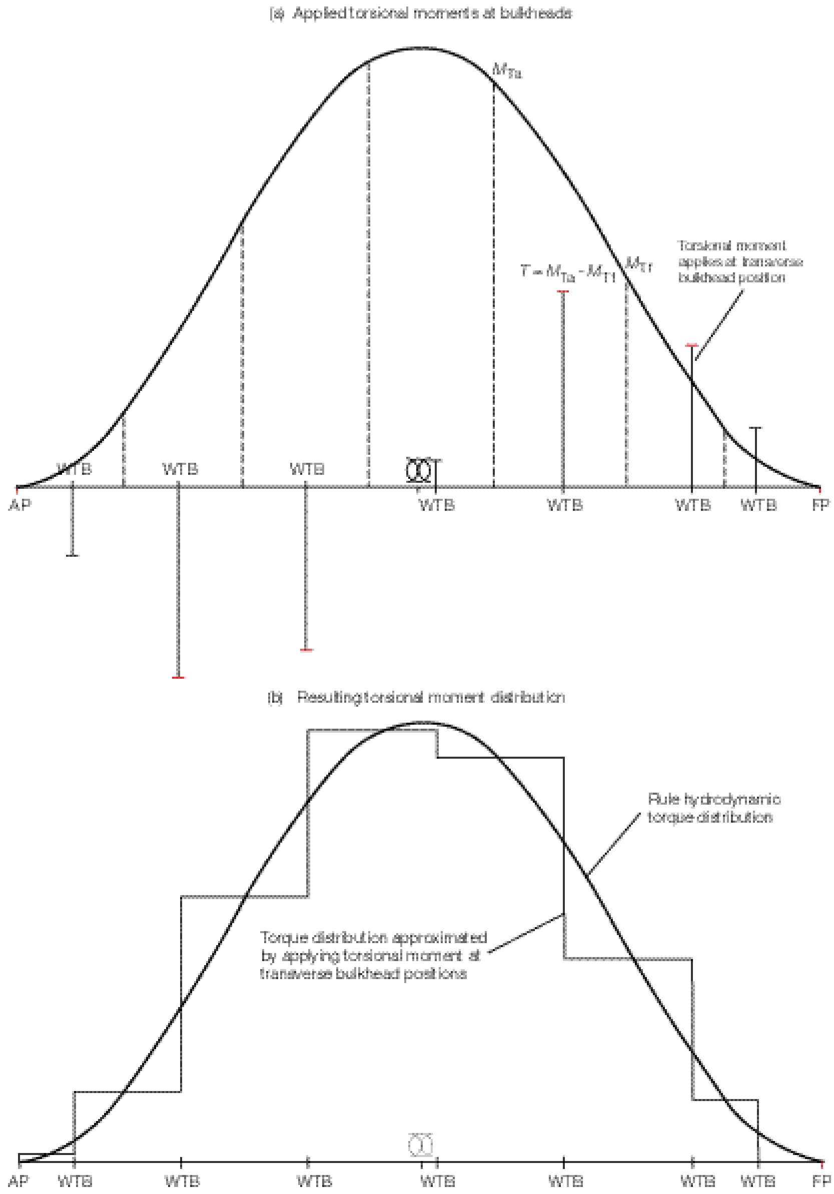

Fig. 2.3.7 Application of Rule hydrodynamic torque distribution to FE model

3.8.2. The moment is to be applied as a distributed force couple on all nodes in the 'vertical' portion of the bulkhead where it intercepts the side shell.

3.8.3. The torsional moment, *T*, required at each bulkhead position can be calculated from:

$$T = M_{Ta} - M_{Tf}$$

where

> M_{Tf} is the Rule torsional moment value midway between the bulkhead under consideration and the next bulkhead forward
>
> M_{Ta} is the Rule torsional moment value mid-way between the bulkhead under consideration and the next bulkhead aft.

