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EFFECTIVE TECNHICAL SOLUTIONS FOR FAR EAST SHALLOW-WATER BASINS

Особенностью восточных бассейнов является то, что максимальные размеры судна и состава определяют не шлюзы, а условия управляемости (радиусы поворотов, ширина судового хода). Плюс общая «беда» внутренних водных путей – недостаточные глубины.

Проведенный анализ существующего флота речных пароходств восточных бассейнов позволяет сделать вывод, что в ближайшие 5-10 лет эти суда необходимо будет списать в силу фактического возраста, морального старения, износа машин, механизмов, а также, в некоторых случаях, корпуса.

В результате исследований, выполненных Морским Инженерным Бюро, были разработаны технические проекты мелкосидящих баржебуксирных составов с ограниченой осадкой в нефтеналивном (самоходный танкер-толкач проекта RT63 плюс нефтеналивная баржа проекта ROB21) и сухогрузном исполнениях (самоходное сухогрузное судно-толкач проекта RD63 плюс сухогрузная баржа проекта RDB21), а также в комбинированном варианте (самоходное нефтеналивное-сухогрузное судно-толкач проекта RT63A плюс нефтеналивная-сухогрузная баржа проекта ROB21A).

***Ключевые слова**: барже-буксирный состав, недостаточные глубины, нефтеналивное судно-толкач, сухогрузное судно-толкач, баржа.*

Особливістю східних басейнів є те, що максимальні розмірення судна й состава визначаються не шлюзами, а умовами керованості (радіуси поворотів, ширина суднового ходу). Плюс загальна «біда» внутрішніх водних шляхів – недостатні глибини.

Проведений аналіз існуючого флоту річкових пароплавств східних басейнів дозволяє зробити висновок, що в найближчі 5-10 років ці судна необхідно буде списати в силу фактичного віку, морального старіння, зношування машин, механізмів, а також, у деяких випадках, корпуса.

У результаті досліджень, виконаних Морським Інженерним Бюро, були розроблені технічні проекти мілкосидячих барже-буксирних составів з обмеженною осадкою у нафтоналивному (самохідний танкер-штовхач проекту RT63 плюс нафтоналивна баржа проекту ROB21) і суховантажному виконаннях (самохідне суховантажне судно-штовхач проекту RD63 плюс суховантажна баржа проекту RDB21), а також у комбінованому варіанті (самохідне нафтоналивне-суховантажне судно-штовхач проекту RT63A плюс нафтоналивна-суховантажна баржа проекту ROB21A).

Ключові слова: *барже-буксирний состав, недостатні глибини, нафтоналивне судно-штовхач, суховантажне судно-штовхач, баржа.*

The feature of Far East basins is that the maximal vessel's and tug-barge combination's (TBC's) dimensions are defined with controllability conditions (turning radiuses, navigable pass width). Plus common «problem» of internal waterways is insufficient depths.

The carried-out analysis of existing fleet of Eastern river shipping companies allows to draw a conclusion that in the next 5-10 years these vessels will be scrapped due to actual age, moral aging, machines and mechanisms wear and also, in some cases, due to hull wear.

As the result of Marine Engineering Bureau researches technical projects of shallow-draught TBCs with limited draught in oil-tanker variant (self-propelled tanker-pusher of RT63 project plus tanker barge of ROB21 project) and dry-cargo variant (self-propelled dry-cargo-pusher of RD63 project plus dry-cargo barge of RDB21 project), and also in combined variant (self-propelled tanker-dry-cargo-pusher of RT63A project plus tanker-dry-cargo barge of ROB21A project) were developed.

Keyword: *tug-barge combination, insufficient depths, tanker-pusher, dry-cargo-pusher, barge.*

Problem statement. People say that new is well forgotten old. Problems of low-water and small depths at Eastern basins, especially in Sakha (Yakutia) are known not since year before last. Native engineers who created Lena River fleet in the second half of the XX century, widely applied tag-barge trains, composite vessels, special hull's shapes for shallow water, paddle wheels, combined dry-cargo/tanker vessels and a lot of other technical solutions, many of which are considered as innovations now. Today there is ability to use modern economic and ecological safe machines and mechanisms, comfort and habitability ideas have improved, vessels themselves became automated and more reliable. But it does not mean that it is impossible to use those basic ideas which inspired our predecessors, especially as operating conditions have not changed and the similar problems are solved.

