Target ship design and features of navigation for motion stabilization and high propulsion in strong storms and icing

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ABSTRACT

Statement of the design problem for ocean vessel of unlimited sailing can be based on the active use of the historical experience of designing of the good-quality ships. Such experience includes good sea practice of the most authoritative seafarers. It is reflected in the navigational instructions on achievement of efficient operation of ships, in pilot recommendations of practical navigation and unwritten rules of carrying out dangerous and hard sea work in the complicated, storm and ice conditions. Particular specialization of the ship for a concrete type of sea activity in the originally specified geographical and navigational conditions allows the use of achievements of noncontradictory design. It is formally reduced to global optimization (as well as in mathematician) under the terms of minimum external impact on a ship hull. Such approach certainly requires special navigator skills or adaptation of the automated navigation complexes in a variety of special or emergency situations, unpredictable in long ocean voyages. Each new design solution of the vessel of the improved seaworthiness should be complemented by the corresponding techniques on efficient carry out of sea works in storm conditions. In this paper, various examples show how to implement this concept in order to address the engineering problem of the highest efficiency of maritime activities of specialized ships. As target parameters are considered safety of navigation (including in extreme situations), achievement of optimum propulsion in strong storms and severe icing.

Keywords: *seafaring, shipbuilding, sensible target design, trochoidal wave, ninth wave, propulsive and pitching quality of the ship*

1. INTRODUCTION

Seamanship and maritime infrastructure development is an important indicator of efficiency of use of high technologies, general geographic knowledge and creative art marine engineers and navigators authoritative, in general, forming the foundation of "good seamanship" and exclude the possibility "of vainly invention not for mariners".

The concept of a consistent target of ship design is aimed at full harmonization of engineering solutions to well-defined geographical, navigational and meteorological conditions of navigation; for a given level arrangement of regional marine infrastructure and adequate competence shore-based and ship crews. Priority in the selection of design decisions and responsible for the formation of sailors ship's architecture; for the layout of ship equipment and mechanisms, as a consequence, lead to a mismatch of formal methods model shipbuilding and claim new research to test the special instructions on the efficacy and safety of navigation and marine operations for the intended purpose of the vessel.

A sensible design of the ship means the execution of the whole complex of marine research to optimize engineering solutions in shipbuilding for extremely accurate and complete realization of the real operating experience and good seamanship all-weather control of the ship in specific geographical areas of the ocean, that the Russian Far East is the need of understanding all aspects of navigation in complex, ice and storm conditions navigation ensuring with all-season and all-weather works maintenance of ship for its original purpose, and without the possibility of reliable shelter while waiting for the sea "fair weather".

2. THE EVOLUTIONARY GENESIS OF THE SHIP'S AFFAIRS AND GOOD SEAMANSHIP

Appearance, contours and architecture of the historic ship uniquely determine the possibility of its maneuvering in a storm winds and waves (Khramushin, 2011). Historically, as well as in real engineering and seamanship, seaworthiness of ships predetermined by relative strength of the shiphull and reserves its weighting to achieve the best propulsion in rough weather, or to keep the storm safe course in any one of the three historically verified modes storming, relying only on the ability of the crew to provide maneuvering in complex and storm sailing conditions:

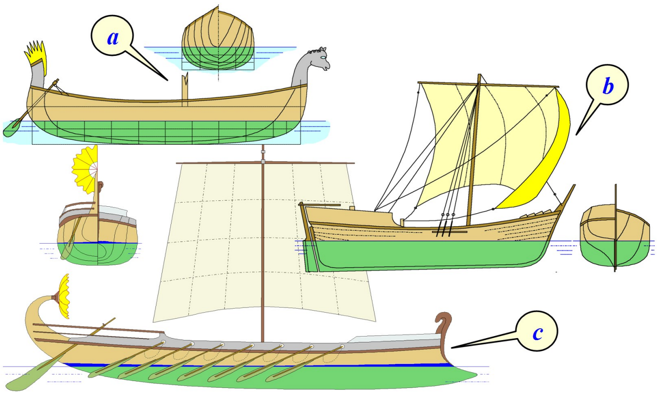

Figure 1 Design solutions ancient shipbuilding techniques associated storm navigation:
a) - with a course along to a wave;
b) - active move in the wind and wave;
c) - passive storming bow on a wave.

