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A stochastic solver based on the residence time algorithm for crystal plasticity models. (English) Zbl 1479.74132

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Summary: The deformation of crystalline materials by dislocation motion takes place in discrete amounts determined by the Burgers vector. Dislocations may move individually or in bundles, potentially giving rise to intermittent slip. This confers plastic deformation with a certain degree of variability that can be interpreted as being caused by stochastic fluctuations in dislocation behavior. However, crystal plasticity (CP) models are almost always formulated in a continuum sense, assuming that fluctuations average out over large material volumes and/or cancel out due to multi-slip contributions. Nevertheless, plastic fluctuations are known to be important in confined volumes at or below the micron scale, at high temperatures, and under low strain rate/stress deformation conditions. Here, we develop a stochastic solver for CP models based on the residence-time algorithm that naturally captures plastic fluctuations by sampling among the set of active slip systems in the crystal. The method solves the evolution equations of explicit CP formulations, which are recast as stochastic ordinary differential equations and integrated discretely in time. The stochastic CP model is numerically stable by design and naturally breaks the symmetry of plastic slip by sampling among the active plastic shear rates with the correct probability. This can lead to phenomena such as intermittent slip or plastic localization without adding external symmetry-breaking operations to the model. The method is applied to body-centered cubic tungsten single crystals under a variety of temperatures, loading orientations, and imposed strain rates.

MSC:

74S60 Stochastic and other probabilistic methods applied to problems in solid mechanics
74C20 Large-strain, rate-dependent theories of plasticity
74E15 Crystalline structure

Keywords:

stochastic crystal plasticity; residence time algorithm; rate-dependent plasticity; kinetic Monte Carlo method; body-centered cubic crystal; plastic burst

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