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

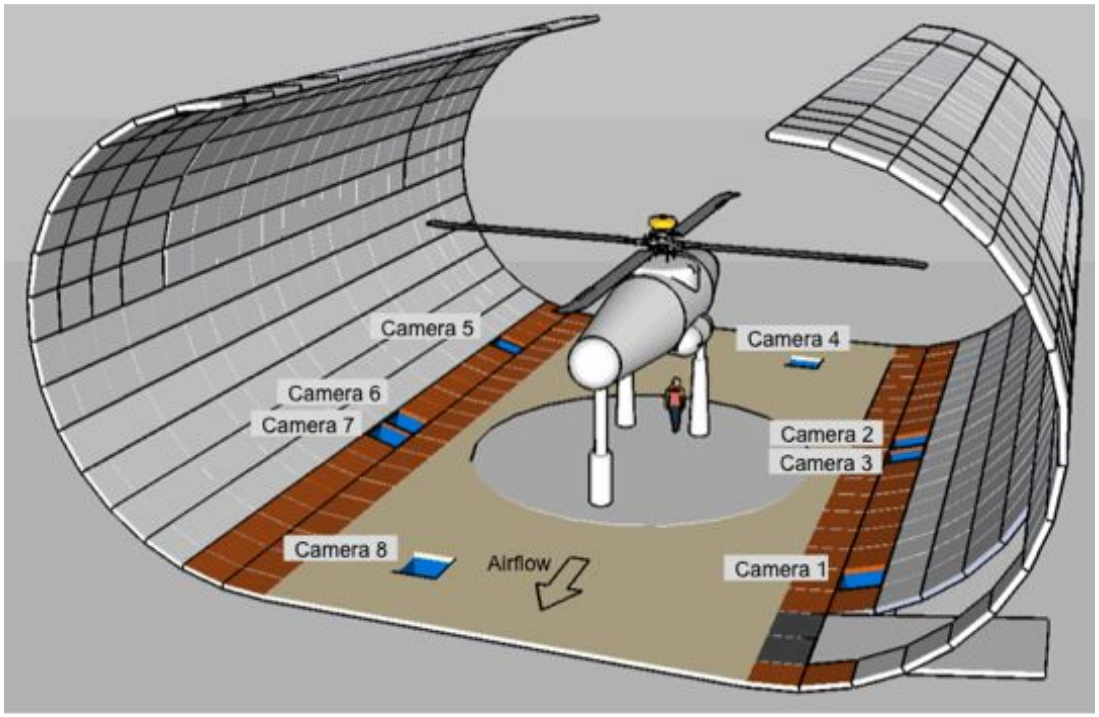
- Data evaluation/reduction efforts
  - Blade pressures and integrated parameters
    - Completed pressure evaluations for 6 complete runs (including stall and speed sweeps)
    - Reviewed “bad” pressures, threw out bad revs, re-integrated when possible
  - Blade root motion measurements (laser, crabarm)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

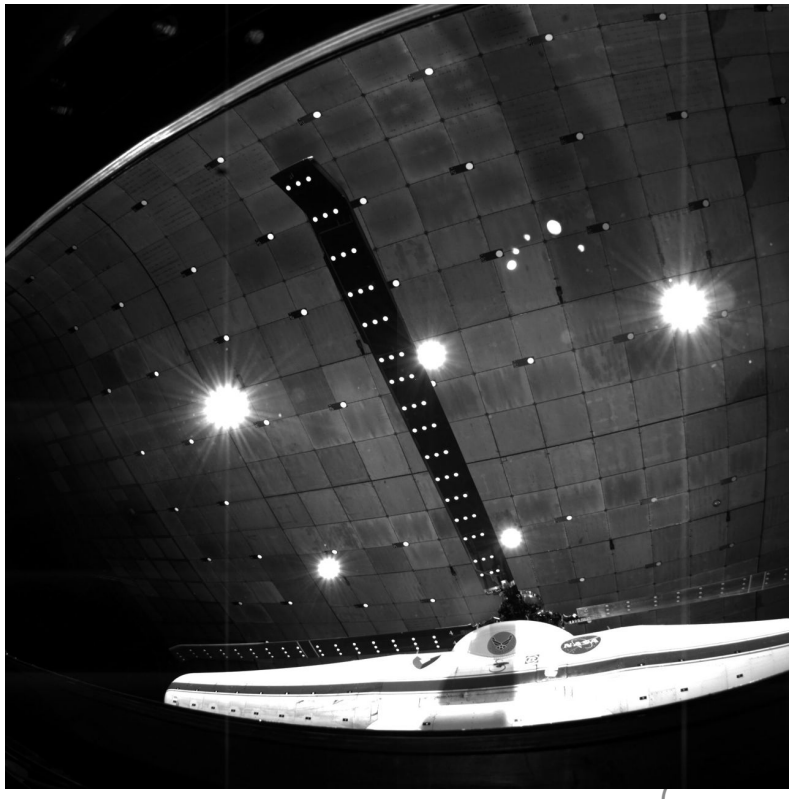
Airloads Database – To Do

- 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)



