A Non-oscillatory Forward in Time Formulation for Incompressible Fluid Flows

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NFT Framework

For the generic equation

$$\frac{\partial \vec{\Phi}}{\partial t} + \nabla \bullet (\mathbf{V}\vec{\Phi}) = \mathbf{R}$$

The NFT framework is written as

$$\mathbf{\Phi}_i^{n+1} = \mathbf{\Phi}_i^* + 0.5\delta t \mathbf{R}_i^{n+1}$$

$$\mathbf{\Phi}^* \equiv \mathcal{A}(\mathbf{\Phi}^n + 0.5\delta t \mathbf{R}^n, \widehat{\mathbf{V}}^{n+1/2})$$

Explicit

Implicit

$$R^{n+1} = R(t + \delta t) + \mathcal{O}(\delta t^3)$$

(non-symmetric Krylov subspace elliptic solver)

(P.K.Smolarkiewicz et.al., Monthly weather review,1993)

Governing Equations

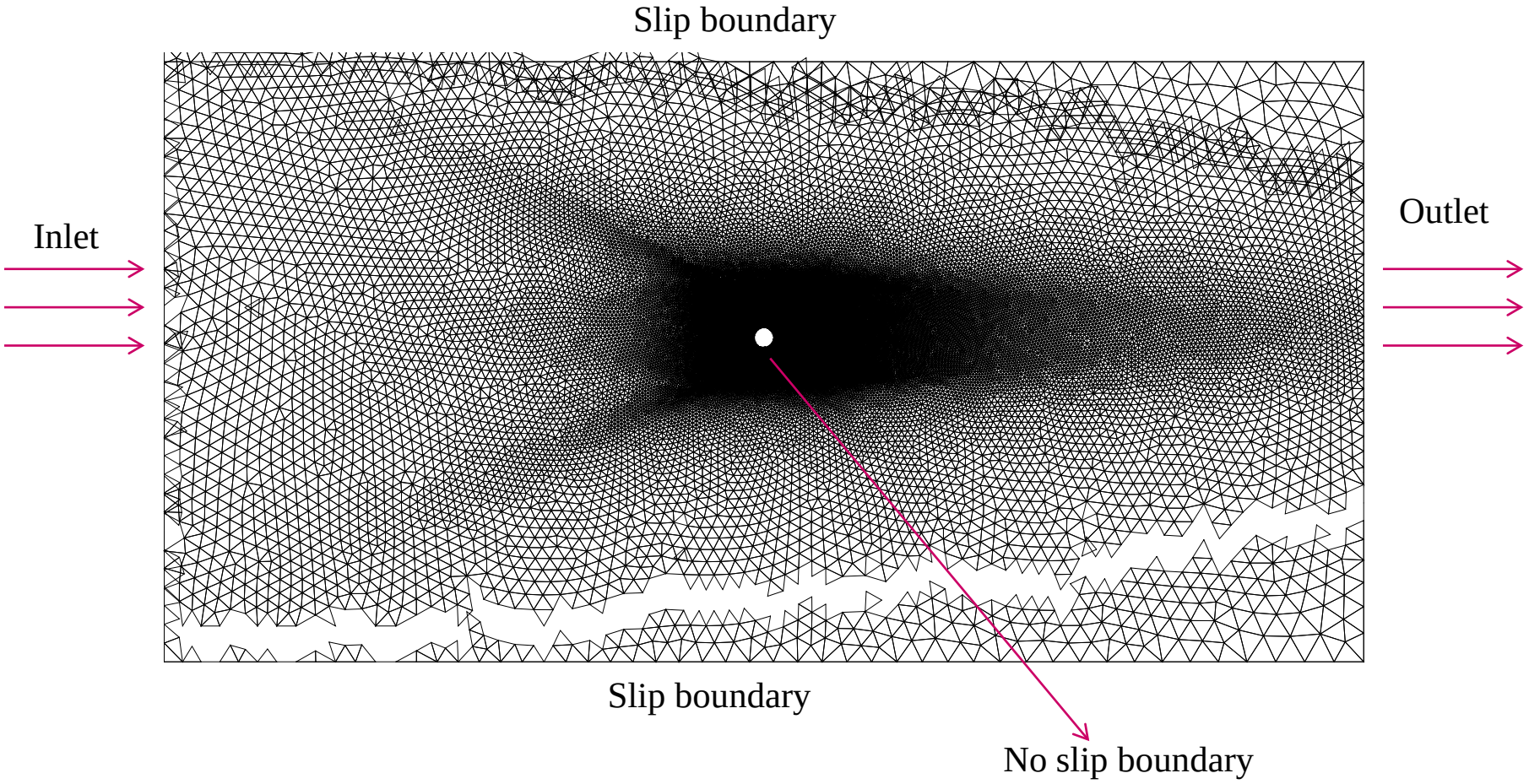
Continuity equation

$$\nabla.(\vec{u}) = 0$$

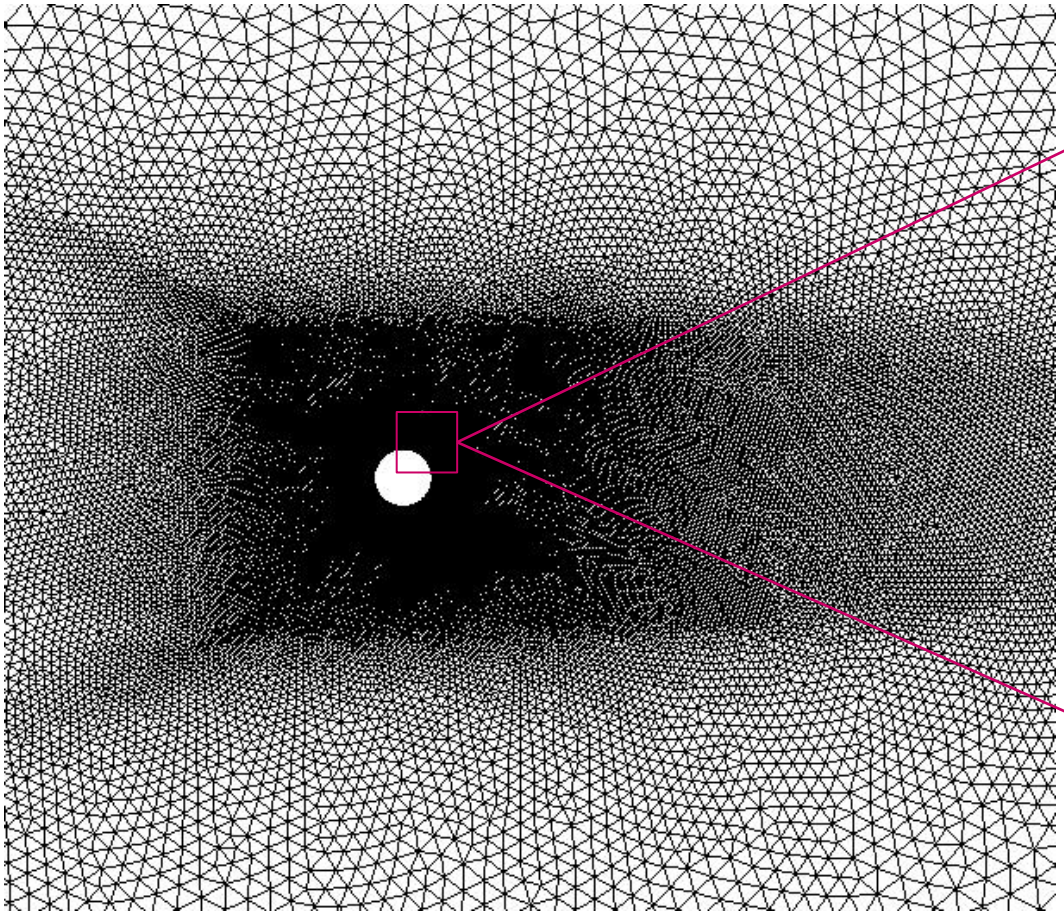
Momentum equation

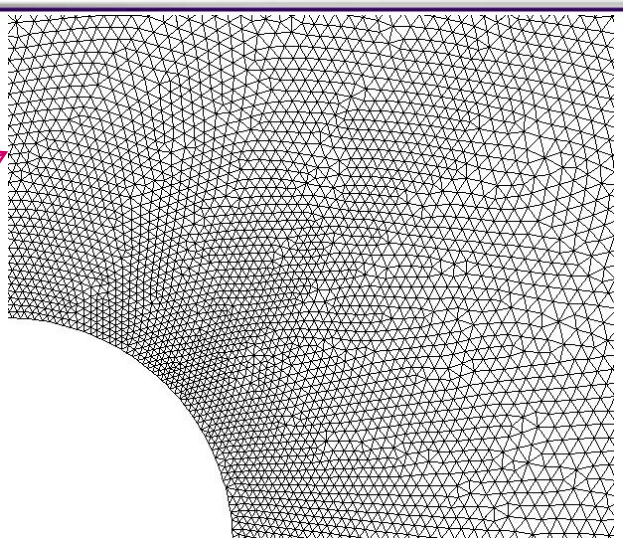
$$\frac{\partial \vec{u}}{\partial t} + \vec{u}.\nabla\vec{u} = -\nabla p + \mu\nabla^2\vec{u}$$

