УДК 629.5

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CONCEPT OF ARTIC CLASS SEA FERRY FOR SAKHALIN REGION

A new generation of railway-car-passenger ferry for the line Vanino-Kholmsk was developed by Marine Engineering Bureau.

In comparison with existing ferries the new Marine Engineering Bureau project provides improve cargo capacity, operation without weather restrictions and at hard ice conditions, can effect independent mooring operations (several times a day) without tug assistance, astern movement through constrained port of Kholmsk. Service speed of 18 knots and 2 hours for loading operations in each of port allow makes round voyage per day. The new concept should carry up to 150 passengers; she can carry dangerous cargoes.

Ice-going capability of the new ferry on moving ahead in ice thickness 1.48 m at speed of 3 knots, 1.04 m at 6 knots and moving astern in ice thickness 0.85 m at speed of 1.5 knots. Forward part of the hull structure are designed on higher ice category (ARC 7). It allows to provide independent operation in heavy ice conditions of port Vanino.

Keyword: *car-passenger ferry, Sakhalin, CNF11CPD.*

Морским Инженерным Бюро был разработан новый автомобильно-железнодорожно-пассажирский паром нового поколения для линии Ванино-Холмск.

По сравнению с существующими паромами новый концепт Морского Инженерного Бюро обеспечивает повышенные грузовые свойства, не имеет ограничений по погоде, может работать в тяжелых ледовых условиях, в состоянии выполнять самостоятельные (несколько раз в сутки) швартовки без буксирного обеспечения, длительное движение задним ходом по стесненной акватории порта Холмск, выдерживает суточный цикл кругового рейса (скорость в эксплуатации 18 узлов) и 2-х часовую стоянку при выполнении погрузочно-разгрузочных работ. Новый концепт перевозит до 150 пассажиров; может перевозить опасные грузы.

Ледопроходимость нового парома на переднем ходу при скорости V = 3 узла составит 1,48 м, при скорости V = 6 узлов составит 1,04 м, на заднем ходу при скорости V = 1,5 узла составит 0,85 м. Кроме того, конструктивно носовая оконечность спроектирована по более высокой ледовой категории (Arc 7). Данная особенность позволяет работать парому самостоятельно в тяжелых ледовых условиях порта Ванино.

Ключевые слова*: автомобильно-пассажирский паром, Сахалин, CNF11CPD.*

Морським Інженерним Бюро був розроблений новий автомобільно-залізнично-пасажирський пором нового покоління для лінії Ванино-Холмськ.

У порівнянні з існуючими поромами новий концепт Морського Інженерного Бюро забезпечує підвищені вантажні властивості, не має обмежень по погоді, може працювати у важких льодових умовах, в стані виконувати самостійні (кілька раз на добу) швартування без буксирного забезпечення, тривалий рух заднім ходом по стиснутій акваторії порту Холмск, витримує добовий цикл кругового рейсу (швидкість в експлуатації 18 вузлів) і 2-х годинну стоянку при виконанні вантажно-розван-тажувальних робіт. Новий концепт перевозить до 150 пасажирів; може перевозити небезпечні вантажі.

Льодопрохідніть нового порома на передньому ходу при швидкості V = 3 вузла складе 1,48 м, при швидкості V = 6 вузлів складе 1,04 м, на задньому ходу при швидкості V = 1,5 вузла складе 0,85 м. Крім того, конструктивно носовий край спроектований по більш високій льодовій категорії (Arc 7). Дана особливість дозволяє працювати порому самостійно у важких льодових умовах порту Ванино.

***Ключові слова**: автомобільно-пасажирський пором, Сахалін, CNF11CPD.*

Problem statement. The ferry line «Vanino-Kholmsk» a sea railway passenger-and-freight 140 sea miles ferry line in Tatar strait which connects Sakhalin island with a continental part, providing more than 75 % of all freight traffic and about 25 % of passenger transportations. Normal functioning all branches of economy of Sakhalin and supply of its population depends on stability of this ferry communication.

Existing railway ferries «Sakhalin» type for a ferry line «Vanino-Kholmsk» design and built during the period from 1972 till 1992 on Russian Register class of 1st Restricted navigation area. In total 10 ferries had been built.

