2017 Sessions

Egolf, T.A., Hariharan, N., Narducci, R., Reed, E., "AIAA Standardized Hover Simulation: Hover Performance Prediction Status and Outstanding Issues," AIAA-2017-1429, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> The AIAA Rotorcraft Simulation working group activity has resulted in 3 years of special sessions focused on the prediction of hover performance for the S-76 rotor blade with different tip shapes. Over the last three years, 33 papers have been presented under these special sessions. More years are anticipated as the fourth year session is already scheduled for SciTech 2017. At the start of this effort many issues regarding the prediction of hover performance were known. As a result of this multi-year effort, some of these issues are better understood and perhaps resolved, while other issues have become better known to the rotorcraft community. And as is always the case, new issues have been identified with varying degrees of importance to predicting hover performance. This paper focuses upon the common threads seen over the last three years of standardized S-76 invited sessions for the prediction of hover – especially some of the outstanding computational issues and sensitivities.

Narducci, R., "Comparison of Steady-State and Time-Dependent Solutions for the S-76 Model-Scale Rotor in Hover," AIAA-2017-1430, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> The AIAA Rotor Simulation Discussion Group is addressing the ability of rotor comprehensive codes, CFD, and hybrid methods to predict isolated rotor hover performance of a helicopter. Of interest is the application of these methods towards rotor design which means accurately and efficiently predicting incremental hover performance due to changes in operating conditions or geometric features. Long-running simulations have only minimal impact as typical design cycles are constrained by time and budget. Time-dependent CFD methods have been shown to predict incremental hover performance but are computationally intensive. Steady-state hover calculations offer the potential for rapid analysis of rotor systems by ignoring time-dependent content in the flow field. Furthermore, steady-state calculations can be computed on a portion of the domain that encompasses only one blade of the rotor system. Assuming symmetry, periodic boundary conditions can account for the remaining blades. Comparisons of steady-state and time-dependent hover solutions are made for the model-scale isolated S-76 rotor, including three blade tip shapes. Results show that, for the most part, solutions are nearly identical including overall performance and the details of the flow field with the important exception of regions where separation is predicted.

Abras, J.N., Hariharan, N., "Parameter Studies on the S-76 Rotor Using HELIOS," AIAA-2017-1431, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> The S-76 rotor is used as a baseline case to assess the isolated rotor hover predictions of the HELIOS CFD solver. These predictions are compared to the available test data as well as to one another. This paper focuses on parametric studies of the options available within HELIOS. These parameter studies include a study examining the impact of the hub and root region grid structure on the performance predictions as well as a trim distance study examining the impact of the position of the interpolation boundary on the rotor performance. The results show that, in addition to blade tip grid refinement, leading edge and trailing edge grid refinement are important to compute the hover performance. The dual mesh methodology is shown to preserve the wake for a longer distance when compared to the fully unstructured methodology. This has some impact on the final wake structure. The presence of the hub is found to have a small impact on the final integrated performance parameters. However, there is a greater impact on the convergence rate of these performance parameters as well as the magnitude of the 4/rev time history characteristics. The study concludes with an evaluation of this case using the mStrand solver. This analysis examines the

unsteady data, both integrated and distributed, in more detail. Overall it was found that the mStrand solver provides results comparable to NSU3D, but with greater efficiency.

Coder, J.G., "OVERFLOW Rotor Hover Simulations Using Advanced Turbulence and Transition Modeling," AIAA-2017-1432, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

The S-76 and PSP rotor blades are simulated for a tip Mach number of 0.65 and a range of collective pitches using a structured, overset computational fluid dynamics solver. Grid generation and solution strategies are described for both rotors. Two different hybrid RANS/LES methods are used to predict the turbulence in the flow field, and the use of an advanced laminar-turbulent transition model is also explored. Predicted values of thrust, torque, and figure of merit are compared with experiment for the S-76 rotor. Qualitative assessments of the flow fields from the two turbulence modeling strategies are made and the impact of laminar-turbulent transition modeling is described. Predicted values of thrust, torque, and figure of merit are listed for the PSP rotor, and the behavior of its flow field is also assessed and compared to the S-76.