a) – <u>course of along to a wave</u> (Figure 1-***a***) so far implemented on a wooden boat on the Volga river; previously used by the ancient Egyptian ships on the Nile river; as well as the broad Norwegian boats for shallow water areas, including long-range maritime and ocean navigation. Such vessels have excessive initial stability, why are experiencing intense rolling and pitching in the tempo of fast surface slope of storm waves, and, of course, need to be active course correction to keep the shiphull along the ridge for largest and most dangerous storm waves that ancient vessels was performed with a feed fin oars. This mode of stormy navigation fundamentally unacceptable to consider as the base for the vessels with a large displacement;

b) – <u>active storm course on a wave fronts</u> (Figure 1-***b***) is sometimes used by modern sailing yachts with a broad stern, as well as quite large rescue tugs with advanced bow superstructure; previously been used extensively the sloops Russian Pomors on a northen latitudes of the Arctic Ocean. The vessel medium displacement on the course with the wind must feels smooth pitching with a significant reduction in power loads on the shiphull by large ridges for passing storm waves, that provided the maintenance of sustainability and maneuverability via hinged aft rudder, effectively operating at a relatively high speed movement under the bow square sail;

c) – storming the course bow on a wave (Figure 1-***c***), unfortunately, has now become is practically the sole means of aimless containment of forward propulsion to provide its safety in heavy weather at extreme external loads on the host machine and the steering gear. This method has historically inherited from the ancient Phoenician warships with bulbous bow-ram; in the Middle Ages storming by a bow wave created conditions for safety far ocean sailing expeditions of the Geographical Discovery Age. Asymmetry forms of fore and aft ends shiphull gives the ship weathervanes properties in relation to the wind and the waves, which is achieved by the creation of special contours and perfecting form a surface part shiphull to minimize power influence on the intensity of the storm loads on the hull of the vessel by the oncoming wave fronts, and this asymmetry is quite enough to safely the sea waiting for good weather with no active of the crew.

Last method of a stormy timelessness on course "bow on a wave" is a special captain's ability to save the ship in a stormy sea, which often require a hazard to pull by the main engines, with extremely high overloading mechanisms of steering device, that ship changes a favorable course before impact with each storm wave ridges – with the dangerous ninth wave. This ability does not correct the disastrous mistakes shipbuilders, and the use of such "skills" in a large vessel is limited by the fact that the crew and passengers survive unbearable conditions of habitability; until main deck sheer strake belt of shiphull is not broken under the blows of the ship's cargo in the cycles of rise in weightlessness - to fold multiplication of forces under the influence of the weight onboard and heaving; and immense overload onboard mechanisms do not overpower the technical capabilities and resources efficiency of main machine and control systems.

3. TARGET SHIP DESIGN AND EFFECTIVENESS OF STORM NAVIGATION

Modern fleet with the current power availability by each ocean ships can be used in combination regimens of maneuvering in heavy weather, and steady maintenance of propulsion by arbitrary course throw hurricane winds on stormy waves, if the original design of the ship provides a thorough engineering study of ship contours, the hull shape and the ship's architecture for specific geographic conditions, with the obligatory agreement of all the navigator's requirements and practical methods of seafaring and exploitations of perspective fleet in a predetermined maritime area. Search and optimization of technical solutions determines are "sensible target ship design", is the key results of which are discussed in this paper.

At the time the Great Geographical Discoveries ocean fleet (Figure 2-***a***) has gained universal understanding of good seamanship for a far transoceanic expeditions, which was supported by a universal ship's architecture for reducing impacts to ship from stormy waves, and provides passive storming on the course bow on a wave. Draught becomes comparable with half the width of the shiphull and freeboard tumblehome inwardly to compensate for the hydrodynamic force action of storm waves. The external appearance of ocean ship has a high aft superstructure – as storm weather vane, and very low deck of bow under privy head and vessel there (knee of the head)), dived under the ridges of counterpropagating waves for a hydrodynamic compensation of pitching, and as a result, prevent the wave impact loads on a wooden shiphull and deck superstructures, which has a relatively lower strength.