Now in operation only 4 ferries: «Sakhalin-7», «Sakhalin-8», «Sakhalin-9» and «Sakhalin-10».

Insufficient ice-going capability and reduction in operational parameters of existent «Sakhalin» type ferries in connection with physical deterioration of the hull and the ship equipment have led to that time of voyage has increased from 8 up to 14-18 hours.

The main feature of functioning of «Vanino-Kholmsk» ferry line is seasonal independent operation in heavy ice conditions – 3-4 months in a year on a short part of route (in area of port Vanino) there is heavy ice conditions. Significant idle times of the ferry waiting icebreaking assistance, or its high cost in case of individual assistance, lead to necessity of independent movement of the ferry in heavy ice conditions that imposes corresponding requirements on an ice class of a vessel. Besides existing vessels basically are

focused on transportation of railway cars (there is only one cargo deck), and today the basic freight traffic falls at road trains.

The aim of the paper is to describe and ground features of new generaton arctic ferry for Sakhalin island.

Main text. As shows the analysis of conditions of operation, during winter-spring navigation perspective ferry should move ahead with a speed about 6-8 knots in level ice of 0.80 m thickness and with a speed about 3 knots in level ice of 1.0 m thickness. Thus speed of ferry on a clean water should make not less than 18 knots. New ferries in the greater degree should have increased railway car capacity and passengers capacity taking into account rising demand on vehicles (cars, road trains, roll-trailers) transportations. Thus restrictions by port of Kholmsk conditions do not allow to increase essentially length and draught of a vessel. New ferries should operate with use of existing old ferry moorings terminals, and, any time, in parallel with existent ferries «Sakhalin» type, gradually them superseding. Hence, the method of loading and arrangements of railways cars on board (four railway tracks on width), width of the ferry, system of connection with the shore bridge remains as existent. Comparison of characteristics of existent ferries «Sakhalin» type (project 1809) with new Marine Engineering Bureau generation ferry CNF11CPD project are given in the table 1.

Table 1

Comparison of characteristics of existent ferries «Sakhalin» type (project 1809) with new generation ferry CNF11CPD project

Name of characteristics	«Sakhalin» project 1809	Project CNF11CPD
Length overall, m	127.30	131.00
Breadth overall, m	20.32	22.60
Breadth, m	19.80	22.20
Depth to MD, m	8.80	10.10
Depth to UD, m	14.70	16.15
Draught, m	6.00-6.60	6.00-7.00
ME power, kW	6x1910	4x4640
Speed, knots	16.0	18.0
Area of navigation by seaworthiness	Restricted R1	Non restricted
Ice-going capability	Not fixed	Not less than 3.0 knotsin level ice 1.0 m thickness and 6-8 knots in level ice 0.8 m thickness
Railway trucks length, m	420	440
Line meters,m	394	1036
Number of passengers (in cabin), pers.	82	100
Number of passengers (seats), pers.	38	50

Besides transportations of automobiles and trailers shippers have one more kind of a cargo potentially new for this ferry line: containers and roll-trailers with heavy technical equipment. Therefore on the new ferry at preservation of function of transportation of railway cars (extent of railway trucks length to 440 m from 420 m on existing ferry) increase in 2.6 times vehicle capacity (1036 line m from 394 m on existing). As result it is possible to place on the new ferry 48 trucks with semitrailers (road trains) 12-13.5 m in length and in addition 28 private cars.

General views of 3D model of new ferry CNF11CPD project are given on the fig. 1.

Fig. 1 General views of 3D model of new Marine Engineering Bureau ferry CNF11CPD project

General arrangement of new ferry CNF11CPD project on the fig. 2.

