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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

RESEARCH OF STRENGTH CHARACTERITICS OF DOUBLE BOTTOM AND SECOND SIDE HULL STRUCTURE FOR SHIPS OF THE PROJECT 1598R OF "SHAMAKHI" type

Speciality: 3328.01 – “Special operations technology”

Filed of science: Technical

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GENERAL DESCRIPTION OF THESIS

Urgency of the topic. To improve the efficiency of industrial production and to ensure continuous maritime transport, the main role is assigned to modern, technically equipped ships and ship structures that comply with international conventions. Therefore, it is economically feasible to solve the problem of ships of "old construction" by conversion and reconstruction, without violating the standard norms of the main dimensions of the ship and strength characteristics [6 p. 66 - 68, 72 - 73], [7 p.116-118].

Taking into account the requirements of international conventions, it became necessary to develop new technological production methods that can be applied not only for the conversion and reconstruction of ships and ship structures, but also for ships subject to capital repairs [1 p.2], [3 p.129-130], [9 p.285]. Conversion and reconstruction of ships includes changes in existing structural elements with the subsequent construction of new ones with the maximum economic effect, differing in resistance indicators and with minimal costs [6 p.44-45, p .64-65, p.78-79, p.85, p.87, p.94, p.96], [9 p,285], [10 p. 247-248], [13 p. 266 - 267], [15p.183 -183, p.185 - 186], [17 p.104 -105].

Conversion of "old-construction" ships is an urgent problem of maritime enterprises having such ships on their balance today. At the same time, the applied technology of conversion needs to be improved, since the existing methods do not take into account many important factors that depend on the complex structural characteristics of the ship's hull structure, mechanical and thermo-physical properties of the material, during welding works.

Therefore, application of innovative technologies of technical conversion in the ship-repairing production is limited due to the lack of serious methodological approaches and scientific - research base in this area.

In this regard, we carried out research and set the task: to develop and apply an innovative technology for the construction of a double bottom and a second board, improving the existing one; to calculate the height of the double bottom, the width of the second side, in order to install the main bottom, beam-end and under-deck (sheer stoke area) elements of the hull structure; to develop a technological model - a map for assembly works, which can be used for conversion and repair of ships, afloat; to investigate the resistance characteristics of the constructed hull structure and each block assembled with the framing system[8 c. 88 - 89], [9 c. 286], [12 c. 221-223], [13 c. 267], [14 c. 12].

The purpose of the thesis is to develop a new approach to improve the technological process of conversion of the hull structure of ships with a double bottom and a second side.

To achieve this goal, the following tasks have been set in the thesis:

- the erotically and practically to study the project of the model of the construction of the flooring of the double and second sides on which the elastic forces of compression and tension act.
- to investigate the hull structures of the tanker, in which unbalanced forces arise, the concentration of which has a dangerous effect on the plates, leading to cracks and fractures.
- formulate theoretical tasks and apply in practice a mathematical algorithm and experimental methods for repaired ships and ships to be re-equipped.
- to investigate the wave resistance of the hull, the deformation of the plates, the nature of shrinkage related stresses and fatigue failures that occur in the hull structures

The object of the research is the oil tanker m/v "Shamakhi" to be re-equipped, where a double bottom and second sides were built together with structural elements of the hull set.

Research methods and problem solving. The dissertation uses technological methods for calculating the basic dimensions of all structural elements of the bottom and sides. An effective welding method was applied, taking into account the main provisions of the theory of welding processes. The theoretical and practical models are used to ensure the rational installation of new elements of the hull set.

Scientific novelty. The following scientific results were obtained in the thesis:

- the existing technology for the construction of a double bottom and a second side for oil tankers has been improved, using the finite element method (FEM) and the method of mathematical modeling.

- an efficient welding method was developed, taking into account the algorithm of stability and resistance of structural elements of the design and construction models of the ship's hull.

- technological measures have been developed to reduce welding deformations in the installed elements of the hull set, during work afloat, quality indicators and parameters of the heat-affected zone of welding have been analyzed and determined.

The practical significance of the work. The developed technical and technological solutions for calculating the strength characteristics and conversion of the tanker m/v "Shamashi", allows for the renovation of the sea and river fleet. On the basis of theoretical and practical methods, the technology of building a double bottom and a double side for ships afloat has been improved.