One of decisions which allow working effectively in the conditions of shallow water is creation of composite vessels (i.e. cargo vessels with attached barges).

The aim of the paper is description of such new projects for Far East basins.

Main text. In the Lena Shipping Company operation of the first composite vessel (272a prj.) was begun in 1963. On the Volga River the composite vessel started working in 1964; she consisted of 576 prj. m/v «Ovruch» and attached barge. In 1966 on the Volga River the first-ever section motor ship with 10 thousand tons cargo capacity was accepted into operation. This vessel was designed under the leadership of V.V. Bogdanov on the basis of the 1566 prj. «Volga-Don» type vessel and corresponding attached barge. In

1973 on the Dnepr River 93 % of self-propelled vessels have already worked with the attached barges.

What does determine now and determined earlier the interest to the composite vessels? As it was repeatedly described in our publications, the matter is that the bigger vessel loading in specific way conditions means the bigger efficiency of this vessel. In fact, «Max» concepts [4] give the greatest profit to the future shipowner, and not only for oil products or grain transit, but also for passenger transportation. Feature of Eastern basins is that the maximum sizes of the vessel or composite ones are defined not by locks, but by manoeuvrabi-lity conditions (radiuses of turns, fairway width). Additionally general «trouble» of the inland waterways must be noted, i.e. insufficient depths.

But fully use maximum dimensions that way conditions allow for the single hull (length as a rule) is possible not always. Imagine non-composite river vessel of about 180-240 m length with draught, for example, 1.40-2.35 m (and 3.60 m too). It is clear that general strength of such hull won't be provided. Actually this reason was the main for appearance of composite vessels (strength of the parts of smaller length can be provided easier).

Besides, at the non-regulated rivers way conditions are function of season and weather. Not always it is possible to realize the maximum dimensions, but the ability is kept. When there is «high» water composite vessels can sail in design view. In other situations, for example, on the «side» rivers, composite vessel will be divided into parts, then the self-propelled vessel will work independently; the attached barge also will work independently in coupling with tug-pusher.

Composite vessel can partially realize the «rotator» scheme, leaving barge in the port of call and taking there taking another barge. The non-self-propelled barge can be used for some time as floating storage, etc.

In many cases, seaworthiness and corresponding main engines capacity foresaw for concept of self-propelled vessel become excess for specific river part of the route, particularly vessels' speed is restricted at the considerable part of inland waterways (engines' capacity is defined in order to provide safe work at sea or lakes, including storm reserve or is defined accounting the biggest current's speed). Attached barge availability on certain route's parts allows using this excess of engines' capacity (even with decreasing of whole composite vessel speed). It is clear that for such work in composite condition, the increased crew productivity is required because number of crewmembers of self-propelled vessel will be identical for working with barge or without her.

Thus, the composite vessel allows improving usage of inland waterways' bandwidth especially at Siberian Rivers.

Is possible to recommend providing ща some all-design decisions, namely e.g. optimum assignment of class for the sailing region that will allow to minimize light weight; the greatest possible block coefficient due to actual operating conditions, that will allow to increase the loading capacity of composite vessel; universality, i.e. barge must to has to be able to work with

the existing river pusher-tugs (there is a lot of). It is desirable to provide economy of running time due to passing all the route without composite vessel rearrangement, accepting all available composite vessel's dimensions in accordance with navigation rules and keeping manoeuvrability due to way conditions of the river basin appointed by the requirements specification.

Carried our analyze of the existing fleet of the river shipping companies of eastern basins allows to conclude that it will be necessary to discard all these vessels during the nearest 5-10 years due to actual age, moral obsoleting, wearing of machines and mechanisms, and due to hull wearing in some cases. The mostly representative is tanker fleet, at which the biggest part of the vessels are of single hull type [3; 6; 7].

For example, OJSE Lena United River Shipping Company (LORP) operates in general single-hull tankers now (see table 1).

