GUIDANCE NOTES
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ISClass

INTERNATIONAL SHIP CLASSIFICATION

Guidelines for Small Waterplane Area Twin Hull Craft

2005

CONTENTS

CHAPTER 1 GENERAL

Section 1 General Provisions

1.1.1 Application

1.1.1.1 The Guidelines are applicable to the following small waterplane area twin hull craft for civil use:

(1) High speed small waterplane area twin hull craft—the maximum speed V equal to or exceeding $\nabla^{0.1667}$ m/s;

(2) Non-high-speed small waterplane area twin hull craft—not satisfying (1) above, and with maximum speed limitation $V < 30$ kn, without regard to the hydrodynamic lift produced by the hull and its characteristics in the design.

where: V — speed achieved at the maximum continuous propulsion power for which the craft is certified at maximum operational weight and in smooth water;

∇ — displacement corresponding to the design waterline, in m^3.

1.1.1.2 High speed small waterplane area twin hull craft is to be in accordance with the relevant provisions of high speed small waterplane area twin hull craft in the Guidelines.

1.1.1.3 Non-high-speed small waterplane area twin hull craft is to be in accordance with the relevant provisions of non-high-speed small waterplane area twin hull craft in the Guidelines.

1.1.1.4 Those not covered in the Guidelines are applicable to both high speed small waterplane area twin hull craft and non-high-speed small waterplane area twin hull craft.

1.1.1.5 The statutory requirements for small waterplane area twin hull craft, such as fire fighting, life saving, stability, pollution prevention, etc., are to be in compliance with the corresponding provisions by the Administration of the Flag State.

1.1.2 Equivalent and exemption

1.1.2.1 Unless specified otherwise, equivalent to or substitution for those as required in the Guidelines, such as methods of calculation, criteria of evaluation, manufacturing procedure, materials, surveys and testing methods, etc., may be accepted, subject to agreement of ISC, when necessary tests, theoretical basis or service experience are provided, or recognized valid standards are available.

1.1.2.2 By agreement, ISC may accept the internationally recognized standards as the substitution for those as required in the Guidelines.

1.1.2.3 Where, in machinery arrangement, it is difficult for the relevant provisions of ISC Rules for Construction and Classification of Sea-Going High Speed Craft or ISC Rules for Classification of Sea-Going Steel Ships to be complied with due to the restricted character of a craft (such as shape and dimension, etc.), other arrangement as reviewed and considered equivalent by ISC may be adopted.

1.1.3 Class Notations

1.1.3.1 Each high speed small waterplane area twin hull craft intending to apply for ISC class may be affixed with type notation “SWATH-HSC (Small Waterplane Area Twin Hull HSC)” to its characters of classification.

1.1.3.2 Each non-high-speed small waterplane area twin hull craft intending to apply for ISC class may be affixed with type notation “SWATH (Small Waterplane Area Twin Hull)” to its characters of classification.

1.1.4 Definitions

1.1.4.1 Small waterplane area twin hull（SWATH）craft means double hull craft with narrow linear section of the hulls at waterline in order to improve sea-keeping ability and reduce wave-making resistance. The main body of the craft is composed of the two demi-hulls connected by cross-deck, either of which includes upper hull, vertical struts and lower hulls. A diagram of typical transverse section of small waterplane area twin hull craft is shown in Figure 1.1.4.1.

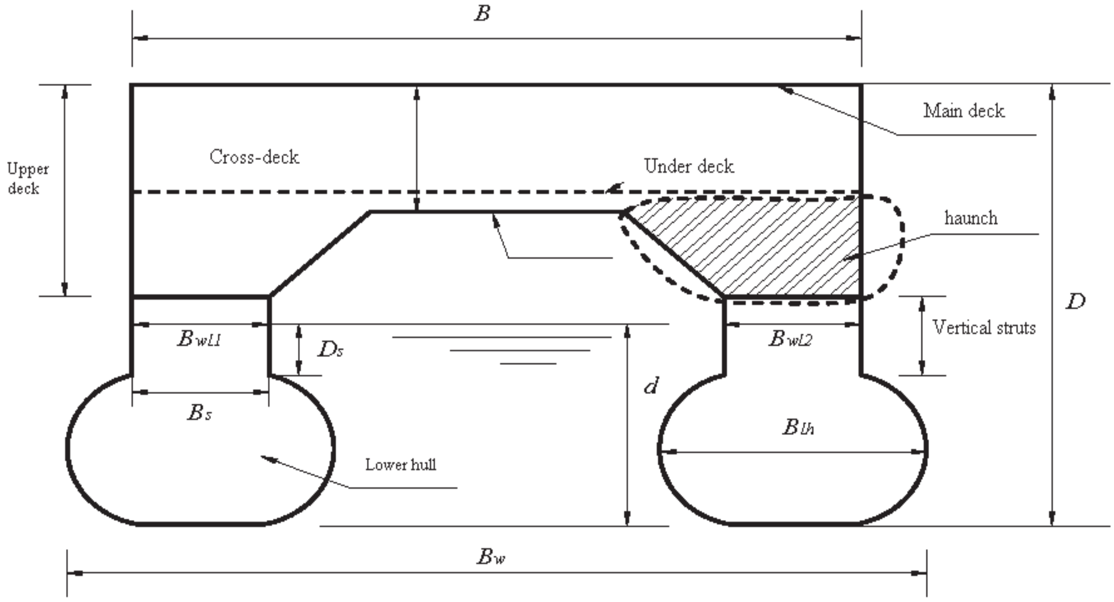

Figure 1.1.4.1 Typical Transverse Section

1.1.4.2 Cross-deck means the deck and other accessory heavy (box-like) structure that spans the port and starboard sets of struts.

1.1.4.3 Wet deck means the lower most plated surface of the cross structure.

1.1.4.4 Upper hull means the structure from main deck to vertical struts.

1.1.4.5 Haunch means the transitional area connecting cross-deck and vertical struts in the upper hull structure.

1.1.4.6 Vertical struts mean long and narrow vertical streamlined structural members that extends from the lower hulls to the haunch or cross-deck at design waterline, whose section of waterline is flat and thin. There are various forms of vertical struts, which may be one or two struts associated with each lower hull.
1.1.4.7 Lower hull means round or oval torpedo-like structure positioned at the base of vertical struts submerged in water.
1.1.4.8 Length L (m):
(1) For high speed small waterplane area twin hull craft, it means the overall length of the underwater watertight envelope of the rigid hull, excluding appendages at or below the design waterline in the displacement mode with no lift or propulsion machinery active.
(2) For non-high-speed small waterplane area twin hull craft, it means the length measured along summer load line from the leading edge of the foremost vertical strut to the trailing edge of the aftermost vertical strut, plus 50% of difference between the length of lower hull from forward to end and the overall length of the underwater watertight envelope of the rigid hull (excluding appendages at or below the design waterline).
1.1.4.9 Length in way of waterline L_w (m) means the longitudinal distance from fore edge to aft edge measured at the design waterline in the displacement mode with no lift or propulsion machinery active.
1.1.4.10 Length of vertical struts in way of waterline l_s (m) means the maximum length of vertical struts measured along the design waterline in the displacement mode with no lift or propulsion machinery active. For the vertical struts arranged independently at forward part and at after part, it means the sum of length of each vertical strut at the same direction from the forward part to the after part of a demi-hull.
1.1.4.11 Length of lower hull l_{lh} (m) means the horizontal length measured from the fore edge to end edge of an individual lower hull. Where there are more than one lower hulls in a demi-hull, the length means the accumulated length.
1.1.4.12 Breadth B (m) means breadth of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages at or below the design waterline in the displacement mode with no lift or propulsion machinery active.
1.1.4.13 Maximum breadth below waterline B_w (m) means the maximum moulded breadth measured below design waterline in the displacement mode with no lift or propulsion machinery active.
1.1.4.14 Waterline breadth B_{wl} (m) means the sum of maximum moulded breadth measured from the design waterline with no lift or propulsion machinery, $B_{wl} = \sum_{i=1}^{2} B_{wli}$, see Figure 1.1.4.1.
1.1.4.15 Breadth B_{lh} (m) of lower hull means the maximum moulded breadth of one lower hull.
1.1.4.16 Breadth B_s (m) of vertical struts means the maximum moulded width of one vertical strut.
1.1.4.17 Moulded depth D (m) means the vertical distance measured from the lowest point in way of longitudinal centerplane of the lower hull of a demi-hull to the top of the freeboard deck beam at side.

1.1.4.18 Depth D_s (m) of vertical struts below waterline means the vertical distance at midship measured from waterplane to the intersection line of lower hull and vertical struts shell.
1.1.4.19 Design draught d (m) means the moulded draught of the rigid waterline hull at midship measured along the design waterline with no lift or propulsion machinery active.
1.1.4.20 Full load displacement Δ (t) means the weight of sea water displaced by a craft with no lift or propulsion machinery active under a full loaded departure condition, usually equal to the maximum operational weight.
1.1.4.21 Waterplane coefficient C_{wp} mean the coefficient calculated according to the following:

$$C_{WP}=\frac{\sum_{i}^{n} A_{w1_i}}{\sum_{i}^{n} l_{s1_i} B_{w1_i}}$$

where: A_{W1_i} — waterline area of No.i vertical strut in a demi-hull cut along design waterline, in m^2;

l_{s1_i} — the maximum length of No.i vertical strut in a demi-hull measured along design waterline, in m;

B_{wl1_i} — the maximum moulded breadth of No.i vertical strut in a demi-hull measured along design waterline, in m.

Where independent vertical struts are provided at forward and after part of a demi-hull, i.e., $n \geq 2$, A_{W1_i} and the rectangular area surrounded by l_{s1_i} and B_{wl1_i} are to be included in the sum of a demi-hull according to the formula.

Section 2 Survey

1.2.1 General requirements

1.2.1.1 High speed small waterplane area twin hull craft applying for ISC survey is to be surveyed in accordance with the relevant provisions of ISC Rules for Construction and Classification of Sea-Going High Speed Craft and of the Guidelines, while non-high-speed small waterplane area twin hull craft applying for ISC survey is to be surveyed in accordance with the relevant provisions of ISC Rules for Classification of Sea-Going Steel Ships (the same as below) and of the Guidelines.

1.2.2 Examination of plans of newbuildings and survey during construction

1.2.2.1 For newbuildings, in addition to the plans and documents to be submitted as specified in ISC Rules for Construction and Classification of Sea-Going High Speed Craft or ISC Rules for Classification of Sea-Going Steel Ships, the following plans are to be submitted to ISC in triplicate for examination:
(1) verification data for stability model test of longitudinal movement /stability calculations of longitudinal movement (to be noted);

(2) calculations of hull structure rules (to be noted);
(3) direct calculations of hull structures (to be approved);
(4) fatigue assessment (to be noted).

1.2.2.2 For survey during construction, the survey and test are to be carried out in accordance with the relevant provisions of Section 3, Chapter 3 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft or of Chapter 3, PART ONE of ISC Rules for Classification of Sea-Going Steel Ships, and in addition, attention is to be paid to hull deformation.

1.2.3 Initial survey of existing craft

1.2.3.1 Existing small waterplane area twin hull craft not constructed under the survey of ISC are to be surveyed according to the requirements of Section 5, Chapter 3 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft or Section 3, Chapter 3, PART ONE of ISC Rules for Classification of Sea-Going Steel Ships, as appropriate, and additionally:
(1) to be assessed according to the submitted plans required by 1.2.2.1 of this Chapter;
(2) to be surveyed according to the special survey requirements in 1.2.4 of this Chapter.

1.2.4 Survey after construction

1.2.4.1 Survey after construction is to be carried out according to the requirements of Section 4, Chapter 3 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft or Chapter 4, PART ONE of ISC Rules for Classification of Sea-Going Steel Ships.

1.2.4.2 During annual survey, in addition to complying with the relevant provisions in Section 4, Chapter 3 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft or Chapter 4, PART ONE of ISC Rules for Classification of Sea-Going Steel Ships, corrosion, damage or other defects in the areas of vertical struts, wet deck structure and haunch structure above waterline are to be inspected and confirmed to be in good condition.

1.2.4.3 During special survey, in addition to complying with the relevant provisions in Section 4, Chapter 3 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft or Chapter 4, PART ONE of ISC Rules for Classification of Sea-Going Steel Ships, the following are to be inspected:
(1) corrosion, damage or other defects in the areas of lower hull, vertical struts, wet deck structure and haunch structure, and the structure is to be confirmed in good condition;
(2) corrosion, damage or other defects in haunch structure area and the structure at the connection of vertical struts and lower hull, and the structure is to be confirmed in good condition.

CHAPTER 2　PRINCIPLE OF STRUCTURAL DESIGN

Section 1　General Provisions

2.1.1　General requirements

2.1.1.1　The requirements of this Chapter are applicable to the small waterplane area twin hull craft specified in Chapter 1. Those not specified in this Chapter are to comply with the relevant provisions of ISC Rules for Construction and Classification of Sea-going High Speed Craft with regard to the high speed small waterplane area twin hull craft and ISC Rules for Classification of Sea-Going Steel Ships with regard to the non-high-speed small waterplane area twin hull craft.

2.1.1.2　For craft operating in restricted service and in designated routes, the relevant requirements in the Guidelines may be reduced, where appropriate, according to the corresponding provisions of ISC Ruless for Construction and Classification of Sea-going High Speed Craft or ISC Rules for Classification of Sea-Going Steel Ships and/or other recognized methods.

2.1.1.3　For high speed small waterplane area twin hull craft, its navigable service is not to go beyond the Greater Coastal Service Restriction.

2.1.1.4　The direct calculation and fatigue assessment of hull structure may be in accordance with the provisions in Chapter 6 and Chapter 7 of the Guidelines.

2.1.1.5　The material and construction technology of small waterplane area twin hull craft are to meet relevant requirements of ISC Rules for Materials and Welding.

2.1.1.6　While the primary structure of a SWATH craft will not typically be constructed from composite/hybrid materials, it is possible that secondary and top-side structures, including parts of deckhouses, may be fabricated from such nonmetallic materials. Designs incorporating composite/hybrid materials will need to be specially considered.

2.1.1.7　Model test, full-scale verification and experience of full-scale construction are to be applied as much as possible during the design stage of small waterplane area twin hull craft.

2.1.2　Structural design and arrangement

2.1.2.1　This Chapter assumes that SWATH structures are of conventional, welded, flat or curved stiffened plate construction. Other forms of structural design and arrangement and/or forms of construction are to be specially considered.

2.1.2.2　The scantlings of main structure of small waterplane area twin hull craft, especially for structural elements subject to hull transverse bending moment, are to be analyzed by direct calculation and determined in accordance with the provisions in Chapter 5 of the Guidelines, and are not to be less than the minimum scantlings required by Chapter 4 of the Guideline.

2.1.2.3 For critical structural details on primary members of hull structure, such as the connecting areas of haunch, cross-deck and vertical struts and of vertical struts and lower hull, direct calculation is to be carried out to assess stress concentration and necessary fatigue analysis is to be carried out in accordance with the provisions in Chapter 6 of the Guidelines.

2.1.2.4 Care must be taken for the cross structure, in which transverse bending generally dominates the design, the transversely oriented structure is to be made continuous through a joint region to ensure structural continuity for primary members, and sharp corners and abrupt changes in structural cross-section are to be avoided. Structural details are to be designed and constructed so as to minimize, as far as possible and practicable, hard spots, notches and other structural discontinuities that will create stress concentrations. Thickness and scantlings for the details above are to be strengthened.

2.1.2.5 In the cross structure decks, including the main deck and the wet deck, transverse stiffeners and beams are in general to be continuous through girders or longitudinal bulkheads unless specially permitted otherwise, but in way of the longitudinal bulkheads they may be intercostals provided continuity of transverse strength and end fixity are maintained by the provision of end brackets.

2.1.2.6 The vertical stiffeners and beams that are fitted within struts are similarly to be made continuous, if possible, at intersections with horizontal framing structures. Longitudinal stiffeners within the lower hulls are to be made continuous to the extent possible.

2.1.2.7 If the lower hulls have proportionately long overhangs, fore and aft of the intersection region with the struts, then the fore and aft, longitudinal stiffeners should be made continuous through the transverse frames and bulkheads. This may be substituted by equivalent method and local strengthening is to be carried out at the intersection region of vertical struts and lower hull.

2.1.2.8 Girders and transverses are to have depths not less than twice the depth of slots for longitudinals and beams or other openings. In general, vertical stiffeners on weather and wet deck girders are to be fitted at every other transverse stiffener and beam.

2.1.2.9 Unless permitted elsewhere or specially required in this Chapter, structural members are to be effectively connected to the adjacent structures. The bracket toe or member ends are not allowed to terminate at the plate not attached to adjacent structures. Where members are not required to be attached at their ends, special attention is to be given to the end taper, by using soft-toed concave brackets or by a sniped end of not more than 30°. Bracket toes or sniped ends are to be kept within 25 mm of the adjacent supporting member and the depth at the toe or snipe end is generally not to exceed 15 mm.

2.1.2.10 Openings in webs, girders and other structural internal members are to be arranged clear of concentrated loads or areas of high stresses. Openings in structural members are generally to be clear of supporting structure. Slots in webs are to be fitted with filler plates. Access and lightening holes are to be arranged clear of areas of load concentration or high stresses, and are to be provided with suitably radiused corners. Besides some compensation requirements, the depths of holes are generally not to exceed 0.5 times the depth of the member and the lengths of the holes not to exceed 0.75 times the depth of the member.

2.1.3 Structural Details

2.1.3.1 Structural details are to be designed and constructed so as to minimize, as far as possible and practicable, hard spots, notches and other structural discontinuities that will create stress concentrations and "hot spots".

