

G.V. Boitsov, A.V. Bukhanovsky, L.I. Lopatukhin. Dependence of MIXED river-sea-GOING ship safety on reliability of wave forecast and storm duration STATISTICS. Pp. 4–15.

Authors analyze wave forecast reliability. They study probabilistic regularities of sea storm duration. Effects of these data on sea service safety for mixed river-sea-going ships are described.

In particular, the obtained refined data on probabilistic regularities of storm duration in sea waters enabled developing methods for analytical estimation of effectiveness of ship shelter places (SP) against waves to decrease extreme wave loadings on mixed river-sea-going ships, as well as detailing recommendations on.

G.V. Boitsov, A.V. Aleksandrov, O.S. Ankudinov. Analysis and evaluation of residual strains in mixed river-sea-going ship hulls under decreased buckling strength of their longitudinal framing. Pp. 16–23.

Data on total strains in mixed river-sea-going ship hulls and possible reasons of their appearance are described. Numerical methods for explaining of these reasons, as well as numerical physical models and software used for their analysis are examined. Main conclusions of the conducted analysis are following: for the subject ship type the main source of total hull residual strains is relatively low bucking strength level of the main longitudinal framing of bottom floors.

As analysis demonstrates, due to structural imperfections and corrosion wear-out this level does not exceed 85–90% of material yield point which is also promoted by the increased level of residual compressive stresses of ship construction and frequent repairs.

Total residual hull strains reaching 0.3–0.4% of the hull length are accompanied by residual stresses in structures reaching 30–40% of the material yield point. These effects are also a result of extreme wave influences on ship hulls in combination with hull overloading caused by increased static loads of transported cargo.

G.V. Boitsov. 50-year tendencies in development of design & regulatory requirements to strength of sea-going ships. Pp. 24–42.

Principal tendencies shown in development of requirements to ship hull strength in *Rules for Classing and Building Ships*, as well as in Strength Standards of *Russian Maritime Register of Shipping* within last 50-year period are described. Physical pre-conditions of these requirements and prospects for their improvement are discussed.

Main mechanisms of modification of practical requirements to transport ship strength for the examined period are described.

Existing contradictions in strength requirements to mixed river-sea-going ships maintained by *Rules of Russian Maritime Register* and *River Register* are given.

The paper illustrates the main phases in development of requirements to ship strength within the last 50 years.

G.B. Kryzhevich. Flat water impact of Ship structures. Pp. 43–59.

A method for definition of ship structural member dynamic bending at water surface impact is proposed. The most severe impact conditions without forming an air layer between the structure and water surface are analyzed. The analysis of beam hydroelastic oscillations induced by its impact against the water surface was made in order to estimate significant influence of hydrodynamic damping upon the beam dynamic deformation level. A method for considering the hydrodynamic damping in dynamical calculations of plates and beams under their impacts against water is suggested, the most severe impact conditions, at which there is small probability of cavities forming in liquid (water detachment from the structure) decreasing the dynamic action on the beam, are realized under the ratios typical for beam and ship hull plating impacts against water. It was obtained that the maximum hydrodynamic pressures increase much faster together with colliding speed as compared to maximum structure displacements at flat impact. A method for definition of ship structural elements dynamic strains at water surface impact is proposed, which can be used for ensuring ship structural local strength and for developing corresponding regulatory documentation.

E.M. Appolonov, A.B. Nesterov, K.E. Sazonov. Regulation of ice loads on azimuthing thrusters of double-ended ships. Pp. 60–86.

In order to resolve the problem of hydrocarbon and ore raw materials transportation from the Arctic shelf and coast of Russia, ice-class ships of new types are presently designed including double-ended ships (DES) operating stern first in ice-infested waters and equipped with azimuthing thrusters. The paper studies methods for regulating loads on DES azimuthing thrusters due to interaction with ice, which allow estimating both fatigue strength and extreme loading level. Approaches to regulating extreme loads on DES azimuthing thrusters based on Norske Veritas requirements to ice-class ship hulls are analyzed. Recommendations for selecting design scenarios of interaction between DES azimuthing thrusters and ice, as well as for forming a matrix of stationary ship operation modes in ice waters are developed. Methods for estimation of parameters that characterise conditions of force interaction between DES azimuthing thruster and ice under various ship operation conditions are proposed. An contact loads estimation algorithm based on modified hydrodynamic model of solid body impact against ice, as well

as ice load matrix procedure for fatigue strength estimation basing on linear damage summation hypothesis are presented.

A.B. Nesterov. Engineering evaluation method for damage caused by collision of ships operating at head-on courses at acute angle. Pp. 87–98.

Known methods for calculation of structural board protection under collisions often assume ramming a rest ship at right angle as the basic scenario. Such an approach is validated for estimation of maximum possible damage depth in protective structures. However, as applied to ships without special protection there is a problem of estimation of the maximum length of a possible breach which is important for stability regulation. Therefore, the paper explains the method of applying calculation data on ram of resting ship at right angle to a case of collision of ships operating under head-on courses at acute angles. Assumptions on concurrency of the interaction force direction to the relative speed vector, as well as on equality of the force transverse component to the interaction force value defined for the direct impact design model are taken. An engineering method for assessing the breach length at various headings, as well as analytic approximation of the ramming ship hull form with straight inclined stem and similar waterlines is introduced. Analytical relationships for a case of equality of colliding ships' speeds are proposed; collision angle causing the longest breach is evaluated.