Table 1

Tanker fleet of LORP

№	Project	RRR class	Cargo capacity, tons	Number of vessels / hull's construction
Self-propelled vessels				
1	P-77 («LenaNeft»)	«M-PR»	2150	16 / single-hull
2	621 («LenaNeft»)	«M-SP»	2100	7 / double sides and bottom
3	1577 («VolgoNeft»)	«O»	4 800	1 / double sides and bottom
4	1754 BM («TO-1500»)	«O-PR»	1 500	1 / double sides and bottom
5	1754 B («TO-1500»)	«O»	1 500	8 / single-hull
6	CK-2000KN/KMN (modernized «CK-2000»)	«R»	920	7 /cargo tanks on deck
7	TO-600 (modernized 414V)	«R»	600	1 / double sides and bottom
8	414V («SPN»)	«R»	600	7 / single-hull
Non-self-propelled vessels				
9	81631	«R»	1 900	4 / cargo tanks on deck
10	KN-16801	«M»	2 300	1 / cargo tanks on deck
11	NM-16801	«M-PR»	2 200	1 / cargo tanks on deck
12	NM-16801	«M»	2 200	2 / cargo tanks on deck
13	16802	«M-SP»	2 380	2 / cargo tanks on deck
14	16800NPB	«R»	2 770	1 / cargo tanks on deck
15	16800N	«O»	2 600	7 / cargo tanks on deck
16	16800N	«R»	2 600	1 / cargo tanks on deck
17	16800N 1	«O»	2 848	1 / cargo tanks on deck
18	BN-2000	«R»	2 000	1/ double sides and bottom

Source: OAO «LORP»

If amendments to the «Technical Regulation Concerning Safety of Inland Water Transport Objects» are adopted, from 01.01.2018 LORP will not be able to carry out transportation of «light» oils, but this cargo is a basis of «northern» delivery. List of the company's vessel that will not have permission to transport «light» oil is as follows: 16 Lenaneft type tankers (P-77 prj.), 8 «ТО-1500» tankers (1745Б prj.), 7 SPN type tankers (414В prj.); total their cargo capacity is 50600 tons. Other Lena's region carrier RLE «Alexeev Repairing Fleet Base» owns 36 single-hull 1745В tankers.

Why it is important? Because only in the territory of the Republic of Sakha (Yakutia) which area makes 18 % of the total area of the Russian Federation, live about 1 million people. More than one and a half thousand fields and over 5 thousand manifestations of different types of mineral raw materials are reconnoitered. Estimation of the minerals reserves potential is 5.5 trillion US dollars, Yakutia is included in the first five of the RF subjects by the capa-city of gross regional revenue. Thus more than 80 % of all necessary material resources are brought from afar [2].

For more than 85 % of the Republic of Sakha (Yakutia), the only transport route is a seasonal waterway of Lena basin rivers from the port Osetrovo to the Laptev Sea.

Extension of inland waterways of the Republic is 20 thousand km. Lena River and other navigable Yakutia rivers are meridional extension of main-line railways. Main cargo flow at Lena River is down-stream, so inland vessels are highly important for this cargo flow.

Over 70 % of oil products are delivered to the Republic of Sakha (Yakutia) by shipping companies from the port of Osetrovo and is carried down-stream to the primary consumers on the main line (at Lensk, Zhatay, Peleduy, Olekminsk) where reserves are created with accordance to Arctic delivery providing. These reserves are attended also for the case of sharp change of the waterway dimensions of Upper Lena in the summer period, at the beginning of vessels' entering into Lena's estuary (the third decade of July) and the beginning of the Arctic cargo delivery.

The maximal delivery of oil products is provided to the settlements of the Vitim, Aldan, Vilyuy Rivers and river's tributaries from the beginning of navigation, using short-term favourable navigational conditions (due to water depth).

Starting from the second half of July, tanker fleet's loading and forwarding towards Arctic settlements are provided. Simultaneously tanker tug-barge trains are used; they are conveyed to the port of Tiksi.

As a rule, the oil products delivery scheme is as follows [1]:

1. Oil products are delivered generally to the Tiksi port in bulk by the 1754Б tankers (in accordance with tankers' sailing region «О») and by the composite vessel.

