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RELIABILITY AND OPTIMIZATION PROBLEMS OF SHIP HULLS ICE STRENGTHENINGS

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ABSTRACT

The working conditions of transport and fishing ships in ices are diverse and they are investigated insufficiently. It creates great difficulties in solution the reliability and optimization problems in the process of design. Sometimes the ice damages are the main reason for making repairs. The operation experience of the ships with ice damages is broad in Russia. This experience and ultimate strength researches show the ability of the ships to sustain more exceeding loads than the designed ones. This paper deals with corrosion wear peculiarities in ice conditions. They are included into optimization calculations. The results of weight optimization include forecasting of corrosion and residual deformations. The durability forecasting of the plating and framing include many calculations. These are the calculations of ultimate strength, plastic deformations, and corrosion wear. The various cases of damage for beams are considered. They include a bend, shift, and deviation of a web from an initial plane and their combinations. The possibility of strengthening ice metal weight decrease is shown on an example of tankers "Samotlor".

1. INTRODUCTION

Operation problems of ships in ice are very urgent for Far East of Russia. Large transport, fishing fleets and military navy works here. The development of rich deposits of Sahalin Island has begun. The questions of ships hulls reliability at action ice loads were and remain priority for the scientists of Far East State Technical University.

The researches began more than 50 years ago under prof. N.Barabanov and proceed now. The researches have complex character and include operation conditions, loads, damages, corrosion wear, durability of plates and beams, experience of designing and modernization. Now these researches have development in optimization of ice strengthenings in the process of design and reliability control during the operation.

The basic circuit of estimation reliability is shown on fig. 1. Casual character loads and durability are taken into account here. The durability is function of time and it decreases because of wear. Loads can also change, if operation conditions to limit. It allows to take reliability (or probability of damages) as function of time with estimation of ship is economic parameters.

2. ANALYSIS OF OPERATION CONDITIONS

To study operation experience of ships in ice is very important. The generalization for tankers "Samotlor" /1/ (length b.p. - 148 m, ice strengthening category - УЛ, displacement - 25000 t, built in Finland - 1972-78 year) was the most complete. Is established, that many damages (50%) was concern when transport ships are close towing by ice-breaker, fig.2. This mode is unsufficiently taken into calculation at designing ice strengthenings. Thickness and concentration of ice at the moment of damage are shown on fig. 3. The moor is dangerous when ice breaks between hulls of ships.

3. DEFORMATION DAMAGES

Integration about deformation damages and replacements of structures at repairs of different ships was made. The analysis has shown significant differences of reliability levels, which allowed at designing. It's illustrated on fig. 4. More than 50 times were replaced in repairs 12 tankers "Samotlor". Their hulls had dents which are not allowed by the Russian Register.

The damages of bow part of cargo ships are more often. Fishery ships usually work in broken ice and damages are distributed almost to over the whole length of the hull, fig.5. It has confirmed specificity of their work in ice and danger of moor in ice. Moors ships in ice until no taken into account at designing even in Russia.

Arrangement of beams not perpendicularly to the plating is rendering the adverse influence on durability, fig.6. When deflections of dents $f < 30$ mm are not find tripping of beams $d=0$. However, with rise of deflections the falls quickly increase up to $d=100-200$mm.

4. CORROSION WEARS

Researches of corrosion covered ships with different sizes and categories. It both smallest fishing seiners and largest ice-breakers for Arctic. In result is established /2,3/ dependence between of corrosion wear speeds and volumes of ice loads, fig.7. The check of this dependence was carried out by its comparisons to meanings, which are received in result gauging of residual thickness and deflections of ships plating, fig.8. The loads was defined by recalculations of deflections sizes.

5. RESEARCH OF LOADS

Ice loads was research in natural experiments for different ships. The special attention was given to the work in broken ice, moor in ice, modes of maneuver, and also ice action to the hull under water. The example of ship equipment for tests in ice near Sahalin Island is shown on fig. 9.

For a mode moor in ice was received the theoretical solution of a problem to compression ice between hulls of ships. The solution has shown strong influence of moor angles to loads, fig.10.a. Here the problem of ships hulls contact through the ice was solved. Comparison of loads at moor and distribution of damages along the hull for different ships has shown good result, fig.10.b.

6. DESIGNING EXPERIENCE

Integration of designing experience of ice strengthening hulls has shown that frequently it not rational. On fig. 11 the distributions along the hull are shown: specification pressure of Russian Register, collapse pressures (yield of plastic hinges) for frame and shell plating. The figure concerns to a large icebreaking tag. Character of strength change to bow and stern is not coordinate with increasing of specification ice loads. Frequently the influence of form angles of hull was taken into account for loads and was not taken into account for durability. Large reserves of strength average part of the hull is excessive.

Similar picture, fig.12, concerns to tankers "Samotlor". Strength of frame is lowered from 135 fr to a bow. Specification loads is increase. Strength of plating is more then of frame and hull have a considerably increasing weight.

Frequently errors of designing are allowed at level of structure units, when designer want to reduce cost of construction. The examples of bad constructive decisions are shown on fig. 13. Such decisions promote formation of very large dents and require modernization at repairs.

7. STRENGTH OF SHELL PLATING

Many problems of ice strengthenings reliability are caused by lacks of designing models. It is very important to take into account not only elastic stage of work, but also the large plastic deformations. Was developed special methods for plates calculation. It takes into account a local action of load, large plastic deflections of plate and supporting frame, and also a non-uniform corrosion wear /4/.

