RUSSIAN MARITIME REGISTER OF SHIPPING

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RULES

FOR THE CLASSIFICATION AND CONSTRUCTION OF HIGH-SPEED CRAFT

PART II

HULL STRUCTURE AND STRENGTH

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RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF HIGH-SPEED CRAFT

Rules for the Classification and Construction of High-Speed Craft of Russian Maritime Register of Shipping (RS, the Register) have been approved in accordance with the established approval procedure and come into force on 1 March 2023.

The present edition of the Rules is based on the 2018 edition taking into account the amendments developed immediately before publication.

The procedural requirements, unified requirements, unified interpretations and recommendations of the International Association of Classification Societies (IACS) and the relevant resolutions of the International Maritime Organization (IMO) have been taken into consideration.

The Rules are published in the following parts:

Part I "Classification";
Part II "Hull Structure and Strength";
Part III "Equipment, Arrangements and Outfit";
Part IV "Stability";
Part V "Reserve of Buoyancy and Subdivision";
Part VI "Fire Protection";
Part VII "Machinery Installations";
Part VIII "Systems and Piping";
Part IX "Machinery";
Part X "Boilers, Heat Exchangers and Pressure Vessels";
Part XI "Electrical Equipment";
Part XII "Refrigerating Plants";
Part XIII "Materials";
Part XIV "Welding";
Part XV "Automation";
Part XVI "Live-Saving Appliances";
Part XVII "Radio Equipment";
Part XVIII "Navigational Equipment";
Part XIX "Signal Means";
Part XX "Equipment for Pollution Prevention";
Part XXI "Craft for Personnel Transportation".

REVISION HISTORY[1]

(purely editorial amendments are not included in the Revision History)

Amended paras/chapters/ sections	Information on amendments	Number and date of the Circular Letter	Entry-into-force date
Para 5.3.13.3	Para has been deleted	—	01.03.2023
Figure 5.2.8	Editorial amendment of 16.03.2023: Figure has been replaced to rectify a typo	—	01.03.2023

[1] Amendments and additions introduced at re-publication or by new versions based on circular letters or editorial amendments.

1 GENERAL

1.1 Application.

1.1.1 The Rules for the Classification and Construction of High-Speed Craft[1] cover sea-going high-speed transport craft (gliders, hydrofoil boats, air-cushion vehicles, high-speed catamarans) and set down requirements for the design and strength of such craft subject to the Register technical supervision.

1.1.2 These Rules cover hydrofoil boats with two hydrofoils (front and aft) and with three hydrofoils (front, central and aft), as well as amphibious air-cushion vehicles and side-wall craft with a displacement up to 200 t.

These Rules apply to hydrofoil boats and air-cushion vehicles capable of moving in the hull-borne mode on seas of forces not exceeding 5 ($h_{3\%} \leq 3{,}5$ m) and in the main mode (foil- or cushion-borne) on seas with $h_{3\%} \leq 3{,}0$ m at speeds corresponding to Froude numbers $F_{r\Delta} \leq 4{,}5$.

This Part is based on the assumption that the ratios of dimensions of hydrofoil boats and air-cushion vehicles would not exceed the following values:

length-to-breadth ratio:

$L/\mathrm{B} > 4$ for hydrofoil boats,

$L/\mathrm{B} > 3$ for air-cushion vehicles; air-cushion-length-to-breadth ratio:

$2{,}5 \leq L_{ac}/B_{ac} \leq 5{,}0$;

side-wall-height-to-air-cushion-length ratio:

$0{,}068 \leq H_{sw}/L_{ac} \leq 0{,}078$;

side-wall-breadth-to-craft-breadth ratio:

$B_{sw}/B \leq 0{,}2$

1.1.3 These Rules also cover gliders of conventional hydrodynamic configuration (with cuneiform cross sections) and craft with an air pocket beneath the bottom (gliders with bottom specially shaped in the central region and in the stem in order to form an artificial air cushion in the main operating modes, which is limited by side walls). These Rules apply to gliders whose speed corresponds to displacement — related Froude numbers $1{,}0 \leq F_{r\Delta} < 5{,}0$ and the design-length-to-hull-breadth ratio amidships lies between 3,5 and 7,0.

1.1.4 These Rules apply to high-speed catamarans with a displacement up to 2,0001 and a relative speed (Froude number $F_r = V/\sqrt{gL}$) between 0,2 and 1,2.

1.1.5 These Rules apply to craft whose parameters are within the following limits:

length-to-depth ratio:

$5 \leq L/D \leq 20$;

hull rigidity during bending:

$I_{\otimes}/(BL^3) > 3 \times 10^{-7}$.

1.1.6 In order the strength of hull and special devices could be tested, the pilot craft of each project shall undergo trials under conditions stipulated by the trials program. The trials program stipulating the sequence and scope of the trials (including measurements as necessary), method of processing the data obtained and strength checking calculations shall be approved by the Register. The trials shall be held before the craft delivery. The results of the trials shall be submitted for the Register approval.

1.1.7 Hull structures scantlings for the ship's hull, which main dimensions and structures are not covered by These Rules, shall be determined in accordance with the RS-approved procedures as well as ISO standards requirements, e.g. ISO 12215.

[1] Hereinafter referred to as "these Rules".

1.2 Definitions and explanations.

1.2.1 Definitions and explanations referring to general terminology shall be found in 1.1 of Part I "Classification" of these Rules and in Part II "Hull" of the Rules for the Classification and Construction of Sea-Going Ships[1].

1.2.2 For the purpose of this Part, the following definitions have been additionally included.

Flexible seal is the upper part of the flexible skirt structure; it is an elastic reservoir connected to the skirt bag, with or without openings for air discharge in its lower portion.

Diaphragm is a flat air-permeable structure of an elastic material, which is fitted on the perimeter of the generatrix of the flexible seal, connecting the latter to the craft hull and serving to shape it as necessary.

Critical design conditions are ambient conditions that are severer than the worst intended conditions, with the parameters agreed by the Register for a particular craft proceeding from its type and service area.

Hydrofoil installations including the front hydrofoil installation, central hydrofoil installation and aft hydrofoil installation are structures consisting of main and auxiliary (starting) lifting surfaces, stabilizers, stanchions and brackets, which serve to ensure the principal mode of the hydrofoil boat operation.

Floating framing system is a system of hull framing with web members lying above main framing and connected thereto, as well as to the shell plating, by means of spacers.

Worst intended conditions are ambient conditions under which the craft operation is permitted. Such conditions are regulated by the following parameters: permissible wind force and wave height of 3 % exceedance level, minimal air temperature, visibility, water depth and other environmental parameters set down proceeding from craft type and service area.

Conventional framing system is a system of hull framing with web members connected directly to the shell plating and main frames passing through notches in webs and connected to them.

Bottom bearer is a structure fitted beneath the bottom of an air-cushion vehicle for the case of its running on a flat shore or a specially prepared platform.

Guy is a flexible connection between the craft hull and the flexible seal envelope, which serves to minimize the deformation of the flexible skirt and to prevent its intensive vibration.

Pylon is a structure fitted on the upper deck of an air-cushion vehicle and serving for the installation of the air propeller.

Pontoon is the main power component of the air-cushion vehicle hull.

Skirt bag represents structures arranged along the pontoon perimeter and serving, together with the hinged elastic structure of flexible skirt, to seal off the air cushion, as well as for fitting the nozzles of amphibious air-cushion vehicles.

Side walls are structures fitted along the sides under bottom, which serve to seal off the high pressure zone (air cushion) and to ensure the longitudinal and transverse stability of side-wall craft and gliders with an air pocket below the bottom.

Cross-structures of catamarans and side-wall craft are structures used to connect catamaran hulls (side walls). They have the shape of a connecting bridge where the structure is not high, and are represented by three-dimensional structures comprising transverse and longitudinal bulkheads and the structures of decks (platforms), if there are spaces between the hulls.

Stabilizer of an air-cushion vehicle is a structure fitted on the upper deck of the craft to ensure its course stability.

Removable component is a readily removable part of the flexible skirt structure which is fitted low on the flexible seal and serves to reduce resistance to the air-cushion vehicle movement and to extend the life of the main flexible skirt unit.

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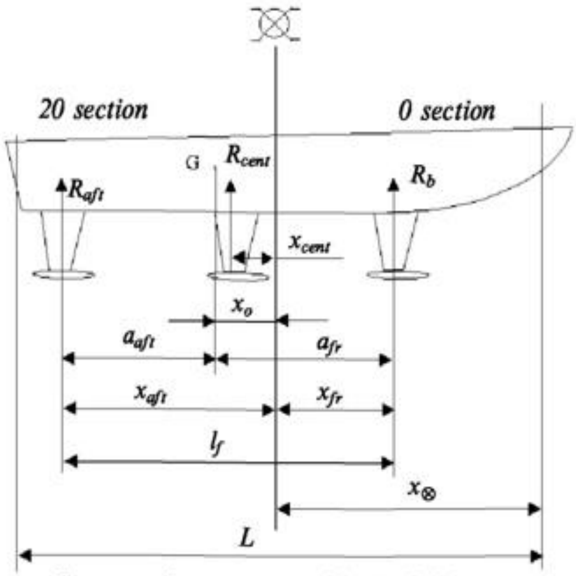
[1] Hereinafter referred to as "the Rules for the Classification".

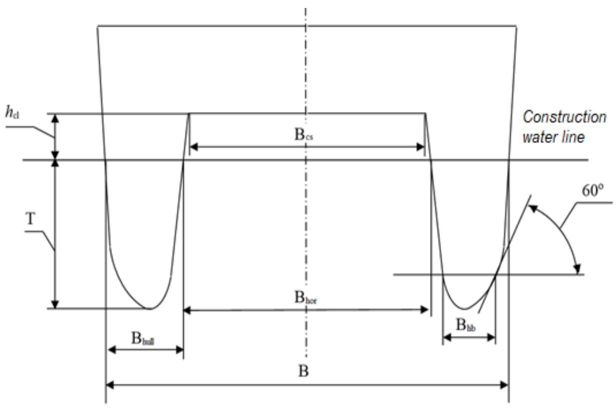
B o o s t i n g t r u n k is a hull structure of an air-cushion vehicle, in which the boosting plant is installed to supply air into the air cushion or skirt bags.

1.3 Symbols.

When interpreting the symbols the explanations below shall be considered, as well as Fig. 1.3:



Structural parameters of hydrofoil boat



Structural parameters of catamaran

Fig. 1.3

L = craft length, in m, between perpendiculars;
B = craft breadth, in m;
D = depth, in m;
Δ = total displacement, in t, of craft;
∇ = cubic displacement, in m^3, of craft;
L_{ac} = air-cushion length, in m;
B_{ac} = air-cushion breadth, in m;
S_{ac} = air-cushion area, in m^2;
B_{sw} = side-wall breadth, in m;
H_{sw} = side-wall height, in m;

H_{fs} = flexible-skirt height, in m;

α = waterline area coefficient of fullness;

h_{cl} = vertical clearance, in m (for high-speed catamarans and side-wall craft, this is the distance between the undisturbed surface of liquid and the connecting bridge at midlength section, and for hydrofoil boats it is the distance between the undisturbed surface of liquid and the keel line);

$h_{cl} = h_{cl}/h_{3\%}$=relative clearance of craft;

$h_{3\%}$ = wave height of 3 % exceedance level, in m, for which provision is made in the craft design for the relevant motion pattern and which shall be adopted on the basis of the scale currently used in the Russian Federation;

$h = h_{3\%}/\sqrt[3]{\nabla}$=relative wave height;

l_{fi} = distance, in m, between the front and aft foil installations;

a_{fr} = distance, in m, between the front foil installation and the mass centre of the craft;

a_{aft} = distance, in m, between the aft foil installation and the mass centre of the craft;

x = distance, in m, between the craft cross section under consideration and the transom;

x_{mid} = abscissa, in m, of the craft cross section under consideration, as measured from the midlength section;

x_g = distance, in m, between the transom and the mass centre of the craft;

$\overline{x}_g$=x_g/L = relative distance, in m, between the transom and the mass centre of the craft;

$x_{fr}, x_{cent}, x_{aft}$ = distance, in m, between the midlength section and the front, central and aft foil installations accordingly;

$x_{\otimes}$ = distance, in m, between the midlength section and the forward perpendicular;

l_{fr} = distance, in m, between the front foil installation and the mass centre of the craft;

x_0 = distance, in m, between the mass centre of the craft and the midlength section;

m_x = craft mass per metre;

ρ_x and ρ_y = inertia radii, in m, of the craft hull mass with regard to the longitudinal and transverse axes accordingly which pass through the mass centre of the craft;

I_x and I_y = inertia moments, in kg-m^2, of the craft hull mass with regard to the longitudinal and transverse axes accordingly which pass through the mass centre of the craft;

$I_{\otimes}$ = inertia moment, in m^4, of hull cross section at midlength;

W = moment of resistance of hull cross section;

V = craft speed, in knots, in the motion pattern under consideration with the specified intensity of the sea $h_{3\%}$;

V_{hb} = craft speed, in knots, in the hull-borne mode (for air-cushion vehicles, V_{hb} will not generally exceed 3 knots proceeding from the flexible skirt strength);

V_{lift} = speed at which a hydrofoil boat reaches the condition when it is borne by the front hydrofoil installation, to be determined by the maximum resistance value;

$Fr_{\Delta} = 0{,}514V/\sqrt{g\nabla^{1/3}}$ = Froude number by displacement;

$Fr_L = 0{,}514V/\sqrt{gL}$ = Froude number by length;

$n = \ddot{y}/g$ = relative acceleration (overload);

n_g = relative acceleration at the centre of mass of the craft when it moves as a solid body;

$\ddot{y}$ = vertical acceleration, in m/s^2, in the hull sections;

C_y^{max} = maximum lifting force coefficient of foil component section, to be determined by experiment;

$R_{fr.}$, R_{cent} and R_{aft} = forces, in t, taken by the front, central and aft foil installation respectively;

$P_{fr.st.w.}$, $P_{cent.st.w.}$ and $P_{aft.st.w.}$ = forces, in t, taken by the front, central and aft foil installation respectively when moving on still water;

$C_{fr.}$, C_{cent} and C_{aft} = lifting force buildup coefficient for the front, central and aft foil installation respectively on the seas as compared to still water;

P_{des} = design force, in t, acting upon the foil installation as a whole and equal to, respectively:

P_{fr}^{max} for front foil installation, in t;

P_{cent}^{max} for the central foil installation, in t;

P_{aft}^{max} for the aft foil installation, in t;

P_{comp} = design force, in t, acting upon the foil installation component in question;

S_{fi}= horizontal-plane projection area, in m^2, of the submerged part of foil installation lifting surface;

S_{comp} = horizontal-plane projection area, in m^2, of the submerged part of the foil installation component in question;

S_{str} = projected area, in m^2, of submerged parts of stanchions and inclined components of foil installation on the centre plane;

β = dead-rise angle, in deg, of the inclined component of foil installation;

g = 9,81 m/s^2 = gravity acceleration;

ρ = 1 t/m^3 (kN-s^2/m^4)= water density;

γ = 10 kN/m^3 = seawater density;

M_{sag}, M_{hog} = design bending moments in hull cross sections during hull sagging and hogging accordingly;

$M_{st.w.}^{sag}$, $M_{st.w.}^{trans}$ = longitudinal and transverse bending moment, in tm, accordingly, on still water in the motion pattern under consideration;

$M_{w.}^{sag}$, $M_{w.}^{hog}$, M_{w}^{trans}, M_{w}^{tw} = wave component, in tm, of bending moment for the case of longitudinal (sagging and hogging) and transverse bending accordingly, as well as for hull twisting, in the motion pattern under consideration;

$M_{d.}^{sag}$, $M_{d.}^{hog}$, M_{d}^{trans}, M_{d}^{tw} = dynamic component, in tm, of bending moment for the case of longitudinal (sagging and hogging) and transverse bending, accordingly, as well as for hull twisting, in the motion pattern under consideration;

$M_{des.}^{sag}$, $M_{des.}^{hog}$, M_{des}^{trans}, M_{des}^{tw}= design values, in tm, of bending moment for the case of longitudinal (sagging and hogging) and transverse bending, as well as for hull twisting, in the motion pattern under consideration;

$M_{st.w.}^{\otimes}$, $M_{w.}^{\otimes}$, $M_{de}^{\otimes}$, $M_{des}^{\otimes}$ = relevant bending moment values, in tm, in the midlength section;

M_{cp} = centre-plane bending moment value, in tm, for the case of transverse bending of hull of a side- wall craft;

M_{ult}= ultimate bending moment, in tm;

$Q_{st.w.}^{sag}$, $Q_{st.w.}^{hog}$, $Q_{st.w.}^{trans}$ = shearing force, in t, for the case of longitudinal (sagging and hogging) and transverse hull bending, accordingly, in the motion pattern in question;

$Q_{w.}^{sag}$, $Q_{w.}^{hog}$, Q_{w}^{trans} = wave component, in t, of shearing force for the case of longitudinal (sagging and hogging) and transverse hull bending, accordingly, in the motion pattern in question;

$Q_{d.}^{sag}$, $Q_{d.}^{hog}$, Q_{d}^{trans} = dynamic component, in t, of shearing force for the case of longitudinal (sagging and hogging) and transverse hull bending, accordingly, in the motion pattern in question;

$Q^{sag}_{des.}, Q^{hog}_{des.}, Q^{trans}_{des}$ = design values, in t, of shearing force for the case of longitudinal (sagging and hogging) and transverse hull bending, accordingly, in the motion pattern in question;

σ_0 = dangerous normal stresses, in kPa;

R_{p02} = yield strength, in kPa, of aluminum alloy;

R_{eH} = upper yield stress of steels, in MPa;

R_m= ultimate strength of material, in kPa;

σ_{per} = permissible normal stresses, in kPa;

σ_{cr} = critical normal stresses, in kPa;

σ_e = Euler buckling stresses, in kPa;

τ_n= shear yield strength of material, in kPa;

τ_0= dangerous normal stresses, in kPa;

τ_{cr} = critical normal stresses, in kPa;

τ_{per} = permissible normal stresses, in kPa;

T = maximum strain of flexible skirt material, in kN/m;

R^b = breaking strengh of flexible skirt material, in kN/m;

x_t =distance, in m, between the point under consideration (hull section under consideration) and transom;

$B_{\otimes}$ = hull breadth, in m, at midlength over the bilge;

B_{tr} = transom breadth (distance between chine lines in way of aft perpendicular), in m;

B_3 = hull breadth over the bilge in way of 3d section;

β_a = dead-rise angle, in deg, for the hull section in question;

β_3 = dead-rise angle, in deg, for 3d hull section;

$\beta_{\otimes}$ = dead-rise angle, in deg, for midlength section;

β_{tr} = dead-rise angle, in deg, in way of transom;

$\beta_{av} = (\beta_{\otimes} + \beta_{tr})/2$ = average dead-rise angle, in deg;

B_{hull} = hull breadth, in m, at midlength on construction waterline level;

B_{hor}= horizontal clearance = inter-hull distance, in m, in the midlength section, as measured on the construction waterline plane;

B_{hb}= hull breadth, in m, at midlength, as measured over the waterline corresponding to hull immersion up to the bilge level;

j = section number;

B_{cs}= cross-structure breadth (inter-hull distance on the cross-structure level), in m;

S_a = area, in m^2, supported by a hull element (load removal area); for plates, the supported area shall be adopted equal to the product of the stiffener span (spacing) and the value corresponding to the greater side length of the plate or to three times the spacing (whichever is less);

T = craft draught, in m, in still water;

x_{mid} = abscissa, in m, of the point under consideration, as counted from the midlength section (a negative value where the point lies aft of midsection);

y = distance, in m, between the hull point under consideration or its longitudinal section, and the centre plane;

Z_i= distance, in m, between the point under consideration and the design waterline level;

$b(x)$ = hull breadth, in m, in the cross section under consideration with the x abscissa.

1.4 Scope of technical documentation is given in Section 5 of Part I "Classification" of these Rules.

1.5 Materials of hull and special devices.

1.5.1 Hull materials of HSC and foil installations of hydrofoil boats shall be in accordance with the requirements of Part XIII "Materials" of these Rules.

These Rules provide for aluminum-magnesium alloys to be used for hull structures, for stainless steels and titanic alloys to be used for foil installations, and for rubber cloth or other polymer materials up to 6 mm thick to be used for flexible skirt. For auxiliary (take-off) components of foil installations, which ensure passing to the foil-borne mode, aluminum-magnesium alloys may be used.

Material grades for flexible skirts shall be chosen on the basis of strength analysis to be carried out in accordance with 5.7 of this Part. Material for flexible skirts shall meet the requirements in Part XIII "Materials" of the Rules for the Classification.

1.6 Welding joints, welding consumables, procedures of welding, control and testing of welding joints shall meet the requirements of Part XIV "Welding" of these Rules.

2 HULL DESIGN PRINCIPILES

2.1 GENERAL

2.1.1 This Part covers hull structures and special devices produced by welding (electric arc, gas- shielded, resistance welding, etc.), riveting, glued riveting and pressure-contact glued welding.

2.1.2 When designing the hull structures of high-speed craft, requirements shall be considered for their strength and life providing a minimal weight and optimal construction procedure. These requirements shall be complied with during all stages of the craft design.

2.1.3 For hull-structural design, provision shall be made for all-pressed and glued-welded panels to be used as widely as practicable, and the components, units and sections forming the hull shall be standardized and typified. As far as practicable, panels (structural blanks) having the largest dimensions shall be used to reduce the number of welded and, in particular, riveted joints in hull structures.

Generally, welded hull structures shall be stipulated in the design. The main welding procedure shall be fusion welding. Riveted joints and spot welds may be used where welding is not feasible or inexpedient due to technical or structural reasons, especially when joining non-weldable or limited-weldable materials, or those which may involve impermissible structural deformations during welding. In welded structures, riveted joints may be applied as barriers (stoppers) for limiting crack propagation.

2.1.4 With all-pressed and glued-welded panels, the floating (longitudinal or transverse) framing system shall be applied to get the utmost of the structural and technical advantages afforded by using the panels. In areas to which considerable concentrated forces are applied, the main framing shall be fitted directly on the shell plating or be aligned with panel stiffeners.

2.1.5 Within the hull, transition from the floating to the conventional framing system shall be effected in way of main framing (stringers, web frames, bulkheads, platforms, etc.).

2.1.6 Along the length and breadth of the hull, a smooth transition of sectional dimensions and plate thickness may be effected in conjunction with the variation of forces due to the total longitudinal and transverse bending of the hull, which shall be substantiated by a relevant strength analysis.

2.1.7 No abrupt variation of plate thickness and section depth is permitted. The difference of butted plates shall not exceed 40 % by thickness (except specially strengthened areas, in way of opening angles, for instance).

Provision for a smooth section depth variation shall be made at intersections with web framing members (stringers, frames, bulkheads, etc.).

2.1.8 All rectangular hull openings and those of other shapes shall have their comers rounded.

For longitudinal hull members, the angle rounding radii shall be at least as follows (whichever is greater):

5 member web thicknesses;

0,15 of the length of the shorter opening side;

30 mm.

2.1.9 For bearing structures, the spot and seam welding is permitted for components up to 3 mm thick.

2.1.10 For bearing structures with the thickness $S \geq 5{,}0\ \mathrm{mm}$, indirect deep penetration welding of butt welds may be permitted. Indirect welding shall not be applied in areas of intensive vibration.

2.1.11 During hull structures manufacture it shall be possible to apply the maximum number of mechanized welding procedures and to make the majority of welds in the downhand position.

2.1.12 The Rules consider standard joints of structural components. When designing new projects, the standard structural components recommended may be optimized and corrected proceeding from the requirements for the particular structure.

2.1.13 Where main hull structures include components essentially different from the standard ones, the former shall undergo full-scale testing in accordance with a program approved by the Register.

2.1.14 For decks, bottom, sides, longitudinal bulkheads, skirt bags and solid superstructures, the longitudinal (conventional or floating) framing system shall be applied. For the hull, mixed framing system is permissible, as well as transverse flaming system for the superstructure.

For additional framing members, a transition from one system to the other is permitted.

In areas to which considerable concentrated forces are applied, web framing members shall be attached directly to the shell plating.

2.1.15 Hull member scantlings shall be determined on the basis of the overall and local strength analysis. The scantlings to be determined by the overall strength analysis for the midlength hull section shall be observed within $0{,}4L$ ($0{,}2L$ forward and aft of midlength) of the midlength region.

2.1.16 Ensuring the continuity of longitudinal bulkheads is mandatory. Where longitudinal members terminate, provision shall be made to ensure smooth variation of their scantlings together with other measures aimed at reducing stress concentration. Where the continuity of members is impaired, including an abrupt change of their direction, a relevant structural solution shall be provided.

2.1.17 Not more than two main longitudinals of decks, sides and bottom (carlings and stringers), symmetrical to the centreline plane, shall terminate in the same hull cross section.

2.1.18 Unless expressly stipulated otherwise in the Rules, provision shall be made for the depth of main longitudinal members of decks, sides and bottom (centreline girder, side and bottom stringers and carlings) to be reduced over a length ≥1,5 of the member depth where these members terminate.

Longitudinal member ends shall be led to the nearest transverse member and connected thereto.

2.1.19 In areas of intensive vibration, as well as in tanks where penetrated by girders or where brackets rest upon tight structures, provision shall be made for stiffeners, shelves or other structural elements to prevent hard spot formation in welded structures.

2.1.20 Openings shall be avoided in strength deck, skirt bag, carlings, centreline girder, stringers and floors. If openings are made in the above members, the latter shall be strengthened. The design of strengthening shall allow for lost area compensation together with reducing the stress concentration. The edges of the openings shall be smooth.

2.1.21 The openings for air supply in the deck plating and cross-structure of side-wall craft shall be strengthened with vertical fillets along their contour, and the plating proper shall be thickened.

2.1.22 Rectangular openings in deck, sides and longitudinal bulkheads shall be arranged with their greater side along the ship's length.

For small rectangular openings (where the opening breadth or the total breadth of openings in a particular ship cross-section would not exceed half the ship breadth), the angle rounding radius shall not be less than:

0,15 of the lesser side of the opening;

10 times the shell plating thickness;

50 mm.

2.1.23 The plate edges shall he not nearer than 1/3 of the opening length to the opening edge, but in any case the distance shall not be less than $2r$ where r is the rounding radius of opening.

2.2 GIRDER ATTACHMENT

2.2.1 For longitudinals, pressed symmetrical bulb and tee-sections shall be used, or pressed panels with symmetrical ribs of bulb or tee-cross-sections.

In structures incorporating riveted, glued-riveted or glued-welded joints, pressed or bent sections of other shapes may be used (angle bulbs, angles, Z-sections).

For bottom, side and deck longitudinals (including superstructures and deckhouses), skirt bag and side walls, unsymmetrical bulb sections and angles may be used. With the floating framing system, the torsion rigidity of unsymmetrical section girders shall be ensured.

It is recommended that web framing members (web frames, floors, side wall brackets, carlings, web beams, stringers, etc.) are made of pressed sections and panels. Welded sections may also be used.

With the conventional framing system, tee-sections shall be mainly used for web members, and with the floating system, I-sections shall be used.

2.2.2 Framing members shall be butt-welded. No lap welding is permitted.

2.2.3 In welded-section butts, the distance between flange butts and web butts shall be adopted not less than half the girder depth.

2.2.4 The web beam depth variation shall take place in way of rigid members (bulkheads, stringers, web frames, beams, etc.) where brackets shall be fitted (refer to Fig. 2.2.4-1).

Where the transitional depth $5(H-h) \geq l$ (refer to Fig. 2.2.4-2), the sectional depth between rigid members may be varied.

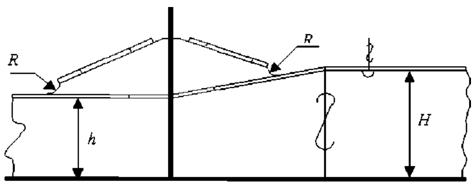
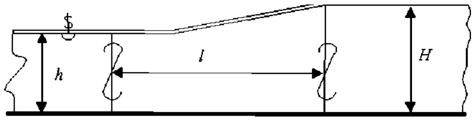


Fig. 2.2.4-1



$l \geqslant 5\ (H-h)$

Fig. 2.2.4-2

2.2.5 The dimensions of brackets connecting the frames in welded structures shall be chosen on the basis of directions contained in the figures of this Part. The bracket thickness shall be chosen equal to the minimal section web thickness of the frame(s) connected (fixed). Deviation from recommended thickness shall be well grounded in each case.

Where necessary, free bracket edges shall be strengthened with face plates which shall be 1 mm thicker than the brackets. Forward-bent flanges may also be used.

The free ends of bracket face plates or flanges shall be snipped on a length equal to 1,5 the bracket face plate (flange) breadth. The blunting length shall be adopted not greater than three times the face plate (flange) thickness. The distance between the face plate end and the blunted bracket shall not be less than two times the bracket thickness. In the case of highly stressed structures working under alternating loads, the above blunted edges shall be rounded to a radius (refer to Fig. 2.2.5).

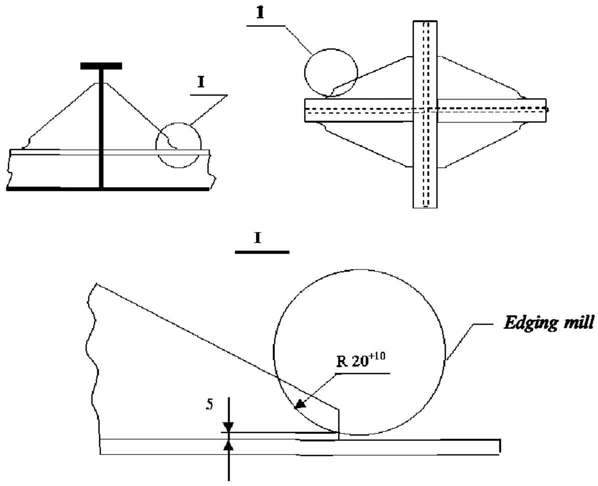


Fig. 2.2.5

2.2.6 Brackets, section webs and other permeable plate structures shall be cut in accordance with Fig. 2.2.6.

N o t e . In non-essential structures, an out with a side size $a = r$ is permitted instead of a cut on the radius r for weld passage.

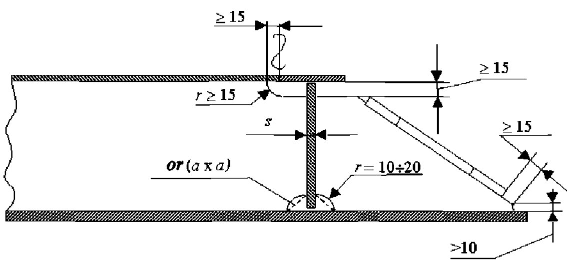


Fig. 2.2.6

2.2.7 Where girders terminate, the flanges and webs of the latter shall be snipped over a length equal to 1,5 flange breadths or 1,5 web depth accordingly, with an unbevelled edge area (blunting) to be left on the free end, equal to three times the flange thickness for flanges and to three times the web thickness at least for webs. Provision shall be made for leaving a distance between the flange end and the girder web end of two times the web thickness at least or 15 mm, whichever is greater (refer to Fig. 2.2.7).

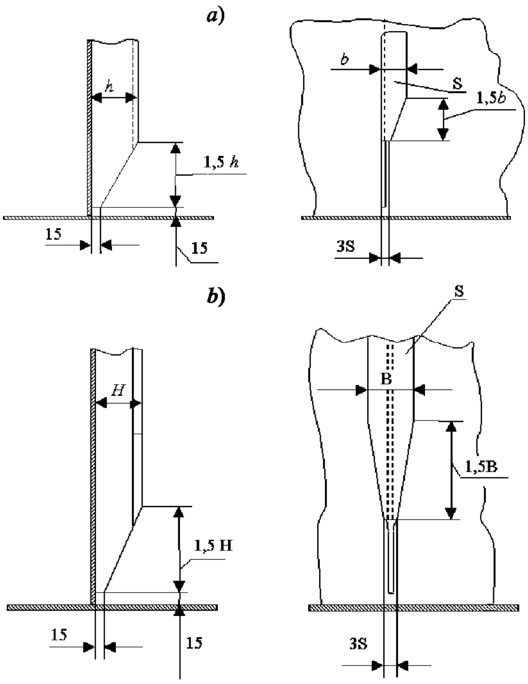


Fig. 2.2.7

2.2.8 The edges of brackets, section webs and connecting plates shall be boxed and shall have no craters.

2.2.9 Where the floating or conventional framing system is applied, the main longitudinal hull members shall be continuous between transverse bulkheads. If the longitudinal and transverse girders of conventional framing have equal depth, the longitudinal girders may be intercostal in way of floors.

The vertical stiffeners of transverse and longitudinal bulkheads shall be continuous between the bottom and deck, as well as between decks. Stiffeners may be terminated on the additional shelf.

2.2.10 Main longitudinal hull members shall be connected to transverse watertight bulkheads and floors in conformity with Figs. 2.2.10-1 and 2.2.10-2. Web girders shall be connected to plate edges in conformity with Fig. 2.2.10-3.

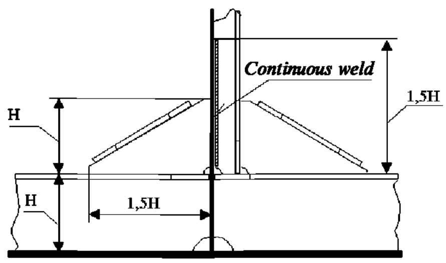


Fig. 2.2.10-1

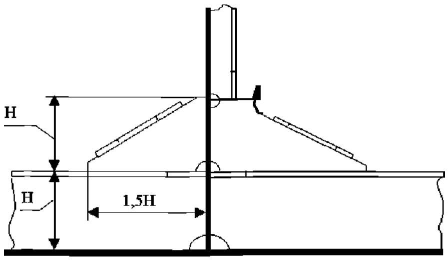


Fig. 2.2.10-2

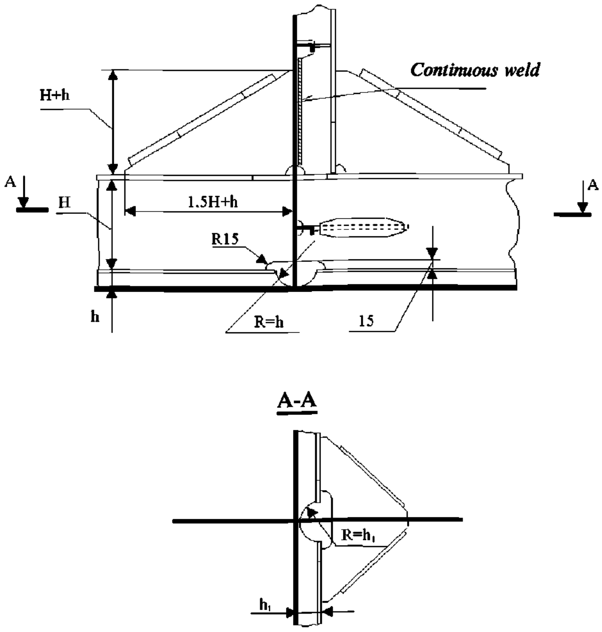


Fig. 2.2.10-3

2.2.11 With the floating framing system, longitudinal frames, except the centreline girder (refer to 2.2.9), whose depth is equal to that of transverse frames shall be intercostal frames. Connecting assemblies shall be in compliance with Fig. 2.2.11-1.

