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Mathematical Modelling of Floating Anchored Objects Behavior under Ice Influence

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ABSTRACT

The paper describes the realization of the dynamic ice loads calculation method. The technique can be used in research or design works related to the development of the new floating objects for the Arctic conditions.

The paper considers the mathematical models of the floating anchored structure behavior under the influence of the level ice, the consolidated part and the keel of ridge. All listed models are combined into one algorithm for the description of floating structure behavior under the influence of the ice formations. There are some results of comparative calculations which confirm the working capacity of the offered techniques presented in this paper.

KEY WORDS: Dynamic ice loads, calculation method, floating anchored structure, level ice, consolidated part of ridge, keel of ridge.

INTRODUCTION

Provision of the necessary facilities for the marine hydrocarbons fields is related to the creation of floating objects working in the high sea for a long time. When developing the deep-water deposits floating anchored objects seem the most promising.

As a rule, the influence of ridges on anchored objects is studied during their designing. Anchored structures, unlike fixed, possess an essential pliability therefore ice loads on these objects depend on structures' movement. Nevertheless, prior estimation of ice loads is quite often carried out without dynamic aspects of this interaction.

The purpose of the present work is the development of the methodology for the dynamics analysis of the interaction between the ice formations (level ice and ridges) and the anchored floating structures.

The static (quasi-static) loads on the motionless constructions have been studied for many years now and the calculation methods for these objects are more or less well known. The basic feature of floating structures is their pliability. That's why loads in this case grow out of the ice/moving object interaction and should be considered in dynamics. And the other feature of the floating anchored structures is that for their safety analysis not only the knowledge of loads is required but also of an anchor systems reaction. A number of laboratory experiments and theoretical researches show that the dynamic interaction - comparing it with the static approach - can lead in some cases to an increase in loads or forces in anchor lines whereas in others - to the decrease in them.

The present paper offers a research method based on the parametrical analysis of the phenomenon: its aim is to define ice loads and tensions in anchoring lines by generalizing the calculation results (using the program developed by the authors) for a wide set of ice conditions, parameters of structures and anchor lines characteristics. The mathematical modeling results are meant to be the material basis to reveal the dependences connecting, on the one hand, ice conditions, construction characteristics, parameters of anchoring lines and, on the other hand, loads and the reaction of anchor system.

PROBLEM STATEMENT AND SIMULATION METHOD

Mathematical simulation of the interaction between ice formations and floating anchored objects is based on a number of the restrictions and assumptions stated below.

- Studying of the ice loads changing in time (from level ice and ridges)
- Considering the load from a ridge as the sum of loads (during the same moments of time) from the consolidated part and the ridge keel defined independently. In spite of inaccuracy this and the subsequent assumptions are used widely.
- Calculating the load of the consolidated part of a ridge by the same technique as the calculating the one of the level ice.
- Defining the load from the ridge keel in quasi-static approach: keel moves with the set speed and the instant load value is proportional to the keel/structure contact area during the considered moment of time. The object surface is divided into elements and a load on each element depending on its area, position is defined in each time moment.

Thus the program considers both quasi-static and dynamic effects. Solving the problem of interaction between level ice or a ridge and the structures is enabled at following preconditions.

Structure

- Representing the structure surface as flat inclined panels which can be in contact with the level ice, the consolidated part of a ridge or its keel. The total ice load on a structure is defined as the sum of the ice actions on the loaded panels.
- Considering the influence of water on the structure movement by introducing the added masses and hydrodynamic damping factors for each degree of freedom in the movement equations.
- The anchor system being comprised of cables, chains and buoyancies. The anchor lines dynamics is examined. The influence of the surrounding water is taken into account by introducing the added masses and the hydrodynamic damping factors of the anchor lines elements.

Ice action calculation (level, rafted ice and consolidated layer)

- It is supposed that ice formations move with the set horizontal speed along a known direction. Neglecting ice floes rotation round a vertical axis and cross-section movement we will believe that