3.8.4. Other proposed methods of modelling the Rule hydrodynamic torque distribution will be specially considered.

3.9 Component I – Transverse torsional moment

3.9.1. The torsional moment about the transverse axis is to be applied as depicted in Fig. 2.3.6. The magnitude of the distributed loads should be determined so that the resulting torsional moment is equal to that specified in Vol 1, Pt 5, Ch 4,3.3.

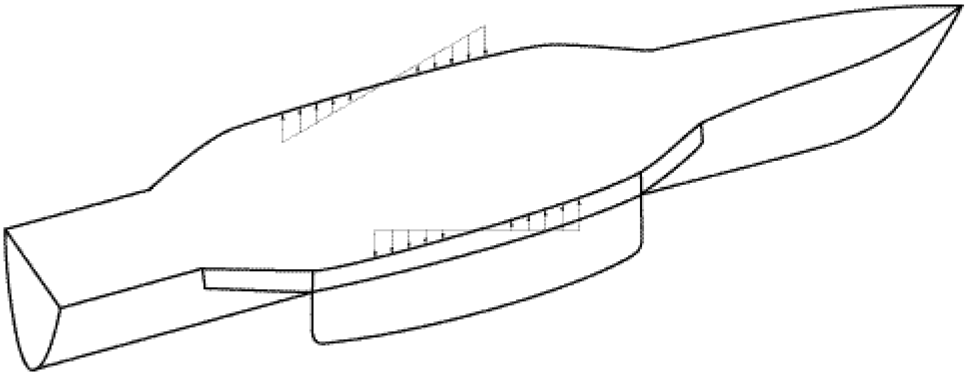

Fig. 2.3.6 Transverse torsional moment

3.10 Component J – Maximum roll

3.10.1. A static roll angle of 30° is to be applied to the model. The draft and trim are to be adjusted in order to balance the hydrostatic loads and the displacement. Still water loads are to be included in this load case. All loads subject to gravity are to be resolved into their correct components given the heeled position of the ship.

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Section 4 Boundary conditions

4.1 General

4.1.1. The load cases specified in Section 3 are to use the boundary conditions described in 4.2.

4.1.2. The boundary conditions described in this Section are preferred. However, alternative equivalent boundary conditions may be used.

4.1.3. Care is to be taken that, within practicable limits, there is no net imbalance of load or moment in any of the six degrees of freedom.

4.1.4. If spring type restraints are used, spring stiffnesses are to be small, equivalent to 10 N/m.

4.1.5. Care is to be taken to ensure that the FE model is not over constrained.

4.1.6. These boundary conditions are also applicable to the loads calculated using the load calculation procedure in Chapter 3.

4.2 Application

4.2.1. All load cases are to have the boundary conditions described in Table 2.4.1 and Fig. 2.4.1.

Table 2.4.1 Boundary conditions for all load cases

Location	Boundary conditions
At or near the neutral axis at the forward and aft ends of the ship	$\delta_z = 0$
At a bulkhead near to the mid-length of the ship: At a point on the deck and a point on the keel	$\delta_y = 0$