2.1.3.2 The thickness of internals in locations that are potentially susceptible to rapid corrosion, such as haunch, wet deck, etc., is to be given special consideration.

2.1.3.3 The proportions of built-up members developed are to comply with established standards for control of local flange and web element buckling strength.

2.1.3.4 The design of structural details, such as details of the ends, the intersections of members and associated brackets, shape and location of air, drainage, or lightening holes, shape and reinforcement of slots or cut-outs for internals, is to be given special consideration to reduce the harmful effects of stress concentration as much as possible.

2.1.3.5 Elimination or closing of weld scallops in way of butts is to be achieved and "softening" of bracket toes is to be adopted as much as possible to reduce abrupt changes of section or structural discontinuities.

2.1.3.6 For high strength steels and higher proof stress aluminum alloys, the effects of proportions and thicknesses of structural members to local buckling and fatigue are to be given special consideration. For steel and aluminum alloys with improved through-thickness properties at intercostal connections of major sub-assemblies subject to cyclical loading (e.g. strut/lower hull connection), "Z" quality steel specified in ISC Rules for Materials and Welding is to be adopted.

2.1.3.7 Care and attention are to be given to the surfaces of these dissimilar metals (such as steel and aluminum, the same below) that are in close proximity, known as the "faying" surfaces. For mechanically fastened connections, a sealant/barrier material must exist between the steel and aluminum components. The external surfaces of such joint regions must also be treated. Such joints must retain required structural integrity under both maximum design and fatigue loading conditions.

2.1.3.8 The use of bimetallic couples, (steel to aluminum transition elements), facilitates the production of hybrid structures. However, such elements are to be positioned as far as possible from high stress regions in order to minimize the possibility of local fatigue problems. Care and attention must be given to the production and weather protection of butt joints between bimetallic couples.

2.1.3.9 A booklet of connection and construction details for all joints (including typical and special joints) is to be documented and submitted to ISC for review and approval.

CHAPTER 3 DESIGN LOADS

Section 1 General Provisions

3.1.1 General requirements

3.1.1.1 The structure of the small waterplane area twin hull craft must have the ability to withstand the maximum forces that are applied to it due to the natural environment, and to ensure the intended service operations through-out the planned life-time of craft.

3.1.1.2 For small waterplane area twin hull craft, the hull structural design loads and load combination, and the scantlings of major structural elements of the vessel subject to hull transverse bending are to satisfy the requirements of this Chapter.

3.1.1.3 Load probability related to waves is to be based upon 20 years. For the vessels operating in restricted service and in assigned route, the relevant requirements in this Chapter may be reduced, where appropriate, according to the corresponding provisions of ISC Rules for Construction and Classification of Sea-going High Speed Craft or Chapter 2 of ISC Rules for Classification of Sea-Going Steel Ships and/or other recognized methods.

Section 2 Global Loads

3.2.1 General requirements

3.2.1.1 Special analysis is to be carried out to the ship's motion response to derive the wave load data. In general, the analysis is to adopt three dimensional potential flow theory (Green function based on zero speed is allowed). If strip theory is adopted, the analysis is to consider the hydrodynamic interaction between twin hulls. At least 20 stations are to be included in motion and load calculation model. All the calculation methods and procedures together with verification results are to be approved by ISC. Verification may be based on the comparison with model test or comparison with the calculation results of the software approved by ISC.

3.2.1.2 Wave loads may be obtained from model testing or calculation by the program. The test program or calculation program is to be approved by ISC.

3.2.1.3 During the design stage, if without appropriate information, global wave induced load may be initially estimated in accordance with the requirements of this Section. The more accurate load determination is to be based on 3.2.1.1 and/or 3.2.1.2.

3.2.1.4 On considering loads, transverse split force (transverse bending moment) and the moment (horizontal torque, transverse and longitudinal torque) between two hulls induced by waves of key design loads for the small waterplane area twin hull craft are to be included.

3.2.1.5 The effects of inertia force are to be considered in general analysis, and the inertia force and the corresponding external environmental loads, such as loads induced by waves, etc., are to be superimposed.

3.2.2 Global transverse bending moment

3.2.2.1 The transverse wave load where small waterplane area twin hull craft is at zero speed is generally the maximum transverse load. The global transverse bending moment M_{TR} of small waterplane area twin hull craft is combined by bending moment M_F due to transverse split force F_y and bending moment M_{DL} due to hull buoyancy (P_s + P_{LH}) and hull gravity load (P_{DL_B}+P_{DL_S}). The above combined moment can be estimated by the following equations, and the action position of each load is shown in Figure 3.2.2.1:

$$M_{TR} = M_F \pm M_{DL} \qquad \text{kN} \cdot \text{m}$$

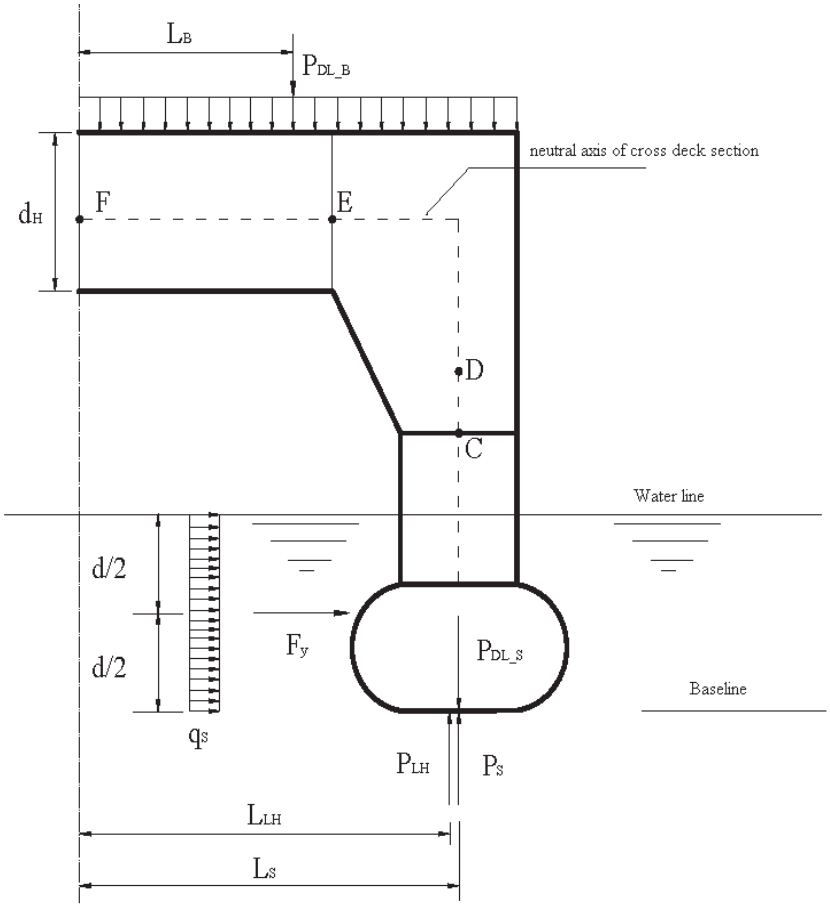

Figure 3.2.2.1

3.2.2.2 Bending moment M_F, kN • m due to transverse split force F_y is to be calculated according to the following formula:

$$M_F = \begin{cases} F_y(d_x - d/2) & \text{above design waterline} \\ q_s d_x^2/2 & \text{below design waterline} \end{cases}$$

where: F_y — transverse split force, see 3.2.2.3;

d_x — vertical distance from baseline to calculating points (points C, D, E and F as shown in Figure 3.2.2.1), in m;

d — design draught, in m, see1.1.4.19;

q_s — equivalent to F_y acting on vertical struts and lower hulls, in the form of distributed loads, i.e. $q_s = \frac{F_y}{d}$.

3.2.2.3 The transverse split force F_y is to be calculated according to the following formula. It is assumed that the transverse split force F_y is linearly and evenly distributed on vertical direction from baseline to design draught height, and the position of resultant action point is to be at 1/2 draught, see Figure 3.2.2.1. Outward and inward split forces are to be taken independently as two directions for combination of transverse split force F_y and other loads.

(1) For non-high-speed small waterplane area twin hull craft:

$$F_y = \pm 9.81 D_F T L_F \Delta \quad \text{kN}$$

where: D_F — coefficient, $D_F = 3.24 - 0.55\log_{10}\Delta$;

T — coefficient, $T = 1.754d/\Delta^{1/3}$;

L_F — coefficient, $L_F = 0.75+0.35\tanh(1.65l_s/\Delta^{1/3} - 6.0)$;

Δ — full load displacement, in t, see1.1.4.20;

d — design draught, in m, see 3.2.2.2;

l_S — waterline length of vertical struts, in m, see 1.1.4.10.

(2) For high speed small waterplane area twin hull craft:

$$F_y = 57 C_1 d \Delta^{2/3} a_1 L_F \quad \text{kN, for } L \leqslant 50 \text{ m}$$

where: C_1 — coefficient, to be obtained from Table 4.8.6 of Chapter 4 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft;

α_1— coefficient, to be calculated as follows:

$$a_1 = 1.55 - 0.75\tanh(\Delta/11000)$$

Other symbols are the same as above (1).

Note: ① The formula is applicable to vertical strut type small waterplane area twin hull craft with displacement not more than 10000t;

② If the maximum design sea condition is 4 to 5 wave scale, F_y may be appropriately reduced but not less than $0.8F_y$, and to be verified by model test.

3.2.2.4 Bending moment M_{DL}, kN • m due to hull buoyancy(P_S+P_{LH}) and hull gravity loads (P_{DL_B}+P_{DL_S}) is to be calculated according to the following formula:

$$M_{DL} = P_S L_S + (P_{LH} - P_{DL\_S}) L_{LH} - P_{DL\_B} L_B$$

where: P_S —buoyancy of vertical struts, in kN, to be calculated in accordance with the following formula:

$$P_S = 10(l_S B_S D_S C_{WP})(F_{DL})$$

where: B_S— width of vertical struts, in m, see 1.1.4.16;

D_S— depth of vertical struts, in m, see 1.1.4.18;

l_S— waterline length of vertical struts, the same as in 3.2.2.3;

C_{WP}— waterplane coefficient of small waterplane area twin hull craft , see 1.1.4.21;

F_{DL}=1±0.35, dynamic factor;

L_S— horizontal distance from P_S action point to the centre line of the hull, in m, see Figure 3.2.2.1;

P_{LH} — buoyancy of lower hull, in kN, to be calculated in accordance with the following formula:

$$P_{LH} = 9.81(\Delta/2)(F_{DL}) - P_S$$

where: Δ — full load displacement, in t, the same as that in 3.2.2.3;

P_{DL_S} — weight of strut and hull, in kN, to be calculated in accordance with the following formula:

$$P_{DL\_S} = 9.81(\Delta/4)(F_{DL})$$

L_{LH}— horizontal distance from PLH action point to the centre line of the hull, in m, see Figure 3.2.2.1;

P_{DL_B} — gravity loads of cross deck and upper structure, in kN, to be calculated in accordance with the following formula:

$$P_{DL\_B} = 9.81 \Delta F_{DL}/4$$

where: B— ship breadth, in m, see 1.1.4.12.

3.2.2.5 The above estimated formula for hull gravity load is determined based on the assumption that hull gravity load is equal to whole ship displacement and the load is distributed as follows:

$$P_{DL\_B} = 9.81\Delta F_{DL}/4$$
$$P_{DL\_S} = 9.81\Delta F_{DL}/4$$

where: for symbols, see 3.2.2.4.

The corresponding formula is to be appropriately corrected if the acutual condition is greatly different from the assumption.

3.2.2.6 The values of F_y , P_S, P_{LH}, P_{DL_B} and P_{DL_S} as mentioned above are considered as the load acting on one demi-hull.

3.2.3 Global horizontal torsional moment

3.2.3.1 While small waterplane area twin hull craft is subjected to oblique sea and/or an actural difference occurs in the linear arrangement of hull, thus transverse split force F_y is distributed unevenly along ship' s length, the difference of forces form yaw splitting moment between two demi-hulls and relative torsion occurs, then the action of horizontal torsional moment may be simulated according to the following loading methods:

(1) under the condition that the wave direction angle is 90° (beam sea), transverse split force F_y is in trapezoidal distribution along ship length, see Figure 3.2.3.1(1), and the values of W_1 and W_2 at both ends of distributing force are calculated respectively according to the following formula:

$$W_{11} = 1.12F_y/l_s \; W_{12}$$
$$= 0.88F_y/l_s$$

where: F_y— transverse split force, see 3.2.2.3;

l_S — waterline length of strut, the same as that in 3.2.2.

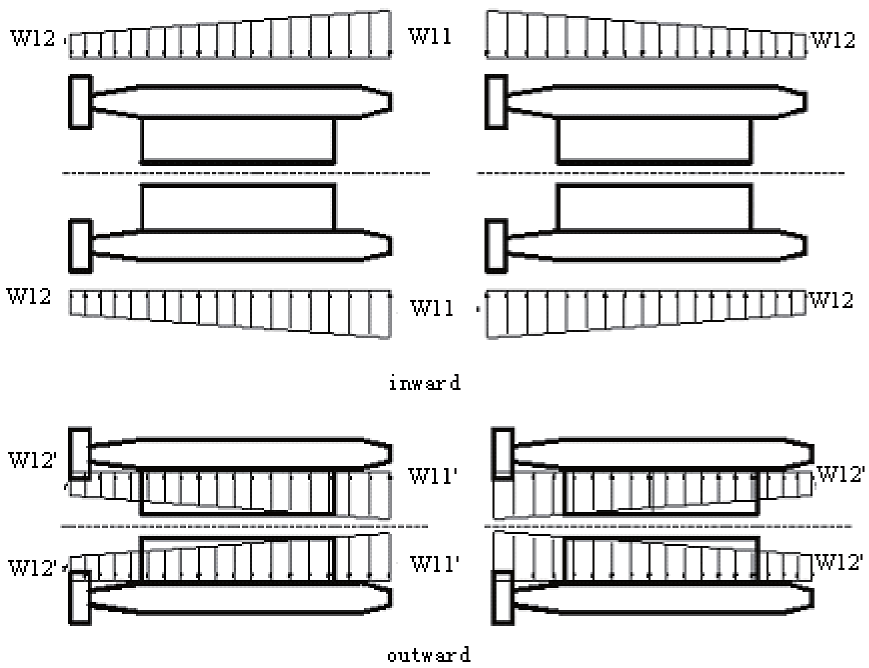

Figure 3.2.3.1(1)

(2) under the condition that the wave direction angle is 135°/45° (oblique sea), transverse split force Fy is in triangle distribution along ship length, see Figure 3.2.3.1(2), and the values of W_1 and W_2 at both ends of distributing force are calculated respectively according to the following formula:

$$W_{21} = 1.20F_y/l_s$$
$$W_{22} = 0$$

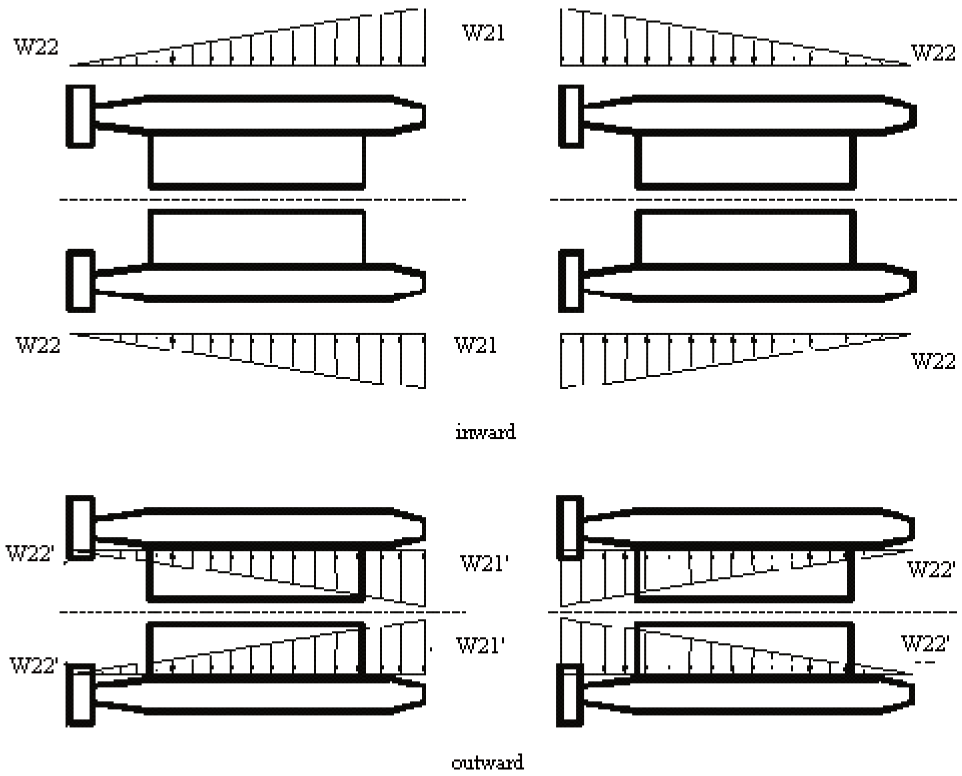

Figure 3.2.3.1(2)

3.2.4 Global pitching connection moment

3.2.4.1 For pitching connection moment M_P, in $kN \cdot m$, between two demi-hulls of small waterplane area twin hull craft about the horizontal transverse axis due to pitching motion, the value is obtained from the following formula, whichever is greater:

$$M_{P1} = 0.125\Delta a_{cg} l_{lh}$$

$$M_{P2} = 0.25\Delta a_{cg} b$$

where: Δ — full load displacement, in t, the same as that in 3.2.2.3;

a_{cg} — vertical acceleration at gravity center of ship, in m/s^2.

