UH-60A Airloads
Wind Tunnel Data Update

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Airloads Workshop – August 9, 2012
Outline

• Data Availability
• Publications
• Recent Test Findings
• Current Activities
• Wind Tunnel/Flight Test Comparisons
Data Availability

• Selected wind tunnel data made available to Workshop participants Nov 2011
  – Includes speed sweep (8 pts) and thrust sweep (12 pts)
  – Data accessible through NASA’s NSC Knowledge Now website

• 8 organizations currently have approved access (NASA, Army, Sikorsky, Bell, Boeing, Penn State, CDI, Georgia Tech)
Publications Since March 2012

• 6 conference papers at 2012 AHS Forum
  – Aero/Structural Loads
    • “Loads Correlation of a Full-Scale UH-60A Airloads Rotor in a Wind Tunnel”, Yeo et al
    • “Evaluation of Wind Tunnel and Scaling Effects with the UH-60A Airloads Rotor”, Norman et al
  – High Advance Ratio
    • “Investigation of Performance and Loads of a UH-60A Rotor at High Advance Ratios”, Yeo
    • “Computational Investigation and Fundamental Understanding of a Slowed UH-60A Rotor at High Advance Ratios”, Potsdam et al
  – Experimental Capabilities
    • “Wind Tunnel Measurements of Full-Scale UH-60A Rotor Tip Vortices”, Yamauchi et al
    • “Blade Displacement Measurement Technique Applied to a Full-Scale Rotor”, Abrego et al
Recent Test Findings

• From March 2012 Meeting
  – LRTA control system stiffness measured - similar to aircraft (somewhat stiffer under collective loading)
  – As-tested blade tab angles measured – similar to flight measurements
  – 7 deg azimuth difference identified between wind tunnel data and currently used CFD model
    • Must correct model or data for valid comparisons
    • Also identified azimuthal “errors” with flight test data due to anti-aliasing filter corrections

• New information
  – Post-test blade inspections identified error in locations of TE blade pressure transducer
    • All TE transducers actually at x/c=93.9% instead of 96.3%
    • Effect on flight test airloads (correct value used for WT) is minimal for normal flight condition
Current Activities

• Continuing data evaluation efforts for blade pressures and integrated parameters
• Making progress with PIV and Blade Displacement data reduction efforts
  – PIV processing procedures nearly finalized; significant data reduction to begin this CY
  – Initial comparisons of blade displacement measurements with CFD helping to identify necessary improvements in data reduction
• Continuing CFD validation efforts with both OVERFLOW and FUN3D
• Completed coupling of hi-res CAMRAD with OVERFLOW

• Currently modeling in-board blade shank for better performance calculations

• Using wind tunnel and LRTA models to investigate effects on rotor loads and performance
  – Also investigating differences between wind tunnel and flight test measurements
Troubleshooting coupling of hi-res CAMRAD with FUN3D (working with Romander)

Developed model for LRTA fuselage and preparing for computations

Preparing to perform detailed validation with thrust sweep data
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
Background

• Full-scale UH-60A Airloads wind tunnel test conducted in USAF National Full-Scale Aerodynamic Complex (NFAC) 40- by 80-Foot Wind Tunnel (2010)
• Test provided unique opportunity to evaluate tunnel and scaling effects by comparing acquired data with
  – 1994 UH-60A Airloads flight test
  – 1989 UH-60A Airloads small-scale wind tunnel test in German-Dutch Wind Tunnel (DNW)
Flight Comparisons - Airloads

Flight (c8424)
Section Normal Force ($M^2c_n$)
$\mu=0.30$, $C_T/\sigma=0.088$

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Flight Comparisons - Airloads

- NFAC baseline matches well with flight, although noticeable differences outboard

Flight (c8424)
Section Normal Force ($M^2c_n$)
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NFAC
Section Normal Force ($M^2c_n$)
$\mu=0.30$, $C_T/\sigma=0.088$
Flight Comparisons - Airloads

Difference between Flight and NFAC
Section Normal Force ($M^2c_n$)

$\mu = 0.30, \ C_T/\sigma = 0.088$

- NFAC baseline matches well with flight, although noticeable differences outboard
Flight Comparisons - Airloads

Section Normal Force – $\mu=0.30$, $C_T/\sigma=0.088$ (c8424)

- Biggest differences near negative lift peak and on retreating side for outboard stations
Flight Comparisons – Structural Loads

Blade Bending Loads – $\mu=0.30$, $C_T/\sigma=0.088$

- NFAC flap bending and torsion match well with flight
Flight Comparisons – Structural Loads

Blade Bending Loads – $\mu=0.30$, $C_T/\sigma=0.088$

- NFAC flap bending and torsion match well with flight
- NFAC chord bending shows significant differences
Flight Comparisons – Structural Loads

Chord Bending Harmonics – $\mu=0.30$, $C_T/\sigma=0.088$

- Notable differences at 1, 2, 4, and 5/rev
  - 1 and 2/rev differences consistent with damper responses
  - 4 and 5/rev may be caused by differences in lag modal frequencies (drive train differences)?
Conclusions

- NFAC measured rotor power compares well with matched flight and DNW test conditions
  - Procedures and trim targets used to match conditions are valid
- Flight comparisons
  - Airloads match well although some waveform differences found at outboard stations
  - Rotor structural loads match well except for chord bending
  - Further investigation necessary to determine cause of differences
Blade Tab Angles

- Re-measured tab deflections on all 4 blades
- New measurements 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 for 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)