Accelerating OpenFOAM on Frontier GPUs for Fusion Multiphysics Simulations

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At Oak Ridge National Laboratory, we are developing coupled multiphysics simulation suites for integrated assessment of fusion devices. This includes plasma physics codes for understanding plasma behavior and instabilities coupled with engineering simulations for design of fusion blankets. One of the major computational bottlenecks in fusion blanket simulations is the computational fluid dynamics (CFD) analysis of liquid blanket concepts and cooling of the first wall. CFD simulations need to account for turbulent fluid flow, heat transfer in high heat flux environments, buoyancy effects and magnetohydrodynamic (MHD) effects in magnetic confinement devices. CFD+MHD simulations of fusion blankets are required for proper pumping power and material temperatures analysis. These directly inform viability of the fusion blanket design. However, such simulations in fusion relevant conditions are extremely time consuming. This causes parametric studies and design optimization extremely hard to perform within reasonable time scales. The goal of the present work is to leverage exascale computing architectures to accelerate such simulations.

In the present work, we demonstrate the capability of the open-source CFD software, OpenFOAM in resolving the metrics for fusion blanket design assessment. A clear path towards accelerating OpenFOAM simulations on architecture agnostic GPUs is outlined with a demonstration of its performance on the world's fastest supercomputer, Frontier. Presently, about 3x speed-up is obtained on Frontier GPUs. However, there is room for considerably improvement which is presently being explored. In this presentation, the approach to GPU acceleration of OpenFOAM using ECP (exascale computing project) developed tools such as PETSc, Kokkos, and Hypre will be outlined. The scaling and performance of GPU-enabled OpenFOAM on Frontier GPUs for fusion blanket simulations will be discussed along with a roadmap of planned activities. It will be shown that CFD+MHD simulations of fusion blanket can be performed much quicker on GPUs leading to simulations results which can give insight into the effects of MHD on engineering metrics such as pressure drop and heat transfer.