UH-60A Airloads Wind Tunnel Data Update

Airloads Workshop

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Outline

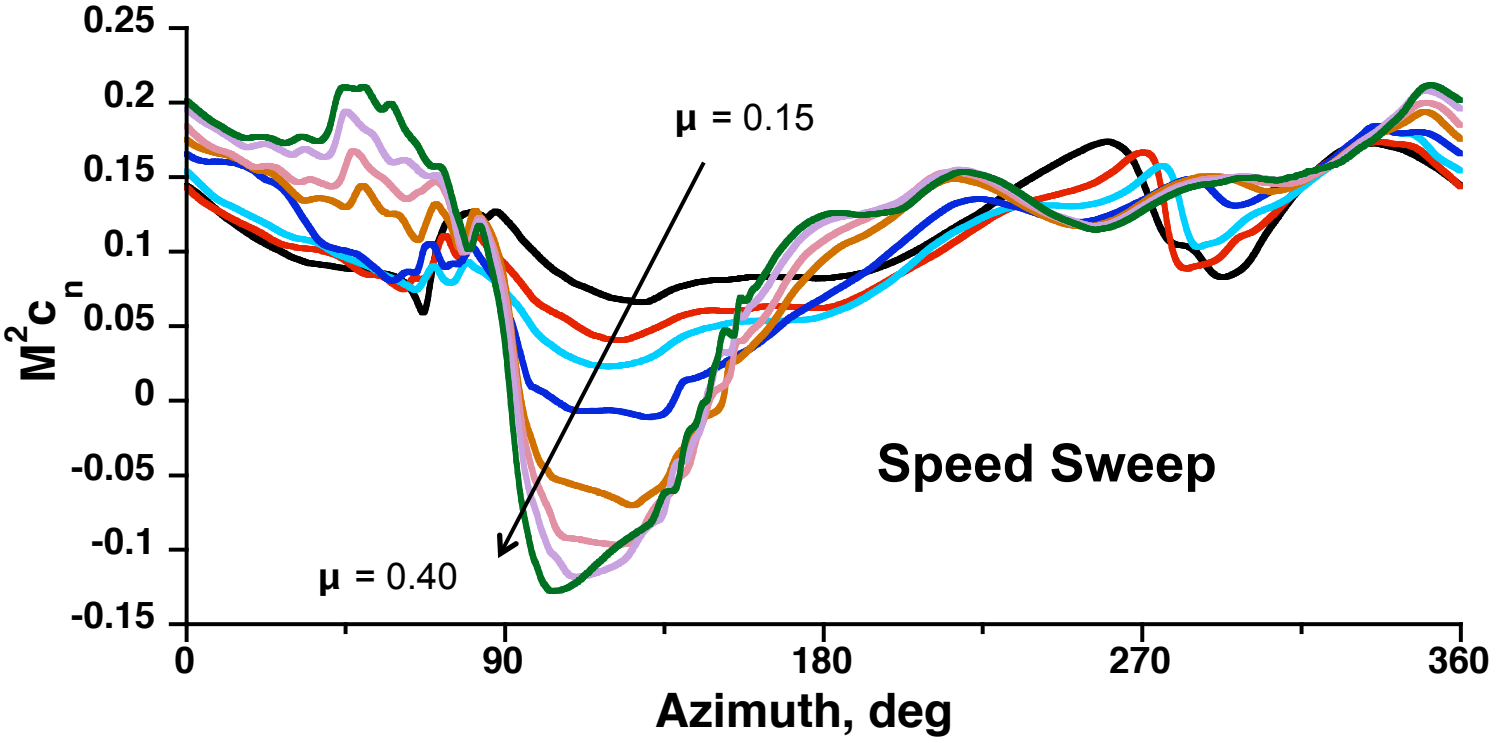
- Data Availability
- Publications
- Other efforts since August 2011
- Near-term plans

Data Availability

- Selected wind tunnel data **now available** to Workshop participants (as of 11/1/11)
  - Data accessible through NASA's NSC Knowledge Now website (https://nsckn.nasa.gov/community/Views/Home.aspx?Filter=930)
  - Requires approved data request form
    - Send email to Tom Norman (tom.norman@nasa.gov) to request form
  - Website includes multiple files, including
    - Selected wind tunnel data and format description
    - Parameter and test condition descriptions
    - PDF files of related papers and workshop presentations
- 8 requestors have approved access (3 NASA, Sikorsky, Bell, Boeing, Penn State, CDI)

Currently Available Data

- **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



Publications

- 6 conference papers have been presented
  - 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"
  - 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"
  - AHS Design Conference (Jan 2012)
    - **High advance ratio predictions** – "Performance and Loads Correlation of a UH-60A Slowed Rotor at High Advance Ratios"