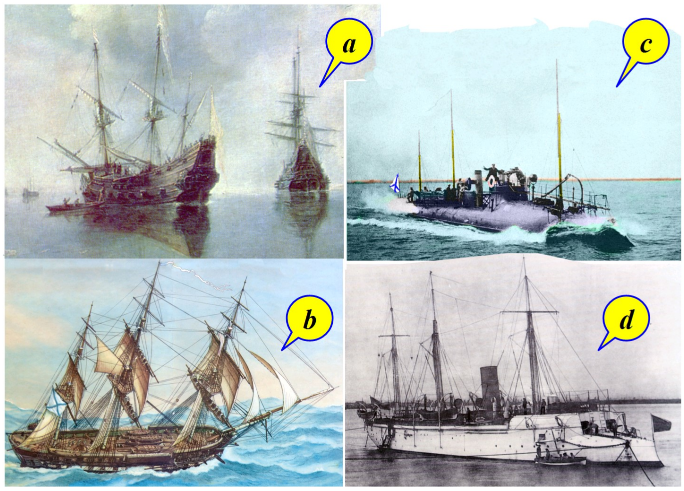

Figure 2 The optimal design for a ocean sailing ships: left side – ***a***) and ***b***); and their evolutionary improvement to a ships with enhanced stormy seaworthiness by using the power-driven propulsion: right side – ***c***) and ***d***).

By the beginning of the XIX century a structure and governance by sailing equipments was up to the highest technical perfection, and, as evidence of optimal engineering solutions – there is a universal uniformity of sailing fleets all over the world. In the latest projects of sailing ships begins traceable target concept of designing to achieve the highest efficiency seafaring in a fresh ocean winds and intense stormy waving for specific geographical conditions maritime communications. On the example of the cruiser-frigate "Pallada" (Figure 2-***b***) there is a decrease of height and alignment of the continuous upper deck, which indicates assurance of the crew in the adequacy of sailing equipments for all-weather control and manoeuvrable of yours best ship. Noncontradictory design concept, however, keep it up in using the old method of passive support storming course by the "bow on a wave", that enables the use of storm the aft mizzen instead of high aft superstructure, and in the event of the hazard of hurricane force winds, and still foremast can go overboard as a drogue anchor, which also weighting and stabilizing the ship bow on a stormy waves.

sharpen the waterlines and reduce the risk of intense pitching.

4. KEY TECHNICAL SOLUTIONS TO ACHIEVE THE BEST STORM SEAWORTHINESS

The main engineering solutions to achieve efficiency of navigation in heavy weather, and especially their involvement in good seamanship outlining maritime forum STAB-2009 in St-Petersburg in the report "Key design solutions and specifics of operation in heavy weather, fluid mechanics approach to stabilization of ship in heavy seas" (Khramushin). And we restrict ourselves the illustrations and brief explanations necessary in subsequent submis-

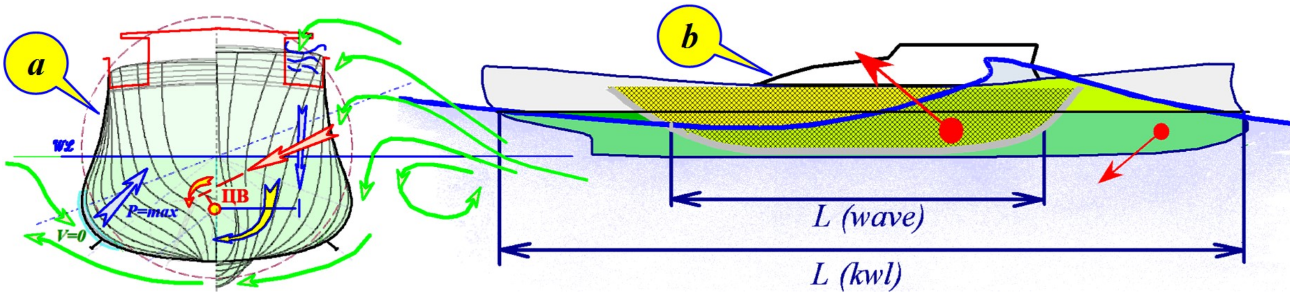

Figure 3 The hull form must given the hydrodynamic compensation: ***a***) – a rolling using by minimizing height of tumblehome board in the middle, and: ***b***) – pitching of ship through the redistribution of pressures in trochoidal wave on board.