For high speed small waterplane area twin hull craft, the value of a_{cg} may be determined according to the results of model testing or 3.3.2 of this Chapter.

For non-high-speed small waterplane area twin hull craft, the value of a_{cg} may be calculated according to the results of model testing or the calculating method approved by ISC, but it is not to be less than 0.35g. (g=9.81 m/s^2).

l_{lh}——length of lower hulls, in m, see 1.1.4.11;

b—— spacing between centerlines of demi-hulls, in m, see Figure 3.2.4.1;

M_P may be equivalent by evenly line-distributed load p , see Figure 3.2.4.1, or by other appropriate method, but the center position of each portion is to be kept at the center of the fore and aft part of the hull.

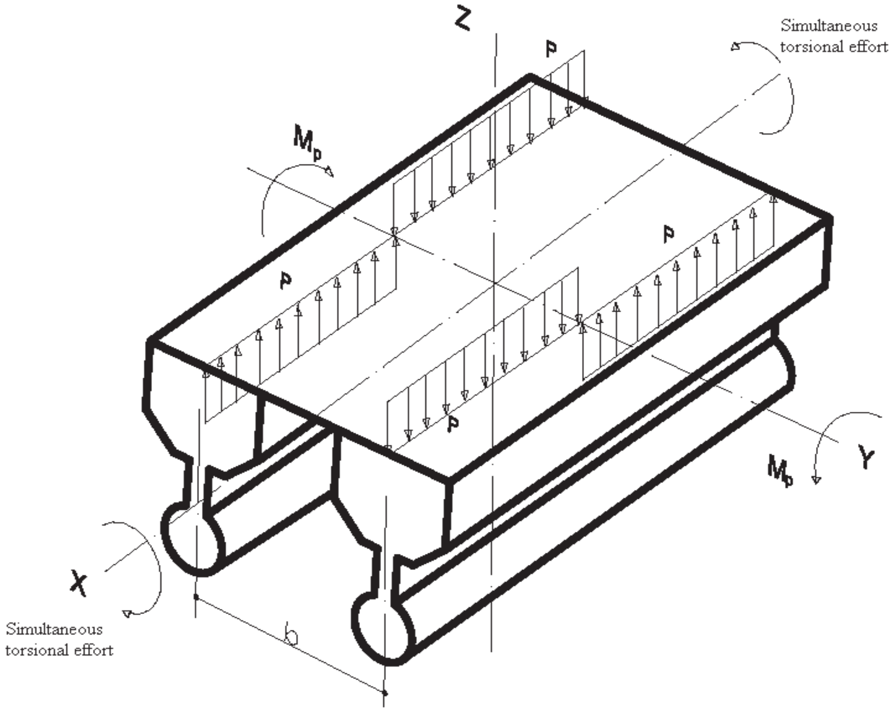

Figure 3.2.4.1

3.2.5 Vertical shear force at the centre line of the hull

3.2.5.1 The cross deck structure of small waterplane area twin hull craft has vertical shear force Q at the centre line of the hull and the parallel sections. The shear force is combined due to unsynchronous heaving motion between two demi-hulls and the gravity loads at upper hull. The vertical shear forces at the centre line of the hull and the parallel sections at the ends of longitudinal bulkhead are to be simulated according to the following loading methods, and the superimposition effects of inertia force of motion is also taken into account:

(1) Q_1, in kN , obtained at the centre line of the hull, is to be calculated according to the following formula:

$$Q_1 = 0.25F_y$$

(2) Q_2, in kN, obtained at the centre line of the hull at the ends of longitudinal bulkhead, is to be calculated according to the following formula:

$$Q_2 = 0.25F_y + 1.35 \times 9.81(\Delta/4)$$

(3) The area between both ends is in trapezoid distribution along ship's width, see Figure 3.2.5.1.

where: F_y— transverse split force, see 3.2.2.3;

Δ — full load displacement, in t, the same as that in 3.2.2.3.

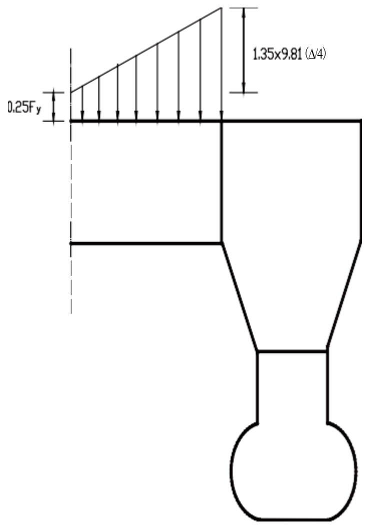

Figure 3.2.5.1

When using FEM to do calculation, the shear forces at locations (1) and (2) due to external loading on the model are to meet the above-mentioned requirements.
When loading practically, the above-mentioned loads may be equivalently applied to the bottom of lower hull.

3.2.6 Global transverse shear

3.2.6.1 For high speed small waterplane area craft, the larger of overall longitudinal bending moment in 4.8.3, Chapter 4 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft and the direct calculation result of hydrodynamic load with equivalent probability level is to be taken for longitudinal hogging (sagging) moment M_h, M_s.

3.2.6.2 For non-high-speed small waterplane area craft, global longitudinal hogging moment M_L（＋）and global longitudinal sagging moment M_L（—）are to be calculated according to the following formula：

$$M_L(+)=M_W+M_{SW} \quad \text{kN·m}$$

$$M_L(-)=M_W-M_{SW} \quad \text{kN·m}$$

where: M_W — longitudinal wave bending moment, in $kN \cdot m$, to be calculated according to the following formula:

$$M_W=0.082\,(C_{WP}/0.75)^{2.5} l_s^{2.5} B_s$$

where: C_{WP}— waterplane coefficient of small waterplane area craft, see 1.1.4.21;

l_S — waterline length of strut, in m, the same as that in 3.2.2.3;

B_S — breadth of strut，in m, see 3.2.2.4;

M_{SW}— longitudinal still water bending moment，in kN • m.

During the initial design stage, if without any appropriate information, 20% of the value of the global longitudinal wave bending moment M_W is to be taken into account.

3.2.7 Load combination

3.2.7.1 In general, the hull's maximum loads reflected by each wave direction angle of small waterplane area twin hull craft are as follows:

(1) wave direction angle 90°— maximum transverse bending moment and vertical shear;

(2) wave direction angle 45°/135°— significant torsion combination;

(3) wave direction angle 0°/180°— maximum longitudinal bending moment.

The load calculation condition of overall structure analysis of small waterplane area twin hull craft is to be combined according to the above-mentioned principle, and transverse strength, torsional strength, longitudinal strength and shear strength at sections parallel to the centre line are to be checked. The design load calculation condition for direct calculation using FEM of ship's global structure is shown in Table 3.2.7.1.

Design load calculation condition **Table 3.2.7.1**

Design load condition	wave direction angle	Condition No.	Types of loads								
			Buoyancy	Transverse force (inward)	Transverse force (outward)	Horizontal torque	Pitching/ racking moment M_P	Longitudinal bending moment $M_L(+)$	Longitudinal bending moment $M_L(-)$	Hull gravity loads	Vertical shear force
For transverse strength	90°	1	0.65	√	/	Bow 1.0 W_{11} Stern1.0 W_{12}	/	/	/	0.65	/
		2	1.35	/	√	Bow 1.0 W_{11} Stern 1.0 W_{12}	/	/	/	1.35	/
		3	0.65	√	/	Stern 1.0 W_{11} Bow 1.0 W_{12}	/	/	/	0.65	/
		4	1.35	/	√	Stern 1.0 W_{11} Bow 1.0 W_{12}	/	/	/	1.35	/
		5	/	/	/	/	/	/	/	/	1.0
For torsional strength	135° / 45°	6	/	√	/	Bow 1.0 W_{21} Stern 1.0 W_{22}	0.8	/	/	/	/
		7	/	√	/	Stern 1.0 W_{21} Bow 1.0 W_{22}	0.8	/	/	/	/
		8	/	/	√	Bow 1.0 W_{21} Stern 1.0 W_{22}	0.8	/	/	/	/
		9	/	/	√	Stern 1.0 W_{21} Bow 1.0 W_{22}	0.8	/	/	/	/
For longitudinal strength	180° / 0°	10	/	/	/	/	/	1.0	/	/	/
		11	/	/	/	/	/	/	1.0	/	/

Notes: ① The values in the Table are conmbination coefficients of each loading component in the same condition number. Each loading component is obtained by calculation method defined in 3.2.2 to 3.2.6 of this Chapter. "√"indicates condition needing consideration and "/" indicates condition without consideration.

② In addition to the loading method defined in above-mentioned requirements, each load is generally to be applied to the model by equivalently distributed load.

③ The transverse linear load applied according to 3.2.3 is equivalent to the combined effects of transverse split force and horizontal torsional moment.

④ For transverse strength check, the items listed in the Table are represented as the action of transverse split force from both sides of out shell to the center line (outward to inward) only. When applicable, the action from inside to outside are also to be taken into consideration, see Figures 3.2.3.1(1) and (2).

⑤ On calculation, some similar calculation conditions in the Table may be merged according to actual working condition.

3.2.7.2 In addition to the conditions described in Table 3.2.7.1, special consideration is to be given on design to the greater loads generated during construction and maintenance period, such as construction, docking, launching and lifting, etc. Necessary strength calculation, deformation control and strengthening measures are to be carried out.

Section 3 Local Loads for High Speed Small Waterplane Area Twin Hull Craft

3.3.1 General requirements

3.3.1.1 Unless stated otherwise, this Section is only applicable to high speed small waterplane area twin hull craft.

3.3.2 Vertical acceleration at gravity centre of a craft

3.3.2.1 External loads applied on the hull structure for a craft are different from a normal ship. When a craft navigates with high speed at wave which may be present in its service restriction, the more significant impact pressure of wave will act on the hull. The impact pressure is related to vertical acceleration at gravity centre of a craft.

3.3.2.2 The average 1/100 highest vertical acceleration at craft's gravity centre is to be taken as the design value to determine the design loads. The relation among the vertical acceleration a_{cg} and significant wave height $H_{1/3}$ and craft's speed V_H corresponding to the wave height is as follows:

$$a_{cg} = \frac{K_T}{426}\left(\frac{V_H}{\sqrt{L}}\right)^{1.4}\left(\frac{H_{1/3}}{B_{WL}} + 0.07\right)(50-\beta)\left(\frac{L}{B_{WL}} - 2\right)\frac{B_{WL}^3}{\Delta}g$$

where: g— acceleration of gravity, $g = 9.81$, m/s^2;

V_H— speed navigating at sea with significant wave height $H_{1/3}$, in kn;

$H_{1/3}$— significant wave height, in m;

β— deadrise angle at LCG(°), $\beta_{max} = 30°$; $\beta_{min} = 10°$, the value of β is shown in Figure 3.3.2.2;

K_T— hull type factor, to be taken as 0.8.

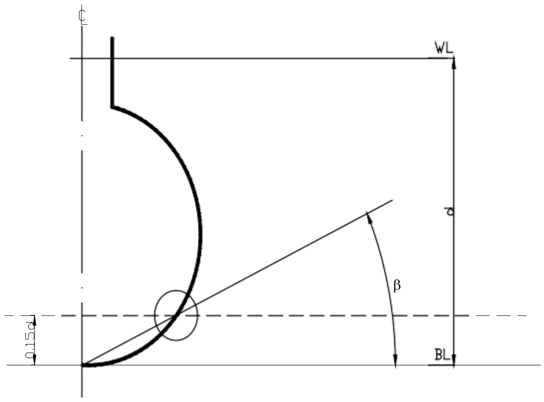

Figure 3.3.2.2

3.3.2.3 A series of significant wave heights $(H_{1/3})_1$～$(H_{1/3})_i$ which may be encountered by the craft is assumed by design unit according to the craft's service restriction. The maximum value $H_{1/3}$ of the assumed wave height is not to be more than the following values:

$H_{1/3max}$ = 6.0 m for Greater Coastal Service Restriction;
$H_{1/3max}$ = 4.0 m for Coastal Service Restriction;
$H_{1/3max}$= 2.0 m for Sheltered Water Service Restriction;
$H_{1/3max}$= 1.0 m for Calm Water Service Restriction.

3.3.2.4 A series of speed $(V_H)_1$～$(V_H)_i$ corresponding to the series of assumed significant wave heights specified in 3.3.2.3 are to be established by design unit which may refer to model tests or full scale measurement of the sister craft or other reasonable method with the consent of ISC.

3.3.2.5 According to a pair of ($H_{1/3i}$, V_{Hi}) specified in 3.3.2.3 and 3.3.2.4 , the corresponding vertical acceleration acgi is to be calculated according to the formula in 3.3.2.2. The design unit may take $a_{cgi} \le 1.0g$ (for passenger craft) and $a_{cgi} \le 1.2g$ (for cargo craft) as the design vertical acceleration. But the speed V_{Hi} is to be reduced until the acceleration acgi is not to be more than the value taken according to the formula in 3.3.2.2.

3.3.2.6 The maximum vertical acceleration of a series of acgi determined by 3.3.2.5 is to be taken as the design vertical acceleration at centre of gravity.

3.3.2.7 A group of $H_{1/3}$~V_H which is calculated in accordance with the formula in 3.3.2.2 and corresponding to the design vertical acceleration at gravity centre of a craft finally determined by the designer or shipowner is to be drawn in "Limited Speed Curve while the Craft Navigates in Wave", submitted to ISC for review, and then a signal board is to be permanently fixed in the navigation room. When the craft is being operated, the speed is to be limited in accordance with significant wave height measured with eyes.

3.3.3 Slamming pressure on bottom

3.3.3.1 This provision applies to small waterplane area twin hull craft whose parts of hull immerse in seawater at high speed in full loading condition. Their bottoms will withstand the slamming force. The bottom means the part under the maximum breadth of the lower hulls, generally indicating the lower part of the oval or cylinder.

3.3.3.2 The slamming pressure on bottom P_{sl1} is to be taken as:

$$P_{sl1} = 1.16 K_{l1} \left(\frac{\Delta}{nA}\right)^{0.3} \frac{50-\beta_x}{50-\beta} a_{cg} d_w \qquad \text{kN/m}^2$$

where: K_{l1}— longitudinal pressure distribution factor:

$K_{l1}=1$ for forward,

$K_{l1}=0.5$ for stern,

The factor for the other place is to be obtained by linear interpolation;

A — design load area for element considered, in m^2, not to be less than $0.002\Delta/d$;

For plating, A is not to be taken greater than 2.5 S^2;

For stiffener or girder, A is to be taken as the product: spacing × span;

n— number of demi-hulls, n=2;

β— deadrise angle at LCG(°), see 3.3.2.2;

β_x— checked deadrise angle（°）at transverse section, $\beta_{xmax}=30°$, $\beta_{xmin}=10°$;

a_{cg}— the design vertical acceleration at gravity center, in m/s^2, see 3.3.2.6;

d_W— slamming draught while a craft navigates in wave, $d_W=cd$;

where: d— draught of craft in full loading condition with no lift or propulsion machinery active, in m;

c— coefficient, c=1.0;

Δ — full load displacement, in t, see 1.1.4.20.

3.3.3.3 Slamming pressure on bottom P_{sl1} is not to be less than the value calculated in accordance with that in 3.3.5.1 in this Section.

3.3.4 Slamming pressure on cross-deck bottom (wet deck)

3.3.4.1 Cross-deck bottom (wet deck) means the lower surface of the cross deck structure above water surface. This structure will withstand the slamming force when the craft sails at sea with high speed.

3.3.4.2 The slamming pressure P_{sl2} specified in 3.3.4.1 is to be determined according to the data obtained by model testing or full-scale test, if there is no test information, it is to be taken as:

$$P_{sl2} = K_{l2}\left(\frac{\Delta}{A}\right)^{0.3} a_{cg}\left(1-\frac{H_{tx}}{CL}\right) \qquad \text{kN/m}^2$$

The pressure P_{sl2} is not to be less than the side pressure according to 3.3.5.1.

where: K_{l2}— longitudinal pressure distribution factor, to be obtained according to the following:

area between stern and amidcraft: $K_{l2}=1.3$

area between bow and L/3 after bow: $K_{l2}=3.9$

area between L/3 forward amidcraft and amidcraft: K_{l2} is to be obtained by linear interpolation;

C— coefficient, $C=0.0925+0.014\,\dfrac{100\text{-}L}{80}$;

H_{tx}— vertical distance from pressure calculation point of cross-deck bottom to water surface, in m, $H_{tx\max}=CL$;

L— length of craft, in m, see 1.1.4.8(1);

The other symbols are the same as those in 3.3.3.2.

3.3.5 Side and deck pressure

3.3.5.1 Side is composed of upper parts of the lower hulls (cylinders or ovals) and struts, upper hull structure, whose pressure P_s is determined by following formula:

$$P_S = 9.81h + 0.15\,P_{sl} \quad \text{kN/m}^2$$

where: h — vertical distance from the point for pressure calculation to main deck, in m, which is not to be less than 0.8 m but not necessarily more than 0.8 times the extent height of side;

P_{sl} — pressure on bottom in the same frame, calculated in accordance with 3.3.3.2 of this section.

3.3.5.2 Pressure Pd1 acting on exposed deck is to be taken as:

$$P_{d1}=K_{l3}(0.2L+C) \quad \text{kN/m}^2$$

where: K_{l3} — longitudinal pressure distribution factor:

$K_{l3}=1.0$ for forward amidcraft,

$K_{l3}=0.75$ for stern,

The factor between amidcraft and stern is to be obtained by linear interpolation;

C — service restriction coefficient:

$C=7.6$ for Greater Coastal Service Restriction and Coastal Service Restriction;

$C=4.6$ for Sheltered Water Service Restriction and Calm Water Service Restriction;

L — length of craft, in m, see 1.1.4.8(1).