Assemblies connecting main longitudinal frames to transverse frames of lesser depth shall be in conformity with Figs. 2.2.11-2 and 2.2.11-3. Where the difference in the depth of a longitudinal member is small as compared to that of a cross girder, the connecting assembly may include brackets (refer to Fig. 2.2.11-4) or restraints (refer to Fig. 2.2.11-5).

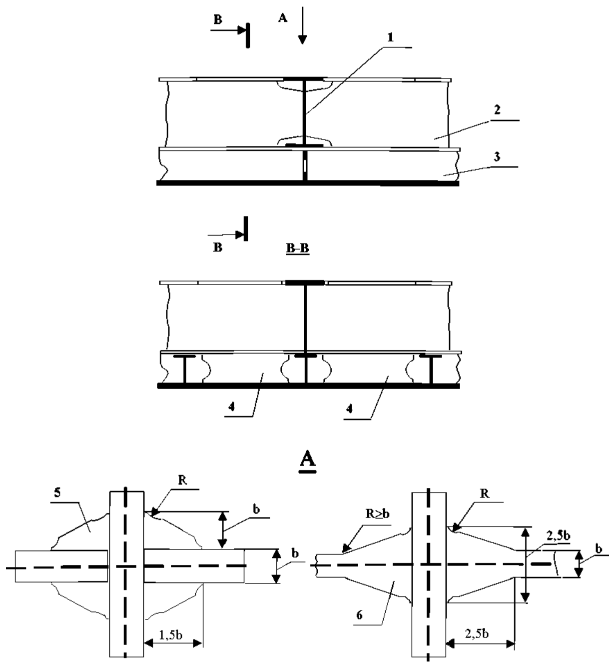


Fig. 2.2.11-1:

1 – floor, *2* – bottom stringer, *3* – bottom longitudinal,
4 – connecting plate, *5* – horizontal bracket, *6*–face plate expansion

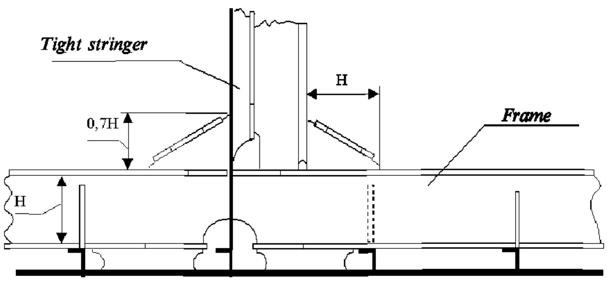


Fig. 2.2.11-2

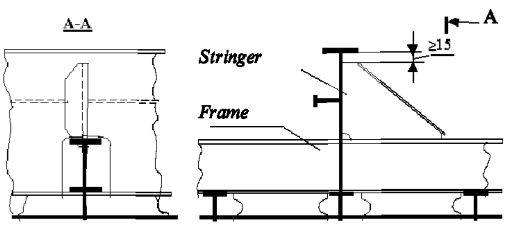


Fig. 2.2.11-3

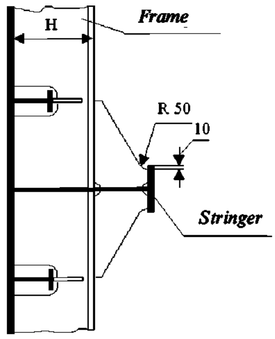


Fig. 2.2.11-4

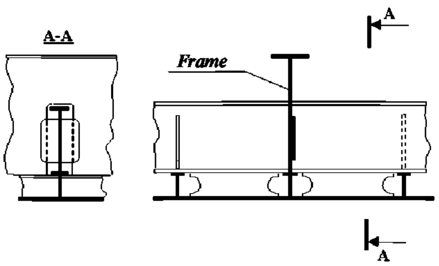


Fig. 2.2.11-5

2.2.12 With the floating framing system, floors shall be connected to the centre girder in accordance with Fig. 2.2.12-1 or 2.2.12-2 (flat or raised bottom) proceeding from their relative depth.

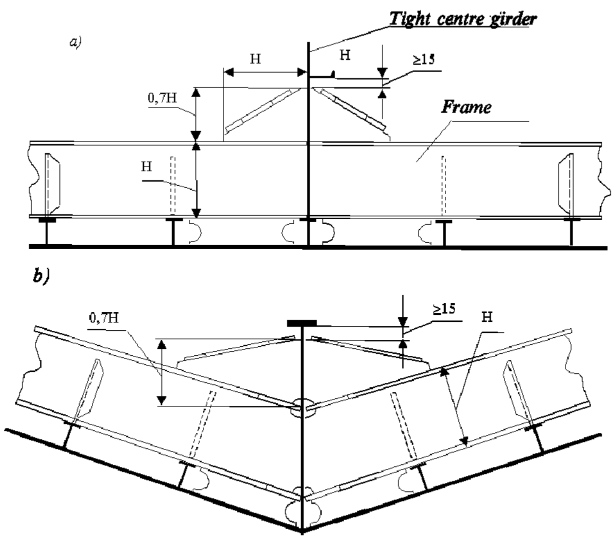


Fig. 2.2.12-1

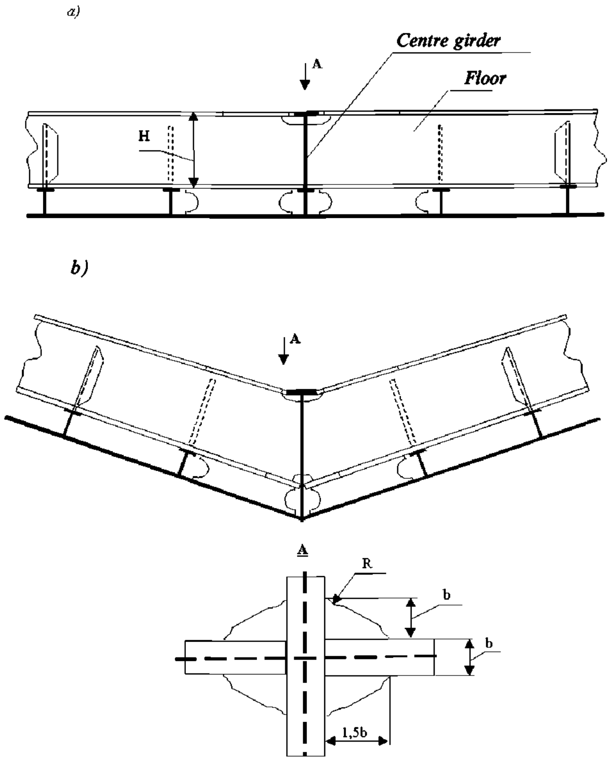


Fig. 2.2.12-2

2.2.13 With the conventional framing system, web frames shall be connected to floors in accordance with Fig. 2.2.13-1, and with the floating framing system, in accordance with Fig. 2.2.13-2. The distance between the member web edge and the opening therein for longitudinals shall not be less than 100 mm. With a small spacing of panel stiffeners (below 200 mm), this distance may be reduced (and it is recommended that all sections between edges and openings are equal).

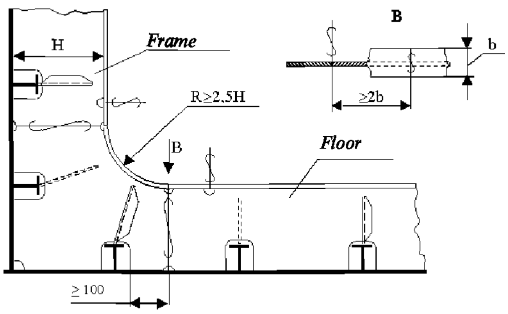


Fig. 2.2.13-1

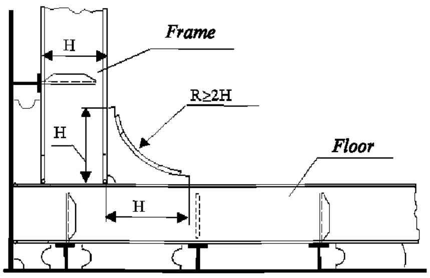


Fig. 2.2.13-2

With floor depth below 200 mm, the connecting assemblies of web frames shall be in accordance with Fig. 2.2.13-3 where conventional framing system is applied.

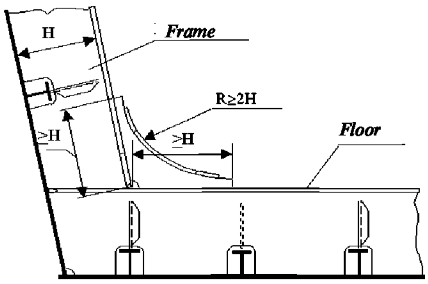


Fig. 2.2.13-3

The connecting assemblies of continuous web frames and the web beams of decks and platforms at penetrations through the latter shall be in conformity with Fig. 2.2.13-4, while the connecting assemblies of web frames that are intercostal in way of decks and platforms, and the web beams of decks and platforms shall be in conformity with Fig. 2.2.13-5.

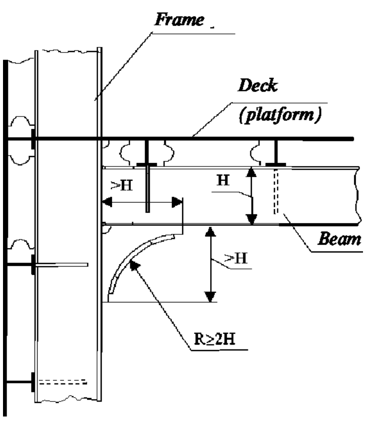


Fig. 2.2.13-4

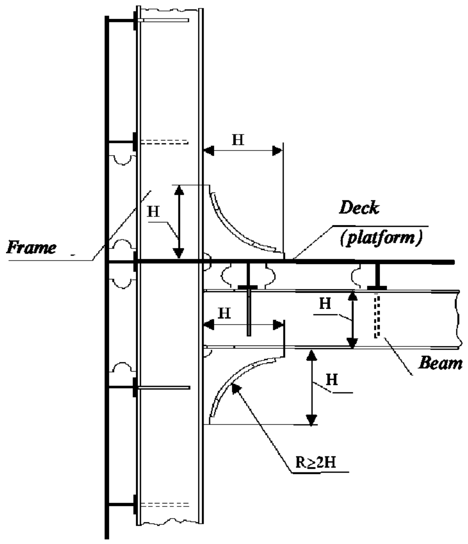


Fig. 2.2.13-5

The connecting assemblies of web frames and the web beams of superstructure deck shall be in conformity with Fig. 2.2.13-6.

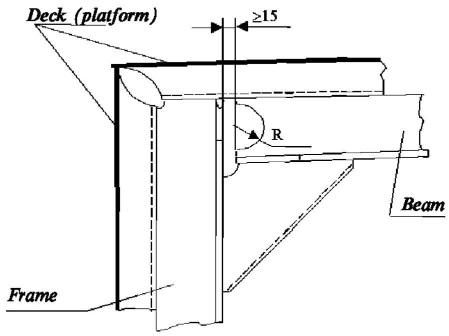


Fig. 2.2.13-6

2.2.14 For assemblies by which the penetration of longitudinal girders through non-tight structures is ensured, either clear openings (refer to Fig. 2.2.14-1) or openings where the girder web is welded directly to the opening edge by double-side welding (refer to Fig. 2.2.14-2) shall be used proceeding from the girder height.

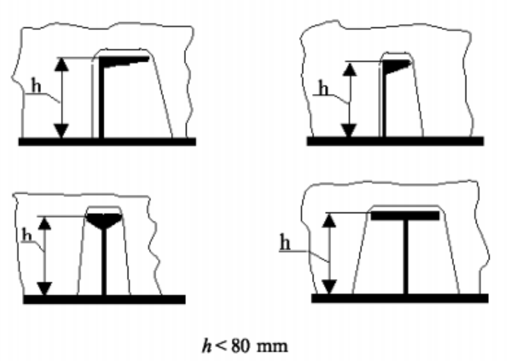


Fig. 2.2.14-1

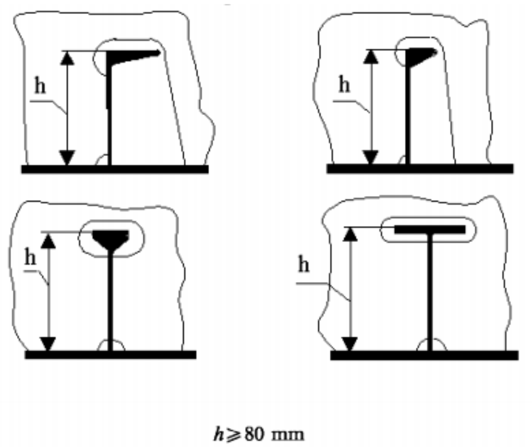


Fig. 2.2.14-2

2.2.15 For non-tight structures, welding of effective flanges of girders to opening edges is not permitted. The angles of openings shall be rounded to a radius not less than three times the wall thickness of the structure in which the opening is made, or 10 mm, whichever is greater.

2.2.16 In web members, the separation of any opening edge from the edge of the opening for girder penetration shall equal the girder height at least, unless a greater value is specified proceeding from the strength conditions.

2.2.17 With the floating framing system, no openings in centre girder or floors are permitted.

In carlings and stringers, openings for frames are permitted, which shall not exceed 1/2 the member web height in the section under consideration.

Where this is not feasible, the web strength deterioration shall be compensated by its thickening, fitting of restraints or in another way.

2.2.18 With the conventional framing system, non-tight structures with clear openings and two brackets (fitted on each side of the supporting structure) measuring not less than $2h$ (h being girder section height) shall be applied where the girder height is below 80 mm. When the girder height equals or exceeds 80 mm or when the girders are intercostal in way of web girders and are welded to the webs of the latter, the brackets size shall not be less than $1,5h$.

Where the distance between the effective flange of a longitudinal and the girder flange of web framing is less than:

$2,0h$ with the girder height <80 mm,

or $1{,}5h$ with the girder height ≥80 mm,

the brackets shall be welded to the effective flange of web framing girder.

When applying both framing systems, continuous girders may be connected to web framing girders of bottom, sides and decks by means of brackets fitted in staggered rows. Where h<80 mm, brackets may be fitted in accordance with Fig. 2.2.21.

2.2.19 The connecting assemblies between longitudinals and transverse tight bulkheads or floors shall be executed in conformity with Figs. 2.2.19-1 (variant 1) or 2.2.19-2, and where pressed panels are used to connect the beams of continuous panels, in conformity with Figs. 2.2.19-3 and 2.2.19-4 (variant 1).

The possibility of applying variants 2 of connecting assemblies (refer to Figs. 2.2.19-1 and 2.2.19-4) shall be substantiated by the assembly service life analysis.

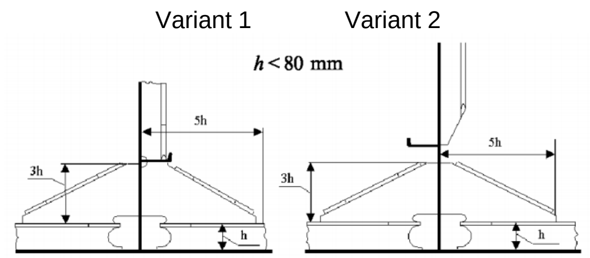


Fig. 2.2.19-1

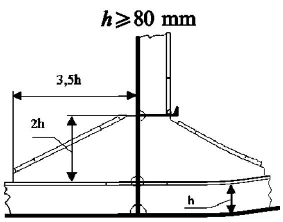


Fig. 2.2.19-2

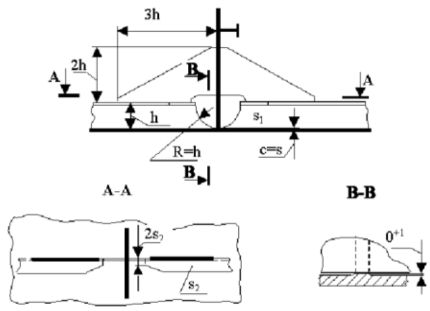


Fig. 2.2.19-3

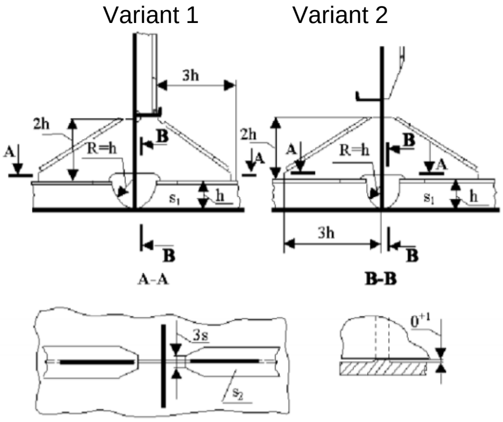


Fig. 2.2.19-4

2.2.20 If pressed panels are used in structures, the main longitudinal hull members shall be welded to the flanges of longitudinals, and if welded panels are used, they shall be welded directly to the plating.

2.2.21 With the floating framing system, connecting plates (brackets) shall be fitted in way of crossover assemblies between the main members (panel sections) and intersecting members (web framing) of the hull (including the bilge area and the intersections of the side with platforms and deck) on the planes of the web plates of the intersecting members. Where the panel section height exceeds 70 mm, the connecting plate edges shall be rounded on a radius (refer to Fig. 2.2.11-1).

At girder intersections, the effective flanges of panel sections and web members shall be connected by welding with brackets fitted in staggered rows (refer to Fig. 2.2.21). If the effective flange thickness of panel sections is less than 50 mm, brackets alone would suffice.

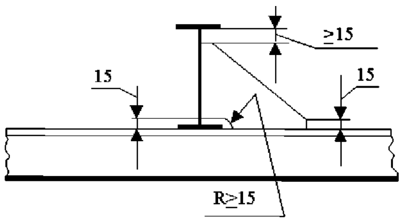


Fig. 2.2.21

2.2.22 When pressed panels are used, the connecting assemblies between framing members and adjacent structures shall be in conformity with Figs. 2.2.22-1 and 2.2.22-2, and the connecting assembly between deck girders and the longitudinal bulkhead girders shall be in conformity with Fig. 2.2.22-3.

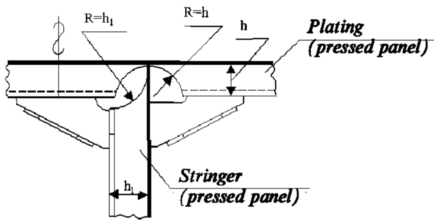


Fig. 2.2.22-1

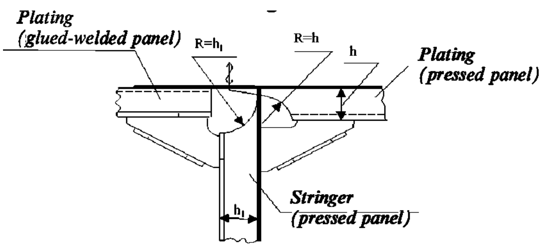


Fig. 2.2.22-2

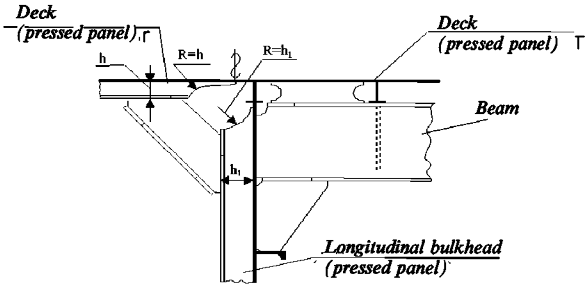


Fig. 2.2.22-3

2.3 COMPONENTS OF WELDED STRUCTURES

2.3.1 The free edges of girder webs and flanges, brackets, etc. shall undergo mechanical treatment and shall not be rough. When brackets, knees, stiffeners, etc. are welded to the effective flanges of girders being stiffened, they shall not reach the effective flange edge by a margin of 15 mm or double thickness, whichever is greater. The flanges of knees and brackets fitted to stiffen web girders (longitudinal bed-plate girders included) shall be snipped.

2.3.2 The right angles of brackets with which the connecting assemblies of girders are stiffened shall be executed so that the cut edge is removed from the contour of the opening for girder passage through web member by 15 mm at least (refer to Fig. 2.3.2).

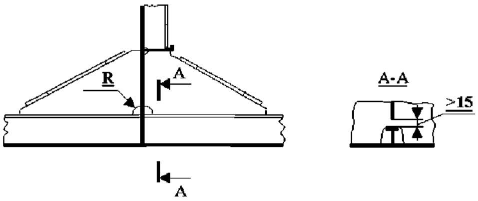


Fig. 2.3.2

2.3.3 Welding of bed-plate girder flanges to bottom plating or to transverse bulkhead plating is not permitted. In the above areas, the flanges shall be snipped.

2.4 WELD LOCATION

2.4.1 Welds shall be located in the most unstressed sections of the structure and shall, as far as practicable, be parallel to forces applied and be removed to the maximum extent possible from areas of abrupt change of member scantlings, opening diameter, and from other stress concentrators.

2.4.2 Clusters of welds, their intersection at right angles and location of parallel butt welds or fillet welds (tee welds) and butt welds in close proximity shall be avoided.

Butt welds in plate structures shall be removed from each other by 100 mm at least on the length within sections and assemblies, if made earlier than the welds with which they intersect.

In case of construction welds, the minimal distance between butt welds and fillet welds parallel thereto shall not be less than 100 mm or 10 times the plate thickness, whichever is greater. Where the above welds are shorter than 2 m, they shall be removed from each other by 50 mm at least.

The angle between two butt welds shall not be less than 45° (refer to Fig. 2.4.2).

2.4.3 It is recommended to arrange the effective flange butts of web framing members (stringers, callings, floors, beams) at an angle of 45° to the longitudinal axis of the member.

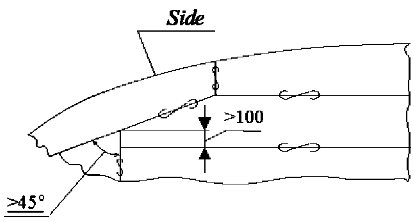


Fig. 2.4.2

2.5 WELDS

2.5.1 Butt welds.

2.5.1.1 It is recommended that welds in supporting structures having a thickness of 4 mm or above shall be made with edge preparation.

In components up to 10 mm in thickness, welds are permitted without edge preparation on condition automatic indirect welding is used to ensure weld-root formation.

2.5.1.2 When plates of different thickness are abutted, the difference in their thickness is generally not to exceed 40 % of the thicker plate thickness. This does not apply to thickened plates fitted under hawse pipes, pylons, bottom supports, etc. The thicker plate edge shall be bevelled until it reaches the thickness of the thinner plate (refer to Fig. 2.5.1.2).

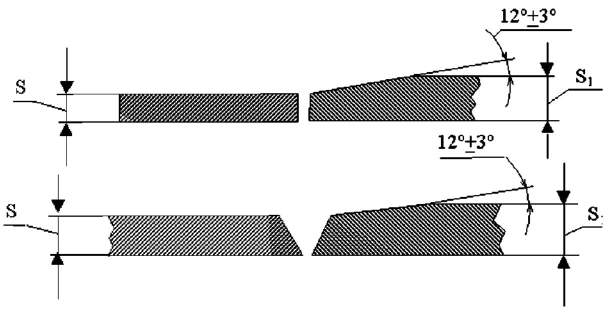


Fig. 2.5.1.2

2.5.1.3 Butt joints in girders shall be welded by direct welding using runoff blocks. Strapped lap joints are not permitted. In hard-to-reach areas, indirect welding on removable backing is permitted (also using runoff blocks).

2.5.2 Tee joints.

2.5.2.1 The leg length of tee welds in hull structures will be determined on the basis of strength analysis, but it shall not be less than stated in Table 2.5.2.1.

Table 2.5.2.1

Welded plate thickness (web/flange), in mm	$\frac{3}{3 \div 5}$	$\frac{4}{4 \div 15}$	$\frac{6}{6}$	$\frac{6}{8 \div 15}$	$\frac{8}{8 \div 15}$	$\frac{8}{15}$	$\frac{10}{10}$	$\frac{10}{15}$	$\frac{15}{15}$
Minimal leg length, in mm	3^{+1}	3^{+1}	4^{+1}	5^{+1}	5^{+1}	6^{+1}	6^{+1}	7^{+1}	7^{+1}

2.5.2.2 Welds in tee joints made by direct welding with edge preparation shall be used where the thickness of plates (components) is 4 mm or above in:

connecting assemblies of main hull girders, namely, web frames and stringers, floors and web frames, stringers and bulkheads, etc., as well as in bracket joints, flange joints and girder stiffeners;

structures and stiffeners coming under dynamic and vibration loads (pylon footings, machinery seatings, bottom supports, etc.).

2.5.2.3 Continuous welds in tee joints made by direct welding without edge preparation may be used in connecting assemblies of web members (stringers, carlings, web frames, etc.) and shell or plating except for members coming under alternating loads.

2.5.2.4 Welds not less than 50 mm in length made on the opposite side of the wall of the component being welded by indirect continuous welding in tee joints arranged 150 — 200 mm from each other (refer to Fig. 2.5.2.4) are permitted for welding longitudinals to shell plating and to deck and platform plating, for welding bulkhead stiffeners to bulkhead plating and for welding flanges to welded section walls, etc., except for areas of longitudinals and web framing intersection and intensive vibration areas, only when the stress level is low in the structure.

When joints of this kind are used, the member ends shall be boxed on a length not less than 1,5 of the section height.

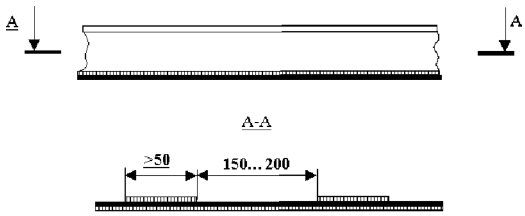


Fig. 2.5.2.4

2.5.2.5 Double intermittent fillet welds with beads overlapping at least than 20 mm on the opposite side and beads of 150 — 200 mm in length (refer to Fig. 2.5.2.5) are permitted in tee joints outside of intensive vibration areas with thickness not more than 3,0 mm; in case of non-destructive testing of the joint (ultrasonic or X-ray methods) — not more than 5,0 mm. In any case, the stiffeners shall be welded to shell plating and plating in way of supports and stiffeners ends by double continuous welding. The weld bead length to each side from the support (stiffener end) shall be at least than 1,5 times of height of bracket or higher stiffener from stiffeners being connected, whichever is greater.

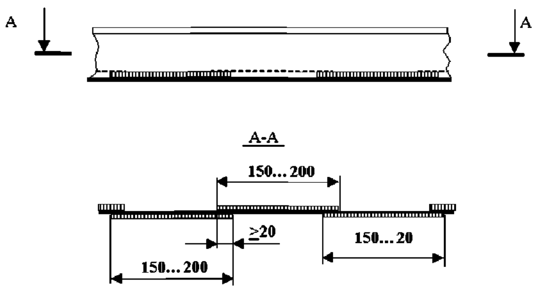


Fig. 2.5.2.5

2.6 ALL-PRESSED PANEL JOINTS

2.6.1 All-pressed panels shall be generally connected by welding.

For panels less than 3,0 mm in thickness, riveting or glueing and riveting is recommended.

In panel connections, the seams on the surface and edges shall be made on the same plane.

2.6.2 It is recommended that the panel length shall be adopted equal to the length of one or several compartments.

Panels shall be used whose edges have a symmetrical bulb or tee section.

2.6.3 For panels with unsymmetrical edges, the torsional rigidity of stiffeners shall be increased, where necessary, by the fitting of brackets proceeding from the stiffener web thickness in accordance with Fig. 2.6.3-1 (the thickness being not less than 3 mm) or with Fig. 2.6.3-2 (the thickness being less than 3 mm).

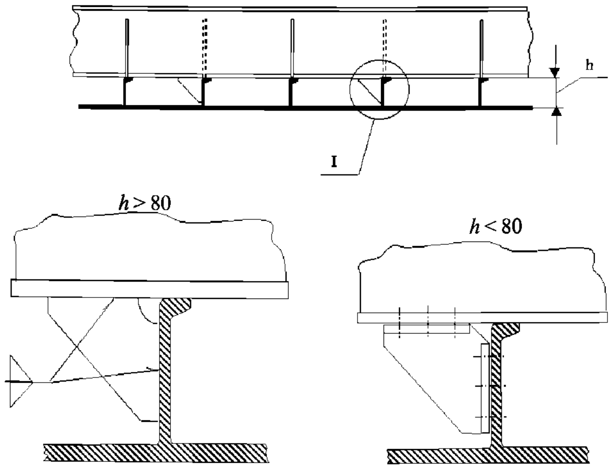


Fig. 2.6.3-1 Fig. 2.6.3-2

2.6.4 The butt joints of panels, except low-loaded structures in which the section height is not greater than 90 mm, shall be strengthened with stiffeners (Figs. 2.6.4-1, 2.6.4-2*a*, 2.6.4-2*b*).

The cross-sectional area of stiffeners shall not be less than 0,5 of the cross-sectional area of panel edges. A deviation from this requirement or from recommendations for executing the connecting assemblies (Figs. 2.6.4-1, 2.6.4-2*a*, 2.6.4-2*b*) is only permissible where it is substantiated by test results obtained on panel connecting assemblies and by calculations.

Where necessary, tee sections shall be used to increase the plane bend resistance of connecting assemblies.

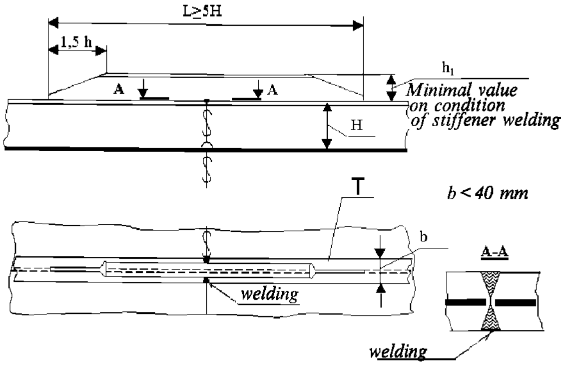


Fig. 2.6.4-1

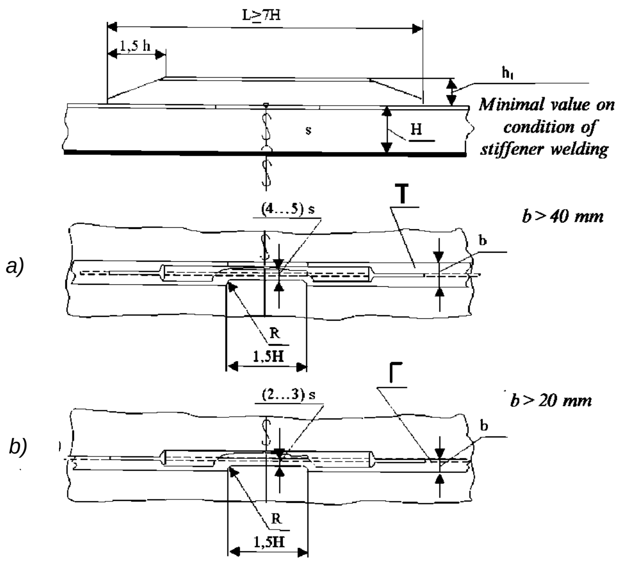


Fig. 2.6.4-2

2.6.5 Solid panels shall be connected to watertight bulkheads, floors and stringers in accordance with Figs. 2.2.19-3 and 2.2.19-4.

Combined connecting assemblies inside blocks or between sections of pressed panels shall be executed in conformity with Figs. 2.6.5-1, 2.6.5-2 and 2.2.22-1, 2.2.22-2, 2.2.22-3, and similar assemblies between pressed panel blocks shall be executed in conformity with Fig. 2.6.5-3. The cross-sectional area of a bracket fitted above the panel joint shall not be less than 0,7 of the edge cross-sectional area. A deviation from these recommendations is only possible if substantiated by assembly test results and calculations.

Where the bracket cannot be abutted or welded to the shelf, this shall be substantiated by assembly durability analysis.

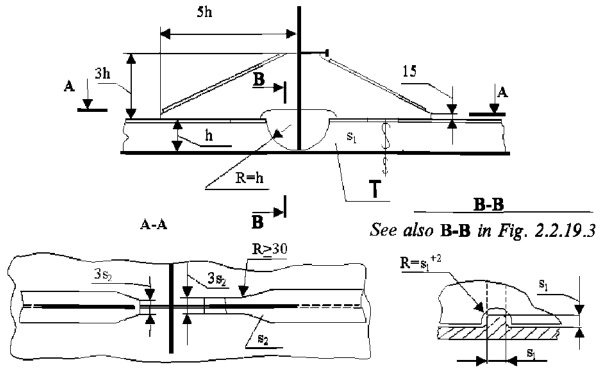


Fig. 2.6.5-1

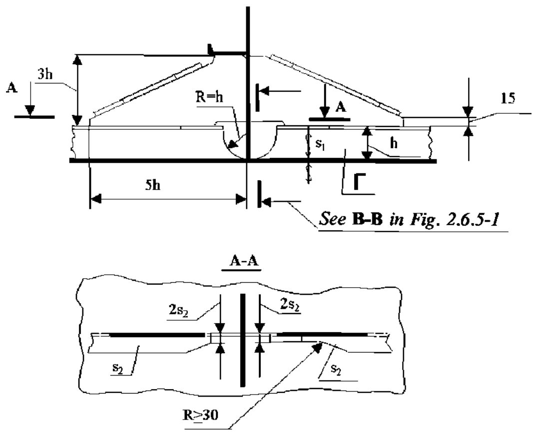


Fig. 2.6.5-2

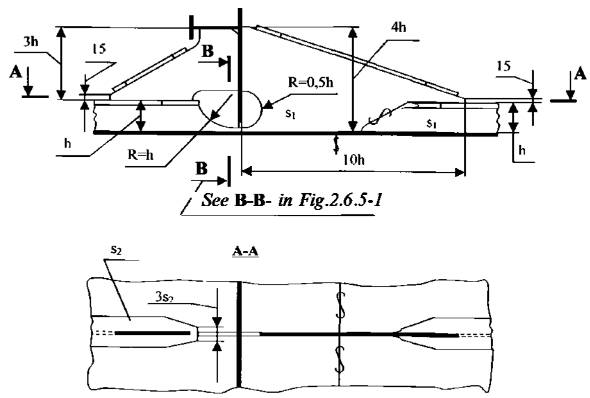


Fig. 2.6.5-3

2.6.6 When connecting structural components composed of all-pressed panels, one shall also be guided by 2.2.20, 2.2.22 and 2.12.5.

2.7 RIVETED AND GLUED-RIVETED JOINTS

2.7.1 These requirements apply to hull structures manufactured by riveting and glueing-riveting.

Glued-riveted joints are recommended for structures manufactured from glued-riveted billets (panels), as well as for structures exposed to vibrations.

2.7.2 For the design rivet diameter, the nominal rivet body diameter shall be adopted.

2.7.3 Riveting shall be carried out using cold rivets.

2.7.4 Riveted and glued-riveted joints may be executed in overlap and end-to-end on strips.

2.7.5 The rivet material shall be chosen proceeding from the grade of aluminum alloy from which the structure is manufactured.

