Accurate modeling of the fracture of plates using the phase-field method

T. H. Tuan Tran[1*], J. Rahmoun[1, 2], H. Naceur[1, 2], D. Kondo[3]

[1] Univ. Polytechnique Hauts-de-France, CNRS, UMR 8201 - LAMIH, F-59313 Valenciennes, France, thanhhaituan.tran@uphf.fr

[2] INSA Hauts-de-France, F-59313 Valenciennes, France

[3] Sorbonne Université, Institut Jean le Rond d'Alembert - UMR 7190, F-75005 Paris, France

Since the last decade, the phase-field method has been increasingly developed [1]. This is due mainly to its good performance in capturing localized plasticity and damage in mechanical structures. The nonlocal nature of the phase-field method [2, 4, 5] is a key to its success in analyzing the damage and fracture propagation without dependency on the mesh size.

This work proposes a new numerical technique based on a strong coupling of damage and kinematics variables for the damage analysis of thin shell structures. To this purpose, the 4-node MITC4 shell element has been developed. It uses six kinematics variables per node (three translations and three rotations) and one extra degree of freedom representing the damage. The developed approach is based on the variational phase-field method proposed by Ambrosio and Tortorelli [3] and adapted to brittle fracture [2]. The condition of damage irreversibility was forced at each step using the penalty technique, not only for its simplicity but also for its effectiveness because it does not increase the size of the problem. The proposed technique has shown to be effective in solving several numerical applications involving thin and thick shell structures, including transverse shear with and without initial cracks. The results were compared to those from the literature using other numerical techniques such as XFEM and the Peridynamics, as well as some experimental results.

References

[1] T.H.T. Tran, J. Rahmoun, H. Naceur, D. Kondo, Analyse incrémentale basée sur les résolutions alternées pour la modélisation d'endommagement et de rupture fragile par champ de phase, CSMA 2022, 15ème Colloque National en Calcul des Structures, 16-20 mai, Presqu'île de Giens (Var), 2022.

[2] B. Bourdin, G.A. Francfort, J.J. Marigo, Numerical experiments in revisited brittle fracture, Journal of the mechanics and physics of solids, 48 (4), 797-826, 2000.

[3] L. Ambrosio, V.M. Tortorelli, Approximation of functionals depending on jumps by elliptic functionals via Γ-convergence, Commun. Pure Appl. Math, 43 (8), 999-1036, 1990.

[4] Josef Kiendl, Marreddy Ambati, Laura De Lorenzis, Hector Gomez, Alessandro Reali, Phase-field description of brittle fracture in plates and shells, Comput. Methods Appl. Mech. Engrg, 312, 374–394, 2016.

[5] G. Kikis, M. Ambati, L. De Lorenzis, S. Klinkel, Phase-field model of brittle fracture in Reissner–Mindlin plates and shells, Comput. Methods Appl. Mech. Engrg., 373, 2021.