Annotated Bibliography

Summary

The bibliography here lists papers, reports and peer-reviewed journal articles that discuss the flight test portion of the UH–60A Airloads Program. The bibliography is in chronological order and is current through the 1998 AHS International 54th Annual Forum. In most cases a brief description of the reference is included.

Bibliography

Robert M. Kufeld and David Nguyen, "Full-Scale UH–60A Rotor Blade Nonrotating Modal Analysis Shake Test," NASA TM 101005, November 1989.
[Modal frequencies and shapes are measured for a single UH–60A blade and compared with CAMRAD/JA results. Good agreement is obtained for the lower frequency modes.]

Robert G. Gagnon, "Sub-miniature Pressure Sensor Installation for UH–60A Main Rotor Blade Air Loads Flight Test Program," International Telemetry Conference, 1989.
[Tests on sample pressure transducers are described and the selection of the Kulite XCQ–2T–070–20. The installation of the transducers in the blade is discussed as is the methods of powering the transducers and routing the wires.]

Karen S. Hamade and Robert M. Kufeld, "Modal Analysis of UH–60A Instrumented Rotor Blades," American Helicopter Society Specialists' Meeting: Innovations in Rotorcraft Test Technologies for the 90's, Scottsdale, AZ, October 8-12, 1990.
[Six blades (four production, a strain-gauged blade, and a pressure-instrumented blade) were suspended vertically and the free-free modes were measured and compared to a NASTRAN analysis of the production blade and the pressure-instrumented blade. The comparison examined six flap modes, two chord modes, and two torsion modes. Summary results of the calculation and testing are presented and very good agreement is observed between experiment and analysis indicating that the blade mass and stiffness properties are properly quantified.]

W. J. Snyder, J. L. Cross, and Robert Kufeld, "NASA/Army Rotor System Flight Research Leading to the UH-60 Airloads Program," American Helicopter Society Specialists' Meeting: Innovations in Rotorcraft Test Technologies for the 90's, Scottsdale, AZ, October 8-12, 1990.

Karen S. Hamade and Robert M. Kufeld, "Modal Analysis of UH–60A Instrumented Rotor Blades," NASA TM 4239, November 1990.
[Six blades (four production, a strain-gauged blade, and a pressure-instrumented blade) were suspended vertically and the free-free modes were measured and compared to a NASTRAN analysis of the production blade and the pressure-instrumented blade. The comparison examined six flap modes, two chord modes, and two torsion modes. Very good agreement is observed between experiment and analysis indicating that the blade mass and stiffness properties are properly quantified. More detail is contained in this TM than is in the summary paper of the same name.]

Robert M. Kufeld and Paul C. Loschke, "UH-60 Airloads Program: Status and Plans," AIAA Aircraft Design Systems and Operations Meeting, September 1991
[The program objectives are discussed and summarized. The measurement system is described as well as the data processing, reduction, and storage. Intermediate testing is discussed and plans for the future outlined.]

Joseph Totah, "A Critical Assessment of UH-60 Main Rotor Blade Airfoil Data," 11th AIAA Applied Aerodynamics Conference, August 1993.
[The nine sets of existing airfoil data for either the SC1095 or SC1094 R8 profiles were examined in the manner used by Jim McCroskey for the NACA 0012 in 1987. Two sets of data met McCroskey's Group 2 standards, but none met the Group 1 standards.]

Dwight L. Balough, "Estimation of Rotor Flapping Response Using Blade-Mounted Accelerometers," American Helicopter Society Aeromechanics Specialists Conference, San Francisco, CA, January 19-21, 1994.
[Blade-mounted accelerometers were used to estimate first and second mode flapping response. These estimates were compared with measured blade flapping and the first mode estimates are satisfactory, but the higher mode estimates are not.]

Colin P. Coleman and William G. Bousman, "Aerodynamic Limitations of the UH–60A Rotor," American Helicopter Society Aeromechanics Specialists Conference, San Francisco, CA, January 19-21, 1994.
[An overview is provided of data obtained during level flight speed sweeps with a focus on limiting conditions at high speed and at high thrust coefficient. At high speed there are extensive regions of supercritical flow on the rotor blade and high moments are induced on the control system that are caused by unsteady, three-dimensional effects. At the highest thrust condition two dynamic stall cycles are seen on the rotor with the greatest stall occurring inboard at about 0.865R. Examples shown indicate that the data are quite steady for level flight conditions. Note that the claimed azimuthal stepsize of 3 deg for this data is in error. The actual stepsize is just under 1.5 deg.]

Robert M. Kufeld, Jeffrey L. Cross, and William G. Bousman, "A Survey of Rotor Loads Distribution In Maneuvering Flight," American Helicopter Society Aeromechanics Specialists Conference, San Francisco, CA, January 19-21, 1994.
[Three maneuvers were examined in detail, a symmetric pull-up, a symmetric pushover, and a roll-reversal. Substantial load augmentation occurs in all of the maneuvers and the loading character is, in many respects, different from the loading behavior in level flight. This is particularly true as regards blade-vortex interactions that are common in these maneuvers, but have smaller effects in high-speed level flight.]

