# Direct parametrisation of invariant manifold with shell finite element: nonlinear dynamics of thin structures using reduced order modeling


Zixu Xia*[1], Yu Cong†[1], Boumediene Nedjar[1], Jean Lerbet[1], Hamid Zahrouni[2], Shuitao Gu[3], and Zhi-Qiang Feng[1]

[1]Université d'Évry-Val-d'Essonne – LMEE, Univ Evry, Université Paris-Saclay – France
[2]Université de Lorraine – Université de Lorraine - LEM3 (UMR7239) – France
[3]Chongqing University [Chongqing] – China



### Abstract

The nonlinear dynamics of thin structures is a prominent research focus in modern mechanics. Compared to solid elements, shell elements are particularly attractive due to their reduced degrees of freedom and the straightforward application of displacement assumptions in the transverse direction. Despite having fewer degrees of freedom, shell elements still require considerable computational resources when used in nonlinear frequency domain analysis. As a result, developing an accurate and efficient Reduced Order Model (ROM) is critical for advancing the study of the dynamic behavior of thin structures. In this work, we propose the numerical framework of ROM incorporating the Direct parametrization of invariant manifold (DPIM) and 7-parameter solid-shell element to investigate the nonlinear dynamic behavior. Unlike traditional shell theories such as Kirchhoff-Love and Reissner-Mindlin, the solid-shell element directly applies three-dimensional constitutive relations without any modification. It inherently considers Enhanced Assumed Strain (EAS) through a mixed variational principle to prevent Poisson locking. Numerical examples demonstrate that our reduced-order model can accurately compare with the full-order model based on the Harmonic Balance (HB) method. Through this validation, we analyzed several cases to further explore nonlinear vibration behavior.



*Speaker
†Corresponding author: yu.cong@univ-evry.fr