At the keel of each of the side hulls	$\delta_x = 0$

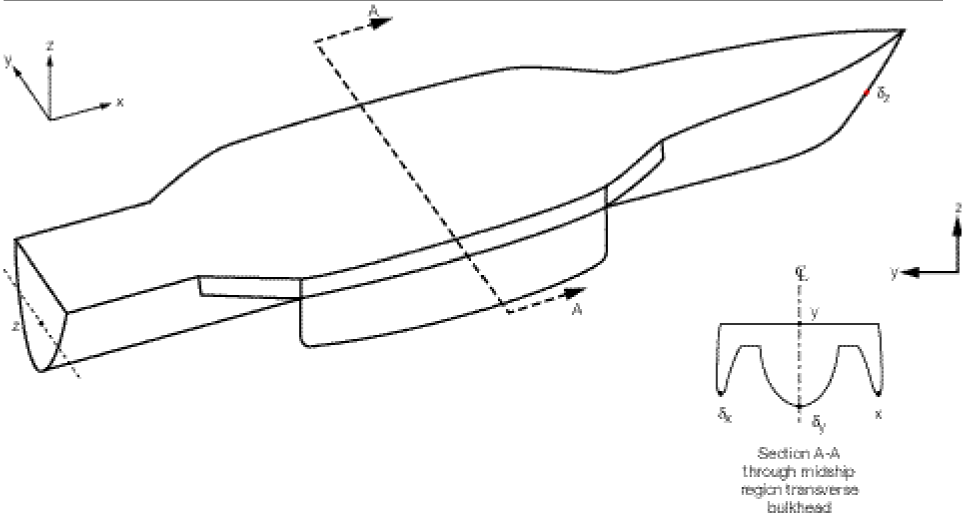

Fig. 2.4.1 Boundary conditions for all load cases

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Section 5 Acceptance criteria

5.1 General

5.1.1. The global structure must comply with the acceptance criteria described in this Section.

5.2 Stress

5.2.1. The stress acceptance criteria given in Table 2.5.1 apply to all of the combined load cases described in Table 2.3.1, for all structure.

5.3 Buckling

5.3.1. A minimum factor against buckling, λ, of 1.1 is to be achieved for the cross-deck structure and cross-tank structure (bulkheads and web frames). All other structure is to have a minimum factor λ_2 of 1.0. In addition, all structure is to comply with the buckling requirements described in the Complementary Rules.

5.3.2. Panel buckling calculations are to be based on the proposed thickness reduced by the standard thickness deduction for corrosion given in Table 2.5.2.

Table 2.5.2 Stress acceptance criteria

Structural item	Complementary Rule Set	
	Ship	NSR/SSC
Boundaries and internal structure of tanks	1	0
Bottom shell and side shell not in way of tanks Other internal structures (except the boundaries of tanks) Exposed decks protected by sheathing or protective coatings	0	0

5.3.3. The combined interaction of bi-axial compressive stresses, shear stresses and 'in plane' bending stresses are to be included in the buckling calculation. In general, the average stresses acting within the plate panel are to be used for the buckling calculation.

5.3.4. The factors against buckling are to be derived using the computer program LR Buckle (ShipRight IS) or program *Buckling of lat rectangular plate panels* (ShipRight Direct Calculation program no. 10403) or equivalent.

5.3.5. In calculating the factors against buckling, the edge restraint factor may be taken into account in calculating the critical buckling stress of wide panels subjected to compressive loading on the long edge of the panel. The edge restraint factor is not to be used in the calculation of the critical buckling stress for compression applied on the short edges. The edge restraint factor is defined in the Complementary Rules as follows:

. Rules for Ships: ‘C’ defined in Pt 3, Ch 4,7.

. Rules for Special Service Craft: ‘C’ defined in Vol 1, Pt 6, Ch 7,4.

. Rules for Naval Ships: ‘C’ defined in Table 2.4.1 in Vol 1, Pt 6, Ch 2.

5.3.6. When the calculated elastic critical buckling stress exceeds 50 per cent of the specified minimum yield stress then the buckling stress is to be adjusted for the effects of plasticity using the Johnson-Ostenfeld correction formula, given below:

$$\sigma_{crp} = \sigma_{yd} 1 - \frac{\sigma_{yd}}{4\sigma_{cr}}$$

where

σ_{crp}, σ_{yd} and σ_{cr} are defined in Pt 1, Ch 3,1.

Chapter 3 Load Development

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Section 1 General

1.1 Introduction

1.1.1. This Chapter explains the alternative procedure for load development. This procedure provides more realistic loading scenarios, improving the user’s confidence in the loads which are to be applied to the finite element model.

1.1.2. This Chapter provides guidance on:

(a). A method to derive the design loads using direct calculation techniques. These loads may be used instead of the Rule loads in all aspects of structural assessment provided that the proposed loads are submitted and approved by LR.