3.3.5.3 Pressure P_{d2} acting on unexposed deck (including decks of superstructures and deckhouses) is to be taken as:

$$P_{d2} = 0.1L + 4.6 \quad \text{kN/m}^2$$

3.3.5.4 Pressure P_d acting on accommodation deck is to be taken as:

$$P_d = 4.5 \quad \text{kN/m}^2$$

3.3.5.5 Where the deck is designed to carry heavy unit, the influence of the vertical acceleration of a craft is to be considered as well as the weight of the unit. The vertical acceleration of the heavy unit may be taken as $0.5a_v$.

The vertical acceleration av of the craft is to be taken as:

$$a_v = K_a a_{cg} \quad \text{m/s}^2$$

where: K_a— vertical acceleration distribution factor,

K_a= 1.0 for aft amidcraft, K_a=2.0 for bow, the factor between bow and amidcraft is to be obtained by linear interpolation;

a_{cg}— design vertical acceleration at LCG specified in 3.3.2.2, in m/s^2.

3.3.6 Pressure acting on superstructures and deckhouses:

3.3.6.1 Pressure P_{sd} acting on end and side walls is to be taken as:

$$P_{sd} = 15.6K_1K_2(CL+0.8 - 0.3h) \quad \text{kN/m}^2$$

where: K_1— location factor, to be taken as follows:

K_1= 1 for fore end bulkhead of 1st tier superstructure,

K_1= 0.75 for fore end bulkhead of 2nd tier superstructure,

K_1= 0.5 for aft end and sides of superstructure and deckhouse;

K_2— location factor, obtained according to the location of superstructure and deckhouse:

K_2= 1.0 for area of forward amidcraft;

K_2= 0.75 for area of aft amidcraft;

C— service restriction coefficient:

C= 0.047 for Greater Coastal Service Restriction and Coastal Service Restriction;

C= 0.035 for Sheltered Water Service Restriction;

C= 0.024 for Calm Water Service Restriction;

h— vertical distance from point for pressure calculation to full load water line, in m.

3.3.6.2 Pressure P_{sd} of roof/floor is not to be less than 4 kN/m^2, but pressure P_{sd} of roof/floor of 1st tier superstructure or deckhouses forward amidcraft is not to be less than 6.6 kN/m^2.

3.3.6.3 Minimum pressure Pmin of front end of the first tier superstructure is not to be less than the pressure of exposed deck forward amidcraft in the formula of 3.3.5.2. The minimum pressure of other casing wall of superstructure and deckhouse is not to be less than 4 kN/m^2.

3.3.7 Pressure of bulkheads P is to be taken as:

3.3.7.1 Watertight bulkhead:

$$P=10h \quad \text{kN/m}^2$$

where: h— vertical distance from point for pressure calculation to the highest point of bulkhead deck, in m.

3.3.7.2 Bulkhead of liquid tank: the greatest of the following to be taken:

$$P = (9.81+0.5a_v) \quad \text{kN/m}^2$$

$$P = 10\left(h + \frac{2}{3}h_p\right) \quad \text{kN/m}^2$$

$$P = 10(h+1.0) \quad \text{kN/m}^2$$

where: a_v — vertical acceleration of craft at the position of the bulkhead, in m/s^2, obtained according to 3.3.2.2;

h— vertical distance from point for pressure calculation to top of the liquid tank, in m;

h_p— vertical distance from top of the liquid tank to top of the air-pipe, in m.

3.3.7.3 Collision bulkhead:

$$P = 12.5h \quad \text{kN/m}$$

where: h——vertical distance from point for pressure calculation to the highest point of bulkhead deck, in m.

Section 4 Local Loads for Non-high-speed Small Waterplane Area Twin Hull Craft

3.4.1 General requirements

3.4.1.1 Unless stated otherwise, this Section is only applicable to non-high-speed small waterplane area twin hull craft.

3.4.2 Local loads

3.4.2.1 Local loads include hydrostatic pressure/tank pressure and lateral water pressure induced by waves, slamming, green sea load, machinery equipment of deck and its operation area and operation weight, cargo and crew. Unless for special reason, the effects of sloshing load are generally not taken into account.

3.4.2.2 Whether local loads are to be superimposed and combined with global load may be determined by the influence degree to overall strength. The repetition of the same load is to be excluded on superimposition.

3.4.2.3 During design stage, loading plan is to be stated on the relevant documents, such as maximum distribution loads and concentrated loads with their action point. If the designed purpose includes carriage of car, the weight of car intended to be carried and the tyre print position which is most disadvantageous to structural stress by those may be moved into area for design consideration.

3.4.2.4 For hydrostatic pressure/tank pressure, lateral water pressure induced by waves and green sea load, see the relevant provisions in Section 3 of Chapter 4.

3.4.2.5 Slamming loads encountered by shell plates in the area near waterplane are to be adequately taken into consideration. The wave slamming design pressure of wet deck panel, stiffener and grillage may be determined according to model testing or parent craft. If without above-mentioned information, initial estimation may be carried out according to 3.4.2.6, and the slamming design pressure acting on panel, stiffener or grillage in different area may be amended according to 3.4.2.7. Recognized methods may be adopted subject to approval of ISC. In general, the superimposition effect of slamming load and global load is not taken into consideration.

3.4.2.6 Pressure forces resulting from slams will vary in magnitude, location and area effected with time. For the design of plating and local stiffening, the instantaneous localized peak pressure values are clearly the most important. After the clearance is selected reasonably, the peak value Pmax of slamming pressure is to be calculated according to the following formula, and the distribution of slamming pressure is shown in Figure 3.4.2.6(1):

$$P_{max} = nL_P (L_b)^{1.08} \quad kN/m^2$$

where: n= 6.78;

L_P— Longitudinal impact load factor, given in Figure 3.4.2.6(2);

L_b— length of cross deck box structure, in m.

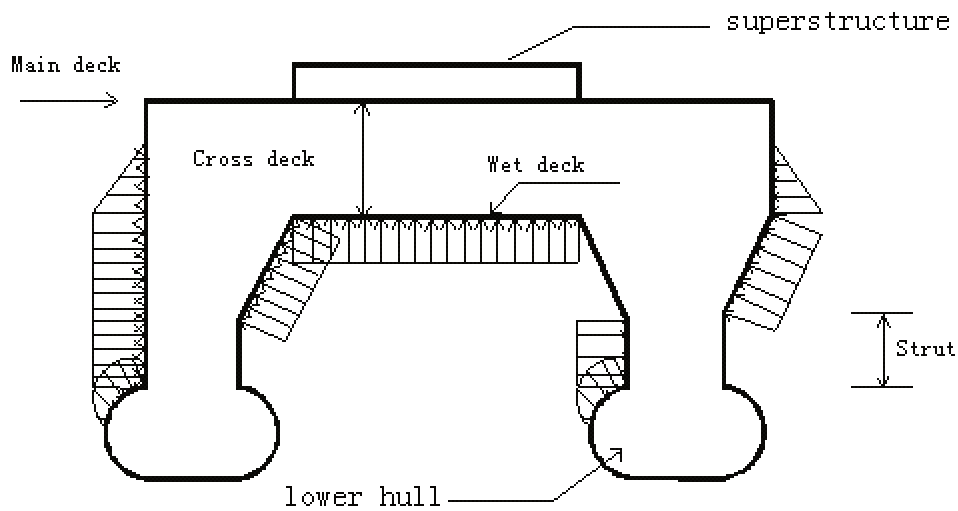

Figure 3.4.2.6(1)

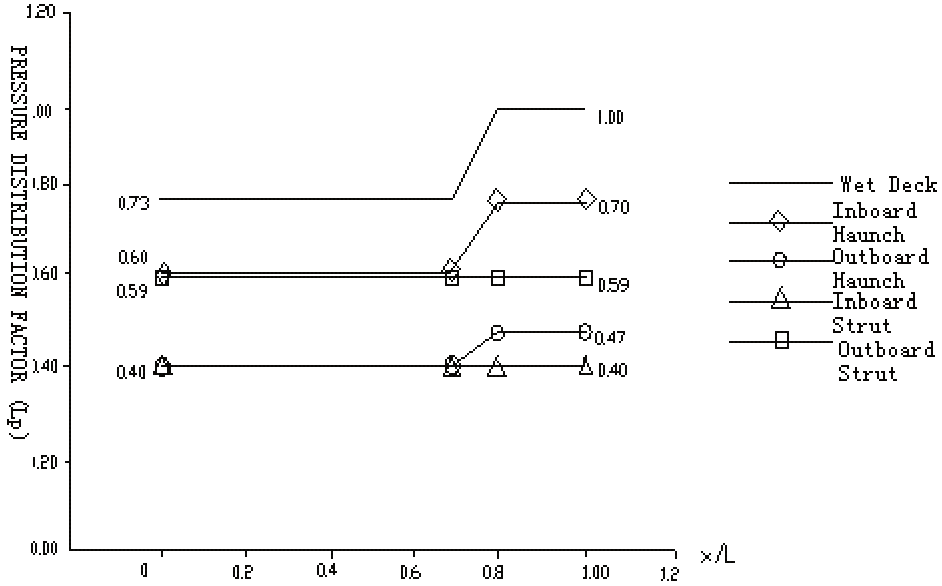

Figure 3.4.2.6(2)

3.4.2.7 As a slam develops, a progressively larger area is subjected to the pressure forces. The average vertical design pressures P_{des} uniform over the whole surface of the panel and the grillage, is to be taken as follows:

$$P_{des} = P_{max}[K_d/K_n] \quad \text{kN/m}^2$$

where: K_d— factor, to be taken as follows:

$$K_d = \begin{cases} 1.0 & \text{for } A_d/A_r < 0.00025 \\ 0.2776 + 0.0154[-\log_{10}(A_d/A_r)]^3 & \text{for } 0.00025 \leqslant A_d/A_r < 0.0226 \\ 0.09 + 0.37[-\log_{10}(A_d/A_r)]^{1.5} & \text{for } 0.0226 \leqslant A_d/A_r < 1.0 \end{cases}$$

K_n— factor, equal to K_d, but A_d is taken as 1m^2 ;

A_d— design area on which P_{des} is to be applied, with the same unit as A_r;

A_r— the reference area, in m, to be taken as follows:

$A_r = 0.06 L_b B$

where: L_b— length of cross deck box structure, in m;

B— craft breadth, in m, see 1.1.4.11.

3.4.2.8 For greater weight load such as machinery equipment, inertia forces due to motion are to be considered.

3.4.2.9 In the preparation of the loading plan, the following loads in Table 3.4.2.9 are to be considered as notional minimums, unless it can be clearly demonstrated that a lesser loading is the most that can be achieved in practice.

The notional minimums of the loads on deck Table 3.4.2.9

Location	Loads
Crew spaces and walkways	4500 N/m^2 (0.64 m design head)
Work areas	9000 N/m^2 (1.28 m design head)
Storage areas	13000 N/m^2 (1.84 m design head)

3.4.2.10 In the absence of any other data and special considerations, the sea water head of weather deck is to be assumed as follows:

(1) forwards end: 2 m;

(2) rear end: 1 m;

(3) between both ends: linear interpolation.

CHAPTER 4 SCANTLINGS

Section 1 General Provisions

4.1.1 General requirements

4.1.1.1 This Chapter specifies the minimum scantlings of some structural members enduring normal local loads. For the structural members subjected to strength verification required by Chapter 5, their scantlings are also to meet the relevant strength requirements of this Chapter and not inferior to the provisions of this Chapter.

Section 2 Scantlings of High Speed Small Waterplane Area Twin Hull Craft

4.2.1 General requirements

4.2.1.1 The scantlings of high speed small waterplane area twin hull craft are to be determined in accordance with the relevant requirements of Chapter 4 of ISC Rules for Construction and Classification of Sea-Going High Speed Craft, and the relevant local loads are to be calculated in accordance with the requirements of Section 2, Chapter 3 of the Guidelines. In addition, the following requirements are to be complied with.

4.2.1.2 As to the plate keel, the breadth and the minimum thickness tmin of the plate are to be the same as the requirements for catamarans in ISC Rules for Construction and Classification of Sea-Going High Speed Craft, and not less than that of the bottom plate at its place.

4.2.1.3 The thickness of plate and scantlings of members in way of the cross-area connecting wet deck to haunch are to be used for strength verification by finite element calculation. Fatigue assessment to key parts is to be taken into consideration, if applicable.

Section 3 Scantlings of Non-high-speed Small Waterplane Area Twin Hull Craft

4.3.1 General

4.3.1.1 Symbols and relevant definitions used in this Section:

t: plate thickness required by the Rules, in mm;

W: section modulus of members (including band plate) required by the Rules, in cm^3;

σ_s: yield stress of material, in N/mm^2, to be determined according to the following requirements:

For steel, it means minimum yield strength of steel, but the value is not more than 72% of the specified minimum tensile strength.

For aluminum alloy, it means minimum yield strength of aluminum alloy after welding, the value is to be 0.2% of the specified nonproportional elongation stress in the annealed condition, see ISC Rules for Materials and Welding.

m: material factor for aluminum alloy. For steel plate, *m*=1.0; for aluminum alloy plate, see Table 4.3.1.1;

Material factor m for aluminum alloys **Table 4.3.1.1**

Aluminum alloys	Material factor m	Delivery condition
5083	1.23	All delivery conditions
5086	1.46	All delivery conditions
5454	1.62	All delivery conditions
5456	1.23	All delivery conditions
6061-T-6	1.75	welded with 5183, 5356 or 5556 filler wire

k: correction factor for plate panel， to be calculated according to the following formula:

$k = (3.075a^{1/2} - 2.077)/(a + 0.272)$ for $1 \leqslant a < 2$

$k = 1.0$ for *a* ” 2

a — aspect ratio of plate panel;

Primary members mean the main supporting members of hull, such as web frames, side girders, web beams, deck girders, bottom girders, bulkhead girders, etc.

Secondary members generally mean stiffening members of plate, such as frames, longitudinals, beams, bulkhead stiffeners, etc.

4.3.1.2 The dimensions of brackets are to be determined in accordance with Table 4.3.1.2, and the length of bracket arm means the length of longer bracket arm:

4.3.1.3 Unless specified otherwise, the spans taken for calculating members in this Section are all effective spans between span points. Span points are to be determined as follows:

(1) The span point of secondary members is to be at the connection with the web of primary members. Where effective brackets required by 4.3.1.2 are fitted at the ends of members, the span point is located on the bracket arm at the distance from the toe equal to 25% of the length of the bracket.

(2) The span point of primary members is to be at the supporting point of supporting structure which includes pillars, bulkheads, etc. Where effective brackets required by 4.3.1.2 are fitted at the ends of members, the span point is located on the bracket arm at the distance from the toe equal to 25% of the length of the bracket.

4.3.1.4 The structural members are to be continuous across their supporting points or effectively attached to supporting structure providing full end fixity against inplane rotation. If the supporting structure at the end of the structural member can not satisfy the fixing requirement, the section modulus is to be increased by 50%.

The dimensions of brackets **Table 4.3.1.2**

Length of bracket arm (mm)	Thickness of bracket without flange (mm)	Thickness of flanged bracket (mm）	Width of flange (mm ）
150	6.5	—	—
175	7.0	—	—
200	7.0	6.5	30
225	7.5	6.5	30
250	8.0	6.5	30
275	8.0	7.0	35
300	8.5	7.0	35
325	9.0	7.0	40
350	9.0	7.5	40
375	9.5	7.5	45
400	10.0	7.5	45
425	10.0	8.0	45
450	10.5	8.0	50
475	11.0	8.0	50
500	11.0	8.5	55
525	11.5	8.5	55
550	12.0	8.5	55
600	12.5	9.0	60
650	13.0	9.5	65
700	14.0	9.5	70
750	14.5	10.0	75
800	—	10.5	80
850	—	10.5	85
900	—	11.0	90
950	—	11.5	90
1000	—	11.5	95
1050	—	12.0	100
1100	—	12.5	105
1150	—	12.5	110
1200	—	13.0	110

4.3.1.5 The web height of primary members is generally not to be less than twice the height of notch where secondary members pass through, but the web height of primary members on tank boundary is generally not to be less than three times the height of notch where secondary members pass through.

4.3.2 Deck plating

4.3.2.1 Platform deck plating in enclosed spaces

(1) The thickness of platform deck plating within enclosed cargo spaces is not to be less than:

$$t = m[(skh^{1/2}/254) + t_c] \text{ mm, but not less than 5mm}$$

where: m— material factor for aluminum alloy;

s — spacing of deck beams, in mm;

k — correction factor for plate panel;

h— design head, in m, to be normally the height between decks. When a design load is specified as p(kPa), h is to be taken as 0.142p. h is not to be less than the requirement in 3.4.2.9 of Chapter 3;

t_c— a corrosion allowance, 1.5mm in general.

(2) The thickness of platform deck plating within enclosed passenger spaces is not to be less than:

$$t = m(0.0058s + t_c) \text{ mm, but not less than 4.5mm}$$

where: t_c — a corrosion allowance, 1.0mm in general;

m, s — see 4.2.3.1(1).

4.3.2.2 Weather deck plating

(1) The thickness of weather deck plating is not to be less than:

$$t = m[(skh^{1/2}/254) + t_c] \text{ mm}$$

where: for m, s, k and t_c , see 4.3.2.1(1);

h—design head, in m, h =1.43h_{gs};

h_{gs}—the green-sea head, 2m at forward end, 1m at aft end by linear reduction.