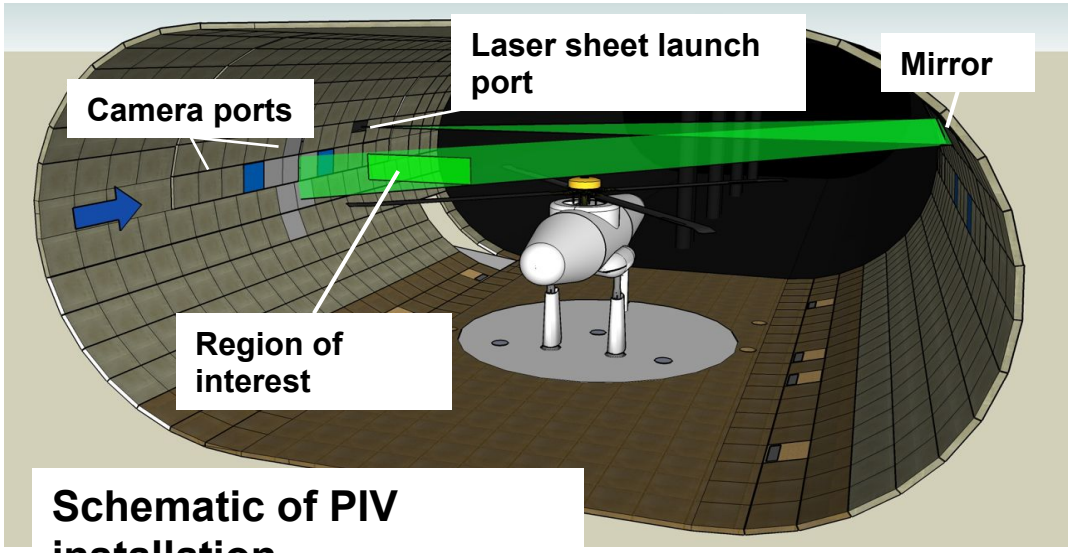


Blade Displacement Status and Plans

- 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
- 2011 AIAA Applied Aerodynamics Conference: Presented paper describing PIV installation, sample PIV data
- 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

