A Simple Sub-domain Collocation Method as the Generalization of the Finite Point Method

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Abstract

A new mesh-less method based on a sub-domain collocation approach is proposed. Sub-domains are defined around each node and the equilibrium equations are weakly satisfied. The method can be regarded as an advanced version of the Finite Point Method (FPM). One of the important features of the method is that a set of closed form integrals are taken on the sub-domain boundaries. This leads to reduction of the computational cost in comparison with other integral based mesh-less methods. Moreover, it will be shown that the order of differentiation needed in the new method is less than that of the conventional FPM. Since the accuracy of the procedure depends on the size of the sub-domains, the optimal sizes are found by a series of patch tests. The final results of the patch tests and the optimization procedure are presented in a series of tables for further use. The efficiency of the method in the solution of two dimensional elastic problems is shown by presenting the results for several benchmark problems while comparison is made with the results of other methods such as the finite element and finite point methods.

Keywords: Mesh less, sub domain, collocation, finite point method.

1. INTRODUCTION

Conventional numerical methods usually require a predefinition of connectivity of the nodes. To define this connectivity they rely on a mesh of elements. The Finite Element Method (FEM) is the most well known mesh-based method with great success in application but it is not without limitation. The mesh generation part in FEM is a time consuming task especially for complex three dimensional domains. Moreover the use of low quality meshes usually leads to some large errors in the solution. This effect may especially be seen in the analysis of problems with large deformations where the mesh based methods need a successive remeshing procedure to avoid numerical failure due to mesh distortion. The sensitivity of calculations to mesh alignment in crack propagation and shear bands problems is another example of non-efficiency of mesh-based methods.

To eliminate these disadvantages a new class of numerical methods named Meshless Methods (MMs) were born and developed during the last three decades. These methods differ from the mesh-based ones mainly in two basic features; interpolation of functions and discretization of governing equations. Various types of interpolation methods such as Reproducing Kernel Particle Method (RKPM), Least Square (LS) method, Weighted Least Square (WLS) method and Moving Least Square (MLS) method are available in literature. Smoothed Particle Hydrodynamic (SPH) is known as the first meshless method. In this method the kernel particle method is utilized for interpolation and strong form of governing equations is used in the discretization [1]. In the Reproducing Kernel Particle Method (RKPM) which is a modified version of SPH, the kernel particle approximation is replaced by RKPM interpolation technique [2]. By introducing the moving least square method by Lancaster and Salkauskas in 1981 [3] a new family of meshless methods was developed. The Diffuse Element Method (DEM), by Nayroles *et al* [4], was the first in this category. Although not noted by Nayroles *et al* the interpolation used in their method is exactly the same as the moving least square method. In the diffuse element method a Galerkin form of weighting was employed on a background mesh. Since the diffuse element method did not pass the general patch tests the modified version of this method named Element Free Galerkin (EFG) method [5] was proposed by Belytschko *et al* in 1994. The authors considered parts of the