ABSTRACT

This paper discusses mathematical models of iceberg towing that considered iceberg shape characteristics in an explicit form. These models allowed to analyze oscillations appearing in towing system at the stage of the beginning of the movement of the system and during its mode change, when dynamic action is applied into stationary towing process. The obtained results showed good consistency and wide possibilities for investigation of non-linear processes appearing in the single line iceberg towing systems. Evaluation of the forces peak values allowed to formulate recommendations for safe and efficient iceberg towing operations.

KEY WORDS: Arctic; iceberg towing; tow line tension, numerical modelling, oscillations.

INTRODUCTION

For safe prospecting and exploration of the Arctic shelf a complex ice management system is required. Physical impact on drifting icebergs is one of the means to prevent their collision with offshore drilling rigs. The most effective way of changing iceberg’s drift trajectory is its deflection with the help of a tug vessel equipped with special towing system. This operation is complicated by a number of technological challenges associated with the iceberg and towing system interaction, their dynamics, etc. Some of the recently published works are devoted to theoretical study of the iceberg towing process works (Eik et al., 2010; Yulmetov et al, 2016; Yulmetov et al., 2017; Marchenko et al., 2005).

In (Marchenko, 2010; Sazonov, 2010) the issues of the towing process stability have been analytically investigated, as well as a numerical study of the oscillations appearing in the “vessel-rope-iceberg” system. At the same time, authors underline the need to reduce the vessel acceleration time at the beginning stage of towing due to maneuverability problems experienced by the vessels at low speeds. At present, problems of dynamical processes taking place in the towing system and significantly affecting safety and reliability of the icebergs towing process remain to be the least investigated. The above mentioned publications include very rough approximations of the icebergs’ shape, that significantly affects dynamics of their behavior in towing process and, hence, the appearing oscillations.

Description of the dynamic processes appearing in the iceberg towing system is a difficult task that requires a comprehensive assessment of possible external impacts on the mechanical system, as well as reasonable consideration of the physical model's assumptions.

Mathematical and numerical modeling can specify and refine the analytical results, and give a more substantiated assessment of the “vessel-rope-iceberg” system dynamics influence on the peak loads during iceberg towing.

In this work, numerical mathematical models have been implemented, which made it possible to take into account explicitly the individual features of the shape of icebergs, and to analyze the oscillations arising in the towing system at the stages of the beginning of the movement of the system and changing the mode of movement when a dynamic disturbance is introduced into the process of stationary towing.

MATHEMATICAL MODEL

In order to create general 3D mathematical model of the iceberg towing non-stationary process with regards to environmental characteristics, it is required to employ mathematical tools of continuum mechanics. Using apparatus of fundamental conservation laws it is possible to build a coupled system of non-linear equations, that will give with minimum assumptions the full description of the processes taking place in the “vessel-rope-iceberg” system.

Solution of the obtained system is possible only using numerical methods with space-time sampling and requires significant