Publications

- 7 conference papers accepted for publication
  - AHS Forum (May 2012)
    - **CFD structural load correlation** – “Loads Correlation of a Full-Scale UH-60A Airloads Rotor in a Wind Tunnel”
    - **CFD correlation** – “An Examination of Unsteady Airloads on a UH-60A Rotor: Computation vs. Measurement”
    - **PIV technique** – “Wind Tunnel Measurements of Full-Scale UH-60A Rotor Tip Vortices”
    - **Blade displacement technique** – “Blade Displacement Measurement Technique Applied to a Full-Scale Rotor”
    - **High advance ratio predictions** – “Investigation of Performance and Loads of a UH-60A Rotor at High Advance Ratios”
    - **High advance ratio predictions** – “Computational Investigation and Fundamental Understanding of a Slowed UH-60A Rotor at High Advance Ratios”
    - **Scale/Wind Tunnel Effects**- “Evaluation of Wind Tunnel and Scaling Effects with the UH-60A Airloads Rotor”

Other Efforts Since August 2011

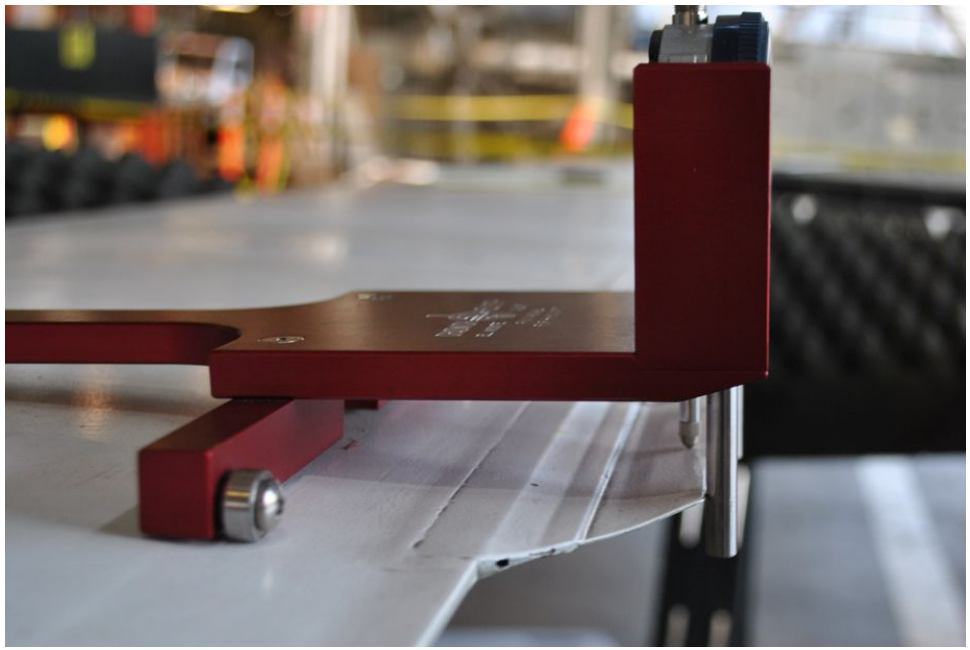
- Continued data evaluation efforts for blade pressures and integrated parameters
  - Have completed pressure evaluations for 17 complete runs (out of 35)
- Continued making progress with PIV and Blade Displacement data reduction efforts
  - PIV processing now providing vortex core properties
  - Multiple Blade Displacement processing techniques applied to data set to identify best approach
- Completed control system stiffness testing
- Measured blade tab angles
- Investigated azimuthal differences between flight and wind tunnel

