MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures - Dynamics and Microdynamics (3)

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APPLICATION OF FAST MULTIPOLE BOUNDARY ELEMENT METHOD FOR UNIFIED FMBEM-FEM ACOUSTIC-STRUCTURAL COUPLING

Abstract

Structural-acoustic interaction, which is a significant issue found in many applications, including spacecraft structures and their payloads, can be analysed using Boundary and Finite Element Coupling modelling and analysis on their physically relevant governing equations, addressing the vibration of structures due to sound wave. The computational scheme developed for the calculation of the acoustic radiation and scattering as well as the structural dynamic response of the structure using coupled BEM/FEM for generic test cases has given satisfactory results for acoustic disturbance in the low and high frequency range. which includes the numerical treatment to overcome the appearance of irregular or fictitious frequencies, for example by using a method known as CHIEF (Combined Helmholtz Interior integral Equation Formulation). In the field satisfying the three dimensional Helmholtz equation, the sound pressure p at a point on the boundary is described, using the Kirchhoff-Helmholtz integral equation, expressing the sound pressure p as a surface integral on the boundary of the normal derivative of the pressure field times the Green function and the pressure field times the normal derivative of the Green function, Taking the normal derivative of the Kirchhoff-Helmholtz integral equation so defined at point yields the alternative form. By using boundary elements, the Kirchhoff-Helmholtz integral equation can be discretized with the prevailing boundary conditions of the equation, and the following matrix equation in the basic form (BF) is obtained as symbolically defined by

(E + B + C).p=j omega rho A v (1) where p is the sound pressure vector (unknown), and v is the velocity vector (given), and the entries of the influence coefficient matrices are formulated as appropriate. In a similar way, the following matrix equation in the normal derivative form (NDF) is obtained from the above equation as

(G + H + J) . p =- j omega rho (F + I) . v (2) where the corresponding influence coefficient matrices are formulated as appropriate. As it is well known, some special schemes are required for the singular integral in equations appearing in the coefficient matrices A and C of equation (1) , and also for the hypersingular integral in equation appearing in the coefficient matrix G. Moreover, the use of some kinds of linear or higher order elements involves advanced treatments due to the duplicity of the normals at the nodes on the edges. At the present stage, constant elements are employed here. The singular and the hypersigular integrals are evaluated by the transformed integration over the periphery of the element. The acoustic-structural coupling method developed earlier needs to be further improved to allow computation of large and complex structures. The fast multipole method (FMM) which has been developed based on the fast multipole algorithm has been regarded as one of the top 10 algorithms in scientific computing and has progressed very significantly, is then available to be combined with the boundary element method (BEM) to solve large-scale problems with very high degrees of freedom on a desktop computer within reasonable time. This method, known as the Fast Multipole BEM (FMBEM) can significantly accelerate an iterative solution of large-scale linear systems, without composing the dense influence coefficient matrices used for the conventional BEM. Computational method utilized for the boundary integral equations follow two schemes, one originating from the basic form and the other in the normal derivative form, where the fast multipole algorithm is introduced over the multipole levels, by employing a concept of cells clustering

boundary elements and hierarchical cell structure. The fast Multipole BEM is then utilized in the Unified BEM-FEM Acoustic-Structural Coupling developed earlier, following a unified integrated scheme carried out in the author's earlier work [1] [2]. In general, the sound pressures of all nodes on the boundary can be obtained by numerically solving the liner system of either equation (1) or (2). However, it is well known that the fictitious eigenfrequency difficulties arise when dealing with external problems with rigid bodies. Although several techniques have been developed to overcome this deficiency, a technique which linearly combined the two sets of equations is integrated with the two direct approaches into the FMBEM. With the intention of applying the FMA, an iterative method is used to solve the linear systems. First, the matrix-vector multiplication with the given vector is executed to obtain the vector as y = j omega rho A . v for BF y = j omega rho (F + I) . v for NDF (3) (4) which corresponds to the right side of equation (1) and (2), respectively. In general, after giving certain values as the initial vector , the matrix-vectormultiplication in the left side of the equations is recursively evaluated to calculate the residual vector at successive step, defined for BF and NDF schemes..Convergence criterion is defined accordingly.

The computational scheme for the Fast Fast Mutiple Boundary Element Method for Acoustic Field follows the scheme developed by Sakuma and Yasuda [3]. The effectiveness and accuracy of the developed FMBEM approach.to the earlier BEM approach for generic cases investigated in earlier Unified BEM-FEM Acoustic-Structural Coupling will be demonstrated.

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