sions by the refined of geometric constructions ship contours and shape of the hull of ships and vessels enhanced storm seaworthiness and ice passability, which is very important for navigation on the Russian Far East seas.

Evolutionary perfection design of contours, hull shapes and ship's architecture in general for new fleet is achieved by implementation of steam engines, propeller screws and highly durable steel hulls of ships and vessels at the end of XIX – beginning of XX centuries (Figure 2-***c***, ***d***). In the external appearance the newest ships disappear multitude bulky devices except the mizzen mast gaff on, indicates the possibility of quickly setting the mizzen storm sail to bring the ship on course bow on a wave during storm strong wind. Draught of ship hull was remains relatively deep, and the freeboard has a tumblehome form to compensation force action of the waves and reduce roll. The bow deck is very low, the stem to the stern tumblehome, or is almost vertical stem, it is necessary to

In real navigating practice are preserving the tradition visual interpretation the force distribution and hydrostatic pressure changes of flow field (by Bernoulli's law) in the hydrodynamics ascent by account of water flows near the hull and outboard stabilizers, also under the influence of sea waves, which performed by analogy of engineering decision-making for maneuvering using of spatial images and laws ship fluid mechanics, generally accepted in the international language of navigator communication on duty watches, with pilots, marine rescuers and captain's mentors from a coastal services. The scheme of hydrodynamic effects of storm waves impact to the shipboard, was built on navigator's principles, mentioned (Figure 3) in the design and optimization of contours and shape of the hull to minimize rolling (Patent of invention № 2360827, 2009) (Figure 3-***a***) and pitching (Order of invention 2007133625, 2007) (Figure 3-***b***), found experimentally confirmed for almost complete compensation rolling under the influence of extremely high ridges storm waves (Figure 3-***a***), which free passing under the tumblehome shiphull, and emerging from the other board with little or no shape distortion and intensity collapsing wave's ridges, as well as visually complete transformation pitching hull in the heaving (Figure 3-b), which helps to maintain the best propulsion and better habitability conditions in the active movement of the ship relatively an arbitrary course of progressive wave ridges and ninth wave, resulting in packages trochoidal wave structures.

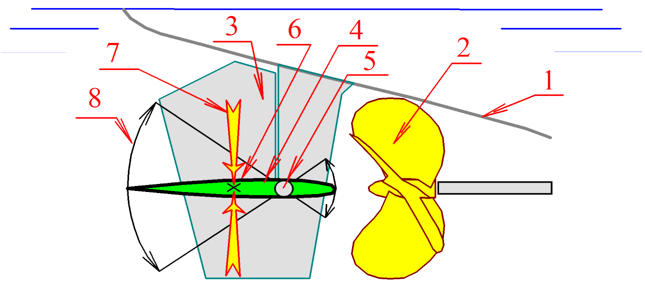

Figure 4 Screw steering system (2, 3) with stabilizing wings (4) - storm emergency propulsion. 1 – the ship's hull; 5 – axis of blow in the stream behind the propeller-driven and allows the elastic rotation of the wings; 6 – the abscissa of summary forces (7) of the heaving motion of a stern extremity; 8 – the turn angles for the plane of stabilizing – propulsion wing.

Hydrodynamic compensation effects on the hull by storm trochoidal waves in deep water is formally responsible solution of the inverse problem of the project is minimal body reaction to external force is well-defined wave nature. If the ship would be under the influence of any other roll and different forces, such as in the circulation; mode porpoise on a wave; or in the zone of cnoidal wave ridges in shallow water; et al., the ship may be subject to unacceptably large angles of roll or different of uncontrollably increasing, with a sweeping flow of water on upper decks on the bow and aft decks; and the like. Assuming that the external forces of nature nonwave have significantly lower intensity may direct opposition to their negative impact with active wing devices to compensate for residual pitch and roll (Patent 2384457, at 2010).