Flow over a cylinder

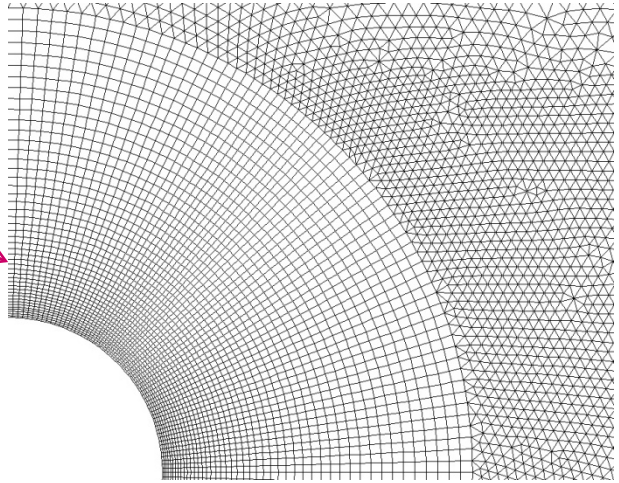


Computational mesh



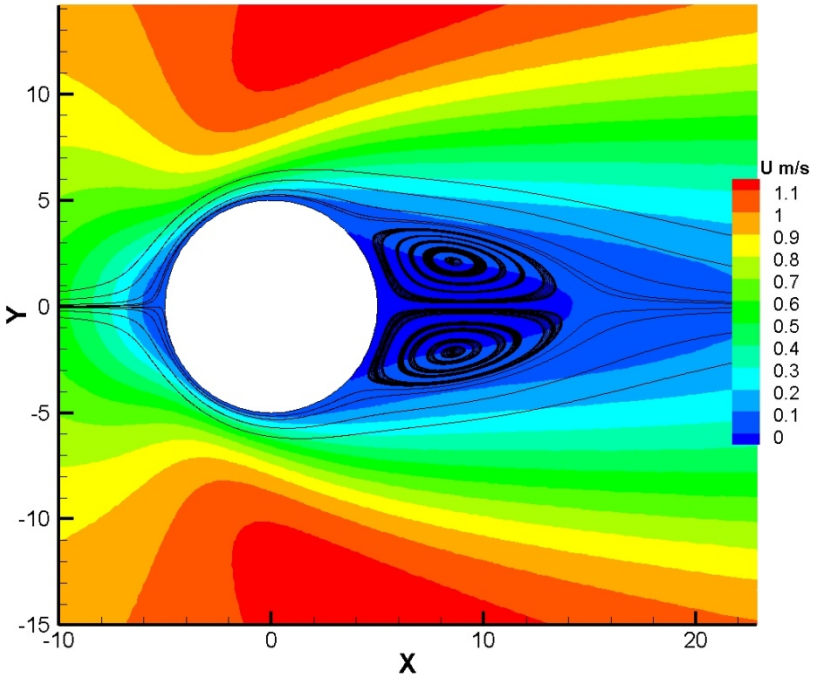


Triangular

