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A direct hybrid wave based – finite element modeling of poroelastic materials

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Abstract

This work presents a newly developed hybrid modeling technique for the analysis of poroelastic materials. The motivation of the hybrid modeling is to take the advantages of both of the wave based and the finite element methods for the efficient and accurate analysis of poroelastic materials. When it comes to the finite element method, it has great geometrical flexibility since the modeling is carried out based on the discretization of a domain into many elements. On the other hand, due to the discretization into a large number of small elements, the computational cost in the finite element method becomes huge, especially for modeling of large problems or in mid and high frequency ranges analyses. Considered the frequency-dependent properties and more degrees of freedom of poroelastic materials compared to those of other acoustic materials, the difficulty in the finite element method becomes worse. In this circumstance, the wave based method which was originally proposed for the modeling of vibro-acoustic problems was recently extended to the modeling of poroelastic materials. Wave functions which correspond to three types of waves in poroelastic materials are used to describe the dynamic response of poroelastic materials. Since the wave based method is based on the analytical wave functions that exactly satisfy Biot's poroelastic equations, the accuracy of the modeling is high. Moreover, smaller model size in the wave based method yields much efficient modeling which can be applicable for the analysis of large systems in mid and high frequency ranges. These merits of the wave based method, however, are shown in geometrically moderate problems which are divided into a small number of large convex subdomains. Since the different characteristics of the finite element and the wave based methods, the hybridization of them can maximize the advantages of both modeling methods while the drawbacks of them can be minimized by compensating each other in the modeling of poroelastic materials.

In the newly developed hybrid wave based – finite element modeling technique, a target region

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filled with poroelastic materials is divided into two set of domains. Large and convex domains are modeled by the wave based method which gives the computational efficiency in the modeling. On the other hand, the other set of domains which has complicated geometric dimensions can be modeled by the finite element method. Then, the two set of domains that are modeled by the different modeling methods are combined along their interfacial surfaces. This coupling process of the physical quantities between two differently modeled surfaces is the key step of the hybrid modeling technique. According to the primary variables which are used to describe poroelastic materials in the finite element method, the coupling with the quantities in the wave based method should be differently carried out. In this work, (u,U) and (u,p) poroelastic formulations which have been typically used in the finite element method are successfully hybridized with the wave based method which is based on the analytic solutions of Biot's equations. Various numerical examples are tested to show the validity and efficiency of the hybrid modeling technique by comparing its performance with those modeled by the finite element and the wave based methods.

(Oral presentation preferred)