Proceedings of Krylov Shipbuilding Research Institute

39(323)

E.M. Appolonov, A.V. Alexandrov, A.B. Nesterov. **The investigation on the influence of the material defect development process on the margins of limiting plasticity and bearing capacity of the ice reinforcement plating in Arctic vessels.** Pp. 4–28.

The investigation subject is the influence of the internal and external material defects arising in the course of construction and operation on the actual margins of plasticity and bearing capacity limits of ice reinforcement plating in the Arctic vessels.

The investigation contains the statistic analysis of the data concerning the ice reinforcement plating defects, and the assessment of their average development speeds in the course of the operation, which make it possible to justify the importance of the task and precise the range of defect parameters' variations to be analyzed.

The investigation contains the FEM analysis regarding the reduction of the material limiting plasticity characteristics and the limiting bearing capacity parameters of the deficient structures which make it possible to conclude that the linear and groove-type wear are highly dangerous.

E.M. Appolonov, A.B. Nesterov, I.M. Belov. **Scientific aspects of hull design for the large-size Arctic gas carriers.** Pp. 29–44.

To create an efficient sea transportation system for the export of the natural gas produced at the Russian Arctic coast and offshore it is required to solve the problems related to the design of the large-size gas carriers, capable of highly reliable and safe operation in Arctic ice.

Since the practical experience of such vessels' construction and operation is currently absent, the appropriate scientific justification of the design solutions is becoming of great importance. In a wide range of the scientific and technical problems related to the design of hull structures for such vessels it is possible to highlight the following major challenges: determination of the ice loads on the hull considering the specifics of large-size gas carriers; advancement of the requirements regarding the cold resistance of hull structures; development of recommendations concerning the achievement of excellent vibration properties of the hull; development of the hull strength monitoring system during navigation in ice.

This investigation makes it possible to conclude the following.

Because of the structural complexity and the lack of operational experience with the large-size vessels in the Arctic it is required that the Arctic gas carrier design should be supported by competent scientific organizations.

For specification of ice loads for the hulls of the large-size Arctic gas carriers it is recommended to consider the necessity of breaking through heavier ice ridges because of the poorer maneuverability, and the increase of the load on the intermediate area of the ice reinforcements during the «widening» of the channel behind an ice breaker of less beam.

In case the bulbous bow it is recommended to avoid the situation when variable draught area overlap the vertical sections of the hull sides and use analytical methods to estimate the ice load on the bulb and adjoining hull areas.

E.M. Appolonov, A.B. Nesterov, K.E. Sazonov. **Regulation of extreme ice loads on the azimuth propulsion system pods of the ice-going vessels.** Pp. 45–68.

Vessels with azimuth propulsion system (APS), including the double-acting tankers (DAT) designed for autonomous ice navigation in astern-running mode which makes it possible to improve their icebreaking capability and their operation performance in open water by means of the bow shape optimization, are considered to be promising ship types for the hydrocarbon and ore materials transportation along the Arctic Passage routes. This paper covers the regulation issues of the extreme ice loads on the APS pods of conventional ships and DATs.

It was traditional for Russian practice to use a hydrodynamic model (HDM) of solid body/ice impact, however the latest full-scale and laboratory experiments carried out in Russia as well as abroad, showed the higher degree of ice load localization (or peaks) as compared to HDM predictions. For the regulation of the ice loads on the DAT azimuth propulsion system a modified hydrodynamic model (MHDM) is used, which provides both satisfactory agreement with the experimental data and a good succession of the HDM's approaches and empiric coefficients. The paper suggests an approximate formula for the ice force determination, and this formula is based on MHDM approaches.

The paper covers the methods of regulating the calculated parameters for the APS ice impact under ahead-running, astern-running and in circulation mode. It also considers the possibility to create an efficient APS protection from ice impact under astern-running, and takes into account the double-acting tanker APS specifics.

The paper suggests an engineering calculation model to determine the load on DAT APS when the vessel goes through an ice ridge under astern-running. It examines the case of the ridge keel interaction not only with the blades of the pulling propeller, but with APS pod as well. The paper also considers the circumstance that the areas of the ridge keel adjacent to the zone destroyed in the course of interaction with the propeller blades, are rather hollow.

