2015 Sessions

Hariharan N., Egolf T.A., Narducci, R., Sankar, L.N., "Helicopter Rotor Aerodynamic Modeling in Hover: AIAA Standardized Hover Evaluations," AIAA 2015-1242, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

Good hover performance is a very important rotorcraft design criteria, but despite advancements in the ability to predict and preserve the tip vortex, the limiting aspect of accurate hover performance prediction, the capability to consistently and reliably predict the performance for a new rotor-blade has not yet been demonstrated. This challenge provides the motivation for the AIAA Applied Aerodynamics Technical Committee Rotorcraft Simulation Working Group's efforts. This paper compares and summarizes results from the AIAA 1st Hover Invited Session at SciTech 2014, the first step to assess in a standardized fashion the different approaches by government, industry and academic participants to evaluate and further rotor-in-hover performance predictions. A baseline S-76 rotor planform was used in this first step. Comparisons of the results across the spectrum of analyses used by the participants show a prediction spread of ~3 counts in Figure of Merit and the correct trending with experimental results. The AIAA APA 2nd Hover Session at SciTech 2015 will build on this work by refining the baseline results and adding additional tip geometries to the study as the next step of the effort.

Narducci, R., "Hover Performance Assessment of Several Tip Shapes using OVERFLOW," AIAA 2015-1243, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

Several rotor blade tip shapes based on the S-76 model scale rotor are assessed for performance in hover using OVERFLOW and compared against experimental data collected in the Sikorsky Model Hover Test Facility. The calculations use a time-accurate approach and produced solutions across a range of thrust conditions. Comparisons are made among the rotors for thrust-power, Figure of Merit, distributed air loads, and vortex trajectories. The effect of coning is also examined. Best practices are offered for predicting relative hover performance improvements among rotor blades.

Jain, R., "Hover Predictions for the S-76 Rotor with Tip Shape Variation using CREATE™-AV Helios," AIAA 2015-1244, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

Computational Fluid Dynamics validation of the S-76 model-scale rotor in hover is performed using the US Department of Defense Computational Research and Engineering Acquisition Tools and Environments – Air Vehicles (CREATE™-AV) Helios software. The effect of blade tip shape variation is studied for three tip shapes, rectangular, swept-tapered, and swept-tapered-anhedral. Additionally, the effect of tip Mach number is also studied for the swept-tapered tip. High-resolution, time-accurate, simulations are performed, and results including rotor performance, blade airloads, and wake vortex strength and position are presented and analyzed. The performance predictions are compared against the test measurements and good agreement is obtained.

Anusonti-Inthra, P., "The Effects of Turbulence Modelings on CFD Simulations of S76 Hovering Rotor," AIAA 2015-1245, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

Helicopters are designed to operate in various flight conditions such as hover, low speed and high speed forward flights. Hovering is the most critical flight condition for helicopters, and hovering rotor wake consists of tip vortices from many rotor revolutions that form very complex helical wake structure beneath the rotor plane. This fact makes simulating flow field of the hovering rotors an extremely complicated task. An ideal hover simulation must provide sufficiently accurate flow field variables e.g. - (i) tip vortex strength and structure, (ii) boundary layer definition (laminar to turbulent transitions), (iii) shedded boundary layer wake strength and location. These requirements push the limits of what the current CFD software can offer. In the current study, CFD simulations of a hovering S76 rotor will be performed with the emphasis on capturing the tip vortex strength and structure, the effects of turbulence modelings, and the tip geometry configurations. The simulations are performed using commercial CFD software to assess methodologies to capture the tip vortices structure from a hovering rotor. The hover performance results from the present study emphasize on the effects of steady-state/transient solvers, turbulence models, grid resolution (for capturing the tip vortices), and tip shape geometries.

Hwang, J.Y., Choi, J.H., Kwon, O.J., "Assessment of S-76 Rotor Aerodynamic Performance in Hover on Unstructured Mixed Meshes," AIAA 2015-1246, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

In the present study, numerical prediction of the aerodynamic performance of the S-76 rotor in hover was conducted by using an unstructured mixed mesh flow solver. In the present mixed mesh methodology, the near-body flow domain is modeled by using body-fitted prismatic/tetrahedral cells, while Cartesian mesh cells are filled in the off-body region. To better resolve the flow characteristics in the off-body flow region, high-order accurate weighted essentially non-oscillatory (WENO) scheme is employed. An overset mesh technique is adopted to transfer the flow variables between the two different mesh regions. The calculations were made for three different blade configurations, including swept-taper, rectangular, and swept-taper-anhedral tip shapes, and the results were compared with experimental data. The calculations were also made to investigate the effect of blade tip Mach number. The detailed flow characteristics, such as tip-vortex trajectory, vortex core size, and first-passing tip vortex position depending on the tip shape, were also examined.

