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Visualization of CAE-Solutions of Ice Navigation Partial Problems. Joint Maneuvering of Vessels

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Abstract

The article notes that ensuring efficiency and safety of ice transport operations on the water transport is distinguished by a wide range of necessary actions, maneuvers, modes and dynamic working methods of the vessels. The assessment of vessel ice performance in special operating conditions is of current interest.

Using CAE technologies the range of actual tasks of vessel movement and joint maneuvering in different ice and navigational conditions is considered: the prediction of forming speed and qualitative condition of the ice channel in thick and limit compact ices due to different tactical working methods of several icebreakers; the efficiency and safety of the slow-moving transport vessel icebreaking assistance in compact ices.

Due to the result analysis of multiple CAE modeling recommendations for the operation of the studied icebreaker and cargo fleet of different ice categories are given. These recommendations concern the choice of safe maneuvering distances, vessel control laws, performance of standard operations.

Keywords: ice conditions, ice channel, icebreaker, ice-class vessel, CAE-system, finite element modeling.

1.Introduction

This work continues the author publication series devoted to the use of visualization tools of modern CAE-systems while estimating vessel ice performances in special operating conditions [1,2].

The CAE-system (Computer Aided Engineering) is a computer technology modeling and visualizing space time development of the studied process. The basis of the CAE-system is the numerical system solver of the differential equations describing behavior of the previously sampled space area (environment, bodies). Except for the fulfilled numerical methods the convergence of the decision here is also provided using special «artificial» program procedures, algorithms and acceptances.

The essentially significant stage of CAE technologies is the post-processing implementing modeling results processing by means of scientific visualization. Post-processor tools are the three-dimensional graphics with a rich set of options for the model analysis (scaling, detailing, measurement tools, gradient fields of parameters, levels, isolines, traces, sections, cuts, vectors, transparency, etc.), animation and also the graphics processor creating different nodal and element space time functions with the possibility of their rendering.

All the complex of the sea and river ice technology problems belongs to the extensive class of problems of deformable environments mechanics. The scientific novelty of CAE technologies while considering the problems of mechanics consists in object interaction modeling unlike modeling of loads offered by the traditional semi-empirical and analytical methods. Theoretical bases of CAE modeling concerning interaction of the vessel hull and its propulsion and steering complex with the water ice environment in the LS-DYNA system [3] (types and models of the finite elements, material reaction features to loads, contact borders behavior algorithms, methods of structure geometry forming and finite element grids for them, initial and boundary conditions, ways of model resource intensity decrease) are given in the monograph [4].

Scientific and technical author activity is connected with the assessment of ice performances of the internal and mixed (river and sea) vessels mostly belonging to non-arctic categories due to the ice criteria of classification societies. Safety and efficiency of such fleet ice operation can be guaranteed only in the conditions of ice cakes and small ice cakes. At present forming of such ice environment and safety of ice navigation are ensured by the icebreakers with multishaft propulsions and steering complexes (the projects 1191 and 1105 «Captain Evdokimov» and «Captain Chechkin» respectively). Ice channels forming for transport fleet traffic, caravan support, icebreaking assistance provided to single vessels, auxiliary operations are generally connected with ice joint maneuvering of several vessels. Analytical methods of quantitative effect forecast of such maneuvers have not yet developed. Therefore, due to the absence of representative natural or empirical information ice experts are forced to use virtual modeling of ice joint maneuvering processes.

2. Ice channel forming

Icebreaker collaboration is recognized to be effective in thick, limit and especially in compact ices due to icebreaking capability of icebreakers [5, 6]. The kinds of joint channel forming by means of two icebreakers are aimed at accelerated creation of significantly widened ice channel, but at the same time sufficient enough for safe transport fleet passage due to the broken ice fragmentation degree criterion.

The prevailing part of the domestic inland and mixed navigation cargo fleet has admissible permission of classification societies to navigate only in ice cakes and small ice cakes of no more than 0,5 m thick. Due to this the above mentioned way of ice channel forming is connected with the probable movement of icebreakers at small beam distances. This creates a problem of justification of these distances from the positions of icebreakers joint maneuvering safety. At the same time it should be noted that even a single working icebreaker of project 1191 forming the channel in thick ices does not differ in satisfactory route stability with the parameters being very sensitive to the chosen vessel control law.