2. Products are delivered from the port of Tiksi to the port of Nizhneyansk (Yana River) by river-sea vessels; further delivery to the river's settlements is carried out by 414B prj. (СПН type) tankers. Delivery from port of Tiksi to the estuary sandbar of the Indigirka is carried out by river-sea tankers and further by the 414V tankers.

Capacity of the cargo transported by all shipping companies of the Lena Basin has grown last years comparing with 2006-2008 (5-5.5 million tons versus 4 million tons).

In general, the main cargo flow in the Lena Basin occupies branch Osetrovo-Lensk; further it decreases about twice in the region of Yakutsk.

Nomenclature of «north delivery» is as follows:

1. Liquid cargoes include diesel oil, kerosene, gas condensate (as fuel oil), crude oil, gasoline and methanol. As a rule these cargoes are «light» with s.g. less than 0.90; their flash point is about 60 ºC.

2. Dry cargoes include black coal, round timber, lumber, building materials, containers, machinery, equipment, pipes. As a rule these cargoes are that are able to be transported on platform vessels.

Capacity of transported oil cargoes wass 764.0 t for the 2013 navigation.

Main dry cargoes at Lana basin by the 2012 data are, as follows: building materials (1.64 million tons, or 35 % of all dry cargoes); coal and coke (1.01 million tons, or 21.6 %); timber (0.185 million tons, or 4.0 %). Total dry cargoes transported capacity was 4.68 million tons including 0.69 million tons of containerized cargo (14.8 %) and 0.46 million tons of packed cargo (9.8 %).

Waterways of Lena basin have various duration of the navigating and operational periods at different parts of rivers, various operational conditions for using fleet on these waterways (small draught vessels for the lateral and small rivers, mixed river-sea going vessels for providing cargoes delivery to the Arctic rivers' settlements) demands creation and maintenance of corresponding dimensions of a running way for providing free sailing through fairway and bar areas of Yana and Indigirka Rivers in order ensure cargoes delivery during short-term Arctic navigation.

Cargo transportation due to duration of the operational period at the upper regions of the Vitim, Aldan and Vilyuy Rivers corresponds to expeditionary cargo delivery to the small rivers; existence of the small-draught fleet is necessary for fleet usage at these rivers during the whole navigational period. Cargo delivery to the Artic settlements of Yana, Indigirka, Kolyma, Anabar, Olenek and Hatanga River has its own specifity and distinction, that requires cargo accumulation first of all , including composite vessels usage.

The main preconditions of new TBT generation for cargo delivery to the RF Arctic regions are as follows:

• active development of the Northern Sea Way; due to CJSE CRMFI information, till 2020 capacity of cargo transportation may reach 60-65 million tons, coasting and transit transportations may reach 7 million tons (taking into

consideration mixed river-sea transportation at Lena, Yenisei and Ob-Irtysh basins.

• realization and necessity for support of realized industrial and logistic projects (gas pipeline «Siberian Power», port of Sabetta, «Yamal-SPG», «SMC «Norilsk Nickel», «Vankorneft», systematic arrangement of towns and enterprises, etc.);

• considerable physical and moral obsolete of river and river-sea vessels of the shipping companies of Lena, Yenisei and Ob-Irtysh basins, while cargo flow is stable;

• absence of alternative for water transport at main part of Arctic regions (especially at the Lena basin; there it is possible to deliver material or energetic resource to some far settlements or enterprises by river at navigation period only).

As a result of Marine Engineering Bureau investigations, several technical projects of small-draught composite vessel with restricted working draught were fulfilled, as follows: tanker variant (RT63 tanker pusher vessel plus ROB21 tanker barge), dry cargo variant (RD63 dry cargo pusher vessel plus RDB21 dry cargo barge), and combined variant (RT63A dry-cargo/tanker pusher vessel plus ROB21A dry-cargo/tanker barge).

Draught for small draught composite vessel for the Siberian rivers was appointed as a range 1.40-2.35 m. It was necessary to take into consideration that Lena River has long-term spring high water.

Basing on the analyze of existing coupling devices used at eastern basins, coupling unit UDR-100 was accepted for both variants (dry-cargo and tanker ones) of small-draught composite vessel.

