2024 Sessions

Jain, R, "CFD-CSD Pre-test Hover Predictions Validation for the HVAB Rotor," AIAA 2024-0893, 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> Pre-test hover predictions obtained for the 11.08-foot-diameter, 4-blade, Mach-scaled Hover Validation and Acoustic Baseline (HVAB) rotor were compared with the recent hover test measurements obtained in the National Full-Scale Aerodynamics Complex (NFAC) 80- by 120-Foot Wind Tunnel at NASA Ames Research Center. The predictions were obtained using high-fidelity Computational Fluid Dynamics (CFD)-Computational Structural Dynamics (CSD) coupled simulations in the CREATETM-AV Helios framework. Helios used NASA OVERFLOW and NASA FUN3D solvers for near-body CFD modeling and RCAS for CSD modeling. A comprehensive comparison was performed that included rotor performance, blade motions and deformations, laminar-turbulent transition location, airloads, surface pressure, and wake trajectory. Overall, the predictions agreed well with the test data.

Narducci, R., Liu, J., Wells, A., Mobley, F., and Mayer, R., "CFD Simulations of a Hovering Tiltrotor in Ground Effect," AIAA 2024-1115**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> Tiltrotors, like the Bell-Boeing V-22 Osprey, have a distinct advantage functioning as a helicopter and a fixed wing aircraft. Its ability to outrun conventional helicopters and still operate in hover makes it uniquely qualified for many missions. The rotor/airframe interactions produce complex flow fields that, to a large extent, have been understood with high-quality wind tunnel and flight-test data. Advances in high performance computing systems and CFD software make it possible to improve the understanding of the aerodynamics. Complementary simulations fill in the gaps between data points and add supplemental information to existing test conditions. The HPCMP CREATE-AV Helios software was used to model the V-22 at various wheel heights above the ground and at several gross weights to first, replicate hover in-ground effect performance as measured in several flight tests and second, to understand aircraft download as a function of wheel height, rotor thrust, aircraft pitch attitude, and light winds. The results correlate well to flight test power data and simulations quantify hover performance sensitivity to deck angle and winds. The simulations suggest deck angle should remain level with winds less than 3 knots to obtain consistent hover flight test measurements.

Moushegian, A., "Fast High-Fidelity Analysis of a Hovering Rotor with a Dual-Solver Hybrid CFD Methodology in HPCMP CREATE-AV Helios," AIAA 2024-1116**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> Detailed aerodynamic analysis of rotorcraft with unsteady Reynolds-Averaged Navier-Stokes (uRANS) solvers strains the computational resources of even the most well-funded programs, driven by small time step and large computational grid requirements to adequately resolve the flow field. A state-of-the-art dual-solver hybrid computational fluid dynamics methodology has been implemented in the Department of Defense's uRANS analysis tool for rotorcraft, HPCMP CREATE-AV Helios, with the objective of reducing the computational cost of standard main rotor analysis without sacrificing the accuracy of blade aerodynamic predictions. The hybrid method was modified and improved to permit robust operation within the Helios framework, including the development of a new Loosely-Coupled Steady Rotating Solution Frame (Lo-CoSt RSF) hybrid CFD simulation method. Predictions of the Tilt-Rotor Aeromechanics Model (TRAM) rotor were performed and compared to experimental data and previously-published Helios predictions for both inertial solution frame (ISF) and rotating solution frame (RSF) simulations. Numerical experiments were performed to investigate the effect of new user-input parameters in the Lo-CoSt RSF method, and the chosen values were applied to an investigation of hover performance over a range of collective pitch angles. The hybrid method provides highly

accurate hover performance predictions (within 1.2% of experiment) an order of magnitude faster than conventional Helios predictions.

Heintz, A., Schwarz, C., Wolf, C., and Raffel, M., "Influence of Configurational Parameters on the Vortex System of a Rotor in Hover" AIAA 2024-0896**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> The blade tip vortices in the wake of a rotor are essential for the aerodynamic behavior of a helicopter. Due to the high complexity, a detailed and high resolution simulation of a rotor wake is challenging and in many cases requires experimental validation. In particular, the study of secondary vortices that occur between the helically arranged blade tip vortices is part of the current research. Therefore, this paper presents an experimental study of the influence of different configurational parameters on the development of secondary vortices and their contribution to the vortex breakdown of a rotor in hover. The aim is to gain insight into which configurational parameters have an influence on the occurrence of secondary structures. An extensive database of more than 30 different configurations was created to validate the numerical simulations and methods. It was found that the blade passing frequency is the main contributor to the occurrence of secondary structures. Taking into account all the cases studied, a linear dependence between the number of secondary vortices detected and the blade passing frequency was found.

