HVAB General Information Readme

Version History

9/28/23 Initial Release

9/24/24 v2: Update descriptions and Table 1 to include PIV data acquisition information and correct typos. Add additional references.

This document provides a general description of the HVAB test as well as identifying other documents which may be useful in understanding how best to use the resultant data.

HVAB Test Summary

Data were acquired during a model-scale hover test of a 4-bladed, 11.08-ft diameter rotor (designated the Hover Validation and Acoustic Baseline (HVAB) rotor) conducted inside the National Full-Scale Aerodynamics Complex 80- by 120-Foot Wind Tunnel test section. The primary objective of the test was to acquire key experimental data for a hovering rotor of sufficient quality and quantity to allow validation of state-of-the-art analysis codes. A comprehensive measurement set has been acquired, including rotor performance, blade airloads, flow transition locations, blade deflections, wake geometry, and vortex properties for a range of tip Mach numbers and collective settings. A summary of this test program, including descriptions of the test hardware, test objectives, approach and sample results, was presented at the VFS 79th Annual Forum (Ref. 1). Detailed descriptions of the blade geometry, instrumentation, and structure are provided in Ref. 2. Additional information about the photogrammetry and PIV data acquisition is provided in Refs 3-4. Other pertinent information, including blade surface geometry and a representative CFD volume grid, can be found on the website of the AIAA Rotorcraft Hover Prediction Workshop (Ref. 5).

Test Configurations and Acquired Data

As described in Ref. 1, data were acquired for three distinct blades-on configurations: 1) standard HVAB blades with natural boundary layer transition, 2) standard HVAB blades with forced boundary layer transition, and 3) pressure blade with natural boundary layer transition. Detailed descriptions of each configuration, with the resultant research test conditions, run numbers and types of data acquired, are described below and listed in Table 1.

Table 1. Test Configurations and Conditions

Performance (P), Photogrammetry (PG), Thermography (TG), Shadowgraphy (SG), Airloads (A), PIV (PIV)

Configuration	M_{tip} or RPM	Run Numbers	Collective	Key Measurements	Primary Objective
Standard blades, natural transition	1160 RPM	36	4, 6, 8, 10, 12	P, PG	Blade deformation
	1250 RPM	30, 36	4, 6, 8, 10, 12, 13, 14		
	1310 RPM	34	4, 6, 8, 10, 12, 14		
	0.600	46	4 to 15, 1 deg incr	P, TG	Performance and transition
	0.650	44	4 to 15, 1 deg incr		
	0.675	48	4 to 14, 1 deg incr		
	0.600	54	8, 10, 12, 14	P, TG, SG	Performance, transition, and wake geometry
	0.650	50	8, 10, 12, 14		
	0.675	52	8, 10, 12, 14		
	0.650	92, 95	8, 10, 12, 14	P, PIV	Performance and PIV
Standard blades, forced transition	0.600	61	4 to 15, 1 deg incr	P, TG	Performance and transition - fully tripped
	0.650	59	4 to 15, 1 deg incr		
	0.675	63	4 to 14, 1 deg incr		
	0.600	65	10, 12, 14	P, TG	Performance and transition – tripped lower surface only
	0.650	65	4, 6, 8, 10, 12, 14		
	0.675	65	10, 12, 14		
Pressure blade	0.600	72	4 to 12, 1 deg incr	P, TG, A	Blade Airloads
	0.650	77	4, 6, 8, 10, 11, 12, 13		

The first configuration utilized the three sparsely instrumented HVAB blades (SN001, SN002, SN003) along with the more highly instrumented strain-gaged blade (SN005). As shown in Table 1, this was the configuration for which most of the blade deformation, transition, wake geometry and PIV data were acquired. Testing in this configuration was separated into four phases. The objective of the first phase was to acquire blade deformation data for three rotor RPM's (1160, 1250, and 1310) over a range of collectives/thrusts. RPM (rather than M_{tip}) set points were used for this phase since dimensional loads directly impact the blade deformation. Note that although the performance data (especially torque) from this testing were affected by the installation of the retroreflective targets on the blade lower surfaces, the measured deformation data (for a given collective/thrust) are not expected to be significantly affected and thus can be used to compare with aeroelastic predictions. The objective of the second phase of testing was to acquire performance and transition data for closely spaced collective settings at three tip Mach numbers (0.60, 0.65, and 0.675). These data can be used to evaluate the effects of smaller collective changes on transition locations (and subsequently performance), especially at lower collectives. The objective of the third phase was to acquire simultaneous performance, transition, and wake geometry data for a select number of collective settings at each of the three tip Mach numbers. Collective settings for this phase were limited to the higher values ($\theta_0 \geq 8°$), when the shadowgraphy vortices were most visible. Finally, the objective for the fourth phase was to acquire performance and Particle Image Velocimetry (PIV) data at one tip Mach number and four collective settings. The primary variable for this phase was the wake age at which PIV velocity data were acquired.

