Marine Structures 57 (2018) 72–86

Contents lists available at ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Ice loads on inclined marine structures - Virtual experiments on ice failure process evolution

Janne Ranta [a, b, *], Arttu Polojärvi [a, b], Jukka Tuhkuri [a, b]

[a] Aalto University, School of Engineering, Department of Mechanical Engineering, P.O. Box 14300, FI-00076 Aalto, Finland
[b] Sustainable Arctic Marine and Coastal Technology (SAMCoT), Centre for Research-based Innovation (CRI), Norwegian University of Science and Technology, Trondheim, Norway

A R T I C L E I N F O

Article history:
Received 17 January 2017
Received in revised form 17 August 2017
Accepted 20 September 2017

Keywords:
Ice load
Ice failure process
Marine structures
Arctic
Finite-discrete element method
Time-series analysis

A B S T R A C T

Failure of level ice against an inclined marine structure has been simulated using a two-dimensional finite-discrete element method. The simulation model is deterministic, but very sensitive to initial conditions. This allowed us to create ice load data and to study the evolution of the ice failure process. The mean load, the standard deviation, and the maximum load increased during the ice failure process. Ice thickness had a strong effect on the ice load and also the plastic limit of ice had an effect, especially when the ice was thick. The coefficient of variation of the ice load was initially high and then continuously decreased during the ice failure process. This suggests that the ice failure process did not reach a stationary stage, showed high probability of extreme peak loads, and that distributions with a constant coefficient of variation should not be used for this kind of ice loading processes. Extreme value analysis, with the assumption that the ice load follow a log-normal distribution on each time step, fitted the data well and suggested that the maximum ice load increases with sample size. Further, it appears that the peak ice loads are bounded by the crushing capacity of the ice even in the case of an inclined structure. The statistical analysis of simulated ice load data further suggests that observations from short interaction processes, or with small sample sizes, may lead to very inaccurate ice load estimates.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Arctic marine operations increase continuously. This includes developments in Northern sea transportation, offshore drilling operations, and offshore wind energy. The Arctic is a sensitive environment and imposes stringent safety requirements for all operations. One of the key factors in developing safe Arctic operations is a reliable prediction of sea ice loads. Sea ice loads are induced by ice-structure interaction processes where the sea ice failure process has a key role. This paper focuses on the sea ice failure process against an inclined, rigid marine structure and the related ice loads. Inclined structures are often used in Arctic offshore installations, since the ice loads caused by bending of an ice sheet are traditionally assumed to be lower than the ice loads due to ice crushing [1].

* Corresponding author. Aalto University, School of Engineering, Department of Mechanical Engineering, P.O. Box 14300, FI-00076 Aalto, Finland.
E-mail address: janne.ranta@aalto.fi (J. Ranta).

https://doi.org/10.1016/j.marstruc.2017.09.004
0951-8339/© 2017 Elsevier Ltd. All rights reserved.

Full-scale experiments are invaluable to the understanding of ice-structure interaction processes. Measurements have suggested that peak ice loads are stochastic [2,3] and the results from full-scale (and also from model-scale) experiments show wide scatter. The scatter is due to several reasons, including natural inhomogeneity of sea ice and the practical difficulties in conducting field measurements; but the end result is that it is challenging to repeat an experiment with the same parameters. This makes analysis of the data challenging. A further obstacle to reliable predictions of ice loads is the limited availability of experimental data, and new approaches on studying ice loads are beneficial.

Here we aim to increase the understanding of ice loads on marine structures by first creating a large amount of ice load data through two-dimensional finite-discrete element (2D FEM-DEM) simulations, and then performing a statistical study on the simulated ice load data. In our simulations, an initially continuous ice sheet, modeled as a homogeneous floating beam, breaks into ice blocks as the ice sheet is pushed against an inclined structure with a constant velocity (Fig. 1). In a simulation, the ice blocks that have broken off the ice sheet interact with each other and with the structure. Discrete approaches, where individual ice features are accounted for with some level of accuracy, have been used in a number of studies on ice mechanics [4–21].

