Effect of iceberg shape on wind force parameters

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ABSTRACT

The article examines iceberg movement under the influence of wind force, with detailed analysis of the influence of the iceberg shape (both underwater and above) on the parameters of this movement. For four icebergs, studied during 2016-2017 trials, hydrodynamic characteristics of the under- and above-water parts were determined by the means of numerical and basin modeling. For these icebergs orientation, direction and speed of movement are calculated for different wind speeds and directions. Regression between the wind load on the iceberg under wind load.

METHODOLOGY OF NUMERICAL MODELING

The purpose of numerical modeling is to determine the positional components of the hydrodynamic characteristics of the iceberg underwater and above-water parts in the case of uniform motion at different heading angles.

The turbulent flow of a viscous incompressible ponderable fluid can be described by the averaged equations of continuity and Reynolds (1,2):

\[
\frac{\partial (\bar{u}_i)}{\partial t} + \frac{\partial \langle u_i u_j \rangle}{\partial x_j} = - \frac{1}{\rho} \frac{\partial \bar{p}}{\partial x_i} + \nu \frac{\partial^2 \langle u_i \rangle}{\partial x_i \partial x_j} - \frac{\partial \langle u_i u'_j \rangle}{\partial x_j}
\]

where \( u \rightarrow \) velocity field \([m/s]\), \( t \rightarrow \) time \([s]\), \( \rho \rightarrow \) density of the fluid \([kg/m^3]\), \( \nu \rightarrow \) kinematic viscosity \([m^2/s]\), \( p \rightarrow \) pressure \([Pa]\).

It is assumed here that the motion of the fluid is absolute and the flow region moves relative to a fixed coordinate system.

To close the Reynolds equations, the (3,4,5) gradient-diffusion hypothesis and the k-\( \omega \) SST turbulence model (Menter, 1994) are used:

\[
\nu_t = \frac{\alpha_1 k}{\max(\alpha_1 \omega, S F_2)}
\]

\[
\frac{\partial k}{\partial t} + \langle u_i \rangle \frac{\partial k}{\partial x_i} = P_k - \beta^* k \omega + \frac{\partial}{\partial x_j} \left( (v + \sigma_k \nu_t) \frac{\partial k}{\partial x_j} \right)
\]

\[
\frac{\partial \omega}{\partial t} + \langle u_i \rangle \frac{\partial \omega}{\partial x_i} = \alpha S^2 - \beta \omega^2 + \frac{\partial}{\partial x_j} \left( (v + \sigma_\omega \nu_t) \frac{\partial \omega}{\partial x_j} \right) + 2(1-F_3)\sigma_{w2} \frac{1}{\omega} \frac{\partial k}{\partial x_i} \frac{\partial k}{\partial x_i}
\]

\[
\delta = \frac{1}{\omega} \frac{\partial k}{\partial x_i} \frac{\partial k}{\partial x_i}
\]

where \( \nu_t \rightarrow \) kinematic eddy viscosity \([m^2/s]\), \( k \rightarrow \) turbulence kinetic energy \([m^2/s^2]\), \( \omega \rightarrow \) specific rate of dissipation of the turbulence kinetic energy into internal thermal energy \([1/s]\), \( F_3 \) and \( F_2 \) - blending functions, \( P_k \rightarrow \) production limiter, \( S \rightarrow \) strain rate magnitude, \( \alpha, \alpha_1, \beta, \beta^* \rightarrow \) constants based on (Menter, 1994).

The proposed methodology of the turbulent flow modeling of a viscous incompressible fluid is presented described in (Ali et al, 2019), and numerical modeling described in this work was carried out. Analysis of the numerical modeling results made it possible to divide regression dependences, as well as to clarify the behavior of a drifting iceberg under wind load.

KEY WORDS: ice management, iceberg, towing, drift, wind, shape

INTRODUCTION

For development of the Arctic shelf an important factor influencing iceberg safety is the possibility to assess in sea conditions one or another characteristic of an iceberg based only on the above-water part. For this research it is useful to refer to previously studied icebergs with a known shape of the surface and underwater parts. Informative data on the Russian Arctic icebergs are published in (May et al, 2019), (Buzin et al, 2016), (Buzin et al, 2020) and on the derived correlations of the iceberg’s above water shape in the papers:

• on iceberg stability (Kornishin et al, 2020);
• on towing load (Pashali et al, 2018), (Kornishin et al, 2019), (Efimov et al, 2019);
• on iceberg detection distance (Pavlov et al, 2018).

The same philosophy of research was chosen to study the wind impact on iceberg, including iceberg drift speed and its behavior under tow: during 2016-2017 trials aerial photography and sonar survey of icebergs were performed, then 3D models of icebergs were constructed.