2.7.6 The rivet types and kinds of glue to be used shall comply with the current standards.

2.7.7 The riveted and glued-riveted joint diameters for plates shall be chosen on the basis of Table 2.7.7.

When plates are riveted, the minimal overlapped width for single-row joints shall be $4d$, $6d$ for doublerivet joints and $8d$ for three-rivet joints.

Table 2.7.7

Design component thickness, in mm	Rivet diameter, in mm	
	recommended	permissible
0,5	2	$2,6 \div 3$
1,0	2	$2,6 \div 3$
1,5	3	$2,6 \div 4$
2,0	4	$3 \div 5$
2,5	5	$4 \div 6$
3,0	6	$5 \div 8$

Notes: 1. For the design thickness, the lesser thickness of components being connected shall be adopted.
2. Where the joints are made on strips, the thickness of the latter shall not be taken into consideration.

2.7.8 The margin between rivet axis and plate edge shall be at least $2d$.

2.7.9 The parameters of riveted and glued-riveted joints to be used in butts, slots and other structural assemblies shall be chosen on the basis of strength analysis proceeding from forces to be applied and the purpose of the joint. For the purpose of strength analysis, the glue interlayer shall be disregarded, i.e. glued-riveted joint parameters shall be adopted as for riveted joints.

2.7.10 Recommended values of the rivet pitch *t*, spacing and number of rivet rows are given in Table 2.7.10.

Table 2.7.10

Type of joint	Joint parameters in connection with rivet diameter			Rivet arrangement
	Rivet joint pitch	Rivet row spacing	Minimal number of rows	
Strength	$6 \div 7$	2÷5	1 for framing, 2 for butts and slots,	Staggering and chainlike
Composite	$3,5 \div 5,5$	2	2÷3 for butts and framing,	Staggering
Tight	$3,5 \div 5$	2	2 for butts and framing	Staggering

Note. A strength joint is one for which strength, but not tightness is required.
A tight joint is one for which tightness is required.
A composite joint is one for which strength and tightness are required.

2.7.11 If rivets up to 8 mm in diameter are made of aluminum alloys, their stud length shall be chosen from Table 2.7.11.

Table 2.7.11

Closing head type	Countersunk	Raised countersunk	Hat	Cup
Stud length, in mm	$S + 0,d$	$S + 1,1d$	$S + 1,2d$	$S + 1,d$
Note. S is the total thickness, in mm, of components being joined, including the strip, if fitted. d is the rivet diameter, in mm.				

2.7.12 It is recommended that holes for rivets shall be made by drilling.
2.7.13 The diameter, in mm, of rivet holes shall be determined from the formula

$$d_r = d_0 + \Delta_1 \quad (2.7.13)$$

where d_0 is rivet diameter, in mm;
A_1 = 0,1 where d_0= 2–5 mm;
A_1 = 0,2 where d_0= 6–8 mm.

2.7.14 All defective rivets (wear ones with eccentric and cracked heads, with heads loose on the plate surface or section flange, with improperly closed up or small-sized heads, etc.) shall be replaced.

2.8 GLUED-WELDED JOINTS

2.8.1 These requirements cover hull structures manufactured using glued-welded joints.

Glueing-welding process is recommended for connecting girders to the plating of skirt bag, recesses, etc., except for sections of these structures coming under loads strong enough to tear the framing from the plating.

2.8.2 The weld types and glue quality to be used shall comply with the current standards.

2.8.3 The glued-welded joint parameters shall be determined by calculation proceeding from forces applied and the thickness of plates to be joined.

The optimal values of welded point diameter (d), spacing of point centres in a row (t), spacing of point row aces (c) and welded flange (flanging) breadth (a) are given in Table 2.8.3.

Table 2.8.3

Design components thickness S, in mm	Welded point diameter d, in mm	Spacing of point centres in a row, t, in mm	Spacing of point row aces, c, in mm	Flanging breadth (breadth of flange edge), a, in mm
0,5	3,0	10	12	10
0,8	3,5	13	15	12
1,0	4,0	15	18	14
1,2	5,0	17	20	16
1,5	6,0	20	24	18
2,5	8,0	30	36	22
3,0	9,0	35	42	26
2,0	7,5	25	30	20

Notes: 1. For the design diameter of welded points, the diameter d shall be adopted.
2. For the design thickness S, the smaller thickness of components being joined shall be adopted.
3. The thickness ratio of components being welded shall be not greater than 2:1 for category II structures or 3:1 for category III structures.

2.8.4 The margin between the extreme row axis and the flange edge (flanging) shall not be less than 8,0 mm where the plate thickness is 0,5 — 1,5 mm or less than 15 mm where the thickness is 2,0 — 3,0 mm.

2.8.5 In the free ends of stiffeners, the welds shall be made on a length equal to twice the stiffener height where the spacing of point centres in a row is 0,5t. Rivets may be fitted in free ends (refer to Fig. 2.8.5).

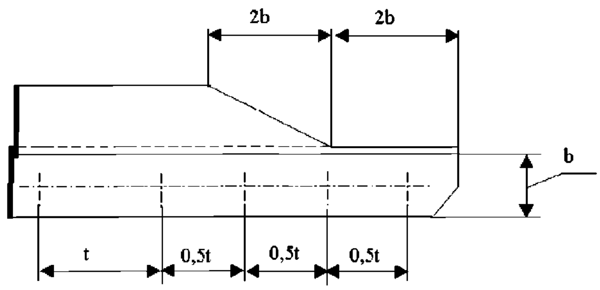


Fig. 2.8.5

2.9 GLUED-WELDED PANEL JOINTS

2.9.1 It is recommended that the butt joints of glued-welded panels shall be executed using glueing-riveting procedure. The butts may be manufactured by riveting.

In glued-welded panel joints, the panel surfaces and edges shall be arranged on the same planes.

2.9.2 The panel length shall be adopted equal to that of a compartment or section. Panels shall be used having edges of bulb angular or Z section.

For secondary structures, other sections (angles, etc.) may be used.

2.9.3 The connecting assemblies between glued-welded panels shall be preferably executed in conformity with Fig. 2.9.3-1.

A recommended structure of a composite connecting assembly between panels and a transverse bulkhead is shown in Fig. 2.9.3-2.

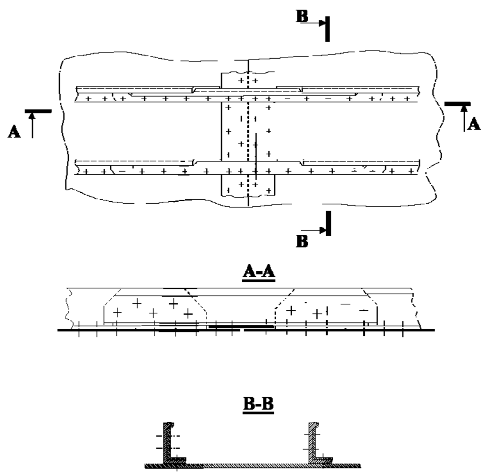


Fig. 2.9.3-1

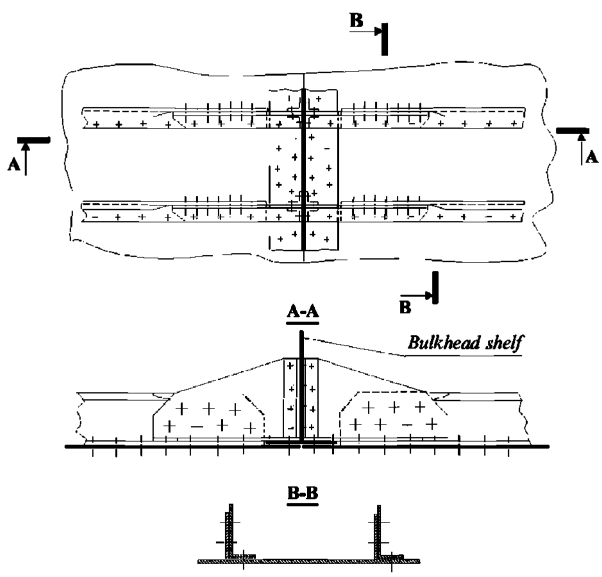


Fig. 2.9.3-2

2.10 DECK AND SHELL PLATING

2.10.1 The thickness of the deck stringer and (if the ratio of ship design length to breadth is less than 5,0) the thickness of deck plating adjacent to longitudinal bulkheads shall be 20 % greater than thickness of deck plating. The breadth (in meters) of deck stringer and thickened plates near by longitudinal bulkheads shall be not less than the value determined by the formula

$$b = 0{,}014L + 0{,}1. \qquad (2.10.1)$$

In the ship's ends as well as for the lower decks (pontoon plating) increment of the thickness of deck stringers and plates adjacent to the longitudinal bulkheads is not required.

2.10.2 Connection of the sheer strake to the deck stringer and strengthened deck plates to longitudinal bulkheads shall be made by the double-sided welds.

It is recommended to round connection of the sheer strake to the deck stringer. Sheer strake rounding radius shall be equal to at least its 20 thicknesses.

2.10.3 If deck is discontinued in any compartment (for instance, engine room) then side stringers of increased height shall be mounted in the plane of deck along side. Connection of side stringers to the deck continuation (and transverse bulkheads) is recommended to apply to Figs. 2.10.3-1 and 2.10.3-2.

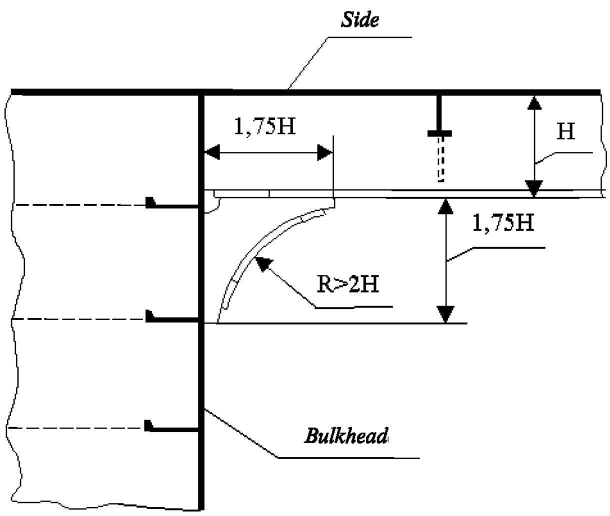


Fig. 2.10.3-1

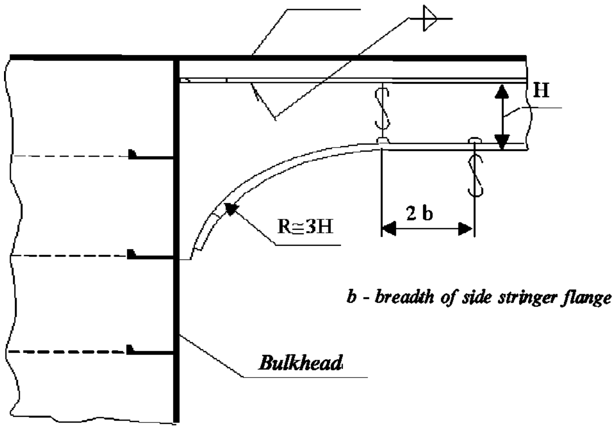


Fig. 2.10.3-2

2.10.4 Shell plates and deck plating in the fixing points of bottom bearers, pylons, stanchions, shaft brackets, stabilizers and hydrofoil installations shall be 20 % greater while shell plates exposed to significant mechanical wear shall be 40 % greater than thickness of adjacent plates outside the area of increased wear.

If all-pressed boards are used for the shell plating the said thickening of plating is allowed to be made by installation of superimposed plates welded by perimeter.

2.11 SUPERSTRUCTURES AND DECKHOUSES

2.11.1 Superstructures which length is three times greater than their height and deckhouses which are supported at least by 3 rigid transverse members (bulkheads, transverse frames supported by cross ties etc.) are treated as a solid one.

2.11.2 Reduction of the superstructure (deckhouse) contribution to the total bending of ship hull is allowed due to:

use of movable (expanding, flexible or sliding) joints along perimeter of the deckhouse section;

supporting of deckhouse by two rigid transverse members of hull (transverse bulkheads, web beams supported by cross ties, etc.).

2.11.3 Stanchions of the superstructure walls and deckhouses shall be located in the plane of deck framing and fixed to the deck by brackets. If stanchions do not coincide with deck framing, stiffeners or other structures ensuring unload of a moment at a support shall be provided under brackets.

2.11.4 Superstructure or deckhouse end bulkheads shall be supported by transverse bulkheads. Otherwise rounded brackets of sufficient size ensuring transmission of loads to the sides and pontoon shall be fitted under end bulkheads.

2.11.5 Door openings in longitudinal walls (including longitudinal bulkheads of superstructures and deckhouses located within $0,6L$ amidships) shall be supported by thickened plates above and below opening.

Rounding of the opening comers is sufficient if the distance between expanding and sliding joints is less than three heights of superstructure (deckhouse).

Upper and lower edges of the side-scuttle openings shall be enforced by strengthened longitudinal members remoted from the opening edge at least by $10S$ where S is the thickness of the superstructure (fast deckhouse) plating; meanwhile, opening comers shall be additionally strengthened (refer to Fig. 2.11.5).

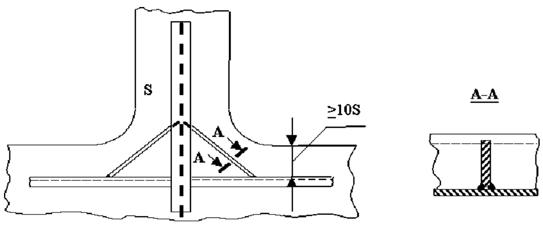


Fig 2.11.5

2.11.6 If the window span in superstructure or deckhouse is less than window width (for two or more windows) plate thickness in the area of window shall be enlarged by 40 % as opposed to adjacent superstructure plates.

2.12 BULKHEADS

2.12.1 Arrangement of longitudinal and transverse bulkheads shall be agreed with arrangement of stringers and floors. Longitudinal bulkheads shall be strengthened by horizontal members.

2.12.2 Stanchions of transverse and longitudinal bulkheads as well as walls of superstructures and deckhouses shall be located in the plane of bottom and deck framing.

Lower ends of stanchions shall be fixed on the horizontal stiffener (refer to Figs. 2.2.10-2 and 2.2.19-2) for the floating framing system and conventional framing system of side-walls (with dead-rise of lines).

If local operating loads are symmetrical relative to the bulkhead and it is impossible to fix lower ends of stanchions on the horizontal stiffener, it is allowed to leave them unattached provided horizontal stiffener is mandatorily mounted on the opposite side of bulkhead plating (variant 2 on Figs. 2.2.19-1 and 2.2.19-4).

2.12.3 Ends of the longitudinal bulkhead stanchions above stringers shall be fixed in accordance with Figs. 2.2.10-3 and 2.12.3-1.

Ends of stanchions above carlings and beams shall be fixed in accordance with Fig. 2.12.3-2.

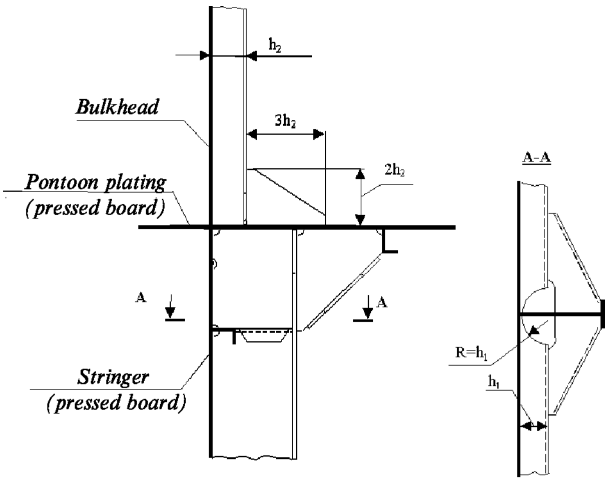


Fig. 2.12.3-1

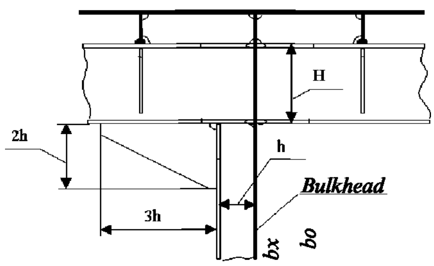


Fig. 2.12.3-2

2.12.4 Upper ends of the bulkhead stiffeners located outside area of intensive vibration (excluding tank bulkheads) are allowed to snip.

2.12.5 Stanchions of transverse and longitudinal bulkheads in the passages through permeable decks and platforms shall be continuous. These passages shall be made in accordance with Fig. 2.12.5-1.

It is recommended to make intercostal vertical bulkhead stiffeners on the watertight decks (platforms) and secure them to the deck (refer to Fig. 2.12.5-2).

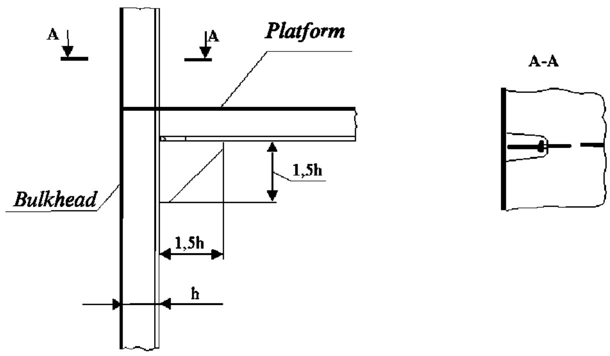


Fig. 2.12.5-1

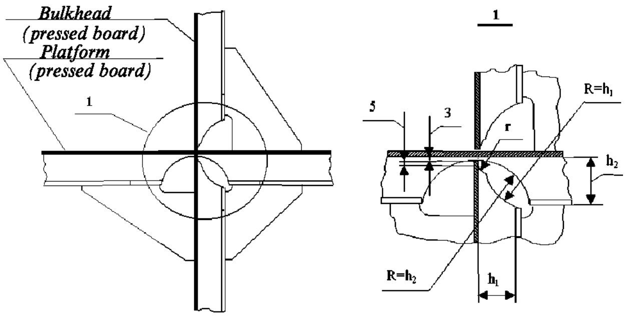


Fig. 2.12.5-2

2.12.6 The thickness of the bulkhead plating adjacent to the bottom shall be increased by 1 mm. If pressed boards are applied it is allowed not to increase thickness.

2.12.7 Longitudinal bulkheads shall end on the transverse bulkheads. They shall end by rounded brackets (refer to Fig. 2.12.7) connecting longitudinal bulkhead to the main deck and bottom longitudinals located in its plane (bottom stringers, carlings).

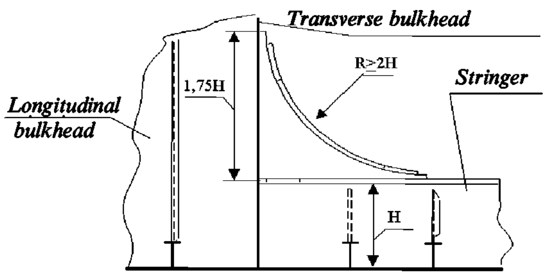


Fig. 2.12.7

2.13 BULWARK

2.13.1 Bulwark shall be fitted in places specified in Part III "Equipment, Arrangements and Outfit" of these Rules.

Height of the bulwark measured from the upper edge of the gunwale shall comply with the requirements of 8.1 of Part III "Equipment, Arrangements and Outfit" of these Rules.

2.13.2 Thickness of the bulwark plates, in mm, shall be not less than the value determined by the formula

$$S = 0{,}05L + 1{,}5. \qquad (2.13.2)$$

2.13.3 The thickness of the gunwale of bulwark made of strip or section material shall be at least by 1 mm thicker that the bulwark plates. It is allowed to use light-wall tubes as a bulwark.

2.13.4 The bulwark shall be strengthened by stanchions at a distance not more than 1,2 m one from another.

Thickness of stanchions shall be at least by 1 mm greater than thickness of the bulwark plates. Width of the lower end of stanchion shall be not less than the width of the gunwale.

The width of the stanchion flange shall be not less than 60 mm.

If there are openings in the bulwark, then stanchions adjacent to such openings shall be strengthened.

2.13.5 Stanchions shall be located in the plane of underdeck framing, bulkheads or specially mounted strengthenings and be secured to the deck, bulwark and gunwale by welding or riveting.

2.14 MACHINERY FOUNDATION

2.14.1 Foundations for ship machinery shall provide reliable mounting of machinery to rigid hull members. Rigidity of machinery foundations and grillages on which they are mounted shall comply with the requirements, technical standards applied to mounting and operation of such machinery.

2.14.2 Structural components and foundation members shall be manufactured from the same material as the main case. Foundation and case shall be connected by welding or riveting (refer to 2.5 and 2.7).

2.14.3 Foundation longitudinals under main machinery shall be aligned with bottom stringers or there shall be provided additional members ensuring smooth transmission of loads to hull.

2.14.4 Ends of foundation longitudinals shall be connected with transverse bulkheads or reinforced floors and to finish by brackets located in the area of longitudinals and be attached to the transverse member (floors and web frames).

2.14.5 Webs of foundation longitudinals shall be by 40 % thicker than webs of bottom stringers. Deviation from these requirements is allowed if it is justified by foundation strength and rigidity calculation.

2.14.6 Horizontal face plates made of continuous strips which thickness shall be by 40 % greater than thickness of plates of foundation wall shall be mounted on the upper edge of foundation longitudinals.

Horizontal face plates of foundation longitudinals in the area of securing bolts shall be strengthened by vertical brackets. Vertical size of these brackets shall be not less than two times larger than their horizontal size while thickness shall be equal or by 1 mm less than thickness of the foundation walls.

2.14.7 Foundation longitudinals shall be strengthened at each floor by transverse brackets connecting longitudinals together and by brackets mounted on the outer side of longitudinals beginning from the center line of shaft. The width of brackets shall be not less than their height while thickness — 20 % greater than thickness of floor webs. Free edges of brackets for the length exceeding 40 thicknesses of brackets shall have a face plate or flange. Ends of face plates shall be snipped.

2.14.8 There may be lightening openings in brackets.

2.14.9 It is allowed to make openings in the web plate of foundation longitudinals. Openings shall be strengthened.

2.14.10 Foundations of small auxiliary machinery may be made as a bracket fixed on framing. Foundations shall be located on the least strained parts of members in such a way that foundation supporting components are mounted in the plane of web plate of framing.

2.15 PLATFORMS

2.15.1 Scantlings of the platform framing shall be assigned on the basis of strength calculations.

Aluminium allows with inferior mechanical properties as opposed to the main case material are allowed for use in platforms as well as three layer boards with aluminium and polymeric base layers.

It is recommended to align platform stiffeners with vertical framing (frames, bulkhead stiffeners).

2.15.2 It is recommended to use zee, bulb angle, angle beams as the platform stiffeners.

2.16 ENCLOSURES

2.16.1 The following requirements refer to the strengthened enclosures which support web frames.

2.16.2 Thickened plates shall be provided in the lower and upper parts of enclosures. Their width shall be not less than two heights of frames passing through them and thickness:

equal to the thickness of frame webs passing through the lower part of framing — for the upper part;

increased by 1 — 2 mm relative to frame webs — for the lower part.

2.16.3 Plating of enclosures shall be strengthened by zee, bulb angle, angle stiffeners. Stanchions may be affixed to plating by glued-welded joint, glued-riveting joint, seam welding or riveting.

Bending (clamping) of vertical edges of plates may substitute metal sections. Connection of plates throughout bulkhead width shall be made by riveting or contact welding of bent edges.

It is allowed to use horizontal or vertical box-shaped or wavy corrugated bulkheads and three-layer boards.

2.16.4 Door openings in enclosures shall be strengthened by thickened plate or additional stiffeners.

2.17 STRUCTURAL FEATURES OF CONNECTING BRIDGES OF SPEED CATAMARANS AND SIDE-WALL HOVERCRAFT

2.17.1 Main structures of connecting bridge shall be all-welded from plates, section and all-pressed boards. Plates of structures shall be strengthened by transverse frames (web frames or brackets).

2.17.2 Structures of the connecting bridge in the bow end within 0,35L shall be made in accordance with the conventional framing system.

2.17.3 It is recommended to connect transverse frames of connecting bridge with web frames as shown in Figs. 2.17.3-1 and 2.17.3-2.

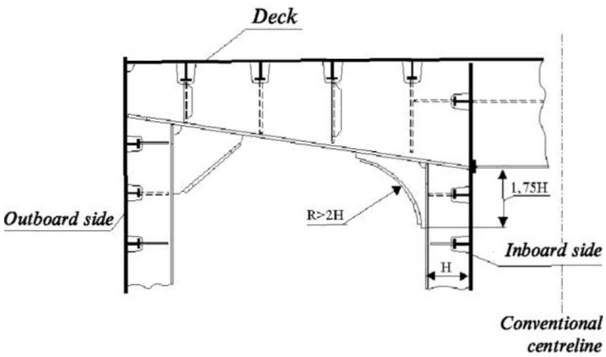


Fig. 2.17.3-1

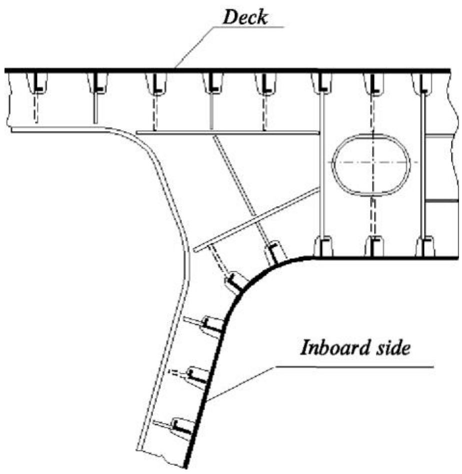


Fig. 2.17.3-2

2.17.4 It is recommended to fit together connecting bridge to the transverse bulkheads by means of thickened plates in the area of transition of connecting bridge plating to the bulkhead plating or elongation of reinforced web of the bridge frame and its smooth transition to the bulkhead plating (refer to Figs. 2.17.4-1 and 2.17.4-2).

It is allowed to use web permeable bridge structures amidships (within $0{,}25L$ to both ends from the midship section) (refer to Fig. 2.17.4-2).

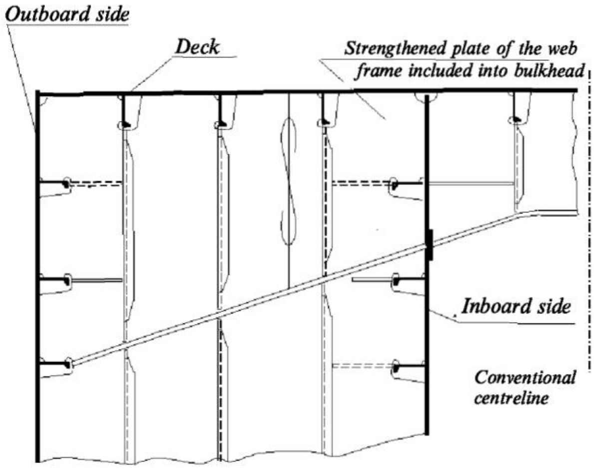


Fig. 2.17.4-1

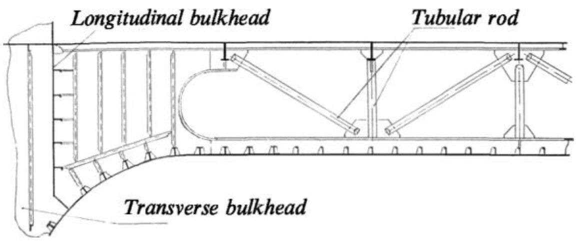


Fig. 2.17.4-2

2.18 SPECIAL FEATURES OF THE HOVERCRAFT HULL STRUCTURES

2.18.1 Apron.

2.18.1.1 Usually apron is made of the all-welded plates, sections and all-pressed boards.

2.18.1.2 The thickness of the apron plating is chosen on the basis of the strength properties and it shall be taken not less than the deck thickness designed for wheeled cars.

2.18.1.3 Dimensions of the apron members are assigned on the basis of strength calculations.

2.18.2 Skirt bag.

2.18.2.1 Usually skirt bag is riveted of plates, sections and boards.

It is allowed to weld skirt bag or make it from non-metal materials in case the strength calculations are provided made according the RS-approved procedure.

It is recommended to use bulb angle and zee beams as longitudinals.

2.18.2.2 The thickness of the skirt bag plates adjacent to side which is not less than 300 mm shall be 20 % greater than thickness of the rest skirt bag thickness.

Strengthened skirt bag plate is connected to the side by welding.

2.18.2.3 Part of skirt bag made of the pressed boards shall be strengthened by web beams.

2.18.2.4 Flexible skirt shall be continuously secured along length of skirt bag.

2.18.3 Side-walls.

2.18.3.1 Side-walls shall be made of welded plates, sections and pressed boards. Parts of side- walls exposed to hydrodynamic blows shall be made according to the conventional framing system.

2.18.3.2 Boards (welded, pressed boards) of side- walls shall be strengthened by brackets or web frames.

2.18.3.3 Bottom and side plating of side-walls are connected by the double-sided welds.

2.18.4 Pylons.

2.18.4.1 Pylons shall be riveted (glued-riveted) from the plates, sections and all-pressed boards.

2.18.4.2 Boards of pylons (riveted boards with the stiffeners of bulb angle and zee beams) shall be strengthened by horizontal (rib) and vertical (spar) brackets.

Vertical brackets shall be continuous.

2.18.4.3 Thickness of pylon plating adjacent to the foundation under pylon shall be at least 40 % greater than the thickness of pylon plating.

Pylon shall be connected to the engine gondola and foundation on casing by riveting (bolts).

2.18.5 Air trunks.

2.18.5.1 It is recommended that air trunks shall be glued-riveted from plates, sections and all-pressed boards. It is allowed to weld or rivet trunk structure.

It is recommended to use bulb angle and zee stiffeners as vertical stanchions.

2.18.5.2 Thickness of trunk shell ring adjacent to the plating shall be 10 — 20 % greater than thickness of plates of shell ring.

2.18.5.3 Recommended structural scheme of the air trunk is set forth in Fig. 2.18.5.3.

Trunk shell ring shall be strengthened by horizontal framing (rings) located on the outer side of the shell ring.

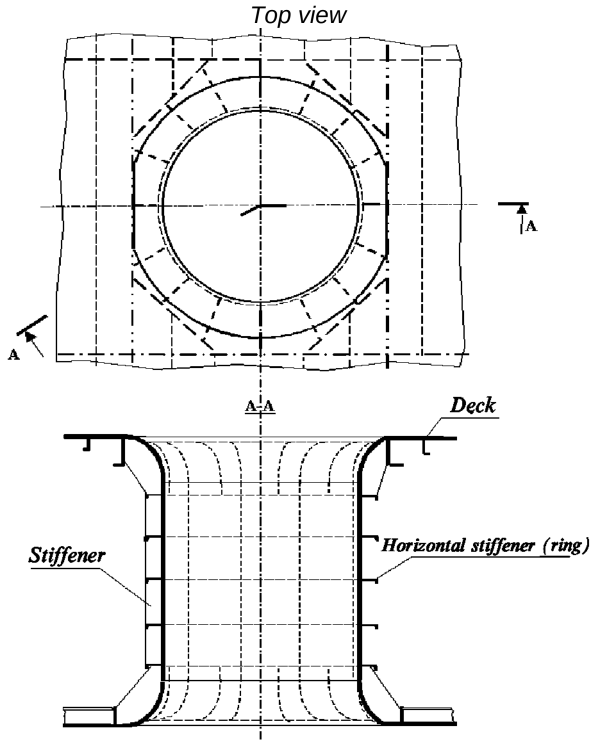


Fig. 2.18.5.3

2.19 HULL STRUCTURAL FEATURES OF THE HYDROFOILS AND GLIDERS

2.19.1 Stem.
2.19.1.1 Usually, stems are riveted from plates.
2.19.1.2 Thickness of the welded stem plates (in mm) shall be at least:

$$S = 1,2\,(0,05L + 3). \qquad (2.19.1.2)$$

Accepted thickness of the stem plates shall be not less than the thickness of the horizontal keel in the spot of its connection to the stem.

The width of the stem transverse section, in mm, measured in the waterline plane in the water displacement mode shall be at least $(2,5L + 200)$.

2.19.1.3 Stem plates shall be strengthened by horizontal brackets mounted at most each 0,5 m. Arrangement of brackets throughout stem height shall be accorded with the hull framing. If distance between brackets is reduced to 0,3 m, it is allowed to reduce stem plates thickness by 20 % as opposed to the value given in 2.19.1.2. However, in all cases thickness of stem plates shall be not less than the thickness of adjacent shell plating.

2.19.1.4 Thickness of brackets shall be equal to the thickness of shell plating adjacent to the stem.

2.19.1.5 Brackets shall overlap butts between stem and shell plating by the value of at least 10 thicknesses of the latter and, if possible, reach the nearest frame and be welded to them. Brackets which cannot be connected to the framing shall have edge which ends on the shell plating which is shaped by smooth curve.

2.19.1.6 The stiffener (plate) with face plate on the free edge shall be mounted in the centreline from keel to the deck. Thickness of web and flange of stiffener shall be not less than the value adopted for transverse brackets.

2.19.2 Strengthening of hull in the area of struts and brackets of hydrofoil installations and shafts.

2.19.2.1 Usually, at least one longitudinal and two transverse members (stringers, web frames or floors, bulkheads) shall be under each strut or bracket of hydrofoil installation and shaft.

Additional members under struts and brackets may be required in some cases.

2.19.2.2 Shell plating in the area of struts and brackets of hydrofoil installations and shafts shall have an increased thickness in accordance with 2.10.4.

2.19.2.3 Strengthened openings for examination and painting of a hard-to-reach area are allowed in strengthenings.

2.19.2.4 Floating framing system in the area of strengthenings, floors and web frames shall be welded to the shell plating (refer to 2.1.14).

2.19.2.5 Welding of superimposed plates made of the hull material is allowed from the outer side of shell plating in the areas of strengthening of brackets of hydrofoil installations and shafts. Thickness of plates shall be at least double thickness of the shell plating in the area of the installation.

Plate thickness shall be such that the distance between a plate weld and flange edge shall be not less than three thicknesses of a plate.

Insulating gaskets shall be used when steel brackets are connected to plates if brackets are made of steel.

3 REQUIREMENTS FOR HYDROFOIL INSTALLATION DESIGN

3.1 GENERAL

3.1.1 The general arrangement of a hydrofoil installation, location and dimensions of main and auxiliary planes, stabilizers, brackets, and stanchions, as well as the shape of hydrofoil installation component cross-sections shall be chosen with due regard for ensuring the required hydrodynamical characteristics. The most rational structural layout for the hydrofoil installation shall be adopted in order to ensure its strength.

3.1.2 The main plane and lower stanchion and stabilizer sections adjoining thereto shall be generally made solid.

In the surfaces of non-tight hydrofoil components, two openings shall be drilled, one in the upper surface and the other in the lower surface.

In the hollow, tight hydrofoil installation components, drain plugs shall be provided for water discharge.

3.1.3 Hydrofoil installation components of solid structure shall be made of a single plate. Auxiliary (take-off) components of the hydrofoil installation shall be manufactured from aluminum-magnesium alloys, and they shall be solid.

