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PARALLEL IMPLEMENTATION OF 2-D BOUNDARY ELEMENT FORMULATION FOR A MICROFLUIDIC PARTICULATE FLOW

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Manipulation of bioparticles within the microchannel networks is a key ingredient for many microfluidics-based biomedical and chemical applications. Therefore, for an efficient design of microfluidic systems, the simulation of the motion of the bioparticle(s) with different shapes and size is crucial. A rigorous method to simulate the particle motion is the stress tensor approach in which the field variables are solved with the presence of the finite-sized particle. The resultant force on the particle can be obtained by integrating the appropriate stress tensor on the particle surface. In each incremental movement of the particle, the field variables need to be resolved. A rigorous simulation of the particle motion utilizing tensor approach requires massive remeshing. For methods involving domain discretization, such as finite element method (FEM) or finite volume method (FVM) not only the remeshing process is computationally expensive, but also at each remeshing step, some interpolating algorithms relating the field variables in the new mesh in terms of the variables of the old mesh are required which cause some loss in the accuracy. Moreover, the determination of the forces induced on the particles requires the calculation of gradient of the field variables. Therefore, for an accurate calculation of gradient of field variables, fine mesh is required on and within the close neighborhood of the particle surface. This requirement also creates some problems in the remeshing process when working with methods involving domain discretization, especially when a particle moves in the vicinity of the wall or two particles come close to each other. To overcome the remeshing problem for the simulation of particulate flow at macroscale, immersed boundary method [1] and fictitious domain method [2] have been proposed and implemented. Although these methods are computationally very efficient, to model the particle-particle interaction, some contact modeling is required which has a resolution that cannot be accepted for the simulation at microscale. Moreover, these methods are well established for flow simulations, but very rare studies exist for the coupling of the flow with other external forces such as the electrical and/or magnetic fields. At this point, BEM introduces a unique advantage for these kind of problems since it only discretizes the boundary (hence less computational effort in remeshing) and the derivative quantities within the solution domain is determined by analytical differentiation (hence more accurate computation).

Implementations of BEM for linear problems are very well-developed and are almost straight forward. Considering the flow in microfluidic systems, typically the flow speed is low (resulting in very low Reynolds number) and the inertia forces are negligible (in magnitude) when compared with the pressure or the viscous forces. The flow can be considered as the so-called creeping flow. The governing equations of the creeping flow are those of the Stoke's flow, which are linear partial differential equations which makes BEM is a perfect match for the microfluidic applications. suitable for solution with the BEM.

In this study, a formulation to simulate the particle trajectory the motion of the particles within a microchannel flow is presented. The method involves the re-organization of the BE matrices in such a way that the only unknowns of the linear system of equations are the motion parameters (e.g., the translational and rotational velocities of the centers of gravity) of the particles. With such manipulation, the dimension of the linear system of equations to be solved is reduced drastically, resulting in a comparably faster solution. Since the proposed formulation heavily relies on matrix multiplications, the formulation is suitable for parallelization. A GPU parallellization is implemented and the performance is compared with sequential implementation. It has been seen that the present formulation offers an efficient parallellization and is a good numerical model to be used for the simulation of the particle trajectory for microfluidic applications and can easily be extended for 3D multiphysics simulations.

REFERENCES

[1] A. L. Fogelson and C. S. Peskin. A fast numerical method for solving the three-dimensional stokes equations in the presence of suspended particle. *J. Comput. Phys.*, **79**,50–69, 1988.

[2] R. Glowinski, T. W. Pan, T. I. Hesla, D. D. Joseph, and J. Periaux. A fictitious domain approach to the direct numerical simulation of incompressible viscous flow past moving rigid bodies: Application to particulate flow. *J. Comput. Phys.*, **169**, 363–426, 2001.