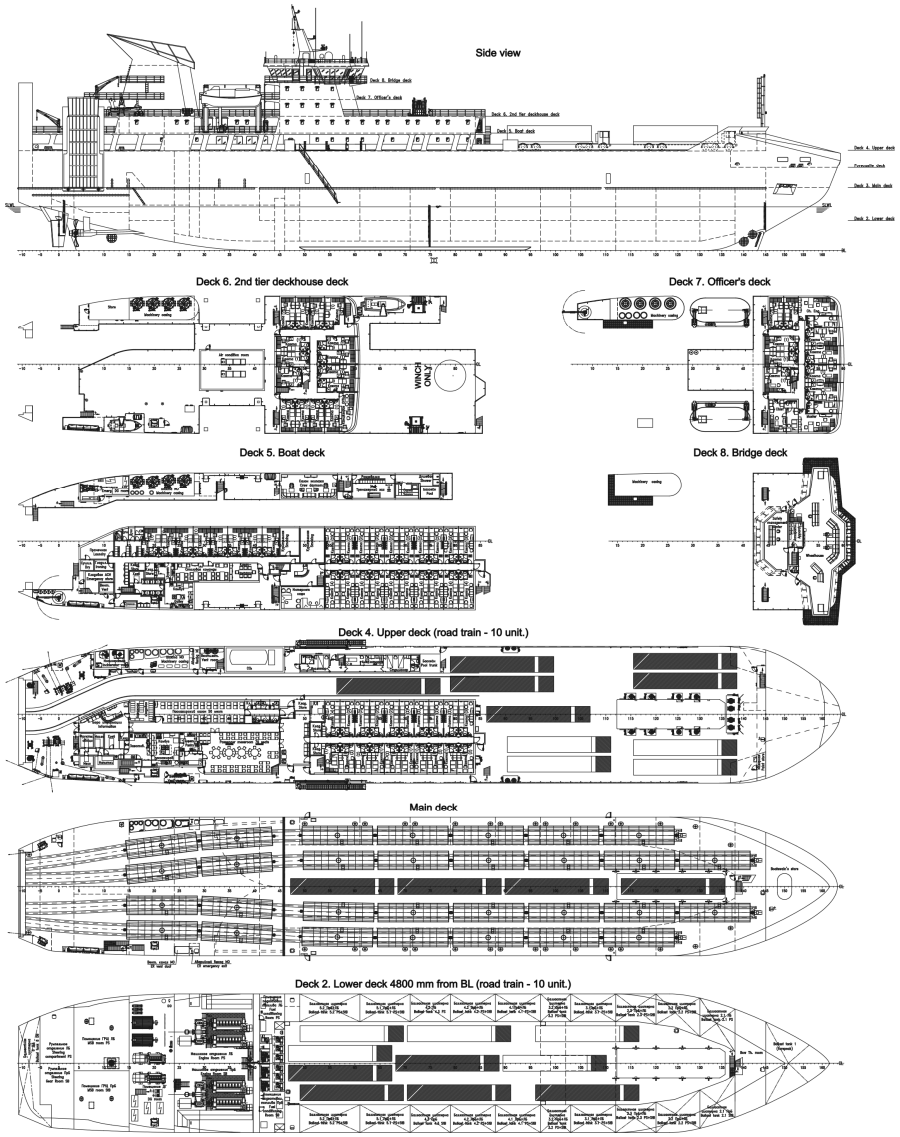

Fig. 2. General arrangement of new Marine Engineering Bureau ferry CNF11CPD project

There are 150 passenger's places on new ferry (cargo-passenger variant). 5 from them in in the improved single cabins; 42 – in double cabins; 9 – in three-berth cabins; 44 – in four-berth cabins and 50 – in armchairs of seating saloon are placed. All cabins have wet-units with lavatory and douche.

For maintenance of round voyage during one day and observance of the constant schedule limited time of port standing is required, i.e. full cargo and passenger load operation of a vessel should be carried out within 2 hours. Aft ro-ro loading method is applied for this purpose on a vessel by means of

shore railway bridge, and also there is an opportunity of loading of upper deck by the shore stationary upper level auto bridge. Side ramp for a loading / unloading of various vehicles on the main deck is provided for a case of voyage to other ports.

Hull form. Operating conditions: approximately 80-90 % of running time, i.e. state a major problem of an optimum variant of hull form. The hull should have form of a high-speed vessel and simultaneously provide seasonal independent operation in heavy ice (3-4 months in a year, on a small extent of transition). I.e. the form of the hull should provide both high icebreaking, and high speed performance of a vessel.

These requirements are answered with two alternative decisions under the form of the case:

- optimized icebreaking;
- double Action Ship (DAS).

Optimized isebreaking hull form. The first variant has bow with icebreaking type stem and transom aft extremity with the skeg-stabilizer in CL.