Joon W. Lim and Tassos Anastassiades, "Correlation of 2GCHAS Analysis with Experimental Data," American Helicopter Society Aeromechanics Specialists Conference, San Francisco, CA, January 19-21, 1994. Also: Journal of the American Helicopter Society, Vol. 40, (4), October 1995, pp. 18–33.
[Includes correlation with both Phase 1 and Phase 2 flight test data. Examines problem of predicting 3/rev loads and, to better understand these problems, compares 2GCHAS and CAMRAD/JA predictions of airloads and structural loads with flight test data from a low-speed and a high-speed case. Significant problems with these predictions are noted.]

Karen Studebaker, "A Survey of Hub Vibration for the UH-60A Airloads Research Aircraft," American Helicopter Society Aeromechanics Specialists Conference, San Francisco, CA, January 19-21, 1994.
[Rotating hub accelerations and fixed system accelerations are examined over a wide range of level flight conditions to show the general vibratory loading on this aircraft. Of most interest, perhaps,

is evidence of non-integer responses in the fixed system and it is speculated that these are a result of small mass and stiffness dissimilarities in the blades.]

Robert M. Kufeld, Dwight L. Balough, Jeffrey L. Cross, Karen F. Studebaker, Christopher D. Jennison, and William G. Bousman, "Flight Testing the UH–60A Airloads Aircraft," American Helicopter Society 50th Annual Forum Proceedings, Washington, D.C., May 11-13, 1994, pp. 557–578.
[Summarizes the entire test program with information on instrumentation, data acquisition, data processing, and data validation. Some sample results from the test program are shown as well. This will be the primary documentation for the program for the next few years.]

Keeyoung Choi and Ronald W. Du Val, "The Use of Flight Simulation to Support Flight Test Activities," SFTE Silver Symposium, August 1994.
[The use of FLIGHTLAB as a software tool for simulation and data analysis is described and a number of examples based on UH-60A flight test data are provided.]

Arnold W. Mueller, David A. Conner, Charles K. Rutledge, and Mark R. Wilson, "Full Scale Flight Acoustic Results for the UH-60A Airloads Aircraft," American Helicopter Society Vertical Lift Aircraft Design Conference, San Francisco, CA, January 18-20, 1995.
[An overview of the ground-acoustic testing of the UH-60A is presented. The ground acoustic measurements and test conditions are discussed in detail. The selection of data records for analysis based on various criteria is described. Examples are provided of acoustic radiation in flyover conditions, hemispherical sound fields for a variety of conditions, blade pressure distributions during BVI events, and noise footprints extracted from the data.]

Charles K. Rutledge, Arnold W. Mueller, and Mark Wilson, "A Study of the Variability Difference Between Model Scale Wind Tunnel and Full Scale Flight Test Airloads Data," American Helicopter Society Vertical Lift Aircraft Design Conference, San Francisco, CA, January 18-20, 1995.
[Five matching conditions were examined for the DNW test of a 5.73-scale model of the UH-60A and the full-scale data obtained during ground-acoustic testing. The data from both experiments were reanalyzed to allow for the different sampling approaches and different bandwidths. Qualitatively the matched conditions show good agreement with each other. However, the variability over 64 revolutions of data is at least an order of magnitude greater for the flight test data when blade-vortex interactions are present.]

Mark R. Wilson, Arnold W. Mueller, and Charles K. Rutledge, "A New Technique For Estimating Ground Footprint Acoustics For Rotorcraft Using Measured Sound Fields," American Helicopter Society Vertical Lift Aircraft Design Conference, San Francisco, CA, January 18-20, 1995.
[A new method for computing ground footprint data from measured acoustics is described. Flyover data measured on the ground are converted to a hemispherical sound source at five rotor radii and this sound source, derived from measured data, is used to compute the foot prints.]

Robert M. Kufeld and William G. Bousman, "High Load Conditions on a UH-60A In Maneuvering Flight," American Helicopter Society 51st Annual Forum Proceedings, Ft. Worth, TX, May 9-11, 1995, pp. 421–433.
[Flight test maneuvers were examined to determine the highest loading conditions and two maneuvers were selected for a detailed examination. One maneuver, a pull-up from level flight, showed high control system loads and the airloads data clearly show that the loads are a consequence of dynamic stall. The second maneuver was the limit dive speed condition and the high mid-span flap and chord bending loads appear to be a result of the high dynamic pressure on the blade in this condition.

Joon W. Lim, "Analytical Investigation of UH–60A Flight Blade Airloads and Loads Data," American Helicopter Society 51st Annual Forum Proceedings, Ft. Worth, TX, May 9-11, 1995, pp. 1156–1175.
[Two comprehensive analyses, 2GCHAS and CAMRAD/JA, were compared with level flight data at two airspeeds. At high speed there is a noticeable phase difference between the airloads predicted by the two analyses and the measured loads. An extensive parametric investigation was not able to explain the difference.]

