MESHFREE simulations for solution mining processes

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ABSTRACT

Experimental and field investigations for solution mining processes have improved intensely within the last years. Due to today's computing capacities, 3D simulations of potential salt solution caverns can further enhance process understanding. They serve as a "virtual prototype" of a projected site and support planning in reasonable time.

Classical simulation methods are meshbased. Moving geometry parts, free surfaces, phase boundaries, or large deformations are difficult to handle or require time-consuming re-meshing algorithms. This is not the case for meshfree methods. They show their strengths best for these applications. The meshfree Finite Pointset Method (FPM) uses a generalized finite difference approach on a cloud of numerical points. There are already successful applications of the method in CFD and continuum mechanics. Examples are water crossing of cars, water turbines, hydraulic valves, soil mechanics, or metal cutting (see [1, 2]). The current development of the integrated tool MESHFREE has eliminated previous shortcomings concerning robust and scalable solutions of sparse, linear systems. MESHFREE combines the advantages of FPM and the fast linear solvers of SAMG. In this contribution, we present its capabilities with respect to the simulation of solution mining processes on microscopic and macroscopic scales.

Originally, FPM uses a Lagrangian formulation, i.e. the point cloud moves according to the flow velocity. Thus, there is an accurate and natural transport of physical information. The basic physical model consists of the conservation equations for mass, momentum, and energy. For solution mining processes, we extend it by the k-epsilon turbulence model and equations for the concentration of the occurring species. The conducted microscopic simulations illustrate a method to determine the necessary effective model parameters of a macroscopic problem. For macroscopic simulations, the Lagrangian formulation leads to a significant restriction of the time step size due to the necessary explicit movement of the point cloud. To enable simulations in reasonable time, the Eulerian formulation should be preferred (see [3]). Thereby, the point cloud is fixed and convective terms represent the transport of physical information. The necessary movement of the boundary of the salt cavern is implemented based on the solution rate. Close to the boundary, interior points are subject to an ALE-approach (Arbitrary Lagrangian-Eulerian). This procedure gives rise to covering the complete life cycle of a salt cavern by a meshfree simulation. We demonstrate the advantages of the Eulerian formulation for a simplified macroscopic example.

REFERENCES

[1] Jefferies, A. and Kuhnert, J. and Aschenbrenner, L. and Giffhorn, U. Finite Pointset Method for the Simulation of a Vehicle Travelling Through a Body of Water. In: Griebel, M. and Schweitzer, M. (eds) Meshfree Methods for Partial Differential Equations VII. Lecture Notes in Computational Science and Engineering, Vol. 100. Springer, Cham, pp. 205–211, 2015.

[2] Michel, I. and Bathaeian, S.M.I. and Kuhnert, J. and Kolymbas, D. and Chen, C.-H. and Polymerou, I. and Vrettos, C. and Becker, A. Meshfree generalized finite difference methods in soil mechanics – part II: numerical results. Int. J. Geomath., Vol. **8(2)**, pp. 191–217, (2017).

[3] Seifarth, T. Numerische Algorithmen für gitterfreie Methoden zur Lösung von Transportproblemen. PhD Thesis, University of Kassel. Fraunhofer Verlag, 2018.