Gahlot, A., and Sankar, L., "Effects of Rain on Hover and Forward Flight Performance of the S-76 Rotor," AIAA 2024-1117**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> A two-phase flow solver capable of modeling single and multi-rotor configurations is being used to model the effects of rain on the S-76 rotor performance. The volume fraction of the liquid water and the droplet velocity conditions are computed on the same computational body grid that moves with the rotor as the blades rotate, pitch, flap, and elastically deform. Additional enhancements to the flow solver include the implementation of an algebraic transition criterion that is used to detect transition and turn off the eddy viscosity production terms in the Spalart-Allmaras model. The studies indicate that the difference in the velocity of the air molecules and that of the slower moving water droplets gives rise to a Stokes drag force exerted by the aerodynamic flow on the droplets. A reaction force is exerted by the droplets on the air flow. These effects are significant over the upper surface of the rotor, near the region where suction peaks occur. The loss in suction forces, and the adverse streamwise Stokes forces profoundly affect the lift and drag characteristics of the rotor sections, ultimately affecting the rotor performance.

Liu, Y., and Wang, L., "High-Fidelity Simulations of Lift+Cruise VTOL Urban Air Mobility Concept Aircraft in Hover," AIAA 2024-1118, 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> This paper presents progress of high-fidelity multidisciplinary simulations for the NASA lift+cruise vertical takeoff and landing (VTOL) urban air mobility concept aircraft in hover. The study focuses on the unsteady flow solutions featuring strong wake interactions between rotors and the airframe. The simulations couple a high-fidelity aerodynamic model with a comprehensive rotorcraft aeromechanics tool with rotor rotation-speed trim. The aerodynamic model is based on the Reynolds-averaged Navier-Stokes equations using the one-equation Spalart-Allmaras turbulence model with rotation correction. Unsteady aerodynamic flows are computed on a dynamic, deformable, unstructured, overset grid system. An integrated overset-grid assembler is used to construct the composite grid from 23 component grids and facilitate communications between individual component grids. Rotor performance and airframe forces and moments are computed and compared on two unstructured grids. The study demonstrates capabilities of high-fidelity multidisciplinary analysis tools to capture the strong unsteady flowfield around this multi-rotor aircraft in hover.

Stratton, Z., and Spyropoulos, J., "Isolated and Installed Rotor Simulations of a Scaled Helicopter Rotor in Hover Using Wall-Modeled Large-Eddy Simulation," AIAA 2024-0897**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> The Hover Validation and Acoustic Baseline (HVAB) rotor in hover is studied using wall-modeled large-eddy simulations. Performance of the isolated rotor is evaluated for three thrust conditions and validated with the experimental measurements. Additionally, the HVAB rotor was mounted on the Robin-Mod7 fuselage to evaluate the installed impact on the blade forces and fuselage. Three installed configurations are evaluated including hover-out-of-ground-effect (HOGE), hover-in-ground-effect (HIGE), and HIGE with a 6 knot headwind. Results show that the isolated rotor performance agrees well with the experimental force measurements; qualitative agreement is also seen in the skin-friction contours. The installed configurations highlight how the fuselage and ground effect augment the rotor thrust. The download was shown to become negative on average in HIGE, however, depending on the blade position over the fuselage, this can range between -3% to 2% of the rotor thrust.

Jung, Y., Lee, B., and Baeder, J., "Prediction of HVAB Hovering Rotor Performance and Ground Effect using Mercury Framework," AIAA 2024-0895**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> Simulations of the HVAB rotor in a hovering state were conducted using the Mercury framework, a multi-mesh paradigm, and a heterogeneous CPU-GPU overset CFD framework. The CFD framework employs the Spalart–Allmaras delayed detached eddy simulation (SA-DDES) turbulent modeling. The analysis focuses on the AIAA Hover Focus Problem Steps 1 to 3. Initially, isolated hovering rotor simulations were performed, and the efficiency parameters were compared with available reference data at various collective pitch angles. For installed rotor simulations, the NASA ROBIN-Mod7 fuselage was utilized. The blade sectional thrust increased when passing over the nose and tailboom of the fuselage due to the ground effect, while the fuselage download decreased the total lift. Hover in ground effect was investigated for the rotor-fuselage configuration at various rotor heights from the ground: h/�� = 0.5, 1.0, and 1.5. Ground effect increased as the helicopter approached the ground, resulting in an increased rotor Figure of Merit and decreased fuselage download. The blade sectional thrust increased in ground effect, except in the region near the tip; otherwise, sectional torque was not significantly affected. Finally, groundwash velocity was computed for the installed hovering rotor at a collective 10◦. Due to the highly unsteady flow features, the results were phase- or time- averaged. The ground velocity profiles at various azimuth and radial locations were compared to study the effect of rotor height, fuselage existence, and ground wall boundary condition.

Zhao, Q., and Sheng, C., "Predictions of HVAB Rotor in Hover Using Hybrid Method With Grid Sensitivity Study," AIAA 2024-0894**,** 62nd AIAA Aerospace Sciences Meeting, Orlando, FL, January 8-12, 2024

> In this study, a four-bladed HVAB rotor with cone and lag effects in hover is numerically investigated using an unstructured grid CFD solver. The rotor integrated hover performance, intricate flow field on rotor surfaces, and trailing tip vortices in the rotor downwash are investigated using a hybrid RANS-LES method. An innovative blending function is utilized to merge the near-wall RANS region and the off-wall LES region in the current hybrid simulations. Grid sensitivity studies are conducted to assess the impact of surface and volume grid resolutions on the prediction of rotor performance and flow field. Computed rotor performance and flow field are compared with the experimental data to assess the CFD scheme and mesh requirements for rotor hover predictions.