As numerical experiments show, channel forming in thick and limit compact ices with parallel operation of icebreakers at beam distances over 40 - 45 m does not give desirable effect. At the same time there is no advantage neither in the speed of channel forming, nor in its qualitative state (Fig. 1, 2).

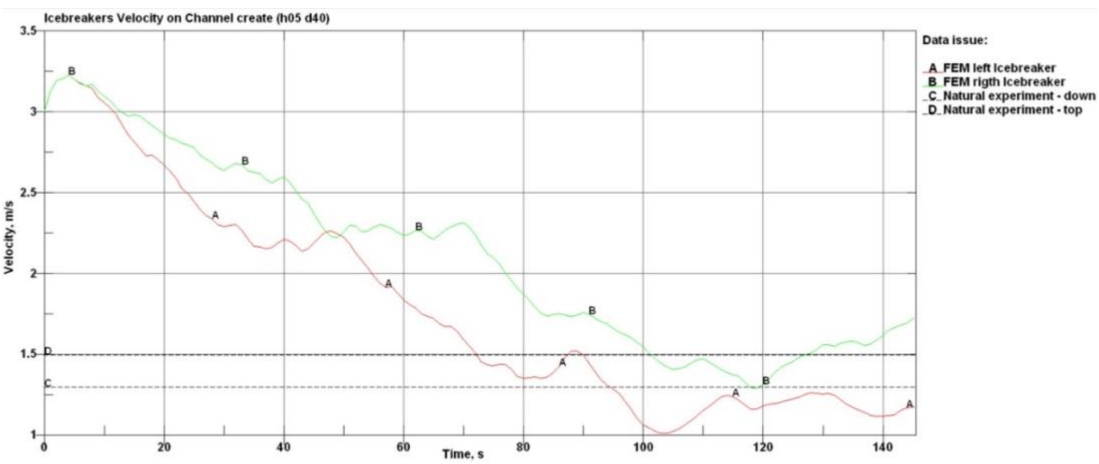


Fig. 1. Propulsion ability of icebreakers of the project 1191 at their parallel operation on channel forming in compact ices 0,5 m thick at initial beam distance of 40 m

