

Elastoplastic Multi-Layer Folding of Rocks with Finite Deformation Frictional Contact Kinematics

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ABSTRACT

In this work we present a numerical model to investigate folding processes of sedimentary rock layers using finite elements and large deformation contact mechanics. Movements experienced by folded layers are typically very large and may include significant rigid body translation and rotation, considerable straining, localized deformation, and relative slip at the interface between layers. Rocks are cohesive-frictional materials characterized by inelastic deformations and shear-induced dilatancy; yielding is pressure-dependent and the yield stress is higher under compression than extension. We employ a three-invariant plasticity model to define plastic loading and a non-associated flow rule to control inelastic dilatancy of the layers. The mechanical models involve a composite made up of individual continuous layers with distinct constitutive properties. In order to allow relative slips to occur at interface boundaries between adjacent layers, a finite deformation frictional contact model is implemented [1]. This approach uses a node-to-segment element discretization of the contacts, where arbitrary sliding of a node over the entire contact area is allowed. The method considers a penalty regularization of the Coulomb friction law. The implementation of the model includes a consistent linearization of the weak form of the linear momentum balance to enable optimal convergence for Newton-Raphson iteration. A fully Lagrangian approach with multiplicative plasticity theory for finite deformations and a return mapping algorithm scheme is used to integrate the stresses [2], as well as to predict the onset of localization during the deformation process. This study is useful for integrating mechanical and geological principles in order to formulate models constrained by available geological data. It also provides a framework to understand the relationship among folded shapes, internal stress states, and the occurrence of deformation bands and/or relative slip at the layer interfaces.

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References

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