Due to analyze of operational and weather conditions at investigated sailing regions and accumulated experience, the following RRR classification notation was accepted for discussed small-draught composite vessel: ✠ «O 2,0» (ice 20)A for pusher cargo vessel (at both dry-cargo and tanker variants) and ✠ «P 1,2» (ice 20) for barge. These classes allow to transport cargo at Lena basin during the whole navigation period.

Due to analyze of way restrictions [5], the maximal length till 170 m (summarized length of the pusher plus barge) was recommended f. It will be necessary to decrease running speed at Lena River part from Ust-Kut till Kirensk with waterway radius 300 m.

Several berths will require separate operations near them due to their insufficient length; such situation corresponds to operational models of prototype composite vessel, at which CK type vessels (CK-2000, CK-2000K, CK-2000KH projects) were used as pusher ones.

The maximal composite vessel's breadth may be accepted from the region 17.2-22.8 m. High end usage will initiate construction problems if building at Russian shipyards.

Due to shipping experience, self-propelled cargo pusher vessels of СК type (СК-2000, СК-2000К, СК-2000КН) are the mostly efficient for work with dry cargo or tanker barges at swallow water Siberian rivers. So this allowed to use these vessels as prototypes for new concepts.

Developed perspective projects RT63, RD63 and RT63A of small-draught self-propelled inland waterway vessels are successors of project ТО-1400, that was made for class «О» river tanker (project was developed out in the beginning of 2000s for Lena River Shipping Company). These new projects are intended to substitute in perspective existing tankers of 1754Б, СК-2000КН, 414Б, 414В project and dry cargo vessels of СК-2000, СК-2000К, Р-25Б projects.

For information: in 2008 construction of the hull of the head ТО-1400 tanker was completed; then hull was towed to the Zhataysk Shipyard harbour for construction finishing.

RT63, RD63 and RT63A project vessels are steel single-deck self-propelled double-screw ones with inclined stem and transom stern, with ER located aft, with living superstructure and wheelhouse located fore, with bow thruster, with fore UDR-100 coupling unit for providing pushing of dry cargo, tanker or combined barges, including existing ones. General arrangement of RT63 vessel is shown in the fig. 1.

New barge projects ROB21, RDB21 and ROB21A are the successors of the БН-2000 concept, which also was developed in the beginning of 2000s for Lena River Shipping Company. These new projects enhance operational abilities of tanker pusher vessel, increase cargo capacity of TBT, and provide loading multiplicity for river-sea tankers.

For information: the head БН-2000 barge was constructed at Zhataysk Shipyard in 2006.

Main characteristics of RT63+ROB21, RD63+RDB21, RT63A+ ROB21A composite vessels are given in the table 2.

Finally, the new RT63+ROB21 concept has deadweight 4788 t at draught 2.35 m, deadweight 3280 t at draught 1.80 m and deadweight 2195 t at draught 1.40 m; all this is much more that existing fleet vessels have. Accordingly, despite increasing thickness of hull elements and appearing of additional constructions such as double bottom and double sides, specific transportation self-cost will decrease by about 10-15 % comparing with old vessels.

For information: the most up-to-date composite vessel of LORP consists of ТО-1400 tanker and ВН-2000 barge; she has cargo capacity 3560 t at draught 2.35 m (i.e. by 1055 t less).