In stormy conditions stabilized in the direction of flow of the water near the ship's hull, going full speed ahead, there is only a flow of working propellers (Figure 4-4). There is also is possible to obtain the greatest moments of forces for active roll stabilization and pitch of the ship in stormy weather on the fast circulation et al.

In case of loss of ship way ahead, the influence of storm waves may there are heave for aft in a large amplitude, which will lead to the wing unit with elastic axis shaft to mode flapping fin propulsion, which auto activating in a dangerous conditions on stormy sailing of the ship with the machine stopped. Passive fin propulsion requires no additional power or control actions on the wing device, and elastic rotation (backlash) on the rudder angle of ± 30 ° to protect the ship from hitting the surface of the water that is no less important and active stabilization mode on the fly pitching ship.

5. GEOMETRIC CREATION OF LINE CONTOURS AND FORM OF THE HULL FOR A NEW SEAFARING VESSEL

The result of research into the historical evolution of shipbuilding, it is possible to formulate the main design features of construction contours and form of the hull of the typical ship and a low-speed vessel, which considering the need to achieve effective navigation in ice and storm on the Far Eastern seas.

Stem and bilge contours of the high-speed surface ship (Figure 5) or relatively low-speed commercial vessel (Figure 6) determine the conditions of preservation of the storm propulsion at arbitrary courses; lessening all kinds of stormy hull motions; prevent dangerous icing upper decks; and to enable autonomous navigation in ice conditions. A large series of computational and towing experiments with models of ships and vessels of different classes, has identified the most important geometric elements and design features of the stem and hull lines in the bow:

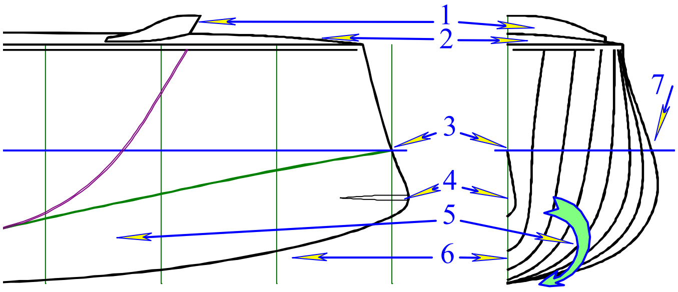

Figure 5 The bow with tumblehome stem of fast ship hull, capable to actively maneuvering in a gale-force winds, stormy waves, and also for autonomous navigation in the ice conditions with average continuity.

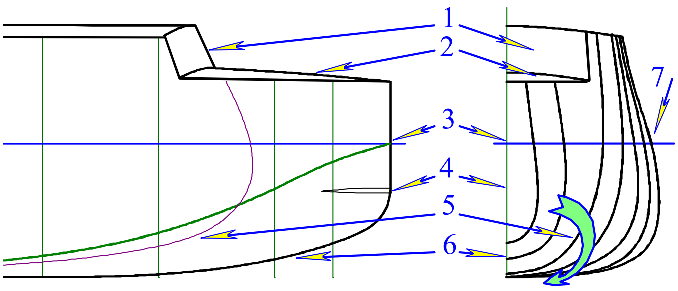

Figure 6 The bow with plumb stem of slow-speed vessel hull, capable to keep a given course with relative slowly way under hurricane-force winds and waves, and for autonomous sailing throw average continuity ice fields.