3.1.4 Hollow components of hydrofoil installations whose structure is tight shall be tightness-tested by filling with water with a head of 50 kPa or by air blowing under an over pressure of 20 kPa.

3.2 MAIN PLANE

3.2.1 The main plane shall be continuous along the span and shall not be intercostal in way of stanchions. When the dead-rise angle of main plane or the setting angles of its components are modified, the plane may be partitioned in way of stanchions (refer to Fig. 3.2.1).

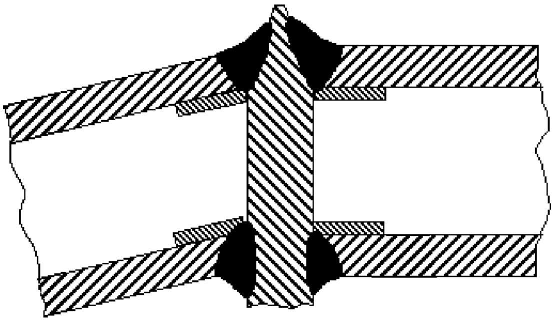


Fig. 3.2.1

3.2.2 Where the hydrofoil is of a hollow structure, the stiffeners shall be arranged along its span (refer to Fig. 3.2.2-1).

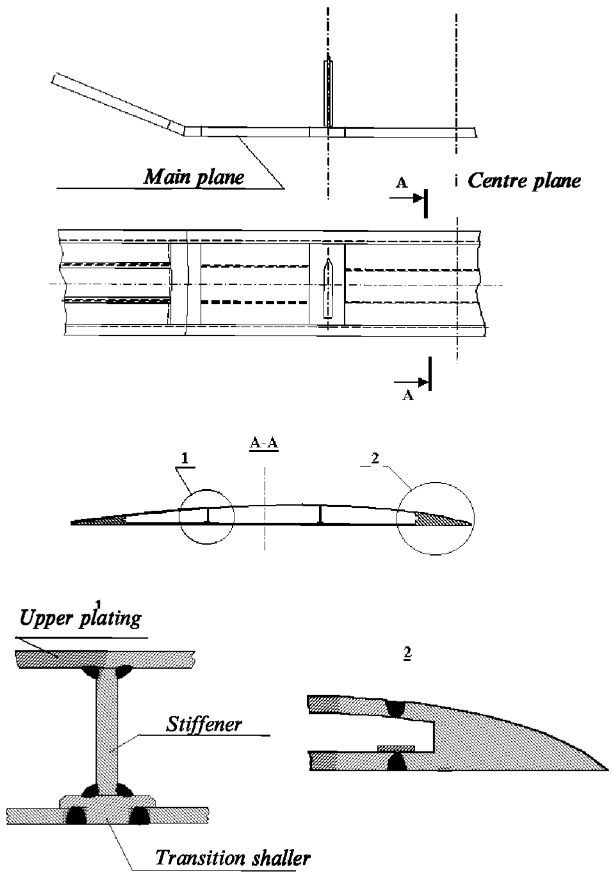


Fig. 3.2.2-1

Stiffeners may be used which are fitted along the hydrofoil chord (refer to Fig. 3.2.2-2). Each stiffener shall be welded to the upper or lower section of hydrofoil plating.

Stiffeners fitted along the span shall be connected to the upper plating of main plane and to the lower plating of the take-off plane without use of the transition shaller (refer to Fig. 3.2.2-1).

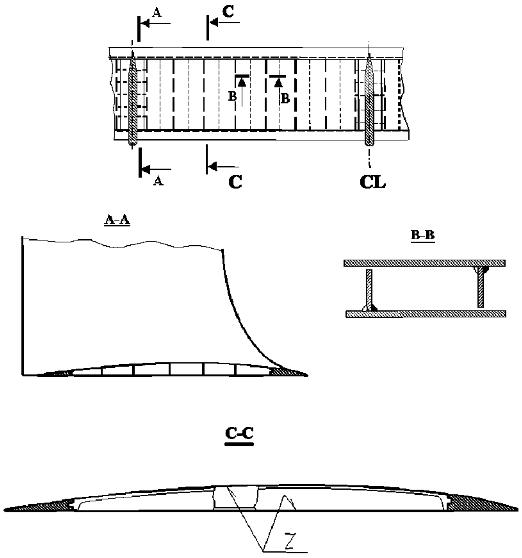


Fig. 3.2.2-2

3.2.3 Where a hollow hydrofoil is adjoined by other structures (stanchions, stabilizers), provision shall be made for solid inserts in the hydrofoil, made of thick plates or forgings ((refer to Fig. 3.2.3-1), and in the adjoing structures provision shall be made for thickened plates (refer to Fig. 3.2.3-2).

Thickened plates strengthened with additional stiffeners or brackets (refer to Fig. 3.2.3-3) shall be used instead of solid inserts.

The plates shall be fitted symmetrically with regard to the neutral axis of the hollow component plating.

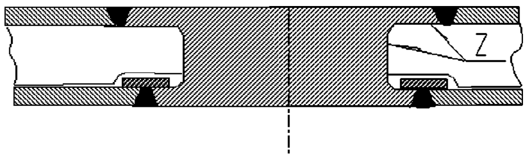


Fig. 3.2.3-1

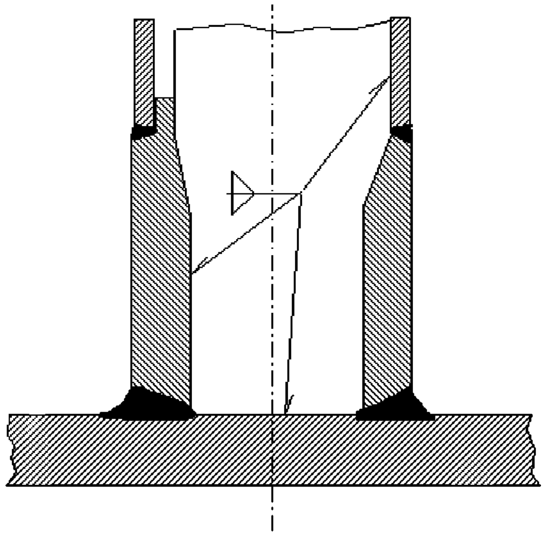


Fig. 3.2.3-2

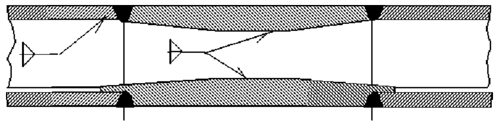


Fig. 3.2.3-3

3.3 STABILIZERS, STANCHIONS AND BRACKETS

3.3.1 All the requirements of 3.2 apply to the design of stabilizers and stanchions.

The lower sections of hollow structures of stabilizers and stanchions adjoining the main plane shall be strengthened with solid inserts or with thickened plates reinforced with additional stiffeners or brackets.

3.3.2 The stiffeners of a hollow stabilizer shall be arranged along its span. In case there is no solid insert between the main plane and stabilizer, the stabilizer stiffeners shall be arranged in such a way as to form a continuation of the main plane stiffeners, as shown in Fig. 3.3.2.

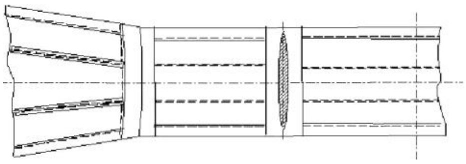


Fig. 3.3.2

3.3.3 The stiffeners of the hollow section of a stanchion shall be arranged along the stanchion. The stiffeners shall be attached to the shell plating in accordance with the requirements of 3.2.2.

3.3.4 A stanchion shall be attached to the hull by means of a vertical, horizontal or inclined flange. The input edge of the stanchion shall be rounded where the stanchion is attached to the main plane and flange to ensure a smooth transition in way of abutments (refer to Fig. 3.3.4).

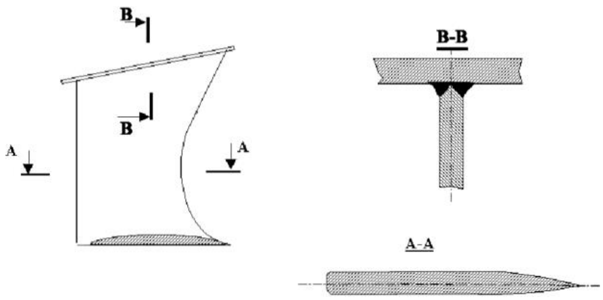


Fig. 3.3.4

3.3.5 Side brackets shall have a hollow structure.

The stiffeners of side brackets shall be arranged along the length of the latter. The stiffeners shall be attached to the shell plating as stipulated in 3.2.3. On the input and emergent edges of the bracket, connecting elements of solid cross-section shall be fitted.

3.4 WELDED JOINTS

3.4.1 General.

3.4.1.1 In hydrofoil installations, the welded joint assemblies shall be located in areas with the lowest stresses.

3.4.1.2 The weld types and structural elements of edge preparation for welding shall be in accordance with the standards agreed with the Register.

3.4.1.3 On water-washed surfaces, the butt-weld strengthening shall be machined flush with the base metal and ground.

3.4.1.4 On water-washed surfaces, fillet welds shall be ground so as to ensure a smooth transition to the base metal.

3.4.2 Butt welds.

3.4.2.1 The butt welds in solid components of hydrofoils shall be made using direct welding with double-groove edge preparation.

3.4.2.2 The plates of hollow hydrofoils shall be connected to each other and to other elements of external hydrofoil surface by means of butt welds with edge preparation (direct or indirect welding with a backing run). Where the opposite side is inaccessible for welding, butt welds shall be made on a permanent backing or halved (refer to Fig. 3.4.2.2). The backing material shall be of the same grade as the base metal.

The upper plating of main plane and the lower plating of the take-off surface of a hydrofoil shall be connected to the end elements (fillers) by means of direct butt welds.

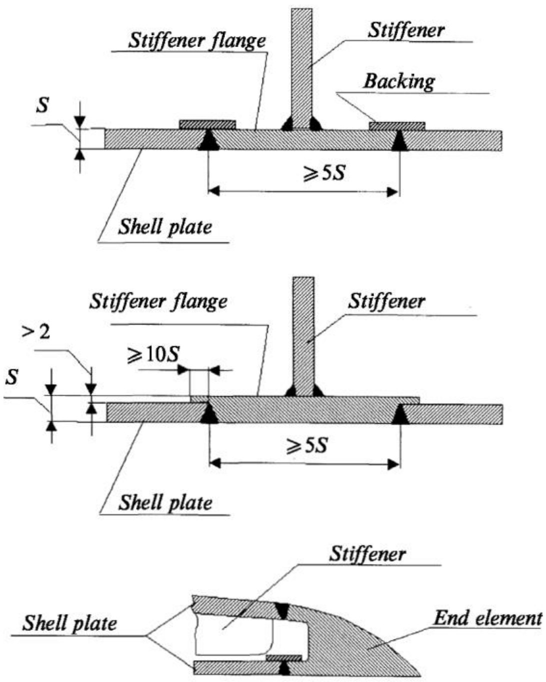


Fig. 3.4.2.2

3.4.2.3 The stiffener flanges forming a part of the hollow-hydrofoil shell plating shall be connected to the shell plating in conformity with Fig. 3.4.2.2.

3.4.3 Tee joints.

3.4.3.1 The tee and fillet joints of solid hydrofoil components shall be made by double-groove welding with full penetration. If the plate being joined is more than 1,5 times thicker than the plate to which it is joined and its thickness is equal to or greater than 40 mm in a tee joint, double-groove welding without full penetration shall be used. In this case, the design cross-section of the weld shall not be less than 0,7 times the thinner plate thickness.

3.4.3.2 The tee joints of internal stiffeners and hydrofoil plating, side brackets and flanges shall be made using continuous direct welding. In side bracket structures, stiffeners shall be connected to shell plating by tonguing (refer to Fig. 3.4.3.2).

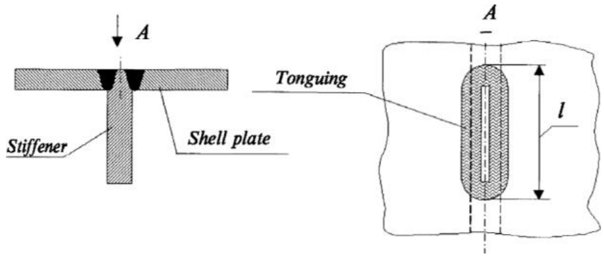


Fig. 3.4.3.2

4 REQUIREMENTS FOR FLEXIBLE SKIRT DESIGN

4.1 GENERAL

4.1.1 The requirements below apply to the flexible skirts of amphibious and side-wall craft which are made from fabric-backed materials or other materials approved by the Register, having a thickness ($s \leq 6$ mm), and in which glued, glued-punched, bolted or other joints are used.

4.1.2 The type of flexible skirt and its structural layout shall be set down on the initial design stages proceeding from the conditions of ensuring the required nautical, navigational and other service qualities of air-cushion vehicles.

4.1.3 The choice of dimensions, design and type of the principal joints and components of flexible skirts shall be made with due regard for the experience accumulated during the design and operation of similar craft, and also proceeding from the results of laboratory strength tests of pilot specimens manufactured under the Register technical supervision by the procedure and under conditions specified by the manufacturer. The list of components subject to laboratory testing and the types of required tests shall be agreed with the Register.

4.1.4 In the absence of a pilot specimen, the joint and component dimensions for the flexible skirt shall be set down proceeding from the condition of ensuring strength equal to that of the base metal under static tension.

4.1.5 The results of laboratory strength testing of components shall be submitted to the Register.

4.1.6 Where satisfactory experience of operating a similar pilot specimen is available, the laboratory tests of materials, joints and components of flexible skirts shall be omitted partially or completely. The resolution concerning the omission or reduction of the scope of laboratory testing shall be agreed with the Register.

4.1.7 The total scope of testing shall be determined considering the degree of novelty and structural continuity of the flexible skirts being developed with regard to existing ones. In the case of flexible skirt designs in which principally new technical solutions are implemented, new structural materials are used or where new service conditions are anticipated, provision shall be made for a pilot set of flexible skirt components to be manufactured and tested.

4.1.8 The pilot set of flexible skirt components shall be tested under operating conditions during the prescribed service time and in accordance with a program agreed with the Register. In well-grounded cases, the manufacture and testing of two or more pilot sets of flexible skirt components or pilot assemblies shall be advisable in order to choose the optimal design.

4.1.9 During pilot specimen operation, the results of periodical examinations of the technical condition of flexible skirt equipment shall be drawn up into relevant reports containing recommendations on its servicing and further elaboration of design. The periodicity of the examinations shall be agreed with the Register. The report on the results of testing the pilot set of flexible skirt equipment, which contains data on the actual performance characteristics of the structure, shall be submitted to the Register.

4.1.10 To increase the reliability of the flexible skirt, preference shall be given to materials, when choosing the material quality, whose properties are stable under service conditions (long immersion in water, exposure to oil products, solar radiation, low temperatures, etc.). The material properties deterioration as a result of water absorption for a long time shall not exceed 20 %.

4.2 MAIN TYPES OF ASSEMBLIES AND JOINTS IN FLEXIBLE SKIRT

4.2.1 The main structural assemblies of a flexible skirt (refer to Fig. 4.2.1) are as follows:

erection joint assembly (sectional connection);

assembly by which the flexible skirt is attached to the hull of the air-cushion vehicle;

plate connection assembly (connecting joints);

other assemblies (connecting guys, diaphragms and coamings to plates and plates to openings; connecting assemblies of removable components).

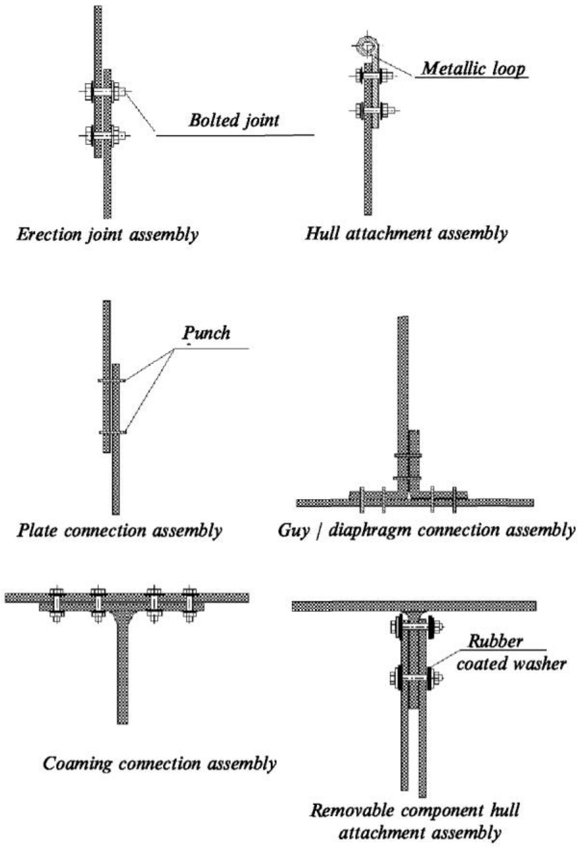


Fig. 4.2.1

4.2.2 The flexible skirt assembly design shall be chosen proceeding from the conditions of ensuring its serviceability within the prescribed service life in accordance with the requirements of 4.1.3 and 4.1.4.

4.2.3 Aluminium rivet joints are recommended instead of punched joints for highly loaded flexible skirt assemblies made of high-strength materials (breaking strength of 4,000 N/m or above).

4.3 FLEXIBLE SKIRT DESIGN

4.3.1 The design of the flexible skirt shall ensure its reliable operation under any service conditions and under the service factors specified in the request for proposal.

4.3.2 To ensure the serviceability and repairability of the flexible skirt during its service life it shall be so designed as to make replacement of components possible which are subject to accelerated wear.

4.3.3 The connecting assemblies shall not involve damage to adjacent flexible-skirt components. The metal components of flexible-skirt connecting assemblies shall be made of corrosion-resistant materials or shall have a corrosion-resistant coating.

4.3.4 All materials applied in the flexible-skirt structure shall comply with specified service conditions and loads and shall have the smallest mass possible.

4.3.5 The flexible-skirt structure shall, as far as practicable, be simple, producible, easy to operate and to maintain, to assemble and to disassemble and shall provide the possibility to make replacement of worn components from the outside and repair work aboard the craft possible.

In well-grounded cases, the flexible skirt structure shall incorporate erection joints in order to facilitate its manufacture, assembly, disassemble and repair. As far as practicable, the flexible-skirt sections shall be standardized.

4.3.6 Openings for air supply from the flexible seal to the removable components of the flexible skirt shall, as far as practicable, be as small as possible. An increase in the number of openings is recommended to provide the necessary air-flow area.

4.3.7 The request for proposal made in connection with the flexible skirt development shall contain technical requirements for the flexible skirt design, taking into consideration the structural peculiarities and anticipated service conditions of the craft.

5 STRENGTH NORMS

5.1 GENERAL

5.1.1 The present norms set requirements put forward by the Register for the strength and reliability of hull structures and special devices of the high-speed craft (including dynamically supported ships) as well as for performance verification strength calculations.

The strength norms are obligatory in design, construction and conversion of ships which are covered by these norms and technical projects submitted to the Register.

5.1.2 Strength calculations performed in accordance with the present norms shall be available for the exhaustive verification of all initial data contained therein. After approval of the project by the Register, responsibility still rests with the design bureaus for possible consequences which shall take place as a result of calculation errors or other omissions.

N o t e . If strength calculations are made on PC, software used for such calculations shall be certified by the Register.

5.1.3 Strength calculations of hull structures and special arrangements shall check finally determined dimensions of these structures at a given nominal thickness of applied plates, panels, materials.

5.1.4 Strength calculations submitted to the Register shall include:

external force calculations for general and local hull strength;

external force calculations for special arrangements strength;

general hull strength calculation;

local hull strength calculation;

calculation of strength of special arrangements;

results of experimental strength research of components and joints of hull and special arrangements (if such researches are stipulated);

strength conclusion made upon results of testing of the prototype (experimental) ship.

5.1.5 Calculations of the general and local hull strength, strength of special arrangements shall confirm that if design loads are applied; maximum normal and tangential stresses as well as maximum strain in flexible skirt do not exceed allowed limits given in 5.2 as well as sufficient strength margin for ultimate loads.

5.1.6 Besides verification of structure resistance to stresses, rigidity of the whole structure and of its components shall be tested, if this is required by the present norms and structure operating condition.

5.1.7 Stability of superstructure, bottom and side wall deck longitudinals as well as carlings, bottom stringers and vertical keel in grillage shall be ensured with at least two times safety margin as opposed to design calculation of general bending of hull corresponding to design section under review.

For hovercraft and high-speed catamarans with such margin strength, resistance of frames and beams to design stresses caused by transverse general bending of hull shall be ensured.

5.1.8 Loss of resistance of shell plating and deck plating of superstructure is allowed if design stresses are caused by general bending of hull.

5.1.9 When making calculation of frames rigidity it is necessary to consider influence of variation of the material elasticity by the value of critical normal stress (refer to Fig. 5.1.9); this consideration is not applied to plates.

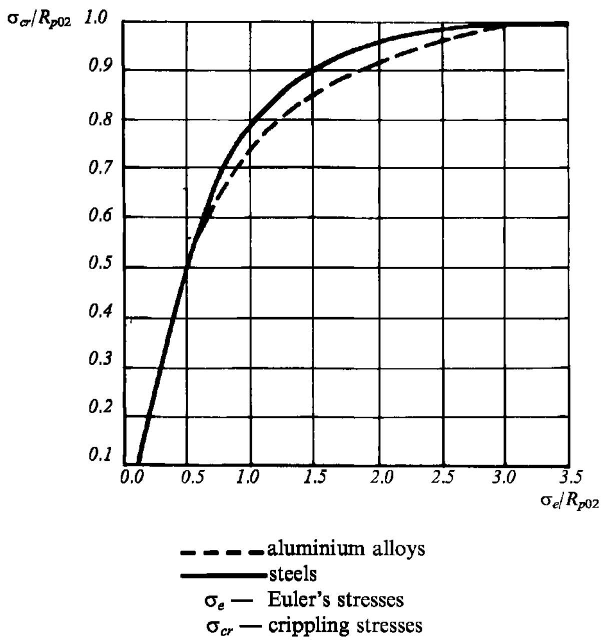


Fig. 5.1.9

5.1.10 Generally, strength calculation shall include the following:

determination of the value and character of design loads;

determination (in relation to the stressed condition) of maximum normal and tangential stress in sections of structures for the given design loads;

assignment of norms for dangerous stresses;

assignment of the required safety margin, norms of permissible stresses and verification of strength conditions.

5.1.11 External loads applied to ship hull and its separate structures shall be determined for the hardest operational conditions. Maximum external forces expected over the whole service life shall be taken for design loads.

5.1.12 Verification of strength conditions and resistance shall be carried out for the maximum normal and tangential stresses depending on the stressed condition of structure.

5.1.13 When stresses are calculated in the structural sections, loss of rigidity by some plates shall be considered by introduction of appropriate reducing coefficients.

When tangential stresses are determined, plates which have lost rigidity due to shift shall be introdueed with the reducing coefficient:

$$\varphi = 0{,}65. \qquad (5.1.13)$$

5.1.14 Scantlings of members which are not calculated by the norms shall be chosen in accordance with recommendations set forth in Sections 2 — 4.

5.1.15 Required duration of operating life of main (type) components and joints determined in accordance with 5.2.18 shall be ensured for hull and special arrangements.

For structures differing from typical ones, their operating life determined by the technical request for the design shall be supported not only by safety margins but by thorough fitting components of these structure, assessment of their operating life keeping due note of experimental researches as well as performance of periodical surveys and repairs during operation.

5.2 NORMS FOR PERMISSIBLE STRESSES

5.2.1 Values of permissible stresses in general and local hull strength calculations shall be taken in accordance with 5.2.8 and 5.2.14 as a proportion of dangerous stresses.

5.2.2 Dangerous condition of structures during assessment of its strength is considered such state when design stresses or deformations reach values at which destruction of the whole structure, violation of integrity or appearance of abnormal deformations become possible. The value of dangerous stresses (deformations) is evaluated while destruction testing of components and structural joints.

Attainment of dangerous states while verification calculations is deemed inadmissible.

Note. Norms of admissible deformations are designated on the basis of conditions of normal operation of hydrodynamical system and mechanisms.

5.2.3 Dangerous normal stresses for welded structures of hydrofoil installations made of steel are taken equal to the material yield point $\sigma_0 = R_{eH}$.

5.2.4 Dangerous normal stresses for welded structures made of aluminium are taken for the proportion of the material yield point:

$$\sigma_0 = KR_{p02} \quad (5.2.4)$$

where K is chosen in accordance with Table 5.2.4.

Table 5.2.4

Alloy category	1530, 1550, 1561	1561H, 1575
K	0,90	0,85

For riveted structures made of aluminium alloys, dangerous stresses are taken equal to $\sigma_0 = 0{,}9R_{p02}$.

Dangerous normal stresses used for general strength assessment of the welded and riveted structures made of light alloys shall not exceed R_{p02}, minimal for this category of material with no regard for the condition of delivery.

5.2.5 Dangerous shearing force T_0 and breakout power Q_0 of weld nugget for structures produced by spot welding or glued-welded joint shall be taken from Table 5.2.5.

Table 5.2.5

Alloy category (alloy grade)	Thickness of connected plates, mm	Weld nugget dangerous force	
		T_0 shear, kN, to the weld nugget	Q_0 breakout, kN, from the weld nugget
1530 1550 1561	2 ÷ 2	4,4	2,2
1561H 1575	3 ÷ 3	7,4	3,7

5.2.6 The following is taken for dangerous tangential stresses of welded and riveted structures:

$$\tau_0 = 0{,}57R_{p02}. \quad (5.2.6)$$

5.2.7 The following is taken for dangerous stresses for compressed parts of structure:

normal stresses — stresses causing loss of frame rigidity determined considering variation of normal elasticity modulus (refer to 5.1.10);

tangential stress ($\tau_{cr} \leq \tau_n$)

$$\tau_0 = K\frac{R_m + \tau_{cr}}{2} \quad (5.2.7)$$

where K is taken from Table 5.2.4.

5.2.8 Permissible stresses σ_{per} while calculation of general longitudinal (all types of ships) and transverse (hydrofoils, high-speed catamarans) of hull strength when bending moments arise while foil motion (hydrofoil), air cushion and staying on bearers (hovercraft) as well as water displacement regime are taken equal to:

$$\sigma \leq \sigma_{per} = n_s\sigma_0 \quad (5.2.8)$$

where n_s is the safety factor taken from Fig. 5.2.8.

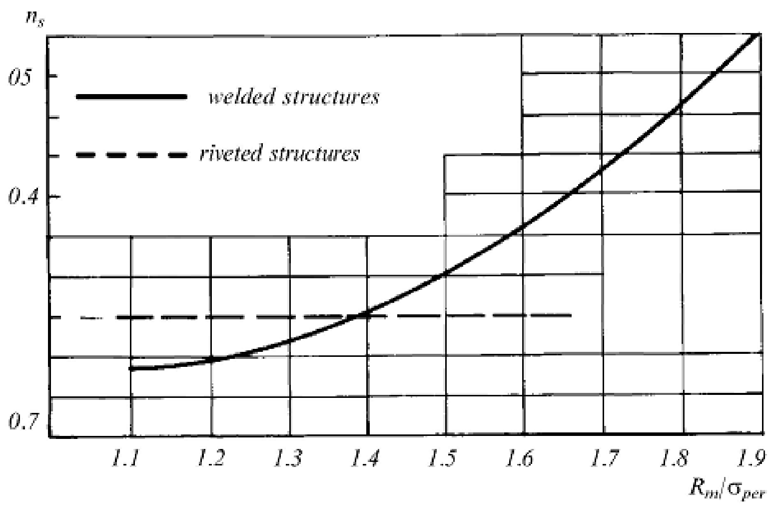


Fig. 5.2.8
Safety margins for hull (aluminium alloys)

5.2.9 Verification of longitudinal general strength shall show that ratio of ultimate moment to the design bending moment at motion in seaways and staying on bearers (hovercraft) complies with the following requirement:

$$M_{ult}/M_{des} \geq n_s;$$

$$M_{ult} = \sigma_0 W_0 \quad (5.2.9)$$

where σ_0 is the value of dangerous stresses taken in accordance with 5.2.3 — 5.2.7;
W_0 is the transverse section modulus which estimation is based on assumption that stresses in end fibers are equal to dangerous ones;
n_s is the safety margin taken from 5.3.10.5 (for hydrofoils and gliders) and from 5.3.11.2 (for high-speed catamarans and hydrofoils).

5.2.10 Stresses permissible for structures of high-speed catamarans and hydrofoils arising due to tangential stresses arising in longitudinal and transverse hull bending as well as influence of longitudinal torsion torque while motion at seaways and staying on bearers are taken equal to:

$$\tau_{per} = 0{,}30R_{\rho 02}. \qquad (5.2.10)$$

5.2.11 Stresses permissible at calculation of local strength of bottom, side, side wall plating (high-speed catamarans and hovercraft) on plate contour for loads set forth in 5.4 are taken equal to:

$$\sigma_{per} = \sigma_0. \qquad (5.2.11)$$

5.2.12 Stresses permissible at verification of local strength of framing of bottom structures, side, deck plating, superstructure deck, superstructure sides, bulkheads, platforms as well as rigid skirt bags, side walls (hovercraft) and inside plate contours for application of loads set forth in 5.4 are taken equal to:

$$\sigma_{per} = 0{,}8\sigma_0. \qquad (5.2.12)$$

5.2.13 Stresses permissible for application of normal stresses in carrying components of foils, struts, stanchions, stabilizers, brackets are taken equal to:

$$\sigma_{per} = n_s\sigma_0 \qquad (5.2.13)$$

where n_s is the safety margin taken from Fig. 5.2.13.

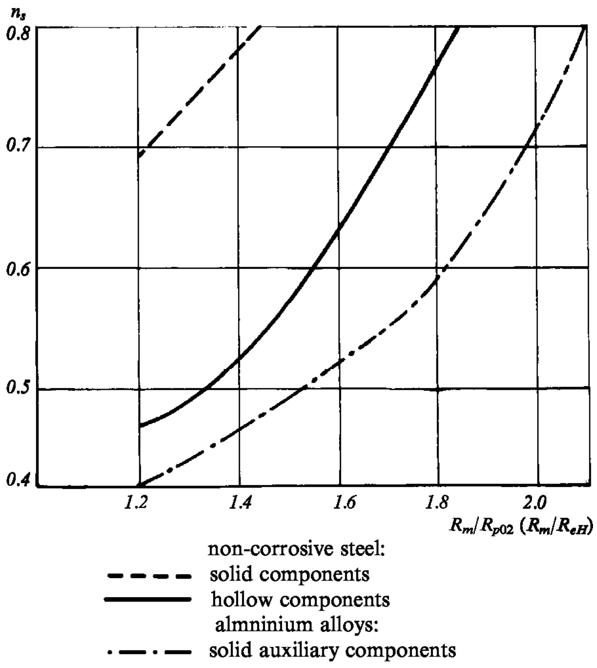


Fig. 5.2.13

5.2.14 Stresses permissible for calculation of influence of shell plating strength and framing of hollow components of hydrofoil installations on the hydrodynamic pressure arising due to flow about foil are taken equal to:

$$\sigma_{per} = 0{,}5\sigma_0. \quad (5.2.14)$$

5.2.15 Stability factor of stanchions, framing and plating of hollow components by normal stresses is given in 5.5.1.7 and 5.5.1.9.
5.2.16 Flexible skirt shall comply with the following strength conditions:

$$KT \leq R^b \quad (5.2.16)$$

where K is the safety factor assigned in accordance with Table 5.2.16.

Table 5.2.16

Design case	Safety factor (K)
1. Flexible skirt general strength	
Vaporing above surface without motion	14 (15)[1]
Motion in specification seaways conditions	7(5)
Motion in seaways conditions exceeding specification parametres	3,5
2. General strength of removable components	
Motion in specification seaways conditions	10 — 15
3. General strength of guys and diaphragms	
Motion in seaways conditions exceeding specification parametres	5 — 7
[1] Safety factor for flexible skirt of the side-wall hovercraft is given in brackets.	

5.2.17 Refinement of safety factor as regards specific project is carried out at the flexible skirt operation testing stage of head complex.
5.2.18 Strength norms are based on respective strength margin considering specific working conditions and responsibility of each structure under review.

Structural requirements in conjunction with special measures are aimed to ensure fatigue life of a large number of fatigue cracks in main (standard) joints and components over the whole period of ship service life.

5.3 HULL GENERAL STRENGTH CALCULATION

5.3.1 General.

5.3.1.1 Hull general strength shall be verified during following types of stressed/strained conditions:

general longitudinal bending (all types of ships);

general transverse bending (high-speed catamarans and hydrofoils);

torsion (high-speed catamarans and hydrofoils).

The following motion regimes shall be reviewed:

navigation in water displacing state on seaways designed in the project;

hydrofoil motion (hydrofoils), motion at air cushion (hovercraft), gliding (gliders) at design speed at design seaways.

5.3.1.2 The scope of general strength calculations shall be defined by the designer depending on the architectural and design peculiarities of the ship and shall be agreed with the Register.

5.3.1.3 Verification of general strength shall be carried out for the full ship displacement for the most representative from the strength standpoint transverse (all types of ships) and longitudinal (hydrofoils and catamarans) hull sections: in the areas of maximum bending, torsion torque (hydrofoils and catamarans) and cutting forces; in the areas of large openings in deck, superstructure etc. at least in three transverse and two longitudinal hull sections (hovercraft and high-speed catamarans) where large stresses may be expected.

Number of sections verified lengthways and breadthways (hovercraft and high-speed catamarans) of hull shall be justified in strength calculations submitted to the Register.

5.3.1.4 Weight and external forces distribution diagram as well as calculation of bending moments and cutting force made in accordance with consecutive chapters of these Rules shall be carried out by the number of ordinates which shall be not less than the number of theoretical spacings assuming that distribution of loads is equal along each area between such ordinates provided the latter is not conditioned separately.

The weight of ship ends lying beyond end ordinates shall be fully considered as regards its value and moment.

Non-closure of bending moment diagrams shall not exceed 5 % of maximum ordinates of these diagrams.

5.3.1.5 The maximum moment applied amidships at a distance of 5 % to the fore and aft end from the section where maximum bending moment is effecting shall be taken for the design moment.

For the ship sections located beyond above-mentioned 10 % of ship length, the design bending moment is the maximum bending moment effecting in the section located 5 % of ship length away from the section under review.

5.3.1.6 Carlings, stringers and other carrying longitudinal beams of bottom, side walls, decks, sides, skirt bags, etc. shall be fully included into calculation of hull girder. If plates lose rigidity while compression and shear, the area of their section shall be reduced.

5.3.1.7 Rigidity of grillage during compression and shear shall be tested in general and of each component separately: flumes, brackets, plates etc. This shall ensure sufficient rigidity of members supporting structure affected by compressing and shearing loads.

As regards elongated grillage without bulkheads across its length it is allowed to consider variation of compressing loads over its length.

5.3.1.8 Verification of the general strength for permissible stresses shall be carried out by comparison of design normal stresses in end members of hull girder with permissible stresses as well as the maximum tangential stresses against respective permissible stresses.

