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RESEARCH PAPERS

用改进的单元胞模型数值模拟液体穿过球形颗粒群的流动

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摘要　The cell model developed since 1950s is a useful tool for exploring the behavior of particle assemblages,but it demands further careful development of the outer cell boundary conditions so that interaction in a particleswarm is better represented. In this paper, the cell model and its development were reviewed, and the modificationsof outer cell boundary conditions were suggested. At the cell outer boundary, the restriction of uniform liquid flowwas removed in our simulation conducted in the reference frame fixed with the particle. Zero shear stress conditionwas used to evaluate the outer boundary value of the stream function. Boundary vorticity was allowed to evolve tovalues compatible to existing stream function at the free shear outer boundary. The fore-aft symmetry of vorticitydistribution at the outer boundary is thought critical to ensure the continuity of inflow and outflow between touchingneighbor cells, and is also tested in the modified cell model. Numerical simulation in terms of stream function andvorticity based on the modified cell models was carried out to shed light on the interaction between liquid andparticles. Lower predicted drag coefficient by the modified cell models was interpreted with the feature of flowstructure. The drag coefficient from the simulation was also compared with correlations of drag coefficient reportedin literature. It is found that the modified cell model with the uniformity of external flow relaxed and the fore-aftsymmetry of boundary vorticity enforced was the most satisfactory on the overall performance of prediction.

关键词　cell model　numerical simulation　particle assemblage　boundary condition　drag coefficient　correlation

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Numerical Simulation of Viscous Flow Through Spherical Particle Assemblage with the Modified Cell Model

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Abstract The cell model developed since 1950s is a useful tool for exploring the behavior of particle assemblages,but it demands further careful development of the outer cell boundary conditions so that interaction in a particleswarm is better represented. In this paper, the cell model and its development were reviewed, and the modificationsof outer cell boundary conditions were suggested. At the cell outer boundary, the restriction of uniform liquid flowwas removed in our simulation conducted in the reference frame fixed with the particle. Zero shear stress conditionwas used to evaluate the outer boundary value of the stream function. Boundary vorticity was allowed to evolve tovalues compatible to existing stream function at the free shear outer boundary. The fore-aft symmetry of vorticitydistribution at the outer boundary is thought critical to ensure the continuity of inflow and outflow between touchingneighbor cells, and is also tested in the modified cell model. Numerical simulation in terms of stream function andvorticity based on the modified cell models was carried out to shed light on the interaction between liquid andparticles. Lower predicted drag coefficient by the modified cell models was interpreted with the feature of flowstructure. The drag coefficient from the simulation was also compared with correlations of drag coefficient reportedin literature. It is found that the modified cell model with the uniformity of external flow relaxed and the fore-aftsymmetry of boundary vorticity enforced was the most satisfactory on the overall performance of prediction.

Key words cell model; numerical simulation; particle assemblage; boundary condition; drag coefficient; correlation

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