Implicit integration methods for dislocation dynamics

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In dislocation dynamics simulations, strain hardening simulations require integrating stiff systems of ordinary differential equations in time with expensive force calculations, discontinuous topological events and rapidly changing problem size. Current solvers in use often result in small time steps and long simulation times. Faster solvers may help dislocation dynamics simulations accumulate plastic strains at strain rates comparable to experimental observations. This paper investigates the viability of high-order implicit time integrators and robust nonlinear solvers to reduce simulation run times while maintaining the accuracy of the computed solution. In particular, implicit Runge–Kutta time integrators are explored as a way of providing greater accuracy over a larger time step than is typically done with the standard second-order trapezoidal method. In addition, both accelerated fixed point and Newton's method are investigated to provide fast and effective solves for the nonlinear systems that must be resolved within each time step. Results show that integrators of third order are the most effective, while accelerated fixed point and Newton's method both improve solver performance over the standard fixed point method used for the solution of the nonlinear systems.