The comparison of calculation method with different experiments (more than on 300 plates) has shown good coordination. On fig. 14 the comparison of decisions made with this method and method FEM /5/ for the problem of contact of deck plate with the wheel is shown. Method was used for estimation of ship's damages and for solution of designing problems.

8. STRENGTH OF BEAMS

Developed method for calculation ultimate strength of beams. It takes into account local action of load in span and at supports. Here uses idea of plastic hinges which known and also combined hinges, fig.15. Such hinges have allowed receiving more correct results for ultimate loads and show resistance effect of beams flange, (when a web have shearing plastic hinge). More complex schemes of beam destruction take into account opportunity fallen of a web (output from plane).

9. WEIGHT OPTIMIZATION

Points above methods were used for develop of weight minimization of ice strengthening constructions with takes into account operation period and corrosion wear. The calculations have shown, that beams with flange and without them (just the web the thickness and height of which is more) appear to be equally effective, fig.16.

10. RELIABILITY CONTROL

All researches and large experience have shown that ships hulls with high ice categories can be designed with using of reliability as step type function. High reliability (category) supporting for all operation period is very expensive for ship. In certain moments of operation, when wear increasing and strength decreasing, (fig.1) and repair expenses rise a category of ship can be lowered. It will have to reduce of damages probability, (fig.17), and opportunity to prolong of a ship operation time. On fig. 17 probabilities of damages (condition Q>R the symbol are accepted according to fig. 1) as functions of operation period. It was supposed, that ice conditions and loads correspond to the ice category of the ship.

Was developed economic model for calculation of such problems. Results of economic profit which calculations for a ship are shown on fig.18. The net profit is accepted as a difference between the incomes and expenses. Here the reduction of ice category (Л1-Л2-Л3-Russian classification) in the period of 10 and 20 years allows to gain more 70 % of net profit. It is possible to prolong ship operation time more than for 5 years. It was supposed that reduction of category is decreasing average annual incomes by to 15 %. The incomes do not reduce so considerably in reality.

11. CONCLUSION

Works described in the article is allowed to improve theory and practice of ships hulls ice strengthenings designing. The results are widely and successfully used for repairs and modernizations of ships in Far-Eastern region of Russia.

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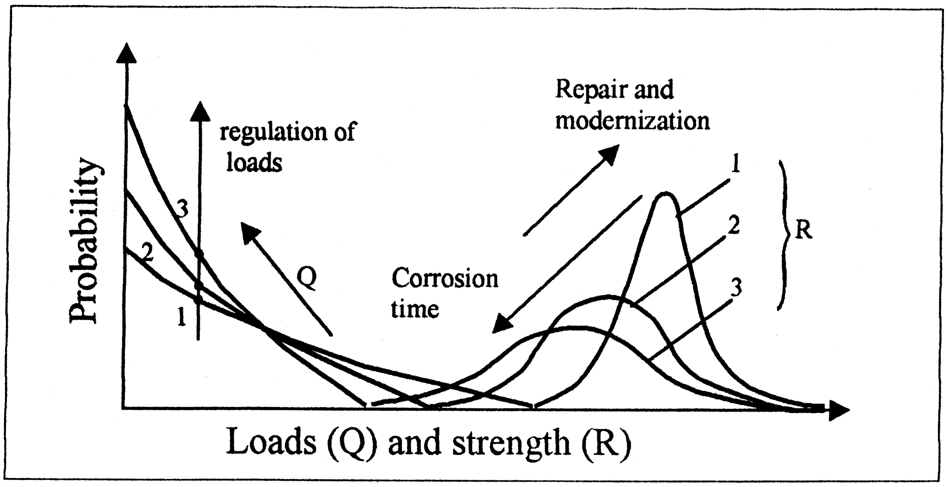

Figure 1. Loads and strength in operation.

