Analysis of the current state of the Northern Sea Route and the potential development of the icebreaker fleet

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Abstract. The article provides a general description of the current state of the Northern Sea Route (NSR), highlights existing problems and prospects of the Northern Sea Route development. There is a tendency to increase the volume of sea freight traffic on the Northern Sea Route, which is facilitated by the development of new oil and gas fields in the Arctic and increased safety of navigation in the NSR. It is noted that despite the revival of transport infrastructure in the western part of the NSR, its eastern part is characterized by a depressed state. The main drawback of the Northern Sea Route is the severe natural conditions that limit the navigation time. Special attention is paid to the Russian nuclear icebreaker fleet. Both its current state and promising nuclear icebreakers, which are currently under construction or in the design stage, are considered. The main requirements for the characteristics of nuclear icebreakers are identified, which are necessary for their effective use on the routes of the Northern Sea Route in the context of increasing volumes of cargo transportation. Thus, an important requirement for maintaining the growth in cargo traffic is to ensure year-round icebreaker assistance to cargo ships along the Northern Sea Route. There is a need for the construction of new nuclear-powered icebreakers due to the expiration of the lifetime of nuclear icebreakers of the Arctic and the Taimyr classes. In the future, in the next decade, the main core of the Arctic nuclear icebreaker fleet should be universal icebreakers capable to provide icebreaking assistance for ships both in coastal areas and estuaries and in the western part of the Arctic.

1. Introduction

The Northern Sea Route (NSR) is the shortest sea route between the Far East and European Russia, which runs through the Arctic Ocean and the Bering Sea. The Arctic zone of the Russian Federation is a specific region, which together with the sea zone and continental shelf occupies about 30% of the country’s territory. The strengthening of Russia's multi-purpose presence in the Arctic and the socio-economic development of this region largely depends on transport communications.

At the current stage of development of the Arctic zone of Russia, long-term target programs typically prevail, which implies a detailed scientific, technical and economic justification of large-scale projects, taking into account their impact on the environmental security of the region [1], [2], [3]. The development of the Arctic resources requires a clearer understanding of the possibilities for using its transport corridors [4], [5].

In that regard, the development of the Northern Sea Route is strategically important. Besides Russia's internal interests, the NSR is also of great importance for the other countries of the Eurasian continent as the shortest transport route between Europe and Asia [6].
Constant growth in the volume of goods exchange, in the context of globalization, increases the load on existing transport systems. At the same time, maritime transport is currently the most cost-effective and accounts for more than half of all world freight traffic [7], [8]. Climate warming, which has been progressing in the last decade, makes it possible to increase the navigation time along the Northern Sea Route. The Northern Sea Route is an alternative to the Panama and Suez transport canals. Thus, in particular, by 2025 China plans to carry out up to 20% of sea freight traffic along the NSR highway [9]. The member countries of the Arctic Council Special express particular interest to the NSR as a transport highway leading to the Arctic [10], [11], [12]. The members of the Council, besides Russia, are the USA, Canada, Norway, Denmark, Iceland, Sweden, and Finland.

With regard to the above, it seems relevant to analyze the state of the Arctic maritime transport system in terms of current economic conditions and the potential development of maritime transport vehicles for cargo transportation.

2. Current state and potential of the Northern Sea Route

Since 2016, there has been a trend of increasing maritime freight traffic:

- 2016 - 7.3 million tons;
- 2017 - 9.93 million tons;
- 2018 - 20.2 million tons;
- 2019 - 31.5 million tons;

The analysis of the volume of transportation at the NSR shows that the dynamics of cargo transportation mainly depends on the transport development of oil and gas fields in the Arctic. An increase in maritime safety in the waters of the NSR, achieved through monitoring and information support of icebreaker assistance and ice pilotage by the NSR Administration also has a positive impact on the growth of transportation volumes.