E.M. Appolonov, M.A. Kudrin, E.A. Maslich, N.N. Fedonyuk, V.M. Shaposhnikov. Design-experimental method for structural detail fatigue strength estimation for advanced ship hull structures. Pp. 99–107.

At present time application of polymeric composite materials (PCM) for bulkheads, partitions, superstructure elements and other structures contributing to the hull global bending is considered as one of promising structural decisions for hull weight decrease. The complexity of the stressed state of such structures, mutual influence of materials they are made of, their geometry and manufacturing complicate evaluation of serviceability parameters of these details without special tests under variable operation loading, as well as ANSYS – type software package calculations.

When developing a design-experimental method for fatigue strength evaluation, a comprehensive approach based on experimental assessing fatigue strength of test specimens and further computational interpretation of obtained results for calculating full-scale ship hull details is used.

Experimental modeling of mutual operation of atypical structures made of different materials (PCM – metal) as a part of a hull faces objective difficulties. In this case the large-scale model has to include a full-scale structure of an attachment point connecting PCM element with metallic hull structures, which represents a Π -shaped or Υ -shaped steel coaming welded to the metallic hull and connected with the PCM with the help of double-shear double-row glue-bolted joint. The main goal of the tests consists in fatigue strength check for the attachment point elements (glue-bolted joint, steel coaming) being under alternate stresses caused by global and local ship hull bending.

Large-scale model test results were used to check fatigue strength of advanced hull structures ensuring connection of PCM elements with metal ship hull structures, as well as to develop options of their rational design. Basing on multipurpose software package ANSYS, a global finite-element model of the ship hull as a whole, as well as sub-models of PCM element attachment point to metal hull structures are developed. When generating finite-element submodels, structural design of the attachment point connecting a PCM element with the steel ship hull is varied that: enables selecting its optimal structural design basing on fatigue strength provision.

The developed design-experimental method for fatigue strength evaluation opens wide possibilities for applying in shipbuilding new atypical hull structures of various shape and material.

V.N. Tryaskin. Technique and algorithm for simplified structural modeling of main framing beams for evaluation of ship hull technical state. Pp. 108–121.

Methodological principles of automated structural modeling of ship hull main framing beams with the use of hull geometrical model and structural drawings data are explained. Algorithms for resolving main problems of structural modeling are described. The algorithms are demonstrated as applied to problems of simplified structural modeling of transverse and longitudinal main framing of shell plating. The paper presents the results obtained by automated system *SYSHECK* developed in St.Petersburg State Marine Technical University and designed for verification of ship hull structure compliance to Rules of Russian Maritime Register of Shipping and estimation of hull technical state. The system could be used for designing of new structures based on checking calculation procedure.

V.N. Tryaskin. Methodological principles and algorithms for modeling of ship hull and its structural components under automated parametric design of structures. Pp. 122–145.

A concept of structural modeling under automated parametric design of ship hull structures is given. Methodological principles of ship hull structural decomposition and rules for encoding hull structural members are examined. Examples of structural decomposition of shell plating, inner bottom, longitudinal and transverse double-bottom framing are provided. Specific features of decomposition and structural modeling for complicated frame beams, webs of which have varying height and strengthening in the form of stiffeners and brackets, are indicated. A technique of formal presentation of structural modeling results in the form of a matrix of codes, which determines

unambiguously structure type, geometry of its elements and normative requirements of the Rules to each structural member incorporated in the structure.

E.M. Appolonov, V.E. Segal. Method on ultimate load calculation for complicated side structures. Pp. 146–152.

Presently the Rules of Russian Maritime Register of Shipping are changing over from the structural analysis as per allowable stresses to the structural analysis as per ultimate loads considering material plastic deformation reserves. Basing on this method the paper examines strength analysis of complicated side structures including ones of «double side» type.

The side structure is modeled by a system of intersecting horizontal and vertical beams with asymmetrical H-sections (in the general case). Possible structural asymmetry relative to the longitudinal axes caused by the difference between vertical beam fixing at the deck and at the bottom, as well as variations in plating flange thickness and framing size along the side depth are taken into account. The sea-induced load acting on side structure is assumed to be trapezoidal.

The ultimate load is determined through a static approach basing on an equilibrium equation for horizontal and vertical beams in the side structures limit condition. Taking into account the high stiffness of the «double side» – type structure, nonlinear interdependency between the ultimate bending moments and shearing forces in the beam supporting sections is considered. Due to this the obtained systems of the equilibrium equations for beams are nonlinear. An analytic solution is obtained for these equations.

Basing on the developed method calculations for a representative series of tankers were made enabling estimating a standard value for safety factor.