Min, B.Y., Wake, B., "Analysis of a Hovering Rotor using UT-GENCAS: A Modified Hybrid Navier-Stokes/Free-Wake Method," AIAA 2015-1247, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

Analysis of rotors in hover has always been a significant challenge. The presence of strong vortices underneath the rotor requires a large amount of grid points to properly capture the vorticity and many time steps are required to reach a time-independent state. In this study, a hybrid Navier-Stokes/free-wake method is used to preserve trailing vortices with a lower grid count. In order to achieve fast steady performance solution, two wake modeling approaches are introduced. One is a free-wake model with relaxation, and the other is a constrained down-wash wake model based on Landgrebe model. In this hybrid method, Navier-Stokes and free-wake solvers are loosely coupled for fast convergence in hover. The S-76 model-scale blades with three tip designs were studied to assess current approaches. The proposed approaches showed reasonable to good correlation with measured Figure of Merit, thrust and torque data, and the impacts of tip design and tip speed variations were captured well.

Whitehouse, G.R., Wachspress, D.A., Quackenbush, T.R., "Predicting the Influence of Blade Tip Shape on Hovering Rotor Performance with Comprehensive Analyses," AIAA 2015-1248, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

The ability to predict and understand the influence of rotor tip shape on hovering rotor performance from first-principles is critical to rotorcraft development. Comprehensive rotorcraft analysis methods can be used to reduce the risk and cost associated with developing new rotor designs by being able to rapidly and cost-effectively predict performance. Moreover, these methods are ideal for traversing the design space in order to identify promising, or interesting, designs for more detailed analysis, testing and optimization. In this paper the ability of three distinctly different comprehensive rotorcraft methods – EHPIC, CHARM and VTM – to predict the hover performance of a rotor with a variety of tip shapes is evaluated. The assessment indicates that good predictive fidelity is achieved for many of the cases considered, though dependence on airfoil data remains a limiting factor in the generality of the analysis results.

Abras, J.N., Hariharan, N., "Comparison of CFD Hover Predictions on the S-76 Rotor," AIAA 2015-1711, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

The S-76 rotor is used as a baseline case to assess predictions made by different CFD solvers. These predictions are compared to the available test data as well as to one another. Both grid and parametric studies of the options available within each code are included. The grid studies look into not only blade grid density, but also Cartesian and unstructured far field grid computations, and the use of AMR. 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.

Garcia, A.J., Barakos, G.N., "Hover Predictions on the S-76 Rotor using HMB2," AIAA 2015-1712, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

A comparative study of the effect of different tips on the hovering Sikorsky S-76 model main rotor blades is performed using the multi-block CFD solver of Liverpool University HMB2. Rectangular tips with rounded and at tip-cap, as well as tips with anhedral and sweep are selected for computations. Figure of Merit (FoM), thrust and torque coefficients, spanwise blade loading distributions and surface pressure coefficients are obtained for a range of collective pitch settings, from 4° to 11°, using an overset method. For this study, three tip Mach numbers were also employed, 0.55, 0.60 and 0.65 using as turbulence closures the Shear-Stress Transport (SST) k-ω turbulence model of Menter1 and the k-ω-γ $Re_{\theta t}$ transition model with the empirical correlation of Langtry. Flow visualization of the rotor wake, comparisons of the trajectory of the tip vortex and comparisons with theory were also obtained after CFD computations. Overall, the HMB2 method was found to predict the rotor performance very well, though the lack of more detailed data for comparisons shows the need for modern experiments for hovering rotors where on and off-blade data is measured. In addition, a comprehensive investigation of the role of transitional model in the prediction of the location of the transitional onset over the rotor blades of the B0-105 helicopter was attempted using Michel and Cebeci-Smith's empirical criteria.

