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Prediction of Multiple Cracks in Multiple Length Scales in Heterogeneous Viscoelastic Solids

Roberto F. Soares and David H. Allen

Summary

For heterogeneous solids, energy dissipation is the main cause of new internal boundaries development. It is not uncommon to have the growth of multiple cracks in one structural member, on multiple length and time scales. However, accurate prediction of where these cracks will go and when they will form is a complex task yet to be solved. Experimentally-based design procedures are extremely costly, therefore suggesting the need for improved models. Components that possess multiple length scales happen often in nature, such as composite materials used in aircraft industry, geologic media, tank armor and asphalt roadways, giving the model a broad range of applications. The propagation of multiple cracks in a body ultimately leads to failure of the material to perform its intended task. Therefore it is imperative the evolution of damage be accurately predicted. The problem of energy dissipation is particularly complicated for inelastic media where two forms of dissipation occur simultaneously when a crack grows: fracture energy and bulk material dissipation. Furthermore, cracks can coexist over a wide range of length scales simultaneously, making it appropriate to use a multi-scale algorithm. Then, as opposed to individually modeling every crack at all length scales in the continuum, which makes the problem untenable even with state of the art computers, a multiscale analysis has the advantage of taking into consideration the physical details pertaining to the heterogeneity of the component constituents. This type of algorithm has been untenable until recently because the problem must be solved recursively at all locations in which the material microstructure is evolving in time. Nevertheless, with the advancement of computer speed, it is possible to solve problems of this type using a desktop computer. The model is implemented into a time-marching, multi-scale finite element formulation that employs a micromechanic, viscoelastic cohesive zone model to predict rate-dependent damage evolution in the form of hundreds of cracks. The solution of each length scale is linked by homogenization theorems. An automatic load stepping integration scheme is proposed which features an automatic subincrementation algorithm of the load increments. Several example problems are presented to facilitate the understanding of how the multi-scale method works.