Lines drawings (Frames view) of the first variant with icebreaking type stem is given on the fig. 3, 3D model of hull on the fig. 4.

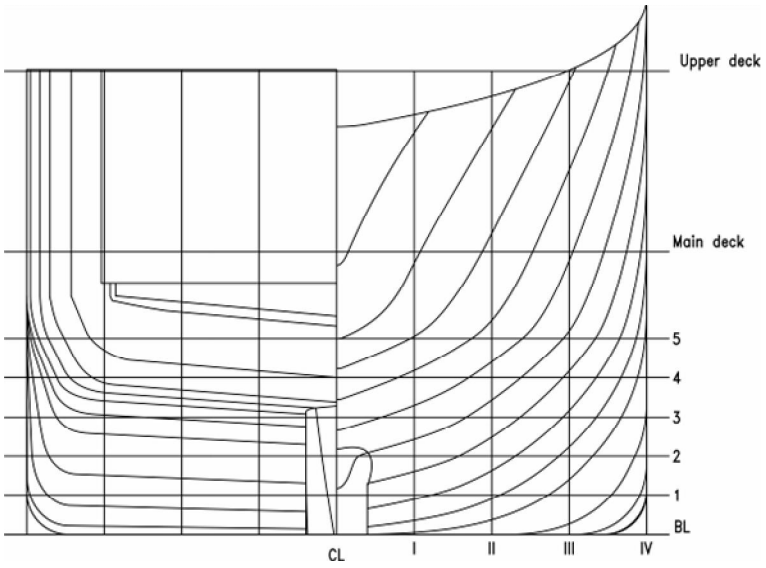

Fig. 3. Lines drawings (Frames view) of the variant with icebreaking type stem

DAS hull form. The DAS hull form proposed by Aker Arctic company (AARC) connects icebreaking forms and forms of a high-speed vessel. Forward part is carried out as at a high-speed vessel with bulbous bow, the aft part is carried out as an icebreaking vessel. Movement in heavy ice is carried out astern.

Lines drawings (Frames view) of the DAS variant is given on the fig. 5.

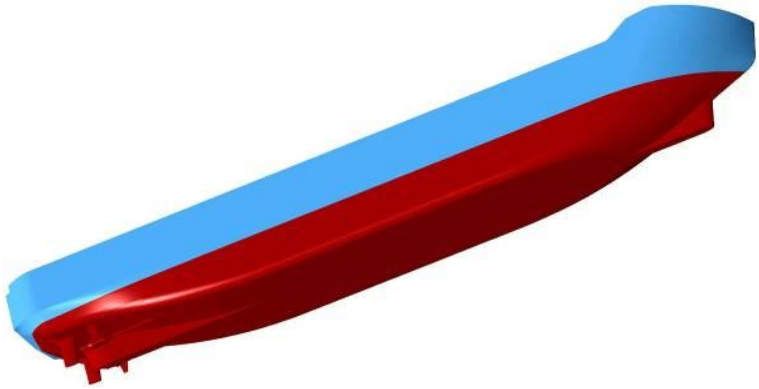

Fig. 4. 3D model of hull of the variant with icebreaking type stem

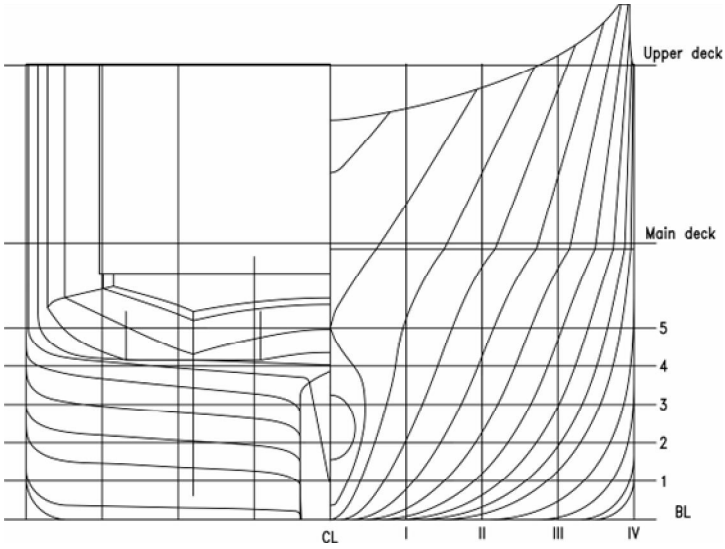

Fig. 5. Lines drawings (Frames view) of the DAS variant

Model tests. CFD modeling. Numerical modelling towing tests analytical 3D models of hull with the help of computing hydrodynamics has been made at the first stage with the purpose of preliminary definition of hull performance in the set range of speeds [4].

