CATAMARAN IN HIGH SPEED CONTEXT

Lebedeva, Maria N., *Volga State University of Water Transport, Nizhny Novgorod, Russia.*

ABSTRACT

The article presents the results of development of high-speed catamaran vessel of large cargo capacity with minimal environmental wave load on river channel intended for joint operation within the supply chain together with road transport. Conditions for model testing, comparing waves caused by river cargo vessels of various types are described. The results of measurements of prototype's impact and expansion of parameters of considered waves for calculation of intended model of a real vessel are given.

Keywords: inland water transport, catamaran, river, channel load, logistics, clearance, compatibility, road transportation.

Background. *The transportation of such highly tariffed cargo as containers and semi-trailers, as well as organization of mixed road-water transportation of general cargo on inland waterways require movement of cargo ships at a speed of 30 km/h or higher to provide for transit speed (taking into account road transit as well) of at least 1500 km/day. This is conditioned by high cost of goods and, consequently, by a high growth of the final price of the goods, taking into account transportation costs. Now, however, almost all self-propelled river vessels and mixed navigation vessels have a speed of about 20 km/h, which is insufficient for economically efficient organization of transportation [1].*

Objective. *The objective of the author is to consider vessels of a catamaran type in the context of possible mixed high speed freight transit with regard to the impact of waves produced by them.*

Methods. *The author uses general scientific and engineering methods, modeling, simulation, natural experiments, comparison, graph construction, analysis.*

Results.

Waves press, push, inhibit

Movement of river vessels with high speeds is accompanied by a significant wave formation, which leads to increased resistance to movement of the vessel, as well as to negative environmental impact on inland waterways. In this context a problem arises to achieve high speed for heavy roll-on-roll-off vessels (Pic. 1) with a proviso that they can carry general cargo (in the supply chain with road transport) with an acceptable level of wave formation.

It is advisable to choose as a criterion of permissible speed for large-capacity roll-on-roll-off vessels a practically achievable and economically reasonable speed at which their wave formation will not exceed wave formation caused by currently operated vessels.

It is known [2] that catamaran type vessels have a lower wave formation as compared to single-hulled vessels of similar carrying capacity due to large relative length L / B and smaller fullness of the body.

When considering vessels with similar full load weight a single hull of catamaran will be more «subtle body» in comparison with single-hulled vessel and thus will generate waves of lesser height at equal speed. It is logical to assume that catamarans have a so-called «ecological reserve», which consists in the fact that they may have higher speed compared to single-hulled vessels of similar tonnage (or higher tonnage) for the same (permissible) wave formation.

Research methodology

For comparative evaluation of wave formation following movement of cargo ships we held towing tests of their models and measurements of wave heights occurring at different speeds. Research was carried out in test tank of Volga State University of Water Transport with dimensions 35x4x1,5 m at a water level of 1,1 m and with gravitational towing system. Characteristics of vessels for which models were made are given in Table 1.

For tests parametric towed models were used of 1:50 scale for single-hulled vessels (Pic. 2) and of 1:75 scale for double-hulled vessel (Pic. 3). They were made of wood and foam plastic, and further coated and colored.

For each model, following the results of weighing the weight of cargo was determined that was required to provide designed displacement. At launching of models their trim on an even keel was made. Main characteristics of tested objects are shown in Table 2.

Following parameters were recorded during tests: speed and towing resistance of a model, height of waves, caused by movement of the model.

Wave height was measured by float-type wave recorder of resistor type. After converting the signal via analog-to-digital converter (ADC) its processing was performed via a program PowerGraf as a real-time record of wave heights measured at the point of installation of the float.

Towing was made subject to the passage of models at a distance of 1,87 m from the wall of the tank. Float of wave recorder was located at 0,83 m from the wall, the choice was made for conditions of

Pic. 1. Large-capacity roll-on-roll-off catamaran.