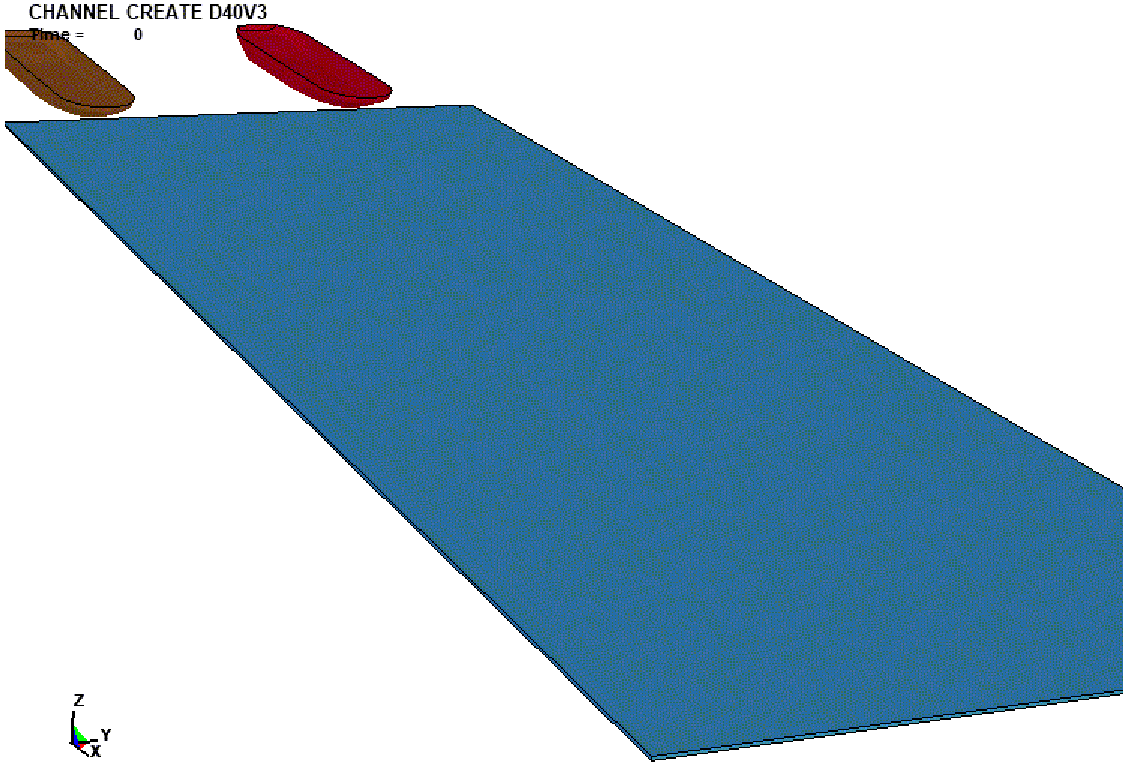


Fig. 2. A qualitative condition of the channel during parallel operation of two icebreakers of the project 1191 in compact ices 0,5 m thick at initial beam distance of 40 m

Data presented Fig. 1 show that motion speeds of the icebreakers at the beginning of the period concerning the established movement (line A and B approximately in 1,5 min. from the beginning of calculation) are close to propulsion ability of these vessels during the autonomous work due to the data of the full-scale tests (C and D line). In addition the formed ice channel due to the degree of ice fragmentation is unsuitable for the operation of the studied transport fleet with the low level of ice categories. To ensure the required ice cake crushing the additional passage of the icebreaker is necessary (Fig. 2).

The decrease of beam distance between the icebreakers up to 20-25 m with the attempts of their retention within the route lanes is fraught with repeated «slow impacts» of the vessels that is hardly acceptable from the positions of their safety. At the minimal initial distances of parallel operation (less than 15-20 m) the icebreakers quickly get opposite set and drift and then continue the movement «board to board». At the same time the acceptable qualitative condition of the channel suitable for the passage of transport vessels is obtained due to the width and the degree of ice fragmentation (Fig. 3). And the speed of forming (lines A and B, Fig. 4) increases more than 1,5 times in comparison with the autonomous work of the single icebreaker (horizontal dotted lines of C and D, Fig. 4).