(2) The weather deck is to meet the requirements in 4.3.2.1. The thickness must also be suitable for local surface and deck cargo loads that are in accordance with the vessel’s loading plan.

4.3.2.3 Strength deck plating

Strength deck plating is to comply with the requirements of overall strength, and in addition, local loads are to comply with the requirements in 4.3.2.1 and 4.3.2.2.

4.3.2.4 In way of tanks, the deck plating is to meet the requirements to tanks in 4.3.9.

4.3.3 Deck framing

4.3.3.1 Section modulus of deck beam and longitudinal is not to be less than:

$$W = 585shl^2/\sigma \quad \text{cm}^3$$

where: h — design head, in m, as defined in 4.3.2 and 3.4.2.9 of Chapter 3;

s — spacing of stiffeners, in m;

l — span, in m;

σ— allowable bending stress, in N/mm^2, σ =0.55σ_s.

4.3.3.2 For deck beams and longitudinals at top of tank, in addition to satisfying the requirements of 4.3.3.1, section modulus is not to be less than:

$$W = 877shl^2/\sigma \quad \text{cm}^3$$

where: s, l— the same as those in 4.3.3.1;

h— design head, in m; 2/3 of vertical distance from the top of the tank to the top of the overflow pipe or 0.91m above the top of the tank is to be taken, whichever is greater;

σ— allowable bending stress, in N/mm^2, σ=0.45σ_s.

4.3.3.3 The section modulus of deck girder and web beam is not to be less than:

$$W = 585hbl^2/\sigma \quad \text{cm}^3$$

where: h, l and σ are the same as those in 4.3.3.1;

b— mean breadth of the area of the deck supported, in m.

4.3.3.4 For deck girders and web beams at top of tank, in addition to satisfying the requirements of 4.3.3.3, section modulus is not to be less than:

$$W = 877hbl^2/\sigma \quad \text{cm}^3$$

where: h, l andσare the same as those in 4.3.3.2;

b— mean breadth of the area of the deck supported, in m.

4.3.3.5 Steel deck girders and web beams are to meet the following requirements:

(1) The height of web clear of tanks is not to be less than 0.0583 times the span, and the height of web in way of tanks is not to be less than 0.0833 times the span.

(2) The web thickness is not to be less than (0.01d＋4) mm, where d is the web height, in mm.

(3) Tripping brackets are to be fitted at intervals of about 3m, and where the width of the unsupported face plate on either side of the web exceeds 200mm, the tripping brackets are to support the face plate.

4.3.3.6 Aluminum deck girders and web beams are to meet the following requirements:

(1) The height of web clear of tanks is not to be less than 0.0672 times of the span, and the height of web in way of tanks is not to be less than 0.0958 times the span.

(2) The web thickness is not to be less than (0.018d＋6.5) mm, where d is the web height, in mm.

(3) Tripping brackets are to be fitted at intervals of about 2.25 m, and where the width of the face plate on either side of the web exceeds 150 mm, the tripping brackets are to support the face plate.

4.3.3.7 The shear stress of deck girders and web beams is not to be greater than 67% of the allowable bending stress. Cutouts in the web are to be deducted when calculating shear stress.

4.3.4 Shell plating

4.3.4.1 Shell plating includes shell plate of wet deck, side shell regions of the upper hull, strut and shell plate at both sides of lower hull.

4.3.4.2 The minimum thickness of shell plate is not to be less than the requirements to tank in 4.3.9.

4.3.4.3 For wave impact, the platings of the wet deck, haunch internal surface and strut external surface are not to be less than:

$$t = uskH^{0.5}/J \quad \text{mm}$$

where: s— spacing of stiffeners, in mm;

H— the equivalent head (seawater), in m; $H = P_{des}/10.5$, where P_{des} is design pressure, in kPa, as specified in Section 4 of Chapter 3 or from model testing;

k— correction factor for plate panel;

J— determined according to Table 4.3.4.3;

u— 1.0 for steel, $u = (235/\sigma_s)^{0.5}$ for aluminum alloy.

Factor *J* **Table 4.3.4.3**

Material	*J*
Ordinary steel	304
H32 steel	334
H36 steel	348
Aluminum alloy	304

4.3.5 Shell framing

4.3.5.1 Shell framing is not to have less strength than required for water-tight bulkhead members in the same location. In way of tanks, shell framing is not to have less strength than required for tank members in the same location.

4.3.5.2 The section modulus of frame and longitudinal is not to be less than:

$$W = 877shl^2/\sigma \quad \text{cm}^3$$

where: l— span, in m;

s— spacing of stiffeners, in m;

h— design head, in m, minimum of 2.1 m; for vessels less than 90 m in length, this is given by the vertical distance from the middle of the span to the deck at side; for vessels not less than 90 m in length, at the forward perpendicular, h is given by the vertical distance from the middle of span to the bulkhead deck; aft of amidships, h is given by the vertical distance from the middle of span to a point located at two-thirds of the distance to the bulkhead deck; between the forward perpendicular and amidships, *h* may be linearly interpolated;

σ— allowable bending stress, in N/mm^2, $\sigma = 0.50\sigma_s$.

4.3.5.3 The section modulus of web frames and side stringers is not to be less than:

$$W= 877bhl^2/\sigma \quad cm^3$$

where: h, l and σ, are the same as those in 4.3.5.2;

b— mean breadth of the area of the side supported, in m.

4.3.5.4 The shear stress of the web frame and side stringer is not to be greater than 67% of the allowable bending stress. Cutouts in the web are to be deducted when calculating shear stress.

4.3.5.5 Steel web frames and side stringers are to meet the following requirements:

(1) The web height is not to be less than 0.125 times the span. However, the web height of side stringers need not exceed that of web frames to which they are attached.

(2) In general, the web thickness is not to be less than $(0.01d+3.5)$ mm, where d is the web height, in mm.

(3) Tripping brackets are to be fitted at intervals of about 3m, and where the width of the unsupported face plate on either side of the web exceeds 200 mm, the tripping brackets are to support the face plate.

4.3.5.6 Aluminum web frames and side stringers are to meet the following requirements:

(1) The web height is not to be less than 0.144 times the span. However, the web height of side stringers need not exceed that of web frames to which they are attached.

(2) In general, the web thickness is not to be less than $(0.018d+4.5)$ mm, where d is the web height, in mm.

(3) Tripping brackets are to be fitted at intervals of about 2.25 m, and where the width of the unsupported face plate on either side of the web exceeds 150 mm, the tripping brackets are to support the face plate.

4.3.5.7 The shell framing is to be strengthened for wave impact as follows:

(1) The section modulus of beams on the wet deck, beams of haunch internal surfaces and frames of strut external surfaces is not to be less than:

$$W= 83.3Psl^2/\sigma \quad cm^3$$

where: s— spacing of stiffeners, in m;

l— span, in m;

P— design pressure, in kPa, as specified in Section 4 of Chapter 3;

σ— allowable bending stress, in N/mm^2, $\sigma=0.80\sigma_s$.

(2) The section modulus of girders and supporting structures of the wet deck, haunch internal surfaces and strut external surfaces is not to be less than:

$$W= 83.3Pbl^2/\sigma \quad cm^3$$

where: P, l and σ are the same as those in 4.3.5.7(1);

b— mean breadth of the supporting area, in m.

The shear stress is not to be greater than 67% of the allowable bending stress. Cutouts in the web are to be deducted when calculating shear stress.

4.3.6 Pillars

4.3.6.1 It is to be ensured that the structure at the upper and lower ends of pillars can effectively withstand and transfer loads, and the loads on the pillars are not to be greater than allowable loads.

4.3.6.2 The loads on the pillars P_c are to be calculated in accordance with the following formula:

$$P_c = 7.04abh \quad \text{kN}$$

where: a— mean breadth of area supported, in m;

b— mean length of area supported, in m;

h— calculating head, in m, see 4.3.2.

4.3.6.3 The allowable loads Pp of pillars are to be obtained from the flowing equation:

$$P_p = f\,(m_1 - nl/r)\,A \quad \text{kN}$$

where: l— length of the pillar, in m, the whole length of pillar is taken;

r— minimum inertia radius of cross section of pillar, in cm;

A— cross sectional area of the pillar, in cm^2;

f— 1.0 for steel, $f=\sigma_s/167$ for aluminum alloys;

m_1 and n are specified in Table 4.3.6.3.

Factors m_1 and n **Table 4.3.6.3**

Material	m_1	n
Ordinary steel	12.09	4.44
H32 steel	16.11	7.47
H36 steel	18.12	9.00
Aluminum alloys	10.00	5.82

4.3.6.4 Pillars in tanks are to meet the requirements in 4.3.6.1 as well as the following requirements:

(1) Pillars are to be of solid sections, i.e. hollow and box sections are not permitted, such as tubular pillar and pillar of hollow rectangular section.

(2) The cross sectional area of pillars is not to be less than:

$$A = CP_c/f \quad \text{cm}^2$$

where: f is specified in 4.3.6.3;

C is specified in Table 4.3.6.4;

Factor C **Table 4.3.6.4**

Material	*C*
Ordinary steel	0.1035
H32 steel	0.0776
H36 steel	0.069
Aluminum alloys	0.146

P_c=10.5*abh*, in kN, where *a*, *b* are mean breadth and mean length of area supported respectively, in m; calculating head *h* is taken as 2/3 of vertical distance from the top of the tank to the top of the overflow pipe, in m.

4.3.7 Lower hulls

4.3.7.1 The scantlings of plate bulkhead and flat of lower hulls incorporating interior tank boundary and the longitudinally framed shell and shell frame of lower hulls are not to be less than the requirements for watertight bulkhead as given in 4.3.8, at the same time, they are also to meet the requirement for deep tank as given in 4.3.9, but the design head h is to be determined according to following requirements:

(1) Where the internal space is not a tank, the head is to be taken to a point located at the load line or two-thirds of the distance to the bulkhead deck, whichever is greater.

(2) Where the internal space is a tank, the head h is to be taken to a point located at two-thirds of the distance from the top of the tank to the top of the overflow pipe, or to a point 0.91 m above the top of the tank, whichever is greater, but not less than the requirement of (1).

4.3.7.2 In these calculations, the effects of any local shell plate curvature is generally ignored.

4.3.7.3 The flat structureof non-tank boundary is to satisfy the requirements of 4.3.4 and 4.3.5.

4.3.8 Watertight bulkheads

4.3.8.1 The plate thickness of watertight bulkhead is not to be less than following requirements:

$t=m[(sk(qh)^{1/2}/C)+t_c]$ mm

$t=m(s/200+2.5)$ mm

$t_{min}=6$ mm, if the length of the ship≥100 m

$t_{min}=5$ mm, if the length of the ship＜100 m

where: *m*— material factor for aluminum alloys;

s— spacing of stiffeners, in mm;

k— correction factor for plate panel;

C— for collision bulkhead, *C*=254; for ordinary watertight bulkheads, *C*=290;

q— 1.0 for aluminum alloys, $q=235/\sigma_s$ for steel;

h— design head, in m; vertical distance from the lower edge of the plate strake to the bulkhead deck at center:

t_c— design corrosion allowance, 1.5 mm in general.

4.3.8.2 The section modulus of watertight bulkhead stiffener is not to be less than:

$$W=877shl^2/\sigma \quad \text{cm}^3$$

where: s— spacing of the stiffeners, in m;

l— span of the stiffeners, in m;

h— design head， in m; vertical distance from the middle of the span to the bulkhead deck at the center; For vessels not under 46 meters in length, where the distance is less than 6.10m, h is to be taken at 0.8 times the distance plus 1.22 m.

For bulkheads that are considered to be effective for overall hull bending response,σ=0.45σ_s.

For bulkheads that are not considered to be effective for overall hull bending response, σ= 0.75 σ_s.

4.3.8.3 The section modulus of primary members (girder or transverse supporting members) on watertight bulkheads and flats is not to be less than:

$$W=877bhl^2/\sigma \quad \text{cm}^3$$

where: b— mean breadth of area supported, in m;

l— span, in m;

h— design head, in m, vertical distance from the middle of the area supported to the bulkhead deck at center; however where that distance is less than 6.1 m, the value h is to be 0.8 times the distance plus 1.22 m.

σ— as defined in 4.3.8.2.

The shear stress of the primary members is not to be greater than 75% of the allowable bending stress. Cutouts in the web are to be deducted when calculating shear stress.

4.3.8.4 Stiffeners and primary members on collision bulkheads are to have a section modulus which is at least 25% greater than the value obtained by 4.3.8.2 and 4.3.8.3.

4.3.8.5 Steel primary members are to meet the following requirements:

(1) Webs are to have a height not less than 0.0833 times the span.

(2) In general, the web thickness is not to be less than (0.01d＋3) mm, where d is the height of the web, in mm.

(3) Tripping brackets are to be fitted at intervals of about 3 m, and where the width of the unsupported face plate on either side of the web exceeds 200 mm, the tripping brackets are to support the face plate.

4.3.8.6 Aluminum primary members are to meet the following requirements:

(1) Webs are to have a height not less than 0.0958 times the span.

(2) In general, the web thickness is not to be less than $(0.015d+4.5)$ mm, where d is the height of the web, in mm.

(3) Tripping brackets are to be fitted at intervals of about 2.25 m, and where the width of the unsupported face plate on either side of the web exceeds 150 mm, the tripping brackets are to support the face plate.

4.3.9 Tank bulkheads

4.3.9.1 The scantling of tank bulkhead is to meet the requirements to watertight bulkhead in 4.3.8.

4.3.9.2 The plate thickness of tank bulkhead is not to be less than the following requirements:

$t= m[(sk(qh)^{1/2}/254)+ tc]$ mm

$t= m(s/150+2.5)$ mm

$t_{min}= 6.5$ mm. if the length of the ship ≥100m

$t_{min}= 5.5$ mm, if the length of the ship＜100m,

where: m— material factor for aluminum alloys;

s— spacing of the stiffeners, in mm;

k— correction factor for plate panel;

q— 1.0 for aluminum alloys, $q= 235/\sigma_s$ for steel;

h— design head, in m, the greatest distance from the lower edge of the plate strake to:

(1) a point located at two-thirds of the distance from the top of the tank to the top of the overflow pipe;

(2) a point located 0.91 m above the top of the tank;

(3) load line;

(4) a point located at two-thirds of the distance from the lower edge of the plate strake to the bulkhead deck.

t_c— design corrosion allowance, 2.5 mm in general.

4.3.9.3 The section modulus of stiffeners on tank bulkhead is not to be less than:

$$W= 877shl^2/\sigma \text{ cm}^3$$

where: s— spacing of the stiffeners, in m;

l— span of the stiffeners, in m;

h— design head, in m; the greatest distances from the span center to:

(1) a point located at two-thirds of the distance from the top of the tank to the top of the overflow pipe;

(2) a point located 0.91 m above the top of the tank;

(3) load line;

(4) a point located at two-thirds of the distance from the span center to the bulkhead deck.

For bulkheads that are considered to be effective for overall hull bending response, allowable bending stress $\sigma = 0.45\sigma_s$.

For bulkheads that are not considered to be effective for overall hull bending response, allowable bending stress $\sigma = 0.75\sigma_s$.

4.3.9.4 The section modulus of primary members (girder or transverse supporting members) on tank bulkheads is not to be less than:

$$W = 877bhl^2/\sigma \quad \text{cm}^3$$

where: b— mean breadth of area supported, in m;

l— span, in m;

h— design head, in m, specified in 4.3.9.3;

σ— specified in 4.3.9.3.

The shear stress of primary members is not to be greater than 75% of the allowable bending stress. Cutouts in the web are to be deducted when calculating shear stress.

4.3.9.5 Steel primary members are to meet the following requirements:

(1) Webs are to have a height not less than 0.145 times the span, and webs are to have a height not less than 0.0833 times the span if pillars or struts are fitted.

(2) In general, the web thickness is not to be less than $(0.01d+3)$mm, where d is the height of the web, in mm.

(3) Tripping brackets are to be fitted at intervals of about 3 m, and where the width of the unsupported face plate on either side of the web exceeds 200 mm, the tripping brackets are to support the face plate.

4.3.9.6 Aluminum primary members are to meet the following requirements:

(1) Webs are to have a height not less than 0.167 times the span, and webs are to have a height not less than 0.096 times the span if pillars or struts are fitted.

(2) In general, the web thickness is not to be less than $(0.015d+4.5)$ mm, where d is the height of the web, in mm.

(3) Tripping brackets are to be fitted at intervals of about 2.25 m, and where the width of the unsupported face plate on either side of the web exceeds 150 mm, the tripping brackets are to support the face plate.

CHAPTER 5 STRUCTURAL DIRECT CALCULATIONS

Section 1 General Provisions

5.1.1 General requirements

5.1.1.1 The provisions of this Chapter are applicable to the direct calculation analysis of structural strength of small waterplane area twin hull craft.

5.1.1.2 For first constructed small waterplane area twin hull craft, direct strength analysis of the global hull structure is necessary in general. For the craft type with effective loads as important additional value for design, it is recommended to adopt direct calculation to assess hull structural strength. For small waterplane area twin hull craft navigating in the restriction services and assigned routes, whether direct calculation is used to directly assess hull strength is determined according to sea conditions.

5.1.1.3 For cross-deck structure, especially the wet deck in haunch area, special calculation analysis of local strength is to be carried out.

5.1.1.4 Direct calculation is to be based on loads and load combination defined in Chapter 3 and the allowable stress defined in this Chapter.

5.1.1.5 The recognized finite element analysis programme for structure is to be used for structure analysis.

5.1.1.6 The plate thickness used in the direct calculation in the Guidelines adopts the thickness marked in the drawing (gross thickness). If other methods are used, special consideration is to be given.