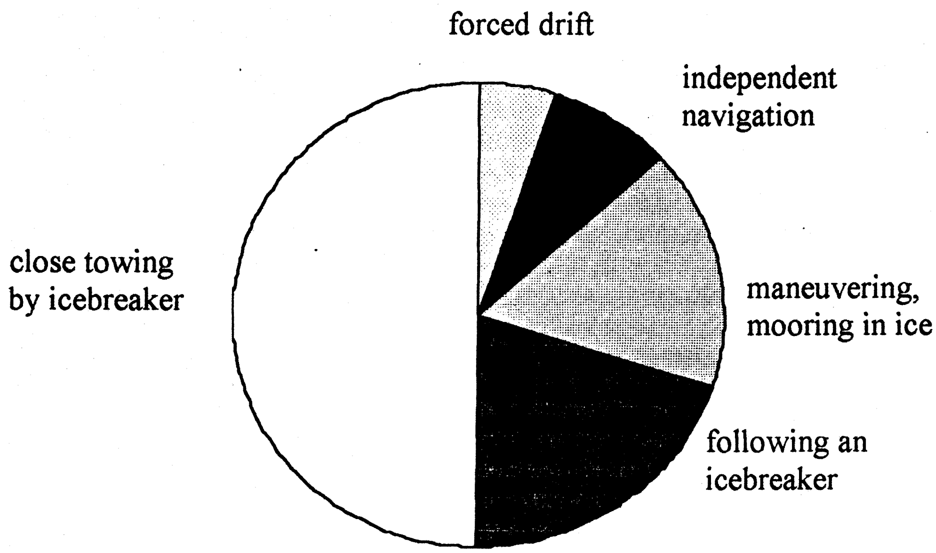

Figure 2. Damaging distribution of operational modes

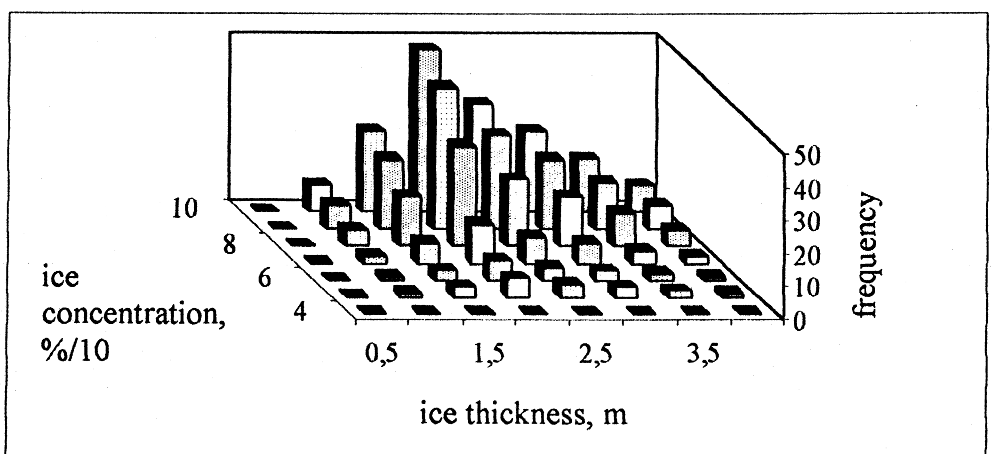

Figure 3. Damaging distribution of performance dates. for "Samotlor" type ships.

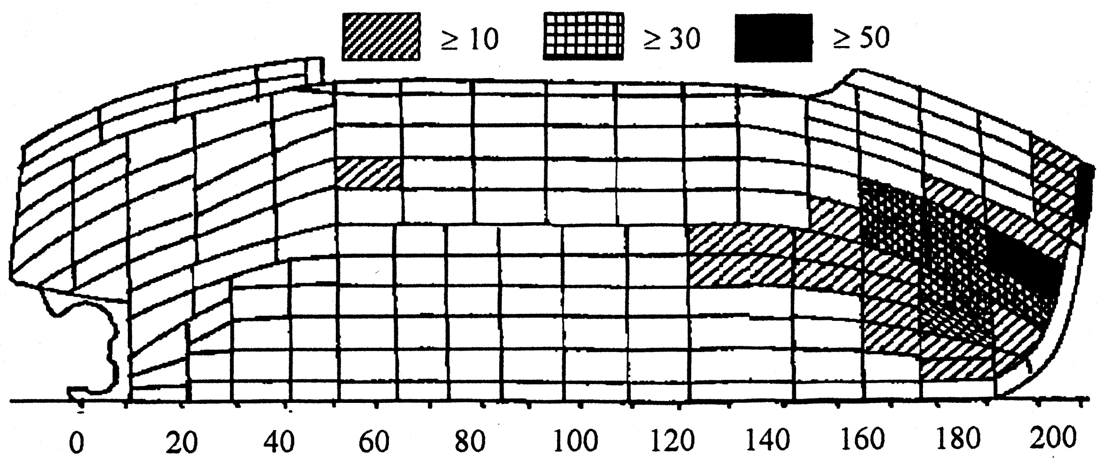

Figure 4. Quantity of damages (replacements) hulls of tankers as "Samotlor".

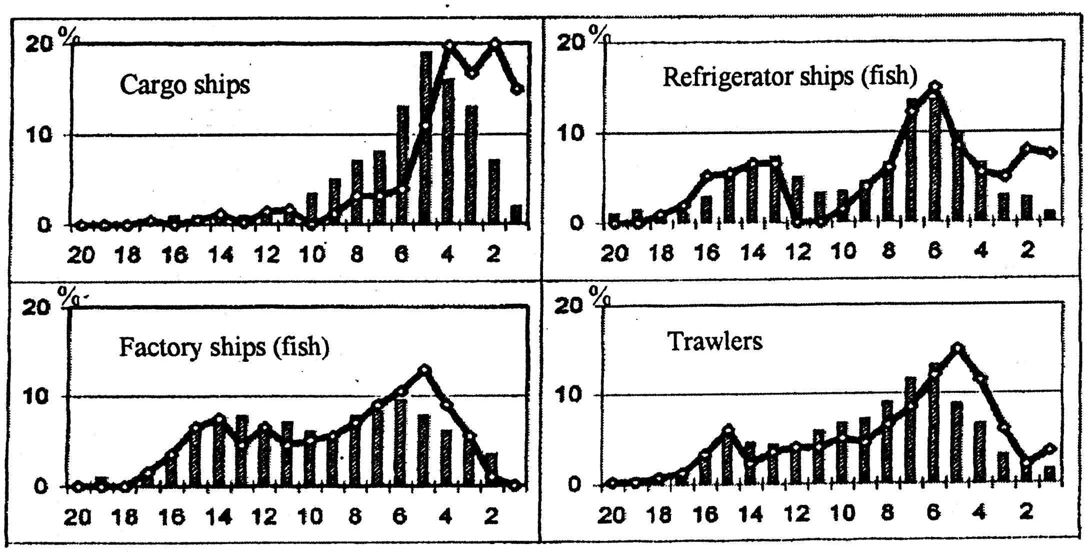

Figure 5. Damages distribution of shell (columns) and beams (curve) along the ships.

