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Unstructured High-order Solutions of Hovering Rotors with and without Ground Effect

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This work describes the implementation, computational cost and accuracy of high-order numerical schemes on a simplified concept of multiple reference frame (MRF) technique using mixed-element unstructured grid framework widely tested for aerospace applications [4, 5, 6, 7, 1]. The Reynolds averaged Navier-Stokes equations are approximated with up to fourth spatial order using Spalart Allmaras turbulence model [8] on two types of reconstruction scheme: monotonic upwind scheme for conservation laws (MUSCL) and weighted non-oscillatory (WENO). The calculations were made for both out-of-ground-effect (OGE) and in-ground-effect (IGE) cases and compared with experimental data in terms of pressure distribution, tip-vortex trajectory, vorticity contours and integrated thrust and torque. The predictions were obtained for several ground distances. Our findings suggest that the resolution of the vortex path and wake breakdown were considerably improved with increased scheme order. It is noticeable how low-order scheme struggles to deal with the large amount of diffusion. This numerical nature contributes to the vortex system settle down and achieve this stable ring state structure as seen on a couple radii downstream the rotor. As the wake is transported downwards, it can be clearly seen the interaction primary and secondary structures, which stretch between the tip vortices making an S-shaped path also seen experimentally [3]. The presence of the vortex-ring close to the rotor blade contributes to a larger induced flow and under predictions of thrust coefficient [2]. As we increase the scheme-order, it becomes more evident how the helical system convects down and breakdown toroidal vortex into smaller scales.

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