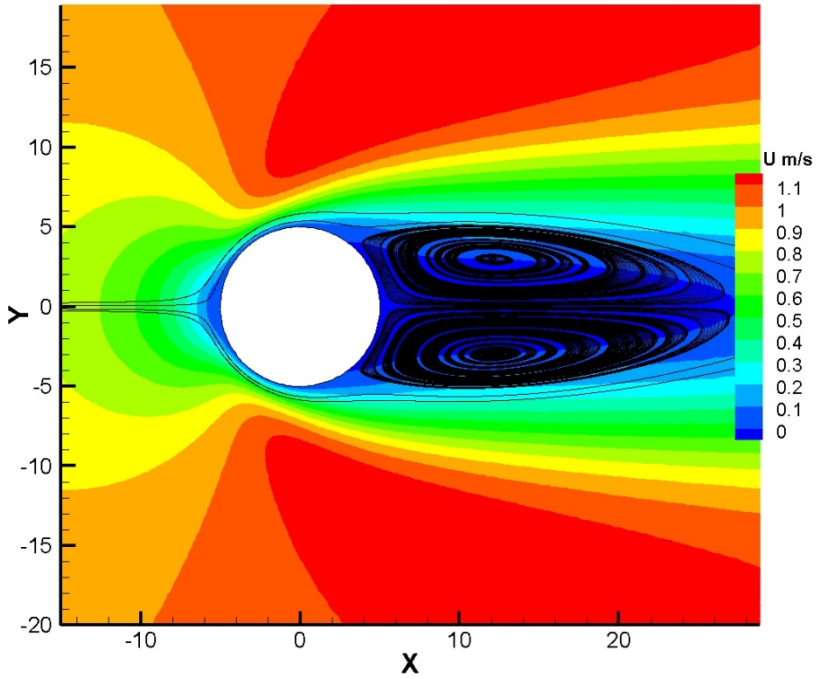


Hybrid

Velocity contours

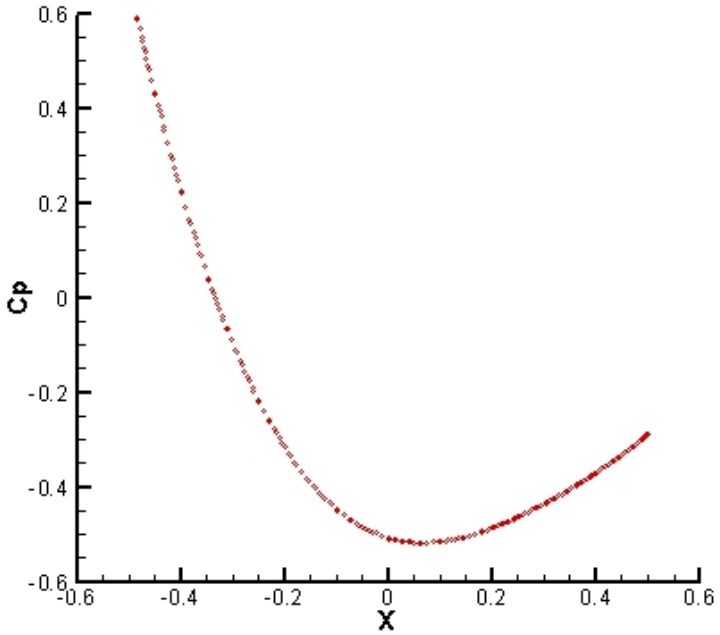


Reynolds number 20

