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NUMERICAL MODELING OF RATE PROCESSES DURING ICE-STRUCTURE INTERACTION

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ABSTRACT

The mechanics of the indentation of ice at low to moderate rates of loading is studied using the finite element method. The material model used for the simulation study consists of a multiaxial flow model and a smeared cracking model. The flow model is developed in the formalism of irreversible thermodynamics and, in particular, includes transient creep as an internal rheological variable. A multiaxial criterion is used in the smeared cracking model to predict tensile failure. To solve the initial boundary-value problem, a two-level iterative algorithm is developed. This uses an incremental-iterative method to solve the discretized finite element equations, and a Newton-Raphson technique to solve the constitutive equations of the material model. The objective of the investigation is to study (i) the effects of cracking and transient creep on the ice response, and (ii) the failure modes experienced by the ice sheet during indentation. The influence of velocity and indenter size on the global and maximum local pressures are also investigated. The accuracy of the solutions is examined by varying the time increment and the mesh size used in the analysis.

INTRODUCTION

The prediction of ice forces on fixed offshore structures is one of the classic problems in the study of ice indentation and impact. Recent studies have shown that the magnitude of ice forces is influenced by many parameters including (i) the environmental and loading conditions, e.g., temperature, rate of loading, and type of confinement, (ii) the structural state, e.g., the material integrity and the degree of textural anisotropy, and (iii) the size and shape of the indenter, the aspect ratio, and the type of contact between ice and indenter. Depending on some of these parameters ice can display very complex behavior including elasticity, delayed elasticity, viscous creep, distributed cracking or damage, and tensile cracking. Field observations and small-scale experimental investigations have shown that ice can fail by crushing, spalling, radial and circumferential cracking, buckling, and by a combination of these modes (see,