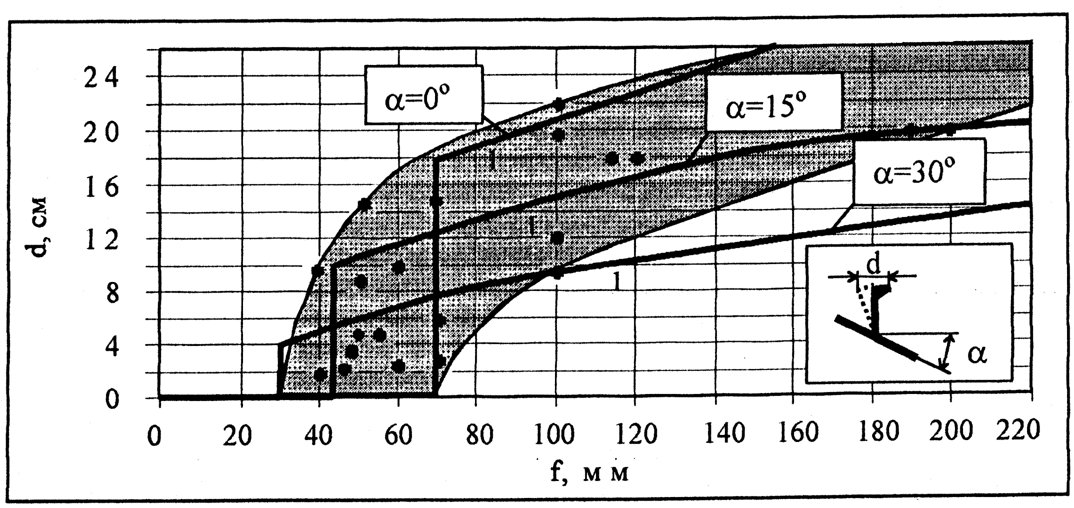

Figure 6. Deflections and tripping of beams (points – experience data, section HP 220-280, structural angles $\alpha=0\div28^{\circ}$; bow; lines – calculated dependence).

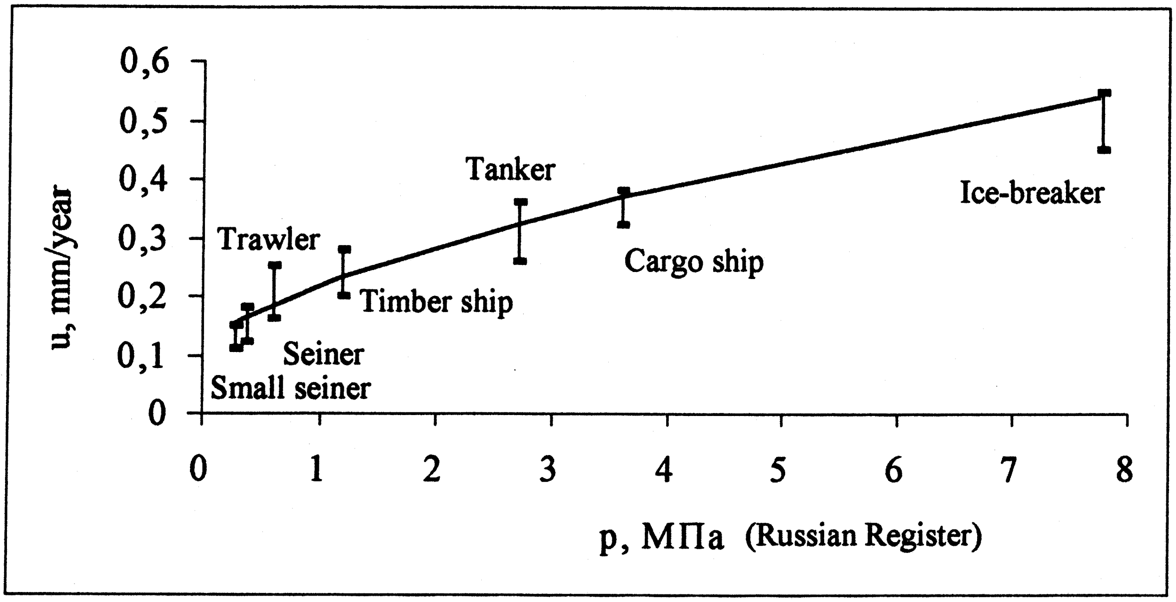

Figure 7. Dependence between of actual corrosion wear speeds and specification ice pressures.