Table 1

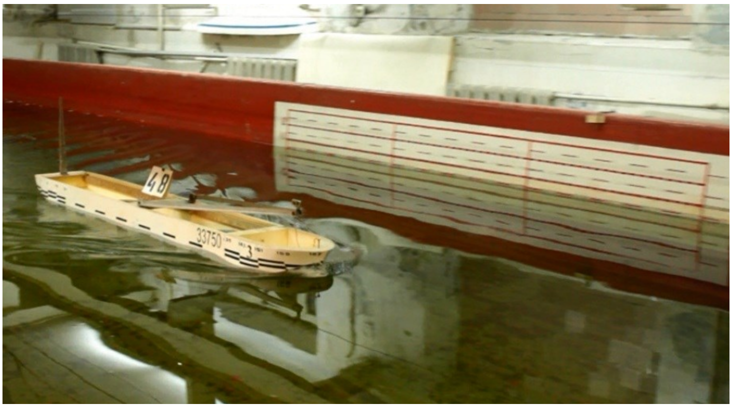
Designs and characteristics of test vessels

№	Project, type of vessel	Length at designed waterline, L, m	Width at designed waterline (single hull), B, m	L/B	Draught at designed waterline, T, m	Block coefficient, Δ	Displacement of vessel, D, t
1	pr. 33750	103,5	15,4	6,68	3,6	0,831	4770
2	pr. 507	103,75	16,5	6,28	3,5	0,845	5060
3	pr. 558	135	16,5	8,18	3,52	0,845	6460
4	pr. 1743	105	14,8	7,09	2,5	0,831	3230
5	Catamaran type «Transit»	150	28,0 (10)	5,36 (15)	2,8	0,630	5300

Table 2

Main characteristics of test models

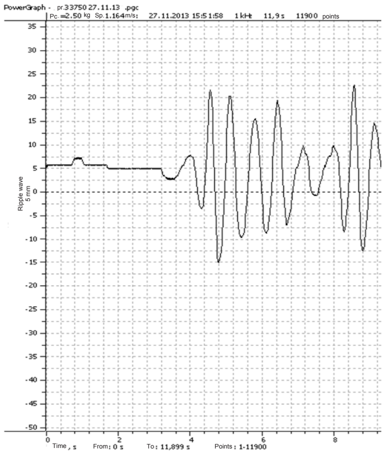
№	Model of vessel project		Displacement of a model, D_m, kgr	Length of a model, L_m, m	Width of a model (single hull), B_m	L_m/ B_m	Draught of a model, $T_{m,}$ m	Scale, λ
1	Single-hulled vessels	pr. 33750	38,16	2,070	0,31	6,68	0,072	1:50
2		pr. 507	40,48	2,075	0,330	6,28	0,070	1:50
3		pr. 558	51,68	2,70	0,330	8,18	0,071	1:50
4		pr. 1743	25,84	2,10	0,296	7,09	0,05	1:50
5	Double-hulled vessel type «Transit»		12,56	2,00	0,373 (0,133)	5,36 (15)	0,037	1:75



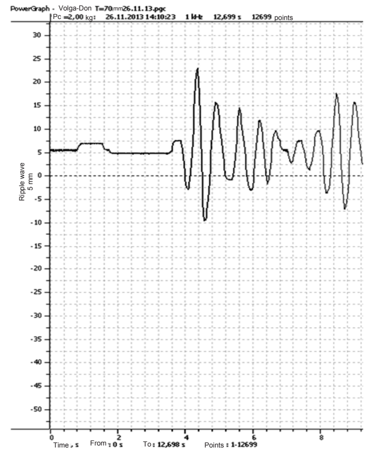
Pic. 2. Test of a single-hulled model.

Pic. 3. Test of a catamaran model.

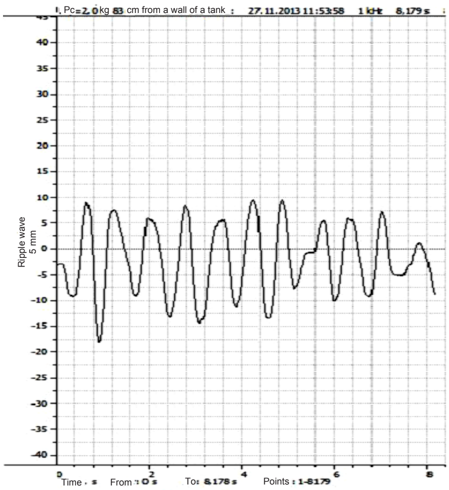
a)



b)



Pic.4. Results of measurements of wave heights for models of single-hulled vessels pr.33750 and 570:
4a) Towed cargo P_c = 2,50 kg. Sensor is located at 83 cm from a wall of a tank. Speed of real vessel V_r = 29,63 km/h.
4b) Towed cargo P_c = 2,00 kg. Sensor is located at 83 cm from a wall of a tank. Speed of real vessel V_r = 30,52 km/h.