(b). A method to apply the Rule load value or direct calculation load value to the finite element analysis.

1.1.3. Design loads are to be determined (i) theoretically by using a suitable hydrodynamic program and/or (ii) experimentally through model tests.

(a). The theoretical procedure for developing wave-induced design loads acting on the structure by a ‘first principles’ approach is specified in Section 2.

(b). Details of the model experiments required to be carried out are specified in Section 3. Results from full scale measurements may also be acceptable.

1.1.4. Application of design loads for structural analysis and verification is to be carried out as follows:

(a). Each design load value is to be applied to the structural analysis by the application of a characteristic regular wave which is associated with a particular ship speed, heading, specific height *H* and frequency ω determined using this procedure.

(b). The corresponding external pressures and inertial loads of the characteristic regular wave calculated at a particular time instant are to be derived and applied to the FE model to generate the design value.

1.1.5. Fig. 3.1.1 provides an overview of the steps of the load calculation procedure, as described in this Chapter.

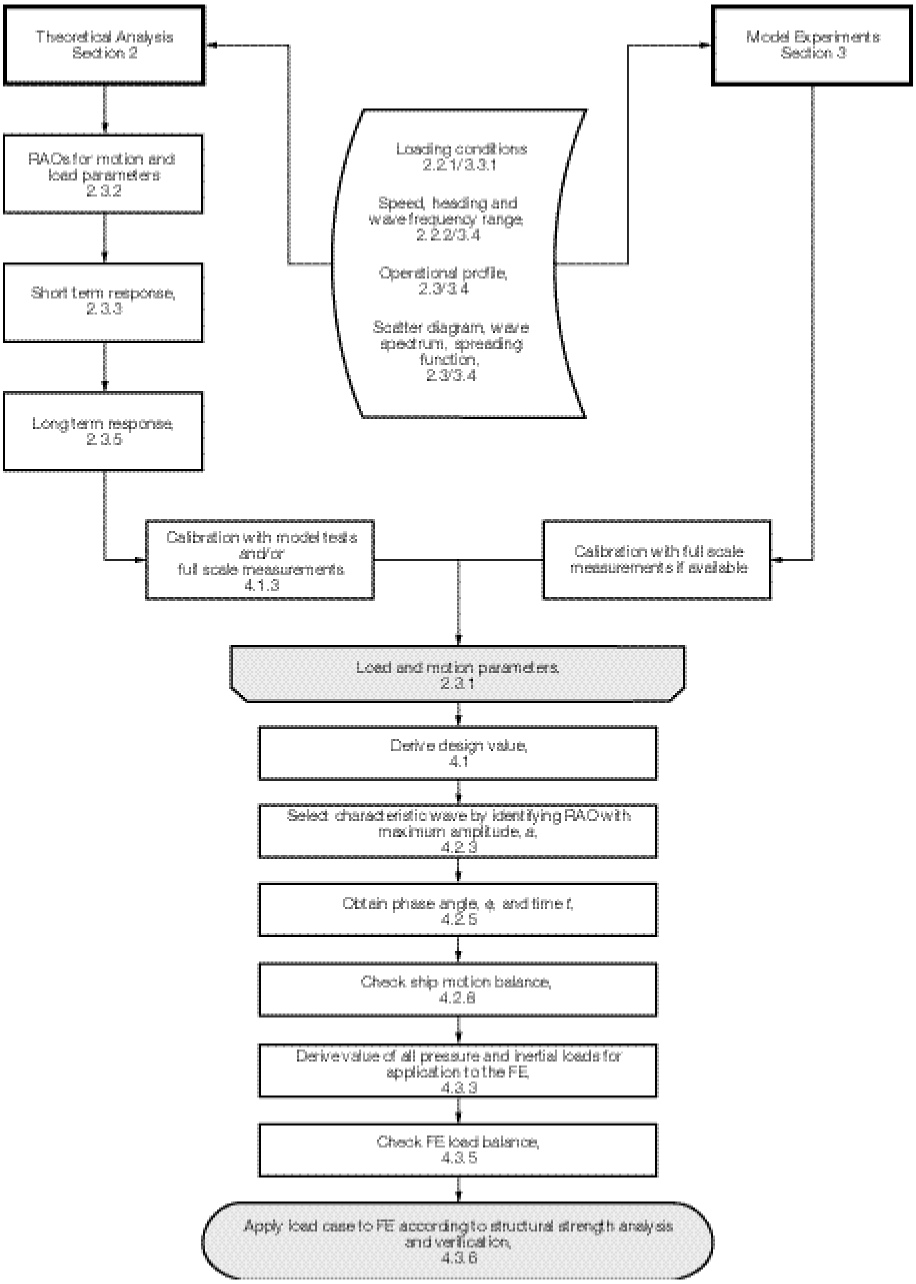

Fig. 3.1.1 Load development procedure

1.1.6. Full details of the scope of the analysis and the procedures to be adopted are to be submitted and agreed with LR prior to commencement of any analysis.

Section 2 Theoretical analysis

2.1 General

2.1.1. The determination of dynamic loads is to be based on theoretical analysis of ship load and motions and a long term prediction method.

2.1.2. Hydrodynamic analysis is to be undertaken to determine the long term values of the main load and motion parameters. The ship load and motion analysis will provide the phase relationship between each load component to be applied to the FE model.

2.1.3. The necessary level of complexity of the hydrodynamic software and its validation procedure is to be agreed upon with LR.

2.2 Input requirements

2.2.1. It is likely that only one sailing condition will need to be evaluated for the Trimaran. However, if other sailing conditions exist where there is a large variation of draft, trim, VCG, GM or distribution of cargo or deadweight, then additional conditions may need to be evaluated.

2.2.2. It is suggested that the following range of data is used in the program:

- **Ship speeds** – For calculation of long term values in high sea states, analysis is to be based on a manoeuvring speed of 5 knots. For ships operating at higher speeds in high sea states, speeds should be selected that are representative of this operational range, i.e. 75 per cent and 100 per cent of full service speed. However, speed selection should consider the operational limitations of the vessel in the selected sea state.
- **Ship headings** – The motion and load responses should be determined for at least every 30 degree from head to stern seas.
- **Wave frequencies** – The range and interval of wave frequencies should cover the complete spectrum of wave energy. The required frequency range is 0,25 radians to 1,5 radians in 0,05 increments.

2.3 Load and motion parameters

2.3.1. The long term response values are to be evaluated for the following load and motion parameters:

(a). Vertical wave bending moment (Hog and Sag);

(b). Horizontal wave bending moment;

(c). Longitudinal torsional moment;

(d). Transverse torsional moment;

(e). Splitting moment in cross-deck structure (Hog and Sag);

(f). Vertical shear force in hull;

(g). Splitting shear force in cross-deck structure;

(h). Maximum roll angle.

2.3.2. Response Amplitude Operators (RAO) are to be generated in regular waves for all load and motion parameters specified in 2.3.1 for each heading/ship speed combination.

2.3.3. A suitable wave energy spectrum is to be applied to the RAOs of each load and motion parameter to calculate the short term response.

2.3.4. In analysing the response data, the short crested option is to be used with a Cos^2 spreading function.

2.3.5. The long term responses for each load and motion parameter are to be derived using the appropriate wave scatter diagram and target design values.

2.3.6. Information about appropriate wave energy spectra and wave scatter diagrams may be obtained from IACS Resolution 34. The sea area considered to produce the worst operating environment is the North Atlantic. Acceptable wave spectra for the North Atlantic sea area include the Pierson- Moskovitz or Bretschneider spectra.

2.3.7. It is to be assumed that the ship has equal probability of encountering waves from all directions. Weighted headings based on the operational profile may only be used if the results are more conservative than the assumption of equal probability of all headings.