5.3.1.9 The values of bending moments applied to the hydrofoil installation components, forces as well as overloads are usually determined upon results of testing respective models (tow elastic and self-propelled ones).

Experimental data shall be compared with the results of calculation following analytical dependencies given in these Rules.

Modelling shall be carried out following principles of Froude scaling.

Correction of results of model tests and strength calculations in order to specify strength and structural life of series ships shall be carried out upon results of sea-keeping tests of prototype ship strength on which basis technical and operational ship characteristics are finally determined.

5.3.1.10 Processing of model test data is carried out by means of statistical methods. Meanwhile, the design value of the strength parameter with probability of 0,975 and reliability of 0,950 shall exceed any value of strength parametre of 5 % provision obtained during tests.

N o t e . Strength parameter in this case means peak values of structural load level (bending moment, stresses, forces, overload etc).

5.3.1.11 Dimensions of self-propelled models and their water displacement as well as program of model tests shall be agreed with the Register prior to model tests.

N o t e s : 1. During testing the model shall pass at least 200 waves at each regime.
2. The number of regimes is at least 30.
3. During testing of elastic models on the open water space such testings are deemed valid at which realisation the height of 3 % exceedance level was at least 80 mm.

5.3.2 Evaluation of bending moments and cutting forces applied to hydrofoil hull during navigation.

5.3.2.1 Navigation regime is the hydrofoil motion with a speed of $V_{hb} \leq V_{lift}$ on seaways in the water displacing position specified in the technical design.

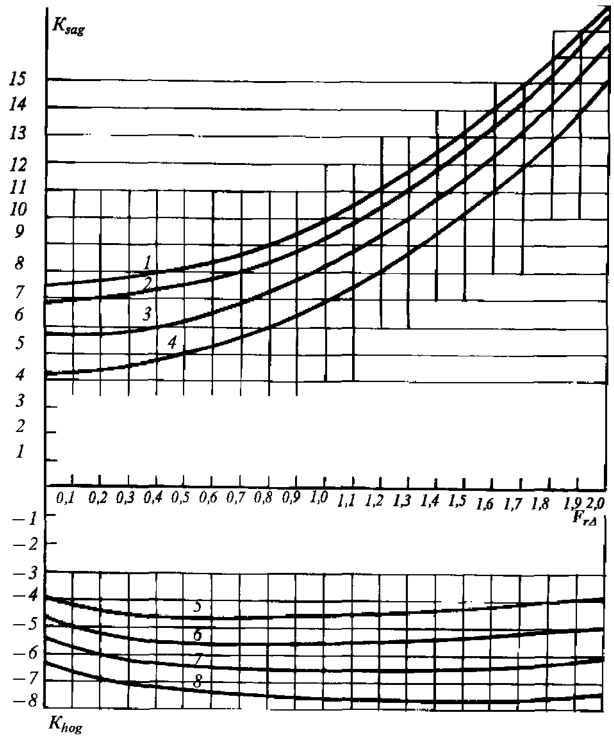
5.3.2.2 The value of the maximum bending moment amidships while sagging and hogging of ship hull is calculated according to the following formulae (the value of the bending moment is deemed positive at sagging and negative at hogging):

$$M_{des}^{sag} = M_w + M_d^{sag}; \qquad (5.3.2.2\text{-}1)$$

$$M_{des}^{hog} = M_w + M_d^{hog} \qquad (5.3.2.2\text{-}2)$$

where $M_d^{sag} = 0{,}01 K_{sag} \Delta L$;
$M_d^{hog} = 0{,}01 K_{hog} \Delta L$.

Bending moment M_w is evaluated by means of static wave simulation; coefficients K_{sag} and K_{hog} are taken from Fig. 5.3.2.2.



1 – $\bar{h}$ = 0,8; 2 – $\bar{h}$ = 0,7; 3 – $\bar{h}$ = 0,6; 4 – $\bar{h}$ = 0,5
5 – $\bar{h}$ = 0,5; 6 – $\bar{h}$ = 0,6; 7 – $\bar{h}$ = 0,7; 8 – $\bar{h}$ = 0,8

Fig. 5.3.2.2

5.3.2.3 The value of cutting forces is calculated according to the following formulae:

$$Q_{des}^{sag} = 4\left|M_c^{sag}\right|/L; \; Q_{des}^{hog} = 4|M_c^{hog}|/L. \qquad (5.3.2.3)$$

5.3.2.4 Distribution of bending moments and cutting forces along ship hull is taken from Fig. 5.3.2.4.

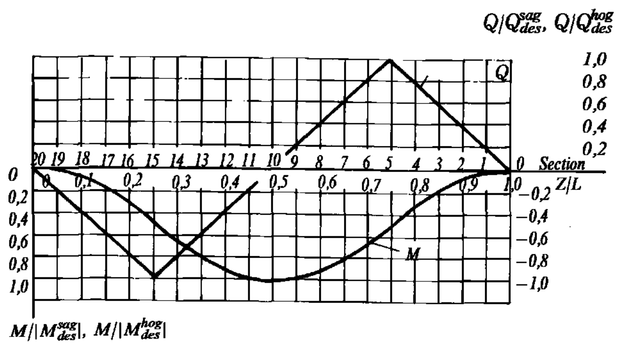


Fig. 5.3.2.4

5.3.3 Evaluation of design forces during hydrofoil motion on foils.

5.3.3.1 General hull strength against external forces arising at foil motion and speed motion specified in design technical request shall be verified for total displacement of the ship.

5.3.3.2 Hull general strength is tested for resistance to weight, hull and equipment mass moments of inertia as well as lifting forces arising in foil system and transmitted to hull in the form of concentrated forces.

5.3.3.3 Design values of cutting forces and bending moments are determined according to the following formulae:

$$Q_{des} = \int_0^x m_x g(n_g+1)d_x + \sigma(x_{\otimes} - x_{fr})R + \sigma(x_{\otimes} - x_{cent})R_{-p} + \\ + \sigma(x_{\otimes} - x_{aft})R_{aft}; \qquad (5.3.3.3\text{-}1)$$

$$M_{des} = \int_0^x\int_0^x m_x g(n_g+1)d_x d_x + \sigma(x_{\otimes} - x_{fr})R_{fr}(x + x_{fr} - x_{\otimes}) + \\ + \sigma(x_{\otimes} - x_{cent})R_{fr}(x - x_{cent} - x_{\otimes}) + \\ + \sigma(x_{\otimes} - x_{aft})R_{aft}(x + x_{aft} - x_{\otimes}) \qquad (5.3.3.3\text{-}2)$$

where $\sigma(x)$ is Hevyside's unit function.

5.3.3.4 While determination of the inertial forces of hull and carried cargoes, the value of the acceleration is taken from Fig. 5.3.3.4-1.

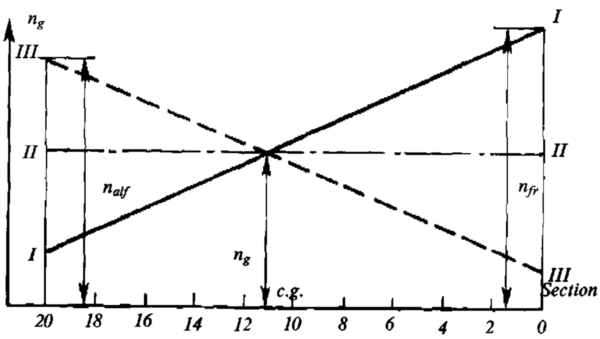


Fig. 5.3.3.4-1

The maximum design values of overloads which determine inertial forces are calculated for the bow perpendicular — n_{fr}, center of mass — n_g and 20 sections — n_{aft} respectively according to the formulae:

$$n_{fr} = 1 + 2{,}7P_{fr.s.w.}/\Delta; \qquad (5.3.3.4\text{-}1)$$

$$n_g = 0{,}55 + 0{,}57P_{fr.s.w.}/\Delta + \Delta n_g; \qquad (5.3.3.4\text{-}2)$$

$$n_{aft} = 1{,}40; \qquad (5.3.3.4\text{-}3)$$

where Δn_g is taken from Fig. 5.3.3.4-2.

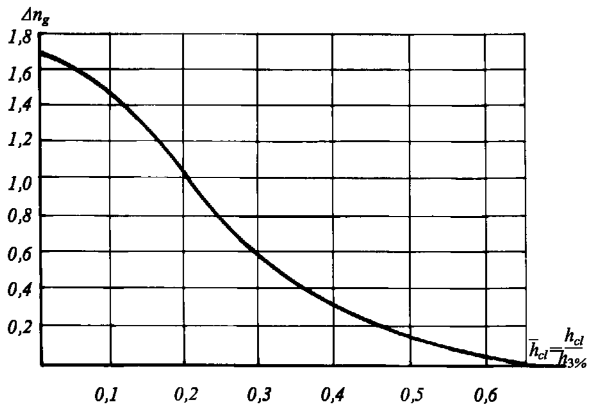


Fig. 5.3.3.4-2

If the hydrofoil automatic control system is available, overloads reduce:
for the ships with the surface piercing foil system — by 10 %;
for the ships with the completely immersed foil system — by 20 %.

Note. The value of the relative acceleration may be revised upon the results of experimental researches.

5.3.3.5 While ship motion on still water lifting forces acting upon the foils are:
for hydrofoils with double foil arrangement scheme ($P_{cent.st.w.} = 0$) are calculated according to the following formulae):

$$P_{fr.st.w.} = \Delta a_{aft}/l_{fi}; \quad (5.3.3.5\text{-}1)$$

$$P_{aft.st.w.} = \Delta a_{fr}/l_{fi}; \quad (5.3.3.5\text{-}2)$$

5.3.3.6 Hydrodynamic loads acting upon hull are determined keeping due note of dependencies:

$$R_{fr} + R_{cent} + R_{aft} + \Delta(n_g + 1); \quad (5.3.3.6\text{-}1)$$

$$R_{fr}(x_{fr} - x_0) + R_{cent}(x_{cent} - x_0) + R_{aft}(x_{aft} - x_0) = \frac{I_y}{x_{fr} - x_0}(n_{fr} - n_g).$$

(5.3.3.6-2)

5.3.3.7 Verification of hull general strength to cutting forces and bending moments is carried out in accordance with 5.3.3.3 — 5.3.3.6. While doing this three design load cases are reviewed:
maximum acceleration is acting in the bow end and distribution of accelerations along hull length is taken in accordance with the line I–I (refer to Fig. 5.3.3.4-1); for the double foil arrangement scheme $R_{cent} = 0$ and for three foil arrangement scheme it is taken $R_{fr} = P_{fr}^{max} + 0{,}3\Delta$; hull inertial forces are calculated in accordance with distribution of accelerations accepted for such case;
equal distribution of accelerations along hull length — the line II–II (Fig.5.3.3.4-1); for the double foil arrangement scheme $R_{cent} = 0$ and for three foil arrangement scheme it is taken $R_{cent} = P_{cent}^{max} + 0{,}3\Delta$; hull inertial forces are calculated in accordance with distribution of accelerations accepted for such case;

maximum acceleration is acting in aft end and distribution of accelerations along hull length is taken in accordance with the line III–III (Fig.5.3.3.4-1); for the double foil arrangement scheme $R_{cent} = 0$ and for three foil arrangement scheme it is taken $R_{aft} = P_{aft}^{max} + 0{,}3\Delta$; hull inertial forces are calculated in accordance with distribution of accelerations accepted for such case.

5.3.3.8 Maximum value of lifting forces acting in the foil system are calculated by the formulae:

$$P_{fr}^{max} = K_{fr} P_{fr.st.w}; P_{cent}^{max} = K_{cent} P_{cent.st.w}; P_{aft}^{max} = K_{aft} P_{aft.st.w}. \quad (5.3.3.8)$$

where $K_{fr}, K_{cent}, K_{aft}$ are coefficients which are calculated according to the formulae:

$$K_{fr} = 1{,}68 + 1{,}26 h_{3\%} / \sqrt[3]{\nabla} - 0{,}42 P_{fr.st.w.} / \Delta;$$

$$K_{cent} = 1{,}02 + 0{,}7 h_{3\%} / \sqrt[3]{\nabla} - 0{,}14 l_{fr} / \sqrt[3]{\nabla};$$

$$K_{aft} = 1{,}20 + 0{,}56 h_{3\%} / \sqrt[3]{\nabla} + 0{,}24 \frac{P_{fr.st.w.}}{P_{aft.st.w.}} \times \frac{P_{cent.st.w.}}{\Delta}.$$

5.3.3.9 Cutting forces and bending moment diagrams for the whole hull length are plotted for each case of loading upon results of the calculation.

General strength is verified for sagging of hull for the double foil arrangement scheme. Envelope curve plotted upon maximum values obtained for all design cases of load in accordance with 5.3.3.7 is taken for the design diagram.

Additionally, hull strength verification shall be performed in case of hogging due to bending moment equal to $M_{des}^{hog} = 0{,}5 M_{des}^{sag}$.

Verification of the general strength of the three foil arrangement scheme is carried out for the two following cases:

sagging; values of the envelope curve of the two diagrams obtained for the first and third design case if they correspond to 5.3.3.7 are taken for the design bending moments. Additionally, verification of the general strength is carried out for hogging if maximum bending moment modulus is applied, it is calculated by the following equations:

$$M_{des}^{hog} = 0{,}5 M_{des}^{sag}; \quad (5.3.3.9\text{-}1)$$

$$M_{des}^{hog} = M_{st.w.} - 0{,}8(M_{des}^{sag} - M_{st.w.}); \quad (5.3.3.9\text{-}2)$$

hogging; the diagram obtained for the second design case in accordance with 5.3.3.7 is taken for the design one. Additionally, verification of the general strength is carried out for sagging if maximum bending moment modulus is applied, it is calculated by the following equations:

$$M_{des}^{sag} = 0{,}5 M_{des}^{hog}; \quad (5.3.3.9\text{-}3)$$

$$M_{des}^{sag} = M_{st.w.} - 0{,}8(M_{des}^{hog} - M_{st.w.}); \quad (5.3.3.9\text{-}4)$$

5.3.4 Determination of design forces in water displacing position of hovercraft motion and during staying on bearers.

5.3.4.1 General hull strength to impact of external forces arising in water displacing position at seaways and speed of motion specified in technical design request shall be verified in full water displacing position.

5.3.4.2 Hull general strength is verified for longitudinal and transverse bending as well as torsion against weight forces, thrust forces initiated by propulsive device; lifting force, hull and equipment mass moments of inertia, hydrodynamic pressure emerging at bow slamming and aerodynamic pressure in the air cushion and hollows of flexible skirt conditioned by interaction of flexible skirt with waves.

5.3.4.3 Design value of bending moments at longitudinal hull bending is determined by the formulae:

sagging

$$M_{des}^{sag} = M_{st.w.} + M_w + M_d; \qquad (5.3.4.3\text{-}1)$$

hogging

$$M_{des}^{hog} = M_{st.w.} - M_w - 0{,}1M_d \qquad (5.3.4.3\text{-}2)$$

where $M_w = 1{,}1 \times 10^{-3}\rho g\alpha BL^3 K_M^w f$; (5.3.4.3-3)

$M_d = K_y^{des}(3{,}04 - 4{,}25\bar{x}_g) \times (1 + m_z)\Delta L K_M^d n_g$; (5.3.4.3-4)

$f = 1{,}0$ with $h_{3\%}/L \geq 0{,}06$;

$f = 32{,}2h_{3\%}/L - 259(h_{3\%}/L)^2 - 0{,}21\sin(52{,}36h_{3\%}/L)$ with $h_{3\%}/L < 0{,}06$;

K_M^w is the coefficient determined in accordance with Fig. 5.3.4.3-1;

$K_{x,y}^{des} = 0{,}322 - 0{,}833\bar{\rho}_{x,y}$; (5.3.4.3-5)

$$\bar{\rho}_y = \frac{\rho_y}{L}\sqrt{\frac{1+m_\psi}{1+m_z}}; \qquad (5.3.4.3\text{-}6)$$

$$m_\psi = \frac{\pi}{48}\eta_1^2\rho g \cdot \frac{B^2 \cdot L^3}{\Delta\rho_y^2} \cdot \frac{\alpha^2}{(3-2\alpha)(3-\alpha)}; \qquad (5.3.4.3\text{-}7)$$

$$m_Z = \frac{\pi}{4}\eta_1\rho g \cdot \frac{B^2 \cdot L}{\Delta} \cdot \frac{\alpha^2}{1+\alpha}; \qquad (5.3.4.3\text{-}8)$$

$$\eta_1 = \frac{1}{\sqrt{1+(B/L)^2}}\left[1 - \frac{0{,}425B/L}{1+(B/L)^2}\right]; \qquad (5.3.4.3\text{-}9)$$

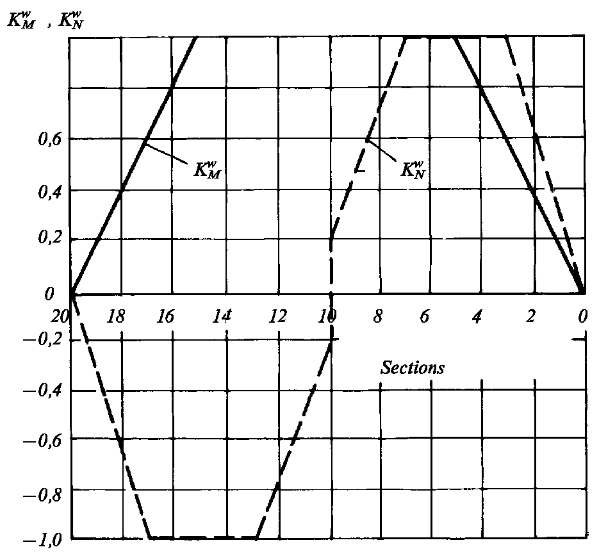


Fig. 5.3.4.3-1

K_M^d is the coefficient determined in accordance with Fig. 5.3.4.3-2;

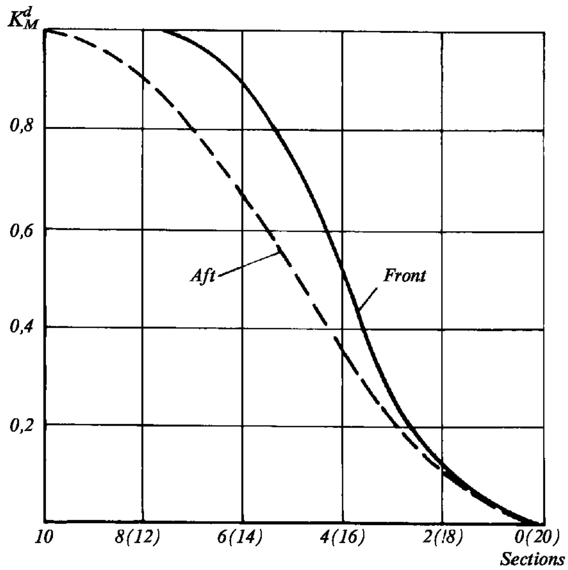


Fig. 5.3.4.3-2

$$n_g = (0{,}074 + 0{,}515 Fr_L) f^{1,3}. \qquad (5.3.4.3\text{-}10)$$

When the Froude number Fr_L is calculated, speed (V) is taken equal to the speed of ship motion in the navigation regime at a given $h_{3\%}$ but not less than 3 knots.

5.3.4.4 Design value of cutting forces at longitudinal hull bending is determined by the formulae:

sagging

$$Q_{des}^{sag} = Q_{st.w} + Q_w^{sag} + Q_d^{sag}; \qquad (5.3.4.4\text{-}1)$$

hogging

$$Q_{des}^{hog} = Q_{st.w} - Q_w^{hog} - Q_d^{sag}; \qquad (5.3.4.4\text{-}2)$$

where $$Q_w^{sag,\ hog} = \frac{3{,}5 M_w^{\otimes}}{L} K_N^w; \qquad (5.3.4.4\text{-}3)$$

$$Q_d^{sag} = \frac{5{,}8 M_d^{\otimes}}{L} K_N^d; \qquad (5.3.4.4\text{-}4)$$

$$Q_d^{hog} = 0{,}1 Q_d^{sag}; \qquad (5.3.4.4\text{-}5)$$

K_N^w and K_N^d are the coefficients determined in accordance with Fig. 5.3.4.3-1 and 5.3.4.4;

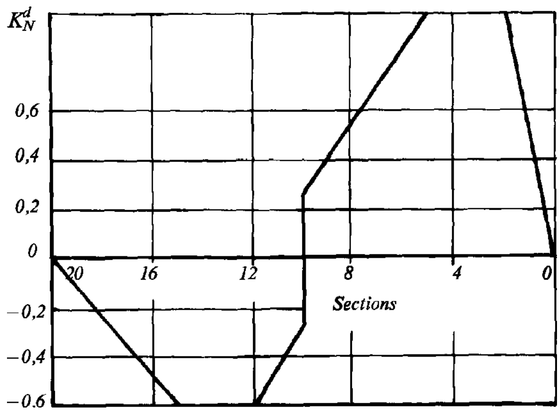


Fig. 5.3.4.4

5.3.4.5 Design value of bending moment at transverse hull bending is determined by the formula:

$$M_{des}^{trans} = M_{st.w.}^{trans} + M_{w}^{trans} + M_{d}^{trans} \quad (5.3.4.5\text{-}1)$$

where $M_{w}^{trans} = 2{,}1 \times 10^{-3} \rho g B^3 L K_M^{trans}$; (5.3.4.5-2)

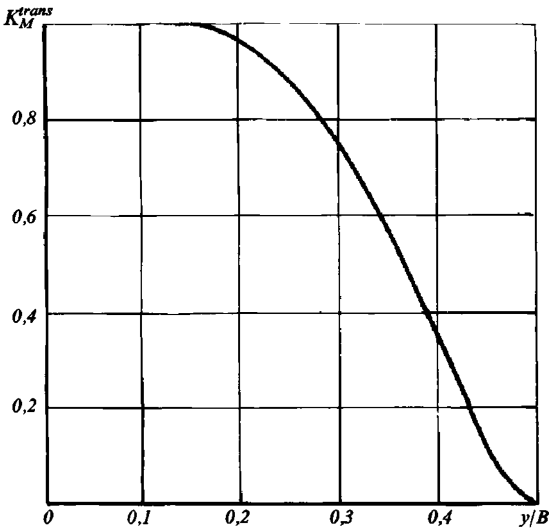
$M_{d}^{trans} = 0{,}6 K_x^{\rho} \Delta (1 + m_z) B n_g K_M^{trans}$; (5.3.4.5-3)

K_M^{trans} is the coefficient determined in accordance with Fig. 5.3.4.5;

K_x^{ρ} is the coefficient determined by the Formula (5.3.4.3-5);

$$\bar{\rho}_x = \frac{\rho_x}{B}\sqrt{(1 + m_Q)/(1 + m_z)}; \quad (5.3.4.5\text{-}4)$$

$$m_Q = \frac{\pi}{96} \frac{\left[1 - \frac{0{,}425 L/B}{1 + (L/B)^2}\right]^2}{1 + (L/B)^2} \rho g \frac{B^3 L^2}{\Delta \rho_x^2} . \quad (5.3.4.5\text{-}5)$$



y is the distance between section and CL

Fig. 5.3.4.5

5.3.4.6 Design value of cutting force at transverse hull bending is determined by the formula:

$$Q_{des}^{trans} = Q_{st.w.}^{trans} + Q_{w}^{trans} + Q_{d}^{trans} \qquad (5.3.4.6\text{-}1)$$

where $Q_{w}^{trans} = \frac{3{,}5M_{wCP}^{trans}}{B} K_{N}^{trans}$; (5.3.4.6-2)

$$Q_{d}^{trans} = \frac{5{,}8M_{dCP}^{trans}}{B} K_{N}^{trans}; \qquad (5.3.4.6\text{-}3)$$

K_{N}^{trans} is the coefficient determined in accordance with Fig. 5.3.4.6 provided $y^{*}/B = 0{,}4$;
M_{wCP}^{trans} and M_{dCP}^{trans} are wave and dynamic bending moments respectively acting in longitudinal hull section along CL.

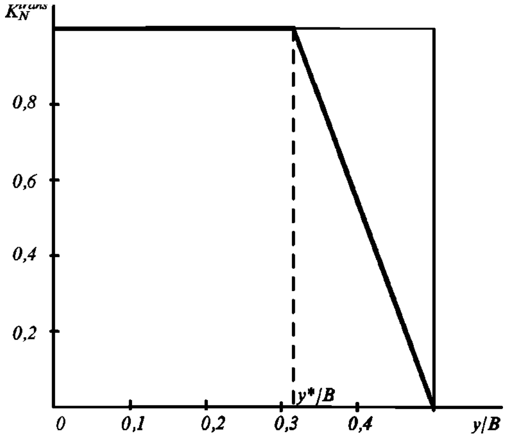


Fig. 5.3.4.6

5.3.4.7 Design value of torsion torque acting in transverse hull section is determined by the formula

$$M_{des}^{tor} = M_{w}^{tor} + M_{d}^{tor} \qquad (5.3.4.7\text{-}1)$$

where $M_{w}^{tor} = (1{,}8 - 1{,}5\ \varepsilon/D)10^{-2}\rho g f L B^{3} K_{w}^{tor}$; (5.3.4.7-2)
$M_{d}^{tor} = 3{,}5 \times 10^{-2} n_{g} \Delta B f^{1{,}3}(1 + m_{z}) K_{d}^{tor}$; (5.3.4.7-3)
ε is the distance between center of twist of the transverse section and base plane;
f is the function calculated in accordance with 5.3.4.3;
K_{w}^{tor} and K_{d}^{tor} are coefficients determined in accordance with Fig. 5.3.4.7.

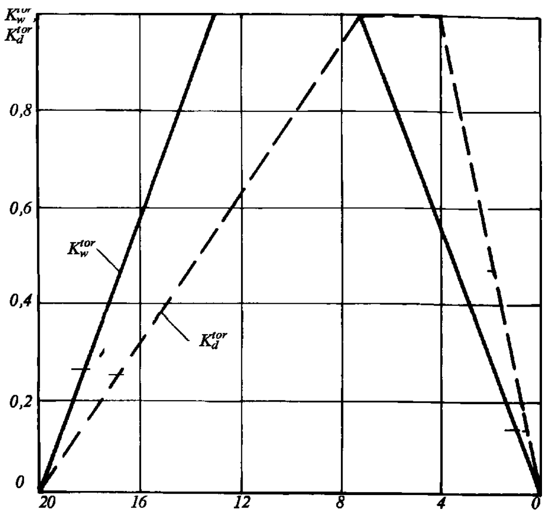


Fig. 5.3.4.7

5.3.4.8 Calculation of longitudinal and transverse bending moments and torsion torques and cutting forces while staying of a ship on bearers is carried out in the same manner as staying of hull on two bottom bearers located cornerwise (refer to Fig. 5.3.4.8). Calculation is made for the hull sagging.

While assessment of the reaction of bearers from the statics equation and the value of bending moment and torsion torques, the weight of ship is increasing in proportion to the amplification factor which is taken equal to K_d= 1,50 for all cases.

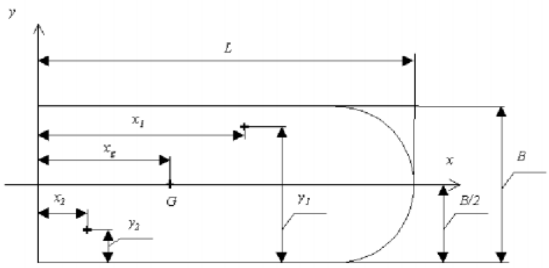


Fig. 5.3.4.8

5.3.4.9 Design values of longitudinal and transverse bending moments, cutting forces and torsion torques are calculated by integration of the ship weight increased in proportion to the amplification factor and external load- reaction of bearers treated as concentrated forces.

5.3.5 Calculation of design forces while hydrofoil motion on the air cushion and during emergency water landing.

5.3.5.1 Design value of the bending moment during bending of hull transversely while hydrofoil motion on the air cushion is determined by the formulae:

sagging of hull

$$M_{des}^{sag} = M_{st.w.} + M_d^{sag}; \qquad (5.3.5.1\text{-}1)$$

hogging of hull

$$M_{des}^{hog} = M_{st.w.} - M_d^{hog}; \qquad (5.3.5.1\text{-}2)$$

where $M_d^{sag,hog} = K_y^{\rho}(3{,}04 - 4{,}25\bar{x}_g)\Delta L K_M^d \times n_g^{sag,hog}$; (5.3.5.1-3)

$K_{x,y}^{\rho} = 0{,}286 - 0{,}75\bar{\rho}_{x,y}$; (5.3.5.1-4)

$\bar{\rho}_y$ is determined according to the Formula (5.3.4.3-6).

The value of relative acceleration $n_g^{sag,hog}$ shall be determined upon results of tests of dynamically similar model of ship in accordance with 5.3.1.9 and 5.3.1.11. In absence of such data the value may be determined by the formulae:

sagging of hull

$$n_g^{sag} = (0{,}7Fr_L + 0{,}21)f^{1,3}\ \frac{0{,}16 + 0{,}66h_{3\%}/H_{fs} + 0{,}08(h_{3\%}/H_{fs})^2}{2{,}57 + 170h_{3\%}/L + 332(h_{3\%}/L)^2}\ \frac{L}{H_{fs}}; \qquad (5.3.5.1\text{-}5)$$

hogging of hull

$$n_g^{hog} = \begin{cases} (0{,}41Fr_L + 0{,}23)Fr_L f^{1,3}, & \text{if} \quad n_g^{hog} < 0{,}8n_g^{sag}; \\ 0{,}8n_g^{sag}, & \text{if} \quad n_g^{hog} \geq 0{,}8n_g^{sag}. \end{cases} \qquad (5.3.5.1\text{-}6)$$

5.3.5.2 Design value of cutting forces at longitudinal bending during hydrofoil motion on the air cushion is determined by the following formulae:

sagging of hull

$$Q_{des}^{sag} = Q_{st.w.} + Q_d^{sag}; \qquad (5.3.5.2\text{-}1)$$

hogging of hull

$$Q_{des}^{hog} = Q_{st.w.} - Q_d^{hog}; \qquad (5.3.5.2\text{-}2)$$

where Q_d^{sag} is calculated by the Formula (5.3.4.4-4) in which
$M_d^{\otimes}$ is the moment amidships determined by the Formula (5.3.5.1-3);
Q_d^{hog} is calculated by the Formula (5.3.4.4-5).

5.3.5.3 Design value of bending moment at transverse bending during hydrofoil motion on the air cushion is determined by the following formula:

$$M_{des}^{trans} = M_{st.w.}^{trans} + M_d^{trans}; \qquad (5.3.5.3\text{-}1)$$

where $M_d^{trans} = 0{,}8K_x^o \Delta B K_M^{trans} \times n_g^{sag}$; (5.3.5.3-2)
K_x^o and K_M^{trans} are determined in accordance with the Formula (5.3.5.1-4) and Fig. 5.3.4.5 respectively.

5.3.5.4 Design value of cutting forces at transverse bending during hydrofoil motion on the air cushion is determined by the following formula:

$$Q_{des}^{trans} = Q_{st.w.}^{trans} + Q_d^{trans}; \qquad (5.3.5.4)$$

where Q_d^{trans} is determined by the Formula (5.3.4.6-3).

5.3.5.5 Design value of torsion torque during hydrofoil motion on the air cushion is determined from the formula

$$M_{des}^{tor} = n_g^{sag} \Delta \left[0{,}23B(1 - 0{,}24Fr_L) f^{1,3} K_d^{tor} - \frac{0{,}375 H_{fs} L}{S_{ac}} (0{,}5H_{fs} + \varepsilon) K_w^{tor} \right] \qquad (5.3.5.5)$$

where K_d^{tor}, K_w^{tor} are determined in accordance with Fig.5.3.4.7;
ε — refer to 5.3.4.7.

5.3.5.6 Design values of integral characteristics of external forces acting during emergency water landing are determined by the load conditioned by the blow of hull against water.

The value of the dynamic component of longitudinal bending moment emerging at blow of hull against water for the sagging and hogging of hull are determined by Formula (5.3.5.1-3). The value of coefficient at hull sagging is determined by Formula (5.3.4.3-5), at hull hogging — by the formula

$$K^{\rho}_{x,y} = 0{,}49\bar{\rho}_{x,y} - 0{,}017; \quad (5.3.5.6\text{-}1)$$

The value of relative acceleration is calculated by the following equation:

$$n = \frac{0{,}\mathrm{i}K_{\psi}vV}{(\Delta/g)(1+\bar{l}^2_y)^2} \quad (5.3.5.6\text{-}2)$$

where K^{i}_{ψ}, $\bar{l}_y$ and v are equal parametres:

a) sagging

$K_{\psi} = 1{,}4$;

$\bar{l}_y = 0{,}9$;

$v = v_o + v_n$;

$$v_o = 2{,}5\frac{h_{3\%}}{h_{3\%}+1{,}2}; \quad (5.3.5.6\text{-}3)$$

$$v_n = \frac{1}{S_{ac}}\left(Q_{min} + n_{tr}\varepsilon_{tr}S_{tr}\sqrt{\frac{2\Delta}{\rho_{air}S_{ae}}}\right) \quad (5.3.5.6\text{-}4)$$

where S_{ac} is the area of air cushion, in m^2;

Q_{min} is the minimum airflow charged to the air cushion by fans which ensures ballooning of removable components of flexible cushion seal (this airflow corresponds to the end of motion "on the bubble" to the motion "on the cushion", in m^3/sec;

n_{tr} is the number of air trunks;

S_{tr} is the calculated (minimal) area of air duct cross-section of air trunk, in m^2;

ε_{tr} is the coefficient of air outflow to the atmosphere through the vent trunk (in absence of more exact data it is taken for $\varepsilon_{tr} = 0{,}5$);

ρ_{air} is the air density at the atmospheric pressure, in t/m^3;

b) hogging

$K_{\psi} = 1{,}0$;

$\bar{l}_y = 0{,}5$;

$v = v_n$;

v_n is determined by Formula (5.3.5.6-4).

5.3.5.7 Design values of the transverse bending moment are determined by Formula (5.3.5.3-2) with the use of the relative acceleration conditioned by bow slamming against water which is calculated by Formula (5.3.5.6-2) for sagging of hull.

5.3.5.8 Cutting forces at hull bending longitudinally and transversely are calculated by Formulae (5.3.4.4-1) and (5.3.4.6-3).

5.3.5.9 Design value of torsion torque is determined by the following formula:

$$M^{tor}_d = 0{,}035DBnK^{tor}_d \quad (5.3.5.9)$$

where n is the relative acceleration conditioned by bow slamming during emergency landing (Formula (5.3.5.6-2), sagging of hull);

K^{tor}_d is the coefficient determined in accordance with Fig. 5.3.4.7.

