6-way CFD-DEM-FEM partitioned momentum coupling using preCICE

Prasad ADHAV[1], Xavier BESSERON[2], Bernard PETERS[3]

[1 2 3] University of Luxembourg, Campus Belval, 2, Avenue de l'Université, L-4365
[1]prasad.adhav@uni.lu, web page: https://luxdem.uni.lu/

Many real-life complex phenomena can be described using momentum transfer between fluids, particles, and solids. These descriptions can represent countless applications in industrial sectors such as manufacturing, production, aerospace, medical, pharmaceutical, energy, and waste management. It is expensive and difficult, if not impossible, to create experimental tests for such complex processes. Hence it is crucial to perform numerical simulations. To achieve simulations for such applications, diverse numerical methods among them Computational Fluid Dynamics (CFD), Discrete Element Methods (DEM), and/or Finite Element Methods (FEM) need to be coupled with each other to represent a multi-physics application.

Our prototype relies on the preCICE [1] coupling library to couple 3 numerical solvers: eXtended Discrete Element Method [2] (XDEM) (for DEM), OpenFOAM [3] (for CFD), and CalculiX [4] (for FEM). The XDEM solver receives various CFD data fields such as fluid domain properties, and flow conditions exchanged through preCICE, which are used to set boundary conditions for particles. XDEM handles the particle motion, and forces on structures. Many drag transfer laws have been implemented in XDEM to steer source term computations. The source terms computed by XDEM are transferred to the CFD solver and added as source terms representing particle contribution to CFD. CalculiX uses the forces coming from the fluid solver and particle solver as boundary conditions to solve for the displacements.

This work illustrates the rapid development of a simulation environment to achieve the momentum coupling capabilities through various test cases. We demonstrate the 6-way coupling between CFD-DEM-FEM, where CFD-DEM Eulerian-Lagrangian coupling is achieved over a volumetric mesh, CFD-FEM, and DEM-FEM is coupled over a surface mesh. The generic coupling interface of preCICE, XDEM, and its adapter allows us to get closer to a digital twin for the Abrasive Water Jet Cutting (AWJC) Nozzle where we simulate the water jet, entrained particles, as well as the solid nozzle. The results for the AWJC Nozzle are presented.

References

[1] Bungartz, H. J., Lindner, F., Gatzhammer, B., Mehl, M., Scheufele, K., Shukaev, A., & Uekermann, B. preCICE–a fully parallel library for multi-physics surface coupling. Computers & Fluids, 141, 250-258, (2016).

[2] Peters, B., Baniasadi, M., Baniasadi, M., Besseron, X., Donoso, A.E., Mohseni, M. and Pozzetti, G., XDEM multi-physics and multi-scale simulation technology: Review of DEM–CFD coupling, methodology and engineering applications. Particuology, 44, pp.176-193. (2019)

[3] https://openfoam.org/ (Online; accessed 01 April 2020)

[4] Dhondt, G. and Wittig, K., Calculix: a free software three-dimensional structural finite element program. MTU Aero Engines GmbH, Munich. (1998)