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An efficient multiscale modeling framework for nonlinear analyses of composite structures

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Traditional multiscale modeling methods of composite structures are based on the global-local approach whereby the global analysis of structures are first performed to determine potential damage regions, followed by local analyses at those regions to identify detailed damage patterns and failure modes. Such an approach does not take into account the localized effects of critical regions on the global analysis and may become less accurate in general. To address better the behavior of local regions on multiscale analyses, homogenization-based multiscale methods are applied. For each load increment, the global problem is solved simultaneously with one Representative Volume Element (RVE) equilibrium problem for each Gauss point of the global mesh. This approach is successful to capture the local behavior at each material point; however, it is computationally expensive since the RVE is called at all the Gauss points in the global model for each load increment.

We develop an efficient multiscale modeling method whereby the RVE analyses are only called at specialized locations by multiscale elements and run parallel with the global analysis. The constitutive models of multiscale elements are defined in a user-defined element subroutine (UEL) where stiffnesses of the multiscale elements are unknown at the beginning of the analysis. They can only be obtained by performing a series of RVE analyses for each set of loads received from the global analysis. The advantage of the proposed method is that the stiffnesses of the multiscale elements are directly computed from the RVE analyses and keep updated for each global load increment. The nested multiscale modeling is implemented by Python script and highly capable for nonlinear analysis of composite structures.

Reference

1. B. Edmans, D.C. Pham, Z. Zhang, T.F. Guo, S. Narayanaswamy., Stewart G. "Multiscale Finite Element Analysis of Unbonded Flexible Risers". ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering. Volume 6B: Pipeline and Riser Technology, San Francisco, California, USA, 2014.

2. D.C. Pham, T. F. Guo, Z. Zhang, S. Narayanaswamy., B. Edmans. "An Effective Constitutive Model for Unbonded Flexible Riser". Offshore Technology Conference, 2014.