Abstract Submitted
for the DFD15 Meeting of
The American Physical Society

Implicit solution of Navier-Stokes equations on staggered curvilinear grids using a Newton-Krylov method with a novel analytical Jacobian. IMAN BORAZJANI, HAFEZ ASGHARZADEH, The State University of New York at Buffalo (SUNY) — Flow simulations involving complex geometries and moving boundaries suffer from time-step size restriction and low convergence rates with explicit and semi-implicit schemes. Implicit schemes can be used to overcome these restrictions. However, implementing implicit solver for nonlinear equations including Navier-Stokes is not straightforward. Newton-Krylov subspace methods (NKMs) are one of the most advanced iterative methods to solve non-linear equations such as implicit descritization of the Navier-Stokes equation. The efficiency of NKMs massively depends on the Jacobian formation method, e.g., automatic differentiation is very expensive, and matrix-free methods slow down as the mesh is refined. Analytical Jacobian is inexpensive method, but derivation of analytical Jacobian for Navier-Stokes equation on staggered grid is challenging. The NKM with a novel analytical Jacobian was developed and validated against Taylor-Green vortex and pulsatile flow in a 90 degree bend. The developed method successfully handled the complex geometries such as an intracranial aneurysm with multiple overset grids, and immersed boundaries. It is shown that the NKM with an analytical Jacobian is 3 to 25 times faster than the fixed-point implicit Runge-Kutta method, and more than 100 times faster than automatic differentiation depending on the grid (size) and the flow problem. The developed methods are fully parallelized with parallel efficiency of 80-90% on the problems tested.

Hafez Asgharzadeh
The State University of New York at Buffalo (SUNY)

Date submitted: 30 Jul 2015 Electronic form version 1.4