Uh Zapata, M.; **Pham Van Bang, D.**; **Nguyen, K. D.**
Parallel simulations for a 2D x/z two-phase flow fluid-solid particle model. (English)
Zbl 1410.76269

Summary: The importance of the two-phase flow model relies upon the correct simulation of specific problems in which the passive tracer model fails; however, the mathematical and numerical models need to be improved in order to reproduce fluid-solid particle interactions of greater complexity. Such is the case with regard to simulating erosion patterns suffered upon horizontal granular beds by means of a vertical water jet as shown here. Moreover, sequential platforms have proven to be insufficient in providing the required computational power needed to obtain fast and detailed simulations. In this paper, a fully parallel algorithm for a two-dimensional x/z two-phase Eulerian approach is presented and applied for the numerical solution of the erosion of sediment beds. The parallelization is designed by a row and column block domain decomposition technique using a distributed memory platform with message passing interface (MPI). Arising from the numerical method, a Poisson problem for the pressure is solved at each time step. The discretization results in a non-symmetric variable-coefficient linear system which is solved using several parallel successive over-relaxation (SOR) algorithms, including partitioning and coloring methods. The specification of the optimal relaxation parameter to achieve efficiency is found numerically. Results show that SOR methods achieve faster convergence rates and the simulation time achieves an order similar to that required for the typical, widely-used bi-conjugate gradient stabilized (Bi-CGSTAB) method. The performances of the algorithms are evaluated in terms of speedup and efficiency. The results indicate that the parallel code significantly improves the results of the sequential calculation in general.

MSC:

76M12	Finite volume methods applied to problems in fluid mechanics
76T20	Suspensions
65M08	Finite volume methods for initial value and initial-boundary value problems involving PDEs

Keywords:

two-phase flow; sediment erosion; domain decomposition; MPI; SOR; Bi-CGSTAB

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References:

[1] Nguyen, K. D.; Guillou, S.; Chauchat, J.; Barbry, N., A two-phase numerical model for suspended-sediment transport in estuaries, Adv Water Resour, 32, 8, 1187-1196, (2009)

[2] Nguyen, D. H.; Levy, F.; Bang, D. P.V.; Guillou, S.; Nguyen, K. D.; Chauchat, J., Simulation of dredged sediment releases into homogeneous water using a two-phase model, Adv Water Resour, 48, 102-112, (2012)

[3] Hanson, G. J.; Hunt, S. L., Lessons learned using laboratory JET method to measure soil erobility of compacted soils, Appl Eng Agric, 23, 3, 305-312, (2007)

[4] Perng, A. T.H.; Capart, H., Underwater sand bed erosion and internal jump formation by a travelling plane jets, J Fluid Mech, 595, 1-43, (2008) · Zbl 1159.76306

[5] Metzger, P. T.; Immer, C. D.; Donahue, C. M.; Vu, B. T.; Latta, R. C.; Deyo-Svendsen, M., Jet-induced cratering of a granular surface with application to lunar spaceports, J Aerosp Eng, 22, 24-32, (2009)

[6] Weidner, K.; Petrie, J.; Diplas, P.; Nam, S.; Gutierrez, M.; Ellenberg, M., Numerical simulation of jet test and associated soil erosion, Proceedings of 6th international conference on scour erosion, ICSE6, Paris (France), (2012)

[7] Kuang, S. B.; LaMarche, C. Q.; Curtis, J. S.; Yu, A. B., Discrete particle simulation of jet-induced cratering of a granular bed, Powder Technol, 239, 319-336, (2013)

[8] Qian, Z. D.; Hu, X. Q.; Huai, W. X.; Xue, W. Y., Numerical simulation of sediment erosion by submerged jets using an Eulerian model, Sci China, Technol Sci, 53, 12, 3324-3330, (2010) · Zbl 1278.76012

[9] Guillou, S.; Barbry, N.; Nguyen, K. D., Calcul numérique des ondes de surface par un méthode de projection et un maillage eulerien adaptatif, CR Acad Sci (ser II B), 328, 875-881, (2000) · Zbl 1027.76031

[10] Gibou, F.; Min, C., On the performance of a simple parallel implementation of the ILU-PCG for the Poisson equation on

irregular domains, J Comput Phys, 231, 14, 4531-4536, (2012) · Zbl 1245.76065

[11] Erhel, J., A parallel GMRES version for general sparse matrices, Electron Trans Numer Anal, (1998)

[12] Adams, L.; Ortega, J., A multi-color SOR method for parallel computation, ICPP, 53-56, (1982)

[13] Zhang, C.; Lan, H.; Ye, Y.; Estade, B. D., Parallel SOR iterative algorithms and performance evaluation on a Linux cluster, (2005), Naval Research Lab Stennis Space Center MS Oceanography Div

[14] Xie, D., A new block parallel SOR method and its analysis, SIAM J Scient Comput, 27, 5, 1513-1533, (2006) · Zbl 1100.65032

[15] Tanga, T.; Liua, W.; McDonoughb, J. M., Parallelization of linear iterative methods for solving the 3-d pressure Poisson equation using various programming languages, Procedia Eng, 61, 136-143, (2013)

[16] Drew, D. A.; Lahey, R. T., Analytical modeling of multiphase flow, Particulate two-phase flow, 509-566, (1993)

[17] Lundgren, T., Slow flow through stationary random beds and suspensions of spheres, J Fluid Mech, 51, (1972) · Zbl 0229.76067

[18] Graham, A. L., On the viscosity of suspensions of solid spheres, Appl Sci Res, 37, (1981) · Zbl 0476.76095

[19] Hsu, T.; Jenkins, J. T.; Liu, L. F., On two-phases sediment transport: dilute flow, J Geo Res, 108, 14, (2003)

[20] Haider, A.; Levenspiel, O., Drag coefficient and terminal velocity of spherical and non-spherical particles, Powder Technol, 58, 63-70, (1989)

[21] Chorin, A. J., Numerical solution of the Navier Stokes equations, Math Comp, 22, 745-762, (1968) · Zbl 0198.50103

[22] Temam, R., Sur l'approximation des équations de Navier-Stokes par la méthode des pas fractionnaires (II), Arch Ration Mech Anal, 26, 367-380, (1967)

[23] Badr, S.; Gauthier, G.; Gondret, P., Erosion threshold of a liquid immersed granular bed by an impinging plane liquid jet, Phys Fluids, 26, 023302, (2014)

[24] van der Vorst, H. A., Bi-CGSTAB: a fast and smoothly converging variant to bi-CG for the solution of nonsymmetric systems, SIAM J Sci Stat Comput, 13, 631-644, (1992) · Zbl 0761.65023