5.3.6 Determination of design forces in a water displacing regimes of hydrofoil motion.

5.3.6.1 Calculation of the hull strength shall consider two cases (sagging and hogging of hull).

5.3.6.2 The value of longitudinal bending moment amidships is determined by the formulae:

sagging

$$M_{des}^{sag} = M_{st.w.} + M_w + M_d; \quad (5.3.6.2\text{-}1)$$

hogging

$$M_{des}^{hog} = M_{st.w.} - M_w - 0{,}6M_d \quad (5.3.6.2\text{-}2)$$

where $M_w = 0{,}0036\alpha\pi g f B_{sw} L^3 K_M^w$; (5.3.6.2-3)

f is the function calculated in accordance with Fig. 5.3.7.1-1;
B_{sw} is the largest width of side wall in the waterline plane in the water displacing position, in m;
K_M^w is the coefficient determined in accordance with Fig. 5.3.4.3-1;
α is the side wall waterline area coefficient;

$$M_d = K_M^d M_d^{\otimes}; \quad (5.3.6.2\text{-}4)$$

K_M^d is the coefficient determined in accordance with Fig.5.3.4.3-2;

$$M_d^{\otimes} = K_y^{\rho} K_\tau (3{,}04 - 4{,}25\bar{x}_g)\Delta \times (1 + m_z) L n_g; \quad (5.3.6.2\text{-}5)$$

$$K_{x,y}^{\rho} = 0{,}322 - 0{,}833\bar{\rho}_{x,y}; \quad (5.3.6.2\text{-}6)$$

$$\bar{\rho}_y = \frac{\rho_y}{L}\sqrt{(1+m_\psi)/(1+m_z)}; \quad (5.3.6.2\text{-}7)$$

$$m_\psi = \frac{\pi}{2}\rho g \frac{\alpha^2}{(3-2\alpha)(3-\alpha)} \times \frac{B_{sw}^2 L^3}{\Delta \rho_y^2}; \quad (5.3.6.2\text{-}8)$$

$$m_z = \frac{\pi}{2}\rho g \frac{\alpha^2}{1+\alpha} \times \frac{B_{sw}^2 L^3}{\Delta}; \quad (5.3.6.2\text{-}9)$$

K_τ is the coefficient determined in accordance with Fig. 5.3.6.2;

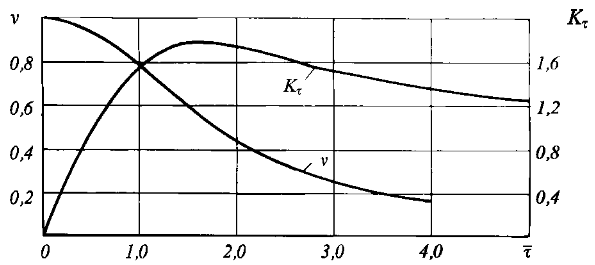


Fig. 5.3.6.2

$$\bar{\tau} = \frac{0{,}2}{\pi}\omega_1\sqrt{(\sqrt[3]{\nabla}/g)}\, n_g; \quad (5.3.6.2\text{-}10)$$

$$\omega_1 = \left(\frac{0{,}43}{\bar{\rho}_y - 0{,}183} + 16{,}2\right)\sqrt{\frac{EJ_{\otimes} g}{(1+m_z)\Delta L^3}}; \quad (5.3.6.2\text{-}11)$$

$J_{\otimes}$ is the moment of inertia of the hull transverse cross-section amidships.

The value of the relative acceleration n_g shall be calculated upon results of model tests of designed ship in compliance with 5.3.1.9 and 5.3.1.11. In absence of such data the value of the relative acceleration may be approximately calculated by the formula

$$n_g = [0{,}5 + (0{,}31 + 0{,}72f^2)Fr_L]f^{1{,}5}. \qquad (5.3.6.2\text{-}12)$$

5.3.6.3 The values of cutting force in transverse hull cross-sections are calculated by the following formulae;

sagging

$$Q_{des}^{sag} = Q_{st.w} + Q_w + Q_d^{sag}; \qquad (5.3.6.3\text{-}1)$$

hogging

$$Q_{des}^{hog} = Q_{st.w} - Q_w - Q_d^{hog} \qquad (5.3.6.3\text{-}2)$$

where $Q_w = \frac{4M_w^{\otimes}}{L}K_N^w$; (5.3.6.3-3)

K_N^w is the coefficient which is calculated in accordance with Fig. 5.3.4.3-1;

$Q_w^{sag} = 5{,}8\frac{M_d^{\otimes}}{L}K_N^d$; (5.3.6.3-4)

$Q_d^{hog} = 0{,}6Q_d^{sag}$; (5.3.6.3-5)

K_N^d is the coefficient which is calculated in accordance with Fig. 5.3.4.4.

5.3.6.4 For calculation of the general transverse strength of side-wall hovercraft during sailing, bending moments are calculated by the formula:

$$M_{des}^{trans} = M_{st.w.}^{trans} + M_d^{trans} \qquad (5.3.6.4\text{-}1)$$

where $M_d^{trans} = K_M^{trans} \times M_d^{CP}$; (5.3.6.4-2)

K_M^{trans} is the coefficient determined in accordance with Fig. 5.3.4.5;

$M_d^{CP} = \overline{M}_{trans}\Delta(1+m_z)Bn_g$; (5.3.6.4-3)

$\overline{M}_{trans} = -2/3\overline{\rho}_x + 0{,}18B_{ac}/B + 0{,}165$; (5.3.6.4-4)

$\overline{\rho}_x = \frac{\rho_x}{B}\sqrt{(1+m_Q)(1+m_z)}$; (5.3.6.4-5)

B_{ac} is the inner distance between side walls in the plane of design waterline, in m;

$m_Q = \frac{1}{16}m_z\left(\frac{B+B_{ac}}{\rho_x}\right)^2$. (5.3.6.4-6)

5.3.6.5 Cutting forces acting in transverse sections of side wall hydrofoils are determined by the formula

$$Q_{des}^{trans} = Q_{st.w.}^{trans} + Q_d^{trans} \qquad (5.3.6.5\text{-}1)$$

where $Q_d^{trans} = \frac{1{,}25B_{ac}/B - 0{,}155}{\overline{M}_{trans}} \times \frac{M_d^{CP}}{B}K_N^{trans}$; (5.3.6.5-2)

K_N^{trans} is the coefficient taken from Fig. 5.3.4.6 at the value of relative kink ordinate $y^*/B = 0{,}11 + 0{,}38B_{ac}/B$.

5.3.6.6 Design values of torsion torque in transverse hull cross-sections are taken equal to:

$$M_{des}^{tor} = M_d^{tor} + M_w^{tor} \qquad (5.3.6.6\text{-}1)$$

Wave component of torsion torque M_w^{tor} is determined by means of skew positioning of a ship on the wave hollow.

Dynamic component of torsion torque M_d^{tor} is determined by the following formulae:

within 0 to 2 sections

$$M_d^{tor} = (-49 + 100\bar{x} - 50\bar{x}^2 + f_m)r, \qquad (5.3.6.6\text{-}2)$$

where $\bar{x} = 1 - j/20$ is the number of section;

$$r = \frac{\Delta(1 + m_z)n_g y_R}{1 + \kappa}; \qquad (5.3.6.6\text{-}3)$$

y_R is the parameter which is taken equal to $0{,}25(B + B_{ac})$ for side-wall hovercraft;

$\kappa = 0$ motion of ship in the navigation regime;

$$f_m = -a\bar{x} - b\bar{x}^2/2 + \frac{c}{\pi}\cos\pi\bar{x} - c/\pi; \qquad (5.3.6.6\text{-}4)$$

$$b = 6(2\bar{x}_g - 1); \qquad (5.3.6.6\text{-}5)$$

$$c = 43{,}7\left(\frac{4 + b}{12} - \bar{\rho}_y^2 - \bar{x}_g^2\right); \qquad (5.3.6.6\text{-}6)$$

$$a = 1 - b/2 - 2c/\pi, \qquad (5.3.6.6\text{-}7)$$

within 2 to 4 sections

$$M_d^{tor} = r(32 - 80\bar{x} + 50\bar{x}^2 + f_m), \qquad (5.3.6.6\text{-}8)$$

within 4 to 20 sections

$$M_d^{tor} = r f_m. \qquad (5.3.6.6\text{-}9)$$

Wave component is calculated according to the formula

$$M_w^{tor} = 0{,}32\Delta B(3\bar{x}_g - 1)\sin\pi\bar{x}. \qquad (5.3.6.6\text{-}10)$$

5.3.7 Determination of design forces during motion of hovercraft in the operational mode.

5.3.7.1 Design value of the longitudinal bending moment is determined in accordance with the formulae:

sagging

$$M_{des}^{sag} = M_{st.w.} + M_w + M_{d1} + 0{,}8M_{d2}; \qquad (5.3.7.1\text{-}1)$$

hogging

$$M_{des}^{hog} = M_{st.w.} - M_w - 0{,}6M_{d1} - 0{,}5M_{d2} \qquad (5.3.7.1\text{-}2)$$

where $M_w = 0{,}0044\alpha(1 + 2{,}2Fr_L - 0{,}33Fr_L^3)(0{,}8 - 4{,}9B_{sw}/L) \times$
$\times (1{,}9 - 0{,}15L_{ac}/B_{ac})\rho g B_{sw} L^3 f K_M^w$; (5.3.7.1-3)

f is the function which is determined in accordance with Fig. 5.3.7.1-1;

K_M^w is the coefficient determined in accordance with Fig. 5.3.4.3-1;

B_{sw} is the width of side wall in the waterline area plane during motion on the air cushion, in m;
M_{d1} is the dynamic bending moment caused by the blow of connecting bridge (bottom in the area of air cushion) against wave;
M_{d2} is the dynamic bending moment caused by the blows of side walls against wave.

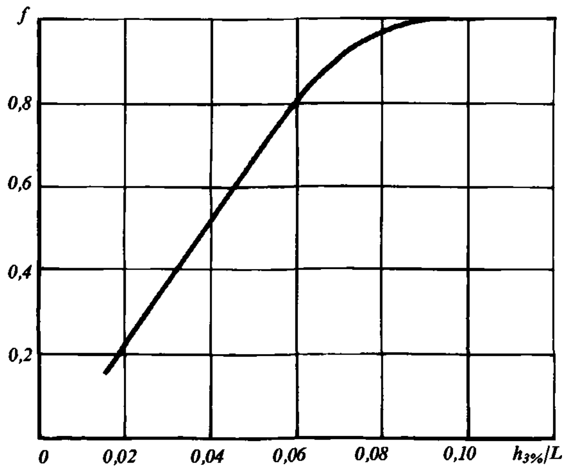


Fig. 5.3.7.1-1

The value of the dynamic bending moment M_{d1} is determined by Formulae (5.3.6.2-4) and (5.3.6.2-5). Meanwhile, the value of the vertical relative acceleration n_g is determined by the formula

$$n_g = n_1(1 - k_g) + n_2 k_g \qquad (5.3.7.1\text{-}4)$$

where $k_g = 3\bar{h}_1^2 - 2\bar{h}_1^3$; (5.3.7.1-5)

$\bar{h}_1 = f - 6{,}5H_{ac}/L$;

$n_1 = (0{,}33Fr_L^2 + 0{,}165Fr_L + 0{,}05)(5{,}7h_2 - 0{,}81h_2 + 0{,}16) + 0{,}42h_2$; (5.3.7.1-6)

$$h_2 = 0{,}077\frac{L}{\sqrt[3]{\Delta}}f;$$

$$n_2 = [0{,}5 + (0{,}34 + 0{,}72f^2)Fr_L]f^{1,5}. \qquad (5.3.7.1\text{-}7)$$

The value of the dynamic bending moment M_{d2} is determined by the formula

$$M_{d2} = 0{,}052\rho B_5^2 L^2 \frac{\omega_1}{\rho_y}[0{,}42a\sqrt{\frac{g}{L}}(2{,}5Fr_L + 1) + 0{,}023V]vK_M^b \qquad (5.3.7.1\text{-}8)$$

where B_5 is the side wall width in the waterline plane which corresponds to its immersion to the bilge in the area of the 5th section, in m;
v is the coefficient determined in accordance with Fig. 5.3.6.2;

$$a = 0{,}045(3{,}1 - 0{,}39Fr_\Delta - 0{,}12L_{ac}/B_{ac} + 0{,}02Fr_\Delta L_{ac}/B_{ac} \times$$

$$\times (1{,}17 - 0{,}66\rho_y/L)(2{,}5 - 5{,}8B_{sw}/B)fL; \qquad (5.3.7.1\text{-}9)$$

$$\bar{\tau} = 0{,}13\frac{\omega_1 T_2}{\sqrt[a]{(g/L)(2{,}5Fr_L + 1)}}; \qquad (5.3.7.1\text{-}10)$$

T_2 is the side wall draught immersed to the bilge in the area of the 2nd section, in m.

5.3.7.2 Cutting forces acting in the transverse sections of side wall hovercraft are determined by the formulae

$$Q_{des}^{sag} = Q_{st.w.} + \frac{1}{L}[4M_w^{\otimes} K_N^w + 5{,}8M_{d1}^{\otimes} K_N^d + 3{,}2M_{d2}^{\otimes} K_N^w]; \quad (5.3.7.2\text{-}1)$$

$$Q_{des}^{hog} = Q_{st.w.} - \frac{1}{L}[4M_w^{\otimes} K_N^w + 3{,}5M_{d1}^{\otimes} K_N^d + 1{,}6M_{d2}^{\otimes} K_N^w]. \quad (5.3.7.2\text{-}2)$$

5.3.7.3 While calculation of the general transverse strength of side wall hovercraft, calculations of transverse bending moments and cutting forces shall be carried out in accordance with 5.3.6.4 and 5.3.6.5. While calculation of bending moment by Formula (5.3.6.4-3) the following value shall be taken for the design relative acceleration:

$$n_g = 29M_{d2}\bar{\rho}_y / L\bar{\tau}\Delta(1 + m_z). \quad (5.3.7.3)$$

5.3.7.4 Design values of torsion torque acting in the transverse sections of side wall hovercraft are determined in accordance with recommendations of 5.3.6.6. Parameter k is taken equal to 0,2 and value of the relative acceleration is determined by Formula (5.3.7.3).

5.3.8 Calculation of loads which determine strength of gliders.

5.3.8.1 Determination of design acceleration.

Vertical acceleration a used during evaluation of inertial forces transmitted by cargoes to the hull structure are determined for two cases of ship bow slamming against head sea: strike against bow end (in the area of the 3rd section) and strike amidships (to the after end off the 3rd section) by the formula

$$a/g = \frac{f_h f_V(1 + k_a)(4{,}83 - 0{,}176\beta_a + 0{,}002\beta_a^2)[0{,}67L/B_{\otimes} - 0{,}08(L/B_{\otimes})^2 - 0{,}35]}{k_p(1 + m_z)}, \quad (5.3.8.1)$$

where $f_h = 13\{1 - \exp[-(17h_{3\%}/L - 2{,}9)^2]\}h_{3\%}/L$, if $h_{3\%}/L \leqslant 0{,}095$;

$$f_h = 1{,}0, \text{ if } h_{3\%}/L > 0{,}095;$$

$$f_V = [0{,}96 + 0{,}48\exp(2{,}5Fr_c - 2{,}5)]/[2{,}27 + 17{,}7\exp(-1{,}1Fr_{\Delta})]$$

$$Fr_c = 0{,}514V/\sqrt{gc};$$

$$c = B_{\otimes}^4 \; l_G^4 / (\Delta/\gamma)^{7/3};$$

$$Fr_{\Delta} = 0{,}514V/\sqrt{g\nabla^{1/3}};$$

$$n = 0{,}5 + 0{,}8\varphi_V;$$

$$\varphi_V = \exp[-0{,}75(Fr_{\Delta} - 0{,}9)^2];$$

$$k_a = \frac{A}{\rho_y^2 L}(x - x_g), \text{ but not less than } 0;$$

$$A = 0{,}539 + 0{,}311\varphi_V - x_g/L \text{ — at strike against ship bow end;}$$

$$A = \varphi_a[3{,}27 - 0{,}205\lambda - (0{,}707 - 0{,}032\lambda)Fr_{\Delta} + (0{,}0707 - 0{,}003\lambda)Fr_{\Delta}^2]\rho_y^2 \; L/B_{\otimes},$$

but not less than 0 and not greater than $0{,}65l_G/L$ — at strike amidships

$$\varphi_a = [1 + (\beta_{\otimes}/30 - 0{,}5)(-0{,}071 + 0{,}067Fr_{\Delta} - 0{,}002Fr_{\Delta}^2)]k_T,$$

λ is the value taken equal to equation L/B (or 5,0 depending whichever is greater);
k_T = 1,0 – for gliders with the usual hydrodynamic arrangement;
1,07 – for the ships with the bottom air cavity;

$$\rho_y^2 = \frac{I_y(1+m_\psi)}{\nabla L^2(1+m_z)};$$

$$m_z = 1{,}3\gamma B_\otimes^2 \ \ l_G(1-\beta_a/180)\frac{a^2}{1+a} \ \ k\zeta^2/\Delta;$$

$$m_\psi = 0{,}39\gamma B_\otimes^2 \ \ l_G^3 \ (1-\beta_a/180)\frac{a^2}{(3-2a)(3-a)} k\zeta^2/I_y;$$

$$a = 0{,}5(1+B_{tr}/B_\otimes);$$

$$\zeta = [1-0{,}425\eta/(1+\eta^2)]\eta/(1+\eta^2)^{0{,}5};$$

$$\eta = 3{,}4l_G/(B_\otimes + B_{tr});$$

k = 1,0 – for gliders without planing steps,
0,85 – for gliders with planing steps,
0,5 – for the ships with the bottom air cavity;
$k_\rho = (0{,}285 - 0{,}737\rho_y, + 0{,}047r)/(1 + r)$ – at strike against bow end
$0{,}36\exp(-0{,}168Fr_\Delta)$ – at strike amidships and the Froude number $Fr_\Delta < 4{,}0$,
0,184 – at strike amidships and the Froude number $Fr_\Delta < 4{,}0$;
$r = 0{,}8(1-\varphi_v)$;
β_a is the deadrise angle of the transverse hull section (at wave strikes against the bow end the 3rd section is viewed, at wave strikes amidships the distance of $x = l_G + AL$ from transom is viewed).

5.3.8.2 Loads determining general hull strength.

5.3.8.2.1 Bending moments and cutting forces acting in the transverse hull sections at sagging and hogging refer to the loads which determine general hull strength of the glider. Distribution of bending moments and cutting forces over ship length is taken in accordance with 5.3.2.4.

5.3.8.2.2 The values of sagging and hogging moments amidships are determined by the formula

$$M_{sag(hog)} = M_{st.w.} \pm k_M \Delta L a_G/g \qquad (5.3.8.2.2)$$

where $M_{st.w.}$ is the bending moment amidships at ship motion on still water;
a_G is the value of the vertical acceleration a which is calculated for the centre of ship gravity in accordance with 5.3.8.1 (at the value of $k_a = 0$);
$k_M = k_\rho$ at wave strike against bow end and sagging of hull.
0,07 at wave strike amidships and hogging of hull.

5.3.8.2.3 Design values of cutting forces at sagging and hogging of hull is determined by the following formula

$$Q_{sag(hog)} = 4{,}5M_{sag(hog)}/L \qquad (5.3.8.2.3)$$

5.3.9 Loads determining strength of high-speed catamarans.

5.3.9.1 Determination of design accelerations.

Design vertical accelerations a which are used for assessment of pressure and forces transmitted by cargoes to the hull structures are determined by the formula:

$$a/g = [1{,}4 + 3{,}4Fr_L \exp(-2{,}7Fr_L)](1 + 2{,}5Fr_L)^2 \times f\sqrt{1 + 48(x_M/L + 0{,}075)^2} + F \quad (5.3.9.1)$$

where g is the gravitational acceleration;

x_M is the abscissa of the point in question which is counted off the midship section (negative if located to the end bow from the midship);

$f = (1 - \frac{1}{\exp(17\frac{h_{3\%}}{L} - 2{,}9)^2})\frac{h_{3\%}}{L}$, if $\frac{h_{3\%}}{L} \le 0{,}095$;

$f = 0{,}077$, if $\frac{h_{3\%}}{L} > 0{,}095$;

$F = (1 + \frac{0{,}9 - l_G/L}{(\bar{\rho}_y)^2 L} x_M)n \ge 0$;

l_G is the distance between the centre of gravity and transom (from the aft perpendicular);

$(\bar{\rho}_y)^2 = \frac{\rho_y^2}{L^2} \cdot \frac{1 + m_\psi}{1 + m_z}$;

ρ_y is the radius of inertia of craft mass about transverse axis, m;

$\bar{\rho}_y$ is the nondimensional cetral radius of gyration of the ship;

$m_z = \frac{\pi}{2}\rho g \cdot \frac{\alpha^2}{1+\alpha} \cdot \frac{B_{hull}^2 L}{\Delta}$;

$m_\psi = \frac{\pi}{24}\rho g \cdot \frac{\alpha^2}{(3-2\alpha)\cdot(3-\alpha)} \cdot \frac{B_{hull}^2 L^3}{\Delta \cdot \rho_y^2}$;

L is the craft length between perpendiculars, m;

I_y is the central moment of inertia of ship mass about transverse axis, kg·m^2;

ρ is the density of sea water, t/m^3;

B_{hull} is the hull width amidships in the plane of the construction waterline, m;

α is the water-plane coefficient;

$n = n_1(1 - k_g) + n_2 k_g$

where $k_g = 3h_1^2 - 2h_1^3$;

$h_1 = 13f - 6{,}5h_{cl}/L$;

$n_1 = (0{,}33Fr_L^2 + 0{,}165Fr_L + 0{,}05) \times (5{,}7h_2^2 - 0{,}81h_2 + 0{,}16) + 0{,}42h_2$;

$n_2 = [24 + (16 + 5700f^2)Fr_L]f^{1{,}5}$;

$h_2 = \frac{L}{\sqrt[3]{\nabla}}f$;

h_{cl} is the hull clearance (distance between unperturbed water surface and connecting bridge in the midship section).

5.3.9.2 Loads determining hull general strength.

Bending moments and cutting forces as well as torsion torques acting in the transverse and longitudinal hull sections refer to the loads which determine hull general strength.

These loads are determined by the formulae given below or by test results of the elastic models equipped with dynamometer sensors (refer to 5.3.1.10 and 5.3.1.11).

5.3.9.2.1 The value of the longitudinal bending moment in the transverse section of hull is determined by the following formulae:

sagging

$$M_{des}^{sag} = M_{st.w.} + M_w + M_d, \text{t}\cdot\text{m}, \quad (5.3.9.2.1\text{-}1)$$

hogging

$$M_{des}^{hog} = M_{st.w.} - M_w - 0{,}6M_d, \text{t}\cdot\text{m}, \quad (5.3.9.2.1\text{-}2)$$

where $M_w = 0{,}059\alpha\rho g\left(0{,}8 - 4{,}9\frac{B_{hull}}{L}\right) \cdot (1 + 2Fr_L - 0{,}3Fr_L^3) \cdot B_{hull}L^3 f k_M^b$, t·m;

$M_{st.w.}$ is the bending moment acting in the transverse section in question during ship motion on still water (positive at sagging);
f is the function which is determined in accordance with 5.3.9.1;
k_M^b is the coefficient characterising distribution of the wave component of the moment along ship length and which is determined in accordance with Fig. 5.3.4.3-1;
α is the waterplane area coefficient;
M_d is the dynamic component of the bending moment. Dynamic component of the bending moment is determined by the formula

$$M_d = k_{\rho_y}\left(3{,}04 - 4{,}25\frac{l_G}{L}\right)\cdot(1+m_z)\cdot\Delta\cdot L\cdot n\cdot k_M^q, \text{ t·m;}$$

where parameters m_z and n are determined in accordance with 5.3.9.1 and coefficient k_M^q is in compliance with Fig. 5.3.4.3-2.

$k\rho_y$ is the coefficient determined by the formula

$$k\rho_y = 0{,}322 - 0{,}833\bar{\rho}_y$$

where parameter $\bar{\rho}_y$ is determined according to 5.3.9.1.

5.3.9.2.2 The values of the cutting force in the transverse hull sections are calculated by the following formulae:

sagging

$$Q_{des}^{sag} = Q_{st.w.} + Q_w + Q_d^{sag}, \text{t;} \quad (5.3.9.2.2\text{-}1)$$

hogging

$$Q_{des}^{hog} = Q_{st.w.} - Q_w - 0{,}6Q_d^{hog}, \text{t,} \quad (5.3.9.2.2\text{-}2)$$

where $Q_w = 4(M_w^{\otimes}/L)k_N^w$; t,
$Q_d^{sag} = 5{,}8(M_d^{\otimes}/L)k_N^d$, t;
$M_w^{\otimes}$ and $M_d^{\otimes}$ are the wave and dynamic components of the bending moment acting in the midship section of hull;
k_N^w and k_N^d are the coefficients determined in accordance with Figs. 5.3.4.3-1 and 5.3.4.4.

5.3.9.2.3 Design values of the bending moment at symmetrical transverse hull bending are calculated by the following formulae:

sagging

$$M_{trans}^{sag} = M_{st.w.}^{trans} + M_{trans}, \text{ t·m;} \quad (5.3.9.2.3\text{-}1)$$

hogging

$$M_{trans}^{hog} = M_{st.w.}^{trans} - M_{trans}, \text{ t·m,} \quad (5.3.9.2.3\text{-}2)$$

where $M_{st.w.}^{trans}$ is the bending moment acting in the transverse hull section during ship motion on still water (positive at sagging);
$M_{trans} = [0{,}12\Delta(1+m_z)Bn + 0{,}0021\rho g B^3 L]k_M^{trans}$, t·m;
B is the width amidships;
m_z and n are parameters determined by 5.3.9.1;
k_M^{trans} is the coefficient determined in accordance with Fig. 5.3.4.5.

5.3.9.2.4 Cutting forces acting in longitudinal hull sections are determined by the formula

$$Q_{des}^{trans} = (5{,}2M_{trans}^{sag(hog)}/\mathrm{B})k_N^{trans}, \mathrm{t} \tag{5.3.9.2.4}$$

where k_N^{trans} is the coefficient determined in accordance with Fig. 5.3.4.6 if relative ordinate in taken $y^*/B = 0{,}11 + 0{,}38B_h/B$;
B_h is the horizontal hull clearance — distance between hulls in the midship section measured in the plane of construction water line.

5.3.9.2.5 Design values of torsion torques in the transverse hull sections are taken equal to:

$$M_{des}^{tor} = \Delta B\left[0{,}32\left(3\bar{l}_G - 1\right)\sin\pi\bar{x} + \bar{M}_d(\bar{x})\right], \mathrm{t\cdot m}, \tag{5.3.9.2.5}$$

where $\bar{x} = 1 - j/20$ (j – number of section);
$\bar{l}_G = l_G/L$ is the relative distance between the gravity centre and transom (from the aft perpendicular).

Function $\bar{M}_d(\bar{x})$ is determined by the following dependencies:

within 0 and 2 section

$$\bar{M}_d(\bar{x}) = (-49 + 100\bar{x} - 50\bar{x}^2 + f_m)r$$

where $r = 0{,}25\Delta(1 + m_z)(B + B_{hor})n$;
$f_m = -\bar{a}\bar{x} - b\bar{x}^2/2 + \frac{c}{\pi}\cos\pi\bar{x} - c/\pi$;
$b = 6\left(2\bar{l}_G - 1\right)$;
$c = 43{,}7(\frac{4+b}{12} - \bar{\rho}_y^2 - \bar{l}_G^2)$;
$\bar{a} = 1 - b/2 - 2c/\pi$;

within 2 and 4 section

$$\bar{M}_d(\bar{x}) = r(32 - 80\bar{x} + 50\bar{x}^2 + f_m);$$

within 4 and 20 section

$$\bar{M}_d(\bar{x}) = rf_m.$$

5.3.9.2.6 Transverse torsion torque (in the longitudinal section of connecting structures by the inboard side) is determined by the following formula:

$$M_{trans}^{tor} = (0{,}1n + 1{,}2f)\Delta L, \mathrm{t\cdot m}. \tag{5.3.9.2.6}$$

5.3.10 Verification of the hydrofoil and glider general strength.
5.3.10.1 General hull strength shall be verified:
for permissible normal and tangential stresses;
for marginal state.
5.3.10.2 Design values of normal stresses in end members of hull girder shall satisfy the following conditions:

$$\sigma_u = \alpha_u M_{des}/W_u \le \sigma_{per} = n_s\sigma_0; \tag{5.3.10.2-1}$$

$$\sigma_l = \alpha_l M_{des}/W_l \le \sigma_{per} = n_s \sigma_0;\qquad (5.3.10.2\text{-}2)$$

where σ_u and σ_l are the design stresses in the upper (superstructure) and lower (bottom) members of hull girder accordingly;
M_{des} is the design bending moment at sagging and hogging acting in the design section and determined in accordance with 5.3.3.3-5.3.3.9, 5.3.8.2.2;
W_u and W_l are the section moduluses for the upper and lower members of hull girder accordingly;
α_u and α_l are coefficients considering superstructures contribution to the general hull bending which is taken equal to $\alpha_u = 0{,}85$ and $\alpha_l = 1{,}4$ (in absence of regularly located window openings in superstructures coefficients $\alpha_u = \alpha_l = 1$);
n_s is the safety margin taken in accordance with Fig. 5.2.8.

Distribution of normal stresses along height of hull section is taken linear.

5.3.10.3 If superstructure extends over practically the whole length of the ship hull, its sides coincide with sides of the ship and they are weakened by a large number of openings, normal stresses in hull σ_h and awning (top) of superstructure σ_s as well as normal σ_{ws} and tangential τ_{ws} stresses in the window soliving in the wall may be calculated by the formulae:

$$\sigma_h = M_{des} y/I - T(1/F + ly/I);\qquad (5.3.10.3\text{-}1)$$

$$\sigma_s = T/f;\qquad (5.3.10.3\text{-}2)$$

$$\sigma_{ws} = \pm absT/4i_0; \tau_{ws} = cT/bt\qquad (5.3.10.3\text{-}3)$$

where M_{des} is the design bending moment (at sagging and hogging) of the section in question, in kN·m;
y is the distance between the member in question and neutral axis of hull section, in m;
I is the moment of inertia of the transverse hull section, in m^4;
F is the area of the transverse hull section, in m^2;
f is the area of the transverse superstructure section, in m^2;
l is the distance between the centres of gravity lines of hull sections from the centres of gravity lines of superstructure awning section, in m (refer to Fig. 5.3.10.3);
a is the window height, in m (refer to Fig.5.3.10.3);

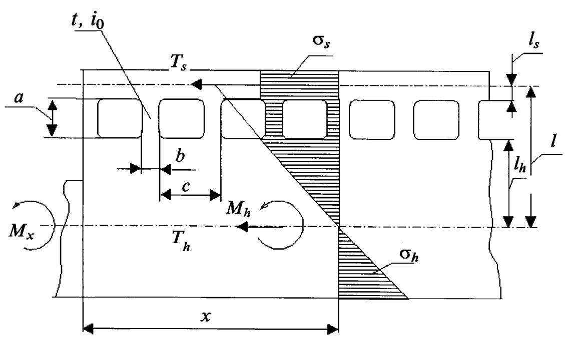


Fig. 5.3.10.3

b is the width of window soliving, in m;
c is the spacing between window openings, in m;
t is the thickness of window soliving, in m;
i_0 is the moment of inertia of the transverse section of window soliving, in m4;
T is the axial force acting along lines of centre of gravity of hull sections T_h of the superstructure awning T_s, kN, equal to:

$$T_h = -T_N = T = T_0\left[\frac{\lambda sh\lambda(l-x)}{sh\lambda l}\int_0^l \frac{M_x}{M_0} sh\lambda\xi d\xi + \frac{\lambda sh\lambda x}{sh\lambda l}\int_0^l \frac{M_h}{M_0} sh\lambda(l-\xi)d\xi\right]; \quad (5.3.10.3\text{-}4)$$

T_0 is the force acting in the section in question if the superstructure awning shalltally involved in hull bending, in kN:

$$T_0 = \frac{M_0 lf}{(F+f)I/F + fl^2}; \quad (5.3.10.3\text{-}5)$$

$M_0 = M_h + Tl$ – design bending moment which is varied along hull length, in kN·m;
M_h is the bending moment acting in the transverse hull section, in kN·m;

$$\lambda^2 = \frac{K}{E}\left(\frac{F+f}{Ff} + l^2/I\right); \quad (5.3.10.3\text{-}6)$$

E is the normal elasticity modulus, in kPa;

$$T = K\delta; \quad (5.3.10.3\text{-}7)$$

δ is the shift of the centre of gravity of hull sections in respect of the centre of gravity of the superstructure awning along axis x, in m;

$$\delta' = T/EF + T/Ef - M_h l/EI; \quad (5.3.10.3\text{-}8)$$

l is the length of superstructure, in m;
K is the coefficient of hull and superstructure members rigidity, in kN/m^2;

$$K = \frac{1}{1/K_0 + 1/K_h + 1/K_s}; \quad (5.3.10.3\text{-}9)$$

K_0 is the stiffness coefficient of superstructure side members which are weakened by regular openings located at equal interval from each other, in kN/m^2;

$$K_0 = \frac{E}{ac(a^2/12i_0 + 2{,}6/bt)}; \quad (5.3.10.3\text{-}10)$$

K_h and K_s are stiffness coefficients taking into account yielding of structure at the level of window openings as well as yielding to shift of the side of superstructure awning and side of hull:

$$K_h = \frac{Et_h}{2{,}6l_h(1 - t_h l_h/2F)}; \quad (5.3.10.3\text{-}11)$$

$$K_s = \frac{Et_s}{2{,}6l_s(1 - t_s l_s/2F)}; \quad (5.3.10.3\text{-}12)$$

t_h and t_s are mean thicknesses of plating adjoining window openings, hull and superstructure awning respectively, in m;
l_h is the distance between the line of centre of gravity of hull sections and the lower edge of window openings, in m;
l_s is the distance between the line of centre of gravity of hull sections and the upper edge of window openings, in m.

5.3.10.4 Design values of tangential stresses at sagging and hogging of hull shall comply with the following conditions:

$$\tau = \frac{Q_{des}S_x}{I_x\delta} \leqslant \tau_{per} = 0{,}3R_{p02} \quad (5.3.10.4)$$

where Q_{des} is the design value of cutting force calculated in accordance with 5.3.3.3 — 5.3.3.9;
S_x is the moment of area of design transverse section relative to zero line, in m^3;
δ is the total thickness of side and longitudinal bulkheads at the level where tangential stresses are determined, in m.

Total design thickness of side and longitudinal bulkheads in absence of sufficient bulkhead plates resistance to shear forces shall be calculated keeping due note of reduction coefficient which is equal to ratio of Euler stress tangents to design ones.

Side plating shall ensure safety margin of at least 1,5 if exposed to tangential stresses.

Note. If critical tangential stresses are determined with due note of change of material modulus of elasticity, it is allowed to take $\tau \leq \tau_{cr}$.

If resistance to tangential stresses is tested, only two hull sections may be verified in the area of maximum cutting forces.

5.3.10.5 Verification of strength ultimate moment shall show that during both sagging and hogging of hull ratio of ultimate moment to the maximum design bending moment in the section under consideration shall comply with the following condition:

$$M_{ult}/ M_{des} \geq 0{,}8/n_s \quad (5.3.10.5\text{-}1)$$

where $M_{ult} = \sigma_0 W_0$; (5.3.10.5-2)

W_0 is the minimum modulus hull section under consideration, in m^3 which is calculated keeping due note of reduction of area of members losing stiffness assuming that in the far ends, the most distant from the zero line of hull members stresses equal to dangerous are acting;

n_s is the safety margin taken in accordance with Fig. 5.2.8.

