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Meshless global radial point collocation method for three-dimensional partial differential equations

Song Xiang [a,*], Yao-xing Jin [b], Shao-xi Jiang [c], Ze-yang Bi [d], Ke-ming Wang [a]

[a] School of Engine & Energy Engineering, Shenyang Aerospace University, No. 37 Daoyi South Avenue, Shenyang, Liaoning 110136, People's Republic of China
[b] Technology Department, Avic Shenyang Liming Aero-Engine (group) Corporation Ltd., Shenyang, Liaoning 110043, People's Republic of China
[c] Manufacturing Factory of Blade, Avic Shenyang Liming Aero-Engine (Group) Corporation Ltd., Shenyang, Liaoning 110043, People's Republic of China
[d] Steel_Making Plant, ShouGang Qian'an Iron&Steel Corporation Ltd., Qian'an, Hebei 064400, People's Republic of China

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ABSTRACT

This study deals with the numerical solution of three-dimensional partial differential equations by the meshless global radial point collocation method based on various radial basis functions. First, second, third, and fourth-order three-dimensional partial differential equations are considered. The effect of shape parameters of various radial basis functions on the numerical accuracy is studied. The effect of grid pattern on accuracy is also studied by several numerical examples.

1. Introduction

The mathematic models have been developed for the physical phenomena in the areas of mechanics of solids, structures, and fluid flows. Different types of partial differential equations have also been derived for these phenomena. The method for solving partial differential equations includes the finite element method, the finite volume method, and the finite difference method. In recent years, a new method called the meshless method has been developed [1–3]. Meshless method is used to establish a system of algebraic equations for the whole problem domain without the use of a predefined mesh [4]. The meshless methods fall into three categories according to the formulation procedures: meshless methods based on weak-forms, meshless methods based on collocation techniques, meshless methods based on the combination of weak-forms and collocation techniques [3].

The meshless collocation methods have the advantages of a simple algorithm, computational efficiency, and truly meshless. Many researchers have utilized the meshless collocation methods to solve partial differential equations. Hardy [5] solved the equations of topography by the meshless collocation methods based on the multiquadric radial basis function. Hardy [6] reviewed the development of multiquadric-biharmonic method from 1968 to 1988. Kansa [7] presented a powerful, enhanced multiquadrics (MQ) scheme for accurate interpolation and partial derivative estimates. The meshless collocation methods based on the multiquadrics radial basis function was used as the spatial approximation scheme for parabolic, hyperbolic, and the elliptic Poisson's equation by Kansa [8]. Golberg et al. [9] interpolated the forcing term of partial differential equations using multiquadric approximations, and then use them to approximate particular solutions. The technique of cross-validation was used to obtain a good shape parameter of the multiquadrics. Sharan et al. [10] applied the multiquadric (MQ) approximation scheme to solve two-dimensional Laplace, Poisson, and biharmonic equations with Dirichlet and/or Neumann boundary conditions. The method is also applied successfully to a problem with a curved boundary. Hon et al. [11–14] studied the numerical solution of a biphasic model, Burgers equation, shallow water equation, and options pricing model by the multiquadric method. Kansa and Hon [15] explored several techniques, each of which improves the conditioning of the coefficient matrix and the solution accuracy. Power and Barraco [16] presented a thorough numerical comparison between unsymmetric and symmetric radial basis function collocation methods for the numerical solution of boundary value problems for partial differential equations. Wong et al. [17] presented the application of the compactly supported radial basis functions (CSRBFs) in solving a system of shallow water hydrodynamics equations. The performances of domain-type meshless collocation methods and boundary-type meshless methods in solving partial differential equations were compared by Li et al. [18]. It was found from their studies that these two methods provide a similar optimal accuracy in solving both 2D Poisson's and parabolic equations. Larsson and Fornberg [19] compared the RBF-baeed collocation methods against two standard techniques (a second-order finite difference method and a pseudospectral method), it was found that the former gave a much

* Corresponding author.
E-mail address: xs74342@sina.com (S. Xiang).

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