– stormy undercut at bottom to stem (Figure 5, 6–6) with an average slope of 20°–30° from the keel line, which need to allow free yaw under heavy rolling and pitching with the active movement of the ship on a stormy seaway;

– slope to aft (*tumblehome*) or vertical (*plumb*) and arrow-headed stem (Figures 5, 6–3) in the range of variables waterlines when sailing at a moderate sea state (about one-third or one-half of the draught) for non-impact cutting of a stormy waves ridges and rising the edge of breaking ice by ship under way, from the ice fields diving under the bilge or the bottom of the hull;

– with a special strengthening of the collision part of stem (Figure 5, 6–4) to an impact load for splitting of medium ice fields on the speed way up to 6 knots, or with immediately stop the ship at speeds up to 3 – 4 knots, with the ability to create maximum force thrust to lower part of large ice floes and ridges, where the ice is warmed up to a temperature of the water, with the vector force on a small rise of the ice edge to prevent of diving an ice fragments to a bilge and under bottom of the ship;

– branches of a bow freeboard frames may have little rake for hydrodynamic compensate of possible burrowing the bow deck under oncoming storm waves ridges for speed movement ship at high speed ahead (Figure 5), or have a tumblehome upper part of the all frame's height contours with descent of connection point with sheerstrake belt under forecastle deck of slow-speed vessels (Figure 6), that is required to compensate for pitching and heaving due to admission to bow deck big flows of water from storm waves ridges;

– wave screen of fast ship (Figure 5-1) and the shelterdeck's superstructure bulkhead of a slow-speed vessel (Figure 6-1) to protect crew on the upper deck of the direct impacts of waves in rough weather;

– at the expense of the bulb-board shell in the range of variables waterplanes (Figure 5, 6-3) creates screw surface on the length of the stem to the area of divergent ship waves breakaway, including comparable in length with external storm waves to tighten the counter-flow and wave ridges under the bow and bilge bottom of the hull;

– just behind the plot waterlines at diverging ship-waves in break-away zone, can begin a convex bend in the frame's loops to form a boules and tumblehome boards in the middle part of the shiphull (Figure 5, 6–7), that it is necessary for the hydrodynamics compensation of rolling when sailing an arbitrary course relative on storm waves, and also creates the conditions for the repulsion of large ice floes floating under the large around ice fields, and, as a consequence, prevent tightening of ice fragments to the zone with propeller-rudder system at the astern part of the shiphull.

Stern-post, bottom bilge, aft quarter and valance above propeller-rudder system, are arranged in a single or twin-screw in the propulsion options, including the ability to install stabilizers residual pitching and rolling in a stabilized flow directly behind the propeller propellers (Figure 7), and optimized under the terms of the hydrodynamic stabilization running trim at movement in calm water and in heavy storm waves, for which:

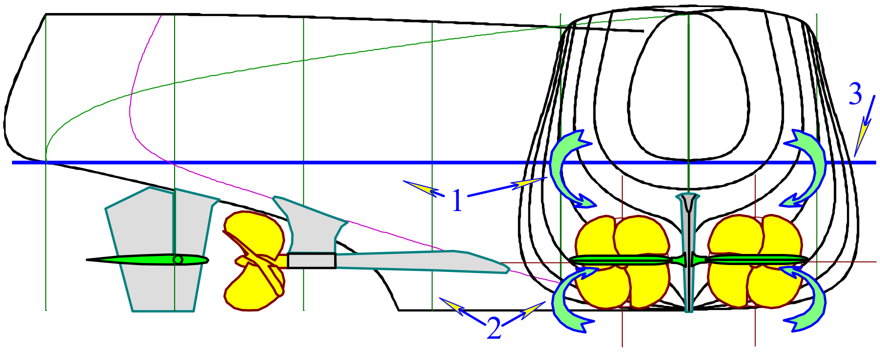

Figure 7 Aft valance, quarter, bottom bilge and stern-post of twin-screw ship, optimized to minimal trim on calm water way

– at the level of a heaving variables waterplanes must created helical surface along from boules on middle board (Figure 7–3) to the astern overhangs (Figure 7–1) for tightening and partial redirection of water flow near the side plating up, thereby compensating cocurrent (hydrostatic) slipstream and break away prevent of the high-frequency component of the ship's wave, followed by the dispersion concentration of wave energy in long-end of the spectrum, with phase shift for damping of interference with the main component of wave – a wave of cross-ship;