Ice tanks tests. Tests in the ice tank of the Krylov State Research Centre. For check of ice-going capability of hull forms have been made modelling Tests in the ice tank of the Krylov State Research Centre [1].

The method of towage of model has been used for definition of ice resistance of the hull on ahead moving.

Propellers are installed on model for tests by definition of ice resistance at astern movement of model. At performance of astern towage in ice fields propellers were resulted in rotation. Speed of propeller's rotation made 12.8 revolutions in a second. On a natural vessel presence of rotating propellers leads to formation of a jet and washout of an ice shirt on the vessel hull. Rotating propellers on model provided modelling of this effect.

Ratio between modelled parameters and a full-size vessel are given in the table 2.

Table 2

Ratio between modelled parameters and a full-size vessel

Name of characteristics	Model	Ship
Ice thickness, m	0.038	0.8
	0.057	1.2
Ice flexural strength, kPa	23.5	500
Speed of towing:	0.3	2.69
Model, m/s	0.2	1.79
Ship, knots	0.1	0.9

By results of data processing the carried out experiment, limiting Ice going capability of the ferry at moving ahead made 1.16 m at speed V = 3 knots and 0.84 m at speed V = 6 knots.

Ice going capability of the ferry at moving ahead are given on the fig. 6.

By results of data processing the carried out experiment, limiting Ice going capability of the ferry at moving astern made 0.67 m at speed V = 1.5 knots.

Ice going capability of the ferry at moving ahead are given on the fig. 7.

Tests in the ice tank of the AARC. Model of the DAS variant of hull form tested in AARC ice tank [2].

The model of the vessel was built to scale 1:22.46 by AARC. It was equipped with two pulling type azimuthing thrusters with stock propellers.

The surface of the model was treated with the special AARC standard method to reach the correct friction between ice and the model, corresponding to a newly painted ship hull and sea ice.

The model performance was tested in both ice thicknesses ahead and astern.

The tests were conducted as self-propulsion tests and the results of the tests are the speeds the vessel can achieve in the tested ice conditions.

The tests were conducted in level ice, in ice rubble channel and in ice ridges. The test series in ice fields level ice thickness corresponded full-scale thickness of 0.8 m and 1.0 m.

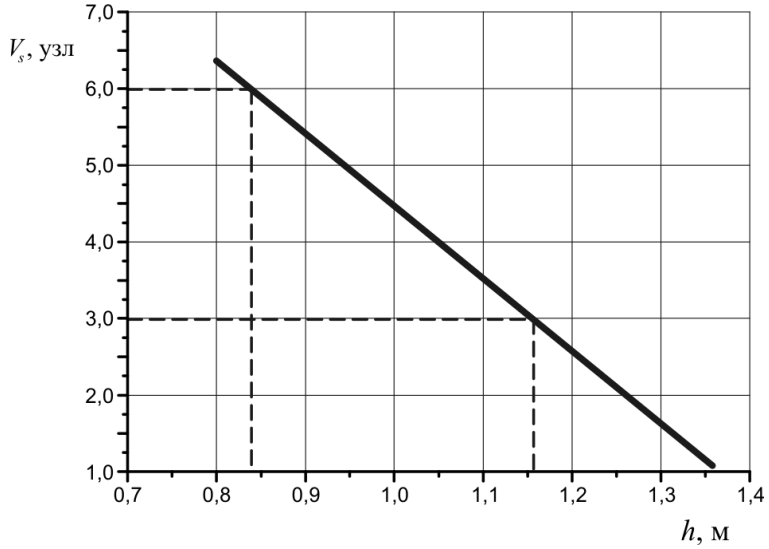

Fig. 6. Ice going capability of the ferry (variant with icebreaking type of stem) at moving ahead