Pic.5. Results of measurements of wave heights for a model of a single-hulled vessel pr. 558 with towed P_c = 2,00 kg. Sensor is located at 83 cm from a wall of a tank. Speed of real vessel V_r = 31,79 km/h.

measuring wave heights at the boundary of wave sector without taking into account the wave reflected from the wall of the tank.

Measurements of wave heights were made in the range of speeeds of prototype single-hull vessels 17–31 km / h, and 23–36 km/h for double-hulled vessels.

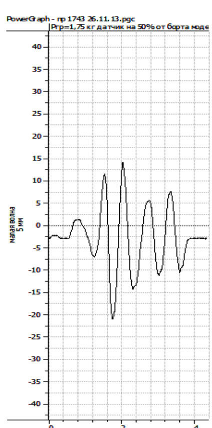
For each model with its speed corresponding to 30 km/h speed of real full-scale vessel, wave height was measured at two additional points: at a distance of 140 cm from the wall of the tank, which is approximately 25% of the distance from the ship's board to the tank wall, and at a distance of 46 cm, which is equivalent to 75% of the distance from the board to the wall.

Conversion of wave heights was produced on the basis of geometric similarity of models and of real ships. The speeds were recalculated based on the Froude hypothesis about equality of coefficients of residual resistance of a model and prototype vessel under the same Froude numbers for length.

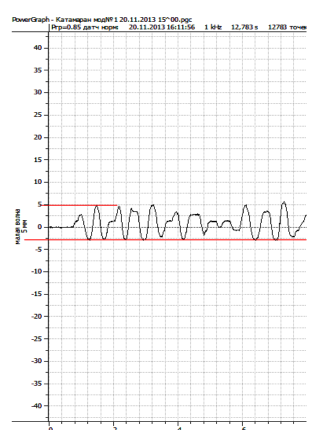
Results and conclusions

Pic. 4–6 show the results of measurements of wave heights for ship models at maximum speed. Data

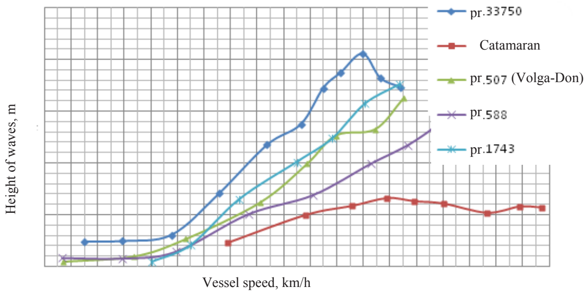
a)



b)



Pic.6. Results of measurements of wave heights for models of a single-hulled vessel pr. 1743 and catamaran:
6 a) Towed cargo P_c = 1,75 kg. Sensor is located at 83 cm from a wall of a tank. Speed of real vessel V_r = 30,37 km / h.
6 b) Towed cargo P_c = 0,85 kg. Sensor is located at 83 cm from a wall of a tank. Speed of real vessel V_r = 35,73 km / h.



Pic. 7. Graphs of dependences of heights of ship waves on vessel speed.

correspond to results obtained at the location of the wave sensor at a distance of 0,83 m from the wall of the tank.

The curves of dependences of heights of ship waves on vessel speed are given in terms of expansion (Pic. 7).

Conclusions. *It is seen that wave height caused by a catamaran at a speed of 30 km / h is by 1,7–3,1 times less than that caused by single-hulled vessels. It should be noted that single-hulled river cargo vessels are not operated at the specified speed due to the lack of technical capability or economic inefficiency. Maximum height of waves of catamaran can be compared with wave heights caused by single-hulled vessels moving at much lower speeds. The experimental results confirmed the assumption about ecological reserve of catamaran vessels compared to typical single-hulled vessels, operated on river waterways.*

We used for the experiment a model with characteristics similar to the data of catamaran «Transit», being now designed. The model has body lines that differ from body lines in the preliminary design of vessel «Transit». When considering the maximum value of curve of heights of catamaran ship waves that refers to the speed of 30 km / h, there is reason to assume that it can be reduced by development of body lines of submerged part of the vessel, so that the maximum of the curve can also be shifted. For this purpose, it is necessary to carry out towing tests of model of designed catamaran.

