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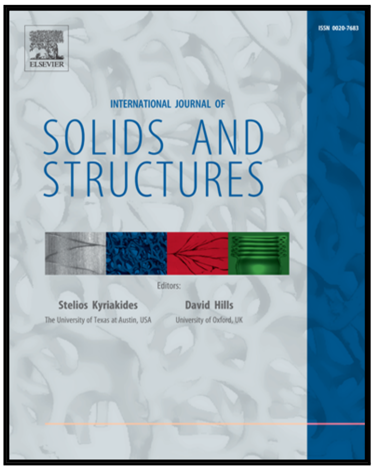

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A model for nonlinear hysteretic and ratcheting behaviour

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Abstract

We present a theoretical model to describe the response of a one dimensional mechanical system under cyclic loading. Specifically, the model addresses the non-linear response on loading, hysteretic behaviour on unloading and reloading, and the phenomenon of ratcheting under very many cycles. The methods developed are formulated within the hyperplasticity framework. The model can be expressed in the form of general incremental relationships, can therefore be applied without modification directly to any loading history, and can be readily implemented within a time-stepping numerical code. A rigorous procedure is described to accelerate the ratcheting process, so that the effects of very large numbers of cycles can be analysed through a reduced number of cycles. A generalisation from unidirectional to multidirectional loading is described, together with a tensorial form for application to material modelling. The original motivation was for the application to design of piles under lateral loading, and an example of this application is provided. However, the model is equally applicable to many other problems involving unidirectional or bi-directional cyclic loading in which the system exhibits a similar character of hysteretic behaviour, with ratcheting under large numbers of cycles.

Keywords: cycling, hysteresis, plasticity, ratcheting

1. Introduction

There are numerous problems in engineering in which the response at small strain (or displacement) is readily characterised as elastic; at larger strains a nonlinear response is observed; and unloading-reloading cycles exhibit hysteretic behaviour. The hysteresis often conforms closely to the "Masing rules" (Masing, 1926). This type of response can be described theoretically by multi-surface plasticity models with kinematic hardening. However, when very large numbers of cycles are applied, many such problems exhibit ratcheting (accumulation of strain or deformation). Our purpose here is to develop a modelling framework capable of capturing this ratcheting response.

The initial motivation for this model development came from the analysis of "monopile" foundations for offshore wind turbines under lateral loading, This is a problem in which many cycles of different amplitude are applied during the lifetime of the structure, and because of a bias in loading due to the predominant wind direction, ratcheting is a potential problem. We are

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