Investigation of the Bottom Relief Change Processes under the Action of Wind-generated Waves, Currents, and Ice Cover in the Russian Section of the Approaches to the Coast of the Designed North-European Pipeline Route

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A.N. Dobrotvorsky, S.A. Druzhevskiy, the State Research Navigation-Hydrographic Institute, MoD of the Russian Federation

The analysis of the world practice has shown that the marine oil and gas industry is one of the most dangerous kinds of the human activities, and the submarine pipelines, being one of its components, are complicated, expensive and potentially dangerous industrial objects. Therefore, when designing such objects in accordance with the requirements of the international standards and Russian normative documents, it is necessary to find the correct relationship between the expenditures and the level of allowable risk. Even in the countries that have been carrying out the exploration and exploitation of the marine oil and gas fields for the recent 30-35 years there remains the probability of the design, technological, construction, and exploitation errors.

In spite of this, it is impossible to realize the export potential of such country as Russia without creating the large marine pipeline systems. The project of the North-European pipeline that will provide the supply of the natural gas to the countries of West Europe along the bottom of the Baltic Sea is one of these projects. The system of DNV-2000 standards is accepted as the normative basis for designing and construction of the North-European pipeline, according to which, in the framework of the Conceptual project development, the problems of classifications, analysis, evaluation and risk control procedures were considered.

Special attention to the problem of operational safety provision for the North-European pipeline, as distinct from the other similar main pipelines, is caused by the specific features of the area where it is to be laid, due to the specific ecological status of the Baltic Sea defined by a number of the signed and ratified international documents.

The analysis of the statistical data on exploitation of the submarine pipelines has shown that among the dangers able to cause the damage to the submarine pipeline not insignificant role is played by the marine environment phenomena.

Among the dangerous factors of this group are various meteorological and hydrological parameters, such as waves, currents, ice cover, as well as the lithodynamic processes caused by them; their extreme values cause the maximum stresses and nonstandard operational

regimes of the marine pipeline. The qualitative risk analysis has shown that the shallow-water areas where the pipeline approaches the coast are the most dangerous sections, as far as the natural factors are concerned, for which the degree of risk is "very high".

To determine and take these factors into account, the specialists of our Institute carried out theoretical and experimental investigations covering the processes of the bottom relief change under the action of the wind-generated waves, currents and ice cover in order to optimize the design solutions for laying the North-European pipeline routes at the approach section near the Portovaya bight, in the Gulf of Finland of the Baltic Sea.

The calculations were based on the analysis of the fund materials and results of investigations for the previous years, using the mathematical modeling. The following models were used:

- the model of the nearwater atmosphere layer, allowing to calculate the atmospheric parameters (including the wind speed and direction) using the basic synoptic data (from the maps of the surface atmospheric pressure and synoptic stations data);
- the hydrodynamic model of the water mass circulation describing the wind drift and positive and negative surge;
- the model of wind-generated waves that enables to calculate not only the elements of wind-generated waves but also the wave movements throughout the depth;
- the model of the bottom relief change as a result of action of ice formations;
- the model of sediment transport in which the results of calculations from the above-mentioned models are used as the basic data.

In order to verify the mathematical models, the experimental investigations were carried out in the area of the Portovaya bight. They included: two hydrographic surveys, before and after the storm event; soil survey with laboratory studies of granulometric composition of the bottom samples; hydrolocation survey in order to determine the geometric dimensions of the furrows made by the keels of the hummocks and grounded hummocks; measurements of waves, sea level, air temperature, atmospheric pressure, wind direction and speed in the area of pipeline outfall ashore.

Based on the general meteorological, hydrological and morphometric information as well as the data on the bottom sediments distribution, the mathematical modeling enables to get the final answers concerning the lithodynamic processes character.

The following results were obtained by numerical calculations:

- extreme values of the wind speed, extreme and mean values of wave heights and periods at the wave-dangerous directions for the points with different water depth at the approaches to and inside the Portovaya bight and possible once in N years;

- speeds of wave movements in shallow water at points with different water depths, at distances from the bottom equal to 0.5 diameter and to 1.0 diameter of the pipeline being designed, taking into account the occurrence and the absence of the surge;
- values of the vertical profiles for the stationary currents and level surface in the Portovaya bight at extreme wind speeds;
- statistical data and results of expert estimate for the ice conditions and ice dynamics in the investigated areas, based on the processed results of the air photography;
- parameters of the possible bottom exaration by the ice formations in the form of maps showing the exaration probability distribution of the given depth for the given area in the given month of the ice season;
- forecast of the bottom relief deformations caused by the sediment transport, ripple formation processes, and deformations connected with relief mesoform formation.

Complex analysis of the obtained results has shown that for a given site the bottom scour does not play a significant role, and the choice of the trench for laying the pipeline is determined by the maximum depth of the ice exaration possible once in 100 years in accordance with the DNV standards requirements. At the same time, the calculations have shown that the length of the pipeline to be laid in the trench can be decreased.

The values of the extreme hydrometeorological parameters obtained as a result of modeling adapted specifically for the given area and describing more accurately the wave processes and their influence on the stability of the submarine structures under the conditions existing in the shallow-water areas of the Baltic Sea, were found to be less conservative than those calculated by the traditionally used standard JONSWAP models, which will allow to reduce the thickness of the cement tube coating, and increase the length of the allowable free spans when calculating the stability of the marine pipelines.

Thus, the results of this work, taking the other factors into consideration (dangers of technogenous origin, defence and economic activities at sea, etc) show, as a preliminary, that it is possible to reduce the work volume and, correspondingly, to reduce the construction cost estimate without increasing the risk level.