Lee, B., Govindarajan, B., Baeder, J.D., "Methods for Efficient Resolution of Vortical Structures of an S-76 Rotor in Hover," AIAA-2017-1664, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

Meshing and numerical techniques are investigated to resolve the vortical structures of an S-76 rotor in hover in an efficient manner. The methodology employs a quarter domain Cartesian background mesh with periodic boundary conditions to reduce the computational costs in simulating all four blades of the rotor. Mesh clustering of the background grid is performed where the strong tip vortex is expected, and overset vortex tracking grids are added to further resolve the near-field evolution of the tip vortex. A compressible, structured, overset RANS based solver (OVERTURNS) is used in this study, and simulations were performed for a swept-tapered tip at a tip Mach number of 0.65 and a collective pitch angle of 9.25°. To minimize the numerical error, a fifth-order Compact-Reconstruction Weighted Essentially Non-Oscillatory (CRWENO) is employed. For turbulence closure, Spalart-Allmaras one-equation model with the rotational correction terms (SA-R) and Spalart-Allmaras Delayed Detached Eddy Simulation (SA-DDES) with modified parameters are tested. The performance parameters are examined, and the vortical structures are analyzed in detail, such as the tip vortex trajectory, swirl and axial velocity profiles, and Eddy viscosity. It was observed that while the vortex tracking grids, mesh clustering techniques, and use of SA-DDES do not significantly affect the predicted efficiency of the rotor, they vastly improve the quality of the wake structure trailed behind the rotor blades.

Vieira, B.A., Kinzel, M.P., Maughmer, M.D., "CFD Hover Predictions Including Boundary-Layer Transition," AIAA-2017-1665, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

Computational fluid dynamics predictions of a helicopter in hover remain a challenge due to the tight interaction between the complex wake system and the rotor. This work focuses on model-scale hover predictions using a Reynolds averaged Navier-Stokes model supplemented with an approximate e^n envelope method transition model. These simulations are performed to evaluate the ability of the model to predict natural laminar-turbulent transition and its impact on rotor performance. The predicted transition locations and rotor figure of merit are compared with experimental measurements obtained from a joint U.S. Army/NASA hover test campaign conducted at NASA Langley Research Center. Figure of merit predictions obtained with and without the transition model align well with experiments with natural and forced transition, respectively. The predicted transition locations are also in good agreement with experiments for most of the thrust conditions. This study suggests that the present modeling approach is reasonably accurate for predicting transition on rotor blades, but also identifies areas for potential improvements.

Garcia, A.J, Colonia, S., Barakos, G.N., "Accurate Predictions of Hovering Rotor Flows Using CFD," AIAA-2017-1666, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> With work on the S-76 rotor providing encouraging results regarding the prediction of integral loads with CFD in hover, the XV-15 rotor is now analysed. Fully turbulent and transitional results are obtained showing the capability of modern CFD methods. The transition onset and distribution of skin friction are well predicted and were found to have a mild effect on the overall figure of merit. This work also shows the potential of transport-based models for transition prediction in complex 3D flows. Finally, hover simulations for the PSP blade are also shown in terms of surface pressure coefficient and wake visualisation.

Wong, T.C., "Application of CREATE™-AV Helios in an Engineering Environment: Hover Prediction Assessment," AIAA-2017-1667, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> Computational Fluid Dynamics validation of the S-76 and Pressure Sensitive Paint (PSP) model-scaled rotors in hover was performed using the HPCMP CREATE™-AV Helios software suite. Steady and time-accurate simulations were performed for a range of collective angles for two blade tip Mach numbers. Effects of blade grid sensitivity on hover performance of the S-76 rotor were performed and compared against available test data. The same gridding strategy was applied to the PSP rotor and hover performance was computed and analyzed. Several best practices of grid requirements and numerical options to achieve reasonable turnaround time in an engineering environment are presented.

