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3D Numerical Investigation of Bio-Inspired Vertical Axis Wind Turbine Rotor using Arbitrary Mesh Interface (AMI)

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Synopsis

This study presents a 3D numerical investigation of bio-inspired vertical axis wind turbine rotors using the Arbitrary Mesh Interface (AMI) methodology in OpenFOAM v-2412. The AMI approach addresses limitations of Multiple Reference Frame (MRF) method for geometries where cross sectional change affects the fluid interaction particularly in single blade savonius rotors where frontal shape changes with azimuth orientation. This improvement of AMI over MRF approach comes at an expense of computational time.

The framework utilizes a sliding mesh technique with prescribed rotational motion to the rotating region in the domain. A conservative interpolation of mass and momentum across the non-conformal AMI cyclic interfaces utilizes area-weighted averaging while maintaining flux conservation and numerical stability. The solidBodyMotionSolver with rotatingMotion function drives the inner rotatingZone while the cyclicAMI boundary conditions handle periodic coupling between the interfaces.

This methodology successfully captured the dynamic torque variations and unsteady flow physics around a bio-inspired rotor shape based on a seedpod with height to diameter ratio of 3.66 under laminar flow conditions (Re = 48000). The study revealed that bio-inspired rotors could achieve better startup characteristics. Torque characterization revealed the major difference of single peak patterns with maximum torque at 0°orientation for bio-inspired rotors while savonius rotors have double peak patterns with peaks at 45° and 225°. Lower thrust coefficients indicated significantly reduced structural loading for bionic turbines.

The investigation revealed that bio-inspired rotors can be the optimal energy solutions for urban locations due to superior startup characteristics at low wind conditions, stable performance across varying Reynolds numbers, and reduced vibration from single-peak torque patterns. Conventional Savonius rotors excel in higher peak power coefficients but require stronger support structures due to elevated thrust loads.

Keywords: Vertical Axis Wind Turbine, Bio-inspired Design, Arbitrary Mesh Interface, OpenFOAM, Computational Fluid Dynamics, Savonius Rotor

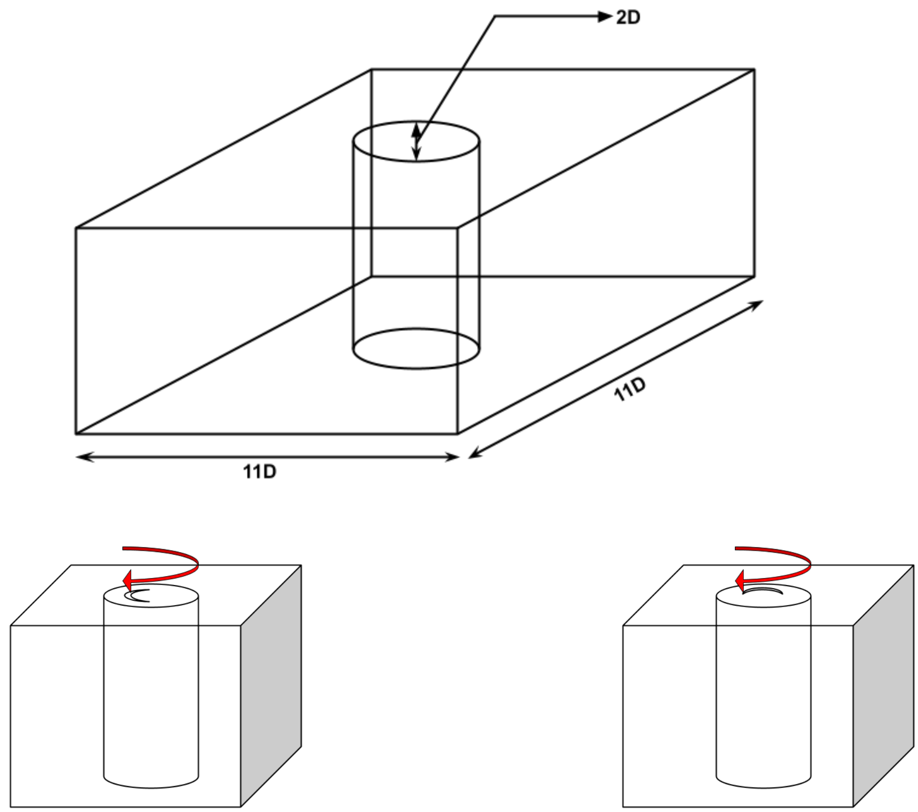

Figure 1: Computational Domain