Smith, M.J., Jacobson, K.E., Grubb, A.L., Daniel A. Wachspress, D.A., Whitehouse, G.R., "Evaluation of Rotor Hover Performance With Differing Blade Tip Shapes Using A Carefree Hybrid Methodology," AIAA 2015-1713, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

A new hybrid computational fluid dynamics-free wake (CFD-FW) method, implemented using both government and commercial grade software, has been applied to the S-76 rotor in hover. NASA's structured unsteady Reynolds-averaged Navier-Stokes (URANS) methodology, OVERFLOW, was used as the computational fluid dynamics (CFD) platform, while Continuum Dynamics Inc's free wake module, CHARM, constituted the free-wake solver. Evaluations of three different blade tip configurations were performed, along with three different tip Mach numbers for a swept and tapered tip. The hybrid method produced performance coefficients comparable to or more accurate than achieved by most full CFD or other hybrid methods. The use of this hybrid method significantly decreased computational time and cost with a reduced-size mesh for both the near-body fitted mesh and the off-body background mesh.

Liu, Z., Kim, J., Sankar, L.N., Hariharan N., Egolf T.A., "High Order Evaluation of S-76 in Hover," AIAA 2015-1714, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

> The aerodynamics characteristics of the S-76 rotor in hover have been studied on stretched non-orthogonal grids using spatially high order symmetric total variation diminishing (STVD) schemes. Several companion numerical viscosity terms have been tested. A baseline finite volume methodology termed TURNS (Transonic Unsteady Rotor Navier-Stokes) is the starting point for this effort. The original TURNS solver solves the 3-D compressible Navier-Stokes equations in an integral form using a third order upwind scheme. It is first or second order accurate in time. In the modified solver, the inviscid flux at a cell face is decomposed into two parts. The first part of the flux is symmetric in space, while the second part consists of an upwind-biased numerical viscosity term. The symmetric part of the flux at the cell face is computed to fourth-, sixth- or eighth order accuracy in space. The numerical viscosity portion of the flux is computed using either a third order accurate MUSCL scheme or a fifth order WENO scheme. A number of results are presented for the S-76 rotor in hover. Comparisons with the baseline third order upwind scheme and experiments are given.

Sheng, C., Wang, J., Zhao, Q., "S-76 Rotor Hover Predictions Using Advanced Turbulence Models," AIAA 2015-1715, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

> The conventional helicopter rotor S-76 hover performance is numerically investigated using an unstructured grid Navier-Stokes CFD solver U^2NCLE. Three S-76 rotor tip configurations including a swept tapered tip, a straight tip, and a swept tapered tip with anhedral are investigated and validated with the experimental data. The rotor Figure of Merit (FM) is predicted over a range of blade collective angles from 4° through 10° using a mesh deformation method. The Spalart-Allmaras's turbulence model (SA) and the Menter's Shear Stress Transport (SST) turbulence model, coupled with a Transition and Stall Delay Model (TSDM), are evaluated in capturing the complex viscous flow phenomena for the S-76 rotor. The numerical computations indicate that the correct capturing of the boundary layer transition and flow separation phenomena is critical for an accurate prediction of the S-76 hover Figure of Merit especially at high collective angles.

Woong Kim, J.W., Sankar, L.N., Marpu, R., Egolf, T.A., Hariharan, N., "Assessment of Planform Effects on Rotor Hover Performance," AIAA 2015-1716, AIAA SciTech 53rd Aerospace Sciences Meeting, 5-9 January 2015, Kissimmee, Florida.

> A hybrid Navier-Stokes/Free Wake methodology is applied to helicopter rotors in hover. Three tip planforms were analyzed: the S-76 rotor with a swept tip, a rectangular planform, and a swept tip with anhedral. The solidity of the three rotors was matched. A pitch sweep was conducted. Computed thrust, power, and figure of merit values have been compared with test data. Where available, comparisons with other calculations for these quantities and the near wake tip vortex trajectory have been done. The simulations are in reasonable agreement with published data for the thrust, power, and figure of merit. The simulations differ from full Navier-Stokes calculations in the predictions for tip vortex descent rate and contraction rate. The simulations correctly predicted the trends. The swept tapered anhedral tip had the highest figure of merit, followed by the swept tapered tip. The rectangular planform had the lowest figure of merit.