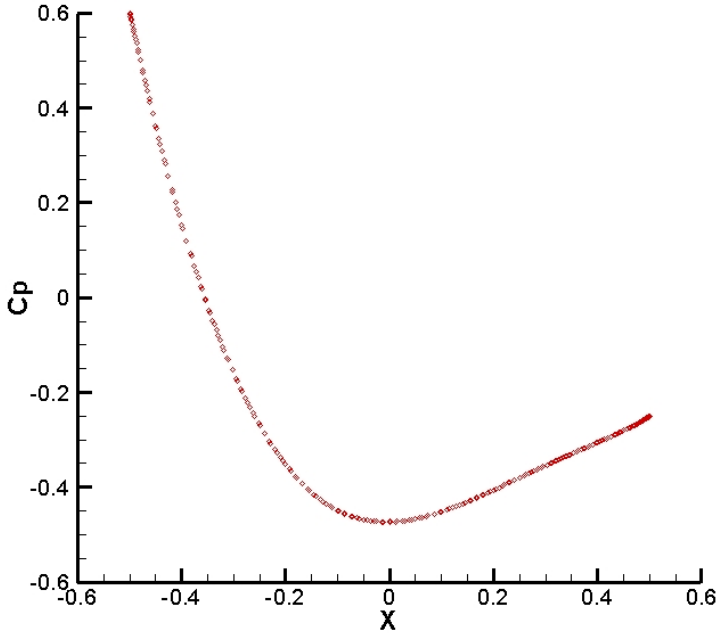


Reynolds number 40

Pressure coefficient

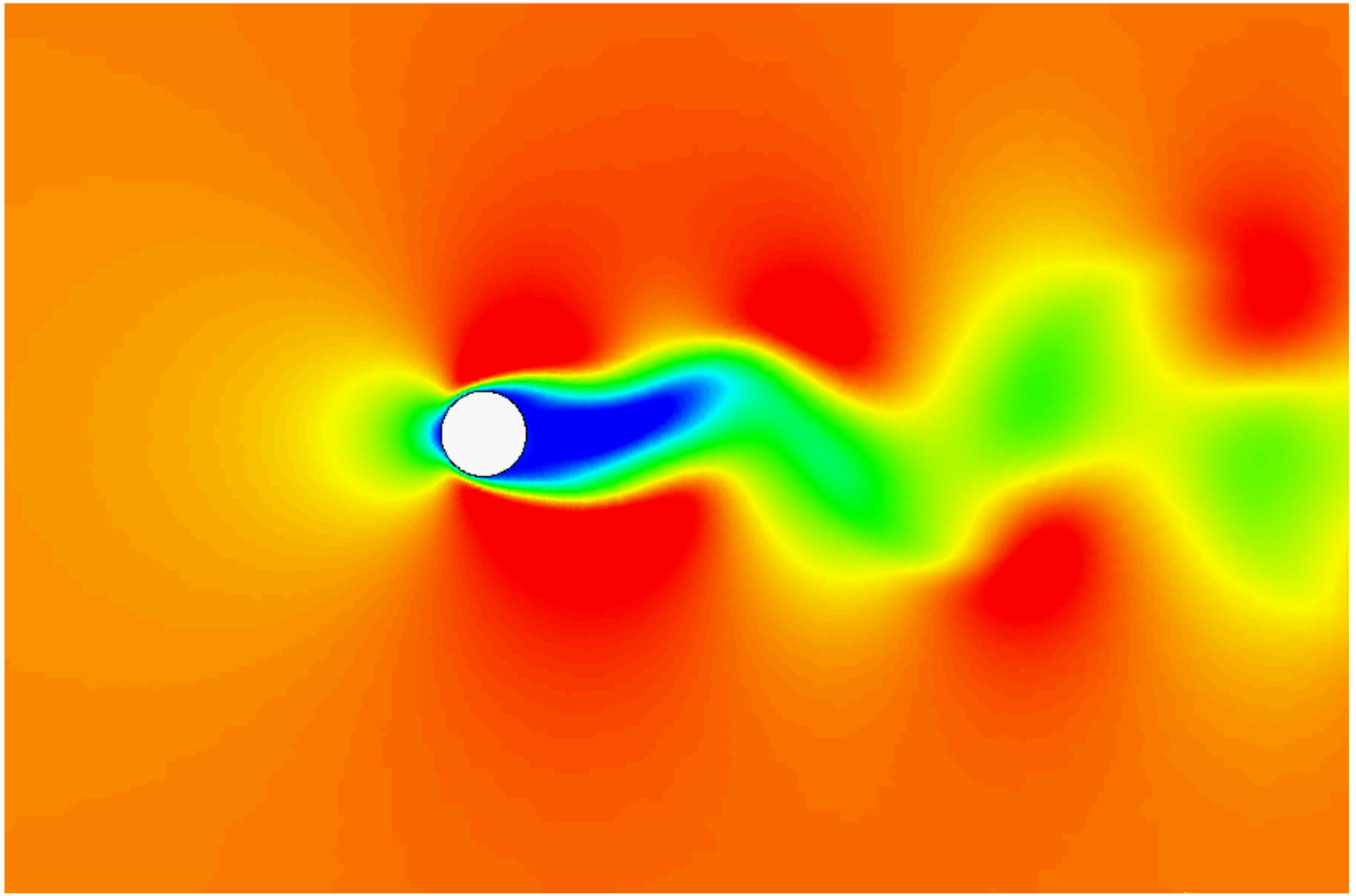


Reynolds number 20