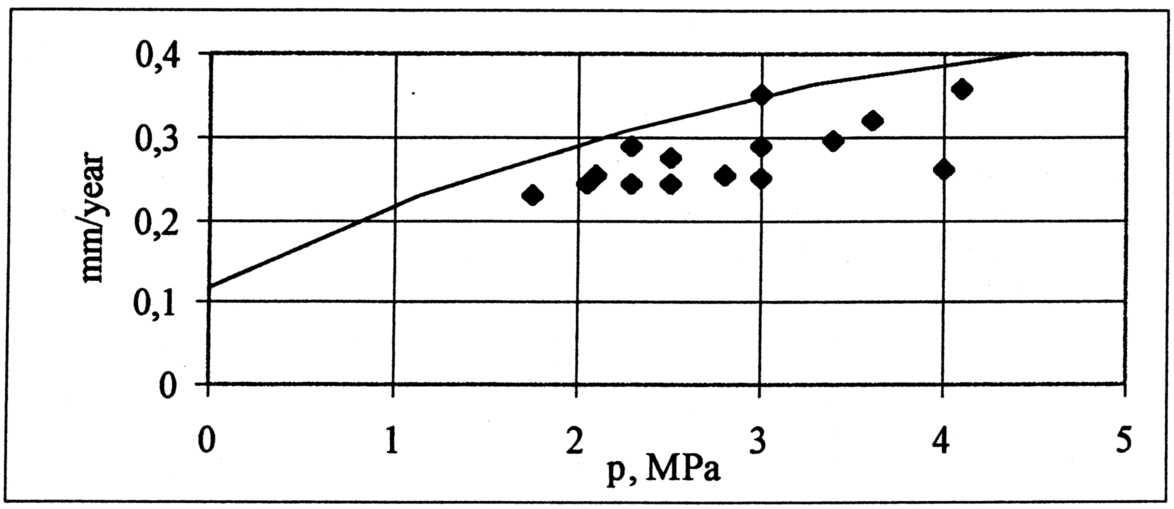

Figure 8. Comparison of calculations and empirical data for "Samotlor" type ships.

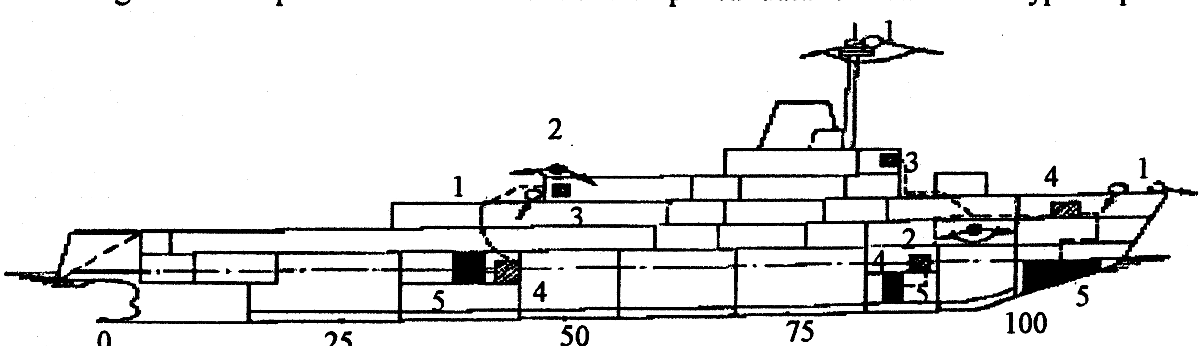

Figure 9. The example of ship (fishing (hunt)-boat, length b.p.-65 m, ice category–УЛ) equipment for tests in solid and broken ice near Sahalin Island in the February and March: 1–photo, 2–video, 3–operation center, 4–equipment, 5 - measurement places.

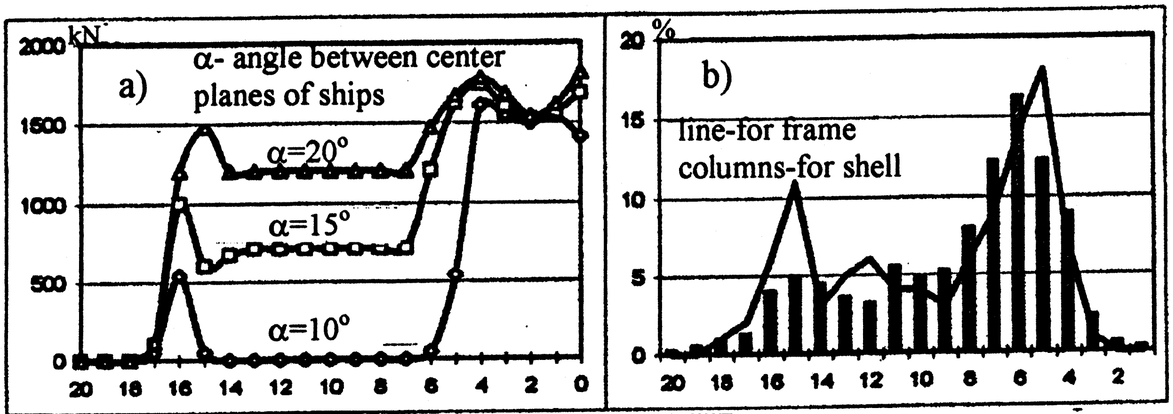

Figure 10. Calculate loads at mooring in ice (a) and typical distribution of damages (b) along the fishery ship hull.

