

2021 Sessions

Narducci, R. P., Jain, R., Abras, J., and Hariharan, N., “[HVAB Rotor Hover Computational Prediction: A Comparative Study Using OVERFLOW and HPCMP CREATE™-AV Helios](#),” AIAA-2021- 0617, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

The AIAA Rotor Simulation Discussion Group is addressing the ability of computational simulation methods to predict helicopter rotor hover performance and the surrounding flow field. Until now, the group has adopted existing experimental databases that have been available in the public domain to validate methods. Here, hover solutions are presented to compare against a future experimental database using best practices from industry and the US Government. The rotor is the NASA/US Army Hover Validation and Acoustic Baseline rotor, scheduled for testing in 2021 in the National Full-Scale Aerodynamics Complex. A thrust sweep serves as pretest predictions for the test. Integrated forces and moments, distributed loads, pressure distributions, vortex trajectories, and boundary layer transition locations are compared between two simulation strategies. One approach is contained within the OVERFLOW code and utilizes a series of concentric cylindrical meshes to capture the wake. The second uses OVERFLOW for computation on the blade and a Cartesian solver, SAMCART, for the wake. This approach is made within the framework of HPCMP CREATE™-AV Helios. Both approaches use the same blade grid and the SST turbulence model with Langtry-Menter laminar-to-turbulent transition prediction. The approaches predict similar rotor performance and wake structure.

Zhao, Q., and Sheng, C., “[Predictions of HVAB Rotor in Hover Using Hybrid RANS/LES Methods](#),” AIAA 2021-0618, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

Aerodynamic performance and flow physics of a Hover Validation and Acoustic Baseline (HVAB) rotor is investigated using both RANS and hybrid RANS/LES methods. Two baseline turbulence models, SA and SST, are used in RANS computations and results are compared with those obtained by hybrid methods. Two global hybrid models are employed based on a simple wall-adaptive local eddy-viscosity model (WALE) coupled with either the Spalart-Allmaras model (HSA) or the Menter’s shear stress transport model (HSST). Computational results are analyzed and compared among both RANS and hybrid methods in rotor hover simulations in terms of rotor performance and flow field.

Park, S. H., Han, J., and Kwon, O. J., “[Numerical Study of HVAB Rotor Using a Mixed Mesh Flow Solver](#),” AIAA 2021-0619, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

In the present study, numerical simulations of the HVAB rotor in hover were carried out using a Reynolds-averaged Navier-Stokes CFD flow solver based on unstructured mixed meshes. The γ -R ϵ -CFE+ model was adopted to predict of laminar-turbulent transition phenomena involving crossflow induced transitions. To capture vortex with high resolution, the ESWENO-P scheme was used for the computation of the inviscid fluxes on Cartesian meshes. A parametric study of the effect of turbulence intensity on the aerodynamic performance of the PSP rotor was first carried out. The influence of the NFAC facility wall on aerodynamic performance was also investigated. Then the aerodynamic characteristics of the HVAB rotor in hover were simulated with the given sets of trim angles. The predicted results, including the aerodynamic performance of the rotor in terms of thrust coefficient, torque coefficient, and figure of merit were analyzed. In addition, flow characteristics such as transition onset locations and tip vortex trajectories were also investigated.

Abras, J., and Hariharan, N., "[Direct Volume Visualization for Deeper Insights on the Physics of 3D Vorticity Dynamics in the Wake of a Hovering Rotor](#)," AIAA 2021-0734, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

Visualization techniques have evolved as increased computing power has enabled niche-techniques such as direct volume rendering to be accessible for visualizing 3D flowfield simulation results. Volume rendering is a compute-intensive visualization technique long familiar to the medical profession, but has only recently been applied to various aerodynamic problems. Until recently, most visualization packages commonly used by the aerodynamics community did not include volume rendering as an option. Recent advances in GPU computing power in workstations are changing this paradigm. Volume rendering allows for the extraction and visualization of three-dimensional volume information without an intermediate projection to two-dimensional iso-surface information. The present work investigates the hover-vortex wake breakdown phenomena using volume rendering visualization techniques. Volume rendering preserves both the volume information lost generating iso-surfaces and preserves the spatial resolution lost generating slices. These characteristic advantages are discussed in detail in the context of 3D vortex dynamics of hovering rotor-blade simulations. The application of this technique has provided deeper insights on how the three-dimensional interplay between the various vortex structures in the wake plays an important role in wake breakdown. It has enabled a better understanding of the impact of differential vortex interplay between various simulation outcomes. It also enabled a look at the rotor-disk mixing layer instability evolution. This information has been used to chart a new path forward to understand the mechanisms behind numerical wake breakdown.