The possibilities of using progressive methods of welding production have been substantiated and technical instructions for repair have been developed to increase strength indicators and reduce stress concentrations and shrinkage both in the welded seam and at the plates.

Found calculated values and parameters of strength indicators can be used to solve the following practical tasks:

- during the construction and repair of the double bottom and the second side of ships afloat;

- in modeling technological processes of assembly and welding of ship structures during overhaul and renovation, using block and panel methods;

- in modeling welding processes during ship repair using semi-automatic and manual welding;

- in calculations to determine the nodal, longitudinal and local strength of the ship's hull.

Approbation of thesis. 29 scientific articles were published on the topic of the dissertation, 17 of which were in publications recommended by the Higher Attestation Commission and one monograph.

Structure and scope of work. The dissertation consists of an introduction, four chapters, main conclusions, a bibliography and an appendix. The work contains 117 pages of main text, a list of 155 references. The volume of the attachments is 33 pages.

MAIN CONTENT OF WORK

The introduction substantiates the importance and importance of the problem, defines the goal, tasks and methods of research, and formulates the scientific and practical significance of the work.

The first chapter is devoted to a literature review and analysis of the history of the appearance of a double bottom and a second side, which provide additional strength characteristics to ships.

The results of studies of the hull structures of oil tankers with one-bottom and single-sided structures, built at different times, are analyzed. Methods are given can reduce the existing inconsistencies in their design [5 p.41-42], [10 p.247-248], [12 p.223-224], [14 p.13-14].

The causes of stress in the hull structures of the ship are considered and the calculations of the total load acting on the bottom of the tanker, depending on the water pressure Q_1 [11 p.65], [14 p.13] and the back pressure Q_2 of the load, at normal T_n, and maximum draft Tm, before conversion are given (Fig. 1):

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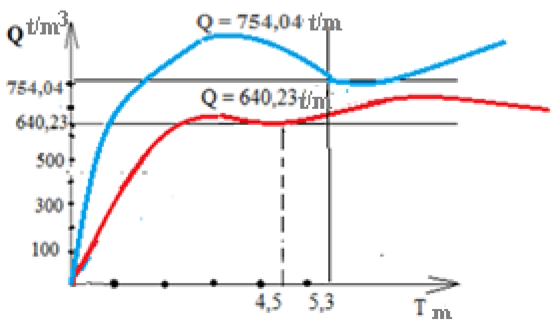


Fig.1. Diagram of the total load Q arising from the water pressure and depending on the ship's draft T, acting on the hull structure of the bottom before conversion.

$Q_1 = B \cdot T_n \cdot l \cdot \gamma = 9{,}95 \cdot 4{,}5 \cdot 13{,}95 \cdot 1{,}025 = 640{,}23$ t/m^3;

$Q_1 = B \cdot T_m \cdot l \cdot \gamma = 9{,}95 \cdot 5{,}3 \cdot 13{,}95 \cdot 1{,}025 = 754{,}04$ t/m^3, (1)

where B - 9.95 width of the bottom in a cargo tank, m; $T_{min / max}$- 4.5 / 5.3 ship's draft, m; γ - 1.025, water density, t/m^3; l - 13.95 distance between transverse bulkheads, m The calculation of the pressure p, acting on the upper sections of the deck:

$p = 0{,}7 \cdot P_w = 9{,}3$мПа $\geq p_{min}$, (2)

where $p_{min} = 0{,}015L + 7 = 9{,}205$кPa;

L - maximum tanker length, m;

$P_w = P_{wo} - 7{,}5 \cdot a_x \cdot z_i = -13{,}29$;

$a_x = K_x(1 - 2x_1/L) = 0{,}74$; $K_x = 0{,}8$; $x_1 = 5{,}3$; $z_i = 4{,}9$m–summer waterline height; $P_{wo} = 5 \cdot C_w \cdot a_v \cdot a_x = 13{,}897$m;

$C_w = 10{,}75 - (300 - L/100)^{3/2} = 9{,}39$ at $90 < L < 300$m;

$a_v = 0{,}8 \cdot v_o \cdot (L/10^3 + 0{,}4) / + 1{,}5 = 0{,}40$.

