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Recent Advances in High Fidelity Wind Applications that Involve Sliding Meshes

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ASCR Project Review

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Goals

- Many unstructured algorithms using disparate mesh interfaces are cell centered-based in which fluxes are constructed between the two interfaces
- The concept of this project is whether or not a Discontinuous Galerkin Method can be applied at the non-conformal surface in the context of node-based schemes
- A mixed FEM/DG method has been implemented and tested as a proof of concept project at the most recent CTR 2010 summer program
- Although this scheme was shown to demonstrate second order spatial discretization error, the core fluids algorithm on which it was based did not handle highly under-resolved meshes well that are commonplace in wind energy applications

Theory: Equation Set

- Consider a two block system over which a set of PDEs is solved
- Let Γ_{AB} represent the common interface

$$\int_{\Omega_A} w\left(\frac{\partial \rho\phi}{\partial t} - S_\phi\right) d\Omega - \int_{\Omega_A} F_j \frac{\partial w}{\partial x_j} d\Omega + \int_{\Gamma \setminus \Gamma_{AB}} w F_j n_j d\Gamma + \int_{\Gamma_{AB}} w \hat{F}^A d\Gamma = 0$$

$$\int_{\Omega_B} w\left(\frac{\partial \rho\phi}{\partial t} - S_\phi\right) d\Omega - \int_{\Omega_B} F_j \frac{\partial w}{\partial x_j} d\Omega + \int_{\Gamma \setminus \Gamma_{AB}} w F_j n_j d\Gamma + \int_{\Gamma_{AB}} w \hat{F}^B d\Gamma = 0$$

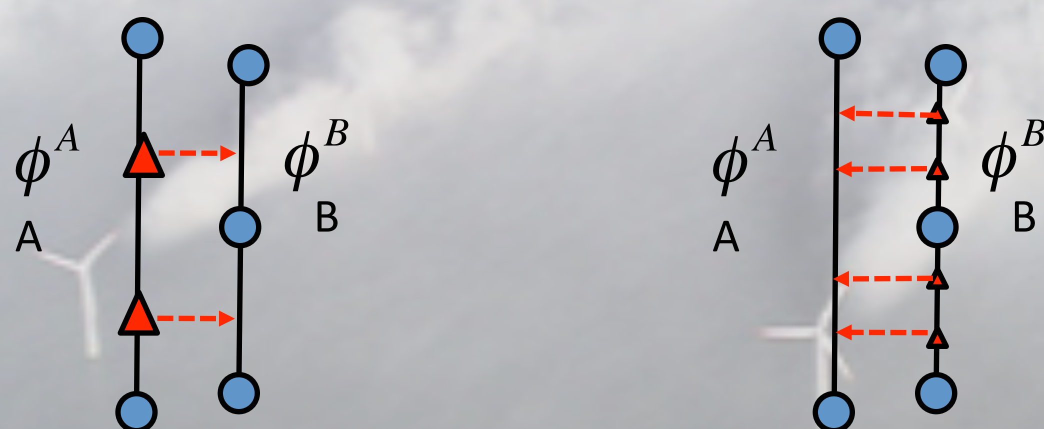
Mixed DG term at non-conformal interface

- With the numerical flux defined as

$$\hat{F}^A = \frac{1}{2}\left[\left(F_j^A n_j^A - F_j^B n_j^B\right) + \lambda(\phi^A - \phi^B)\right]$$

Theory: The Numerical Flux Procedure

- The numerical fluxes and scaling parameter λ must be provided for convection and diffusion contributions
- Diffusion numerical flux form includes lifting operation
  - λ^{diff} is related to diffusivity normalized by length scale
- Advection uses standard Lax-Freidrichs
  - λ^{adv} is related to max eigenvalue of F_j
- A contact search is conducted at each time step to define the intersection of gauss points between block A and B:

