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APPLICATION OF SPECTRAL FINITE ELEMENT METHOD IN ANALYSIS OF TRANSIENT ELASTODYNAMIC PROBLEMS

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Abstract

Dealing with wave propagation phenomena using classical finite element method (FEM) results in some inefficiencies and inaccuracies in the solution. Spectral finite element method (SFEM) as a method based on FEM, presents some new features that makes it much more suitable and useful for solving wave propagation problems. The excellent characteristic of SFEM is that the mass matrix is diagonal because of the choice of the Lagrange interpolation function supported on Legendre-Gauss-Lobatto (LGL) points in conjunction with LGL integration rule. Therefore numerical calculations can be significantly efficient in comparison with the classical FEM. On the other hand choice of high order elements using specific shape functions gives us the possibility to increase the accuracy of the solution while decreasing the total number of elements used for the domain of the problem thus decreasing the analysis time. In this paper, a SFEM-based code is represented and verified, and then some wave propagation problems in elastic solid domains are solved using this code showing the capabilities of SFEM in solving elastodynamic problems. Some problems are solved using different spectral elements, and analysis time, accuracy of the solution and costs of analysis in different solutions is compared to analytical and/or numerical solutions available in the literature.

Keywords: Spectral finite element method; finite element method; elastodynamics; dynamic analysis

1. INTRODUCTION

Realistic numerical simulation of wave propagation phenomena requires huge computational resource. High-order techniques have attracted high interest in the last years, as means to improve computational efficiency and reduce computation time needed for a simulation. They have been introduced within several methodological frameworks, namely finite difference such as FDM[1] [1], finite element such as FEM[2] [2], boundary element such as BEM[3] [3] and pseudospectral methods such as SFEM[4]. Independent of the approach, the approximated solution is described in terms of high-order polynomial basis. High-order techniques are always associated with not only high accuracy and computational efficiency but also some well-known drawbacks. For instance, finite difference methods are not very well suited for describing very complex geometries and heterogeneous media, boundary conditions are difficult to implement. Last but not least, classical high-order finite elements (FEs) are known to generate high-order spurious modes [4].

To overcome these problems, the spectral element method has been developed. Recently, two different kinds of spectral element method (SEM) have been proposed for analysis of wave propagation, namely, fast Fourier transform (FFT)-based SEM and orthogonal polynomials-based SEM [5, 6] which we prefer to call the latter SFEM. The orthogonal polynomials (e.g., Legendre or Chebysev polynomials)-based SEM or SFEM, proposed by Patera [6], is much more suitable for analyzing wave propagation in structures with complex geometry. So called ‘‘spectral-element’’ methods gain the best of both worlds by hybridizing spectral and finite element methods. The domain is subdivided into elements, as in FEs, to gain the flexibility

[1] Finite Difference Method
[2] Finite Element Method
[3] Boundary Element Method
[4] Spectral Finite Element Method