To increase the strength of the shipside and bottom plates and the set, the degree of their rigidity D, which are subject to deformations f, was determined [5 p.41-42], [13 p.267], [15 p.185-186].

The thicknesses of the bottom and side elements are calculated: $S_{min} = (7 + 0{,}02 \cdot L)\sqrt{\acute{\eta}} = 8{,}7$ mm;

The resistance moment of the cross-section (section modulus) of the longitudinal beams for the bottom and deck is determined.

The transverse strength of the frame beam a_k for plastic arching is calculated, depending on the shear stresses and the ultimate yield of steel, arising from the longitudinal moment of resistance f_c [11 p.66], [17 p.104-105].

Revealed the force of loads acting on the transverse bulkheads of the second side $\boldsymbol{J_{strength}}$:

$\boldsymbol{J_{st.}} = S_{bh} \cdot \eta P_r = 67{,}66 \cdot 0{,}78 \cdot 9{,}124 = 481{,}52$ Nm;

$S_{bh} = h \cdot b = 6{,}8 \cdot 9{,}95 = 67{,}66$ m^3 - bulkhead area in a tank;

where h - is the height of the bulkhead in the hold; b - is the width of the bulkhead in the hold.

The requirements Fку-уйor the main elements of the tanker's hull structure and options for determining the height of the double bottom and the width of the second side are considered (Fig. 2, a, b).

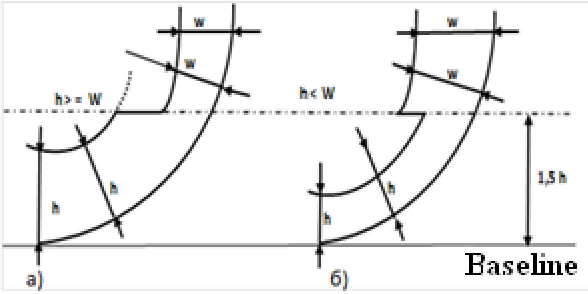


Fig. 2. Design diagram of the height of the second bottom and the width of the ballast compartment.

The second chapter presents the results of the development of an improved technology for the construction of a double bottom and a second side of a sea vessel, with high strength indicators [10 p.246-247], [13 p. 267-268], [17 p.104-106]. This technology makes it possible to ensure the accuracy of the geometric and stiffness parameters of hull structures using finite element method, for single-hull and single-side ships [5 p.40 - 41], [16 p.134-135].

A technological model has been proposed for preparing a tanker for conversion afloat, with the installation of a flat bulkhead with a transverse framing system instead of a corrugated bulkhead and a double bottom flooring (Fig. 3).

The preparation of the inner skin plating of the cargo tanks and the installation of the main structural elements of the bottom and sides, taking into account the wear of the hull structure, have been carried out. When installing new plates:

-the weights of the hull structure to be cut were calculated;

- the thicknesses of the mounting elements of the hull structure of the double bottom and the second side were determined;

- a method of settling and installation of new cross-links of the on-board set made of an equilateral square was developed;

- the strength of the hull structure of the building set and the installed new one was calculated, taking into account the loss of metal mass;

- the action of the press forces of loads arising during the installation of new elements in the bottom and side parts of the ship's hull structure during the renovation of a tanker afloat was determined;

- the design of the bow and stern ends is taken into account, where cracks and faults can occur, leading to the fracture of the ship;

- checking calculations were carried out according to working drawings and methodological instructions were prepared for the implementation of the technological process of conversion of the tanker;

- built-up shipside stringer for the width of the second side equal to 1000 mm, located at a height of 4.500 mm (Fig. 3) from the keel stoke, on both sides;

- a new second shipside stringer was built at a height of 1540 mm (Fig. 4) from the bottom, in the ballast compartment.

A rational technology has been developed for joining new sheets of the hull structure to the building ones [1 p.8-9], [2 p.80-81] [4 p.30-31]. Technological measures are proposed to eliminate stresses and deformations arising during welding.

The loads acting on the plate frame and the bottom stringer are determined as follows:

$Q_1 = B \cdot T \cdot S \cdot \gamma (1\text{-}m) = 9{,}95 \cdot 4{,}5 \cdot 2{,}325 \cdot 1{,}025 \cdot (1\text{-}0{,}4) = 64{,}02 t/m^3$, (3)

where *S – stepping distance, m*.

