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An improved meshless method for analyzing the time dependent problems in solid mechanics

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ABSTRACT

In this paper, the local radial point interpolation method (LRPIM) is developed for the investigation of time dependent problems in solid mechanics. By a new integration scheme considered for the obtained meshless weak form, integrands are approximated up to the second order of the Taylor series and the integrals are evaluated on some points, which are located inside the local quadrature domains, called integration points. In order to show the efficiency of the suggested method, some time dependent mechanical problems are considered for the engineering structures such as beams and plates, which are subjected to dynamical loads, the deflections and stresses are evaluated. Finally, it has been shown that using the proposed method greatly reduces the number of integration points without affecting the accuracy of the results.

1. Introduction

Time dependent problems are of considerable importance in different engineering and science fields. In a few dynamical problems, exact and analytical solutions can be found where the solutions are important for analyzing the system behavior. Therefore, numerical methods are widely used in order to obtain the solutions and the responses of the systems. The traditional mesh-based finite element method (FEM) was recognized as a dominating numerical method for elasto-static and elasto-dynamic problems, especially in practical engineering applications. However, the existence of mesh may confine the accuracy and generality of the solution.

Recently, many studies were done to remove the restriction of meshes such as meshless methods [1–6]. Among them, the element-free Galerkin (EFG) method is considered as a general framework and become an inspiration source for the latter meshless methods [3]. These methods are based on the global weak-forms. The needs of weak-forms to sets of background cells for evaluating the weak-form integrals beside the continuous meshless shape functions over the entire domain, lead to development of the meshless local Petrov–Galerkin (MLPG) method [7–10]. The most important advantages of the MLPG method is the flexibility in choosing shape and weight functions and also, integrations over simply shaped sub-domains.

Al-Gahtani and Naffa'a [11] studied the large deflection of thin plates subjected to immovable loads. The radial basis functions of the fifth order were used in their study to approximate the solution variables of the plate. The radial basis functions (RBFs) have been frequently employed in solving partial differential equations using meshless methods. But Global use of these functions usually leads to dense system matrices and exceptionally high computation cost. However, when the classical RBFs are incorporated into EFG or MLPG schemes, the above mentioned problems are removed because their interpolation is performed in localized domains supported by pre-defined interpolating domain size [12]. Following of the proposed MLPG method, the local point interpolation method was used widely in different studies [13–16]. Liu et al. [13] have been developed the local radial point interpolation method (LRPIM) based on the locally weighted residual method and radial basis functions (RBFs) interpolation. They used the properties of the Kronecker delta function for the simplicity in the boundary conditions enforcement. Although, the removal of background cells is the main advantage of LRPIM and MLPG methods, because of some difficulties demonstrated by Atluri [17] for obtaining more accurate numerical integrations, the local domains should be divided into some regular small partitions, each one contains more Gauss quadrature points, for example, 64 Gauss points for each local quadrature domain [18].

As it was shown in the literature for MLPG and LRPIM, since the integrands are rational functions, Gauss quadrature does not lead to suitable results as in FEM with integrands of polynomial form. So, more sub-partitions and Gauss points are needed to compensate it [17]. But using a polynomial approximation for integrands over small local quadrature domain will improve the performance of integration methods. Furthermore in the MLPG method, besides weight function, which is used in weak form equation, in construction of MLS shape functions also needs weight function to

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