The main users of the Northern Sea Route in Russia are companies engaged in the extraction and processing of natural resources, primarily in the energy sector (NorNickel, Gazprom, Lukoil, Novatek, Rosneft) [13]. At the end of 2018, the total share of oil, petroleum products and LNG transportation in the cargo structure was approximately 90%. Transit cargoes accounted for no more than 1% of the cargo traffic. According to the annual planned volumes of cargo traffic at the NSR established by the Complex plan of modernization and expansion of the mainline infrastructure by 2024, it is planned to increase the volume of cargo traffic up to 80 million tons. The achievement of this indicator directly depends on the results of investment projects for the extraction and processing of mineral resources. According to the Ministry of Energy, the recoverable reserves of oil and gas in the Arctic region of the country amount to 260 billion tons of equivalent fuel or 60 percent of all recoverable hydrocarbon resources in Russia. To achieve the projected volume of cargo turnover, it is necessary to fully provide the entire Northern Sea Route and port infrastructure with a sufficient number of icebreakers and reinforced ice class vessels, to ensure defence in the waters of the NSR. It should be noted that at present the NSR is characterized by the revival of transport infrastructure mainly in the western Arctic region. The Murmansk-Dudinka route is also navigable year-round in this area to support the operations of the Norilsk Mining and Metallurgical Company.

However, at the moment, the depressive state of the NSP remains in the eastern part of the Arctic. In addition, Federal Agency for Marine and River Transport in its 2018 report informs that the degree of technical equipment on the NSR routes was 40% (2019 Cargo transportation in Russia: Current statistics review Bulletin on current trends in the Russian economy 53 Available from https://ac.gov.ru/archive/files/publication/a/24196.pdf [Accessed 07 March 2020]. The main shortcoming of the Northern Sea Route is the severe natural conditions that limit the navigation time. Year-round operation of the NSR is possible only if the route is provided with nuclear icebreakers, which increases its cost. At the same time, icebreaking ships existing in Russia provide a channel for escorting ships of no more than 30 m wide [14], which is not suitable for large tankers of the Panamax and the Snesmax classes (40 and 50 m respectively).
Moreover, one of the main directions of maintaining stable development of the Northern Sea Route is ensuring the safety of ships and infrastructure on all routes from the impact of natural and man-made threats. Due to the large territorial length of the NSR, it is most rational to use both satellite and air monitoring systems that can effectively provide all the necessary information to the coordination centers. The use of unmanned aerial surveillance systems (AAS) by the Russian Emergencies Ministry contributes to the organization of effective intelligence and information activities to resolve the issue of interagency exchange of forces and means of other agencies, such as the Ministry of Defense and the Ministry of Transportation. The need to monitor the entire NSR is also achieved through the use of ground-based measuring systems. It should be noted that AAS and ground-based systems do not duplicate, but only complement each other, solving independent tasks, such as, for example, monitoring transport highways and other elements of the NSR.

3. Current state of the icebreaking fleet of Russia

The maximum number of icebreakers operating in the Arctic, both nuclear and diesel-electric, reached 18 in 1989. By 2002, there were 12 left: 7 nuclear and 5 diesel-electric icebreakers. At present, the Russian icebreaker fleet consists of 38 ships, including nuclear, diesel-electric and diesel-powered icebreakers.

At present, the nuclear icebreaker fleet includes four vessels of two types. These are the icebreakers the Yamal and 50 Let Pobedy of project 10520/10521 Arktika (49 MW), as well as the Taimyr and the Vaigach of project 10580 (32.5 MW), and The Sevmorput nuclear-powered icebreaking LASH carrier and container ship and five service vessels. Since the age of the operating nuclear icebreakers has approached the critical one, the issue of extending their service life should be discussed. Thus, three icebreakers of the Arctic type: the Siberia, the Russia, and the Soviet Union were decommissioned. The service life of the reactor plants installed on the icebreakers currently in operation has been extended. In accordance with the work completed, the end of operation of nuclear-powered icebreakers is going to be:

- 50 Let Pobedy - 2035;
- The Yamal - 2028;
- The Taimyr - 2026;
- The Vaigach - 2024;

Between 2008 and 2016, five diesel-electric icebreakers of project 21900 with a capacity of about 18 MW were commissioned. From 2015 to 2016 the construction of three 16 MW diesel-powered icebreakers was completed. 8 icebreakers of various capacities from 6.8 to 60 MW are under construction. Since the mid-70s, 21 icebreakers of 1101, 1105, 1108 and 1191 projects were built in Finland for the USSR, and 20 of these vessels are still in operation. Their main operator is Rosmorport, but several vessels are owned by the Lena United River Shipping Company and Norilsk Nickel. The age of most Russian diesel-electric icebreakers exceeds 35 years. From 2020 their number will begin to decrease due to the end of their lifetime [15,16].