$Q_c = b \cdot l \cdot T \cdot \gamma (1 - m) = 2{,}5 \cdot 13{,}95 \cdot 4{,}5 \cdot 1{,}025 \cdot 0{,}6 = 96{,}52 t/m^3$, (4)

where *b – distance between bottom stringers, m*.

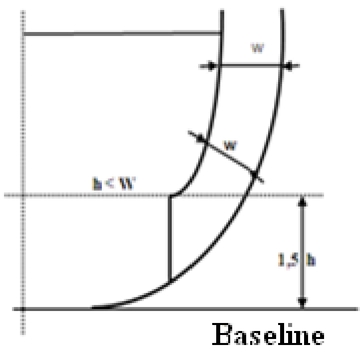


Fig. 3. Scheme for defining the boundaries of a cargo tank and ballast compartment.

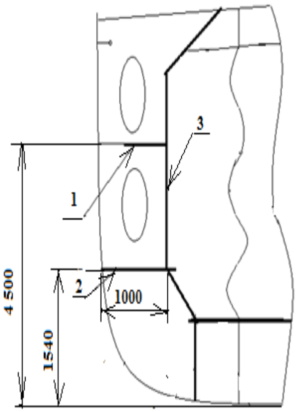


Fig. 4. Installation diagram of side stringers: 1- upper side stringer; 2- lower side stringer; 3- straight longitudinal bulkhead of double side

The external loads acting on the ship's hull at Tn and Tm were determined:

$$\text{a) } P_{\text{ст}} = \rho g Z_1 = 1.025 \cdot 9.81 \cdot 2.5 = 25.14\, mPa$$
$$\text{б) } P_{\text{ст}} = \rho g Z_1 = 1.025 \cdot 9.81 \cdot 3.3 = 33.18 mPa \qquad (5)$$

The third chapter presents the results of strength calculations of the tanker's hull structure after conversion, assembled with the framing system [10 p.247-248], [12 p.223-224)], [14 p.13-14]. The general work of the ship's hull in compression from elastic forces and from intersecting forces has been investigated. The places of rupture in the plates from the accumulation of stress and breaking forces were identified and diagrams of the forces acting on the hull after the ship's renovation were drawn (Fig. 5 and Fig. 6).

The bending moment of the bottom resistance is calculated after the conversion; calculated bending moment for the middle section; bending moment of longitudinal resistance of the bottom hull structure in calm water; wave bending moment (kN • m) causing the arching of the ship; wave bending moment (kN • m) causing sagging of the ship судна [8 p.89-91], [15 p.184-185], [16 p.133-134, p.135-137].

Calculated the thickness of the shipside plates:

$$S = m \cdot a \cdot k \cdot \sqrt{\frac{p}{k_\sigma \cdot \sigma_n}} + \Delta S = 15{,}8 \cdot 0{,}7 \cdot 0{,}354 \cdot \sqrt{\frac{150{,}90}{0{,}8 \cdot 301}} + 2{,}6 = 5.70.\ \text{mm} \qquad (6)$$

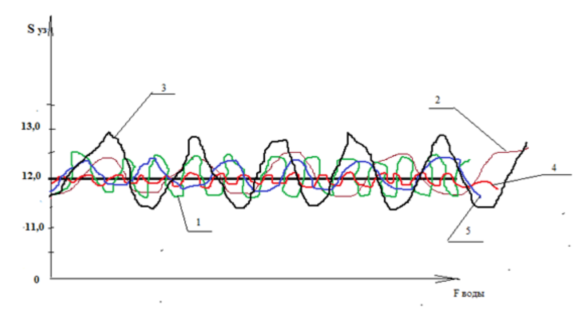


Fig. 5. Diagram of forces F_{water} influencing on the ship's hull, depending on S_{node}: 1- ship in cargo; 2 - empty; 3 - on the wave; 4 - on calm water; 5 - in ballast

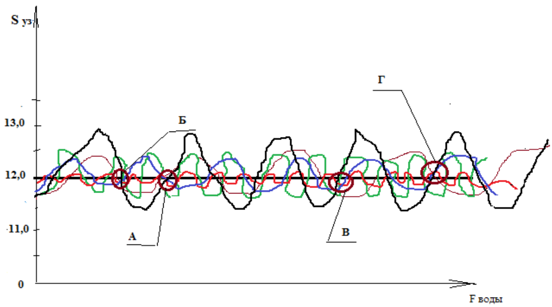


Fig. 6. Diagram of break points A, Б, В, Гin metal plates from uneven actions of forces applied to the ship's hull from the outside and inside.