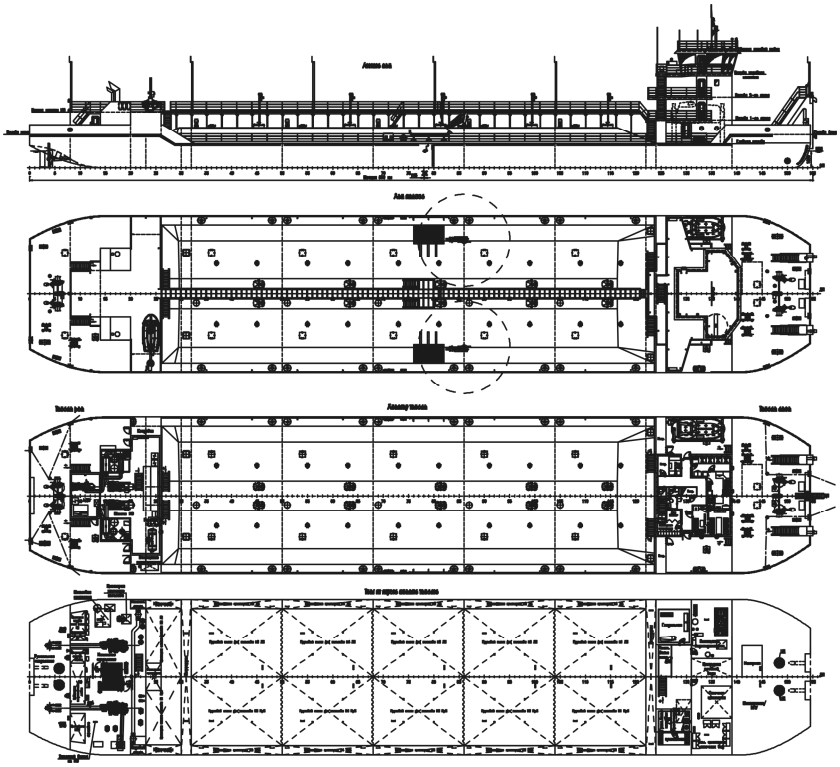

Fig. 1. General arrangement of the RT63 vessel

Table 2

Main characteristics of RT63+ROB21, RD63+RDB21, RT63A+ROB21A composite vessels

Parameter	Characteristics of small-draught composite vessel		
	RT63+ROB21	RD63+RDB21	RT63A+ROB21A
Composite vessel's type	dry cago	tanker	combined
Length overall, m	170.40		
Breadth overall, m	17.20		
Draught (summer free board), m	1.80		
Deadweight at draught 1.40 / 1.60 / 1.80 / 2.0 / 2.15 / 2.35 m in river, t (about)	2008 / 2566 / 3111 / 3656 / 4067 / 4619	2195 / 2736 / 3280 / 3825 / 4236 / 4788	1900 / 2441 / 2985 / 3529 / 3942 / 4493
Fuel autonomy, days	10		
Number of cargo tanks	24	-	24
Capacity of cargo tanks, m^3	5692	-	4831
Number of cargo's kinds for simultaneously loading/unloading	3	-	1
Area of cargo deck (in cargo bunker), m^2	-	1645	1366

Continuied table 1

Permissible load for the cargo part of deck, t/m²	-	5.0	
Cargo bunker capacity (up to coaming's upper edge), m³	-	2362	1996
RRR class notation for the pusher	✠ O 2.0 (ice 20) A		
RRR class notation for the barge	✠ R 1.2 (ice 20)		
Capacity of Main Engines, kW	2 x 746		
Crew / places, people	8 / 10		
Speed, not less than, км/h	19.0		

Conclusions. Due to RosMorRechflot order, Marine Engineering Bureau worked out up-to-date efficient project of small-draught tug-barge train with restricted working draught (1.40-2.35 m) for the Siberian rivers in dry cargo variant (RD63 dry cargo pusher vessel plus RDB21 dry cargo barge) and in tanker variant (RT63 tanker pusher vessel plus ROB21 tanker barge); also combined variant (dry-cargo/tanker) is foreseen. Characteristics of developed tug-barge train correspond to operational conditions of Siberian rivers and are significantly better than existing similar ones (she has bigger cargo capacity with simultaneously increased strength standard; there are fulfilled all current requirements due to ecology, safety, habitability and crew number reduction).

Developed perspective projects RT63, RD63 and RT63A of small-draught self-propelled inland waterway vessels are intended to substitute in perspective existing tankers of 1754Б, СК-2000КН, 414Б, 414В project and dry cargo vessels of СК-2000, СК-2000К, Р-25Б projects.

RosMorRechflot working group on coordination, scientific, technical and organizational support of work on the implementation of the federal target program «Development of civil marine engineering for 2009-2016" accepted introduced projects of small-draught tug-barge trains with restricted working draught (1.40-2.35 m) for the Siberian rivers.

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