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A FOUR NODE DOUBLY-CURVED SHELL ELEMENT BASED ON THE REFINED ZIGZAG THEORY

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Composite laminates are being used extensively in aircrafts, aerospace vehicles and civil structures. In order to exploit the full capabilities of composites structures for primary load-bearing components faster and more accurate analysis methodologies have to be developed. The prediction of the structures stress and strain fields becomes more challenging as the sandwich panel or the multilayered composite becomes thicker; structural theories that account for higher-order deformation effects are hence required. Moreover, multilayered laminates are employed in very demanding applications and they are required to bear complex and extreme loading conditions. Under such conditions, the structure may experience a non-linear behavior due to geometric and material nonlinearities.

Among higher-order theories, the Refined Zigzag Theory (RZT) is a novel formulation that overcomes the drawbacks of the earlier Zigzag theories and yield accurate modeling of homogeneous, laminated composite, and sandwich structures, while maintaining a fixed number of kinematic variables regardless of the number of material layers. The theory's baseline is the First-order Shear-Deformation Theory which is enriched with a micro-scale description of the laminate behavior while retaining the computationally efficient C0-continuous kinematic field.

The present work deals with the development of a doubly curved node shell element in the RZT framework suitable for implicit dynamics with small deformations. Parasitic phenomena characteristic of bilinear shell elements, such as shear locking, have been relieved by way of Assumed Natural Strain methods (ANS). Enhanced Assumed Strain (EAS) methodologies have been employed to improve the performances of the element in membrane-dominated and bending-dominated problems.

Convergence and accuracy of the proposed finite element have been assessed by way of analytical solutions and well-established benchmark problems for shell elements. When composite laminates and multilayer structures have been modeled, the present element showed excellent predictive capabilities.

REFERENCES

[1] A. Tessler, M. Di Sciuva, and M. Gherlone. Refined zigzag theory for laminated composite and sandwich plates. *Technical Report NASA*, **TP-2009-215561**, 2009.

[2] A. Tessler, M. Di Sciuva, and M. Gherlone. A refined zigzag beam theory for composite and sandwich beams. *Journal of Composite Materials*, Vol. **43**, 1051–1081, 2009.

[3] A. Tessler, M. Di Sciuva, and M. Gherlone. A consistent refinement of first-order shear-deformation theory for laminated composite and sandwich plates using improved zigzag kinematics. *Journal of Mechanics of Materials and Structures*, Vol. **5**, 341–367, 2010.

[4] D. Versino, M. Gherlone, M. Mattone, M. Di Sciuva and A. Tessler. C0 triangular elements based on the Refined Zigzag Theory for multilayer composite and sandwich plates, *Composites Part B: Engineering*, Vol. **44**, 218–230, 2013.

[5] A. Eijo, E. Oñate and S. Oller. A four-noded quadrilateral element for composite laminates plates/shells using the refined zigzag theory, *International Journal for Numerical Methods in Engineering*, Vol. **95**, 631–660, 2013.