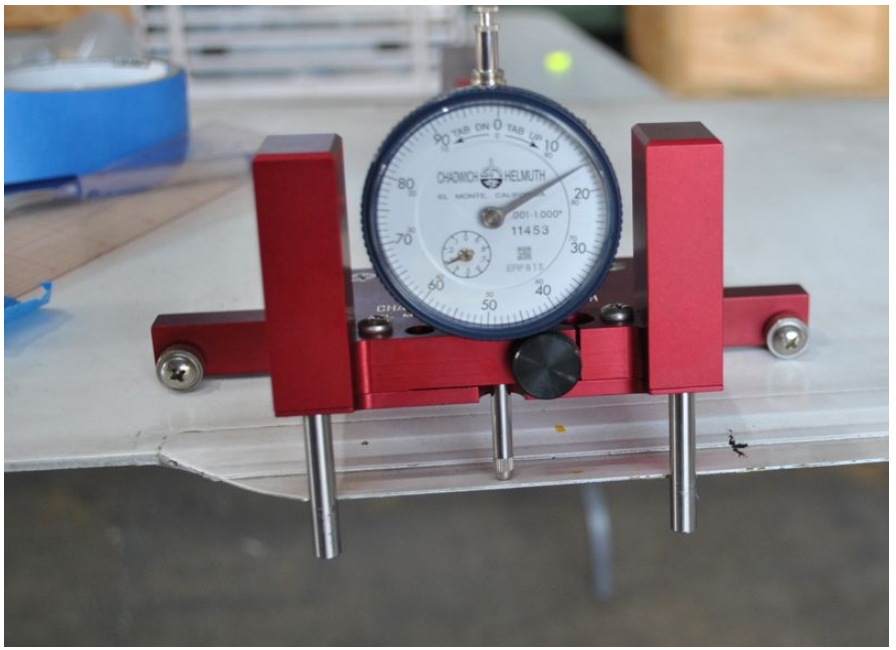
Blade Tab Angles

- 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

Blade Tab Angles

- Re-measured tab deflections on all 4 blades
- Measured deflections very similar to flight test
- Tab angles dependent on location of tab bend radius and location of measurement
  - Approx location of bend radius 0.8 in from TE
  - Approx location of measurement .15 in from TE
- Tab angles vary from 0.3 to 3.6 deg up

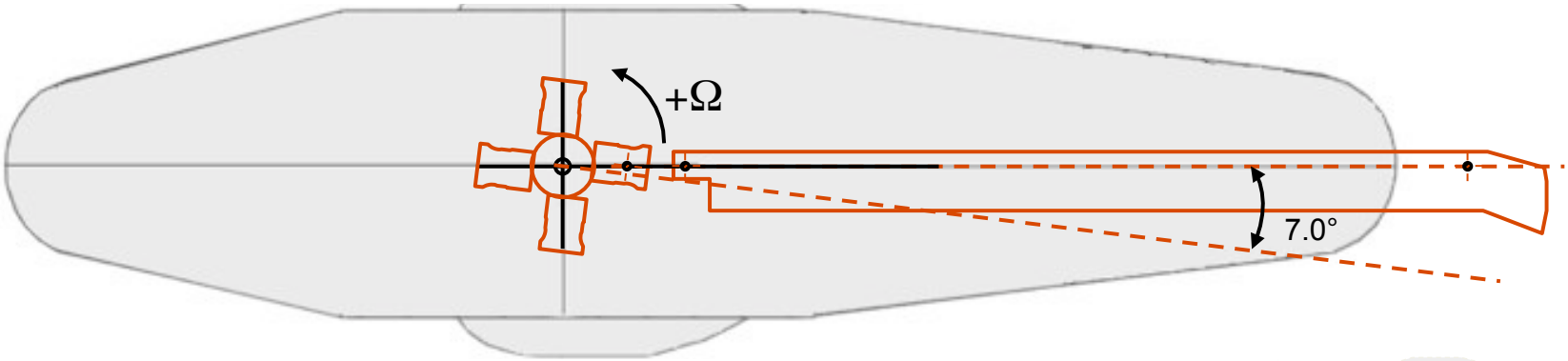




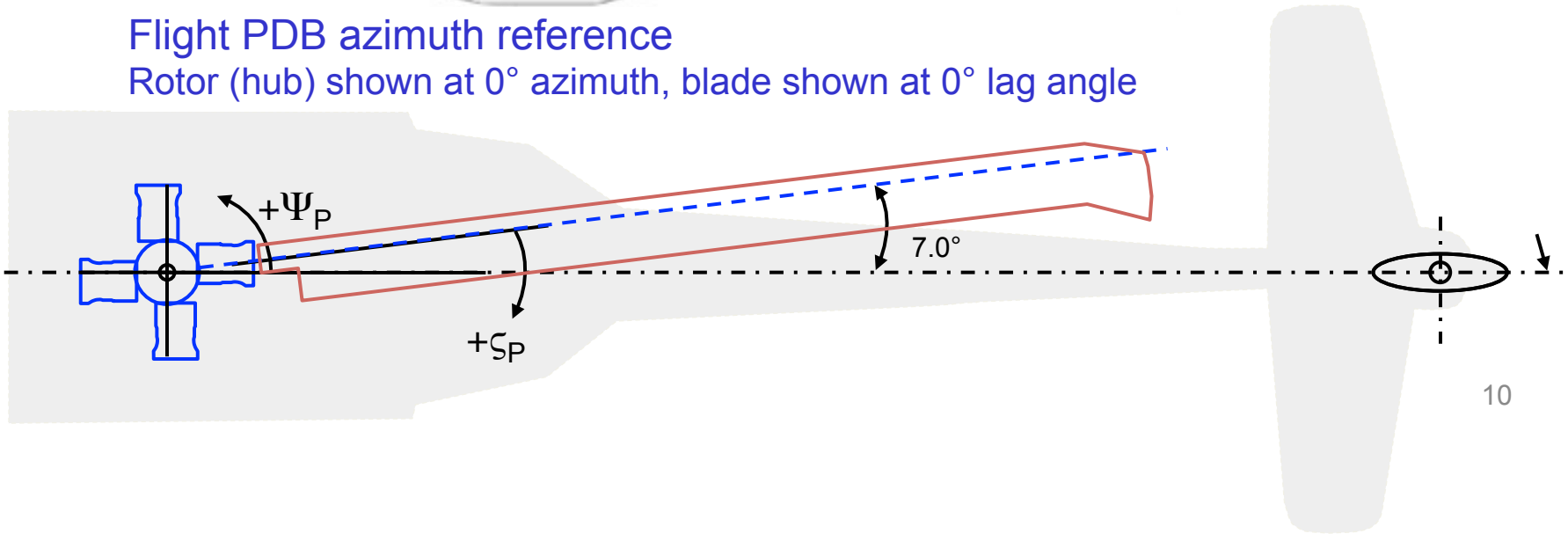
Azimuthal Diff. Between Flight and Wind Tunnel