- thickness of the upper deck flooring in the middle part and in the area of cargo holds:

$$S_{\min} = (7 + 0.02 \cdot L) \cdot \sqrt{\eta} = (7 + 0{,}02 \cdot 141{,}6) \cdot 1 = 9.8.\text{mm} \quad (7)$$

- double bottom floor thickness:

$$S_{\min} = (5 + 0.035 \cdot L) \cdot \sqrt{\eta} = (5 + 0{,}035 \cdot 141{,}6) \cdot 1 = 9.96\,\text{mm} \quad (8)$$

- thickness of double bottom elements:

$$S_{\min} = (5{,}5 + 0{,}025 \cdot L) \cdot \sqrt{\eta} = (5{,}5 + 0{,}025 \cdot 141{,}6) \cdot 1 = 9{,}04\,\text{mm} \quad (9)$$

- thickness of the newly built bulkhead of the second side

$$S_{\min} = 5 \cdot a + 2{,}5 = 5 \cdot 0{,}775 + 2{,}5 = 6{,}375\,\text{mm} \quad (10)$$

The stress arising in the welded joints of the plates and the set of the second side and double bottom floor from the acting forces F_{uneven}, F_{static}, $F_{chaotic}$, F_{water} has been determined. A diagram has been drawn up to determine the forces acting on the ship's hull (Fig. 7) [6 p.44-46, p.61-63, p.68, p.74-75, p.88-89, p93-95], [11 p.64-65], [14 p.13-14].

The load, arising in the hull structures of the tanker, which depends on the influence of the liquid consignment on the stability of the tanker, has been determined. The ultimate acceleration acting on the side plates of the tanker in the vertical direction is calculated:

$a_z = g\cdot(1+k_a) = 0{,}74$ m/s^2; $к_a=1.6(1–2.5x_1/L) = 0{,}048$m/s^2;

where$к_a= 0{,}048 \geq 0$ – ultimate acceleration factor in the bow section of the ship;

$L = 141{,}6$m – length of ship between perpendiculars;

$x_1 = 5{,}5$ m– distance from forward perpendicular

The uneven distribution of forces acting on the tanker's hull along three main planes was established: x, y and z before and after renovation (Fig. 8). As you can see, the actions of forces on the bottom of the side and bulkheads are reduced, and white stripes appeared on the x, y, z axes, indicating a decrease in stress concentration and an increase in the strength of metal plates in this area [14 p.12-14], [15 p.186-187].

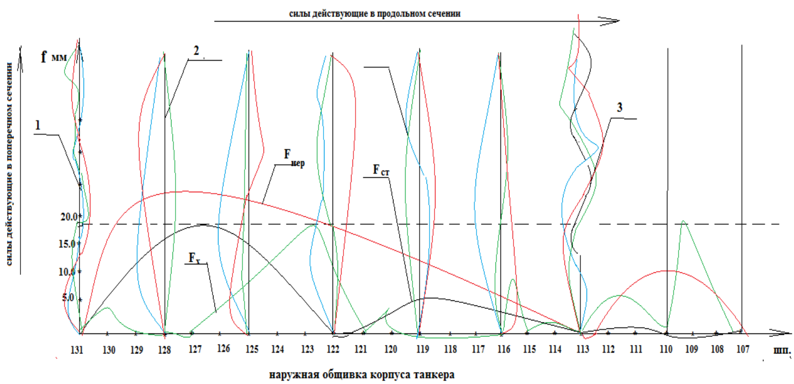
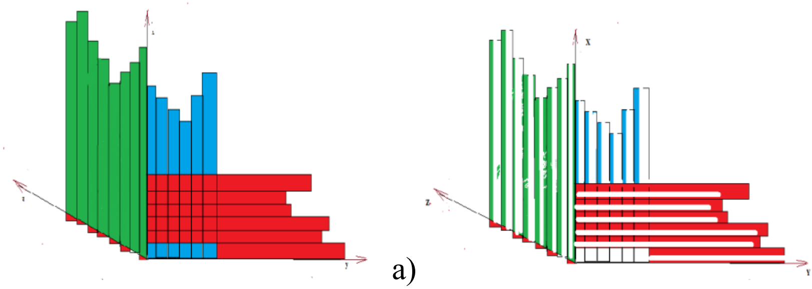


