

Multiscale Modelling by PIC

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Main aims

The objective is to devise a multiscale modelling framework that benefits the advancements in particle-in-cell method.

Background

Problems we are concerned with are complex deformation of materials that are affected by several microstructural detailed phenomena. Such materials are Advanced High Strength Steels including Transformation Induced Plasticity and Dual Phase steels. An example of their applications is in the automotive industry: in forming, springback and high-speed impact analyses, where large deformation and complex loading paths are dominant. In these cases, conventional methods of simulation and prediction of material behaviour face some difficulties. Because material undergoes significant heterogenous microstructural deformation, strain partitions between phases, composite effects become important and phase transformations might happen.

For example, the finite element method is not sufficiently robust in the case of such problems when formulated in the Lagrangian description of motion. The excessive mesh distortions lead to inaccuracies in the solution. In past decade, two groups of computational methods have been developed intensely. One is the so-called Meshless methods and the other is methods formulated in arbitrary Lagrangian-Eulerian description of motion.

Particle-In-Cell (PIC) method is well known in fluid mechanics and can be classified to both mentioned groups due to its features. The method has been adapted to solid mechanic problems by (Burgess, Sulsky et al. 1992). In this research, we use PIC method to build a multiscale framework based on homogenization methods.

Key Findings To Date

Using this framework, macro scale model is simulated by PIC, where a collection of particles spread in an Eulerian mesh carry material properties. The constitutive equations of these material points are enforced by their relevant micro scale model. Therefore, each macro material point is a Representative Volume Element (RVE) of the micro region. The RVE problem is solved either by FEA or by PIC. The resultant averaged micro scale stresses are returned to material points and simulation proceeds. With this method, each microstructural phase is individually modelled by its own constitutive matrix and their contribution to macro deformation is pronounced. The framework is based on a parallel processing scheme developed and used at VPAC.

Publications

Presentation in 7th World Congress of Computational Mechanics Los Angeles, July 2006, "*Application of Radial Return Mapping Algorithm for Finite Strain Elastoplasticity in a Hybrid Finite Element and Particle-In-Cell Model*",

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Reference:

Burgess, D., D. Sulsky, et al. (1992). "Mass matrix formulation of the FLIP particle-in-cell method." Journal of Computational Physics **103**: 1-15.