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The complex variable element-free Galerkin (CVEFG) method for elasto-plasticity problems

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ABSTRACT

Based on the complex variable moving least-squares (CVMLS) approximation and element-free Galerkin (EFG) method, the complex variable element-free Galerkin (CVEFG) method for two-dimensional elasto-plasticity problems is presented in this paper. The CVMLS approximation is an approximation method for a vector function. Under the same node distribution the meshless method based on the CVMLS approximation has higher precision than the one based on the moving least-squares (MLS) approximation. For two-dimensional elasto-plasticity problems, the Galerkin weak form is employed to obtain the equations system, and the penalty method is used to apply the essential boundary conditions, then the corresponding formulae of the CVEFG method for two-dimensional elasto-plasticity problems are obtained. Compared with the EFG method, the CVEFG method can obtain greater precision. For the purposes of demonstration, some selected numerical examples are solved using the CVEFG method.

1. Introduction

The meshless method, which is based on nodes with a minimum of meshing or no meshing at all, can solve many engineering problems that are not suited to conventional numerical methods, such as the finite element method (FEM) and the boundary element method (BEM) [1,2]. The meshless method has shown some advantages over traditional numerical methods, and has been successfully developed and applied to a variety of engineering problems [3].

The moving least-squares (MLS) approximation [4] is an important method to form the shape function in the meshless method. The shape function that is formed with the MLS approximation can obtain a very precise solution. A disadvantage of the MLS approximation is that the final algebra equations system is sometimes ill-conditioned. Thus, sometimes we cannot obtain a good solution, or even correctly obtain a numerical solution with the MLS approximation. The improved moving least-squares (IMLS) approximation was presented by Liew et al. [5]. In the IMLS approximation, the algebra equation system is not ill-conditioned, and can be solved without obtaining the inverse matrix. Combining the boundary integral equation method and the IMLS approximation, the boundary element-free method (BEFM) was presented to solve problems such as elasticity, elastodynamics, and fracture [5–12]. The BEFM method for elasto-plastic implicit analysis is discussed by Miers and Telles [13]. And the improved element-free Galerkin method based on the IMLS approximation was discussed by Zhang et al. [14,15].

However, the MLS and IMLS approximations are approximations of scalar functions, and thus the meshless method that is derived from them requires a lot of nodes in the domain [16,17].

The complex variable moving least-squares (CVMLS) approximation, which is an approximation of a vector function, has been developed [16,17]. In the CVMLS approximation the trial function of a two-dimensional problem is formed with a one-dimensional basis function. The number of unknown coefficients in the trial function of the CVMLS approximation is less than in the trial function of the MLS approximation. We can thus select fewer nodes in the meshless method that is formed from the CVMLS approximation than are required in the meshless method of the MLS approximation without loss of precision. Therefore under the same numerical precision, the meshless method that is derived from the CVMLS approximation has greater computational efficiency. And under the same node distribution the meshless method based on the CVMLS approximation will have higher precision.

Combining the CVMLS approximation with the boundary integral equation method, the complex variable boundary element-free method for two-dimensional elasticity and elastodynamics

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