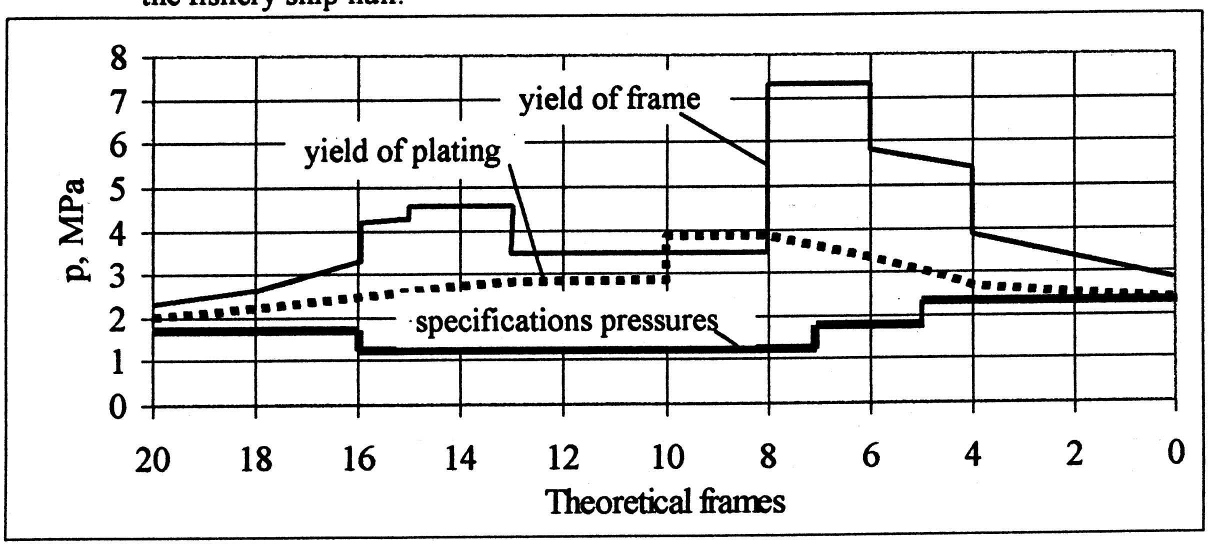

Figure 11. Specifications (Russian Register) ice pressures and start yield of constructions along the hull (tag, ice category - УЛ, length b.p.-64 m).

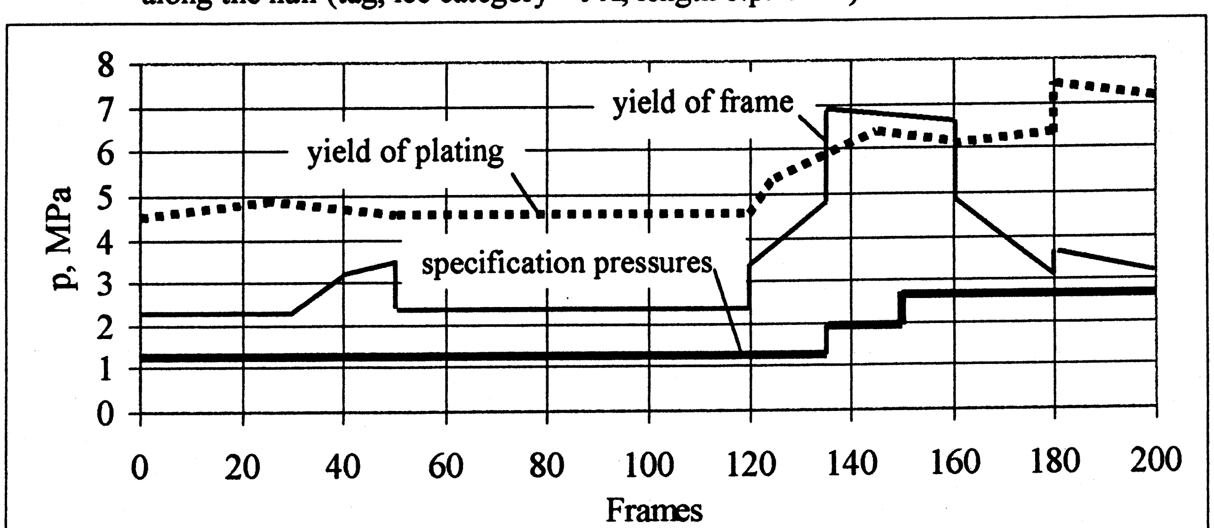

Figure 12. Specifications (Russian Register) ice pressures and yield of constructions (collapse pressures) along the hull "Samotlor" type tanker.

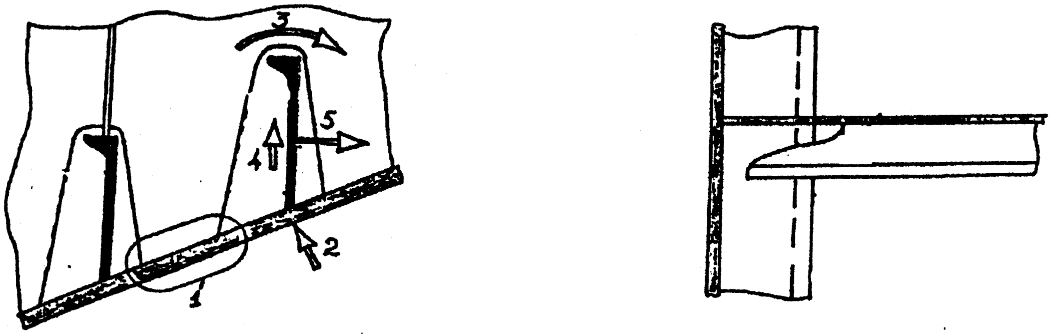

Figure 13. Bad constructive decisions for ice strengthening.

