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Limit Mechanisms for Ice Loads on Inclined Structures: Buckling

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Abstract

This paper focuses on the mechanisms and limits for the peak ice load values on inclined marine structures, and presents a buckling model, which explains well the phenomena behind the maximum peak ice loads. The study is based on two-dimensional combined finite-discrete element method simulations of the failure process of level ice against a structure. The simulations yield ice load records, which show consecutive peak ice load events. The complexity of the failure process makes the analysis on the mechanical phenomena behind the peak ice load events extremely challenging. The introduced buckling model assumes that the ice sheet breaks into separate ice floes in front of the structure before the maximum peak ice loads occur. The model is demonstrated to be able to quantify the effect of force chains, which have an important role in the ice-structure interaction process.

Keywords: Finite-discrete element method, Buckling, Ice mechanics, Arctic technology

1. Introduction

Arctic marine operations increase continuously due to the developments in Northern sea transportation and offshore drilling operations, and offshore wind energy. The Arctic is a sensitive environment and imposes stringent requirements for safety and efficiency of all operations. One key factor in developing safe Arctic operations is a reliable prediction of sea ice loads. Sea ice loads are induced by a complex ice-structure interaction processes where the sea ice failure process has a key role. Arctic offshore installations often have inclined walls, with an aim to provoke the ice to fail due to bending of the ice sheet. It is often assumed that the ice failure in bending causes lower ice loads than, for example, ice crushing.

The study reported here focuses on gaining understanding on what limits the maximum, or peak, ice load values on an inclined marine structure. We base our study on 2D combined finite-discrete element method (2D FEM-DEM) simulations. Figures 1a-f illustrate our simulations, which have a floating and continuous ice sheet pushed against an inclined rigid structure. During the interaction process, the initially intact ice sheet fails into a rubble pile of ice blocks, which then interact with each other and the structure. Similar approaches, where individual ice features are accounted for with some level of accuracy, have been used in a number of studies on ice mechanics (Williams