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A dual reciprocity BEM approach using new Fourier radial basis functions applied to 2D elastodynamic transient analysis

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ABSTRACT

In this paper, a new boundary element analysis for two-dimensional (2D) transient elastodynamic problems is proposed. The dual reciprocity method (DRM) is reconsidered by employing new radial basis functions (RBFs) to approximate the domain inertia terms. These new RBFs, which are in the form of $\zeta+\kappa \sin(\omega r+\alpha)$, are called Fourier RBFs hereafter. Using the method of variation of parameters, the particular solution kernels of Fourier RBFs corresponding to displacement and traction, whose a few terms are singular, has been explicitly derived. Therefore, a new simple smoothing trick has been employed to resolve the singularity problem. Moreover, the limiting values of the particular solution kernels have been evaluated. In order to find the unknown parameters of Fourier RBFs, an optimization problem seeking for the optimum value of the Houbolt scheme parameter β that minimizes the mean squared error (MSE) function of the problem is established. Since the MSE function of the proposed RBFs is a function of five unknown parameters (i.e., ζ, κ, ω, α, and β), the genetic algorithm (GA) has been used to solve the necessary optimization problem. In order to illustrate the validity, accuracy, and superiority of the present study, several numerical examples are examined and compared to the results of analytical and other RBFs reported in the literature. Compared to other RBFs, Fourier RBFs show more accurate and stable results. Moreover, these results are obtained using less degree of freedom without any additional internal points that are commonly used to improve the accuracy of the results.

1. Introduction

Boundary elements have been developed as a versatile and powerful alternative to finite elements especially in situations where better accuracy is required for problems such as stress concentration or infinite domains [1]. Early elastodynamics formulations of BEM may be assigned to the works of Friedman and Shaw [2], Banaugh and Goldsmith [3], and Cruse and Rizzo [4]. Three main elastodynamics formulations of BEM have been reported in the literature: the time domain, the Laplace transform, and the domain integral techniques. The first two methods suffer from the mathematical complications involved in their formulations, and the third one requires domain integrations (see for example Refs. [5–8]). In order to resolve these problems, Brebbia and Nardini [9–11] proposed the well-known dual reciprocity method (DRM). In this method, the integral equation of the domain is expressed in terms of boundary integrals as well a domain integral pertaining to the domain inertia terms. Using a new collocation method to approximate the inertia terms (or, domain accelerations), they [9–11] transformed the domain integral to the boundary integral to eliminate the domain terms from formulations. In this collocation method, various classes of approximation functions, which are called the radial basis functions (RBFs), may be employed [12]. From a general viewpoint, it seems that the RBFs may be categorized into two main classes, namely globally and locally based RBFs. Among the various RBFs, the commonly used conical functions [9–12], the thin plate splines [12–18], the Gaussian functions [13,19], multiquadrics [12,20–22], and Sinusoidal [23] belong to globally based class, while compact supported RBFs [24–28] are locally based ones.

A comparative study was reported by Agnantiaris et al. [13] in which, the behavior of dynamic problems using the conical and the thin plate spline were considered. In the research of Bridges and Wrobel [14] the thin plate spline functions were used to model free vibration problems. They [14] concluded that spline functions present better approximations than the conical functions. This result was somehow on the contrary to the conclusions of Ref. [13] in which, the conical functions had shown the best performance in comparison with other studied RBFs. Mehraeen and Noorzad [18] proposed a hybrid form of conical and spline RBFs and employed it for 2D free vibration problems. Rashed [19] selected the Gaussian functions as RBFs to solve transient dynamic problems and showed that these functions offer good

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