5.3.11 Calculation of hovercraft and high-speed catamarans hull strength at their longitudinal bending.

5.3.11.1 General hull strength during longitudinal bending shall be verified for the cases of sagging and hogging of hull:

permissible normal and tangential stresses if design bending moments and cutting forces determined for accepted design modes of motion are acting in accordance with 5.3.4 — 5.3.7 and 5.3.9;

ultimate moments.

5.3.11.2 Determination of normal and tangential stresses acting in hull members during longitudinal bending as well as determination of ultimate moment is carried out in accordance with 5.3.8. During verification of general strength ultimate moment (refer to 5.2.9) the safety factor n_s is taken equal to 2,0.

5.3.12 Calculation of hovercraft and high-speed catamarans hull strength at their transverse bending.

5.3.12.1 Determination of stresses during verification of the transverse hull strength is carried out by means of the finite element method or by means of the approximate method given below based on the beam models of transverse bulkheads. This method may be used if $B/D \geq 2$ provided transverse bulkheads are located across the whole width of hull. Transverse bulkhead is calculated as a girder experiencing exposure of bending moment and cutting forces. General transverse bending moment and cutting force in the longitudinal section of hull are distributed among separate bulkheads pro rata of their bending/shear rigidity.

If the ship is landing on the bottom bearers retroaction is taken up by those members which are located immediately above bearers.

Bending/shear rigidity of some bulkheads is determined by the formula

$$I_{bs} = \frac{1}{l_b^2/KEI_b + 1/h_b\delta_b G} \quad (5.3.12.1)$$

where

I_b is the moment of inertia of the vertical section of bulkhead with deck and bottom strakes, in m^4;

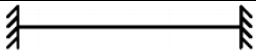
l_b is the length of bulkhead span, in m;

h_b is the average bulkhead height, in m;

δ_b is the average thickness of the bulkhead, in m;

K is the coefficient taken from Table 5.3.12.1 in relation to the bulkhead fixing on sides.

Table 5.3.12.1

Conditions of transverse members ends fixing		K
Simple support		24
Fixed embedment		96

For the purposes of determination of the bulkhead moment of inertia adjoining face plates of bottom, platforms, decks shall be considered which width is taken as the lesser value of those equal to 1/8 length of the span or the distance between neighbouring bulkheads.

5.3.12.2 In absence of transverse bulkheads in the middle (by width) part of hull, the calculation of the transverse strength is carried out in relation to the level of the bearing capacity of members supporting hull in transverse direction. If a twofold stability factor is ensured for transverse members (ratio of the critical compressing load of girder to the force equal to the maximum transverse bending moment is greater or equal to two) then an assumption of the combined action of transverse members of superstructure deck and pontoon beams (beams and floors) making a single hull girder shall be made for strength calculations.

If pontoon members (floors) safety factors comply with condition (5.3.12.4-3), it is permissible to reduce stability factor of transverse members of the superstructure deck (upper deck) to 1,2. In this case strength calculations shall be based on the assumption that beams and floors bend separately (not forming a single hull girder).

If an assumption of the combined action of beams and floors during transverse bending of hull is accepted, calculation of the hull girder is carried out in a usual manner.

Compression stresses of beams and extension stresses of floors found at an assumption of the combined action of transverse members forming an ideal girder during its transverse sagging shall be added to the additional normal stresses conditioned by bending of transverse members among longitudinal bulkheads which was caused by shear forces acting in hull.

Additional bending moments in some beams and floors are distributed in proportion to their bending/ shear rigidity evaluated by the parameter

$$\lambda_{ts} = \frac{1}{l_{ts}^2/(2EI_{ts}) + 1/(GF_{ts})} \qquad (5.3.12.2\text{-}1)$$

where l_{ts} is the distance among longitudinal bulkheads;
F_{ts} and I_{ts} is the web cross-sectional area of transverse member and moment of inertia of its transverse section.

Total bending moment distributed among separate beams is determined by the formula

$$M_E = 0{,}33 Q_{el}^{trans} \lambda_{ts} \qquad (5.3.12.2\text{-}2)$$

where Q_{el}^{trans} is the maximum cutting force in longitudinal hull sections determined in accordance with 5.3.4.4, 5.3.4.6, 5.3.4.8, 5.3.6.3, 5.3.6.5, 5.3.7.3 and 5.3.9.

Determination of the normal and tangential stresses in the transverse member components is carried out by the formulae

$$\sigma = M_{des} y/I; \qquad (5.3.12.2\text{-}3)$$

$$\tau = Qs/I\delta \qquad (5.3.12.2\text{-}4)$$

where M_{des} is the design bending moment in the section under consideration;
I is the moment of inertia of the section area calculated with due account of reduction of members;

y is the distance between the member under consideration from the neutral axis of section;
Q is the design cutting force acting in section;
s is the static moment relative to neutral axis of the part of section area lying above axis under consideration;
δ is the total thickness of section sides at the horizontal level under consideration.

If transverse member represents symmetrical flat girder frame, normal stresses in its strakes are determined by the formula

$$\sigma = M_{des}/a_h F_{gf} \tag{5.3.12.2-5}$$

where F_{gf} is the girder flange area;
a_h is the distance between strakes (height of girder).

Cutting forces are balanced in girder joint by forces in diagonal members and posts which are determined by methods of girder calculation. Normal stresses in diagonal members are calculated as a ratio of the determined axis force to the area of transverse section of respective component.

5.3.12.3 If there are transverse bulkheads amidships critical strength of hull shall be checked against the following conditions:

$$M_{hs}^{trans}/M_{el}^{trans} \geq 2;$$
$$Q_{ult}^{trans}/Q_{el}^{trans} \geq 1{,}5 \tag{5.3.12.3}$$

where M_{el}^{trans} and Q_{el}^{trans} are the maximum values of total bending moment and cutting force in longitudinal section of girder-bulkhead for the mode of operation under consideration;
$M_{hs}^{trans} = \sigma_0 W_k^{trans}$ is the ultimate bending moment of the girder-bulkhead;
$Q_{ult}^{trans} = 0{,}5\Omega_b\sigma_{0,2}$ is the ultimate cutting force for the transverse bulkhead under consideration;
W_k^{trans} is the modulus of section of the girder-bulkhead calculated on the assumption that stresses acting in the end fibres are equal to dangerous σ_0 calculated in accordance with 5.2.3;
Ω_b is the area of the transverse bulkhead (by vertical plane).

5.3.12.4 In absence of transverse bulkheads amidships and use of an assumption of the isolated action of beams and floors at the calculation of transverse strength (refer to 5.3.12.2), the strength of the latter shall be tested by the value of the ultimate moment and ultimate cutting force determined by the formulae:

$$M_{hs}^{F} = \sigma_0 W_e^{F}; \tag{5.3.12.4-1}$$

$$Q_{hs}^{F} = 0{,}5\Omega_F R_{\rho 0,2} \tag{5.3.12.4-2}$$

where W_e^F is the modulus of the floor section calculated on the assumption that stresses acting in the end fibres are equal to dangerous ones (assigned in accordance with 5.2).
Ω_F is the area of the floor web section.

In this case the following conditions shall be fulfilled:

$$W_{hs}^{F}/M_F \geq 2;\ Q_{hs}^{F}/Q_F \geq 1{,}5 \tag{5.3.12.4-3}$$

where M_F and Q_F is the maximum total bending moment and cutting force in the transverse floor sections determined with due account of the moments evolving during general transverse hull bending, local loads (refer to 5.4.6.5) conditioned by cargo (transported equipment, fuel, water, etc.) and additional bending moments determined in accordance with 5.3.10.2.

In absence of transverse bulkheads amidships and use of an assumption of the combined action of beams and floors (refer to 5.3.12.2), the hull strength shall be verified for the ultimate moment in compliance with Condition (5.3.12.3) and verification of the floor critical strength by Condition (5.3.12.4-3). For these purposes only the component conditioned by cargo (equipment, fuel, water, etc.) and additional bending moment determined in accordance with 5.3.12.2 are included into the design value of the total bending moment.

5.3.13 Calculation of the hovercraft and high-speed catamaran hull torsional strength.

5.3.13.1 If there are transverse bulkheads in hull which extend across the whole width of hull, transverse section is considered rigid in its plane during torsion. General torsion torque acting in the section is distributed among single member contours (the contour means a component of transverse section of hull bound by longitudinal bulkheads or by longitudinal bulkheads and sides, deck, bottom) which comprise transverse section in proportion to the torsional rigidity determined by the formula

$$C_i = \omega_c^2 / \sum_{c=1}^{n} (l_c/\delta_c) \quad (5.3.13.1\text{-}1)$$

where l_c is the length of the contour wall, in m;
δ_c is the thickness of the contour wall, in m;
ω_c is the double area bound by c contour, in m^2, (refer to Fig. 5.3.13.1);
n is the number of contour walls.

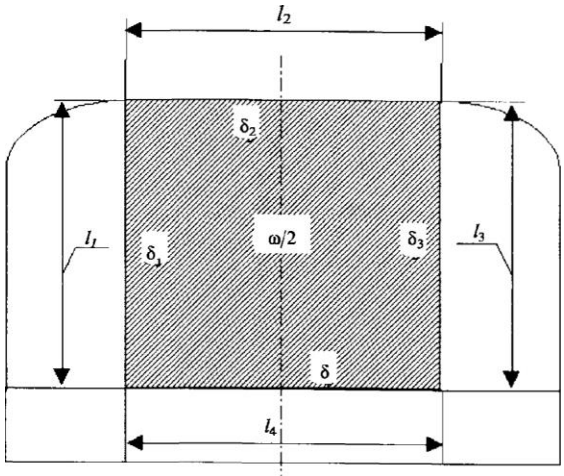


Fig. 5.3.13.1

Tangential stresses caused by torsion in the walls of each contour section are determined by the formula

$$\tau_i = M_i / \omega_i \delta_i \quad (5.3.13.1\text{-}2)$$

where M_i is the share of the torsion torque applied to the i-th contour, in kN·m.

Total of tangential stresses in the common wall of the two neighbouring contours are calculated as the difference of stresses in this wall caused by each contour.

5.3.13.2 Additional normal and tangential stresses in transverse members shall be determined for the ships with the middle cargo compartment where transverse bulkheads are absent over the whole or part of its length.

Additional tangential stresses on the cargo deck and bottom are calculated by the formula

$$\tau_{db} = \pm G h_d \{\alpha[\frac{3}{2}\frac{1}{l/2} - \frac{3}{2}\frac{y^2}{(l/2)^3}] + \beta\frac{1}{l/2}\}, \quad (5.3.13.2\text{-}1)$$

where h_d is the height of cargo deck above the mam deck, in m;
l is the width of cargo compartment (refer to Fig. 5.3.13.2), in m.
Mark (+) refers to bottom,
Mark (-) refers to cargo deck;
y is the distance of hull member under consideration from the neutral axis of hull section, in m (refer to Fig. 5.3.13.2);

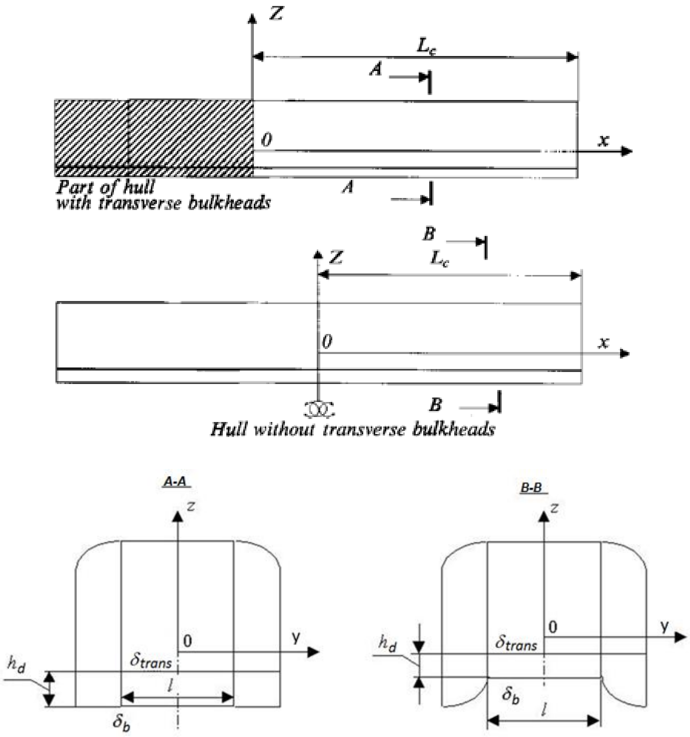


Fig. 5.3.13.2

Parametres α and β are determined by the formulas:

$$\alpha = \frac{F(B-D)}{B^2 - AD};$$

$$\beta = \frac{F(B-A)}{B^2 - AD};$$

$$A = C_g L_c + \frac{E}{G} D_g \frac{L_c^3}{3};$$

$$B = C_\eta L_c + \frac{E}{G} D_{g\eta} \frac{L_c^3}{3};$$

$$D = C_\eta L_c + \frac{E}{G} D_\eta \frac{L_c^3}{3};$$

$$F = \Omega / G L_c$$

Ω is the torsion torque diagram on the section of L_c, in kN·m^2;
L_c is the length of cargo compartment determined in accordance with Fig 5.3.13.2, in m;
C_g, C_η, D_g, D_η, $D_{g\eta}$ are rigidity parametres determined by the formulae:

$$C_g = 4{,}8 \frac{h_d^2}{l} (\delta_d - \delta_b);$$

$$C_\eta = 4 \frac{h_d^2}{l} (\delta_d + \delta_b);$$

$$D_g = (I_F / b_F + I_\delta / b_\delta) \frac{6}{(l/2)^3};$$

$$D_\eta = \frac{I_\delta}{b_\delta} \frac{6}{(l/2)^3} + \frac{G}{E} \frac{4 t_F h_d}{l b_F};$$

$$D_{g\eta} = \frac{I_\delta}{b_F} \frac{6}{(l/2)^3};$$

I_F and I_δ are floor and beam moments of inertia, in m^4;
b_F and b_δ is the spacing between floors and beams, in m;
t_F is the thickness of floor wall, in m;
δ_d and δ_b is the average thickness of cargo deck and bottom, in m.

Normal stresses in floors and beams caused by general torsion of hull are calculated by the formulas:

$$\sigma_F = -E \alpha x \frac{12}{l^2} z_F; \qquad (5.3.13.2\text{-}2)$$

$$\sigma_\delta = -E(\alpha + \beta) \cdot x \cdot \frac{12}{l^2} \cdot z_\delta$$

where z_F and z_δ are distances of the floor or beam point under consideration from the neutral axis of the design member, in m;
x is the section abscissa (refer to Fig. 5.3.13.2), in m;
α and β are parameters determined in the annotation to Formula (5.3.13.2-1).

Tangential stresses in the floor plate are calculated by the formula

$$\tau_F = G \beta x \frac{1}{l/2}. \qquad (5.3.13.2\text{-}3)$$

Maximum stresses σ_F, σ_δ, τ_F are reached in sections at $x = L_c$.

5.4 CALCULATION OF LOCAL STRENGTH

5.4.1 General.

5.4.1.1 The following conditions shall be considered during calculation of grillage, plate frame, framing:

.1 spans between girders constituting plate frame are taken for the distance between intersections of the neutral axis of respective girders;

.2 it is allowed not to consider variability of the girder sections formed by brackets if brackets do not exceed 0,1 of the girder span; presence of spans shall be considered in this case for determination of moment of girder resistance on bearers; if brackets exceed 0,1 girder span, it is allowed to consider influence of variability of the moment of inertia on bending moments;

.3 curvilinear girders with sagging of less than 10 % of span are considered straight.

5.4.1.2 Geometrical components of girder section shall be determined with due consideration of effective flange whose width depends on various factors.

5.4.1.2.1 During bending calculation the width of effective flange is taken equal to the distance between same girders.

5.4.1.2.2 During rigidity calculation the width of effective flange is taken:

at determination of the girder section area — equal to distance between same girders;

at determination of the moment of inertia of the transverse girder section equal to:

$$C = \frac{a}{2}(1 + \varphi) \qquad (5.4.1.2.2)$$

where C is the width of effective flange, in m;
a is the distance between same girders, in m;
$\varphi = \sigma_e/\sigma_s$.

N o t e . If $\sigma_e > \sigma_s$ take $\varphi = 1$.

5.4.1.2.3 For bending calculation — for the transverse girders lying above longitudinal stiffeners (floating framing system), width of effective flange is taken equal to:

if connecting plates are mounted at every second stiffener — 80 % of the normal flange accepted in 5.4.1.2.2;

if connecting plates are mounted at every third stiffener — 60 % of the normal flange accepted in 5.4.1.2.2;

if there are connecting plates mounted only in supporting section — 1/32 of the girder span.

Stresses on the effective flange shall be determined by the formula

$$\sigma_{E.F.} = \sigma^*_{E.F.} \times l/24C \qquad (5.4.1.2.3)$$

where $\sigma_{E.F.}$ are stresses in effective flange, in kPa;
$\sigma^*_{E.F.}$ are stresses in effective flange, calculated on the assumption that plating of 1/32 is included into the girder section, in kPa;
l is the girder span, in m;
C is the width of the normal effective flange of the girder under consideration taken in accordance with 5.4.1.2.2, in m.

If details connecting transverse girders with plating are absent or plating has lost rigidity between connecting details effective flange is not taken into account.

5.4.1.2.4 In all cases the width of effective flange shall not exceed 1/6 design span — for stiffeners and 1/12 girder length (grillage) for reinforced girders.

5.4.1.2.5 Longitudinal stiffeners located on the strake width form a part of effective flange of stringers and carlings.

5.4.1.3 Calculation of shell plates and deck plating side walls as well as bulkhead and superstructure plating shall be carried out on the assumption of their rigid fixing in the supporting contour. If the ratio of the supporting contour sides is greater than 2,5 it is allowed to treat the plate as the one bending by cylindrical surface.

Issue of consideration of membrane stress in the plate shall be resolved in each particular case. If ratio of the smaller side of plate to its thickness is equal to or less than 60, plates shall be usually treated as absolutely rigid.

5.4.1.4 Strength and rigidity (with safety factor of at least 1,5) of supporting structures (decks, platforms, bulkheads etc.) against maximum loads which are transmitted to them from the said grillage shall be tested during strength verification of girders of bottom and side grillage.

5.4.1.5 Local rigidity of framing girders to normal and tangential stresses with safety factor of at least 1,5 shall be verified during calculation of grillage strength.

5.4.1.6 Calculation of transverse bulkheads framing girders to the emergency flooding is permitted for performance following method of ultimate load with the safety factor of at least 1,5.

5.4.2 Loads determining strength of the hydrofoil bottom structures.

5.4.2.1 Strength of bottom structures shall be tested for the impact of external forces arising during ship motion on foils and during entrance to the foil mode in conditions of the design (stated in the performance specification) seaway and speeds corresponding to those regimes as well as exposure to emergency flooding.

5.4.2.2 Strength of bottom components: plates, stiffeners and frame parts between stringers shall be tested for the impact of equally distributed load P_1, in kPa, which is equal to:

$$P_1 = KP_{\max} \qquad (5.4.2.2\text{-}1)$$

where $K = P/P_{\max}$ is the distribution of the relative value of hydrodynamic pressures over the hull length determined in accordance with Fig. 5.4.2.2-1;

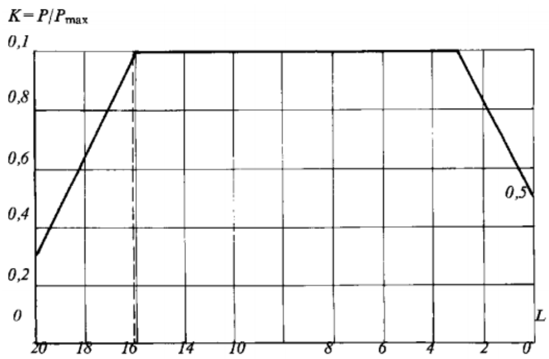


Fig. 5.4.2.2-1

$$P_{\max} = \frac{A\ \rho(V + aV_w)^2}{2} \qquad (5.4.2.2\text{-}2)$$

where $P_{\max}$ is the maximum value of hydrodynamic pressures, in kPa;
A is the coefficient determined in accordance with Fig. 5.4.2.2-2;

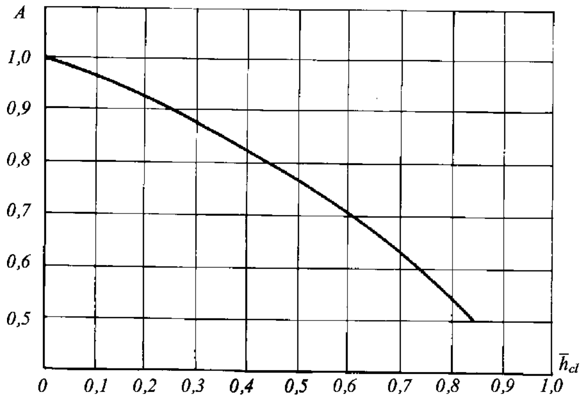


Fig. 5.4.2.2-2

$V_w = 1{,}95(h_{3\%}\% + 1)$;
$a = (54{,}7 - 3{,}4\, h_{3\%})10^{-2}$ at $h_{3\%} \geq 1$ m;
$a = 51{,}3 \times 10^{-2}\, h_{3\%}$ *at* $h_{3\%} \leq 1$ m.

Parts of frame between rigid longitudinals (between keelson — longitudinal bulkhead — side) shall be checked for resistance to equally distributed pressure equal to $\frac{2}{3}\rho_1$.

5.4.2.3 If there are planing steps, pressure at the first step is taken equal to $P_{\max}$. Pressures at further steps are taken equal to 0,85 of the pressure at previous step.

Immediately after these steps pressures are taken for 0,6 from the design one for the respective step but not less than $0{,}3P_{\max}$. Pressure between steps changes along the bottom length according to the linear law.

5.4.2.4 Strength of bottom grillage bound by transverse bulkheads and sides shall be tested for the impact of the hydrodynamic pressures equal to:

$$P_2 = P_{\max}K/3 \qquad (5.4.2.4)$$

where $K = P/P_{\max}$ is taken from Fig. 5.4.2.2-1.

5.4.3 Loads determining strength of the hovercraft bottom structures.

5.4.3.1 Strength of bottom structures is tested by external forces arising in the conditions of design seaway (stated in the technical specification) for the following design modes:

amphibious hovercraft:

.1 hydrodynamic pressures caused by flat bottom slamming during sailing mode at a speed permissible for the given intensity of seaways;

.2 hydrodynamic pressures caused by flat bottom slamming in the hovering mode;

.3 exposure to emergency flooding;

.4 emergency water landing in case of air cushion loss;

side-wall hovercraft:

.1 hydrodynamic pressures caused by flat slamming of pontoon bottom during sailing mode;

.2 hydrodynamic pressures caused by flat slamming of pontoon bottom during air-cushion sailing mode;

.3 exposure to emergency flooding.

5.4.3.2 Blow spot area and its length at flat blow of wave are determined by the formulae:

$$F_y = 0{,}7\sqrt{h_{3\%}}; \quad (5.4.3.2\text{-}1)$$

$$L_y = \sqrt{F_y} \quad (5.4.3.2\text{-}2)$$

where F_y is the area of blow spot, in m^2;
L_y is the length of blow spot, in m.

5.4.3.3 Pressure at flat blow of bottom structures of connecting bridge of side-wall hovercraft and pontoon of amphibious hovercraft is determined by the formula

$$q = \frac{133 \Delta n_g k_0 k_x}{B_x L}, \text{ kN/m}^2, \quad (5.4.3.3)$$

where B_x is the width of structures (width of connecting bridge of side-wall hovercraft or pontoon of amphibious hovercraft);
n_g is the parameter determined by Formulae (5.3.6.2) and (5.3.7.1) (for side-wall hovercraft) and by Formulae (5.3.4.3-10) and (5.3.5.1-5) (for amphibious hovercraft);
k_x is the coefficient characterising pressure distribution along the ship and this coefficient is taken from Fig. 5.4.5.2-1;
k_0 is the coefficient making allowance for relative dimensions of the connecting bridge component under consideration (plates, stiffeners, stringers or floors) which is determined in the following way:

$k_0 = 1$, if $10S_0/BL \leq 0{,}00015$;
$k_0 = \exp[-1{,}9(10S_0/BL - 0{,}00015)^{0{,}2}]$, if $10S_0/BL - 0{,}00015$, but not less than 0,3

where S_0 is the area supported by a component; for plates the supported area is taken equal to product of distance between stiffeners (spacing) by the value equal to the length of the largest plate or triple spacing (whichever is less).

5.4.3.4 Strength of bottom plating shall be tested by pressure determined by Formula (5.4.3.3) for the sailing on air cushion and for sailing in water-displacing mode keeping due note of 5.4.3.2.

5.4.3.5 Strength of longitudinal stiffeners shall be tested by the load of bq intensity where q is determined in accordance with 5.4.3.2 by Formula (5.4.3.3).

5.4.3.6 Strength of bottom grillage shall be tested by pressure determined from 5.4.3.3, which acts on the spot (area F) which is located by the most adverse manner for the strength of grillage while:

$F = P/q$ is the area of application of pressure to the grillage, in m^2;

$P = \Delta n_g(1 + m_z)$ is the grillage impact force, in t;

m_z is the parameter determined by Formulae (5.3.4.3-8) (for amphibious hovercraft) or (5.3.6.2-9) (for sidewall hovercraft);

n_g is the hull overload in the gravity centre at wave impact in the grillage under consideration, determined upon testing of models or similar ships. In absence of such data at early design stages it might be determined on the basis of approximated dependencies (5.3.4.3-10) (hovercraft — sailing), (5.3.5.1-5) (hovercraft — during hovering), 5.3.6.2-12 (hovercraft — sailing) and (5.3.7.1) (hovercraft — on air cushion).

5.4.3.7 Loads arising as a result of the emergency flooding are determined by the formula

$$P_1 = 10(h_1 + H) \qquad (5.4.3.7)$$

where P_1 is the pressure of emergency flooding on bottom, in kPa;
h_1 is the value of emergency flooding according to Fig. 5.4.6.1;
H is the spacing between pontoon deck plating and bottom plating, in m.

5.4.3.8 In case of emergency water landing (if an air cushion has been deteriorated) strength of bottom grillage — plates, stiffeners and parts of webs between stringers — shall be tested for the impact of equally distributed load, in kPa, which value is taken equal to:

$$P_{max} = \rho V^2/2 \qquad (5.4.3.8\text{-}1)$$

where V is the craft speed for the mode of operation under consideration, m/s.

Strength of bottom grillage bound by transverse bulkheads and sides shall be tested for the impact of hydrodynamic pressures, in kPa, equal to:

$$P_{gr} = P_{max}/3. \qquad (5.4.3.8\text{-}2)$$

N o t e. In this case it is necessary to ensure strength and stability of web framing (stringers, frames). The value of permissible stresses $\sigma_{per} = \sigma_0$.

5.4.4 Loads determining strength of bottom structures of the glider.

5.4.4.1 Hydrodynamic pressures on bottom grillage and their components are determined by the following formula:

$$\rho = K_\rho \frac{M_{sag}}{B_3 L^2} \varphi_1 \varphi_2 \varphi_3, \text{ kN/m}^2, \qquad (5.4.4.1)$$

where B_3 is the width of hull in the area of bilge in the section of the 3rd frame;
K_ρ is the parameter which is taken equal to 280 for the cavity vault of the ship with an air cavity in the bottom and equal to 370 for other bottom structures of gliders;
$\varphi_1 = 0{,}4 + 1{,}2x/L$ with $x/L < 0{,}5$
$1{,}0$ with $0{,}5 \le x/L \le 0{,}85$
$3{,}55 - 3x/L$ with $x/L > 0{,}85$;
$\varphi_2 = (70 - \beta_a)/(70 - \beta_\otimes)$;
$\varphi_3 = 0{,}46 - 0{,}35(U^{0{,}75} - 1{,}7)/(U^{0{,}75} + 1{,}7)$, but not less than
0,48 — for plates and stiffeners;
0,35 — for floors and stringers;
$U = 200s/(B_{tr}L)$
where s is the area of load application.

Area s represents the area of grillage; for the floors and stringers — product of distance between girders by their length; for the plates and stiffeners s is taken equal to product distance between stiffeners (spacing) by the value equal to the length of the largest plate side or triple spacing (whichever is less).

5.4.5 Loads determining local strength of high-speed catamarans.

5.4.5.1 Local strength of structures is tested by external forces arising in the conditions of design seaway for the following design cases:

impact (slamming) pressures acting in adverse operational conditions (with an exception of the outer side structures);

wave (static) pressures acting in adverse operational conditions (with an exception of connecting bridge);

impact of emergency flooding determined in accordance with 5.4.6.

5.4.5.2 Impact pressures on structures of the connecting bridge are determined by the formula

$$P_{cs} = \frac{133\Delta n k_0 k_x}{B_{cs} L}, \text{ kN/m}^2, \qquad (5.4.5.2)$$

where B_{cs} is the width of the connecting bridge (distance between hulls at the level of the connecting bridge);
n is the parameter determined by Formula (5.3.9.1);
k_x is the coefficient characterising distribution of pressure along ship length and determined in accordance with Fig. 5.4.5.2;
k_0 is the coefficient taking into account relative dimensions of the connecting bridge component under consideration (plates, stiffeners, stringers or floors) which is determined in the following manner:

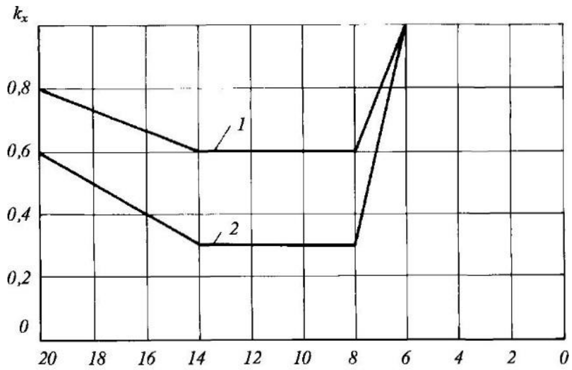


Fig. 5.4.5.2

$$k_0 = 1{,}0, \text{when } \frac{10S_0}{B_{cs}L} \leq 0{,}00015;$$

$$k_0 = exp\left[-1{,}9 \cdot \left(\frac{10S_0}{B_{cs}L} - 0{,}00015\right)^{0{,}2}\right], \text{when } \frac{10S_0}{B_{cs}L} > 0{,}00015,$$

but not less 0,3.

N o t e s : 1. Here S_0 is the are a supported by the component; for the plates the supported area is taken equal to the product of distance between stiffeners (spacing) and the value of the largest plate side or triple spacing (whichever is less).
2. B_{cs} – width of the connecting bridge in compliance with Fig. 1.3.

Δ is the displacement, kN.

5.4.5.3 Impact pressures on the hull bottom structures are determined by the formula

$$P_i = \frac{(56Fr_L^2 + 28Fr_L + 70) \cdot n}{B_h \cdot L} \cdot \Delta \cdot k_x k_0^b k_{sh}\text{, kN/m}^2, \quad (5.4.5.3)$$

where B_h is the hull width amidships measured on the waterline corresponding to immersion of hull to the bilge;
n is the parameter calculated in accordance with 5.3.9.1;
k_{sh} is the coefficient considering bottom shape;
$k_{sh} = 1$ — for components of side structures;
$k_{sh} = 0{,}158/\text{tg}\beta$ — for components of side structures;
β is the parameter which is taken equal to the angle of rise of bottom not less than 10° but not greater than 30°;
k_0^b is the reduction coefficient taken equal to:
$k_0^b = 0{,}46 - 0{,}35(U^{0{,}75} - 1{,}7)/(U^{0{,}75} + 1{,}7)$;
$U = 286 S_o T/\Delta$;
S_0 is the area supported by the component;
T is the ship draught on still water but not less than;
0,48 — for plates and stiffeners;
0,35 — for floors and stringers;
k_x is the coefficient characterising distribution of pressure along ship which is taken from Fig. 5.4.5.2;
Δ is the displacement, kN.

5.4.5.4 Impact pressures on the inner side structures (refer to Fig. 5.4.5.4) are taken distributed in accordance with the linear law from the upper point in which pressure is determined in accordance with 5.4.5.2, to the lower bilge point in which pressure is in accordance with 5.4.5.3.

5.4.5.5 The maximum wave pressures are deemed distributed over the hull surface in accordance with Fig. 5.4.5.4.

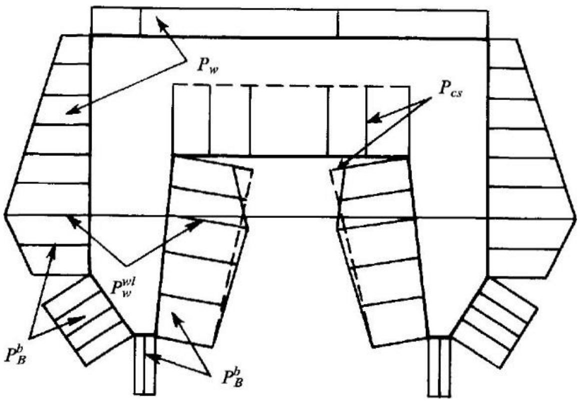


Fig. 5.4.5.4
Distribution of design pressure along the cross section outline:
wave pressures
impact pressures

5.4.5.6 The maximum wave pressures on the level of design water line is determined by the formula

$$P_w^{wl} = 0{,}81fL\rho g\{\alpha(x) + 0{,}25\exp[-(0{,}22\sqrt{L}/h_{3\%}^{0,4} - 1{,}97)^2]\},\ \text{kN/m}^2, \quad (5.4.5.6\text{-}1)$$

where $\alpha(x) = \{a\exp[-8\bar{x}^2 + 10\bar{x} + 3{,}29)] - 1{,}05\}\exp(-2{,}9Fr_L) + a\exp[-(1{,}96 - 4{,}9\bar{x})\exp(-2{,}9Fr_L)] + 1{,}05$,
but not less than 0,62;
$\bar{x} = x/L$ is the relative abscissa of the point counted from midship section:

$$a = (3{,}1 - 0{,}39Fr_\Delta - 0{,}12L/B_{hor} + 0{,}02Fr_\Delta L/B_{hor}) \times (1{,}1 - 0{,}63\bar{\rho}_y)(1{,}0 - 2{,}5B_{hull}/B);$$

$$Fr_\Delta = V/\sqrt{g\nabla^{1/3}};$$

B_{hor} is the distance between hulls amidships measured along the design waterline;
$\bar{\rho}_y$ is the dimensionless central radius of the inertia of ship mass determined in accordance with 5.3.9.1.

The maximum wave pressures above the level of design waterline;

$$P_w = k_w(P_w^{wl} - \rho g z_i),\ \text{kN/m}^2, \quad (5.4.5.6\text{-}2)$$

where z_i is the distance between the point under consideration and the level of design waterline;
k_w = 1 – for freeboard (inner and outer sides);
0,96 – determination of design pressures acting on the structural components of open decks (plates, stiffeners);
0,67 determination of design pressure acting on beams, stringers and grillage of open decks;
ρ is the sea water density, t/m³.