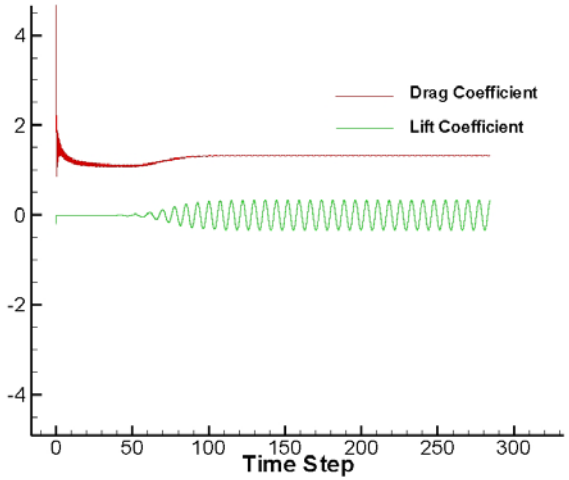


Reynolds number 40

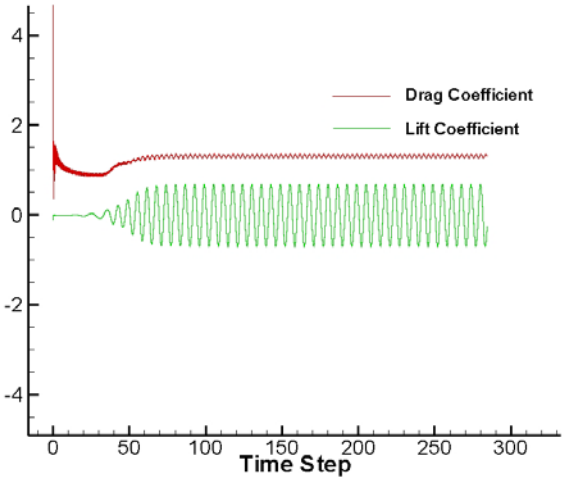
Periodic vortex shedding at Reynolds number 100