Fig. 7. Diagram of forces $F_{strength}$ acting on the hull of the outer skin plating of the ship

The reduction factor of the longitudinal section of the tanker's hull is calculated: Ψ_o = 1+ $\psi/2$ = 1,511 mPa, where ψ_o is reduction factor of the flexible part of the plate.



a) б)

Fig. 8. Diagram of the state of the shipside, bottom plating and building bulkheads along the lines: a - before conversion; b - after conversion.

The reduction factor ψ (Fig. 9) of the flexible part of the compressed surface of the plate is determined [11 p.64-65]:

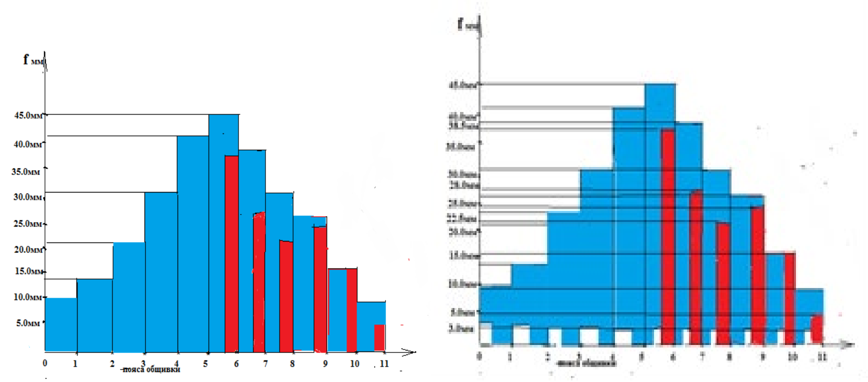
$$\Psi = \frac{\sigma_{\text{кр}}}{\sigma_{\text{ж}}} = \frac{315}{155.72} = 2.0229\, mPa \qquad (11)$$

where $\sigma_{\text{кр}}(\sigma_{cr})$ - critical stresses in the shipside plates compressed

along the long edge; $\sigma_{\text{ж}}$ (σ_{co}) is the absolute value of the compressive stress in rigid bonds, at the level of the center of gravity of the bottom plates.

As a result of the application of the reduction factor, the load acting on the outer skin plating of the ship's hull is reduced (Fig. 9, b) [10 p.246-247].

Due to the construction of a double bottom and a second side, the rigidity of the frame contour is increased, the bending and arching of the structure is reduced [8 p.88-89], [14 p.13-15]. The risk of fracture in the critical zone was reduced due to the smooth transition from the longitudinal framing system to the mixed one [13 p.267-268], [14 p.13-14], [15 p.186-187].



a) b)

Fig. 9. Load acting on the ship's hull before (a) and after renovation (b).

The technical condition of the beams of the hull set, characterizing the main functions of longitudinal and transverse strength, has been studied (Fig. 10 and Fig. 11)

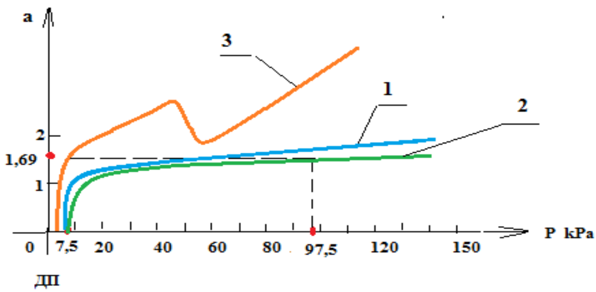


Fig. 10. Change in design pressure acting on waterproof bulkheads: 1-action of internal forces on bulkheads; 2-normal design pressure acting on bulkheads; 3-action of design pressure and forces from the outside on bulkheads.