Our 2D FEM-DEM simulations of the ice-structure interaction process are deterministic, but they indicate that the process is sensitive to its initial conditions [22]. We could use this sensitivity to create sets of simulations using the same simulation parameters, but different initial conditions as follows. For a *set of simulations*, we conducted 50 simulations with constant parameters while the vertical initial velocity v_0 at the free end of the ice sheet was given a random value of the order of 10^{-12} ms^{-1} (see Fig. 1). This was enough to cause different ice failure processes and give us ice load data.

This way of obtaining ice load data contrasts with the earlier studies on the statistics of ice loads which in general have been done using full-scale data from ships [23–25] and offshore structures [3,26–31]. A simulation-based study enables us to look into the statistics of peak ice loads with full control on the parameters. We have already used simulations to study ice load statistics in Refs. [22] and [32]. In Ref. [22] we performed a multivariate regression analysis to find the most important parameters affecting the ice loads, and in Ref. [32] we looked into the statistics of maximum peak ice load values in the interaction process.

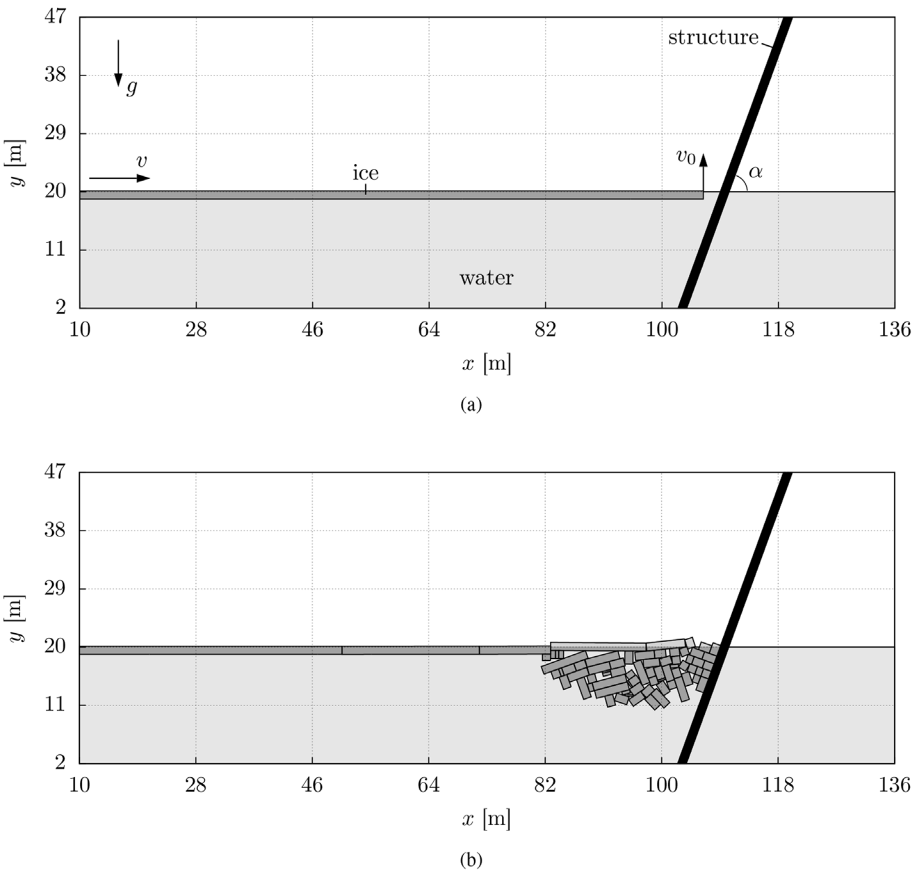

Fig. 1. (a) Simulation set-up: A floating ice sheet (dark grey) is pushed with a velocity of $v = 50$ mms^{-1} towards an inclined ($\alpha = 70^\circ$) structure (black). The water is colored light grey. A perturbation for the initial conditions was created by giving a low vertical velocity v_0 for the free end of the ice sheet. v_0 was of the order of 10^{-12} ms^{-1} and varied randomly between all simulations. (b) A snapshot from a simulation at a stage where the length of the pushed ice $L = 125$ m. Ice thickness $h = 1.25$ m and plastic limit $\sigma_\mathrm{p} = 1$ MPa.

Download English Version:

https://daneshyari.com/en/article/4924997

Download Persian Version:

https://daneshyari.com/article/4924997

Daneshyari.com