Boundary Element Formulation for Viscoelastic Structures Using the SLS Model

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Abstract

In this paper, from the basic assumptions of viscoelastic constitutive equations and weighted residual techniques, a simple but effective boundary element formulation is implemented by the Standard Linear Solid (SLS) viscoelastic model. A response closer to that of a real viscoelastic structure is obtained from the SLS model describing both stress relaxation and creep. This formulation needs only the Kelvin's fundamental solution of isotropic elastostatics with material constants prescribed as explicit functions of time. This approach avoids the use of relaxation functions and mathematical transformations, and it is able to solve the visco-elastostatic problems with any load time-dependence and boundary conditions.

Keywords: BE formulation, Viscoelastic structures, SLS model, Kelvin fundamental solution

1. INTRODUCTION

Analysis of viscoelastic structures is one of the most important subjects in engineering problems. Due to inherent viscoelastic behavior of many engineering structures, analysis of viscoelastic problems has become increasingly important in recent years and should receive more attention in computational mechanics. In the literature of computational mechanics, predictions of viscoelastic behavior usually depend on the numerical approaches, such as Finite Difference Method (FDM), Finite Element Method (FEM) and Boundary Element Method (BEM). During recent years, BEM has found the considerable applications in solution of engineering problems, such as the geomechanics, viscoelasticity, elastoplasticity, elastodynamics, fracture and contact mechanics. More importantly, problems that once seemed completely inflexible for an analytic study can now be analyzed by this technique rather easily. The BEM has advantage of requiring only boundary data as input and, ideally, no division of the domain under consideration into elements. In addition, the BEM is ideally suited for the analysis of infinite domain problems because only their surface has to be discretized.

The viscoelastic structures can be effectively treated by the BEM formulation. Numerous researchers developed the BEM formulation to model viscoelastic behavior. In the following, several important works are investigated. The usual approach, originally adopted by Rizzo and Shippy [1], has been to formulate a BEM solution for the Laplace transforms of all variables satisfying an associated elastic problem, and then the solution in time domain is obtained by numerical inversion. Also, incremental BEM solutions in the time domain were first formulated by Shinokawa et al. [2]. The weighted residual technique, the indirect BEM, the truncated indirect BEM and the direct BEM were used to analyze the soil-structure interaction in time domain by Wolf and Dorbe [3]. Shinokawa and Mitsui [4] presented a combined BEM/FEM approach to analyze viscoelastic problems using the time marching method without the provision of cells, and represented some numerical examples with the tunnel and trench excavation problems in the viscoelastic analysis which confirmed the applicability of BEM to geotechnical analysis. Pan et al. [5] presented a BEM formulation for 3-D linear viscoelastic bodies subjected to gravity body force by the Laplace transformation, where the Green's functions were obtained through the correspondence principle in Laplace domain. Mesquita and Coda [6] implemented the viscoelastic models in a 2-D boundary element methodology based on the viscoelastic differential constitutive relations using the internal cells (Part I) and without cells (Part II). They achieved a simple time marching process from the kinematical relations. Wang and Birgisson [7] presented a time domain BEM to model the quasistatic linear viscoelastic behavior of asphalt pavement, in which the fundamental solution was derived in terms of the elemental displacement discontinuities and a boundary integral equation was formulated in time domain. The equations were solved incrementally through the whole time history using an explicit time -marching approach. Ashrafi et al. [8] presented a simple BEM formulation from the basic assumptions of Kelvin viscoelastic constitutive equations, in which it needs only the Kelvin's fundamental solution of isotropic elastostatic problems.

There is no available, the much literature for application of a direct BEM to the time dependent problems of this kind using a time marching scheme. In this paper, a direct boundary integral formulation is