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Simulation of two dimensional unilateral contact using a coupled FE/EFG method

M. Chehel Amirani *, N. Nemati

Faculty of Mechanical Engineering, K.N. Toosi University of Technology, No. 19, Pardis St., Molasadra Ave., Vanak Sq., Tehran, Iran

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ABSTRACT

In this paper, simulation of two dimensional unilateral contact problems using a coupled finite element/element free Galerkin method is proposed. For the analysis, the element free Galerkin method and Galerkin formulation for two dimensional elasticity problems are considered. Then, the penalty method for imposition of contact constraint is proposed. The finite element shape functions are used in the penalty term of contact constraint. Finally, the accuracy of the presented method is verified through some examples. The numerical results have demonstrated that the presented approach is simple and accurate for frictionless contact analysis of 2D solids.

1. Introduction

Contact problem can be observed in many usual manufacturing processes such as extrusion, metal forming, machining and crash. The phenomenon of contact in mechanical systems introduces dynamic boundary conditions that are normally inactive, but are enforced when parts of the moving mechanical structure come in contact. This introduces a greater level of complexity because it is not always known where or how contact occurs. Thus, unknown contact boundary and its change during the loading, and also the sliding of two bodies in frictional contact make the contact problem one of the most difficult nonlinear problems in the solid mechanics. Many studies have tried to overcome difficulties of contact simulation. Most of the methods have used the finite element method (FEM) to solve the problem (see [1–4]). Typically, two main constraint methods that have been employed in the finite element solution of contact problems are the method of Lagrange multipliers and the penalty approach.

In Lagrange multipliers approach, the contact forces are taken as primary unknowns and the non-penetration condition is enforced [5,6]. Within the framework of classical Lagrange multiplier method, contact condition is exactly satisfied by introducing extra variables called Lagrange multipliers and solution of the resulting optimality conditions. These extra variables add to the computational effort of the solution process. In the penalty method, the penetration between two contacting boundaries is introduced and the normal contact force is related to the penetration by a penalty parameter [7,8]. Penalty method is known to be simple and can be readily interpreted from a physical standpoint. Unfortunately, penalty methods suffer from ill-conditioning and opting a suitable value for the penalty parameter.

Recently, meshless methods have attracted many researchers' interest in the scientific community [9–20]. In meshless methods the process of mesh generation has been replaced by the process of node generation. The process of node generation takes less time and memory in mathematical programming compared to the mesh generation process. Based on the different formulation, several meshless methods have been introduced. Smooth particle hydrodynamics (SPH) [9], element free Galerkin (EFG) [10], meshless local Petrov Galerkin (MLPG) [11], point interpolation method (PIM) [12], reproducing kernel particle method (RKPM) [13] are the most known methods. The element free Galerkin method is one of the meshless methods which has shown a great ability in solving solid mechanics problems [14–20]. In this method, the moving least square scheme is used to approximate the field variable.

Actually, few number of the contact analysis' use meshless methods [21–26]. Li et al. [21] have used a meshless method to study the two dimensional frictional contact problems between a rigid body and a deformable body. Since the shape parameters need to be properly chosen to control the inconformability in the radial point interpolation method (RPIM), they have used a linearly conforming radial point interpolation method (LC-RPIM) to overcome such disadvantages. Their presented method is able to simulate the behavior of contact nonlinearity including contact/departing or adhesion/debonding, and sticking/slipping among the potential contact interfaces in a solid system. Hu et al. [22] have used the MLPG method to simulate the two dimensional

* Corresponding author. Tel.: +98 2188674747; fax: +98 2188674748
E-mail address: Amirani@sina.kntu.ac.ir (M. Chehel Amirani).

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