POAC '89 Conference, Lulea, Sweden

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CONSTITUTIVE MODELING OF POLYCRYSTALLINE ICE

Abstract

This paper examines the constituent elements of a numerical model for simulating ice-structure interaction processes. The discussion emphasizes the fundamental element of the model, i.e., the constitutive model, and compares the micromechanical approach to the macroscopic approach which is phenomenological but physically motivated. The appeal for the latter approach is underlined by the computational intractability of a micromechanical model in a complex initial- and boundary-valued problem, and the incomplete knowledge of the physical mechanisms of deformation in ice. The physically motivated phenomenological approach is elaborated in this paper using as an example the thermodynamic constitutive model proposed by Shyam Sunder and Wu (1988a, b) for flow in polycrystalline ice. Phenomenological equations have also been used to describe inelastic deformations of metals during hot-working (Brown et al., 1988), and of glassy polymers near the glass transition temperature (Boyce et al., 1988). Also discussed are the physical interpretation of material parameters and their determination from standard tests on ice, and the validation of the predictive capabilities of the numerical model.

1. INTRODUCTION

The ultimate objective of numerical modeling as applied to ice-structure interaction is the prediction of ice loads on structures. Within this broad objective at least two roles can be identified for a numerical model. The first is the simulation of field-scale problems without necessarily having to conduct field-scale experiments. This allows one to explore the sensitivity of the ice-structure response to various input parameters associated with the structure, materials and environment at comparatively little cost. Furthermore, a wide range of behaviors can be studied under controlled conditions, particularly those related to extreme conditions of loading.

A second role of numerical modeling is to help establish more rational engineering design procedures that lead to safe and economical systems. For instance, a parametric study enables the identification of field parameters (such as speed of ice feature, ice strength and interaction geometry) that have the most significant effect on the predicted ice force. These parameters could then be obtained with the greatest accuracy, thus improving the accuracy of prediction. Furthermore, on the basis of such studies parametric formulae can be established for design purposes. It may also help to optimize certain