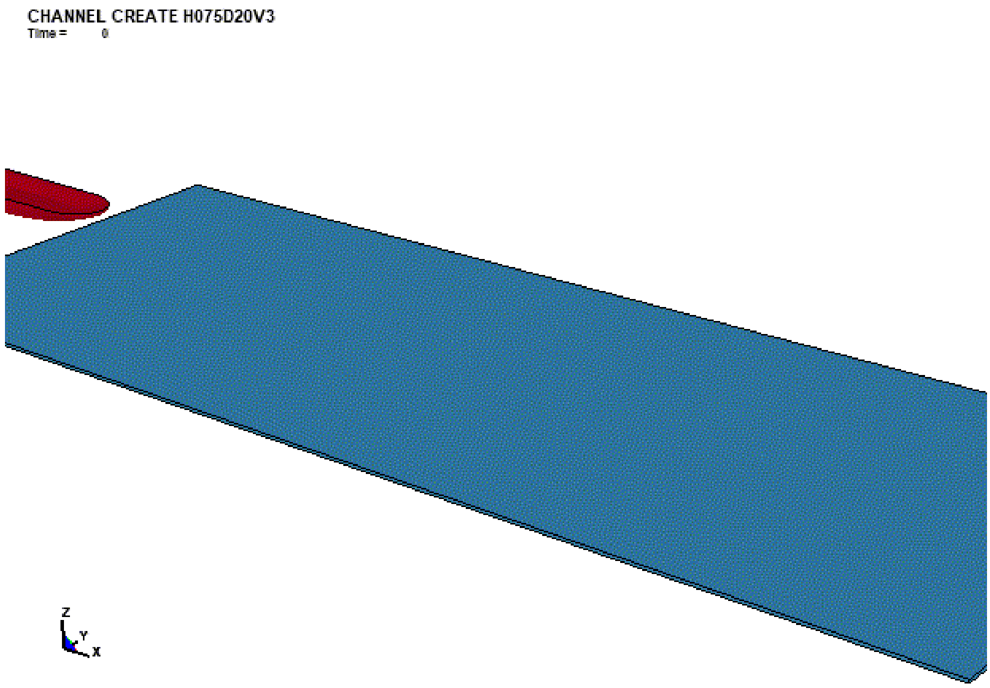
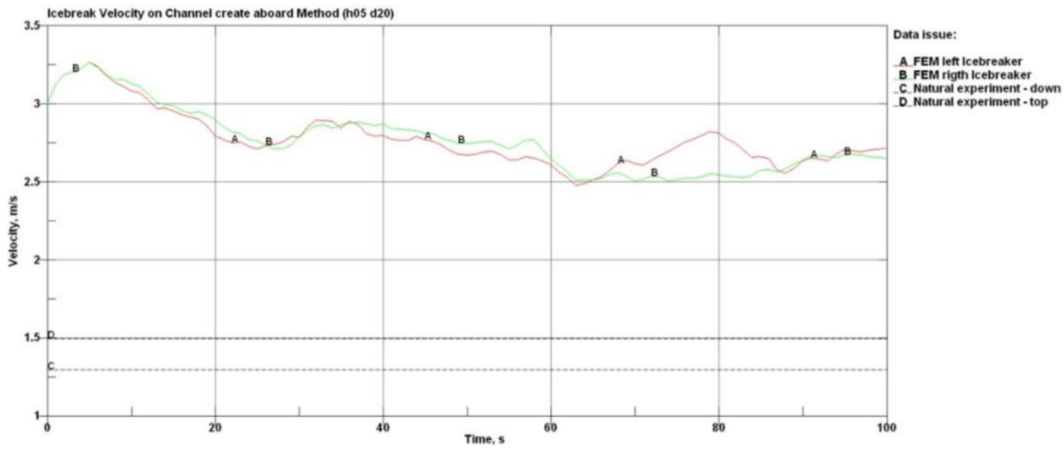
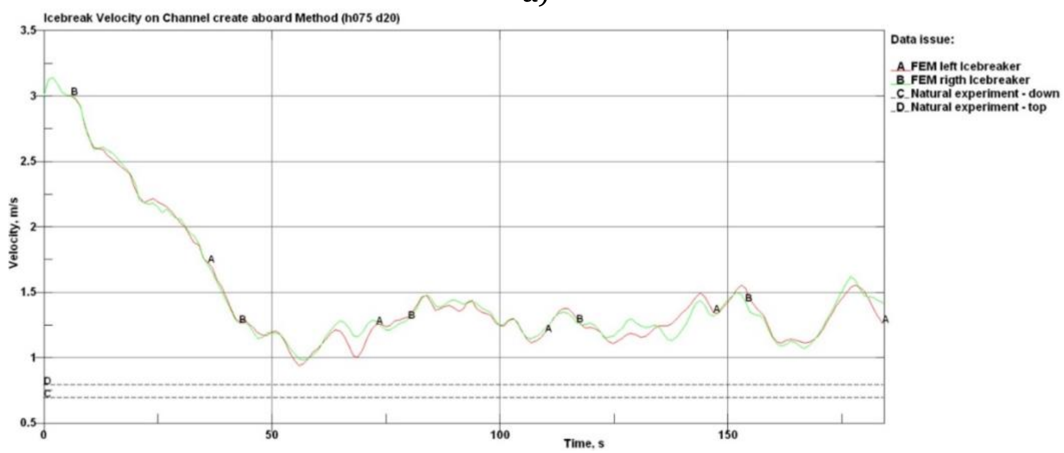


Fig. 3. A mutual «slow impact» of icebreakers at their parallel operation in compact ices 0,75 m thick at initial beam distance of 20 m



a)



b)

Fig. 4. Propulsion ability of the icebreakers of the project 1191 during channel forming in compact ices in «board to board» way
(a – ice thickness of 0,5 m; b – ice thickness of 0,75 m)

It should be noted that in ice practice only closed wakes of icebreakers are approved, widely applied and described in literature («tandem» and in three hulls) [5-11]. Theoretical attractiveness of the method «board to board» requires, at least, debatable discussion among ice experts and, first of all, with the participation of experienced captains of icebreakers.

Among all the variants of channel forming the «ledge» method has established itself as a safe one due to the satisfactory parameters of the obtained ice track (Fig. 5). But the forming speed even at the minimum distances with partial assistance of the slave vessel is limited by the ice propulsion ability of the leading icebreaker (line B, Fig. 6), which in this case is not practically improved in comparison with the autonomous mode of work (C and D lines, Fig. 6).

