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Viscoelastic effective properties of two types of heterogeneous materials.

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In the past, a lot of efforts have been put to describe two end cases of rock behaviors: elasticity and viscosity. In recent years, more focus has been brought on the intermediate viscoelastic cases which describe better the rheology of rocks such as shales. Shales are typically heterogeneous and the question arises as to how to derive their effective properties so that they can be approximated as homogeneous media. This question has already been dealt with at the elastic and viscous limit but still remains for some cases in between.

Using MILAMIN, a fast finite element solver for large problems, we numerically investigate different approaches to derive the effective properties of several viscoelastic media. Two types of geometries are considered: layered and inclusion based media. We focus on two dimensional plane strain problems considering two phase composites deformed under pure shear.

We start by investigating the case of transversely isotropic layered media made of two Maxwell materials. Using the Backus averaging method we discuss the degree of relevance of this averaging by considering some parameters as: layer periodicity, layer thickness and layer interface roughness. Other averaging methods are also discussed which provide a broader perspective on the performances of Backus averaging.

In a second part we move on to inclusion based models. The advantage of these models compared to the previous one is that they provide a better approximation to real microstructures in rocks. The setup we consider in this part is the following: some viscous circular inclusions are embedded in an elastic matrix. Both the inclusions and the matrix are homogeneous but the inclusions are purely isotropic while the matrix can also be anisotropic. In order to derive the effective viscoelastic properties of the medium we use two approaches: the self-consistent averaging and the differential effective medium theory. The idea behind self-consistency is to assume that the inclusions are surrounded by the effective medium. Coupled non-linear algebraic equations are then derived to compute the effective properties. The differential effective medium on the other hand is based on introducing infinitesimal amounts of inclusions and then integrating them all to get the effective properties. We have implemented both approaches and we discuss the advantages and drawbacks specific to each one of them. The evaluation of the performances of each approach is done by comparing the results found numerically to the analytical predictions.