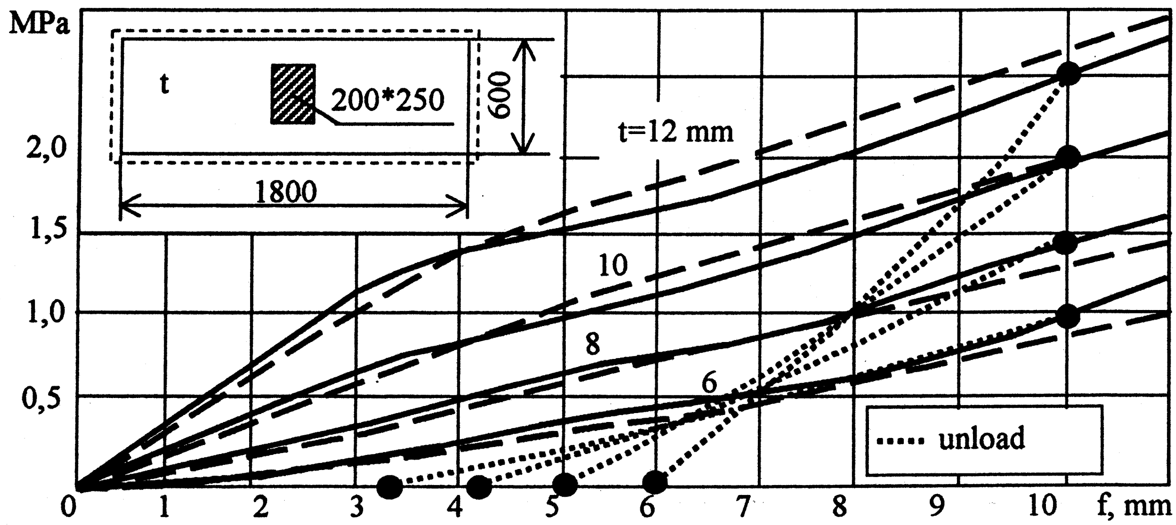

Figure 14. The comparison of calculation by special method (——) with calculation by FEM (— — —).

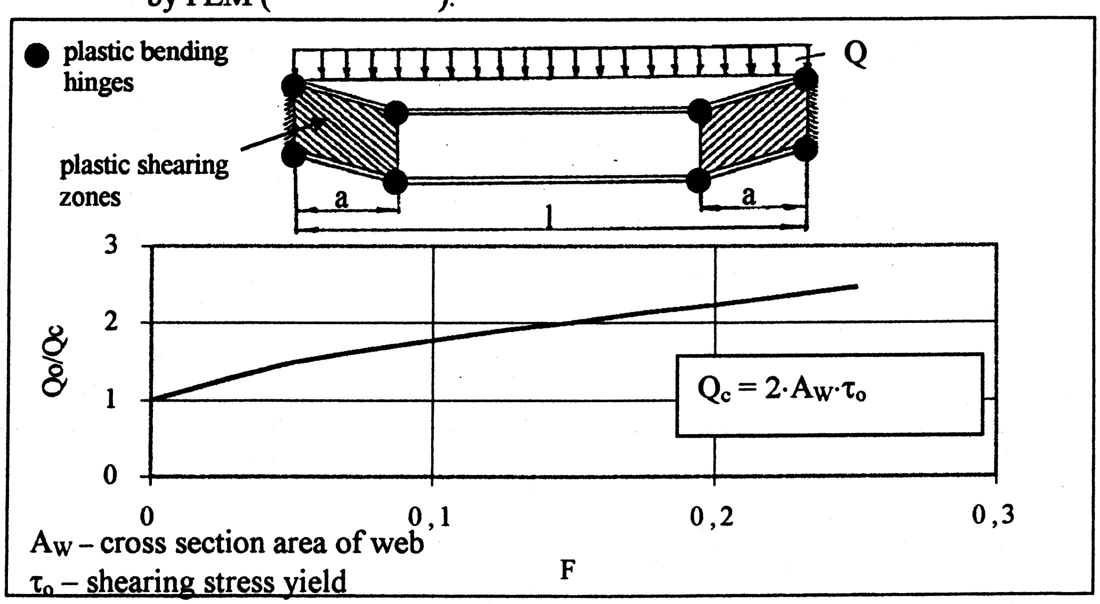

Figure 15. Ultimate shearing strength of beams when parameter of flanges sizes (F) increasing.