Fig. 5. Joint channel forming by the icebreakers of the project by 1191 using «ledge» method in compact ices 0,5 m thick

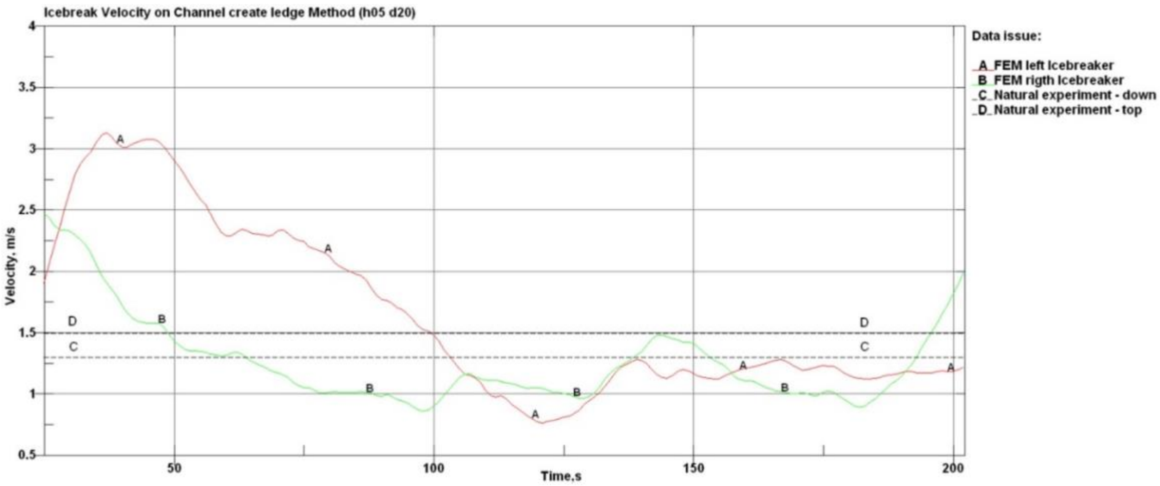


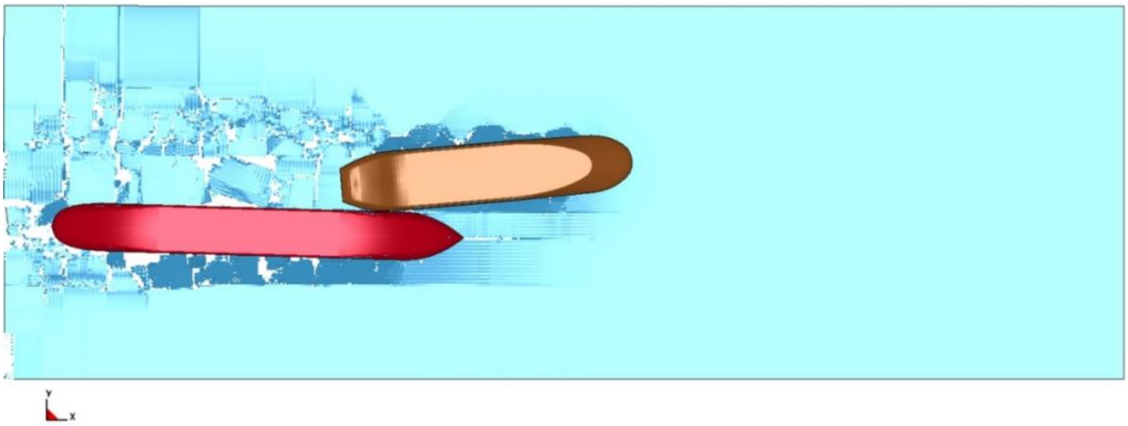
Fig. 6. Propulsion ability of the icebreakers of the project 1191 during channel forming using «ledge» method in compact ices 0,5 m thick

