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Adaptive Quasi Static Ritz Vector (AQSRV)-based Model Reduction Scheme for the Numerical Simulation of Broadband Acoustic Metamaterials

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Abstract

This paper suggests the adaptive quasi static Ritz vector (AQSRV)-based model reduction scheme of applying an error indicator for efficient numerical simulation of the acoustic metamaterial systems with the characteristics of broadband, inhomogeneous, and anisotropic. In contrast to a conventional mode displacement method (MDM)-based model reduction scheme, the proposed method has characteristics of the target expansion frequency, multiple subintervals, and error indicator. Moreover, since AQSRV considers mass matrix, stiffness matrix, and load vector simultaneously in order to obtain the basis vectors, the accuracy and efficiency of overall analysis exponentially increase. In order to model the inhomogeneous and anisotropic acoustic metamaterial systems, this study uses acoustic Helmholtz equation as the governing equation, and then it is discretized by standard finite element method. The proposed method is applied to the various numerical applications such as the 2D simple lateral duct, the zero index metamaterial (ZIM)-based omnidirectional speakers, the gradient index acoustic lens, acoustic cloaking, and S-parameter retrieval simulation for effective material properties of the periodic unit cell structure. Through these numerical examples, the performance of proposed AQSRV-based model reduction scheme is verified in terms of accuracy and computational efficiency. These verification examples shows that the proposed AQSRV-based model reduction scheme can be used for analysis and design of the future various acoustic metamaterial systems.