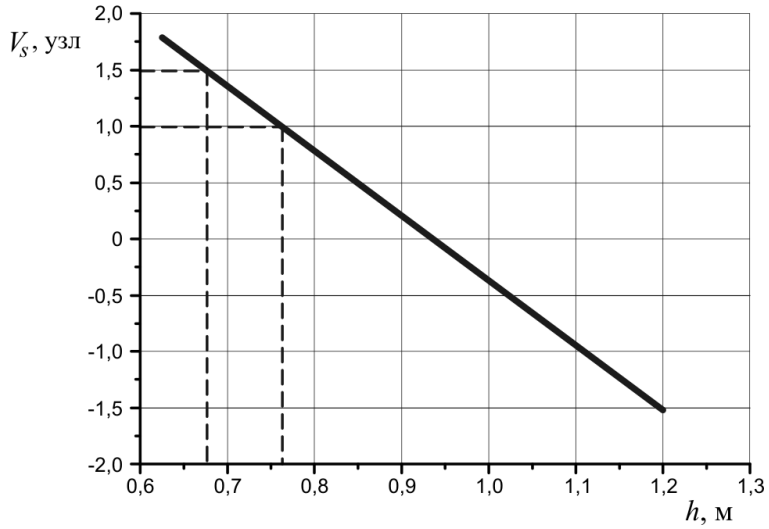

Fig. 7. Ice going capability of the ferry (variant with icebreaking type of stem) at moving astern

Performance in channel was tested to vessel's own channel in level ice by filling the open channel with brash ice.

The channel brash thickness varied between 1.1 m and 1.7 m.

Ice resistance in level/brash ice astern/ahead and the net thrust curve present on fig. 8-10.