2.3.8. When evaluating the long term response, the operating life is generally to be taken as 20 years, which is assumed to correspond to 10^8 wave encounters or a long term probability level of 10^{-8}.

2.4 Submission of load calculations

2.4.1. The following supporting information is to be submitted, as applicable:

(a). Reference to the technical program used and an outline of the load calculation procedure adopted.

(b). Input data.

(c). A summary of analysis parameters including environmental conditions, speeds and headings.

(d). Details of weight distributions.

(e). A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

(f). Verification and validation of the target design values.

2.4.2. Documentation of adequate validation may be required for software used for derivations of loads.

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Section 3 Model experiments

3.1 General

3.1.1. Model experiments should generally follow the procedures recommended by the ITTC (International Towing Tank Conference) for conduct of sea keeping tests to accurately predict the motions, accelerations and structural loads on the vessel.

3.2 Model and data collection requirement

3.2.1. Model scale should be at least 1:50 and its size such that it avoids test tank wall interference. Weight distribution along both the longitudinal and transverse directions of the model must be reproduced as correctly as possible to measure the global loads like vertical and transverse bending moments, torsion loads and shear forces with reasonable accuracy. Model construction should consider scaling of bending stiffness as and where applicable to enable accurate measurement of hydro-elasticity dependent loads or suitable corrections may be incorporated in the analysis of measurements.

3.2.2. The measured data during model tests in waves should be obtained for sufficiently large number of wave encounters, especially in the case of irregular seas to enable reasonably reliable and accurate results.

3.2.3. The data sampling frequency should be sufficiently high, especially for the measurement of loads induced by impact or structural vibration, to enable the dynamic property of the loads be recorded reasonably accurately.

3.3 Loading conditions

3.3.1. Loading conditions to be chosen for model tests are as specified in 2.2.1.

3.4 Model test conditions

3.4.1. The sea area considered to produce the worst operating environment for a vessel in unrestricted service is the North Atlantic. The most onerous wave conditions in the North Atlantic with a return period of 20 years are generally to be used. The wave data and spectrum are as specified by IACS Recommendation 34. The most onerous wave conditions, which are often presented as wave contour, are shown in Fig. 3.4.1.

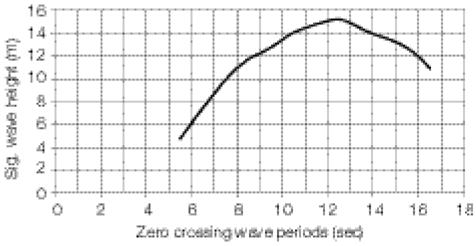

Fig. 3.4.1 North Atlantic Wave Contours in 20 years return period

3.4.2. For a vessel in restricted service, the testing wave conditions are to be determined from the wave data of the specified service area. A prior approval of the wave data by LR is required.

3.4.3. The minimum model test matrix which is required to be carried out is given in Table 3.4.1 to consist of the following.

Table 3.4.1 Minimum model test matrix

Item	Test matrix
Speed	Three speeds: Including a manoeuvring speed of 5 knots, 75% and 100% of full service speed
Heading	Five headings: Including head, bow quartering, beam, stern quartering and stern seas
Sea State	Sufficient number of sea states in terms of H_s and T_z combination, in order to catch the maximum motion and loading components as specified in 3.5.2

3.4.4. Selection of the speed should consider operation limitation of the vessel in the selected testing sea state with agreement of LR. In beam, stern quartering and stern seas, the testing sea states can be reduced to the most onerous wave conditions with return period of 1 year in the North Atlantic, or in the specified service area if the vessel is in restricted service.

3.4.5. The theoretical analysis can be used to select critical conditions to reduce the scope of model tests.

3.5 Parameters to be measured

3.5.1. The basis on which the parameters are chosen for investigation is to be submitted for approval at the earliest opportunity.