– helical surface in variable waterplanes will reduce the volume of the aft freeboard, and natural sharpening shell for cruising ship over astern overhangs, thereby reducing external force by storm waves and corresponding of slowing to heaving and pitching; not least to prevent shock and danger of capture the stern of the ship (*broaching*) by the ridges of ninth waves and especially on dangerous courses to wave moves by slow speed way, and in the case of an emergency loss of moving;

– a pointed cruising stern does not deform hydrodynamic field in storm waves water flows under the aft shell and astern overhangs hull, when stopping the main machinery, which automatically switches from regime of active wing stabilizers for pitching and rolling, to new mode of the passive storm emergency, which thrusters to bring the ship to a safe course of the storm, bringing the total for the device and the shape of the aft end must be optimized in order to maintain control, even at the minimum power, which arises as a result of the elastic reaction on the rudder passive wing propellers;

– on extended from bottom bilge shell to pairing with stern contour must created a second helical surface (Figure 7-2) to the oncoming flow rotation with over waterplanes (supporting) depth, thus allowing for the mutual compensation of the lower and upper flow vorticity in the area aft overhangs and in the scope of the rudder and horizontal stabilizers of residual (nonlinear) pitching and rolling of the ship, as well as through the creation of a total vertical component of flow at small distance from the side shell plating is prevented delays in broken ice from the area of on-board bulls in the area aft propeller-steering and stabilizing the complex, including the possibility of creating a sustainable ice channel at the astern of the ship;

– tumblehome board in the middle of the hull at the level of current waterplane (Figure 7-3) promotes hydrodynamic compensation of the ship rolling, as well as the raised ridge intercepts ship waves ice fields and does not allow them to flooding and diving the area of propeller-rudder system and wing stabilizers under stern overhand.

6. CONCLUSIONS

The paper presents some special engineering solutions for ships and vessels average displacement, showing features of "design target" for storm conditions in the cold polar seas, with options "consistent design" based on matching the experience of good seamanship, navigation practices to achieve efficient and all-weather safe navigation in the precarious waters of the Russian Far East - in the polar latitudes storm the North and South Pacific Ocean, historically successfully develop Sakhalin sailors, fishermen.

Usage target consistent design is characterized by the search for geometric shapes in order to reduce the external power load on the ship from the storm waves, high winds and ice hazards, followed by naturally developing are ship mechanisms, devices, and the appearance of the ship as a whole as it appears in the light engineering the evolution of the best shipbuilding solutions for ocean and coastal fleet – for the effective conduct of offshore operations in specific geographic conditions.

Due to the involvement of competent seafarers to design and build a new and prospective fleet, what allowed to return to seafarers practice a natural concern for the safety of navigation in difficult, storm and emergency conditions using proven captain and boatswain's methods, such as: installation of storm mizzen or staging sea anchor and all other useful nautical fittings to achieve sustainable and safe navigation in all seasons in all meteorological and weather conditions.

7. ACKNOWLEDMENTS

This study summarizes the results of many years of discussion on the creation of contours and ship's architecture and historical perspective ships, covering the time period from the 60s to the ship-modeling studios mentors students in the city of Syzran on the Volga (*Vladimir and Alexander Lagutin, Arkady Aksenov*). followed by the formulation of principles of good seamanship on the authority of mariners and confirmation of the advantages of ships late XIX – early XX centuries from older teachers and navy officers of the Kaliningrad Marine College, insisted on the experimental verification of the historical merits of the steam fleet in the 70s (*Alexander Kamyshev, Gregory Malenko , Dalen Bronstein*). Special gratitude for chair teachers of fluid mechanics and the theory of the ship of the Leningrad Shipbuilding Institute, delivered the first professional seaworthiness experiments for historical views on good-quality design of the ship in the 80s (*Alexander Kholodilin, Walter Amphilokhiev*), and put on the path of the present study thirty years approbation with the sailors and shipbuilders of the Far East of Russia (*Sergey Antonenko, Igor Tikhonov, Nikolai Mytnyk, Sergey Chizhiumov* and *Nikolay Taranukha* et al.), and then - St. Petersburg (Sergey Krolenko, Alexander Promyslov and Alexander Degtyarev).

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