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# Dynamic inelastic structural analysis by the BEM: A review

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ABSTRACT

This review paper describes the most widely used techniques associated with the dynamic analysis of inelastic solids and structures by the boundary element method (BEM). Firstly, a historical overview is presented. Next, the various existing BEM formulations for dynamic analysis of two- and three-dimensional solids and structures as well as plates and shells are briefly described. Inelasticity refers to elastoplastic, damage or elastoplastic plus damage material behaviour. Then, five numerical examples from the literature and three new examples of the authors are presented to illustrate the applicability and accuracy of these boundary element methodologies. Finally, advantages and disadvantages of the various methods as well as future developments are presented in the conclusions.



## 1. Introduction

Structures which are subjected to severe dynamic loads exhibit inelastic material behaviour. Thus, dynamic inelastic analysis of these structures has become an essential part of their design process. Realistic dynamic inelastic analysis of structures is carried out exclusively by numerical methods due to its high complexity. In the last four decades, with the drastic evolution of digital computers, the finite element method (FEM) has assumed the leading role in this type of analysis as applied to practical problems [1]. The boundary element method (BEM), which is about two decades younger than the FEM, plays a secondary role in practical dynamic inelastic analysis [2]. This is because the use of elastostatic fundamental solutions in dynamic analysis and the treatment of inelasticity in nonlinear problems require a domain discretization in addition to the boundary one and thus the BEMs loose their main advantage of the boundary only discretization over the FEMs. However, these problems can be overcome at least for certain classes of problems for which the BEM appears to be a better choice than the FEM [3,4]. Thus, inertia domain integrals can be transformed into boundary ones for finite domain problems and inelastic domain integrals can be restricted only to those regions expected to become inelastic. Furthermore, the size of the matrices involved in BEM does not increase with the domain discretization due to inelasticity but depends on the boundary discretization thereby keeping the size of these matrices much smaller than the corresponding one in FEM. Finally, one can combine the BEM with the FEM in problems with localized nonlinearities and use the FEM for the region expected to behave nonlinearly and the BEM for the remaining of the domain expected to behave linearly. The gain is even larger if the linear domain is of semi-infinite or infinite extent. In all the above types of problems, the BEM alone or in conjunction with the FEM appears to be more efficient than the FEM.

The purpose of this review paper is to critically present the various existing BEMs for dynamic inelastic problems and demonstrate that these methods can represent a powerful alternative to the FEM in applications. Firstly, a historical overview is presented. Then, the various BEMs as applied to dynamic inelastic analysis of two- (2-D) and three-dimensional (3-D) solids and structures as well as plates and shells are briefly presented and discussed. Five numerical examples from the literature and three unpublished examples of the authors are presented to illustrate the applicability and accuracy of these boundary element methodologies. The paper is completed with conclusions pertaining to the advantages and disadvantages of the presented methods and to future developments.

## 2. Historical overview

BEMs constitute a very good choice for the solution of inelastic dynamic problems involving two- and three-dimensional solids and structures, and structures consisting of other structural members, such as beams and plates, as it is evident in the review articles of Beskos [3,4] and Providakis and Beskos [5]. The presently available BEMs for inelastic analysis under dynamic loads can be divided into two major categories: BEMs for two- and

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