BRIDGING MULTI-SCALE METHODS FOR THE SIMULATION OF WAVE PROPAGATION IN DAMAGED, HOMOGENIZED PERIODIC MEDIA

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The analysis of wave propagation through solids has been used extensively as a tool for damage detection. This non-destructive technique is based on the common knowledge that mechanical waves generally propagate unperturbed through undamaged regions while they are affected by localized damages such as cracks, or by the presence of stiff inclusions. In particular reflections are observed when the propagating wave hits the damage: the observation of reflective waves therefore allows an accurate localization of potential damage areas. The numerical analysis of the phenomenon of wave propagation through a damaged medium is useful in order to investigate the problem theoretically and to generate a library of simulated behaviors to be compared with experimental measurements.

The dynamic finite element analysis of non homogeneous media can be computationally very expensive, especially if a very fine mesh is required to properly model the geometric and/or material discontinuities characteristic of damaged areas. The computational costs can be reduced through a multi-scale modeling approach, where a coarse mesh is employed to capture the macroscopic behavior of the structure, and a refined mesh is limited to the small region around the discontinuity. The co-existence of two scales in the model however causes the occurrence of spurious reflective waves at the interface between the coarse and the fine meshes. These spurious waves are the result of the difference in size between neighboring elements belonging to different meshes. These waves can be confused with true reflective waves due to the actual physical configuration of the structure and may interfere with a proper damage detection analysis. The elimination of spurious waves can be achieved through the application of proper bridging relations between the two scales. Interaction forces at the interfaces are added to bridge the two models and to minimize spurious discontinuities. This method allows a coarse description of the global behavior of the structure while simultaneously obtaining local information regarding the interaction of the propagating wave with a small discontinuity in the domain.

The potentials of the bridging multi-scale method are particularly interesting when the technique is used for the analysis of an homogenized periodic medium. Through homogenization it is possible to obtain a continuous representation of the domain, which allows significant savings in computational costs. Once the homogenized mechanical properties are found, a coarse finite element discretization of the continuum on the structure is used in conjunction with a localized fine mesh to capture microstructural effects and the presence of discontinuities. This allows predicting the global behavior of the domain through few homogenized macro-elements, while obtaining detailed observation for a small sub-region in the domain.

References

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