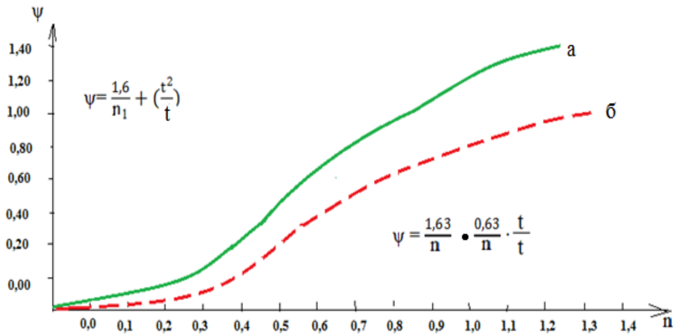


Fig. 11. Changes in the reduction critical moment of the re-installed and building hull structure due to the residual thickness error:

a) a diagram of the extreme ends of the hull set;

b) reduction factors of the flexible part of the shipside plates.

The fourth chapter discusses technological measures for provision of the strength of the hull structure during the technical conversion of the ship. The loads of longitudinal and transverse ties after conversion in cargo tanks and on the re-built flat bulkhead of the second side in the ballast compartment have been determined [8 p.89], [11 p.64-65], [12 p.223-224].

Based on the calculated values of bending moments and moments of resistance of the outer skin plating, the probability of critical loads is predicted, and their nature and ways of elimination are determined [14 p.13].

The welding process of the corner pieces of the second side with the flooring of the second bottom is considered and the modulus of the frequency of the shrinkage stress on the vertical sheet is revealed (Fig. 12, Fig. 13. (3)) [14 p.14].

Based on the analysis of the welding joint and taking into account the thermo physical properties of the metal, criteria are found that stabilize the growth of deformation changes in the installed and newly installed structure.

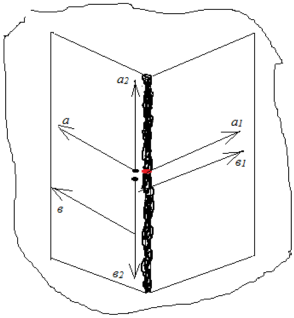


Fig. 12. Forces acting from hot (a, a_1, a_2) and cold (b, b_1, b_2) loops

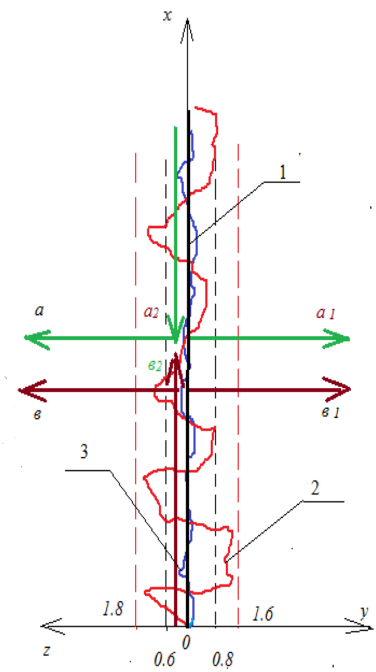


Fig. 13. Forces acting on the welding joint in three planes: x, y, z. 1 – welding joint; 2 - maximum value of shrinkage and modulus of shrinkage stress 1.6-1.8 mm; 3 - allowable shrinkage values 0.6-0.8 mm

The danger of stress in the bottom and side plates at wave resistance from cyclic tension and compression of the metal has been identified and preventive methods have been developed [11 p.64], [12 p.224].

Obtained results of the analysis showed that:

1) re-installed elements of the ship's hull structure during operation should not create stresses and deformations (Fig. 14, Fig. 15);

2) when assembling the hull structure, it is necessary to comply with all standards for permissible mounting clearances;

3) the method of calculating the maximum bending moment of the hull structure was applied, depending on the action of the load forces on the bottom plates;

4) the proposed method allows to carry out the process of conversion of the ship in a short time and with minimal costs.

