Geophysical Research Abstracts
Vol. 17, EGU2015-8071, 2015
EGU General Assembly 2015

Generalization of the slip line field theory for temperature sensitive visco-plastic materials

Martin Paesold (1,2), Max Peters (3), Klaus Regenauer-Lieb (4), Manolis Veveakis (4), and Andrew Bassom (1)

(1) School of Mathematics and Statistics, University of Western Australia, (2) CSIRO Earth Science and Resource Engineering, Australia, (3) Institute of Geological Sciences, University of Bern, Bern, Switzerland, (4) School of Petroleum Engineering, University of New South Wales

Geological processes can be a combination of various effects such as heat production or consumption, chemical reactions or fluid flow. These individual effects are coupled to each other via feedbacks and the mathematical analysis becomes challenging due to these interdependencies. Here, we concentrate solely on thermo-mechanical coupling and a main result of this work is that the coupling can depend on material parameters and boundary conditions and the coupling is more or less pronounced depending on theses parameters. The transitions from weak to strong coupling can be studied in the context of a bifurcation analysis.

classically, Material instabilities in solids are approached as material bifurcations of a rate-independent, isothermal, elasto-plastic solid. However, previous research has shown that temperature and deformation rate are important factors and are fully coupled with the mechanical deformation. Early experiments in steel revealed a distinct pattern of localized heat dissipation and plastic deformation known as heat lines. Further, earth materials, soils, rocks and ceramics are known to be greatly influenced by temperature with strain localization being strongly affected by thermal loading. In this work, we provide a theoretical framework for the evolution of plastic deformation for such coupled systems, with a two-pronged approach to the prediction of localized failure. First, slip line field theory is employed to predict the geometry of the failure patterns and second, failure criteria are derived from an energy bifurcation analysis.

The bifurcation analysis is concerned with the local energy balance of a material and compares the effects of heat diffusion terms and heat production terms where the heat production is due to mechanical processes. Commonly, the heat is produced locally along the slip lines and if the heat production outweighs diffusion the material is locally weakened which eventually leads to failure. The effect of diffusion and heat production is captured by a dimensionless quantity, the Gruntfest number, and only if the Gruntfest number is larger than a critical value localized failure occurs. This critical Gruntfest number depends on boundary conditions such as temperature or pressure and hence this critical value gives rise to localization criteria. We find that the results of this approach agree with earlier contributions to the theory of plasticity but gives the advantage of a unified framework which might prove useful in numerical schemes for visco-plasticity.