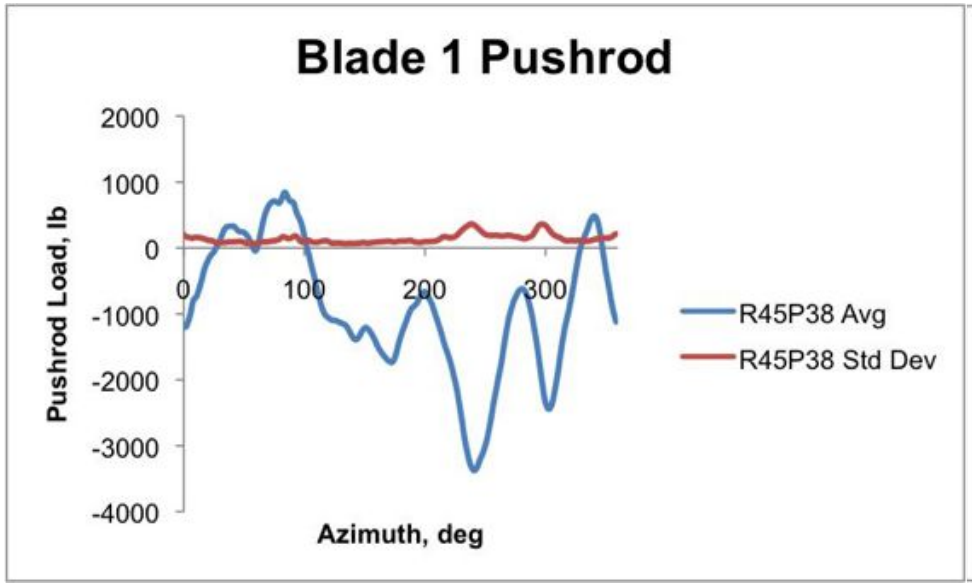
Data Files for Airloads Workshop

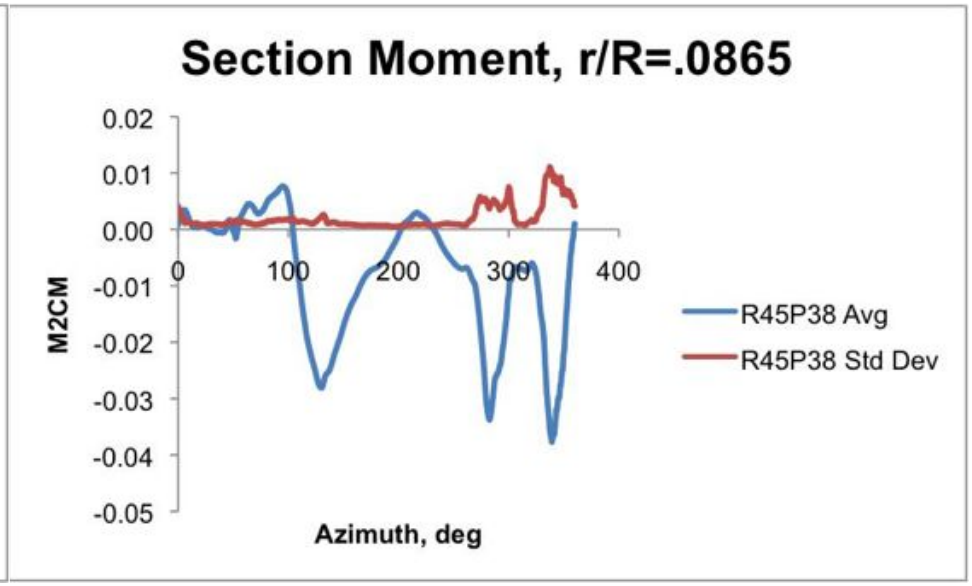
- Section loads
  - 3 section loads at each radial station
  - Two time histories for each section load
    - Section airloads calculated for every sample and then averaged over 128 revs
      - Provides easy determination of std dev
    - Section airloads calculated using averaged pressures
      - 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)

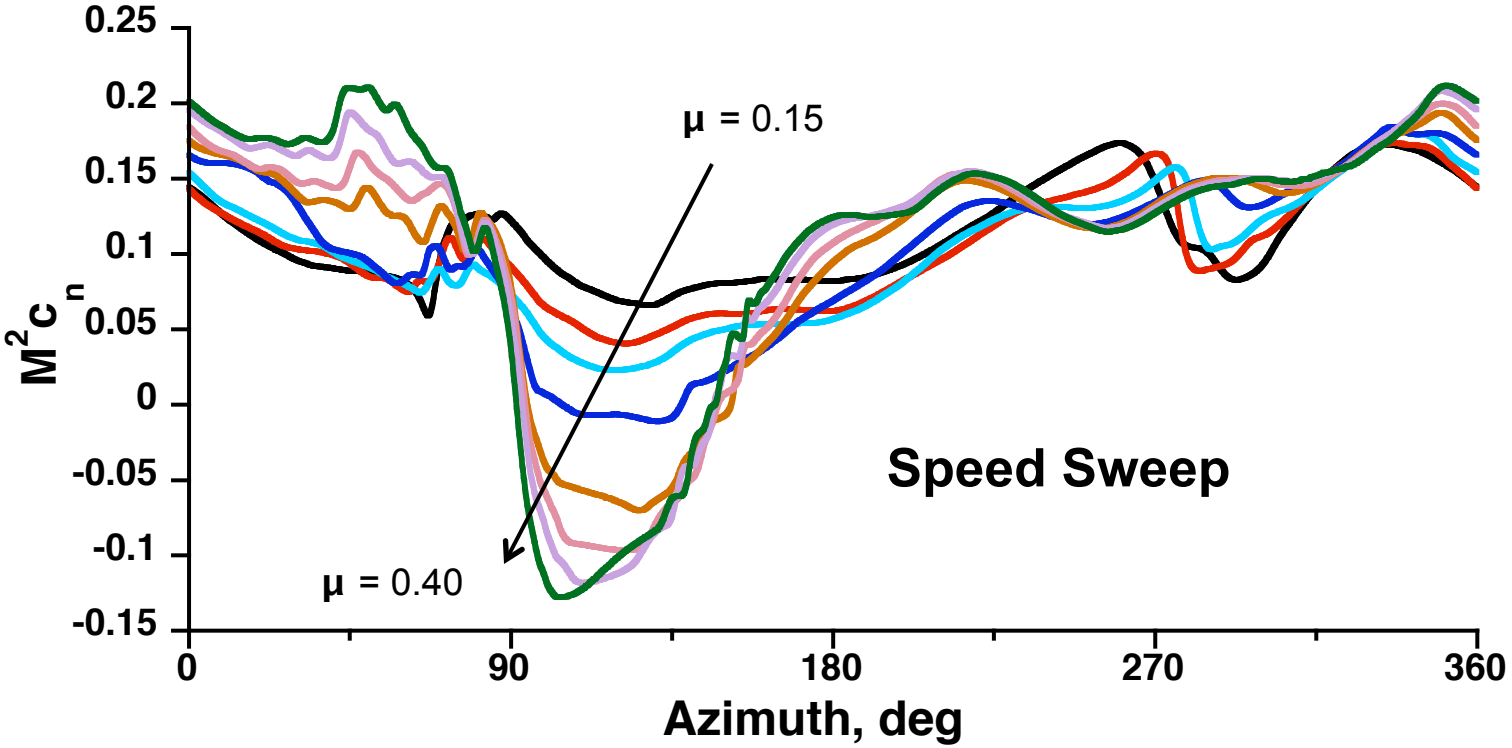
Deep Stall Case, Run 45, Pt 38





Proposed Data for Near-term Release

- **Speed sweep (8 points)**, Ct/s=0.09, Mtip=0.650, representative moments
  - mu = .15, .20, .24, .30, .35, .37, .385, .40
- **Stall/collective sweep (12 points)**, mu=0.30, alpha=0, Mtip=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