On the Pseudo-Incident Wave Technique for Interacting Inhomogeneities in Electromechanical Problems

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ABSTRACT

The mechanical and electrical properties of advanced piezoelectric composite structures are greatly affected by the attached piezoelectric sensors/actuators, debondings, fibres and/or embedded cracks. The interaction between these inhomogeneities will cause the redistribution of the local stress and electric fields, which results in mechanical shielding or amplification effects and affects the overall failure mechanism, and alters the electrical behaviour of the structures. Because of the complexity of the problem, when dynamic loads are applied, the simulation of the dynamic response of such coupled systems possesses a significant challenge. Specifically, since the inhomogeneities may take different forms, such as piezoelectric thin sheets, fibres, particulates, cracks, or even nanotubes, the formulation of general dynamic interaction problems is very complicated and difficult to deal with. Typical numerical methods, such as finite element method or boundary element method, can be used to conduct dynamic simulation of these problems under certain conditions but have their own limitations when multiple interactions are involved, because of the computing resource needed to obtain reliable results. Analytical study of interacting inhomogeneities under dynamic loads is very attractive because of its high reliability and accuracy, but is limited to only simple cases of single inhomogeneity of certain types.

The current paper presents a Pseudo-Incident Wave technique for the theoretical treatment of the dynamic interaction between general inhomogeneities in advanced piezoelectric structures. Instead of simulating the response of such complicated systems using purely numerical or analytical methods, the current technique will take the advantages of the accuracy and reliability of analytical solutions and the flexibility of numerical methods. Using this method the original interaction problem is reduced to the solution of coupled single inhomogeneity problems, for which analytical solutions or simpler numerical solutions could be derived. By considering the consistency condition between different inhomogeneities, the steady state dynamic solution of multiple interaction problems can be formulated in terms of coupled single inhomogeneity solutions. The current method is very general and can provide reliable simulation of complicated interaction problems. Examples of the application of this technique include the dynamic interaction between cracks, fibre-reinforcements, and piezoelectric sensors. Numerical examples are presented to illustrate the effectiveness of the Pseudo-Incident Wave method in simulating dynamic interaction problems of electromechanical structures under complicated geometries.