At present, the Yamal LNG is served by 7 gas carriers, but only one of them is owned by the Russian company Sovcomflot, all tankers are the Yamalmax class. The capacity of these gas carriers is 172.6 thousand cubic meters. They can operate at temperatures of up to minus 50 degrees and are capable of passing ice of 2.1 m thickness.

The accelerated launch of the Yamal LNG and the Arctic LNG is necessary to accelerate the expansion of the gas carrier fleet. In this regard, Novatek has placed an order for the construction of 15 gas carriers with delivery dates in 2022, 2024 and 2025.

In 2017, the Ilya Muromets multi-purpose patrol icebreaker of project 21180 was put into operation as part of the ice-breaker group of the Russian Northern Fleet. Its task is to escort ships and vessels, provide assistance and, if necessary, take part in combat operations.
4. Promising Russian icebreaker-class ships to provide cargo transportation along the Northern Sea Route

As noted above, it is planned to increase the volume of cargo transportation up to 80 million tons by 2024. To master the planned indicators on the NSR routes, several requirements must be met:
- Year-round shipping along the Northern Sea Route, which requires a sufficient number of icebreakers to meet the requirements;
- The use of heavy transport vessels on the NSR routes, which requires the use of icebreakers capable of laying a 45-50 m wide channel;
- The main technical indicators that determine the efficiency of icebreaker operation are [17]:
  - Width of an icebreaker: the wider the channel the icebreaker can make, the wider the cargo vessel will be able to pass through the NSR routes. The existing icebreakers are 30 m wide, which is enough to carry vessels with displacement up to 70 thousand tons;
  - Water-displacement: the higher this indicator is, the higher is the kinetic energy of the icebreaker, allowing to pass the existing obstacles more confidently. Nuclear-powered icebreakers that are currently in operation have a displacement of 19 to 20.9 thousand tons;
  - Ice breakthrough: this indicator determines the thickness of ice in which the icebreaker can lay a channel. The ice conditions on the Arctic water surface are very diverse. The annual ice thickness is 0.8 - 1.8 m, the perennial ice thickness is 3 - 4 m, in some cases the thickness can reach 10 - 15 m.
  - Speed of movement on flat ice: this indicator characterizes the speed at which the icebreaker will pass through the ice of a certain thickness. To keep the effect of winning in the distance and, consequently, in time, when the transport vessel follows the NSR, it is necessary to ensure the average speed when passing through the ice fields on the NSR as 9.3 knots, on other areas as 14 knots.

The core of the Arctic icebreaker fleet should be universal nuclear-powered icebreakers capable of ensuring guaranteed cross-country ability both in coastal areas and estuaries of Siberian rivers and in the western part of the Arctic with an 2.8-2.9 m.

At present, three nuclear icebreakers of project 22220 LK60 are under construction in Russia. The main universal nuclear icebreaker of this project, the Arktika, was launched on June 16, 2016. At the beginning of March 2020, it is undergoing sea trials, the start of operation is scheduled for May 2020. The deadline for delivery of the remaining two icebreakers of project 22220, the Siberia and the Ural, is scheduled for the end of 2020 and the end of 2021, respectively. Comparative characteristics of the nuclear icebreakers of projects 22220, 1052, 1058 are presented in Table 1.

| Feature       | Project 1052 | Project 10580 | Project 22220 |
|---------------|--------------|---------------|---------------|
| Length, m     | 148          | 150           | 173.3         |
| Width, m      | 30           | 29.2          | 34            |
| Displacement, t | 20 900     | 19 600        | 33 530        |
| The ice rush, uh. | 2,25       | 1.7           | 2.8 – 2.9     |
| Power on shafts, kW. | 49 000   | 32 500        | 60 000        |

The main purpose of the universal nuclear icebreakers of the project 22220 is to replace the icebreakers of the projects the Arctic and the Taimyr as they are decommissioned. Due to the two-ship design embedded in the nuclear-powered icebreakers of project 22220, they can work effectively both at the mouths of Siberian rivers and on the NSR routes. However, the icebreakers of this project will not be able to provide year-round navigation along the whole route of the NSR, in the eastern part of the Arctic they can be used only in the summer-autumn period. The assigned lifetime of the icebreakers of this project is 40 years with the possibility of its prolongation up to 50-60 years (18).

