UH-60A Airloads
Wind Tunnel Data Update

Airloads Workshop
Tom Norman
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Outline

• Background
• Efforts since February 2011
  – Database
  – PIV/Blade Displacement
  – Other activities
• Data availability
• Near-term plans
Background

• Airloads wind tunnel test completed May 2010

• Six test phases
  – Parametric Sweeps
  – 1-G Level Flight
  – Airloads Flight Matching
  – DNW Wind Tunnel Matching
  – High Advance Ratio
  – Particle Image Velocimetry (PIV)

• Initial post-test analysis focused on
  – Stall sweep
  – Speed sweep
  – High advance ratio
Efforts Since February 2011

• 5 conference papers presented
  – 3 at AHS Forum (May 2011)
    • Test overview - “Full-Scale Wind Tunnel Test of the UH-60A Airloads Rotor”
    • CFD correlation – “Correlating CFD Simulation with Wind Tunnel Test for the Full-Scale UH-60A Airloads Rotor”
    • High advance ratio – “Experimental Investigation and Fundamental Understanding of a Slowed UH-60A Rotor at High Advance Ratios”
  – 2 at AIAA Applied Aero meeting (June 2011)
    • PIV technique – “PIV Measurements in the Wake of a Full-Scale Rotor in Forward Flight”
    • Blade displacement technique – “Blade Displacement Measurements of the Full-Scale UH-60A Airloads Rotor”
Efforts Since February 2011

• Data evaluation/reduction efforts
  – Blade pressures and integrated parameters
    • Completed pressure evaluations for 6 complete runs (including stall and speed sweeps)
    • Reviewed “bad” pressures, threw out bad revs, re-integrated when possible
  – Blade root motion measurements (laser, crabarm)
    • Reviewed/corrected blade motion calibration coefficients
    • Identified rotation effect on crabarms as well as transducer drift (affects mean)
Airloads Database – To Do

• Blade Pressures and Integrated Parameters
  – Complete pressure evaluation/integrations of remaining runs
• Rotor Performance
  – Evaluate rotor balance drift for high advance ratio runs and correct data if necessary
• Blade Structural Loads
  – Incorporate coupled calibration coefficients (minimal effects on full-RPM data points)
  – Evaluate CF effects on a few gages
  – Evaluate electrical coupling between normal bending and torsion at Station 70
• Blade Root Motion Measurements
  – Incorporate corrections to account for RPM effects and transducer drift (affects mean only)
Blade Displacement

- What was measured?
  - Simultaneous images from multiple cameras of radial and spanwise array of retro-reflective targets on each blade
  - From images, extracting
    - Location of blade section chord lines along the blade span in the rotor coordinate system
    - Accuracies to 0.2 deg (pitch, flap, lag)
Blade Displacement Status and Plans

• Data acquisition and analysis
  • Initial analysis of priority data points complete
  • Follow-on data processing (including refinements) ongoing
    • Improving automation/robustness of image processing (high adv ratios are challenging)
    • Developments for elastic bending and twist underway
  • Analyzing non-rotating checkout data to validate data analysis procedure
  • Comparison of experimental data with computational result to begin shortly
    • Will help to refine data analysis methods
    • Still need to define data requirements and archiving

• Publication schedule
  • 2010 AHS Specialists' Conference: Paper describing test technique
  • 2011 AHS Annual Forum: One test condition for UH-60A overview paper
  • 2011 AIAA Applied Aerodynamics Conference: Paper describing image processing and showing selected results for one test condition
  • 2012 AHS Future Vertical Lift Aircraft Design Conference: Paper describing image processing and showing selected results
PIV Data

• What was measured?
  – 3-D velocity field in stationary cross-flow plane at approximately 90 deg azimuth, covering outer 50% of rotor radius
  – From velocity field, will extract
    • Tip vortex core size
    • Rotor wake geometry (tip vortex trajectory in laser sheet)
    • Vortex strength and vortex structure

Schematic of PIV installation
PIV Status and Plans

• All PIV data have been processed using IDT *proVISION* software with approximate calibration, single pass processing with constant window size.

• Results of *Preliminary Processing* sufficient to reveal all features of interest in the flow (tip vortices of multiple blades in each flow field, trim tab wake, blade wake).