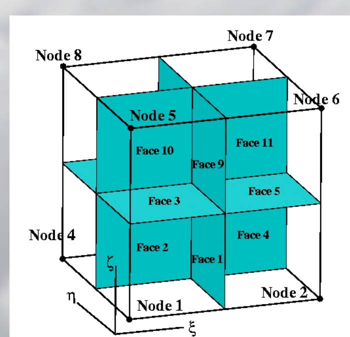


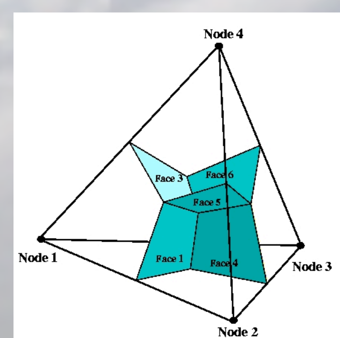
The Choice Discretization

- Thus far, the choice of test function, w has yet to be defined
- When w is the standard shape function, this method becomes a mixed FEM/DG formulation
- However, if is defined as a Heaviside, then $w = w_I$ and

$$\frac{\partial w_I}{\partial x_j} = -\delta\left(x_j - x_{j\,scs}\right)$$

- This forms the basis of our CVFEM discretization



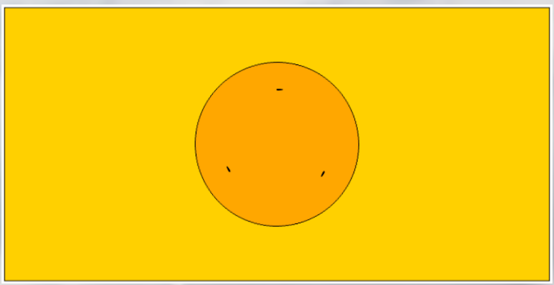


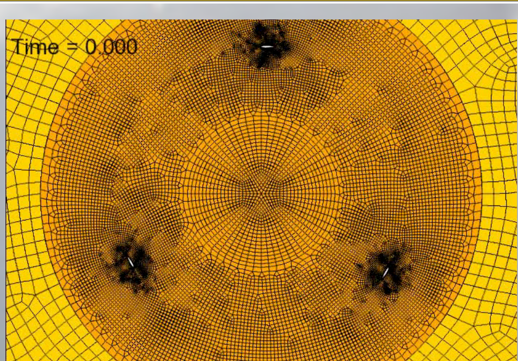
- The scheme is naturally defined as a Petrov Galerkin method since the test function is different from the interpolation rule

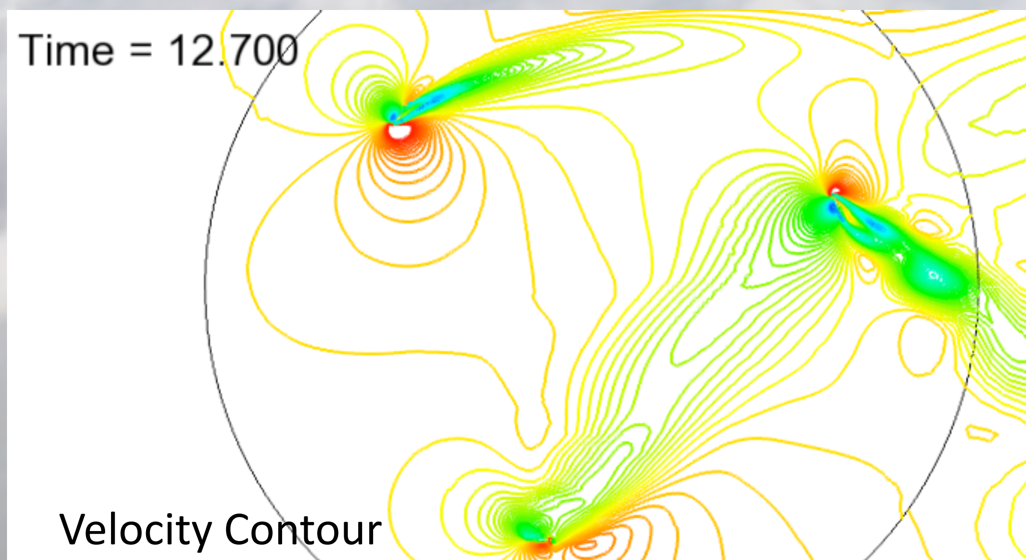
PB2538: [1,p] Wind Energy ASCR

✓ Towards high fidelity sliding mesh algorithms for wind energy applications

- Extended formerly FEM-based algorithm to CVFEM-based
- New regression test added
  - VAWT problem of interest from 6121 has been run as a test case
    - Re = ~350K based on chord length in static and rotating mode (~4 rpm)







Velocity Contour

Path Forward

- Deploy the capability to the SNL Wind Energy Technologies
- Define VAWT operating conditions of interest
- Algorithmic verification
- Pressure Projection algorithmic improvements