The most perspective project is a designed nuclear icebreaker of 10510 of the Leader type. The main feature of the designed nuclear-powered icebreaker is the ability to provide the year-round navigation along the Northern Sea Route, as well as increased hull width up to 47.7 m, which will allow carrying
out large-capacity vessels, including gas tankers, with the displacement of up to 100 thousand tons, throughout the Northern Sea Route. The Leader will also be able to lay deep-water routes in river mouths. Construction of the first icebreaker is expected to begin in 2020, and the commissioning date is scheduled for 2027. The main technical characteristics of the designed icebreaker are shown in Table 2.

Table 2. Technical characteristics of an icebreaker of project 10510 The Leader

| Feature                  | Project 10510 |
|--------------------------|---------------|
| Length, m                | 209           |
| Width, m                 | 47.7          |
| Displacement, t          | 70 674        |
| Power on shafts, kW.     | 120 000       |
| The ice rush, uh.        | 4.3           |
| Main area of operation   | Year-round: all Arctic regions |

In addition to nuclear-powered icebreakers, Russia is building the Viktor Chernomyrdin diesel-electric icebreaker with a capacity of 25 MW, a width of 29 m and a maximum ice-throughput of 2 m. This icebreaker has several unique features, so, unlike the previous generation icebreakers, it has higher maneuverability, remote positioning systems, and two helicopter complexes.

For renewal of the port infrastructure vessels by the Rosmorport’s, a port icebreaker with ice-throughput up to 1 m is under construction, the delivery of the vessel is scheduled for 2021. It is envisaged that the vessels of this project will be equipped with 6.4 MW engines. In its turn, Atomflot is building two 5 MW ice class tugboats and two 7 MW reinforced tugboats, and a 12 MW port ice-breaker.

To operate at the Arctic terminal of the Novoportovskoye field, Gazprom Neft is building two icebreakers capable of operating in solid ice up to 2 meters. They are equipped with an advanced maneuvering system and energy supply automation.

5. Conclusion
As it has already been noted, one of the main priorities of Russia in the Arctic is the development of the Northern Sea Route, in particular, the increase of cargo turnover up to 80 million tons by 2024. Most of the cargoes transported along the NSR routes are oil, oil products, liquefied natural gas, coal, mineral fertilizers, various industrial equipment, so the main condition for achieving the specified cargo turnover is the expansion of the icebreaker, cargo, and auxiliary fleet.

Thus, there is a need for tugboats of the high ice class to provide ice-breaking assistance in freezing ports. In addition, due to the fast obsolescence of the existing diesel-electric icebreaker fleet and only one icebreaker the Viktor Chernomyrdin under construction, there may be an acute need for vessels capable of operating in ice about 2 m thick and in coastal areas. Because of the decommissioning of the nuclear-powered icebreakers the Taimyr and the Vaigach, 2 nuclear-powered icebreakers need to be built in addition to the icebreakers of project 22220 under construction to provide cargo transportation until 2026.

It should be noted that in addition to the construction of new icebreakers, the further development of the Arctic region requires the development of coastal infrastructure, in particular the eastern Arctic region [19-21]. If all the tasks are successfully completed, the Northern Sea Route will allow solving any issues related to the development of the Arctic territories [22-24]. Construction of new nuclear-powered icebreakers and development of port infrastructure will allow using ships more than 40 m wide with the displacement of more than 100 thousand tons for cargo transportation.

In general, to summarize, we can say that in the future up to 2030 and beyond, we should expect a large-scale growth of the Arctic freight traffic. The main determinants affecting this scale will be:
- The rate of development of the Arctic shelf deposits;
- Hydrocarbon demand in the Asian Pacific market;
- Modernization of port infrastructure in the Arctic;
- Construction of the ice fleet.

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