2018 Sessions

Jain, R., "Effect of Facility Walls and Blade Aeroelasticity on PSP Rotor Hover Performance Predictions," AIAA 2018-0305, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

> As a continuation of the Pressure Sensitive Paint (PSP) rotor hover validation study presented in the 4th Hover Working Group meeting held at AIAA SciTech2017, pre-test Computational Fluid Dynamics (CFD) predictions are obtained for the 11.08 ft, 4-blade, Mach-scaled, PSP rotor in order to assess wind tunnel installation effects on hover performance, ahead of the planned hover tests in the US Air Force National Full-Scale Aerodynamics Complex (NFAC) 80- by 120-Foot Wind Tunnel at NASA Ames Research Center. The installation effects studied included the effect of ground plane, ceiling plane, and test stand. The variation in figure of merit is small, around 0.0075, for the various configurations studied. CFD predictions are also obtained to estimate the effect of blade elastic twist on rotor performance where it is found to have a sizeable effect on reducing the thrust-collective slope.

Jimenez-Garcia, A., Barakos, G.N., "Numerical Simulations on the PSP Rotor Using HMB3," AIAA 2018-0306, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

> This work presents CFD analyses of the isolated Pressure Sensitive Paint (PSP) model rotor blade in hover and forward flight using the structured multi-block CFD solver of Glasgow University. In hover, two blade-tip Mach numbers (0.585 and 0.65) were simulated for a range of blade pitch angles using fully-turbulent flow and the *k-!* SST model. Results at blade-tip Mach number of 0.585 showed a fair agreement with experimental Figure of Merit and surface pressure coefficients obtained in the Rotor Test Cell (RTC) at NASA Langley Research Center. Comparisons are presented at blade-tip Mach number of 0.65 in terms of integral blade loads, surface pressure coefficients and position of the tip-vortex cores with published numerical data. Finally, the flow around the PSP rotor in forward flight was also computed at medium thrust (C_T =0.006) and results were compared with published experimental data.

Wood, S., Coder, J.G., Hariharan, N., "Fundamental Investigation of Grid Resolution on Wake Fidelity," AIAA 2018-0307, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

> Simulations of a canonical helical vortex systems are utilized to explore the influence of grid resolutions on vortex wake breakdown. A consistent-strength helical vortex system will be created by an actuator "surface" representation of a rotor. Normal and oblique traversal of grid boundaries by waves and vortices of selected intensities will be analyzed to study the influence on vortex wake break down. The ensemble of simulations includes uniform overset and stretched background grids. The preservation of flow features as the wake field traverses resolution boundaries is described. Recommendations for grid configurations that best preserve the flow field are detailed.

Parwani, A.A., Coder, J.G., "Effect of Laminar-Turbulent Transition Modeling on PSP Rotor Hover Predictions," AIAA 2018-0308, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

> Simulations of the Pressure Sensitive Paint (PSP) rotor in hover were conducted utilizing a transition model. Structured, overset grid solutions were obtained using the OVERFLOW 2.2 compressible flow solver at a tip Mach number of 0.65. The solutions were generated for different collective pitch angles and compared to

previously obtained fully turbulent data. Available hover test data are described along with grid generation and computational methods. Rotor flow field behavior was analyzed, and the effects and significance of transition modeling is assessed.

Weiss, A., Gardner, A.D., Klein, C., Raffel, M., "On the Effect of Rotational Forces on Rotor Blade Boundary-Layer Transition," AIAA 2018-0309, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

Laminar-turbulent boundary-layer transition is investigated on the suction side of Mach-scaled helicopter rotor blades in climb and analyzed in view of the effect of rotational forces. Spatially highly resolved data and precisely detected transition positions are obtained by means of temperature-sensitive paint and accompanied by local surface pressure measurements at two radial blade sections. The effect of rotational forces is investigated by systematic variation of Rossby number from Ro = 4:76 to 6:95 at Re = 3:7_10$_5$ and M = 0:22. The findings do not show a measurable effect of rotational forces on boundary-layer transition in the investigated parameter range and suggest predominantly two-dimensional (2D) flow behaviour, which is confirmed by subsequent validation with 2D numerical tools. Based on quantitative agreement between measured and calculated surface pressures, it is shown that experimentally detected transition positions are predicted to within _4% chord if a critical amplification factor of $N_{cr,MSES}$ = 5:6 is used in MSES for transition prediction in the rotor test facility of the DLR G¨ottingen. The measured transition onset positions are also correlated with the obtained integral growth rates from 2D compressible local linear stability theory to get transition N-factors of N_{cr} = 8:4_0:5. Correlations are shown to be independent of relative chord Reynolds number and incompressible shape factor at the detected transition onset underlining the capability of 2D numerical techniques based on linear stability theory to model boundary-layer transition in the investigated parameter range.