3. Icebreaking assistance

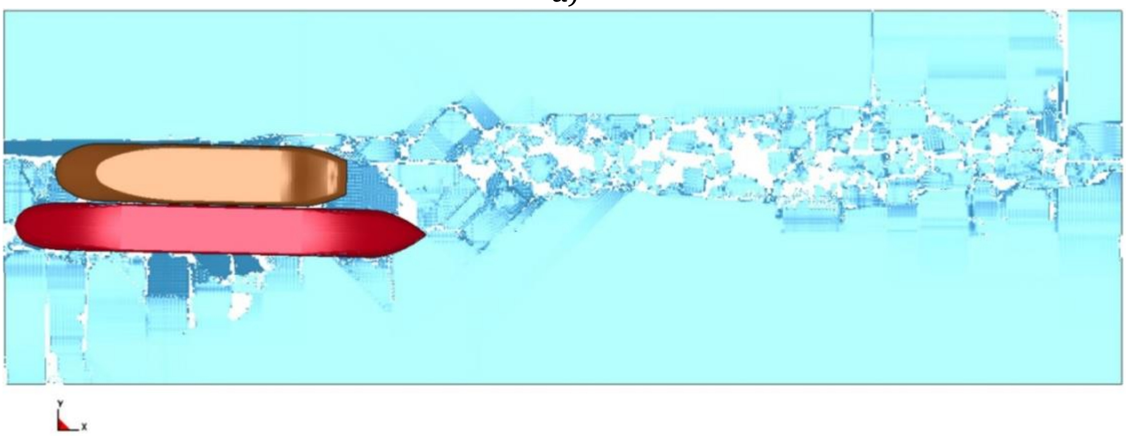
The widespread type of icebreaking services during ice transport operations is cargo fleet cobbing. Assistance to the motionless motor vessels steadily compressed by ice (for the period from several tens hours to several days) requires icebreaking of the increased complexity. It is caused by the necessity of icebreaker maneuvering in close vicinity to the «captivated» vessels.

However the icebreaker maneuvering while cobbing is of considerable danger to the slow-moving transport vessel going at minimal possible speed (less than 0,5 m/s) due to icebreaking capability level in limit compact ices. At the same time the ice in close vicinity to the vessel is in stress-strained state that can provoke icebreaker «slow impact» to the vessel.

As the numerical experiment shows, ice cobbing efficiency increase in such conditions requires icebreaker passing at a minimal distance from the transport vessel (no more than 10 m). But in such a case in the majority of rated options in any icebreaker control modes («with pullout», «without pullout») collision of the vessels is prognosticated (Fig. 7). Therefore, for the purpose of safety provision it is necessary to avoid icebreaker steering wheel changes, having set it to «ahead» position when passing along the board of the transport vessel. In addition, on the counter directions (Fig. 7b) it is necessary to decrease icebreaker speed to the level of the lowest speed (1,2 - 1,5 m/s).



a)



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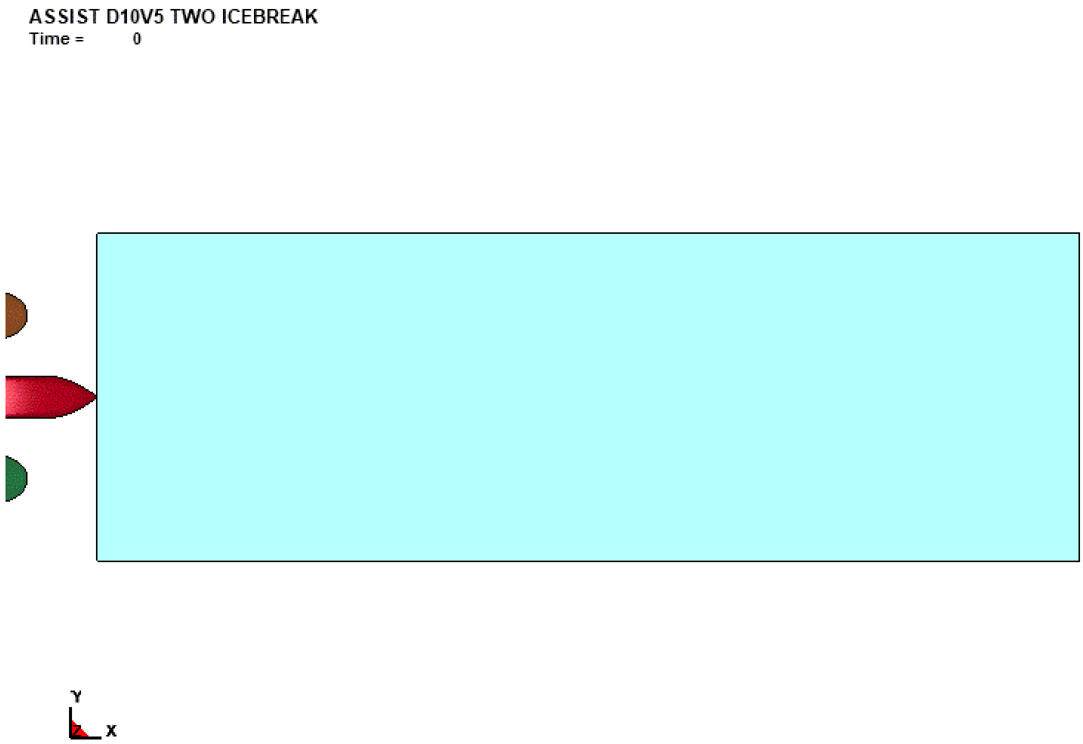

c)