3.5.2. In addition to those quantities which are normally measured in a model experiment, the following data are to be obtained where practicable:

(a). Motions;

(b). Accelerations at:

Bow – 10 per cent of LPP aft of FP

CG – (depends on the condition tested)

Stern – 10 per cent of LPP forward of AP;

(c). Global loads: as given in 2.3.1(a) to (g);

(d). Local loads at bow and wet deck.

3.5.3. Measurement of hull motions should preferably be non-intrusive to avoid the effect of instrumentation on the body motions. Measurement of the encountered waves are more desirable than that of the stationary waves, and non-intrusive method of measurement should be preferred to avoid water run-up on the forward side and ventilation of the back side of the wave probes.

3.5.4. Range, natural frequency, frequency response and linearity of the accelerometers are to be included when reporting acceleration data apart from their sampling rate.

3.5.5. Segmented models are to be used to measure the global loads like, bending and torsion moments, shear forces in hull and cross deck structure or hydro elastic effects like springing and whipping.

(a). Segmented model is to be built in a number of stiff segments connected with force transducers. The side-hulls and the connection between the side-hulls (bridging structure) should also be segmented and joined with force transducers, in the same manner as for the main hull girder. Stiffness in connections must be enough either (i) to ensure no effect of flexibility or (ii) to give correct eigenfrequencies depending on whether a stiff or hydroelastic model will be applied.

(b). A model purely for motion response measurement requires only global mass property to be represented, including mass, centre of gravity and radii of inertia.

(c). A model for load measurement is constructed by modelling both the global mass property and mass distribution as accurately as practicable. Location and number of cuts in the model are to be determined such that they are able to measure the most critical load components and the loads at the critical structural locations.

(d). A hydroelastic model requires modelling the structural properties of the full scale vessel (bending stiffness, eigenfrequencies and eigenmodes) also.

3.5.6. Measurement of local loads should preferably be based on both the point pressures and also forces on a sensibly chosen area on the vessel. Measurements on panels with scaled ‘dimensions and flexural properties’ or with suitable corrections are recommended compared to the point pressure measurements:

(a). For measurement of local loads on bow and wet deck, hydroelasticity of the local plating is to be correctly modelled or suitable corrections to be incorpo

(b). Location of transducers, diameter of the sensor face, the range, frequency response and linearity of the transducer are to be reported.

(c). Measurements should indicate sampling rates, rise time for the experiment data collection system. Generally sampling rates in the order of ‘kHz’ would be required.

(d). Motions and velocities at bow and under wet deck relative to incoming wave crest are to be measured also. They can then be used as basis to analyse or verify the impact pressures based on either dropping test results or theoretical analysis approved by LR.

3.5.7. Test duration for each irregular sea state should be not less than 3 hours in full scale time to determine the critical motions, accelerations and global loads, and six hours for the critical local loads. It is recommended to repeat the most critical test cases for each response to improve reliability of the measured data.

3.6 Data processing and statistical analysis

3.6.1. Appropriate steps are to be taken to ensure the unwanted noises due to instruments or model vibrations be removed from the measured raw data, and the high frequency components, that do not induce local or global structural responses, due to wave impacts be filtered out.

3.6.2. The processed data are to be analysed by appropriate statistic model as agreed by LR, to establish the best statistic fits to the measured responses in critical sea states versus the probability of occurrence.

3.7 Details to be submitted

3.7.1. The following details are to be submitted:

(a). A summary of the model details including its size, weight distribution and construction.

(b). A summary of the testing arrangements and procedures.

(c). A summary of the tank facilities and test equipment.

(d). Details of the different instrumentation used during testing and their calibration including calibration procedures.

(e). Details of the wave/sea state generation, measurements of waves, responses and loads, definitions and notations.

(f). Details of data acquisition, reduction and analysis procedures.

(g). Tabulated and plotted output.

