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Three-dimensional dispersion analysis and stabilised finite element methods for acoustics

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Abstract

Galerkin/least-squares and Galerkin gradient/least-squares stands out among several approaches designed to improve the numerical solution accuracy and counteract the pollution effect by adding terms to the standard Galerkin formulation. These added terms are multiplied by a 'stability parameter', which must be properly defined. In this paper, an original three-dimensional dispersion analysis is performed for the Helmholtz equation, together with the determination of the three-dimensional stability parameters for structured and unstructured meshes. Numerical experiments show the relative efficiency of the proposed methods for solving acoustic problems arising from industry.

Keywords: stabilised finite element, Galerkin Least Squares, Galerkin Gradient Least Squares, dispersion, pollution effect, Helmholtz equation, acoustics

1. Introduction

Boundary-value problems governed by the Helmholtz equation are important in a variety of applications involving time-harmonic wave propagation phenomena, as for example, computational acoustic. It is known and understood that the accuracy of the standard Galerkin finite element method deteriorates rapidly with increasing the wave number [17, 25]. This problem arises from the use of piecewise polynomial shape functions to approximate highly oscillatory wave propagation solutions and this effect is the so-called 'pollution effect' [2, 1, 15]. In fact, when applying numerical methods for the computation of solution to the Helmholtz equation, one obtains 'numerical waves' that is dispersive also in a non-dispersive media [24], which