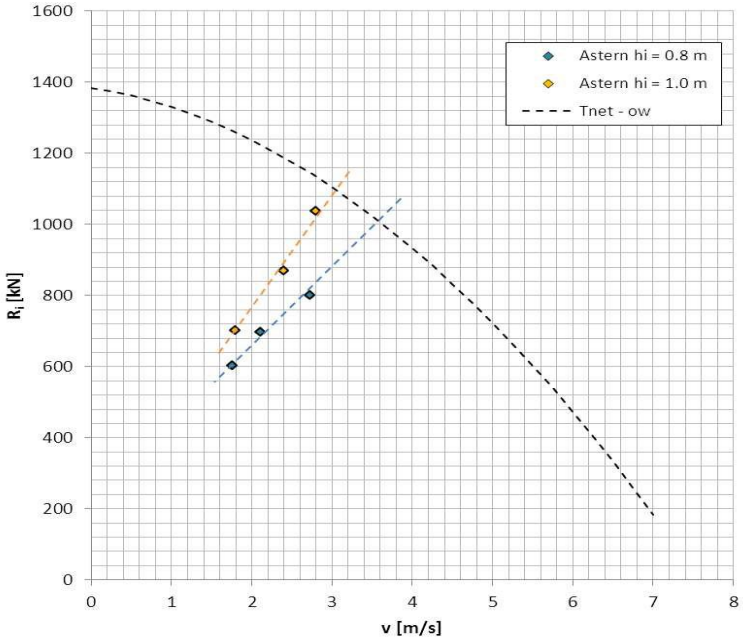

Fig. 8. Ice resistance in level ice astern and the net thrust curve

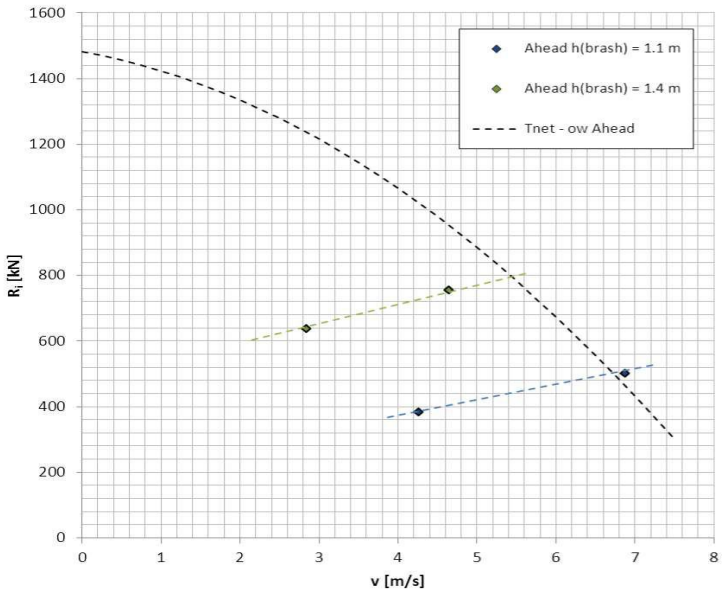

Fig. 9. Ice resistance in brash ice channel ahead and the net thrust curve

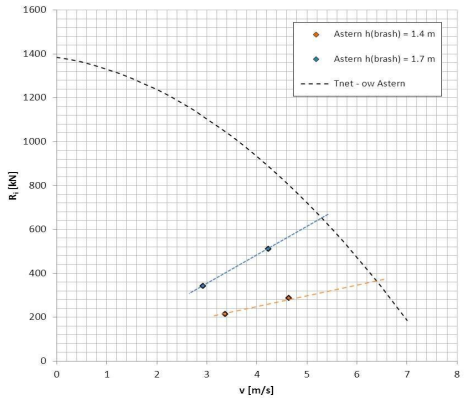

Fig. 10. Ice resistance in brash ice channel astern and the net thrust curve

Seaworthiness model tests. For check of seaworthiness capability of hull forms have been made self-propelled modelling tests in the test tank of the Krylov State Research Centre [3].

Results of calculations of performance and trusts characteristics executed on the basis of the carried out modelling tests are given on fig. 11.

Experimental researches of seaworthiness of the ferry were made for a condition of irregular waves by force of 5 number on the Beaufort scale ($H_{3\%}$ = 3.5 m).

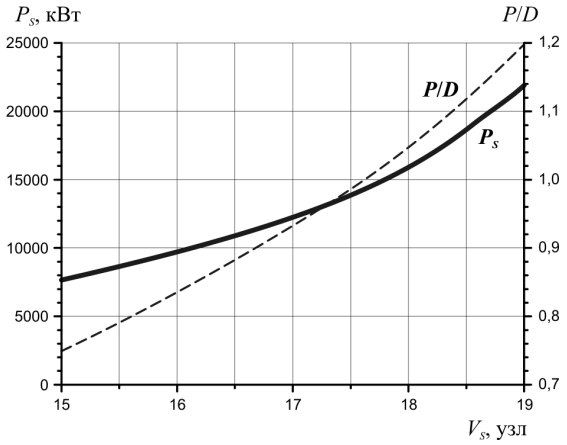

Fig. 11. Relations of required power P_s and required propeller's pitch P/D and speed V_s. Ahead

Amplitudes of rolling with 3 % probability do not surpass the following values: pitch – 1.3 °, heaving – 0.4 m.

Flooding of the ferry it was observed only at speed of 19 knots. Average frequency of flooding of bow extremity of the ferry does not exceed 20 times per hour.

Maneuverability of the ferry. Negative feature of Kholmsk Commercial Seaport (Sakhalin island) in the hydrometeorological attitude are harbor seiche on internal water area which are observed within all year. Storm waves and swell moved to coast, do not collapse completely, and are simply reflected from abrupt shore. In the entrance of port occur standing waves of the double height complicating ship to enter the port. Thus, in addition appear currents along shore which quickly turn slowly going vessels at the entrance of port even in rather calm weather.

Existing ferries of «Sakhalin» type have only FIXED pitch propellers ONE aft and ONE bow and full absence of transverse thrusters (the typical decision for the end of 60th years of the last century when the existing ferry was designed).

Thereof usual practice became forced entrance of ferries in the port astern on raised speeds that raises probability of collisions, creates additional wave formation and contradicts the generally recognized conceptions about safety of navigation in ports.

3 tunnel transverse thrusters (2 bow and 1 aft) with power of 500 kW of each thruster are provided on the new ferry for maintenance of independent mooring and long movement astern on the constrained water area of ports Vanino and Kholmsk, pass of the entrance of Commercial port of Kholmsk.

New ferry for maintenance of controllability moving does not need dangerous entrance in port on high speeds. The ferry goes in port astern on speeds of less than 3 knots at which reduction in transverse thrusters efficiency is not observed.