In accordance with known method of recalculation of results of towing tests of models of ships to the real vessels, calculation of water resistance to movement of vessels and towing capacity at different speeds was performed. For catamaran vessel type «Transit» with its design speed of 29 km / h value of towing capacity of 3,4 MWws obtained. Given the fact that towing capacity is always less than the total capacity of the selected vessel engines, this result is quite consistent with calculations of propulsion quality of catamaran, made by the method Alferiev–Madorsky presented in [3, 4]. In them see efficiency of fixed-pitch screws, working in conditions of restricted draught, the number and power of main engines with reverse gear units has been designed and adopted at 2 x 2000 kW.

REFERENCES

1. Efremov, N. A., Kostrov, V. N., Etin, V. L., Mitroshin, S. G. Development of river transport in XXI century – new technologies [*Razvitie rechnogo transporta v XXI veke – novye tehnologii*] *Vestnik transporta Povolzh'ja*, 2008, Iss. 4, pp. 56–62.

2. Etin, V. L., Lukina, E. A., Mitroshin, S. G., Sirotkin, E. M. Results of comparisons of ship waves parameters caused by various types of vessels by means of model tests [*Rezul'taty sravnenija parametrov korabel'nyh voln ot sudov razlichnyh tipov s pomoshh'ju model'nyh ispytanij*]. Proceedings of 16th International scientific and industrial forum «Great Rivers 2014». Vol. 1. Nizhny Novgorod, VSAWT, 2014, 330 p.

3. Etin, V. L., Lukina, E. A, Milavin, S. A Design of river speed cargo roll-on-roll-off vessels of catamaran type [*Proektirovanie rechnyh skorostnyh gruzovyh nakatnyh sudov katamarannogo tipa*]. *12th International Scientific and Industrial Forum «Great Rivers-2010»: Proceedings of the Congress. Vol. 2.* Nizhny Novgorod, NSABU, 2011, pp. 37–44.

4. Lukina, E. A., Mitroshin, S. G., Bitkov, D. A. Substantiation of application of roll-on-roll-off vessel for ferry-transport freight transportation in Volga-Kama basin [*Obosnovanie primenenija nakatnogo sudna dlja paromno-transportnyh gruzovyh perevozok v Volzhsko-Kamskom bassejne*]. *Vestnik VGAVT*, Iss. 28, 2009, pp. 56–62.

5. Mineev, V. I., Mitroshin, S. G., Efremov, N. A., Kostrov, V. N., Etin, V. L. Innovative technologies – basis of development of river transport in XXI century [*Innovacionnye tehnologii – osnova razvitija rechnogo transporta v XXI veke*]. *Rechnoj transport (XXI vek)*, 2009, Iss. 6, p. 34.

6. Kostrov, V. N., Telegin, A. I., Mitroshin, S. G. Modeling and promotion of new technologies in ferry-transport logistics system [*Modelirovanie i prodvizhenie novyh tehnologij v paromno-transportnoj logisticheskoj sisteme*]. *Vestnik VGAVT*, 2008, Iss. 24, pp. 132–136.

Information about the author:
Lebedeva, Maria N. – Ph.D. student of Volga State University of Water Transport, Nizhny Novgorod, Russia, leb.m.n@mail.ru.

Article received 09.12.2015, accepted 12.02.2016.

The research paper, which served as a basis for the article, was awarded first prize in the category «Development of integrated transport environment of the Russian Federation: organization, legal and economic issues» during the final round of the contest of Russian forum «Young transport scientists and researchers» 2015, organized by the Ministry of Transport of the Russian Federation and held in MIIT University.
The research was performed under the supervision of professor V. L. Etin, D.Sc. (Eng.) and with the assistance of S. G. Mitroshin, Ph.D. (Eng.), head of research and innovation department of Volga State University of Water Transport.