5.1.2 Documents submitted for approval

(1) Drawings and drawing list used in calculation.

(2) The following are to be included as a minimum in the calculation report:

① detailed description of calculation model, including extent of structural model and modeling methods, boundary conditions, basic design conditions and load combination, etc., and diagrams of structure calculation model;

② for the applied loads obtained from the model test, the complete and detailed model test information and load calculation method are to be submitted and approved by ISC;

③ calculation results of each combined condition, including deformation of the global structure and its data, stress distribution in each area and the stress values of primary members, collection of maximum yield and buckling stress and calculation summary including unity ratio of maximum working stress and allowable stress;

④ if modification is needed for major structures, the re-analysis calculation report is to be submitted.

(3) Magnetic medium data or electrical neutral text files are to be submitted.

Section 2 Structural Model

5.2.1 Model extent

5.2.1.1 The extent of finite element model for the global structural analysis is to in general cover the overall structure, such as the hull out shell, longitudinal/transverse bulkhead, deck structure, cross deck, haunch, struts and lower hulls, etc.

5.2.1.2 The extent of finite element model for local strength analysis is to center the position of the analysis object and extend to structural supporting members such as bulkhead plate, girder, web frame and web beam, etc. In general, the model extent of cross deck, hauch and wet deck area for structural local strength analysis is to center one transverse bulkhead in ship length direction and extend at least one or more transverse bulkheads forward or afterward; the full ship breadth is taken in ship breath direction; and in the extent of moulded depth, it is to extend from the upper edge of the upper hull to the structural supporting member at 2/3 length of the strut or to the whole lower hull. The strength assessment is based on the calculation result at model center.

5.2.1.3 Three-dimensional finite element model is to be used for analysis.

5.2.1.4 The finite element model for local strength analysis may be inserted in the whole ship finite element model for analysis, or may be picked up or reestablished for individual analysis. For the model for individual analysis, the boundary condition is to be considered in accordance with the requirements in 5.2.3.6.

5.2.2 Element

5.2.2.1 Real structure may be simulated as plate elements, beam elements and rod elements. In general, all areas of shell plates, decks, platforms, ring frames, girders and web frames are to be modeled by 4-node plate (shell) elements. The shell plate on curved surface may be regarded as flat plate element. All stiffeners on various plates which are subject to external sea pressure and cargo pressure are modeled by eccentric beam elements. The stiffeners on girders, floors and stiffeners as well as face plates of frames and brackets are modeled by rod elements. In high stress areas and areas of significant stress changes, such as lightening holes, manholes, positions adjacent to brackets or structural discontinuities, triangular elements are to be avoided or minimized as practicable as possible.

5.2.2.2 The model meshing of finite element in global structural analysis is to be divided according to a longitudinal spacing or a frame spacing, whichever is lesser. Not less than 3 plate elements are to be arranged in height direction for transverse web framing, girder webs, webs of brackets, etc. The aspect ratio of plate element is to be within 3 and the elements are to be divided as square as possible. For lightening holes and manholes of primary members, plate elements of equivalent plate thickness may be used to consider the effect of these openings.

5.2.2.3 For lightening holes, manholes and other openings on the primary members, structural details and structural discontinuities, model of fine finite elements of fine meshing is to be used to describe and simulate accurately, and local strength analysis may be carried out to review the stress and distribution of local area. The size of the mesh is not to be more than 50 mm × 50 mm and the meshes are to be as square as possible.

5.2.2.4 The finite element hot spot stress model for fatigue analysis is to center the hot spot stress point intended to be analyzed from the fine finite element model for local strength analysis, take out a cubic block along round the adjacent supporting structure and then refine the model according to the relevant requirements in ISC Guidelines for Fatigue Strength of Hull Structure.

5.2.3 Boundary condition

5.2.3.1 For the global analysis, the hull structural model is to be in equilibrium state (in balance) under any load combination for all forces, thus the boundary supports is to satisfy the following requirements:

(1) the reaction forces are to be as zero as possible;

(2) any rigid motion of whole model is to be constricted.

Special attention is to be paid to reduce the effect of calculation result for additional stresses and deformation caused by boundary conditions.

5.2.3.2 Boundary conditions are to be determined based on the corresponding structure response and symmetrical condition. To reduce the untrue effect on cross deck and corresponding structure from calculation as much as possible, it is recommended that boundary supports and constriction condition for global model analysis are to be as follows:

① affected by longitudinal and transverse bending moment and horizontal torsional moment, refer to Table 5.2.3.2(1) and Figure 5.2.3.2(1);

② affected by pitching connection (torsional) moment, refer to Table 5.2.3.2(2) and Figure 5.2.3.2(2) (Support C' as the substitution for support C);

③ affected by vertical shear forces at the centre line, refer to Table 5.2.3.2(3) and Figure 5.2.3.2(3).

Alternatives may be adopted if they can truly reflect the structural response to above-mentioned analysis object.

The boundary condition – available for global longitudinal and transverse bending and horizontal torsional moment **Table 5.2.3.2(1)**

Degree of freedom / Support	*X*	*Y*	*Z*	θ_x	θ_x	θ_x
A	Cons.	Cons.	Cons.	—	—	—
B	—	Cons.	Cons.	—	—	—
C(C')	—	— (Cons.)	Cons. (—)	—	—	—

where: Cons.: constriction;

— : free, as same below.

Notes: 1) Combination of A, B and C’ may be used for torsional condition.

2) On longitudinal bending condition, if Z-direction (upward) force is not balanced, additional reaction at support A and B may occur, then the result at A and B may be neglected (this condition is only applicable to observe mid-craft region).

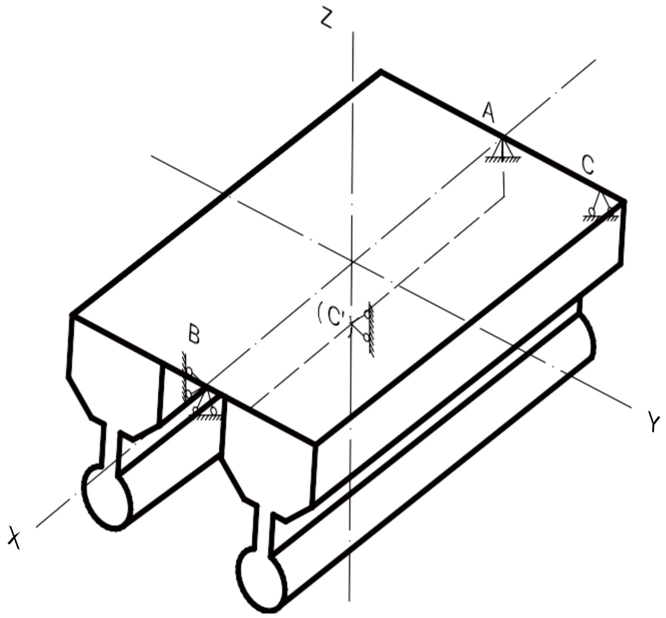

Figure 5.2.3.2(1)

The boundary condition – available for longitudinal torsion and transverse bending

Table 5.2.3.2(2)

Degree of freedom / Support	*X*	*Y*	*Z*	θ_x	θ_x	θ_x
A	Cons.	Cons.	Cons.	—	—	—
B	Cons.	—	Cons.	—	—	—
C(C’)	—(Cons.)	—	Cons.(—)	—	—	—

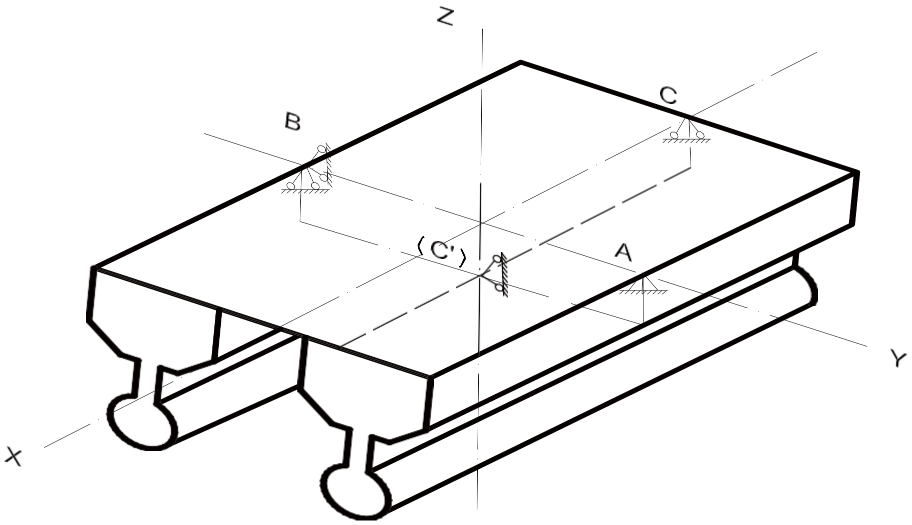

Figure 5.2.3.2(2)

The boundary condition – available for vertical shear forces at the centre line

Table 5.2.3.2(3)

Support \ Degree of Freedom	*X*	*Y*	*Z*	θ_x	θ_x	θ_x
A	Cons.	Cons.	Cons.	—	—	—
B	—	Cons.	Cons.	—	—	—
C	—	Cons.	—	—	—	—
D (provided at the centre line)	—	—	Cons.	—	—	—

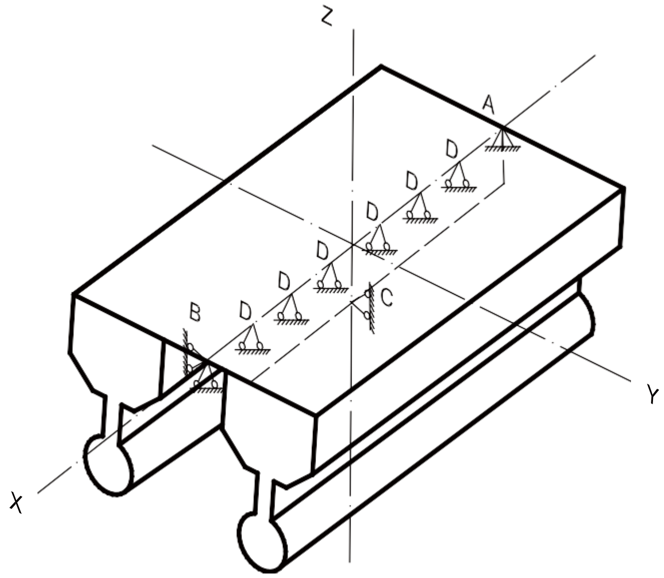

Figure 5.2.3.2(3)

5.2.3.3 For the global finite element model using wave direct calculation, if all external and motion inertia forces are in equilibrium state, the boundary supports and constriction condition are to be arranged by Table 5.2.3.2(1) and Figure 5.2.3.2(1).

5.2.3.4 For the boundary condition of finite element model for local strength analysis and fatigue analysis, adoption of deflection/force response result of global model as boundary stiffness matrix or directly using rigid fixing or simple support as boundary condition depends on the extent of effects on the review results.

Section 3 Yield Strength Check

5.3.1 General requirements

5.3.1.1 Allowable yield stress of structural members is to be obtained according to Table 5.3.1.1:

Allowable equivalent yield stress [σ_{eq}] N/mm² Table 5.3.1.1

Element \ Model	The global finite element model	Local fine finite element model (based on 50 mm × 50 mm mesh）
Plate element	$0.85\sigma_{sw}$	$1.45\sigma_{sw}$ (single element)
Rod element, beam element	$0.60\sigma_{sw}$	——

Note:

① Plate element is calculated according to Von Mises stress, that is:

$\sigma_{eq}=\sqrt{\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y+3\tau_{xy}^2}$ N/mm², and median plane stress (membran stress) at centroid of plate elements is to be considered;

where: σ_x — stress of element in x direction, in N/mm²;

σ_y — stress of element in y direction, in N/mm²;

τ_{xy} — shear stress of element in xy planes, in N/mm².

② Rod element or beam element is calculated according to axial tensile stress, in N/mm².

③ σ_{sw}——yield strength of material, in N/mm²; for aluminum alloys, it means yield strength of material after being welded.

④ For bulkhead, floor, girder web, etc., shear stress of plate element is to be considered (except for local fine finite element analysis). Allowable shear stress is taken as $0.36\sigma_{sw}$, and the average shear stress of the full depth is to be taken for deeper webs.

Section 4 Buckling Strength Check

5.4.1 General requirements

5.4.1.1 Plane plated structures which may occur buckling failure are to be checked for panel buckling strength in accordance with the Guidelines or by a recognized method.

5.4.1.2 The following requirements of buckling strength are only applicable to non-high-speed small waterplane area twin hull craft. Buckling strength of high speed small waterplane area twin hull craft is to be checked according to the requirements in Section 9, Chapter 4 of Rules and Regulations for Construction and Classification of Sea-going High Speed Craft.

5.4.1.3 In the Guidelines, only serviceability buckling limit state of check structure is considered. If the assessment method of ultimate limit state is adopted, ultimate limit strength is to be assessed according to the recognized calculating method and applicable conditions and approved by ISC.

5.4.1.4 In the Guidelines, only unstiffened panels of rectangular plates are considered in panel buckling calculations. The buckling strength of stiffened panel and curved plates may be assessed according to recognized methods and approved by ISC.

5.4.1.5 The buckling strength of plate panels is to be calculated in accordance with the relevant documents of direct calculations of ship structure by ISC, such as the corresponding provisions of ISC Guidelines for Direct Strength Analysis of Oil Tank.

5.4.1.6 Check of buckling strength of stiffeners (such as stiffened framing) is, except for the provisions in 5.4.1.7, to be in compliance with the corresponding requirements in PART TWO of ISC Rules for Classification of Sea-going Steel Ships.

5.4.1.7 For the column buckling mode of stiffeners (such as stiffened framing), the ideal elastic buckling stress is to be calculated according to the following formula:

$$\sigma_E = 0.001E\frac{I_a}{Al^2} \quad \text{N/mm}^2$$

where: E — elastic modulus of material,

$E = 2.06\times10^5$, N/mm^2 for steel;

$E = 0.69\times10^5$, N/mm^2 for aluminum alloy;

I_a — moment of inertia, in cm^4, of stiffener, where the effective width be of attached plate may be taken as:

$$b_e = C_x s \quad mm$$

$$C_x = \begin{cases} \frac{2}{\beta} - \frac{1}{\beta^2} & \beta > 1 \\ 1.0 & \beta \le 1 \end{cases}$$

β — coefficient for slenderness ratio of panel, $\beta = \frac{s}{t}\sqrt{\frac{\sigma_{sw}}{E}}$;

s — in mm, taken as spacing of longitudinals or stiffeners;

t — plate thickness, in mm;

σ_{sw} — see 5.3.1.1;

A — cross-sectional area of stiffener, in cm^2, where the above effective width of attached plate may be taken;

l — spacing of stiffeners, in m;

5.4.1.8 For 5.4.1.7, the compression critical buckling stress σ_{cr} is to be calculated according to the following formula:

$$\sigma_{cr} = \begin{cases} \sigma_E & \sigma_E \le 0.5\sigma_{sw} \\ \sigma_{sw}(1 - \dfrac{\sigma_{sw}}{4\sigma_E}) & \sigma_E > 0.5\sigma_{sw} \end{cases}$$

where: σ_E — ideal elastic buckling stress, in N/mm^2, see 5.4.1.7;

σ_{SW} — see 5.3.1.1.

CHAPTER 6　STRUCTURAL FATIGUE ASSESSMENT

Section 1　General Provisions

6.1.1　General requirement

6.1.1.1　The fatigue strength of small waterplane area twin hull craft is to be calculated in accordance with ISC Guidelines for Fatigue Strength of Hull Structure or by other methods approved by ISC.

6.1.1.2　The possibility of fatigue damages due to cyclic loading is considered in assessment of fatigue strength. As to high stress concentration regions subject to cyclic loading, necessary assessment of fatigue strength is to be carried out in accordance with the relevant requirement of this Section and ISC Guidelines for Fatigue Strength of Hull Structure.

6.1.1.3　Loads for fatigue strength check are to be based on the corresponding tables in Section 2 of Chapter 3, and to be selected as need.

6.1.1.4　The thickness of members of finite element calculation model for fatigue strength check is to be taken in accordance with 1.4.9 of ISC Guidelines for Fatigue Strength of Hull Structure. Other methods will require special consideration.

6.1.2　Locations for fatigue assessment

6.1.2.1　The joints of longitudinals and transverse members (transverse bulkheads and transverse frames).

6.1.2.2　The following locations of transverse bulkhead and/or transverse frames (see figures):

(1)　joints of haunch and struts;

(2)　joints of haunch and wet decks;

(3)　other stress concentrations.

