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Static Instability of Ultra-Thin Elastic Structures using Isogeometric Analysis

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Abstract. An investigation into postbuckling behavior of thin and ultra-thin plates/shells is first performed in this paper. The present formulation is established upon a shell theory using the von Karman assumption and isogeometric analysis (IGA). In the present approach, the bifurcation point in eigenvalue buckling analysis and limit points can be detected simply via the modified Riks method. Hence, eigenvalue buckling analysis and postbuckling analysis are unified in the most simple flowchart. The above advantages allow buckling and postbuckling analyses of ultra-thin, thin and moderate thick plates/shells can be performed directly and conveniently. The obtained results are verified with the reference ones. In addition, the results show that buckling shapes and postbuckling responses of thin structures and ultra-thin structures are significantly different. Effects of slenderness, aspect ratios and curvature on postbuckling response of ultra-thin plates/shells are investigated particularly. Especially, some new results of ultra-thin plates/shells are first provided in this paper.

AMS subject classifications: 65M10, 78A48

Key words: Isogeometric analysis, postbuckling, ultra-thin, plates, shells.

1 Introduction

Thin and ultra-thin structures are used broadly in civil, mechanical and spacial fields from terrestrial applications to space ones such as: shells of ships and submarines, thin-walled beams in buildings, roofs of exhibition buildings and stadiums, shells of airplanes and spacecrafts, solar power collection panels on spacecrafts, etc. Thin structures have been receiving so much attention upon their flexibility and light weight. Because of the above reasons, studies on behaviors of thin and ultra-thin structures are necessary and h-

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ave a practical meaning. In structural analysis, thin structures have small bending and membrane stiffnesses because of their small thicknesses. Hence, these thin structures are easy to occur buckling phenomenon under various loading conditions such as: compressive or shear loads, changes of thermal environment, etc.. Due to instability, a structure can reduce its load-carrying capacity and be collapsed at a load level which is smaller the expected load. Therefore, knowledge of buckling phenomenon plays an important role in structural design. Predicting buckling and postbuckling behaviors of thin and ultra-thin structures is a challenging problem in computational mechanics. For a structure under compression or change of thermal environment, the conventional and popular approach for buckling and postbuckling analyses is to conduct some main steps: prebuckling, eigenvalue buckling analysis and postbuckling analysis [2, 17, 19]. In this paper, postbuckling isogeometric analysis of thin and ultra-thin structures under compression upon the first order shear deformation shell theory (FSDT) is performed. In the present approach, the bifurcation point in eigenvalue buckling analysis and limit points can be detected simply via the modified Riks method [1]. Hence, eigenvalue buckling analysis and postbuckling analysis are unified in the most simple flowchart.

As an improvement of finite element method (FEM), isogeometric analysis [6] was proposed to eliminate the error of geometry description and to fill the gap between computer-aided design and finite element method. Accordingly, complex geometries can be modeled exactly, conveniently and fast. This opened a new door for computational mechanics. So far, IGA has been developed widely for analysis and design of plates and shells. Postbuckling analyses using IGA can be found in [23] for multi-directional perforated FGM plates, laminated composite plates [9, 19], thermomechanical stability of functionally graded plates [20], thermal postbuckling analysis of temperature dependent graphene reinforced composite laminated plates [7], thermal postbuckling of FG-GPLRC laminated plates [8], functionally graded multilayer graphene nanoplatelet-reinforced polymer composite plates [16], functionally graded hybrid plates with cutouts under in-plane shear load [21]. In addition, postbuckling analyses of functionally graded carbon nanotube-reinforced composite shells were conducted in [12, 13]. Further developments of IGA for postbuckling analysis of shells can be found in [4] for thin shells with simple and complicated geometries, multilayer cylindrical and spherical panels [18], composite shells [10] and laminated plates and shallow shells [15]. In this paper, buckling and postbuckling behaviors and responses of thin and ultra-thin plates/shells are investigated. The obtained results show that the behaviors and responses of thin structures and of ultra-thin structures are significantly different. Some new results of ultra-thin structures are first proposed and some major conclusions are drawn.

The structure of the paper is described as follows: The next section presents postbuckling analysis of ultra-thin shells subjected to compression. Postbuckling analysis of ultra-thin shells using NURBS is performed in Section 3. Section 4 presents an efficiency approach for postbuckling analysis of ultra-thin plates/shells under compression. Results and discussions are provided in Section 5. Finally, the paper is closed with some major conclusions.