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A discrete-continuum multiscale method for geomechanics

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This paper presents a general multiscale method for coupling discrete and continuum approaches. Discrete approach has been shown to be particular suitable for capturing physical phenomena at small length scales where continuum mechanics description no longer applies. Its efficiency, however, is limited because of the computational power required. Hence, continuum approach is considered as the practical scale for modeling the majority of problems. A multi-domain analysis coupling discrete model and continuum model is proposed in this paper to reduce the computational cost and improve the accuracy, and a bridging scale term is introduced such that compatibility of dynamic behavior between the DEM-based and FDM-based models is enforced. This multiscale method couples two existing commercial packages: the DEM-based code PFC, and the FDM-based code, FLAC. The new method is applied to dynamic tensile test. Results show this proposed method does not result in spurious wave reflections and does not need additional filtering or damping in the overlapping domain between the FDM meshes and the DEM particles.

In the bridging domain method [1], the total energy is taken as a linear combination of the FDM and DEM model energies. A scaling parameter α is introduced in the bridging subdomain (the overlapping domain). Fig.1 shows the multiscale model and Fig. 2 presents variations of α and $1-\alpha$ in the bridging subdomain.

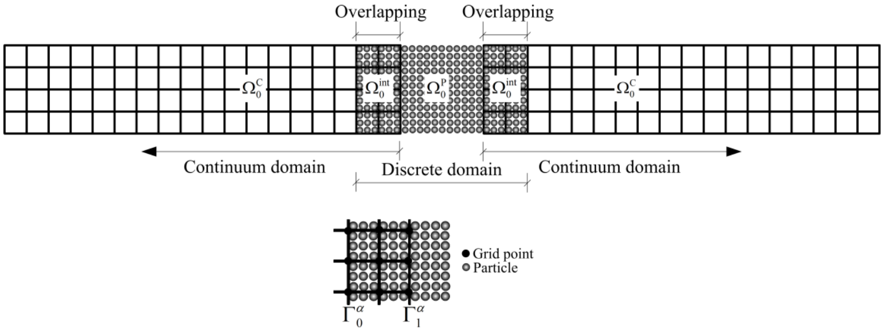

Figure 1. Bridging domain coupling discrete and continuum regions.

$$
\begin{aligned}
H &= (1-\alpha)H^{\mathrm{P}} + \alpha H^{\mathrm{C}} \\
&= \sum_I \left(1-\alpha(\mathbf{X}_I)\right)\frac{\mathbf{p}_I^{\mathrm{P}} \cdot \mathbf{p}_I^{\mathrm{P}}}{2m_I} + \left(1-\alpha(\mathbf{X}_I)\right)W^{\mathrm{P}} + \sum_J \alpha(\mathbf{X}_J)\frac{\mathbf{p}_J^{\mathrm{C}} \cdot \mathbf{p}_J^{\mathrm{C}}}{2M_J} + \alpha(\mathbf{X}_J)W^{\mathrm{C}}
\end{aligned}
$$

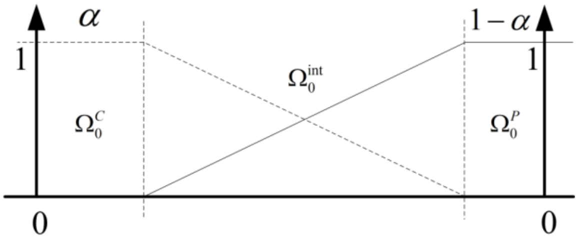

Figure 2. Linear weight function α .

A 2D beam model is adopted for verification, as shown in Fig. 3. The corresponding result is illustrated in Fig. 4. It can be seen from this figure that the proposed multiscale takes advantage of eliminating the spurious wave reflection comparing with the non-overlapping coupling method.

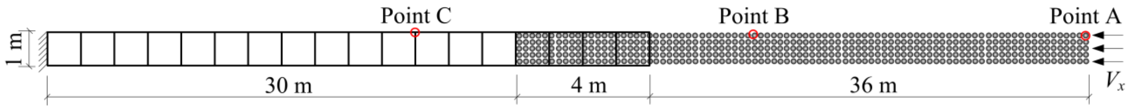

Figure 3. Beam model for wave propagation.

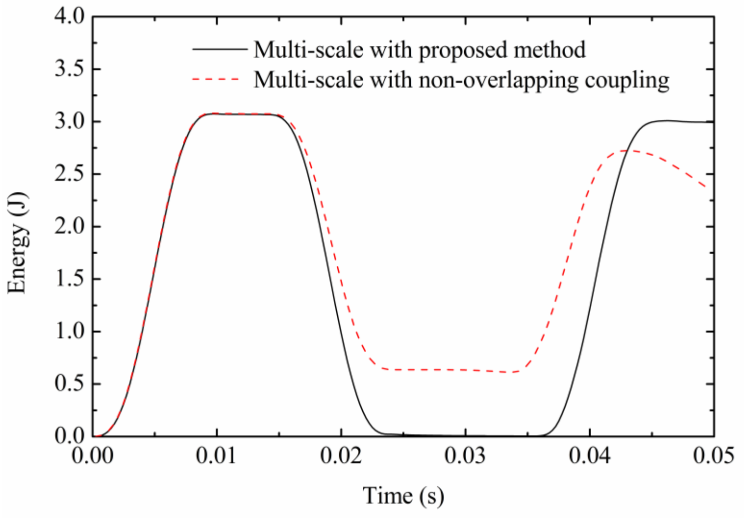

Figure 4. Total energy responses of the discrete model.

REFERENCE

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