Choice of type and main engine power of the new ferry. Under requirements of the Customer the new ferry should have operational speed of 18 knots on free of ice water and have high parameters of ice-going capability (speed of 3 knots in level ice thickness of 1.0 m and 6-8 knots in level ice thickness of 0.8 m). Determining capacity of power installation in this case there were requirements of maintenance of ship's speed on free of ice water and in ice thickness of 0.8 m (see fig. 12).

By results of the calculations, confirmed with modelling tests, at norm of 85 % loading of diesel engines required power of ship's main engine plant has made 17.9 MW.

Twin-screw (with controllable pitch propellers) diesel-reduction main engine plant is chosen for a variant of the ferry with icebreaking stem type. Main engine plant will consist of 4 main diesel engines (two pairs). Each of main engines in pair works on common reduction gear that allows to ensure the functioning diesel engines in an optimum mode: on economic speed of 12 knots (work on 1 diesel engine in each pair), on full – 18 knots work all 4 diesel engines.

Application of ruder-propellers (RP) Azipod type for variant of DAS has determined a choice of diesel-electric main engine power plant.

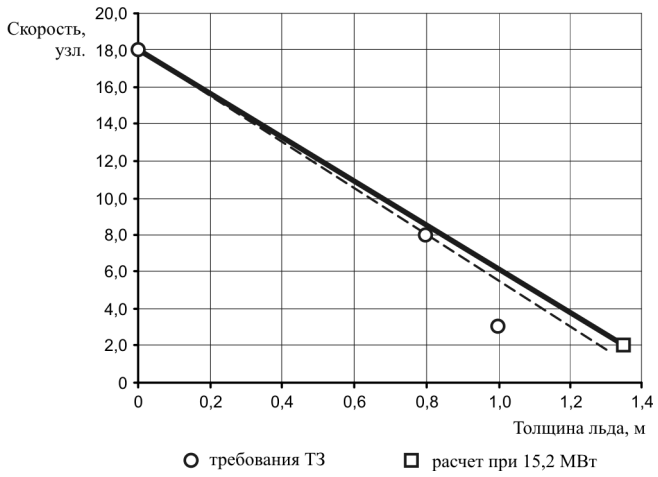

Fig. 12. Relations of speed and ice-going capability at propulsion power of 15.2 MW

Conclusions. Feature of ferry line «Vanino-Kholmsk» is the significant component of running time – approximately about 20 hours per day. Therefore essential influence on profitability of ferry operation as a whole is rendered «high-speed» characteristics of hull form and propulsion complex efficiency. Speed of new Marine Engineering Bureau ferry CNF11CPD project makes 18 knots at 85 % of maximum power of engines (existing ferry have speed about 16 knots). Each of two propellers drives by two main engines through common reduction gear. This well-known (for the European ferries) decision allows to hold economic speed in 12 knots, on full – 18 knots on ferry of CNF11CPD project.

Hull form have been developed with the help of computer modelling and checked up by modelling tests in the test tank of the Krylov State Research Centre and Aker Arctic.

As a result of modelling tests seaworthiness capability of the new ferry are confirmed also. Flooding of the ferry forward part it was observed only at speed of 19 knots. Some decrease in speed to 15-17 knots may be necessary only in a case of deck cargo in forward part.

Characteristics of performance of the railway-car ferry of CNF11CPD project in ice conditions are received as a result of the carried out researches: by results of tests in ice tanks the ice-going capability on moving ahead at speed V = 3 knots will make 1.48 m, at speed V = 6 knots will make 1.04 m, on moving astern at speed V = 1.5 knots will make 0.85 m. More over forward part of the hull structure are designed on higher ice category (Arc7). In aggregate with ice-going capability at a level of ice breaker class (Icebreaker6 according to Russian Register classification) it allows to provide (in contrast to existing ferries) independent operation of the new ferry in heavy ice conditions on a short site of transition (approximately up to 30 miles in area of port

Vanino). In turn it will allow to avoid significant idle times of the ferry of waiting common icebreaking assistance, or superfluous charges in case of individual assistance.

Two ferries of CNF11CPD project are going to be built in near future instead of existing railway ferries of «Sakhalin» type.

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Стаття надійшла до редакції 20.11.2016

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