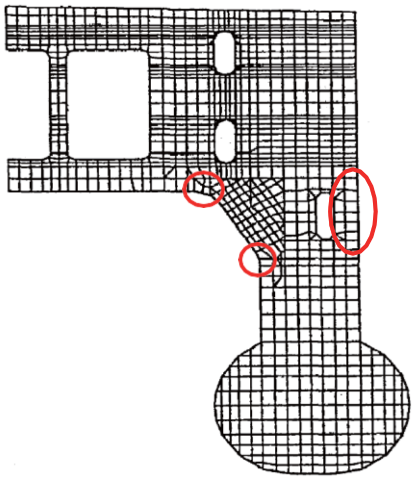

Figure 6.1.2.2(1)　Typical locations for fatigue assessment of transverse bulkhead

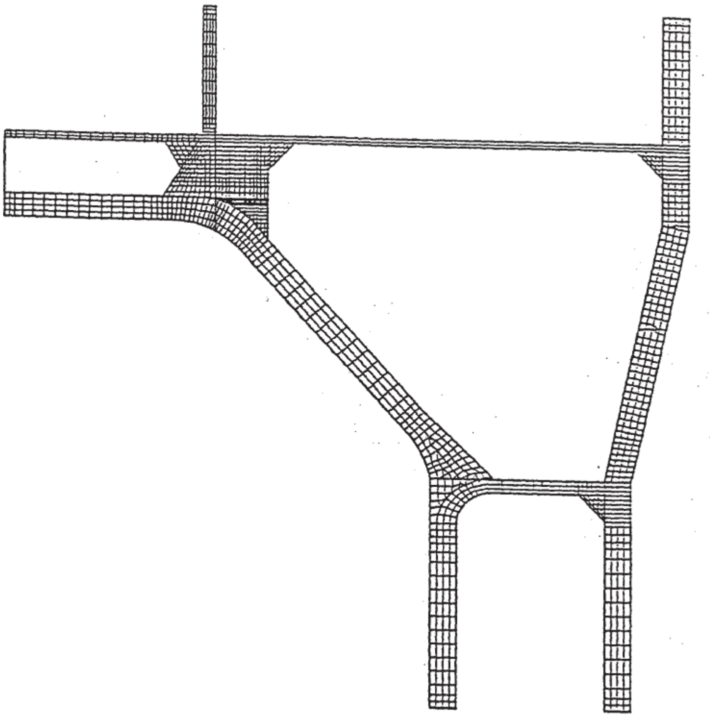

Figure 6.1.2.2(2) Typical locations for fatigue assessment of transverse frame

6.1.3 Long-term distribution of stress range

6.1.3.1 Long-term distribution of stress range of hull structures is assumed as a 2-parameter Weibull distribution, shape parameter ξ of Weibull distribution is determined by the following formula:

$$\xi = 1$$

6.1.4 S-N Curves

6.1.4.1 For S-N curves of steel material, see Section 2.2 of ISC Guidelines for Fatigue Strength of Hull Structure.

6.1.5 Load condition

6.1.5.1 The most probable load condition is to be considered during calculation, of which, the proportion of time distribution among head sea, beam sea and oblique sea is determined by the operation time of 50% of head sea, 25% of beam sea and 25% of oblique sea. See Table 6.1.5.1.

Time distribution coefficient α Table 6.1.5.1

	head sea	beam sea	oblique sea
Distribution coefficient	0.5	0.25	0.25

6.1.6 Calculation of cumulative damage

6.1.6.1 Cumulative damage D of hull structure is to be obtained by the following formula:

$$D = \sum_{i=1}^{3} D_i$$

where: $D_i = \dfrac{0.6\alpha_i \mu K_1 S_{L_i}^3}{18.42^{3/\xi} f_1 K} \times 10^8$;

where: α_i — time distribution coefficient of the corresponding wave direction angle, as shown in Table 6.1.5.1, i=1 for head sea, i=2 for beam sea, i=3 for oblique sea;

K— parameter of S-N curves, to be obtained from Table 6.1.6.1 (1);

S_{Li}— design stress range of the corresponding load condition, in N/mm^2, to be calculated in accordance with the provisions of Chapter 5;

ξ_i— shape parameter, see 6.1.3.1;

K_1— complete GAMMA function value, based on $x = 1 + 3/\xi$ and $\upsilon = \infty$, to be obtained from Table 6.1.6.1(2);

f_1 — correction factor for plate thickness, to be calculated according to the following formulae:

$$f_1 = 1.0 \qquad \text{for } t \leqslant 22$$
$$f_1 = (22/t)^{3/4} \qquad \text{for } t > 22$$

where: t — plate thickness in way of calculating point, in mm;

$$\mu = 1.0 - \frac{\left(K_2 - \upsilon^{-2/\xi} K_3\right)}{K_1}$$

K_2 – incomplete GAMMA function value, based on $x = 1 + 3/\xi$ and υ, to be obtained from Table 6.1.6.1 (2);

K_3 – incomplete GAMMA function value, based on $x = 1 + 5/\xi$ and υ, to be obtained from Table 6.1.6.1 (2);

$$v = 18.42\left(\frac{f_2 S_q}{S_r}\right)^{\xi}$$

S_q — stress amplitude value at intersection point of two segments of S-N curves, to be obtained from Table 6.1.6.1 (1);

f_2 — correction factor for plate thickness, to be calculated according to the following formulae:

$$f_2 = 1.0 \qquad \text{for } t \leqslant 22;$$
$$f_2 = (22/t)^{1/4} \qquad \text{for } t > 22.$$

K and S_q of S-N curves **Table 6.1.6.1(1)**

S-N curves	K	S_q
B	5.800×10^{12}	83.3955
C	3.464×10^{12}	70.2305
D	1.520×10^{12}	53.3680
E	1.026×10^{12}	46.8147
F	6.319×10^{11}	39.8305
F_2	4.330×10^{11}	35.1153
G	2.481×10^{11}	29.1659
W	9.279×10^{10}	21.0136

Appendix 1　GAMMA Function Table

$$\Gamma(x) = \int_0^\infty u^{x-1} e^{-u} du \qquad \gamma(x,\nu) = \int_0^\nu u^{x-1} e^{-u} du$$

Table 1

x \ ν	∞	0.5	1.0	1.5	2.0	2.5
3.4	2.9812064	0.0190124	0.1381650	0.3811613	0.7117815	1.0789950
3.6	3.7170238	0.0155505	0.1290610	0.3836591	0.7535631	1.1853485
3.8	4.6941742	0.0127638	0.1210418	0.3879346	0.8019018	1.3096973
4.0	6.0000000	0.0105097	0.1139289	0.3938547	0.8572592	1.4545432
4.2	7.7566895	0.0086783	0.1075803	0.4013258	0.9202110	1.6228694
4.4	10.136101	0.0071845	0.1018817	0.4102855	0.9914495	1.8182081
4.6	13.381285	0.0059617	0.0967402	0.4206966	1.0717878	2.0447238
4.8	17.837861	0.0049576	0.0920794	0.4325421	1.1621682	2.3073136
5.0	24.000000	0.0041307	0.0878363	0.4458224	1.2636724	2.6117275
5.2	32.578096	0.0034479	0.0839580	0.4605528	1.3775355	2.9647117
5.4	44.598848	0.0028828	0.0804003	0.4767617	1.5051620	3.3741776
5.6	61.553915	0.0024140	0.0771256	0.4944895	1.6481451	3.8494023
5.8	85.621737	0.0020243	0.0741020	0.5137876	1.8082888	4.4012647
6.0	120.00000	0.0016997	0.0713021	0.5347176	1.9876330	5.0425245
6.2	169.40609	0.0014290	0.0687024	0.5573517	2.1884833	5.7881516
6.4	240.83377	0.0012028	0.0662823	0.5817716	2.4134438	6.6557137
6.6	344.70192	0.0010134	0.0640242	0.6080692	2.6654553	7.6658343
6.8	496.60607	0.0008548	0.0619125	0.6363460	2.9478378	8.8427335
7.0	720.00000	0.0007217	0.0599336	0.6667141	3.2643399	10.214864
7.2	1050.3178	0.0006098	0.0580755	0.6992962	3.6191938	11.815666
7.4	1541.3361	0.0005157	0.0563276	0.7342258	4.0171782	13.684453
7.6	2275.0326	0.0004365	0.0546804	0.7716479	4.4636896	15.867460
7.8	3376.9213	0.0003698	0.0531257	0.8117197	4.9648230	18.419083
8.0	5040.0000	0.0003134	0.0516559	0.8546112	5.5274635	21.403345
8.2	7562.2882	0.0002659	0.0502643	0.9005059	6.1593903	24.895617
8.4	11405.887	0.0002256	0.0489449	0.9496015	6.8693938	28.984669
8.6	17290.248	0.0001916	0.0476922	1.0021112	7.6674099	33.775079
8.8	26339.986	0.0001629	0.0465015	1.0582645	8.5646706	39.390092
9.0	40320.000	0.0001385	0.0453681	1.1183082	9.5738762	45.974994
9.2	62010.763	0.0001178	0.0442882	1.1825077	10.709389	53.701106
9.4	95809.457	0.0001003	0.0432580	1.2511485	11.987458	62.770511
9.6	148696.13	0.0000854	0.0422742	1.3245373	13.426463	73.421645
9.8	231791.87	0.0000727	0.0413338	1.4030034	15.047203	85.935914
10.0	362879.99	0.0000620	0.0404340	1.4869011	16.873221	100.64552

Table 2

x \ ν	3.0	3.5	4.0	4.5	5.0	5.5
3.4	1.4401492	1.7677242	2.0481720	2.2781069	2.4603952	2.6010785
3.6	1.6273063	2.0417582	2.4068759	2.7138190	2.9626345	3.1585466
3.8	1.8505973	2.3750080	2.8503873	3.2601479	3.5997824	3.8726130
4.0	2.1166086	2.7802039	3.3991792	3.9462242	4.4098445	4.7898048
4.2	2.4333315	3.2731189	4.0791134	4.8094715	5.4423626	5.9715340
4.4	2.8104382	3.8732825	4.9228649	5.8980088	6.7620044	7.4990046
4.6	3.2596216	4.6048754	5.9717440	7.2737758	8.4533090	9.4797923
4.8	3.7950117	5.4978485	7.2780236	9.0166030	10.626969	12.056684
5.0	4.4336821	6.5893211	8.9079135	11.229514	13.428161	15.419567
5.2	5.1962679	7.9253287	10.945362	14.045640	17.047581	19.821436
5.4	6.1077189	9.5630095	13.496924	17.637241	21.736119	25.599972
5.6	7.1982149	11.573335	16.697980	22.227490	27.824342	33.206676
5.8	8.5042824	14.044535	20.720719	28.105875	35.748433	43.246230
6.0	10.070153	17.086373	25.784353	35.648347	46.084721	56.529757
6.2	11.949419	20.835512	32.168233	45.343697	59.595720	74.146938
6.4	14.207054	25.462234	40.228666	57.828112	77.291547	97.563791
6.6	16.921869	31.178861	50.420523	73.930492	100.51192	128.75535
6.8	20.189515	38.250326	63.324992	94.731894	131.03580	170.38593
7.0	24.126145	47.007429	79.685264	121.64358	171.22790	226.05409
7.2	28.872880	57.863486	100.45243	156.50958	224.23494	300.62609
7.4	34.601266	71.335237	126.84456	201.74147	294.24841	400.68993
7.6	41.519933	88.069117	160.42278	260.49571	386.85677	535.17423
7.8	49.882736	108.87428	203.18923	336.90704	509.51793	716.19226
8.0	59.998699	134.76416	257.71342	436.39581	672.19323	960.19417
8.2	72.244178	167.00868	327.29506	566.07295	888.19902	1289.5407
8.4	87.077727	207.20004	416.17422	735.27386	1175.3508	1734.6547
8.6	105.05828	257.33550	529.80250	956.26251	1557.5017	2336.9628
8.8	126.86743	319.92168	675.19321	1245.1607	2066.6121	3152.9230
9.0	153.33663	398.10589	861.37367	1623.1748	2745.5353	4259.5387
9.2	185.48057	495.84174	1099.9696	2118.2161	3651.7689	5761.9154
9.4	224.53797	618.09784	1405.9610	2767.0418	4862.5095	7803.6205
9.6	272.02164	771.12108	1798.6588	3618.0854	6481.4660	10580.893
9.8	329.77974	962.76861	2302.9689	4735.2001	8648.0483	14362.151
10.0	400.07089	1202.9269	2951.0282	6202.6109	11549.765	19514.768

Table 3

x \ ν	6.0	6.5	7.0	7.5	8.0	8.5
3.4	2.7072930	2.7860296	2.8435006	2.8848968	2.9143737	2.9351534
3.6	3.3091769	3.4227189	3.5068819	3.5683780	3.6127563	3.6444349
3.8	4.0862382	4.2499746	4.3732287	4.4645858	4.5313993	4.5796937
4.0	5.0927767	5.3289023	5.5094075	5.6451272	5.7457193	5.8193455
4.2	6.4012324	6.7417582	7.0061121	7.2077401	7.3591901	7.4714367
4.4	8.1084515	8.5995478	8.9867072	9.2862545	9.5142785	9.6854058
4.6	10.344201	11.052460	11.619485	12.064512	12.407831	12.668729
4.8	13.282749	14.304222	15.134688	15.795861	16.312779	16.710545
5.0	17.158643	18.631876	19.848201	20.830515	21.608822	22.215264
5.2	22.288240	24.413072	26.194570	27.654031	28.825920	29.750526
5.4	29.099114	32.163810	34.773141	36.941551	38.706076	40.115784
5.6	38.170308	42.590684	46.412597	49.634387	52.291288	54.440638
5.8	50.287460	56.663344	62.261441	67.048402	71.049036	74.326142
6.0	66.518443	75.715117	83.915006	91.027625	97.051672	102.04832
6.2	88.317240	101.58295	113.59407	124.16239	133.23336	140.85192
6.4	117.66679	136.80227	154.39636	170.09961	183.75881	195.37522
6.6	157.27562	184.87871	210.65131	233.98479	254.55331	272.26567
6.8	210.84884	250.66737	288.42090	323.09273	354.06597	381.07358
7.0	283.46199	340.90299	396.20803	447.72862	494.37052	535.55193
7.2	382.07723	464.94162	545.95933	622.51752	692.75548	755.54999
7.4	516.25687	635.79962	754.48660	868.25179	974.02448	1069.7763
7.6	699.15048	871.61023	1045.4840	1214.5413	1373.8287	1519.8373
7.8	948.86164	1197.6680	1452.3939	1703.6205	1943.5010	2166.1470
8.0	1290.3420	1649.3007	2022.4822	2395.8218	2757.0775	3096.5906
8.2	1758.0181	2275.9073	2822.6399	3377.4563	3921.5084	4439.2386
8.4	2399.4373	3146.6400	3947.6497	4772.1702	5591.5255	6381.0322
8.6	3280.3319	4358.4074	5531.9762	6757.3273	7991.3128	9195.2766
8.8	4491.6576	6047.1549	7766.5956	9587.6650	11446.127	13282.143
9.0	6159.3842	8403.7753	10923.040	13629.485	16428.491	19228.404
9.2	8458.1208	11696.569	15387.776	19410.118	23625.720	27895.625
9.4	11630.092	16302.974	21711.399	27689.533	34038.769	40550.509
9.6	16011.583	22754.407	30679.078	39564.111	49127.006	59057.738
9.8	22069.808	31799.700	43411.500	56617.137	71020.482	86165.532
10.0	30454.347	44494.876	61509.634	81137.205	102831.38	125928.91

Table 4

x \ ν	9.0	9.5	10.0	10.5	11.0	11.5
3.4	2.9496727	2.9597381	2.9666677	2.9714072	2.9746306	2.9768115
3.6	3.6668319	3.6825323	3.6934546	3.7010008	3.7061822	3.7097208
3.8	4.6142429	4.6387330	4.6559507	4.6679662	4.6762954	4.6820343
4.0	5.8726410	5.9108421	5.9379836	5.9571154	5.9705047	5.9798145
4.2	7.5536510	7.6132396	7.6560255	7.6864881	7.7080118	7.7231141
4.4	9.8122320	9.9051832	9.9726312	10.021136	10.055735	10.080235
4.6	12.864377	13.009371	13.115698	13.192931	13.248551	13.288295
4.8	17.012363	17.238542	17.406159	17.529137	17.618549	17.683023
5.0	22.680872	23.033695	23.297935	23.493754	23.637489	23.742082
5.2	30.468817	31.019201	31.435766	31.747572	31.978637	32.148313
5.4	41.223900	42.082477	42.739182	43.235679	43.607136	43.882398
5.6	56.150160	57.489518	58.524808	59.315406	59.912555	60.359108
5.8	76.963499	79.052883	80.685022	81.943939	82.903917	83.628358
6.0	106.11713	109.37658	111.94968	113.95434	115.49762	116.67288
6.2	147.12920	152.21400	156.27058	159.46277	161.94378	163.85043
6.4	205.05978	212.99226	219.38763	224.47086	228.45944	231.55265
6.6	287.20713	299.58218	309.66488	317.75946	324.17170	329.18993
6.8	404.12569	423.43159	439.32771	452.21768	462.52639	470.66772
7.0	571.11779	601.23654	626.29817	646.82459	663.39765	676.60579
7.2	810.42322	857.41135	896.92356	929.61079	956.25504	977.68354
7.4	1154.4391	1227.7458	1290.0414	1342.0944	1384.9303	1419.6955
7.6	1650.4631	1764.8308	1863.0478	1945.9408	2014.8085	2071.2112
7.8	2367.6913	2546.1210	2700.9742	2832.9800	2943.6999	3035.2077
8.0	3407.5592	3685.9375	3930.0879	4140.3067	4318.3146	4466.7780
8.2	4919.0466	5353.3645	5738.3092	6073.0846	6359.2757	6600.1462
8.4	7121.3583	7798.9753	8405.9118	8939.0488	9399.1741	9789.9704
8.6	10337.585	11394.804	12351.760	13200.799	13940.573	14574.618
8.8	15044.721	16694.213	18203.057	19555.192	20744.584	21773.294
9.0	21948.086	24521.677	26900.710	29054.065	30966.359	32635.405
9.2	32092.177	36107.615	39858.732	43288.106	46362.694	49070.683
9.4	47025.987	53291.125	59205.712	64667.282	69610.645	74004.321
9.6	69049.815	78825.171	88151.099	96849.183	104797.24	111925.97
9.8	101584.11	116836.53	131541.48	145394.14	158173.32	169739.74
10.0	149721.29	173519.77	196706.46	218768.52	239315.49	258082.23