The second configuration utilized the same blades as for natural transition, but with trip dots applied on the leading edges to force transition to turbulent flow. The objective of this configuration was to provide performance data for validation of analyses that do not model transition. To accomplish this, trip dots were applied to the upper and lower surfaces of the blades at a chordwise trip location of x/c=0.05 for both surfaces. To avoid overtripping the boundary layer and introducing excess drag, an initial study was performed to determine the trip dot height needed to force transition. Different heights (ranging from 2 to 8 mils) were applied to each blade on both the upper and lower surfaces, and thermography data were collected over a variety of conditions. The data demonstrated that transition was successfully forced using dots with a height of 3.5 mils on both the upper and lower surface for all conditions. This height dot was then applied to all blade surfaces, and forced transition was then studied at the three primary M_{tip} values, with both performance and thermography data collected. Following this initial testing, the trip dots on the upper surface of each blade were removed so that transition was forced only on the lower surface. The goal of this configuration was to study if the performance would match the fully forced case at high collective (since the upper surface was fully turbulent even during natural transition testing). Performance and thermography data were collected for a range of collectives for M_{tip}=0.65, but only at the three highest collectives for the other two M_{tip} conditions.

The third configuration replaced one of the sparsely instrumented HVAB blades (SN003) with the highly instrumented pressure blade (SN004). The objective for this testing was to acquire performance, airloads, and transition data over the full range of collective values and tip Mach numbers. Ultimately, due to hardware issues, data were limited to a reduced set of collectives for M_{tip} values of 0.60 and 0.65 as shown in Table 1. During testing of this configuration, the measured rotor performance was reduced compared to data acquired with the standard blades (up to 2 counts of FM at lower collectives). Thermography data suggests these differences can be attributed to additional turbulent flow on the blades caused by the pressure transducers on the pressure blade as well as some residue left on the other blades from the trip-dot testing. Fortunately, these issues should have a much smaller effect on the rotor thrust than the torque (for a given collective) and the resulting airloads data should remain valid.

Description of Data Provided

Selected test data, as well as information necessary to understand how the data were acquired and processed, are provided on this website. Each data type (Performance, Thermography, Shadowgraphy, Photogrammetry, Pressure and Airloads, and PIV) are grouped separately with individual readme files providing context for understanding the data. Each data type uses the same identification numbering scheme:

RxxMxxxTHxx

where Rxx is the run number during which the data were acquired (xx between 30 and 95), Mxxx is the tip Mach number for the condition (xxx = 600, 650, or 675), and THxx is the nominal collective setting from the control console (xx between 4 and 15).

Additional Descriptive Files

In addition to this readme file, 3 additional files are provided to help in using the data.

Data Use Recommendations.pdf – This file provides recommended combinations of data points to use for validation, as well as identifying items to consider when performing the comparisons.

Data Recommendations.xlsx – This file provides the specific identification numbers recommended in a spreadsheet format.

HVAB Parameter List.xlsx – This file provides a description of some of the data parameters provided (mostly associated with the performance data), including units and sign convention.

References

1. Norman, T.R., Heineck, J.T., Schairer, E.T., Schaeffler, N.W., Wagner, L.N., Yamauchi, G.K., Overmeyer, A.D., Ramasamy, M., Cameron, C.G., Dominguez, M., and Sheikman, A.L., "Fundamental Test of a Hovering Rotor: Comprehensive Measurements for CFD Validation," VFS 79th Annual Forum Proceedings, West Palm Beach, FL, May 2023. https://rotorcraft.arc.nasa.gov/Publications/files/79-2023-1166-Norman.pdf
2. Overmeyer, A. D., Copp, P. A., and Schaeffler, N. W., "Hover Validation and Acoustic Baseline Blade Set Definition," NASA TM-2020-5002153, May 2020. https://ntrs.nasa.gov/citations/20205002153
3. Schairer, E.T., Heineck, J.T., Dominguez, M., Norman, T.R., "Blade Deformation Measurements of the HVAB Rotor in Hover by Stereo Photogrammetry," NASA TM-2023-0009506, July 2023. https://rotorcraft.arc.nasa.gov/Publications/files/HVAB%20Blade%20Deformation%20TM.pdf.
4. Ramasamy, M., Heineck, J.T., Yamauchi, G.K., Schairer, E.T., and Norman, T.R., "Comprehensive Aerodynamic Analysis of PIV Measurements in the NFAC 80- by 120-ft Test Section Towards Understanding HVAB Hovering Rotor Characteristics," VFS 80th Annual Forum Proceedings, Montreal, Canada, May 2024. https://rotorcraft.arc.nasa.gov/Publications/files/Ramasamy_Forum2024.pdf
5. https://www.aiaa-hpw.org/hvab-rotor (9/24/2024)