E.M. Appolonov, A.B. Nesterov, O.Ya. Timofeev. **Ensuring the ice strength and safe operation of the vessels in Russian Arctic and freezing seas based on the complex system of principal engineering decision making process.** Pp. 69–89.

Each phase of the ice-going vessel life requires solution of both technical and economic problems.

The paper describes a complex system of principal engineering decision making process:

– To determine the ice class, which is optimal for navigation in the specified area, at the design specification phase. The ice class specification is based on the investigation of equivalence between the ice classes assigned by various classification societies and on the analytical prediction of the acceptable conditions for the ice navigation.

– To promptly estimate, in the conceptual design phase, the hull mass by calculating the preliminary required volume of ice reinforcements; to select the hull steel; to solve non-standard engineering problems (for example, for LNG applications).

– To optimize, at the detailed design, the ice belt structure (topology and scantlings), to increase the safety of the hull details, to predict the level of vibration in ice and to determine the structure fatigue life margin.

– To develop, at the operation, the configuration of an integrated monitoring system, to deliver the algorithms and software for the on-line data analysis aboard the ship, to process the data and work out the recommendations regarding the acceptable ice navigation modes.

F.Kh. Gabaidulin, V.S. Boyanovsky. **Design and optimization of the ice reinforcement structures.** Pp. 90–94.

The paper covers the issues of the hull structure design for the active ice navigation ships. The ice-breaker and the research vessel designed by «Baltsudoproekt» Central Design Bureau for the Russian Antarctic Expedition support are taken as an example for the analysis concerning the ice reinforcement structure optimization specifics.

N.Yu. Klementieva, K.E. Sazonov. **The estimation of wave characteristics giving rise to an «ice storm».** Pp. 95–100.

Ice floes accelerated by surface waves can destroy offshore engineering structures. In case of certain relationships between the size of floating ice floes and the wave characteristics an ice floe may be «captured» by the wave. Under these conditions the ice floe starts moving together with the wave crest at the same speed.

The paper describes the investigation results regarding the interaction between the high-amplitude surface waves which occur in the Arctic seas with floating ice floes. The special emphasis is made on the determination and assessment of the wave characteristics which are likely to cause «ice storm». This assessment is made with the consideration of the sea wave probabilistic nature.

V.A. Nikitin, G.V. Boytsov. **Design and construction specifics of the floating production production, storage and offloading structures.** Pp. 101–109.

The paper examines the contemporary methods of liquid hydrocarbons production at the continental shelf and their technical support.

The paper describes the floating production, storage and offloading (FPSO) under various operation conditions, and the requirements to be met by these structures. It also discusses the issues of construction FPSO intended the operation in freezing water areas, including Russian Arctic shelf.

The paper covers the questions of the tankers modification into FPSO as well as optimization of technological operations and processing systems installed on FPSO.

Yu.V. Shvarev, O.P. Orlov, Yu.A. Simonov, V.M. Vorobyev, E.M. Appolonov, V.A. Belyashov. **Problems to be addressed in construction of the new-generation multi-purpose nuclear ice breaker.** Pp. 110–128.

Nowadays it is becoming of great importance for Russia to construct new-generation nuclear ice breakers. It is caused by a series of factors which determine the necessity for the country to have ice-breaking fleet; the necessity to protect Russian strategic interests in the Arctic Region, including the task of the Arctic Passage functioning support; a sharp increase of the planned volume of cargo transportation, mainly oil and oil products, in severe conditions of the Barents and Kara seas; the difficult situation with Russian ice-breaking fleet whose lifetime has practically expired.

Most of perspective mineral fields have been found on the Western Arctic Shelf. So it is the most important task for Russia to ensure their development in the years to come. A new nuclear ice breaker under design intended to ensure a year-round operation of the transportation system for the export of the raw materials produced in these regions is mainly to have a very high icebreaking capability – not less than 2.9 meters of continuous level ice.

Most of the time ice-breakers have to operate in shallow waters, including extremely shallow areas. Nowadays the vessels in shallow waters are assisted by the nuclear icebreakers «Taimyr» and «Vaigach» with the draught of 8.5 m, and icebreaker assistance in deep waters is carried out by the «Arktika» type nuclear icebreakers, whose draught is of 11.0 meters.