Table 5

x \ ν	12.0	12.5	13.0	13.5	14.0	14.5
3.4	2.9782800	2.9792645	2.9799219	2.9803593	2.9806492	2.9808408
3.6	3.7121238	3.7137484	3.7148419	3.7155750	3.7160647	3.7163906
3.8	4.6859665	4.6886472	4.6904660	4.6916948	4.6925224	4.6930767
4.0	5.9862492	5.9906726	5.9936982	5.9957580	5.9971545	5.9980974
4.2	7.7336439	7.7409430	7.7459757	7.7494370	7.7517868	7.7533906
4.4	10.097466	10.109510	10.117881	10.123669	10.127651	10.130378
4.6	13.316492	13.336366	13.350291	13.359993	13.366717	13.371357
4.8	17.729165	17.761960	17.785122	17.801385	17.812742	17.820632
5.0	23.817590	23.871707	23.910235	23.937495	23.956674	23.970094
5.2	32.271879	32.361180	32.425268	32.470963	32.503350	32.526177
5.4	44.084607	44.231969	44.338573	44.415172	44.469865	44.508691
5.6	60.690015	60.933177	61.110516	61.238917	61.331281	61.397319
5.8	84.169879	84.571154	84.866130	85.081368	85.237350	85.349672
6.0	117.55907	118.22125	118.71193	119.07273	119.33615	119.52720
6.2	165.30067	166.39340	167.20962	167.81444	168.25929	168.58424
6.4	233.92597	235.72919	237.08695	238.10081	238.85208	239.40479
6.6	333.07390	336.04959	338.30819	340.00776	341.27649	342.21659
6.8	477.02393	481.93447	485.69160	488.54065	490.68328	492.28232
7.0	687.00793	695.11147	701.36142	706.13739	709.75589	712.47574
7.2	994.70708	1008.0798	1018.4766	1026.4828	1032.5938	1037.2200
7.4	1447.5554	1469.6238	1486.9189	1500.3402	1510.6606	1518.5295
7.6	2116.8056	2153.2242	2181.9949	2204.4938	2221.9232	2235.3079
7.8	3109.8263	3169.9267	3217.7875	3255.5040	3284.9395	3307.7061
8.0	4588.8973	4688.0796	4767.6976	4830.9249	4880.6369	4919.3619
8.2	6800.0054	6963.6846	7096.1324	7202.1259	7286.0823	7351.9521
8.4	10117.060	10387.179	10607.512	10785.199	10926.990	11039.033
8.6	15109.937	15555.715	15922.253	16220.128	16459.594	16650.176
8.8	22649.408	23385.082	23994.842	24494.204	24898.632	25222.809
9.0	34069.279	35283.378	36297.760	37134.901	37817.934	38369.356
9.2	51417.418	53421.084	55108.594	56512.001	57665.569	58603.536
9.4	77845.106	81151.838	83959.166	86311.888	88260.148	89855.635
9.6	118212.03	123669.29	128339.57	132283.77	135574.20	138288.14
9.8	180027.94	189034.39	196803.90	203416.18	208973.42	213589.89
10.0	274920.73	289784.68	302710.18	313795.40	323181.15	331033.88

Table 6

x \ ν	15.0	15.5	16.0	16.5	17.0	17.5
3.4	2.9809671	2.9810500	2.9811043	2.9811399	2.9811630	2.9811780
3.6	3.7166068	3.7167499	3.7168442	3.7169063	3.7169470	3.7169737
3.8	4.6934471	4.6936938	4.6938575	4.6939659	4.6940375	4.6940847
4.0	5.9987317	5.9991569	5.9994411	5.9996304	5.9997562	5.9998395
4.2	7.7544770	7.7552096	7.7557027	7.7560333	7.7562543	7.7564015
4.4	10.132239	10.133503	10.134359	10.134936	10.135324	10.135584
4.6	13.374543	13.376722	13.378207	13.379215	13.379897	13.380357
4.8	17.826089	17.829846	17.832423	17.834183	17.835381	17.836193
5.0	23.979440	23.985918	23.990389	23.993462	23.995567	23.997003
5.2	32.542183	32.553352	32.561110	32.566476	32.570173	32.572711
5.4	44.536103	44.555360	44.568822	44.578193	44.584688	44.589172
5.6	61.444266	61.477466	61.500828	61.517190	61.528601	61.536525
5.8	85.430077	85.487318	85.527857	85.556429	85.576475	85.590479
6.0	119.66490	119.76359	119.83394	119.88383	119.91905	119.94380
6.2	168.82009	168.99024	169.11232	169.19944	169.26131	169.30504
6.4	239.80872	240.10209	240.31392	240.46605	240.57475	240.65203
6.6	342.90840	343.41421	343.78182	344.04747	344.23842	344.37500
6.8	493.46717	494.33927	494.97718	495.44106	495.77653	496.01790
7.0	714.50503	716.00867	717.11564	717.92567	718.51504	718.94158
7.2	1040.6956	1043.2881	1045.2091	1046.6236	1047.6590	1048.4128
7.4	1524.4822	1528.9521	1532.2857	1534.7557	1536.5748	1537.9068
7.6	2245.5031	2253.2101	2258.9949	2263.3081	2266.5039	2268.8580
7.8	3325.1677	3338.4560	3348.4946	3356.0264	3361.6411	3365.8013
8.0	4949.2689	4972.1805	4989.6011	5002.7534	5012.6175	5019.9695
8.2	7403.1749	7442.6789	7472.9099	7495.8771	7513.2070	7526.1996
8.4	11126.764	11194.877	11247.339	11287.445	11317.892	11340.853
8.6	16800.438	16917.879	17008.920	17078.956	17132.446	17173.024
8.8	25480.172	25682.665	25840.655	25962.956	26056.932	26128.643
9.0	38810.157	39159.300	39433.473	39647.043	39812.148	39938.879
9.2	59358.527	59960.529	60436.326	60809.277	61099.348	61323.313
9.4	91148.765	92186.758	93012.454	93663.728	94173.352	94569.156
9.6	140502.99	142292.74	143725.66	144862.96	145758.32	146457.81
9.8	217383.47	220469.43	222956.12	224942.18	226515.24	227751.43
10.0	337531.50	342852.48	347167.90	350636.15	353399.87	355584.56

Table 7

x \ ν	18.0	18.5	19.0	19.5	20.0	20.5
3.4	2.9811878	2.9811941	2.9811981	2.9812007	2.9812023	2.9812034
3.6	3.7169911	3.7170024	3.7170097	3.7170145	3.7170176	3.7170195
3.8	4.6941156	4.6941359	4.6941492	4.6941579	4.6941635	4.6941671
4.0	5.9998946	5.9999309	5.9999548	5.9999704	5.9999807	5.9999874
4.2	7.7564994	7.7565643	7.7566072	7.7566355	7.7566542	7.7566665
4.4	10.135758	10.135874	10.135951	10.136002	10.136036	10.136059
4.6	13.380666	13.380873	13.381012	13.381104	13.381166	13.381206
4.8	17.836743	17.837113	17.837362	17.837529	17.837641	17.837715
5.0	23.997979	23.998641	23.999089	23.999390	23.999593	23.999729
5.2	32.574446	32.575630	32.576434	32.576979	32.577347	32.577594
5.4	44.592257	44.594371	44.595816	44.596800	44.597466	44.597918
5.6	61.542008	61.545787	61.548383	61.550160	61.551373	61.552198
5.8	85.600223	85.606977	85.611641	85.614852	85.617054	85.618560
6.0	119.96112	119.97319	119.98157	119.98737	119.99137	119.99411
6.2	169.33582	169.35739	169.37246	169.38293	169.39019	169.39521
6.4	240.70674	240.74529	240.77236	240.79128	240.80446	240.81362
6.6	344.47223	344.54113	344.58976	344.62395	344.64789	344.66459
6.8	496.19070	496.31386	496.40124	496.46299	496.50645	496.53693
7.0	719.24871	719.46882	719.62584	719.73739	719.81631	719.87193
7.2	1048.9587	1049.3521	1049.6342	1049.8357	1049.9790	1050.0805
7.4	1538.8771	1539.5801	1540.0872	1540.4511	1540.7113	1540.8965
7.6	2270.5824	2271.8390	2272.7501	2273.4076	2273.8800	2274.2180
7.8	3368.8662	3371.1119	3372.7492	3373.9369	3374.7947	3375.4115
8.0	5025.4169	5029.4307	5032.3727	5034.5184	5036.0759	5037.2013
8.2	7535.8816	7543.0554	7548.3420	7552.2181	7555.0460	7557.0999
8.4	11358.061	11370.883	11380.383	11387.384	11392.519	11396.267
8.6	17203.610	17226.525	17243.596	17256.245	17265.568	17272.408
8.8	26183.005	26223.961	26254.637	26277.486	26294.416	26306.896
9.0	40035.501	40108.702	40163.826	40205.102	40235.841	40258.617
9.2	61495.048	61625.879	61724.936	61799.499	61855.314	61896.877
9.4	94874.397	95108.230	95286.234	95420.929	95522.276	95598.122
9.6	147000.34	147418.27	147738.14	147981.47	148165.49	148303.90
9.8	228715.72	229462.69	230037.50	230477.05	230811.20	231063.77
10.0	357298.50	358633.56	359666.48	360460.53	361067.26	361528.18

Table 8

x \ ν	21.0	21.5	22.0	22.5	23.0	23.5
3.4	2.9812040	2.9812043	2.9812045	2.9812046	2.9812046	2.9812046
3.6	3.7170208	3.7170215	3.7170220	3.7170223	3.7170224	3.7170225
3.8	4.6941695	4.6941710	4.6941720	4.6941726	4.6941730	4.6941733
4.0	5.9999918	5.9999947	5.9999965	5.9999977	5.9999985	5.9999990
4.2	7.7566745	7.7566798	7.7566832	7.7566855	7.7566870	7.7566879
4.4	10.136073	10.136083	10.136090	10.136094	10.136096	10.136098
4.6	13.381233	13.381251	13.381263	13.381271	13.381276	13.381279
4.8	17.837765	17.837798	17.837819	17.837834	17.837843	17.837850
5.0	23.999820	23.999880	23.999921	23.999947	23.999965	23.999977
5.2	32.577761	32.577873	32.577947	32.577997	32.578030	32.578052
5.4	44.598223	44.598429	44.598570	44.598663	44.598725	44.598766
5.6	61.552758	61.553138	61.553394	61.553566	61.553682	61.553759
5.8	85.619588	85.620286	85.620760	85.621081	85.621297	85.621442
6.0	119.99600	119.99729	119.99816	119.99876	119.99916	119.99944
6.2	169.39866	169.40103	169.40266	169.40376	169.40452	169.40503
6.4	240.81995	240.82432	240.82733	240.82939	240.83080	240.83176
6.6	344.67620	344.68425	344.68982	344.69365	344.69628	344.69809
6.8	496.55823	496.57307	496.58336	496.59049	496.59541	496.59879
7.0	719.91098	719.93831	719.95737	719.97062	719.97981	719.98616
7.2	1050.1521	1050.2025	1050.2378	1050.2624	1050.2796	1050.2915
7.4	1541.0279	1541.1207	1541.1860	1541.2318	1541.2638	1541.2862
7.6	2274.4589	2274.6298	2274.7507	2274.8359	2274.8958	2274.9377
7.8	3375.8531	3376.1681	3376.3919	3376.5503	3376.6621	3376.7407
8.0	5038.0112	5038.5915	5039.0058	5039.3004	5039.5092	5039.6567
8.2	7558.5849	7559.6542	7560.4211	7560.9690	7561.3590	7561.6357
8.4	11398.990	11400.961	11402.380	11403.399	11404.128	11404.647
8.6	17277.402	17281.032	17283.660	17285.554	17286.915	17287.889
8.8	26316.054	26322.743	26327.607	26331.130	26333.672	26335.499
9.0	40275.410	40287.734	40296.739	40303.290	40308.038	40311.464
9.2	61927.672	61950.380	61967.048	61979.231	61988.099	61994.527
9.4	95654.593	95696.434	95727.290	95749.945	95766.508	95778.568
9.6	148407.46	148484.55	148541.67	148583.80	148614.73	148637.36
9.8	231253.67	231395.72	231501.46	231579.80	231637.59	231680.03
10.0	361876.42	362138.15	362333.89	362479.57	362587.51	362667.13

Table 9

x \ ν	24.0	24.5	25.0	25.5	26.0	26.5
3.4	2.9812045	2.9812044	2.9812043	2.9812041	2.9812062	2.9812061
3.6	3.7170225	3.7170225	3.7170224	3.7170223	3.7170222	3.7170221
3.8	4.6941734	4.6941735	4.6941735	4.6941735	4.6941735	4.6941734
4.0	5.9999994	5.9999996	5.9999997	5.9999998	5.9999998	5.9999999
4.2	7.7566886	7.7566890	7.7566893	7.7566895	7.7566896	7.7566974
4.4	10.136099	10.136100	10.136101	10.136101	10.136101	10.136102
4.6	13.381281	13.381283	13.381284	13.381284	13.381285	13.381285
4.8	17.837854	17.837856	17.837858	17.837859	17.837860	17.837861
5.0	23.999985	23.999990	23.999993	23.999995	23.999997	23.999998
5.2	32.578067	32.578077	32.578083	32.578087	32.578090	32.578092
5.4	44.598793	44.598812	44.598824	44.598832	44.598837	44.598841
5.6	61.553811	61.553846	61.553860	61.553884	61.553895	61.553901
5.8	85.621540	85.621606	85.621650	85.621679	85.621699	85.621711
6.0	119.99962	119.99974	119.99983	119.99988	119.99992	119.99995
6.2	169.40538	169.40561	169.40577	169.40588	169.40595	169.40600
6.4	240.83241	240.83286	240.83316	240.83336	240.83350	240.83359
6.6	344.69932	344.70016	344.70073	344.70112	344.70138	344.70156
6.8	496.60111	496.60270	496.60379	496.60452	496.60503	496.60537
7.0	719.99053	719.99354	719.99560	719.99701	719.99797	719.99863
7.2	1050.2997	1050.3054	1050.3093	1050.3120	1050.3138	1050.3151
7.4	1541.3017	1541.3125	1541.3199	1541.3250	1541.3285	1541.3310
7.6	2274.9669	2274.9873	2275.0014	2275.0112	2275.0179	2275.0226
7.8	3376.7958	3376.8344	3376.8612	3376.8799	3376.8928	3376.9017
8.0	5039.7606	5039.8334	5039.8844	5039.9200	5039.9447	5039.9619
8.2	7561.8313	7561.9692	7562.0660	7562.1339	7562.1813	7562.2143
8.4	11405.015	11405.276	11405.460	11405.589	11405.680	11405.744
8.6	17288.583	17289.076	17289.426	17289.673	17289.846	17289.968
8.8	26336.807	26337.740	26338.404	26338.875	26339.207	26339.442
9.0	40313.929	40315.695	40316.956	40317.854	40318.491	40318.942
9.2	61999.170	62002.511	62004.907	62006.619	62007.839	62008.706
9.4	95787.315	95793.636	95798.187	95801.453	95803.789	95805.454
9.6	148653.84	148665.80	148674.44	148680.67	148685.14	148688.34
9.8	231711.08	231733.70	231750.13	231762.00	231770.57	231776.72
10.0	362725.63	362768.43	362799.63	362822.28	362838.68	362850.50

CHAPTER 7 MACHINERY

Section 1 General Provisions

7.1.1 General requirements

7.1.1.1 In addition to the requirements in this Chapter, the relevant provisions of ISC Rules for Construction and Classification of Sea-Going High Speed Craft with regard to high speed small waterplane area twin hull craft and of ISC Rules for Classification of Sea-Going Steel Ships with regard to non-high speed small waterplane area twin hull craft are to be complied with.

7.1.2 Material

7.1.2.1 The materials to be used in piping systems are to be suitable for the medium and service for which the system is intended. Generally, stainless steel is not applicable to sea water system.

7.1.2.2 The strength of stainless steel pipes on weather deck is to be equal to that of steel pipes. The wall thickness of air pipes on weather deck is to satisfy the following requirements, but is not necessarily to be more than the deck thickness of the same material:

6.0 mm for external diameter $\leq$ 80mm

8.5 mm for external diameter $\geq$ 160 mm

Intermediate thickness values are to be determined by linear interpolation.

7.1.2.3 The approved pipes made of non-metallic material can be used in the following service systems:

(1) sea water cooling system;

(2) fresh water cooling system;

(3) bilge system;

(4) ballast water system;

(5) air and sounding pipes for ballast water tanks and fresh water tanks;

(6) non-significant pipes not used for conveying inflammable liquid.

7.1.2.4 The application, arrangement, installation and test of non-metallic material are to comply with the relevant requirements of ISC Rules for Classification of Sea-Going Steel Ships.

7.1.3 Operation of valves

7.1.3.1 Sea inlet and outlet valves, bilge valves and valves on the fuel oil and lubricating oil tanks which are higher in position than double bottom tanks are to be arranged for local mechanical manual operation.

7.1.3.2 The power supply failure of the remote control valves is not to cause:

(1) opening of closed valves;

(2) closing of open valves on fuel oil tank and in cooling water system for propulsion service and power generating machinery.

7.1.3.3 An indicator is to be fitted in the control station to indicate whether the remote control operating valve is open or closed. In the event that the direct manual operation is required in addition to remote control operation, means of observing the valve position at the valve location is to be provided.

7.1.3.4 Remote control operation of sea inlet and outlet valves, bilge water valves are not to lose functioning due to the compartments, where they are, being flooded.