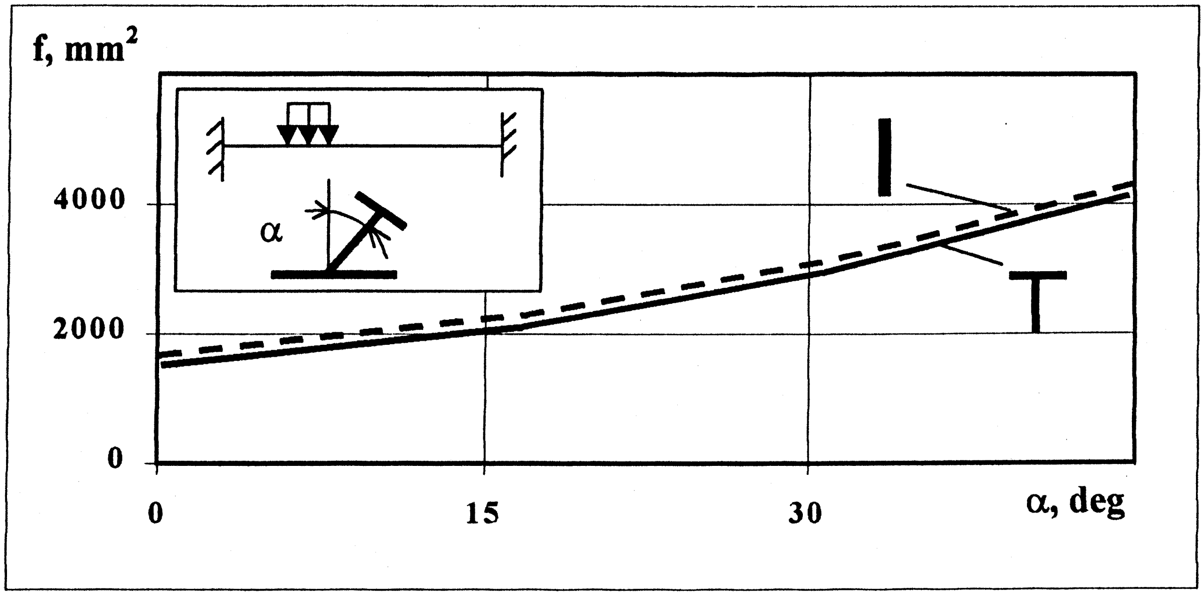

Figure 16. Comparison of beams cross section area, which have equal strength.

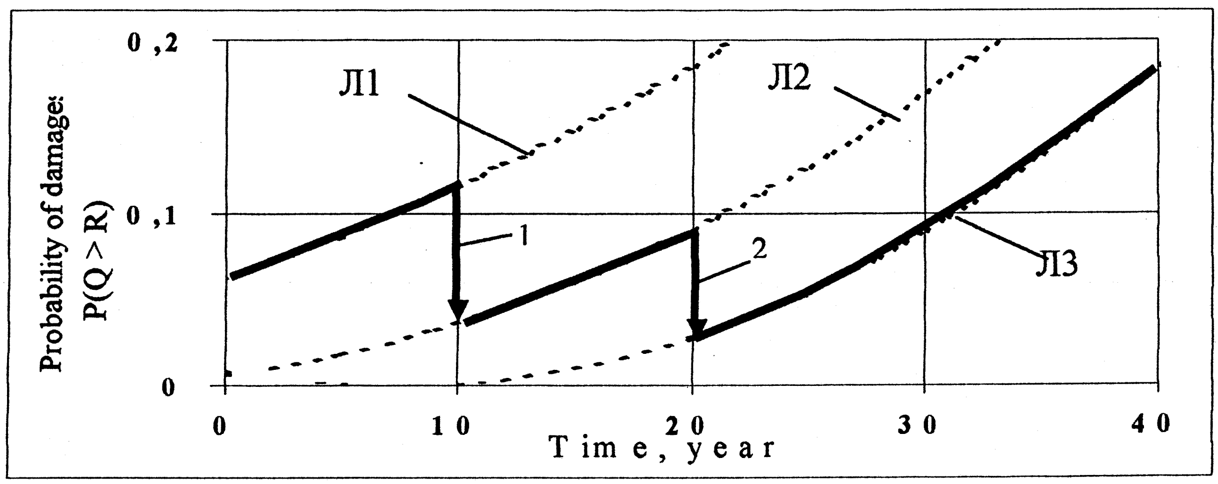

Figure 17. Changing of reliability about the time, when used the operation limits (1,2).
Л1, Л2, Л3 - Russian Register ice strengthening category.

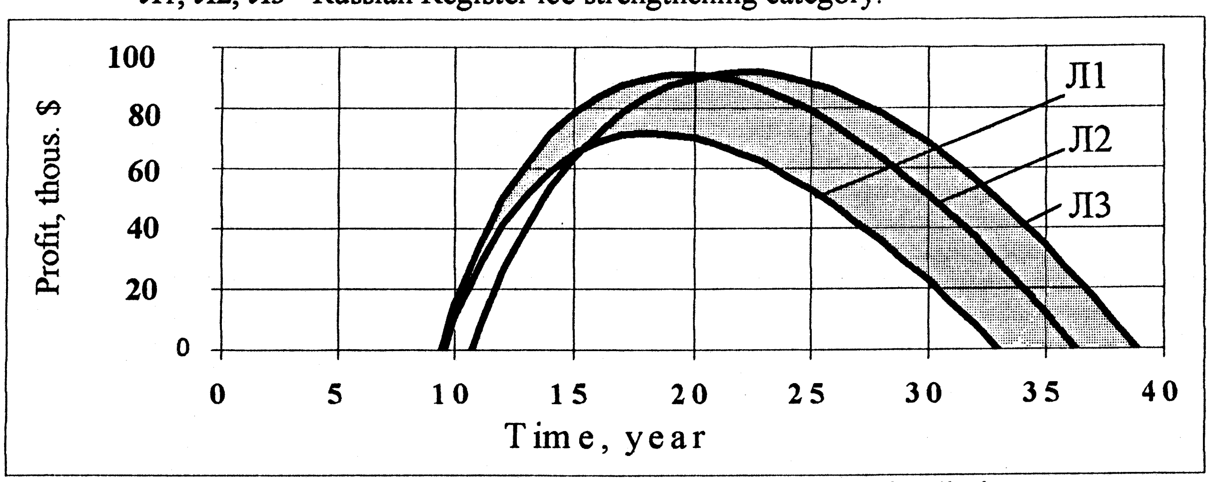

Figure 18. Distribution the profit about the time when used the operation limits.