Dual Domain Material Point Method for Multiscale Modeling of Polymeric Solid

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A polymeric solid can be modeled as a network of polymer chains consisting of chain segments and junction points. In the sense of ensemble average, the effect of the polymer chains between a pair of junction points can be effectively represented by an elastic spring deforming in a polymer liquid with a high viscosity. At the scale of polymer chains, the inertia is negligible. The deformation of the spring is governed by a diffusion equation. Solution to the equation leads to a time integration kernel for the stress relaxation. For a short time period, the kernel decays as the inverse of the square root of time. For a long time, the kernel decays exponentially. This behavior of stress relaxation has been verified experimentally. In the case of material motion where the strain rate changes over several orders of magnitude, direct application of this kernel in a numerical calculation requires store material strain rates at every time step, a significant memory demand for computers.

Using a Poisson summation relation, the kernel can be expanded in series of exponentially decaying terms resembling the Prony series used by many modelers for problems with strain rates varying by several orders of magnitude. With this series expansion of the relaxation kernel, each term can be associated with a Maxwell element. The information related to the Maxwell elements can be stored in material points in numerical simulations .

In this talk statistical theory and ensemble averaging techniques for the polymer network will be introduced. The numerical implementation of the constitutive relation using the dual domain material point method will be presented.