In the course of the new-generation nuclear ice breaker design it was decided to extend their functional capabilities and create a multi-purpose nuclear ice breaker with a deep-water draught of 10.5 meters and a shallow-water draught of 8.5 meters. Such ice breaker is a unique engineering structure which is impossible to construct

without special scientific and technical research because the in the process of construction it is required to cope with serious difficulties, major of which are caused by the limitations of physical nature.

Ice breaker operation in shallow waters sharply increases the danger of cavitation development and penetration of air to the propellers which will reduce the propulsion thrust and the ship's ice performance, damage the hull in the area of bilges and on the bottom structures, and lead to additional sagging of the ship's stern end which increases the danger of the propeller blade damage at impacts with the seabed.

This circumstance makes it necessary to consider the factor of the limited water depth area in the course of perspective ice breaker design and the selection of the vessel's main dimensions. Since all Russian Arctic offshore waters are mainly shallow, these factors have significant influence on the perspective nuclear ice breakers' layout and dimensions, on the level of power effectively processed by the propellers, and on the acceptable draught values.

The central task is to develop the hull form which would meet all these requirements and make it possible to achieve a high icebreaking capability of the vessel with a relatively low power increase as compared to the existing nuclear ice breakers. The hull structure should be optimized to achieve the minimum weight load and meet all the requirements regarding the strength and the equipment arrangement aboard the vessel.

M.A. Kuteinikov. **Improvement of strength requirements for river-sea ships.** Pp. 129–141.

The river-sea ships belong to the most difficult vehicles in terms of marine operation conditions and their strength and safety criteria are still under development. Accidents due to wave and wind effects emphasize the need to address the issue of developing and validating the design environmental conditions and related operation restrictions.

One of the main tasks is to find how design wave heights h_p and wave loads governed by these heights are related to the specified wave heights $h_{3\%}$, restricting allowable operation conditions. A significant factor is the influence of errors in weather forecasts on the actual distribution of wave conditions. The estimated possibility of reaching refuge harbors is of special importance.

The design wave heights h_p are estimated using well-known techniques of converting irregular wave parameters into wave load parameters (wave bending moments) and «equivalent wave heights» based on application of total-probability integration. In this case statistic variations of mean wave periods and ship headings are taken into account. The estimated design wave heights $h_p=h_{eq}$ are compared with the rules of the Russian River Register of Shipping and Russian Maritime Register of Shipping. The results of estimates lead to the following conclusions. The design wave heights as per RRR and RMRS rules are close for relatively long ships, but at $L\leq 80$ m these heights become different. The rules of both classification societies give no instructions regarding the relations between design loads and distances to resort harbors. The wave heights h_p obtained according to the developed method have intermediate values closer to the RMRS rules.

M.A. Kuteinikov. **Limiting wave parameters and ship operation modes based on strength criteria.** Pp. 142–159.

The short-sea ships often sail beyond their specified operation areas, e.g. for relocation, repair, etc. In such cases the limiting sea states during the voyage have to be considered.

For comprehensive prediction of ship behavior in waves it is required to develop a procedure for simulation of ship operation in irregular seas. Such simulations have to provide not only general operation parameters (periods, velocities and accelerations of ship motions, maneuverability, etc.) subject to specification but also forces arising in the process of ship/water interaction (pressure at any point of wetted surface, bending and torsion moments, shear forces).

One of the examples is the method for prediction of the limiting sea states based on global and local hull strength criteria with subsequent specification of safe operation areas and seasons for one-off voyage of a short-sea ship beyond her regular operation area. The main result of this method is determination of allowable wave heights with a 3% probability of exceedance, $h_{3\%}$, based on strength criteria. The overall restriction based on all conditions (global ultimate and fatigue hull strength, local ultimate strength) is specified in terms of the found wave heights with a 3% probability of exceedance.

Test calculations using the proposed method have indicated that in most cases of real voyages the governing condition is global ultimate strength. In case of long-term voyages the global fatigue strength may prove to be the governing condition. The ultimate strength of bottom and side structures and, in particular, plates and primary framing, as a rule, is less stringent requirement, which indicates large ultimate strength margins of bottom and side structures as compared to global strength margins for the one-off voyage cases.