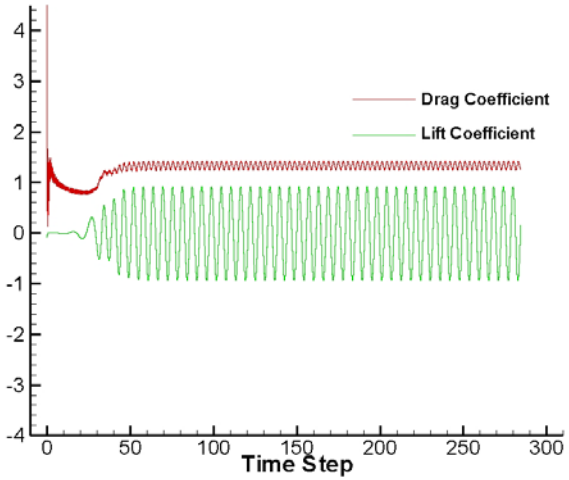
Drag and lift coefficients



Reynolds number 100

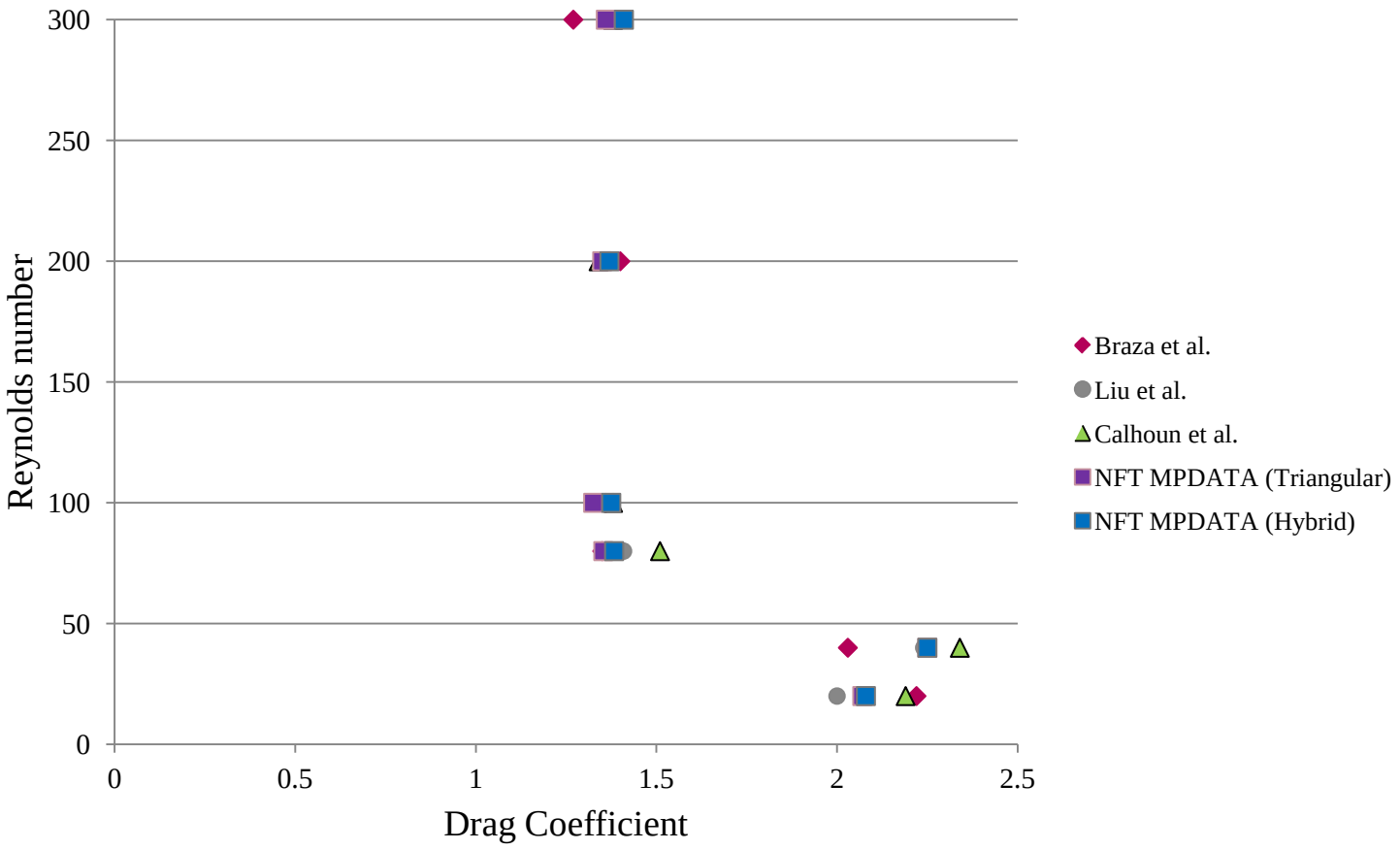


Reynolds number 200

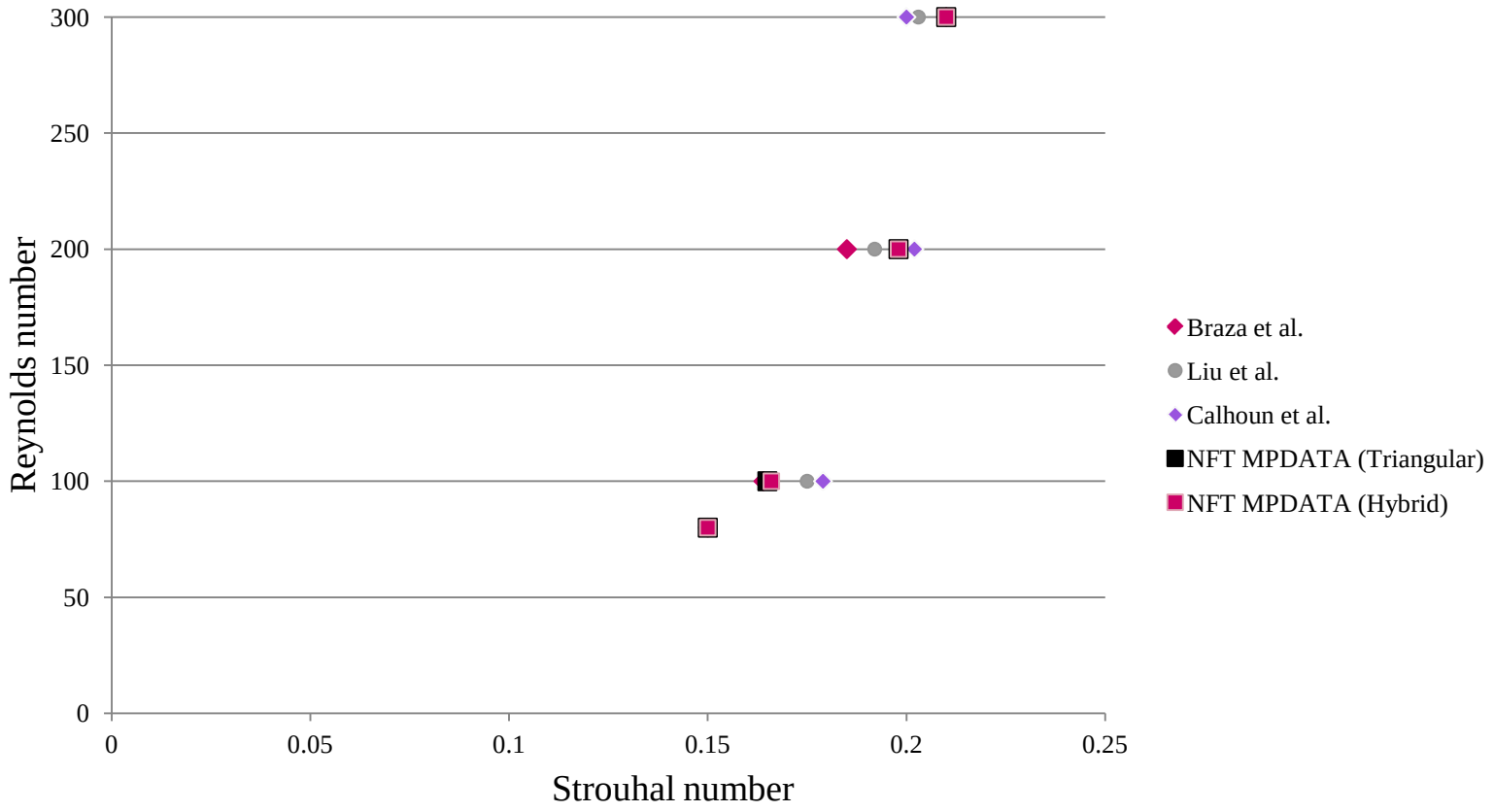


Reynolds number 300

Drag Coefficient



Strouhal number



Summary

The NFT MPDATA edge based solver shows good agreement for the initial computations. The next stage includes further validation for turbulent flows.