5.4.5.7 The maximum wave pressure acting on bottom structures of hulls are determined by the formula

$$P_B^b = \rho g[0{,}81fL\alpha(x)k_\mu(x) + z_b],\ \text{kN/m}^2 \quad (5.4.5.7)$$

where z_b is the distance between point on bottom and level of design waterline;
$k_\mu(x) = \left(1{,}0 - \frac{3b(x)}{L}\right)\cdot\left\{1 - \left[2{,}5 - \left(\frac{1{,}2B_{hor}}{T(x)} + 0{,}63\right)\cdot exp\left(-21\left(Fr_L - 0{,}28\sqrt{\frac{L}{B_{hor}}}\right)^2\right)\right]\cdot\frac{b(x)}{L}\cdot(1 + 2{,}5Fr_L)^2\right\}$;
B_{hor} is the distance between hulls amidships measured along the design waterline;
$b(x)$ is the hull width in the transverse section under consideration with an abscissa x;
$T(x)$ is the hull draught in the section under consideration.

5.4.6 Determination of loads during verification of the local strength of components of other structures.

5.4.6.1 Strength of deck and sides shall be tested for resistance to the emergency flooding, in kPa, determined by the formula

$$P = 10(h_1 + D - Z) \quad (5.4.6.1)$$

where h_1 is the value of the hydrostatic pressure determined in accordance with Fig. 5.4.6.1, meters of lift;
D is the side height in the section under consideration, in m;
Z is the distance between the structure under consideration and the main plane, in m.

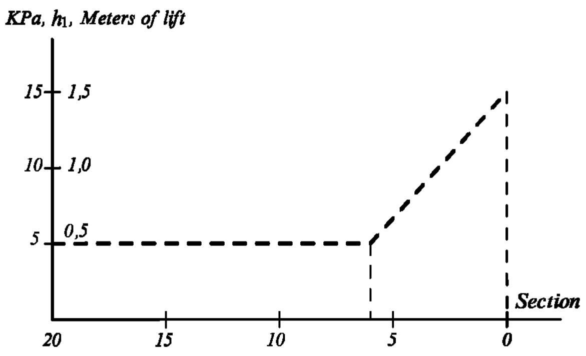


Fig. 5.4.6.1

For the areas of deck where collection of passengers or crew is possible — 0,5 meter of lift (5 kPa).

For the areas of deck where chairs for passengers are located — 0,4 meter of lift (4 kPa).

5.4.6.2 Strength of superstructure components of the I tier and wheelhouses shall be tested for the impact of the following loads:

plating and windows of superstructure front wall (wheelhouses) — uniform pressure corresponding to 2 meters of lift (20 kPa);

for plates and deck longitudinals, roof, side and back walls of superstructures (wheelhouses) and windows — pressure is determined in accordance with 5.4.6.1 but not less than 0,3 meter of lift (3 kPa); superstructure deck beams 0,15 meters of lift (1,5 kPa). Strength of the II tier and above superstructures shall be tested for the impact of load which are 50 % less than loads applied to relevant sides and windows of the I tier.

If front and side windows of superstructure (wheelhouse) are sealed by rubber profiles their strength shall be generally tested during bench tests.

5.4.6.3 Watertight bulkheads are tested by the emergency flooding determined in accordance with 5.4.1.4 and 5.4.6.1.

5.4.6.4 Forepeak bulkhead shall be tested by emergency flooding (refer to 5.4.6.1) plus 0,5 meter of lift which is caused by the head due to motion of ship or during its towing at a speed of $V \leq 3$ knots. If it is necessary to tow a ship at a greater speed, the head equal to $0{,}5(V_{tow}/3)^2$ is added to the emergency flooding (where V_{tow} shallwing speed in knots).

5.4.6.5 Strength of structures guarding tanks with fuel, fresh water etc. shall be tested:

by hydrostatic head, in kPa, up to the top of the gooseneck distributed in accordance with the linear law which maximum value is equal to:

$$\mathrm{P} = 10h_1 \qquad (5.4.6.5\text{-}1)$$

where h_1 is the height from the tank bottom to the top of the gooseneck, in m;

by hydrostatic head, in kPa, of liquid cargo if tank is full to the top keeping due note of inertial forces in accordance with the formula:

$$P_2 = 10h_2(1 + n) \qquad (5.4.6.5\text{-}2)$$

where h_2 is the height from the member in question to the tank top, in m;
n is the excessive acceleration as a share of acceleration of gravity force in the area of tank location arising due to blows and ship roll in heavy seas.

5.4.6.6 Strength of embarkation station, crinoline of life-saving appliances guards, fenders etc. shall be tested by the following loads:

equally distributed pressure of 0,5 meter of lift (5 kPa); compressed knees of crinoline (or other structures) shall be tested for stability in accordance with 5.1.8;

hydrodynamic pressure applied to crinoline (or other structure) from below which arise during ship motion at all modes of operation and determined in accordance with 5.4.2.2 with due consideration of relative clearance of crinoline (or other structures);

inertia forces acting on the crinoline structures which emerge due to masses on it, such as life-saving appliance (liferafts), because of ship roll or impact of waves against stem or crinoline structures. Resulting overloads shall be taken in accordance with 5.3.

5.4.6.7 Structures bounding hovercraft receiver shall be tested by equally distributed pressure of the following intensity:

$$q_{ree} = q_{ac}(1 + n_g) \tag{5.4.6.7}$$

where q_{ac} is the normal pressure in the air cushion, in kPa.

5.4.6.8 Strength of plates, stiffeners, parts of frames limited by stringers for hovercraft side-walls as well as strength of sidewall grillage shall be tested by hydrodynamic pressures which are determined by the formula

$$P_{sw} = 4\frac{f(\upsilon, h_{3\%})}{\text{tg}^2\beta_{sw}}\text{, kPa,} \tag{5.4.6.8}$$

where $f(\upsilon, h_{3\%})$ is the value which is determined in accordance with Fig. 5.4.6.8;
β is the average rise angle of sidewall, in degrees.

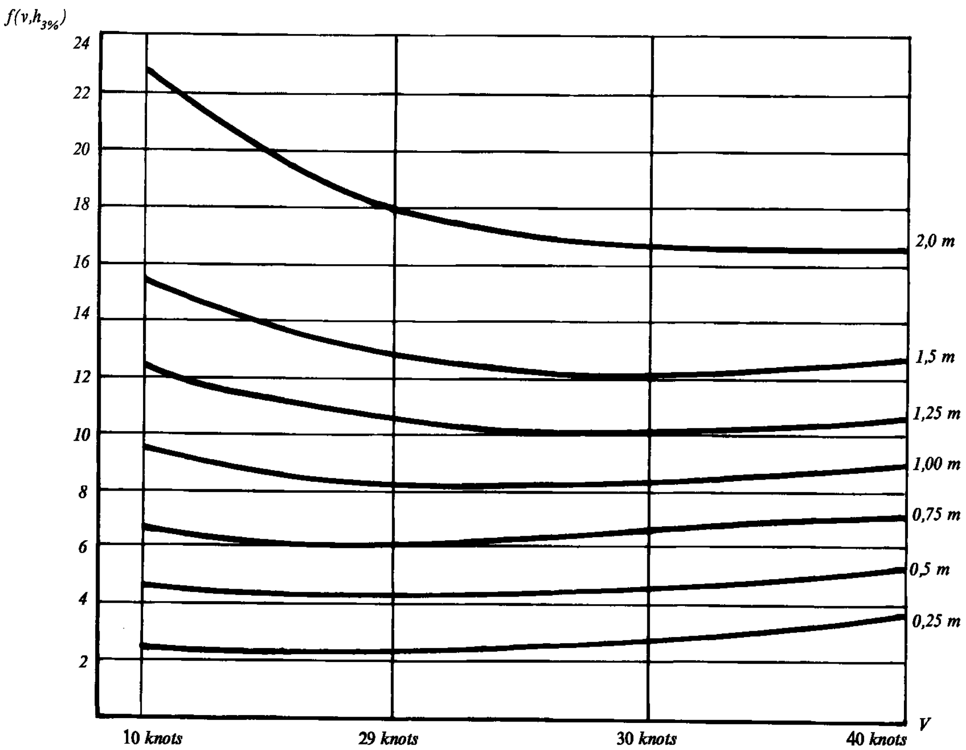


Fig. 5.4.6.8

5.4.7 Determination of stresses during local strength verification.

5.4.7.1 A stress acting in the plate which is dealt with as a strip girder shall be calculated by the formula

$$\sigma = \frac{P}{2}(a/\delta)^2, \text{ kPa}, \qquad (5.4.7.1)$$

where δ is the strip thickness, in m;
a is the length of the shorter side of strip – distance between ribs, in m;
P is the design pressure acting on the plate, in kPa.

N o t e . consideration of membrane stress in plates and norming of their strength is carried out in accordance with 5.4.1.3 and 5.4.8.2.

5.4.7.2 Longitudinal stiffeners of bottom and sides shall be calculated as girders rigidly fixed in frames and stresses acting in them shall be calculated by the formula:

$$\sigma = \frac{Pal^2}{12W}, \text{ kPa}, \qquad (5.4.7.2)$$

where P is the design pressure acting on the stiffeners, in kPa;
W is the transverse modulus of section with adjoining strake of plating, in m^3;
l is the length of stiffener (frame), in m.

5.4.7.3 Deck longitudinal stiffeners shall be calculated as girders rigidly fixed on beams. Pressures are taken in accordance with 5.4.6.1 and stresses are calculated by Formula (5.4.7.2).

5.4.7.4 Carlings, stringers and vertical keel shall be calculated as girders rigidly fixed in bulkheads.

Hydrofoil bottom frames depending on their structure shall be calculated as girders rigidly fixed in the vertical keel and bilge or as girders rigidly fixed in the keel but simply supported at the bilge. Side frames shall be calculated as girders resiliency built in deck and bottom.

5.4.7.5 Conditions of the hovercraft fixing of bottom and side frames as well as deck beams shall be determined in each particular case in relation to their structure and that of supporting members.

5.4.7.6 Beams shall be calculated as whole beams simply supported by carlings and resiliently fixed in sides. In the area of side openings half-beams are treated as simply supported by coamings.

5.4.7.7 Conditions of fixing of transverse bulkhead vertical stiffener shall be determined in relation to their structural design.

5.4.7.8 When stressed condition of side receiver is calculated it is necessary to consider side and horizontal areas assuming that they are rigidly fixed on their junction line.

Calculation of each area is carried out in accordance with calculation methods for flat grillage. Distance between sections with girders is taken for the length of grillage and on these edges grillages shall be treated as rigidly supported. One of the longitudinal edges (on the bound of area junction) is also treated as rigidly fixed. Boundary conditions on the other longitudinal edge are taken in relation to the structural design.

5.4.7.9 Calculation of girders of receiver is made by calculation methods for girders exposed to concentrated loads transmitted by flexible skirt. The value of this load is calculated as a product of a load distributed along the length from the flexible skirt which is determined in accordance with 5.7 and distance between girders.

5.4.7.10 In the absence of a transverse bulkheads in the middle (by width) part of two-hull ships (high-speed catamarans) it is necessary to add stresses caused by bending of transverse girders (floors) of the connecting bridge to stresses from twisting. While doing summation the value of the torsion torque shall be calculated in accordance with 5.3.9.2.5.

5.4.8 Verification of local strength of high-speed craft structures.

5.4.8.1 Verification of the local strength of structural components is carried out on the basis of permissible stresses:

$$\sigma > \sigma_{per};\ \tau \leq \tau_{per} = 0{,}57\sigma_{per}, \tag{5.4.8.1}$$

where σ and τ are design normal and tangential stresses in the structural components.

5.4.8.2 During verification of the outer plating strength (normal stresses in the supporting section of plates) permissible stresses shall be taken for:

$$\sigma_{per} = \sigma_0. \tag{5.4.8.2}$$

5.4.8.3 Stresses permissible during verification of strength of longitudinal stiffeners, frames, stringers and vertical keel are taken for:

$$\sigma_{per} = 0{,}8\sigma_0. \tag{5.4.8.3}$$

5.4.8.4 Stresses permissible during verification of strength of structures in accordance with 5.4.6 for webs (except for webs calculated in accordance with 5.4.1.4) and for plates in the middle of a span are taken for:

$$\sigma_{per} = 0{,}8\sigma_0;\ \tau_{per} = 0{,}40R_{p0,2}. \tag{5.4.8.4}$$

Design stresses in a span shall not exceed $\sigma_{per} = 0{,}8\sigma_0$ for the calculation of emergency flooding acting on the plates of grillage. Stresses in supporting sections are not regulated.

Safety factor for the ultimate state of members of grillage exposed to emergency flooding shall be 1,5.

Note. Tanks containing fuel, fresh water, etc. shall be additionally verified for strength in the supporting sections. Permissible stresses in this case are equal to: $\sigma_{per} = 0{,}8\sigma_0$ and $\tau_{per} = 0{,}40R_{p0,2}$.

5.5 HYDROFOIL INSTALLATION STRENGTH CALCULATION

5.5.1 General.

5.5.1.1 Strength of hydrofoil installation shall be tested for resistance to the maximum loads applied to the ship under consideration at motion on foils on still water and seaways at speed stated in technical specification.

5.5.1.2 Verification of the hydrofoil installation for resistance to external load is carried out in span points and for sections between span points of each component during deformation of the foil in general.

5.5.1.3 Calculation of hydrofoil installation strains and deformations caused by external loads shall consider spatial dimensions of structure. Methods of calculation and verification of the hydrofoil installation strength shall be justified and approved by the Register.

N o t e . If the sweep angle of the supporting plane is less than 200 and the hydrofoil struts are installed at a distance of more than 2/3 chord, etc. it is allowed to apply beam model calculation.

5.5.1.4 Hydrofoil installation calculation shall comprise yielding of bottom framing (grillage, except sides, longitudinal and transverse bulkheads) which supports the hydrofoil installation struts.

5.5.1.5 Hydrofoil installation calculation based on the beam model calculation (for calculation of bending moments) for the components which have a variable rigidity it is allowed to take its average value along the length of the component under consideration.

For determination of stresses it is necessary to take rigidity characteristics corresponding to the section under consideration.

5.5.1.6 Hydrofoil struts exposed to axial compression shall be tested for rigidity to compressing forces determined on the basis of calculation in accordance with 5.5.1.4 — 5.5.1.6. Stability factor of 2 at least shall be ensured.

5.5.1.7 Horizontal (cross-arm) shift of the supporting plane shall be determined for the aft hydrofoil installation equipped with transmissions, driving gears, etc. Struts shall be treated as cantilever beams of rigidity varying along their length which are exposed to side loads and forces and moments in the place of fixing strut to the main supporting plane.

5.5.1.8 Hydrofoil installation plating and framing shall be tested for rigidity at bending of their components if 1,5 times safety is ensured. Compression average stresses calculated for the plate thickness are taken for design stresses keeping due note of their change in respect of the profile neutral axis.

5.5.1.9 If at any component of the hydrofoil installation the flap is hitched by three or more hinges to the back edge of the wing it is necessary to verity strength of hinges against forces arising at a combined bending of the hydrofoil installation component and a flap deflected to the maximum angle.

5.5.1.10 Stresses arising in the hydrofoil installation plating during local strength verification are determined on condition of rigid binding of edges.

5.5.2 Determination of design forces.

5.5.2.1 The value of design forces acting on the supporting plane of the hydrofoil installation during ship motion at seaways are determined in accordance with 5.3.3.5 and 5.3.3.8.

5.5.2.2 At distribution of design forces along the supporting plane the following cases shall be considered:

.1 at waterline corresponding to the immersion of the hydrofoil installation at still water;
.2 at waterline corresponding to fully immersed supporting plane;
.3 at waterline which is by $(h_{3\%}/4)$ lower of the waterline at still water;

.4 unsymmetrical loading of the hydrofoil installation where the waterline is taken in accordance with Fig. 5.5.2.2. For this case permissible stresses may be increased by 10 %.

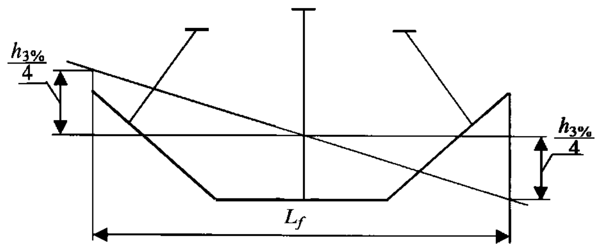


Fig. 5.5.2.2

5.5.2.3 Distribution of design forces along the span of the supporting plane for each design case shall be carried out with due consideration of the free plane, irregularity of load distribution and variability of effective angle of attack along the span supporting plane:

$$q = P_{des}\frac{bf(\bar{h})f(\lambda)}{F_f}\alpha_{ef} \qquad (5.5.2.3\text{-}1)$$

where P_{des} is the design force acting upont the hydrofoil installation (refer to 5.5.2.1), in kN;
f is the function considering free plane effect which is equal to:

$$f(\bar{h}) = \frac{1+(2\bar{h})^2}{2+(2\bar{h})^2} \qquad (5.5.2.3\text{-}2)$$

where $\bar{h} = h/b$ is the relative immersion of the foil section;
h is the current value of the foil section immersion, in m;
b is the current value of the foil chord, in m;
$f(\lambda)$ is the function considering irregularity of distribution of forces along the span of the supporting plane which is determined in accordance with 5.5.2.3;
λ is the relative narrowing of foil (Fig. 5.5.2.3);

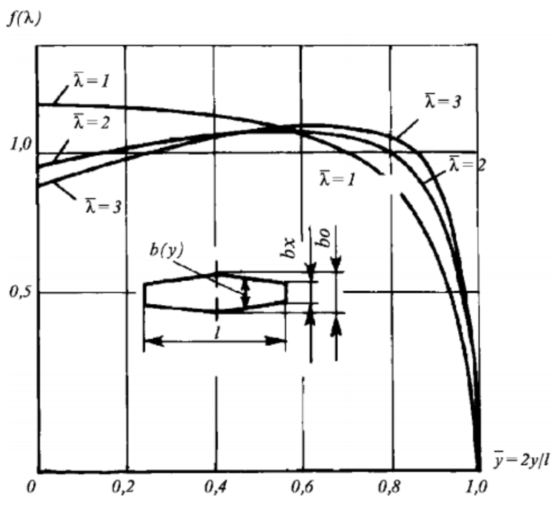


Fig. 5.5.2.3

$\alpha_{ef} = \alpha_0 + \alpha_{mt} + \alpha_{adj}$ is the effective angle of the foil attack;
α_0 is the angle of zero hydrodynamic lift;
α_{mt} is the angle of attack conditioned by the motion trim on still water;

α_{adj} is the current value of the adjusting angle of attack;

$$F_f = \int_{-l/2}^{l/2} b f(\bar{h}) f(\lambda) \alpha_{ef}\, dl \qquad (5.5.2.3\text{-}3)$$

where l is the span of the immersed part of supporting plane, in m.

5.5.2.4 For inclined components of the hydrofoil installation the horizontal (traverse) component of forces shall be considered which is equal to:

$$q' = qtq\beta \qquad (5.5.2.4)$$

where β is the deadrise angle of inclined component.

5.5.2.5 Additionally, the hydrofoil installation strength shall be tested for the impact of the following forces (inclined course, circulation):

forces $P_{i.st.w.}$ determined in accordance with 5.3.3.5;

side loads acting upon struts and inclined components, in kN:

$$P_\delta = 0{,}15\frac{\rho V^2}{2} S_{st} \qquad (5.5.2.5\text{-}1)$$

where S_{st} is the projection of immersed parts of a strut and inclined components on the longitudinal centre plane, in m^2.

For the aft hydrofoil installations side forces acting on struts caused by the declination of rudders shall be considered. Forces in rudder are taken equal to:

$$P_r = 0{,}054 V^2 F_r \qquad (5.5.2.5\text{-}2)$$

where F_r is the area of the immersed part of the rudder body considering immersion by $0{,}7h_{3\%}$ for seaways as opposed to still water, in m^2.

Distribution of forces P_δ among struts and inclined components of the hydrofoil installation is carried out in proportion to the projection of the wetted surface area on the longitudinal centre plane during immersion of the hydrofoil installation as specified in 5.5.2.2.

$$P_{sti} = \frac{P_\delta}{S_{st}} S_{sti} \qquad (5.5.2.5\text{-}3)$$

where P_{sti} is the design force applied to the i-th strut or inclined component, in kN ;
S_{sti} is the projection on the longitudinal centre plane of the immersed part of the i-th strut or inclined component, in m^2.

Distribution of the P_{sti} load along height of strut or along the span of the inclined component of the supporting plane is carried out in proportion to the chords:

$$q_{st} = \frac{P_{sti} b_{st}}{h_{st} b_{st.av.}} \qquad (5.5.2.5\text{-}4)$$

where h_{st}, b_{st} and $b_{st.av.}$ are immersion, current value of the chord and the average chord of the strut under consideration respectively, in m.

5.5.2.6 For the automatically controlled hydrofoils distribution of loads among components of the supporting plane is as follows: loads applied to components, equipping by flaps increases in proportion to the K coefficient (refer to Fig. 5.5.2.6).

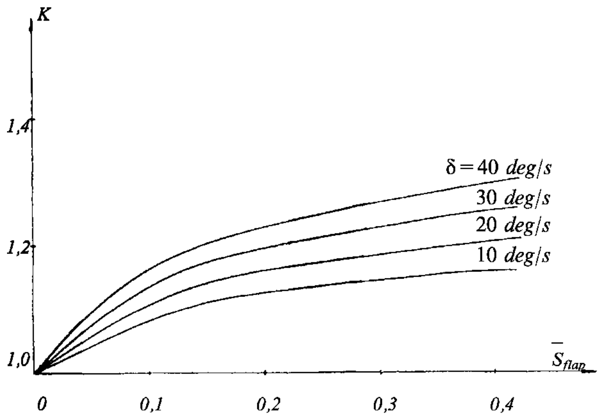


Fig. 5.5.2.6

The following symbols are used on this figure:
$\delta[\mathrm{deg}/s]$ is the speed of the putting of the flap;

$$\bar{S}_{flap} = S_{flap}/S_{comp.flap} \qquad (5.5.2.6)$$

where $\bar{S}_{flap}$ is the relative area of the flap;
S_{flap} is the area of the flap, in m^2;
$S_{comp.flap}$ is the area of the component fitted with the flap, in m^2.

Loads applied to other components reduce on the basis of condition of preservation of the full force applied to the supporting plane.

5.5.2.7 Distribution of loads along the chord of the component under consideration is found by wind tunnel tests or by calculation. In absence of such data loads are distributed across triangle which maximum ordinate starts at the front edge of the profile in accordance with Fig. 5.5.2.7.

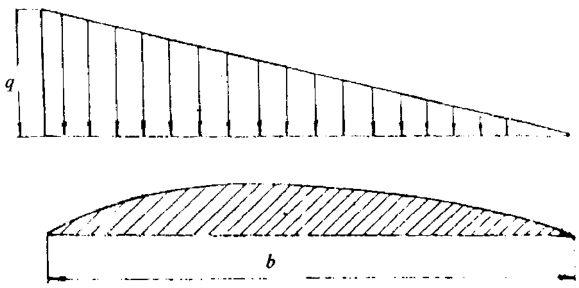


Fig. 5.5.2.7

5.5.2.8 For the components of the hydrofoil installation equipped with flaps the distribution of loads along the main foil chord shall be taken in accordance with Fig. 5.5.2.8-1*a*.

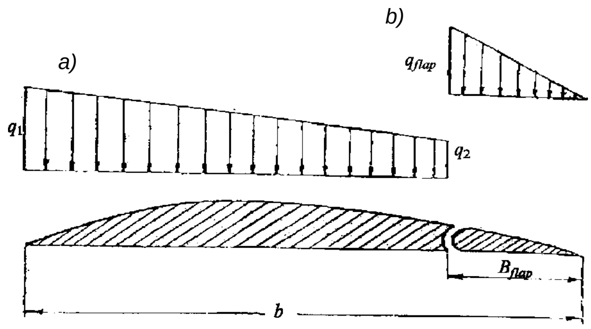


Fig. 5.5.2.8-1

Ordinates of the load intensity q_1 and q_2 are calculated by the formulae:

$$q_1 = 2\frac{P_{comp} - P_{flap}}{S_{comp.flap}}; \tag{5.5.2.8-1}$$

$$q_2 = \bar{b}_{flap} q_1 \tag{5.5.2.8-2}$$

where P_{flap} is the force transmitted by the flap to the respective foil component, in kN;

$$P_{flap} = C_y^{\delta} \frac{\rho V^2}{2} S_{comp.flap} \delta_{max} \tag{5.5.2.8-3}$$

where C_y^{δ} is the coefficient of the hydrodynamic lift of the flap which is determined in accordance with Fig. 5.5.2.8-2;
$\lambda_{flap} = l_{flap}^2 / S_{flap}$ is the relative elongation of the flap;
l_{flap} is the span of the flap, in m;
$b_{flap} = b_{flap}/b$ is the relative chord of the flap (refer to Fig.5.5.2.8-1);
δ_{max} is the maximum angle of the flap declination, in degrees.

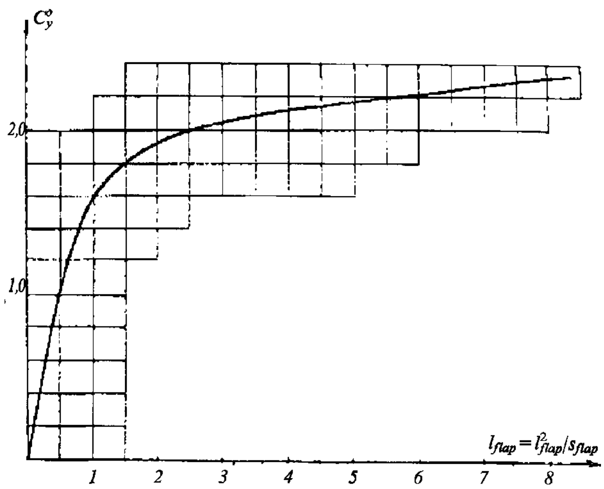


Fig. 5.5.2.8-2

Force $P_{\max}$ shall be equally distributed among hinges which attach the flap to the main foil.

5.5.2.9 Calculation of the flap strength shall consider force determined by Formula (5.5.2.8-3). It is assumed that loads distributed along the chord of the flap are distributed across the triangle (refer to Fig. 5.5.2.8-1*b*) with an ordinate equal to:

$$q_{flap} = 2P_{flap}/S_{flap} \quad (5.5.2.9)$$

Distribution of load along the span of the flap is taken in proportion to the chords of the flap.

5.5.2.10 The strength of the additional foil of the hydrofoil installation which enables rise of the ship on foils shall be tested for the resistance to the load, in kN, calculated by the formula

$$P_{af} = C_{af}^{max} \frac{\rho V_{lift}^2}{2} S_{af} \quad (5.5.2.10)$$

where C_{af}^{max} is the maximum coefficient of the hydrodynamic force of the additional foil profile which is determined upon results of the wind tunnel tests of the profile;
S_{af} is the area of the additional foil, in m^2.

Distribution of the external load among components of the supporting plane and components of the additional foil is carried out in accordance with 5.5.2.2, 5.5.2.4 and 5.5.2.5.

5.5.2.11 The strength of fully immersed turning foils of the steerable hydrofoils installation shall be tested by exposure to loads, in kN, determined by the formula

$$P_{t.f.} = C_{t.f.}^{max} \frac{\rho V_{des}^2}{2} S_{t.f.} \quad (5.5.2.11)$$

where $S_{t.f.}$ is the area of the turning foil, in m^2.

5.5.2.12 The hydrofoil installation plates shall be tested for resistance to hydrodynamic pressures at operating speed for the hydrodynamic lift corresponding to C_y^{max}. Diagram of pressure distribution over the profile surface is determined upon results of wind tunnel test of specific foil profile. In absence of wind tunnel test distribution of loads along the foil chord is taken in accordance with 5.5.2.7 and 5.5.2.8; 60 % of total load will act upon the upper surface and 40 % on the lower surface.

N o t e . In absence of drain holes the hydrofoil installation plates shall be additionally tested by internal pressures.

5.5.3 Verification of strength of the hydrofoil installation.

5.5.3.1 Strength of the hydrofoil installation shall be tested for permissible stresses:

$$\sigma \le \sigma_{per}; \quad (5.5.3.1\text{-}1)$$

$$\tau \le \tau_{per} = 0{,}57\sigma_{per}; \quad (5.5.3.1\text{-}2)$$

where σ and τ are design normal and tangential stresses in the hydrofoil installation components.

5.5.3.2 Stresses permissible during verification of the hydrofoil installation components resistance to design loads shall be determined in accordance with 5.5.2 and they are taken equal to:

$$\sigma_{per} = n\sigma_0 \qquad (5.5.3.2)$$

where n is the safety factor taken equal in accordance with Fig. 5.2.13.

N o t e . Stresses permissible during verification of the hydrofoil installation plates resistance to loads determined in accordance with 5.5.2.12 are taken equal to $\sigma_{per} = 0{,}5\sigma_0$.

5.6 VERIFICATION OF STRENGTH OF GLUED-WELDED JOINT AND SPOT WELDS

5.6.1 During strength calculation of the glued-welded joint and spot welds of framing to plating the spot weld shall be replaced by continuous weld with an adjusted calibre of K_{ad} (presence of glue is not taken into consideration):

$$K_{ad} = Zf/t \tag{5.6.1-1}$$

where Z is the number of rows of spot welds in connection of the members to plating;
$f = \pi d^2/4$ is the area of the spot weld;
d is the diameter of the spot weld taken at normal;
t is the pitch of a spot weld.

Value of shear forces T_{shear} and Q_{det} applied during detachment of spot welds shall be determined by the formulae:

$$T_{shear} = \tau K_{ad} t/Z; \tag{5.6.1-2}$$

$$Q_{det} = \sigma_{det} K_{ad} t/Z; \tag{5.6.1-3}$$

where τ and σ are tangential stresses of shear and normal stresses of detachment of continuous weld determined upon results of the monolithic (continuous weld) structure calculation.

5.6.2 Strength of the glued-welded (spot welded) joints shall be tested for the permissible shear T_{per} and breakout Q_{per} forces for spot welds:

$$T_{shear} \le T_{per} = nT_0; \tag{5.6.2-1}$$

$$Q_{det} \le Q_{per} = nQ_0; \tag{5.6.2-2}$$

where n is the safety factor taken in accordance with 5.2.5;
T_0 and Q_0 are dangerous shear and breakout forces for spot welds determined in accordance with Table 5.2.5.

5.7 FLEXIBLE SKIRT STRENGTH CALCULATION

5.7.1 General.

5.7.1.1 General strength of the main components of the flexible skirt structure shall be verified for compliance with methods accepted for pliant skin for exposure to forces arising in the main design cases.

5.7.1.2 Geometrical characteristics of the flexible skirt component under consideration in each characteristic section shall be determined by finding its equilibrium shape.

5.7.1.3 Excessive normal pressure in flexible skirt bag and air cushion corresponding to the main design cases is taken for the external load. Action of the hydrodynamic loads is considered by the safety factors assigned in accordance with 5.2.16 and 5.2.17.

5.7.2 Verification of the flexible skirt general strength.

5.7.2.1 The following design cases shall be considered during verification of the flexible skirt general strength:

.1 ship hovering above surface without motion;

.2 ship motion on the air cushion in conditions of design seaways;

.3 ship motion in conditions severer than design seaways (loss of air cushion due to fall from wave crest to wave hollow).

The case in which forces acting in the material will be the greatest shall be taken for the design case.

5.7.2.2 Strains in the inner and outer side of flexible skirt in hovering mode without motion shall be determined by the formulae:

$$T_0 = n_{des} P_r r_0; \qquad (5.7.2.2\text{-}1)$$

$$T_i = (P_r - P_c) r_i \qquad (5.7.2.2\text{-}2)$$

where T_0 and T_i are design strains in the material of the outer and inner side of flexible skirt, in kH/m;
P_r and P_c are excessive normal pressures in the skirt bag and air cushion, in kPa;
r_0 and r_i are radii of curvature in the material of the outer and inner side of flexible skirt, in m.

5.7.2.3 Maximum strains in the shell of cylindrical parts of the flexible skirt during ship motion in seaways are determined by the formulae:

$$T_0 = n_{des} P_r r_0; \qquad (5.7.2.3\text{-}1)$$

$$T_i = n_{des} (P_r - P_i) r_i \qquad (5.7.2.3\text{-}2)$$

where n_{des} is the pressure increment factor determined for each design case upon testing results of the similar prototype; in absence of prototype the value of the factor shall be determined in accordance with Table 5.7.2.3.

Table 5.7.2.3

Design case	Pressure overload n_{des}		Note
	Amphibious hovercraft	Side-wall hovercraft	
Motion in design seaway	2,0	3,5	
Motion in seaway higher than design	4,0	5,0	Loss of pressure in air cushion during ship motion in heavy seaway

5.7.2.4 Maximum strains of material of torus-like parts of the hovercraft flexible skirt (bow, angle) shall be determined as for the round torus by the formula

$$T = \gamma T_i \tag{5.7.2.4}$$

where $\gamma = \frac{1-0{,}5\alpha sin\theta}{1-\alpha sin\theta}$;
T_i is the strain of the material inner side of flexible skirt in the design section determined as for the cylindrical part of shell, in kN/m;
Θ is the central angle corresponding to the inner side of flexible skirt in design section, in deg;
$\alpha = r_i/R$;
R is the radius of the part of shell along the centre line to the flexible skirt inner surface, in m.

Main symbols given in this Section are shown in Fig. 5.7.2.4.

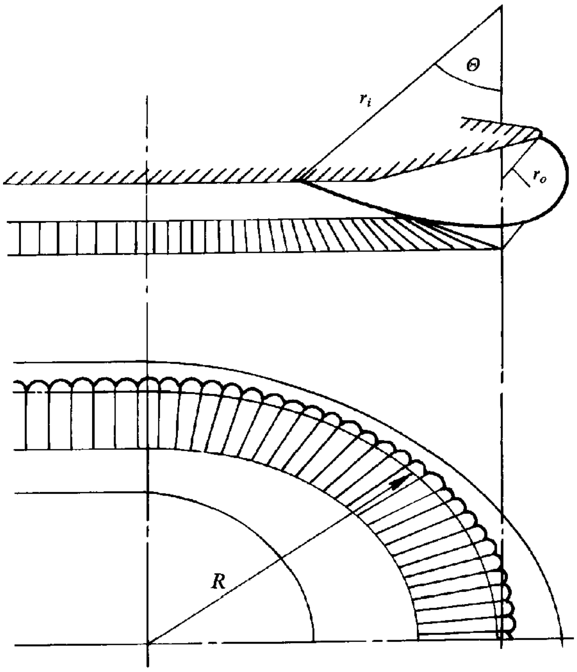


Fig. 5.7.2.4

5.7.3 Verification of the general strength of removable components.

5.7.3.1 Strains in the material of removable component of open type shall be determined by the formula

$$T = n_{des} P_r r \tag{5.7.3.1}$$

where r is the radius of curvature of the outer wall of removable component, in m.

5.7.3.2 For removable components of closed type strains in outer and inner sides of flexible skirt are determined by Formulae (5.7.2.2-1) and (5.7.2.2-2).

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