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Efficient and Practical Newton Solvers for Nonlinear Stokes Systems in Geodynamic Problems

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The most commonly used method by the geodynamical community for solving non-linear equations is the Picard fixed-point iteration. However, the Newton method has recently gained interest within this community because it formally leads to quadratic convergence close to the solution as compared to the global linear convergence of the Picard iteration. In mantle dynamics, a blend of pressure and strain-rate dependent visco-plastic rheologies is often used. While for power-law rheologies the Jacobian is guaranteed to be Symmetric Positive Definite (SPD), for more complex rheologies, especially in combination with compressible models, the Jacobian may become non-SPD. Here we present a new method for efficiently enforce the Jacobian to be SPD, necessary for our current highly efficient Stokes solvers, with a minimum loss in convergence rate. Furthermore, we show how a partially stabilized Jacobian may greatly improve the convergence rate of the Newton iterations compared to a non-stabilized Jacobian. Finally we show the influence of line search and over solving algorithms on selected benchmarks and 3d geodynamic simulations.