Duque, E.P.N, Atsushi Toyoda, A., Burklund, M.D., Hariharan, N "Standardized Post-Processing and Visualization of Participants' Simulations of a Rotor in Hover," AIAA-2017-1668, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> For the AIAA Special Session for Rotors in Hover 2017 Computational Fluid Dynamics (CFD) simulations of two helicopter rotor in hover cases were studied – the S-76 rotor and the proposed PSP rotor. Four participants uploaded their results files to a remote 'cloud server' and then FieldView extract based post-processing tools were used to automatically extract and present the resultant flow features such as tip vortices via velocity contours and iso-surfaces. This automated system enabled researchers to concentrate on understanding the flow physics and perform unbiased comparisons. The paper herein presents the results for four of the participants.

Zhou, C., Sankar, L.N., Eschcol, R.M., Kim, J., "Application of Hover Prediction Methodologies to Anhedral Tip Shapes," AIAA-2017-1870, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

> A hybrid Navier-Stokes/Free Wake methodology, and a wake capturing methodology have been applied to helicopter rotors in hover. Two tip planforms were analyzed: S-76 rotor with a swept tip and a swept tip with anhedral. The solidity of the three rotors was matched. Calculations have been done for a range of pitch settings. Comparisons of the measurements against computed thrust, power, and figure of merit values have been done. Where available, comparisons with other calculations. The simulations are in reasonable agreement with published data for the thrust, power, and figure of merit. The sectional load data and the inflow over the rotor disk have been analyzed to understand the physical mechanisms that cause the anhedral tip to be more efficient than a conventional swept tip. It is concluded that the rotor with

the anhedral tip has a more uniform inflow over the rotor disk, reducing the induced power and the total power.

Jain, R., "CFD Performance and Turbulence Transition Predictions on an Installed Model-scale Rotor in Hover," AIAA-2017-1871, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

High-resolution Computational Fluid Dynamics (CFD) free-transition and fully-turbulent simulations are performed for a 11.08 ft, 4-blade, Mach-scaled, Pressure Sensitive Paint (PSP) rotor installed on a modified Rotor Body Interaction (ROBIN Mod7) fuselage. CFD predictions are obtained using CREATE™-AV Helios, employing the NASA OVERFLOW and FUN3D solver modules. The predictions are compared with the measurements obtained in Rotor Test Cell (RTC) at NASA Langley Research Center. In general, good agreement is obtained between the predicted and measured performance, fuselage download, and turbulence transition locations. CFD predictions are also obtained for the isolated rotor (no fuselage) ahead of the planned hover tests in the NASA Ames Full-Scale Aerodynamics Complex (NFAC) 80-×120-Foot Wind Tunnel, using Helios/OVERFLOW, Helios/FUN3D, and standalone OVERFLOW solvers. Presently, the computed rotor performance, tip-vortex core size, strength, and position, and blade airloads are presented for pre-test comparison with predictions from other tools.

Overmeyer, A.D., Martin, P.B., "Measured Boundary Layer Transition and Rotor Hover Performance at Model Scale," AIAA-2017-1872, AIAA SciTech 55th Aerospace Sciences Meeting, 9-13 January 2017, Grapevine, TX.

An experiment involving a Mach-scaled, 11:08 ft: diameter rotor was performed in hover during the summer of 2016 at NASA Langley Research Center. The experiment investigated the hover performance as a function of the laminar to turbulent transition state of the boundary layer, including both natural and fixed transition cases. The boundary layer transition locations were measured on both the upper and lower aerodynamic surfaces simultaneously. The measurements were enabled by recent advances in infrared sensor sensitivity and stability. The infrared thermography measurement technique was enhanced by a paintable blade surface heater, as well as a new high-sensitivity long wave infrared camera. The measured transition locations showed extensive amounts, $x/c>0:90$, of laminar flow on the lower surface at moderate to high thrust ($C_T/\sigma > 0:068$) for the full blade radius. The upper surface showed large amounts, $x/c > 0:50$, of laminar flow at the blade tip for low thrust ($C_T/\sigma < 0:045$). The objective of this paper is to provide an experimental data set for comparisons to newly developed and implemented rotor boundary layer transition models in CFD and rotor design tools. The data is expected to be used as part of the AIAA Rotorcraft Simulation Working Group.