- Known 7 deg azimuth ref. difference between wind tunnel and flight PdB files

Wind Tunnel (and TRENDS) azimuth reference
Rotor (hub) shown at 0° azimuth, blade shown at 0° lag angle

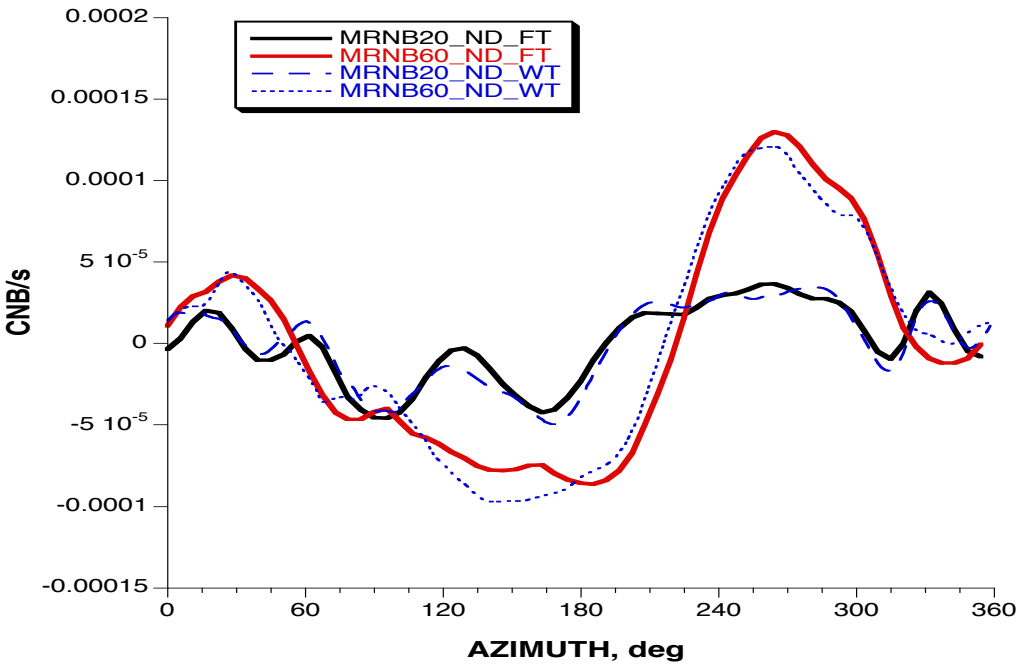


Flight PDB azimuth reference
Rotor (hub) shown at 0° azimuth, blade shown at 0° lag angle



Azimuthal Diff. Between Flight and Wind Tunnel

- Looked at possible causes of additional azimuthal differences
  - Encoder issues, post-processing errors, etc
- Found that wind tunnel data were corrected for phase delays caused by anti-aliasing filters; flight data were not
  - High speed data, 550 Hz Butterworth filter; approximately 1.8 deg delay
  - Low speed data, 110 Hz Butterworth filter, approximately 8.6 deg delay
- Also need to account for flight sideslip angle for comparisons (up to 4 deg)



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Flight/Wind Tunnel Flap Bending
(Flight corrected for phase)

Near-Term Plans

- Continue data evaluation/correction and database updates
  - Pressures/integrated loads – complete remaining runs
  - Blade motion measurements – correct for RPM effects and transducer drift (mean effects)
  - Slowed Rotor runs – account for blade gage coupling and rotor balance drift
- Continue analysis of PIV and Blade Displacement data
- Complete documentation of control stiffness testing and tab deflection measurements
- Investigate blade contour measurements
- Investigate measured dynamic hub loads; evaluate rotor balance calibration issues