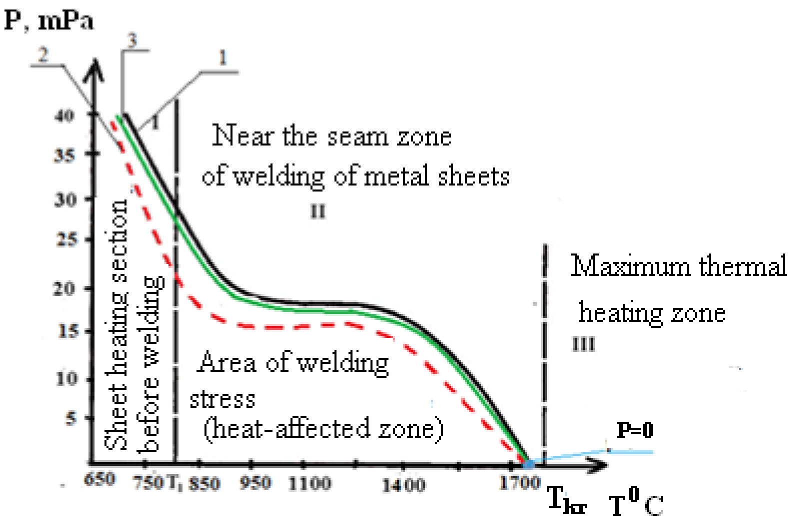


Fig. 14. Dependence of shrinkage on stress arising during welding: 1- theoretical welding joint; 2 - change in the trajectory of the weld after shrinkage; 3 - minimum values of shrinkage after applying improved welding technology

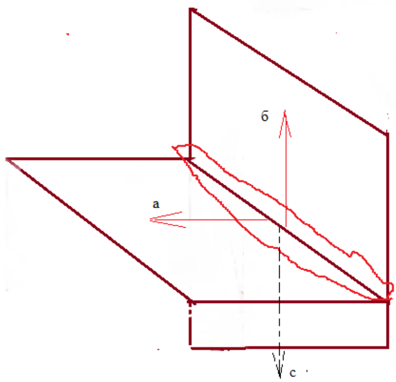


Fig. 15. Transverse shrinkage stresses appearing in the welding joint.

It was determined that non-shrinkage welds (Fig. 15) are obtained in welding structural elements of the double bottom and second side flooring, the concentration of static stresses in the weld affected zone and in the base of metal sheet decreases, the strength characteristics of the hull structure increase and bending and arching decrease.

The obtained results can be applied: for the repair of the ship's hull with a double bottom and second sides, as well as for the construction of new ships with a double side [12 p.224]. The developed technology can be used for all types of repairs of ships, oil platforms, docks and other ship structures [6 p. 36 -37, p.66, p. 72-74, p.82-84].

MAIN CONCLUSIONS

Based on the scientific and practical results obtained in the dissertation, there have been made the following main conclusions and recommendations:

1. A technology has been worked out and methods have been proposed for the construction of a double bottom and a second side

when converting oil tankers afloat, providing strength characteristics with economic indicators and quality of the construction hull struktur.

2. An operational method has been developed and applied for modeling of welding processes when welding new elements to structures during semi-automatic and manual welding, which allows to reduce residual deformations, shrinkage and the occurrence of synchronous vibrations.

3. There has been developed a project for the installation of a flatly inclined longitudinal bulkhead of the second side, providing the minimum support and bending moments of the shipside plates.

4. A method has been developed for modeling of technological processes of assembly and welding by block construction and panel methods during major overhaul and reconstruction of a ship.

5. There has been used a shipbuilding material, which allows to obtain much higher bending moment than other profiles applied in shipbuilding and excludes the occurrence of wave-induced vibration.

6. The nature of stresses arising at the site and re-installed hull structure of the tanker before and after the conversion has been determined, and recommendations have been given on the avoidance of their occurrence.

7. Recommendations on the installation of sloping plates on the re-installed second side have been elaborated and the angle of the lower sloping plate around the bilge has been determined when they are exposed to power loads.

8. There have been found the fixing points of the strength elements of the hull allowing to obtain the maximum moment of resistance from the stiffening ribs of the flooring of the double bottom and second side.

The main conclusions published in the following works:

1. Баширов Р. Д., Рзаева А. Г. Технология сварки новых листов наружной обшивки к построечным // Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, - Баку: -2013, № 1, - с.7-10

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