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Section 4 Target design values

4.1 Design value

4.1.1. In general, the target design value is to be taken as the extreme value in the most onerous conditions as specified in 3.4.1. This value may be used instead of the Rule based value in the structural analysis.

4.1.2. The design value is to be derived from the extreme values for each load and motion parameter, *see* 2.3.1.

4.1.3. The design values obtained through theoretical analysis may need to be adjusted or calibrated to take account of scale issues, non-linearities, etc. This comparison or validation data is to include results from model tests, full scale tests or ship motion analyses of similar size or shape ships. All calibration factors and methods are to be agreed with LR prior to further work being undertaken.

4.1.4. The design values obtained from the model tests are to be determined at an appropriate probability level as agreed by LR based on the statistic fitting for each load and motion parameter as stated in 3.5.2.

4.2 Equivalent design wave

4.2.1. Having established the magnitude of the target design values, it is then necessary to determine an appropriate wave condition which will result in the target design value and then may be applied to the FE model. This wave condition is referred to as the characteristic wave and is to be derived as follows.

4.2.2. RAOs for all relevant speeds and headings are to be reviewed and the RAO, for a particular speed/heading combination, with the maximum response for the specified load or motion parameter is identified.

4.2.3. The peak of this selected RAO curve then provides the encounter frequency, ω_e, and the peak amplitude, *a*, of the required characteristic wave.

4.2.4. The wave height, *h*, required to obtain the specified load or motion parameter is given by:

$$h = \frac{P}{a}$$

where

a = peak amplitude of the RAO curve

P = required design value of load or motion parameter.

4.2.5. The characteristic regular wave is given by the following equation:

$$\varsigma = h\cos(\omega_e t)$$

The corresponding maximised motion response is

$$y = ah\cos(\omega_e t + \phi)$$

where

t = time (seconds)

φ = phase angle of the RAO

ω_e = encounter frequency (radians)

a and *h* are as defined in 4.2.4.

4.2.6. The time instant at which the maximum response occurs is when the cosine response is maximum or minimum as appropriate, hence,

$$\cos(\omega_e t - \varphi) = 1 \text{ or } -1$$

4.2.7. The instantaneous responses of all other load and motion parameters are to be derived at the time instant given by 4.2.6.

4.2.8. The summation of all dynamic pressures and inertial loads acting on the ship at this time instant, as calculated in the ship motion program, are to be checked to ensure reasonable balance is obtained in all global degrees of freedom.

4.3 Load application to the finite element model

4.3.1. The load cases to be applied and assessed are as follows:

(a). Maximum vertical wave bending moment in hog;

(b). Maximum vertical wave bending moment in sag;

(c). Maximum horizontal wave bending moment;

(d). Maximum longitudinal torsional moment;

(e). Maximum transverse torsional moment;

(f). Maximum sagging splitting moment in cross-deck structure;

(g). Maximum hogging splitting moment in cross-deck structure;

(h). Maximum wave shear force in hull;

(j). Maximum splitting shear force in cross-deck structure;

(k). Maximum roll angle.

4.3.2. For cases (a) through (j), the still water loads are to be applied in addition to the pressure and inertial loads. The still water loads are included in case (k).

4.3.3. From the evaluation of the RAOs, there is now a set of characteristic cosine waves for each load parameter with a phase relationship which is unique for each maximised parameter. An appropriate program may be used to convert this information into pressure and inertial loads for application to the structural model.

4.3.4. The pressure and inertial loads are to be applied to the finite element model. All inertial loads are to be applied to both deadweight and lightweight items in the FE model. These loads are dynamic loads. The still water loads, as described in Chapter 2, will also need to be applied to the structural model. It is recommended that this is done as a separate load case and the two load cases are added together using the principle of superposition.

4.3.5. The loads applied to the structural model are also to be checked for reasonable balance in all degrees of freedom.

4.3.6. Alternatively, the loads may be applied to the FE model using sinusoidal analysis techniques where the RAOs are considered to be represented by complex numbers.