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A meshfree adaptive procedure for shells in the sheet metal forming applications

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Abstract. In this paper, a meshfree shell adaptive procedure is developed for the applications in the sheet metal forming simulation. The meshfree shell formulation is based on the first-order shear deformable shell theory and utilizes the degenerated continuum and updated Lagrangian approach for the nonlinear analysis. For the sheet metal forming simulation, an h-type adaptivity based on the meshfree background cells is considered and a geometric error indicator is adopted. The enriched nodes in adaptivity are added to the centroids of the adaptive cells and their shape functions are computed using a first-order generalized meshfree (GMF) convex approximation. The GMF convex approximation provides a smooth and non-negative shape function that vanishes at the boundary, thus the enriched nodes have no influence outside the adapted cells and only the shape functions within the adaptive cells need to be re-computed. Based on this concept, a multi-level refinement procedure is developed which does not require the constraint equations to enforce the compatibility. With this approach the adaptive solution maintains the order of meshfree approximation with least computational cost. Two numerical examples are presented to demonstrate the performance of the proposed method in the adaptive shell analysis.

Keywords: meshfree; convex; shell; adaptivity; metal forming

1. Introduction

Recent developments in the meshfree methods add an additional dimension to computational mechanics (Belytschko *et al.* 1994, Liu *et al.* 1995a, Atluri and Zhu 1998, Chen *et al.* 1996, Wang and Chen 2004, Liu and Zhang 2008). Those methods do not rely on the traditional mesh-based approach to define the approximation functions. In comparison with the conventional finite element methods, the characteristics of smoothness and naturally conforming of the approximation, p-version of the intrinsic basis and higher convergence rate make the meshfree methods attractive alternative numerical techniques for industrial applications (Wang *et al.* 2009, Wu and Koishi 2009). Meshfree method using Moving Least-squares (MLS) (Lancaster and Salkauskas 1981, Belytschko *et al.* 1994) or Reproducing Kernel (RK) (Liu *et al.* 1995a, b) approximation has been successfully applied to the solid and structural analyses in the past decade (Chen and Wang 2006,

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