EFFICIENCY AND STABILITY STUDIES OF A TIME DOMAIN BOUNDARY ELEMENT METHODOLOGY FOR FLUID-STRUCTURE INTERACTION ANALYSIS

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Boundary Element Methods are commonly used to model infinite or semi-infinite transient systems since they inherently satisfy associated radiation conditions. Direct time domain BEM methods for wave propagation in acoustic media find their origin in the Retarded Potential (RP) formulations [1]. RP formulations have two significant drawbacks: (i) the non-local nature of the method in both space and time impose extremely large storage requirements, since the time history of the response must be stored at every step of the solution at all degrees of freedom; (ii) RP methods are conditionally stable and only in a very narrow range of time steps [2].

This paper presents a direct time domain BEM methodology for scalar wave propagation in acoustic media to address efficiency and stability issues mentioned above. Furthermore, Kinematic Fluid-Structure Interaction (FSI) models are developed based on the proposed BEM methodology. This method adopted cubic B-Spline Polynomial as impulse excitation function and developed the associated B-Spline fundamental solutions for scalar wave propagation in 3-D infinite media. The method is used within the B-Spline Impulse Response framework (BIRF) for the calculation of the time history of the response of the acoustic medium and the calculation of the hydrodynamic forces on the wetted surface of the fluid-structure interface [3]. The efficiency and stability studies of the proposed methodology are discussed in the paper.

Although the proposed method is non-local in time, the method is very efficient because: (1) although the duration of the BIRF function is infinite in theory, it can be truncated to only a relatively small number of time steps without sacrificing accuracy making the method very efficient especially for prolonged external excitations; (2) the coefficient matrices of the proposed method can be extremely sparse due to the nature of the geometric characteristics of the wave fronts generated by the small duration B-Spline impulse excitation, allowing, thus, the implementation of algorithms for sparse matrix operations. The proposed B-Spline BEM is also stable as compared to the relevant Retarded Potential formulations reported in the literature. A number of parametric studies are presented that investigate the efficiency and the stability. They include (i) evaluation of the stability of the proposed method in view of the time step duration; (2) selection of time step for accuracy and stable results; (3) study on the effects of the B-Spline support on the convergence of the solution. (4) establishment of the criteria for truncating the BIRF and the effects of truncation on the accuracy of the solution.

Reference

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