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Geometrically nonlinear analysis of thin-shell structures based on an isogeometric-meshfree coupling approach

Weidong Li[a], Nhon Nguyen-Thanh[a,*], Kun Zhou[a,*]

[a]*School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Singapore*

Abstract

This paper develops a novel coupling approach of the isogeometric analysis (IGA) method and the meshfree method for geometrically nonlinear analysis of thin-shell structures. The Kirchhoff-Love (KL) thin-shell theory is employed without the consideration of rotational degrees of freedom. Both parametric domain and physical domain are utilized for the thin-shell structures, and the former one is used to couple the IGA and meshfree methods and to obtain the later one via mapping. The domain is divided into three subdomains: the subdomain described by the IGA method to ensure geometry exactness, the subdomain described by the meshfree method to achieve local refinement, and the coupling subdomain described by both methods. In the coupling subdomain, the reproducing points are obtained based on the consistency conditions to realize smoothness between the IGA and meshfree subdomains. The coupling approach can achieve a higher convergence rate than the IGA and meshfree methods because of the realization of local refinement. The accuracy and robustness of the coupling approach are validated by solving shell benchmark problems.

Keywords: Isogeometric Analysis, Meshfree Method, Thin shell, Consistency Condition

1. Introduction

Shell structures play an important role in industrial applications such as turbine disks, water tanks and aircraft. Two different types of shells can be differentiated by the ratio of the thickness t to the radius of curvature R of the middle surface: thin shells (R / $t \geqslant 20$) and thick shells (R / $t<20$). The deformation of thin shells includes the membrane strains and bending strains without considering the transverse shear strains that are related to the rotational degrees of freedom. The thin-shell analyses are based on the Kirchhoff-Love (KL) theory which requires the continuity of first-order derivatives of displacements (C^1 continuity) [1, 2, 3, 4, 5]. The thick-shell analyses are based on the Mindlin-Reissner theory that requires only the continuity of displacements (C^0 continuity) [6, 7, 8, 9].

The C^1 continuity is difficult to implement with Lagrange polynomial basis functions in the traditional finite element method (FEM) [10, 11]. Various methods have been proposed to formulate C^1 conforming thin-shell finite elements. Rectangular shell elements constructed with bicubic

*Corresponding authors. Email addresses: thanhnhon@ntu.edu.sg (Nhon Nguyen-Thanh), kzhou@ntu.edu.sg (Kun Zhou)