Fig. 7. Collision of the icebreaker with the slow-moving vessel at its cobbing in compact ices 0,5 m thick
(a – passing cobbing by one icebreaker at initial beam distance of 10 m; b – counter cobbing by one icebreaker at initial beam distance of 5 m; c - passing cobbing by two icebreakers at initial beam distance of 10 m)

It is obvious that the level of the effectiveness of the cargo vessel cobbing is to be determined by the mode of speed recovery on the set route lane. For the studied transport fleet this lane as the effective movement environment allows the ice cake and small ice cake of no more than 0,5 m thick. Not any work of the icebreakers while cobbing only for one passage can lead to such condition of ice in the target direction (Fig. 8).

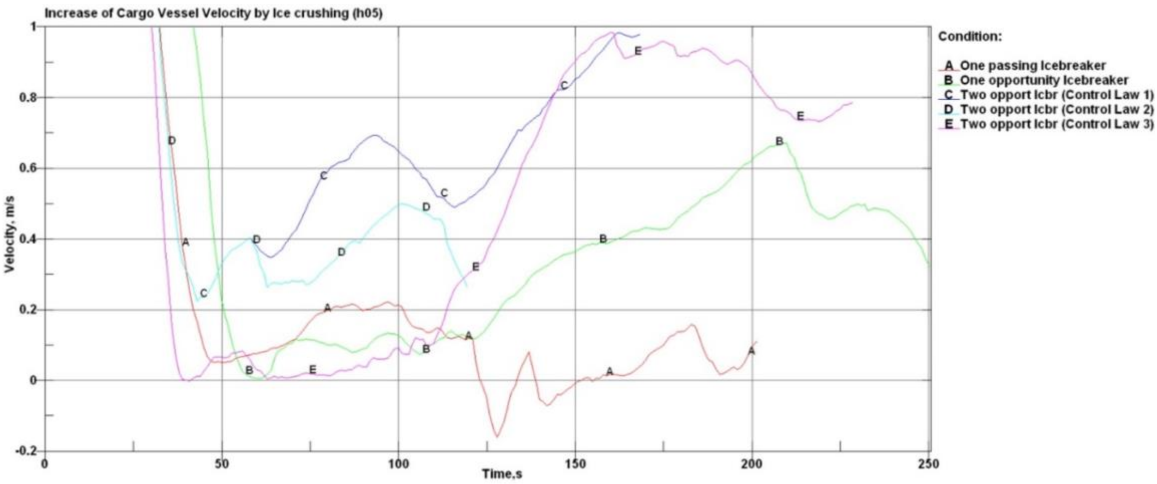

Fig. 8. Speed recovery of the transport vessel at the different modes of cobbing by the icebreakers project 1191 in compact ices 0,5 m thick

The analysis of the dependences given on Fig. 8 shows that joint cobbing of the transport vessel by the icebreakers from both sides, as a rule, contributes to the faster independent (without towage) release and speed recovery (not less than 0,5 m/s, C and E lines, Fig. 8). It is not always achieved by a single icebreaker passage from any side of the transport vessel (lines A and B, Fig. 8).

4. Conclusion

1. The demand for the numerical forecast of the effects of ice joint maneuvering at small distances is caused by the lack of analytical techniques concerning the description of the dynamics of these processes progress.
2. The icebreaker of the project 1191 has unsatisfactory route stability in thick compact ices.
3. Safe operation during joint channel forming by the icebreakers of the project 1191 is ensured by the «ledge» method due to the satisfactory parameters of the ice track formed.
4. Method «board to board» used by two icebreakers of the project 1191 showed theoretical efficiency during ice channel forming in thick and limit ices.
5. The greatest efficiency and sufficient safety of slow-moving transport vessel cobbing in thick compact ices are ensured by simultaneous work of two icebreakers from both sides of the transport vessel at the minimum beam distance (up to 10 m) while passing movement.

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