Abras, J., and Hariharan, N., "[Investigation of the Impact of Deep Convergence on Numerical Wake Breakdown of Hovering Rotors](#)," AIAA 2021-0735, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

The present effort investigates the impact of deep temporal convergence on hover prediction using the results of a higher-order Stream-wise Upwind/Petrov-Galerkin (SU/PG) finite element method. Both rotational reference frame and spinning rotor computations are pursued as is a comparison of 2nd-order and 4th-order temporal convergence. Both the integrated performance and the wake structure are investigated. The results show that the deeper temporal convergence allows for larger time step sizes without a negative impact to the prediction. The wake features are well resolved and convergence of these features is accelerated through initialization using a rotational steady-state simulation. These simulations lay the groundwork for a larger ongoing effort.

Lee, B., and Baeder J., "[The effect of time marching on the wake structure breakdown in a hovering rotor simulation](#)," AIAA 2021-0736, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

This work investigates the effect of the time marching on the wake structure breakdown of a hovering rotor. Several factors are tested such as 1) time step sizes, 2) background meshes 3) BDF2 and BDF1 schemes, and 4) adding temporal damping to the BDF2 scheme. For this, a blended formulation of the BDF2 and BDF1 schemes is derived with a temporal damping variable, n . Simulations are performed for NASA Langley's PSP hovering rotor, and results are compared such as wake structures, integrated rotor performance, and FFT analysis of the thrust coefficient. The investigation shows that adding a temporal damping to the BDF2 scheme reduces unphysical wake structure breakdown by reducing secondary vortex braid instability and makes predicted thrust and torque coefficients more settled down. The blended formulation with a temporal damping can be used as an engineering solution of the wake structure breakdown.

Mobley, F., Carnes, J., and Coder J., “[Modal Decomposition Analysis of Hovering Rotor Wake Breakdown](#),” AIAA 2021-0737, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

The breakdown of a rotor wake in hover is a common phenomenon in eddy-resolving computational fluid dynamics simulations. While such breakdown can be alleviated by employing specific grid topologies and tailored solution procedures, the exact process by which this breakdown occurs and the extent to which it should occur are unknown. In this work, the S-76 rotor in hover is simulated over a range of collective pitches and wake breakdown is investigated by applying proper orthogonal decomposition (POD) to the full solution. POD determines the optimal bases on which a data set can be projected and subsequently reconstructed, providing guidance on coherent structures and fundamental behaviors in the solution. The NASA OVERFLOW 2.3 solver is used with hybrid RANS/LES modeling enabled. Grid generation and computational methods are described. The POD modes of the wake structure are investigated and compared, revealing that there are coherent structures in the wake, but these exist primarily in the young wake-age regions. These features were dominated by the 4/rev forcing of the blades. The wake was analyzed in an isolated state by removing the 4/rev forcing; however, there was no appreciable coherence found in the POD modes with this removal.

Caprace, D., Winckelmans, G., and Chatelain, P., “[Assessment of the Vortex Particle-Mesh Method for Efficient LES of Hovering Rotors and their Wakes](#),” AIAA 2021-0738, AIAA SciTech 59th Aerospace Sciences Meeting, 11-21 January 2021, Virtual Event.

Midway between a vortex method and a grid-based CFD, the Vortex Particle–Mesh method with Immersed Lifting Lines is intended to provide medium-fidelity results on rotor loadings, together with a realistic representation of the 3-D vortical wakes and their dynamics over long distances. We assess the potential of this hybrid approach for the Large-Eddy Simulation of helicopter rotors in hover. A novel Poisson solver with mixed unbounded-outflow boundary conditions here further enables the computation of turbulent hovering scenarios in tight domains. Considering the Knight and Hefner experiment and the S-76 test case as references, we present and compare blade integrated and distributed loads, induction velocities, and wake characteristics. While the quality of the performance predictions highly depends on external polar data, the obtained wakes exhibit similar characteristics to those recently identified in other CFD analyses, here at a moderate computational cost. Based on these results, we further investigate the secondary vortex structures forming between the main tip vortices, and we bring additional clues on their relation to the phenomenon of wake breakdown. We finally discuss the strengths and difficulties of hybrid vortex methods for the challenging analysis of hovering rotors.