Chee Tung, William G. Bousman, and Scott Low, "A Comparison of Airload Data Between Model-Scale Rotor and Full-Scale Flight Test," American Helicopter Society 2nd International Aeromechanics Specialists' Meeting Proceedings, Bridgeport, CT, October 11-13, 1995.
[Wind tunnel and flight-test data were compared for the UH-60A. A number of significant difficulties occur in attempting to match flight test to wind tunnel conditions. These difficulties are due in part to measurement problems as well as the inability of an aircraft to fly to wind tunnel trim conditions. There is good first-order agreement between the two sets of data, but many important differences remain.]

David M. Eccles, "A Validation of the Joint Army/Navy Rotorcraft Analysis and Design Software by Comparison With H–34 and UH–60A Flight Test, M.S. Thesis, US Naval Postgraduate School, December 1995.
[JANRAD, a preliminary design tool developed at NPS, is compared with CH–34 and UH–60A flight test data to validate the method. This comparison illustrates a number of limitations in the JANRAD model that require improvement as well as discrepancies that are not well understood.]

Robert M. Kufeld and William G. Bousman, "UH-60A Helicopter Rotor Airloads Measured in Flight," Paper No. 20, Twenty-second European Rotorcraft Forum, Brighton, UK, September 17-19, 1996. Also: The Aeronautical Journal, Vol. 101, No. 1005, May 1997, pp. 217–227.
[A program summary is provided including a discussion of instrumentation, the test program flown, and data reduction. Some representative results are given for level flight and the aerodynamics of a diving turn are examined in some detail. This latter maneuver includes control system loads that are close to the aircraft design limit and it is shown that these loads are a consequence of both dynamic stall and out-of-phase motion of supercritical flows on the upper and lower surfaces.

Jerry P. Higman, Liu ShouShen, and Daniel P. Schrage, "Inflow and Load Identification of a Coupled Flap-Lag-Torsion Rotor Blade," Paper No. 97, Twenty-second European Rotorcraft Forum, Brighton, UK, September 17-19, 1996.
[A transfer matrix method is used to identify the shears, slopes, and displacements from bending moment measurements and, hence, the external forces for the flap-lag-torsion problem. Using a lifting-line formulation the inflow on the blade is also computed from the external forces. UH-60A flight data is used to create a set of simulated bending moment measurements and the method is shown to effectively calculate the input airloads. The method appears robust in the present of small measurement errors (5%). It is unclear why a demonstration using the flight test bending moment measurements was not undertaken.]

William G. Bousman, "A Qualitative Examination of Dynamic Stall from Flight Test Data," American Helicopter Society 53rd Annual Forum Proceedings, Virginia Beach, VA, April 29-May 1, 1997, pp. 368–387. Also: Journal of the American Helicopter Society, Vol. 43, (4), October 1998, pp. 279-295.
[Examines three conditions: UTTAS pull-up; high-speed, diving turn, and maximum loading, level flight condition. Lift stall, moment stall, and trailing edge pressure are used to map stall characteristics onto the rotor disk plane. Pressure time histories are used to identify sonic points that define supercritical flow boundaries and peaks that mark the dynamic stall vortex passage and these are used to map these details of the dynamic stall process onto airfoil maps.]

Jay W. Fletcher and Mark B. Tischler, "Improving Helicopter Flight Mechanics Models with Laser Measurements of Blade Flapping," American Helicopter Society 53rd Annual Forum Proceedings, Virginia Beach, VA, April 29-May 1, 1997, pp. 1467-1494.
[Accurate blade flapping measurements and simulation modeling are combined to provide a more accurate flight simulation model of the UH-60A. Comparisons are shown of a new laser measurement system for blade flapping with RVDT-based measurements previously obtained on the UH-60A airloads aircraft.]

William G. Bousman, "A Note on Torsional Dynamic Scaling," Journal of the American Helicopter Society, Vol., 43 (2), April 1998, pp. 172–175.
[Blade airloads measured in flight and the wind tunnel for the UH–60A are compared and it is shown that significant differences occur because of the lack of torsional mode scaling.]

Khanh Nguyen and Wayne Johnson, "Evaluation of Dynamic Stall Models with UH-60A Airloads Flight Test Data," AHS International 54th Annual Forum Proceedings, Washington, D.C., May 20-22, 1998, pp. 576–587.
[The capability of five dynamic stall models in the CAMRAD II analysis are examined by first comparing their ability to predict dynamic stall measured on a 2D airfoil and then with airloads from flight test. The latter comparison is largely qualitative and shows that none of the models are adequate. The source of the inadequacies of these models is unclear, but is probably related to the determination of empirical factors in these semi-empirical models.]

Robert M. Kufeld and Wayne Johnson, "The Effects of Control System Stiffness Models on the Dynamic Stall Behavior of a Helicopter," AHS International 54th Annual Forum Proceedings, Washington, D.C., May 20-22, 1998, pp. 589–601.
[Collective, reactionless and two cyclic stiffnesses were measured on a UH-60A as a function of swashplate azimuth angles. These values show substantial azimuthal variation in the rotating system but are relatively constant in the fixed system. The first pitch/torsion mode varies from 3.8P to 4.2P depending on which stiffness is used. CAMRAD II calculations show some qualitative agreement with dynamic stall measurements in level flight but sophistication in the control system modeling does not improve the correlation.]

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