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Fast and Robust Newton strategies for non-linear geodynamics problems

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Geodynamic problems are inherently non-linear, with sources of non-inearities arising from the (i) rheology, (ii) boundary conditions and (iii) the choice of time integration scheme.

We have developed a robust non-linear scheme utilizing PETSc's non-linear solver framework; SNES. Through the SNES framework, we have access to a wide range of globalization techniques. In this work we extensively use line search implementation. We explored a wide range different strategies for solving a variety of non-linear problems specific to geodynamics. In this presentation, we report of the most robust line-searching techniques which we have found for the three classes of non-linearities previously identified.

Among the class of rheological non-linearities, the shear banding instability using visco-plastic flow rules is the most difficult to solve. Distinctively from its sibling, the elasto-plastic rheology, the visco-plastic rheology causes instantaneous shear localisation. As a results, decreasing time-stepping is not a viable approach to better capture the initial phase of localisation. Furthermore, return map algorithms based on a consistent tangent cannot be used as the slope of the tangent is infinite. Obtaining a converged non-linear solution to this problem only relies on the robustness non-linear solver.

After presenting a Newton methodology suitable for rheological non-linearities, we examine the performance of this formulation when frictional sliding boundary conditions are introduced. We assess the robustness of the non-linear solver when applied to critical taper type problems.