• Final Processing will use more sophisticated PIV software: *DaVis* (LaVision), and *InSight 3G* (TSI). Plan for final processing TBD.

• PIV Post-Processing
  Investigating use of planar fit of measured velocity field to analytical vortex model to provide key vortex characteristics.

• Publication schedule
  - 2011 AHS Annual Forum: Provided one test condition (one blade azimuth) for inclusion in UH-60A overview paper
  - 2012 AHS Annual Forum: Paper with analysis of tip vortex trajectory in measurement plane
Efforts Since February 2011

- Investigated numerous approaches for measuring as-built blade contours
  - Most concerned about blade deflections during measurements
  - Will likely use white-light scanning method (later this year)
- Began effort to understand discrepancies between blade tab measurements for flight test and wind tunnel test
  - Investigating differences between measurement tools and methods
  - Sikorsky provided very useful information to help define tab deflection definition for CFD analysis
- Completed preparations for and have begun (this week) control stiffness testing
Control Stiffness Testing
Data Availability

• Have investigated 2 methods for providing data to Airloads workshop participants
  – Direct database access to key run/points (similar to TRENDS for flight test)
    • Provides user access to all data for key points
    • Requires setup of NASA database server
      – Must follow NASA/Army IT security regulations
      – Must have NASA/Army management acceptance of IT risks
    • IT security procedures proposed and requests made for NASA and Army approvals
  – Data files for key run/points (similar to PdB files for flight test)
    • Provides user with pre-specified data only
    • Does not require NASA database server or extra IT approvals
    • Can be implemented in near-term
Data Files for Airloads Workshop

• One file for each data point
  – Header
  – Constants
  – Means (dimensional and non-dimensional)
    • 54 total – tunnel, performance, fuselage, and control loads
  – Time Histories (dimensional)
    • 391 total, including 286 at 2048/rev and 105 at 256/rev
    • 1 rev/parameter averaged over all acquired revs
    • Some measure of repeatability needed – either std dev at each azimuth or max std dev for entire rev
  – List of pressures used in integrations
Data Files for Airloads Workshop

• Section loads
  – 3 section loads at each radial station
  – Two time histories for each section load
    • Section airloads calculated for every sample and then averaged over 128 revs
      – Provides easy determination of std dev
    • Section airloads calculated using averaged pressures
      – Allows addition of corrected pressures (eliminating bad revs on specific channels) to provide better estimate of section loads
      – Will be especially valuable when we started having transducer problems (later test points)
  • Time history methods are identical with same inputs
Data Repeatability

- Std dev at each azimuth or max std dev for entire rev?
  - Std dev at each azimuth will double data file size (to approx. 20 MB)

Deep Stall Case, Run 45, Pt 38
Proposed Data for Near-term Release

- **Speed sweep (8 points)**, $Ct/s=0.09$, $M_{tip}=0.650$, representative moments
  - $\mu = 0.15, 0.20, 0.24, 0.30, 0.35, 0.37, 0.385, 0.40$

- **Stall/collective sweep (12 points)**, $\mu=0.30$, $\alpha=0$, $M_{tip}=0.625$, zero moments
  - Collective = 0.9, 2.5, 4.1, 5.9, 6.9, 8.0, 9.1, 10.4, 11.1, 11.5, 11.9, 12.3
Proposed Process for Data Release

• Send email to Tom Norman (tom.norman@nasa.gov) requesting data release form
• Fill out/sign form and return
  – Data limitations similar to flight test data
  – Will include request for other related documents (data format summary, parameter list, derived parameter equations, rotor properties, blade CAD file, LRTA and 40x80 surface definitions)
• Data to be distributed using encrypted zip files
  – Password to be sent separately (phone call?)
• Data expected to be available within next 1-2 months
Near-Term Plans

• Continue data evaluation/correction and database updates
• Continue analysis of PIV and Blade Displacement data
• Complete control stiffness testing, contour measurements, and tab deflection measurements
• Finalize data release requirements and distribute data as requested
• Begin to look at other parts of database
  – Structural load correlation with CFD/CSD
  – Wind tunnel/flight test comparisons
  – NASA/Army AHS papers - TBD