Min, B.Y., Reimann, C.A. Wake, B.E., Jee, S., Baeder, J.D., "Hovering Rotor Simulation using OVERFLOW with Improved Turbulence Model," AIAA 2018-1779, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

The $\boldsymbol{\gamma - Re_{\theta t}}$ transition model coupled with Spalart-Allmaras turbulence model has been recently developed and implemented to OVERFLOW solver. The Delayed Detached Eddy Simulation method in the OVERFLOW also has been modified with improved boundary layer shielding function and modified length scale definition. In this study, OVERFLOW with the improved turbulence model has been validated with simple 2D flat plate, SC-1095 airfoil, and S-809 airfoil. The validation showed good transition prediction and improved airfoil drag and stall angle prediction. Then, the model has been assessed for hovering rotor performance prediction. The selected rotor is the model scale S-76 rotor with swept-tapered tip. Fully turbulent simulation under-predicted the rotor Figure of Merit. Without known freestream turbulence intensity level, variation has been made from 0.5% to 2% intensity level to demonstrate the impact of transition to hover performance. The result showed performance increase significant enough to cover the error between measured data and fully turbulent simulation. The added DDES model slightly lowered the hover performance prediction with current grid.

Zhao, Q, Wang, J, and Sheng, C. "Numerical Simulations and Comparisons of PSP and S-76 Rotors in Hover", AIAA 2018-1780, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

Two conventional rotor hover performance are numerically investigated using an unstructured grid Reynolds-averaged Navier-Stokes flow solver. The Langtry-Menter local correction-based transition model is used to predict the viscous transitional phenomena on two rotors. The rotor figure of merit is predicted and compared between the PSP and S-76 rotors for the entire collective range. A separation correction method is employed to correct the premature flow separation on both rotors especially at high blade collective angles. Computational results indicate similar hover performance and flow physics for the PSP and S-76 rotors at the same thrust levels.

Wong, T.C., O'Brien, D.M., "Application of CREATE™-AV Helios in an Engineering Environment: Hover Prediction Assessment Part 2", AIAA 2018-1781, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

Computational fluid dynamics based hover performance validations of the Caradonna and Tung two-bladed rotor and model-scale S-76 four-bladed rotor were performed using the HPCMP CREATE™-AV Helios software suite. Time-accurate simulations were performed over a range of collective angles at different blade tip Mach numbers. This effort focused on the use of an overset structured approach for the near-body blade grids and an adaptive Cartesian approach for the off-body grids. Particular emphasis was placed on developing best practices for solver parameters and grid development strategies for daily engineering applications. Quantitative surface pressure tap correlations and qualitative rotor wake visualizations are presented and discussed for the Caradonna and Tung configuration. Computed results of the S-76 with three tip shapes are compared with available rotor force measurements and previously computed unstructured blade grid results. Aeroelastic effects on the S-76 hover prediction are also investigated using RCAS. Several best practices for grid requirements and numerical options to achieve reasonable turnaround time in an engineering environment are presented.

Eshcol, R.M., Yuvraj Dewan, Y., "Numerical Design Optimization of the S-76 Rotor for Hover Performance," AIAA 2018-1782, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

The performance of the S-76 rotor blade in hover was optimized by varying the shape of the baseline rectangular blade tip. The design variables include twist, taper ratio, sweep angle, and anhedral angle. The trim condition in hover was set as a constraint. Hover efficiency measured through figure of merit was chosen as the objective function of the optimization problem. The S-76 rotor blades with modified tip shapes were analyzed using wake capturing computational fluid dynamics methodology to obtain an optimal helicopter rotor blade tip shape for aerodynamic performance in hover flight. A hybrid-adaptive optimization algorithm was used to drive the search of the design space. Sensitivity analysis of the design variables suggests that a slight nose up twist and a moderate anhedral angle favor an improved rotor performance in hover.

Quackenbush, T.R., Whitehouse. G.R., Silabaugh, B.S., Yu, M.K., "Further Assessment of Analysis Methods for Rotor/Airframe Interaction in Hover," AIAA 2018-1783, AIAA SciTech 56th Aerospace Sciences Meeting, 8-12 January 2018, Kissimmee, FL.

Rotor/airframe interaction in hover and, in particular, fuselage download have long been important issues in rotorcraft design, and recent work has led to the initial development and validation of physics-based download prediction methods suitable for use early in the design cycle. A complementary aspect of airframes that generate significant blockage of the main rotor downwash is a substantial effect on installed rotor performance. This paper extends recent assessments of the ability of two contemporary analysis tools to address these topics, building on initial modeling of a single main rotor with a representative wing/fuselage combination, but also executing preliminary extensions of this work to coaxial and tiltrotor systems. Correlation studies involving prediction of hover download and airframe/rotor interaction are presented, using both a comprehensive rotorcraft analysis and a cut-cell octree Cartesian CFD method. To date, these models have produced encouraging results when applied to problems relevant to the study of new configurations, with levels of setup and computational effort consistent with use in early stage design, though significant limitations and development needs remain.