Accelerated Heat and Mass Transfer Simulations Using Coupled CFD and DEM

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ABSTRACT

This work presents a simulation of heat and mass transfer in an aggregate dryer with coupled Discrete Element Methodology (DEM) [1] and Computational Fluid Dynamics (CFD) [2]. The presented model focuses on demonstrating the capabilities and effectiveness of implementing the Graphics Processing Unit (GPU) [3-5] combined with the Central Processing Unit (CPUs) [6-8] technologies to run this simulation. Previous work [9] has shown that coupled CFD-DEM simulations can be beneficial but computationally expensive for industrial scale applications. The aim of this work is to describe the process of simulating aggregate drying while performing accelerated DEM simulations with the use of GPU, and CFD simulations with the use of multiple CPUs.

For efficient mixing, the aggregate material must be completely dried followed by coating with the use of liquid asphalt cement binder. This process is accomplished in a counter flow drum heated by a direct fire burner with internal metal slats (flighting) to facilitate heat transfer (Figure 1). Direct observation of such processes is impossible and thus simulation gives the ability not only to monitor the behavior of the material, but also to optimize the flight design for increased drying efficiency. For this project, commercial codes from DEM-Solutions and ANSYS were coupled using a coupling developed by ANSYS. Particle interactions are solved by the DEM solver. Fluid flow and particle-fluid interactions are solved by the CFD solver which exchange information at regular intervals. The coupling method is based on ANSYS Fluent's Dense Discrete Phase Model (DDPM) with heat transfer and momentum exchange between the fluid and the particle phases. Results show that the coupled model correctly captures the convective heat transfer process.

Furthermore, this project aims to present an innovative way of accelerating such demanding simulations by performing DEM calculations in GPU mode while solving for the fluid in CPU mode. This solver provides very fast computational speeds compared to simulations on multi-core CPUs. This process has been performed with the use of the EDEM GPU solver engine, which has been created by DEM Solutions LTD. Double precision Open Computing Language (OpenCL) [10] framework has been implemented in the EDEM simulation engine for the AMD Radeon R9 Fury X graphic card and includes a physics model equivalent to the CPU version to satisfy the required accuracy.

The simulation is comprised of 539.942 bi-sphered particles and was run for 1 second of simulation time with and without the use of the GPU solver. The CPU configuration assigned 2 CPU cores for the CFD solver and 12 CPU cores for the DEM solver, respectively. The GPU configuration assigned the same number of CPU cores to the CFD solver and employed a combination of GPU and 8 CPU cores for the DEM solver. The results showed that the total computation time for the 1 second of simulated time, under GPU mode, was 85min in contrast with the total computational time under CPU mode which was 189min. This estimates a reduction of around 55% simulation time, highlighting the significance of using GPU technology for complex coupled CFD-DEM calculations. Finally, the

recorded time only used by the DEM solver under GPU mode was 9 minutes, which represents an improvement of 95%. Such fast simulations have a significant impact in large-scale applications with models comprised of millions of particles.

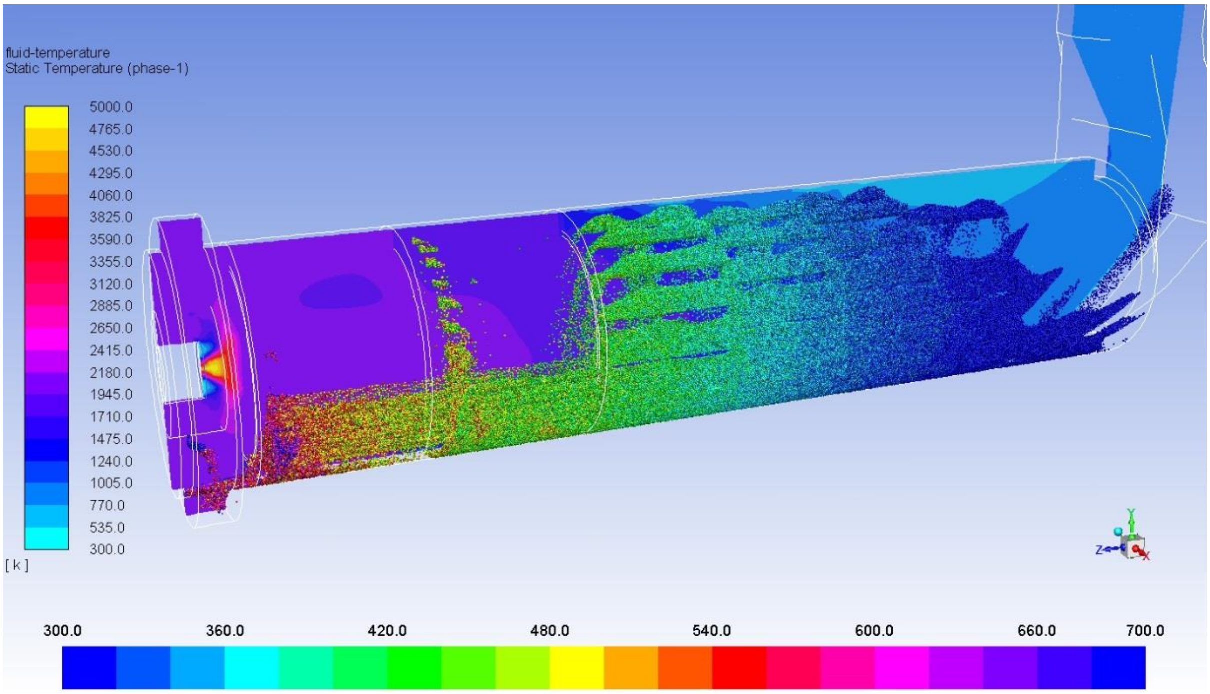

Figure 1 Coupled CFD-DEM simulation of an aggregate dryer demonstrating the fluid - particle temperature distribution.

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