Readme
HVAB Airloads

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November 2023

Version History
11/6/23 Initial Release

This document summarizes the airloads data calculated for the HVAB hover test. A description of the test conditions and data reduction processes are provided, along with a description of the spreadsheet containing the data.

General Test Information

Blade pressure data were acquired as part of the HVAB rotor test conducted in the National Full-Scale Aerodynamics Complex (NFAC) 80- by 120- Foot test section. From these blade pressure measurements, airloads have been computed. A summary of the entire test program can be found in Ref. 1, as well as in the "HVAB General Information Readme" found in the General Information section of this website.

The blade pressure data were acquired using a test configuration of three standard HVAB blades and one highly-instrumented pressure blade. The pressure blade included 187 unsteady absolute pressure transducers distributed evenly across 11 radial stations (17 chordwise locations for each radial station). More details on the pressure blade can be found in Ref. 2 and in the Blade Pressure Readme file found on this website.

Pressure/Airloads Test Conditions and Data Acquisition

Due to hardware issues, blade pressure data were limited to a reduced set of collectives for M_{tip} values of 0.60 and 0.65 as shown in Table 1. Airloads data have been computed for all of these conditions.

Table 1. Pressure/Airloads Test Conditions

Run Numbers	Pt Numbers	M_{tip}	Collective
72	6-106	0.600	4 to 12, 1 deg incr
77	6-78	0.650	4, 6, 8, 10, 11, 12, 13

During testing, blade pressure data were acquired over the same period as the rotor performance data. During data reduction, the 48,800 samples per second time records were resampled to 2048 samples per revolution (for 128 revs) and synchronized to be consistent with other acquired data. More details on the transducers and data acquisition systems can be found in Ref. 1.

Averaged blade pressure data at each condition (M_{tip} and collective) were computed and are provided in the Pressure & Airloads section of this website (averaged rotor performance data are provided in the Performance Data section). As described in the Blade Pressure Readme file, data from several of the transducers are not provided (due to either transducer damage or requiring additional processing). It is possible that data from some of these excluded transducers will be available in future releases of the data, allowing for updates to the computed airloads data discussed below.

Airloads Data Reduction

Sectional airloads are computed at each radial station by integrating the measured pressures along the section chord. The integration approach used here is consistent with that used for the UH-60A Airloads flight and wind tunnel data and is summarized below.

Blade absolute pressures (dimensional) are integrated to provide normal force and chord force at up to 11 radial stations. Pitching moment about the quarter chord is also calculated, including contributions from both normal force and chord force distributions. A 2^{nd}-order numerical integration scheme is implemented (Ref. 3), which uses a polynomial that fits three points and is applicable to unequally spaced data. This method reduces to the well-known Simpson's rule when the independent variables are equally spaced. Integrations are implemented using both mapped (for normal force and pitching moment) and unmapped coordinates (for chord force). For mapped coordinates, the pressures are multiplied by $[x/c]^{0.5}$ and are integrated as a function of $[x/c]^{0.5}$. This mapping takes advantage of the profile's pressure distribution with its bias towards the forward portion of the airfoil.

Only pressure data from working transducers are used in the integrations. Pseudo-measurements are computed for the leading and trailing edges to help improve the integrations. In each case a weighted average is taken of the nearest upper and lower surface pressure transducers. The pseudo-leading edge pressure measurement only affects chord force and chord force contribution to pitching moment.

Using this integration approach, airloads were computed at each radial station for every sample (2048 samples/rev) and then averaged over 128 revs for each data point. Data from multiple data points at the same condition (nominally 10 points acquired over 10 minutes) were further averaged to provide estimates for the mean and 95% confidence interval for each airload value. The confidence interval is based solely on the variations between the (nominally) 10 data points. Any additional uncertainties from the integration method and/or missing transducers are not included.

Description of Spreadsheet Data

Two spreadsheets of airloads data are provided, one for each of the data runs/ M_{tip}'s. Each spreadsheet contains 2 tabs, one with averaged airloads data, and one with confidence intervals. Each tab presents data in run sheet format (separate test conditions in each row and data in multiple columns) as well as re-ordered by test condition (with r/R values in each row).

Note that some of the airload values are left blank; these are typically because of an insufficient number of working pressure transducers at that location.

(As described in other documents on this website, a common identification scheme is used for the various test conditions. These conditions are identified as RxxMxxxTHxx, where Rxx is the run number during which the data were acquired, Mxxx is the tip Mach number for the condition (xxx = 600 or 650), and THxx is the nominal collective setting from the control console (xx between 4 and 13).)

The spreadsheets contain both dimensional and non-dimensional airloads, where the non-dimensional section forces and moment are normalized as follows:

M^2c_m	section pitch moment coefficient, moment/$(0.5\rho\, a_\infty^2 c^2)$
M^2c_n ,M^2c_c	section force coefficients, force/$(0.5\rho\, a_\infty^2 c)$

where ρ is the density, a_∞ is the speed of sound, and c is the local section chord. Example plots of dimensional airloads (M_{tip} = 0.650) are provided in Figs 1-3.

A list of parameter names used in the spreadsheets, as well as the units and descriptions, are provided in Table 2 (xxx is the nominal blade radial station (r/R)).

Table 2. Parameter Names

Name	Units	Positive Dir	Description
RPM	rev/min	CCW from top	rotor RPM
MTIP			tip Mach number
COLL_SP	deg	blade LE up	rotor collective from console
RHO	slug/ft^3		air density
CSND	ft/s		speed of sound
Rxxx_NF	lbf/in	up, perpendicular to local chord	section normal force at xxx r/R station
Rxxx_PM	in-lbf/in	leading edge up	section pitch moment at xxx r/R station
Rxxx_CF	lbf/in	forward, parallel to local chord	section chord force at xxx r/R station
Rxxx_M2CN		up, perpendicular to local chord	section normal force coefficient at xxx r/R station
Rxxx_M2CM		leading edge up	section pitch moment coefficient at xxx r/R station
Rxxx_M2CC		forward, parallel to local chord	section chord force coefficient at xxx r/R station

References

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Measurement in Forward Flight Using an Infrared Camera," VFS 75th Annual Forum Proceedings, Philadelphia, PA, May 2019. 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. Sokolnikoff, S. and Redheffer, R.M., *Mathematics of Physics and Modern Engineering*, McGraw-Hill, New York, NY, 1958.

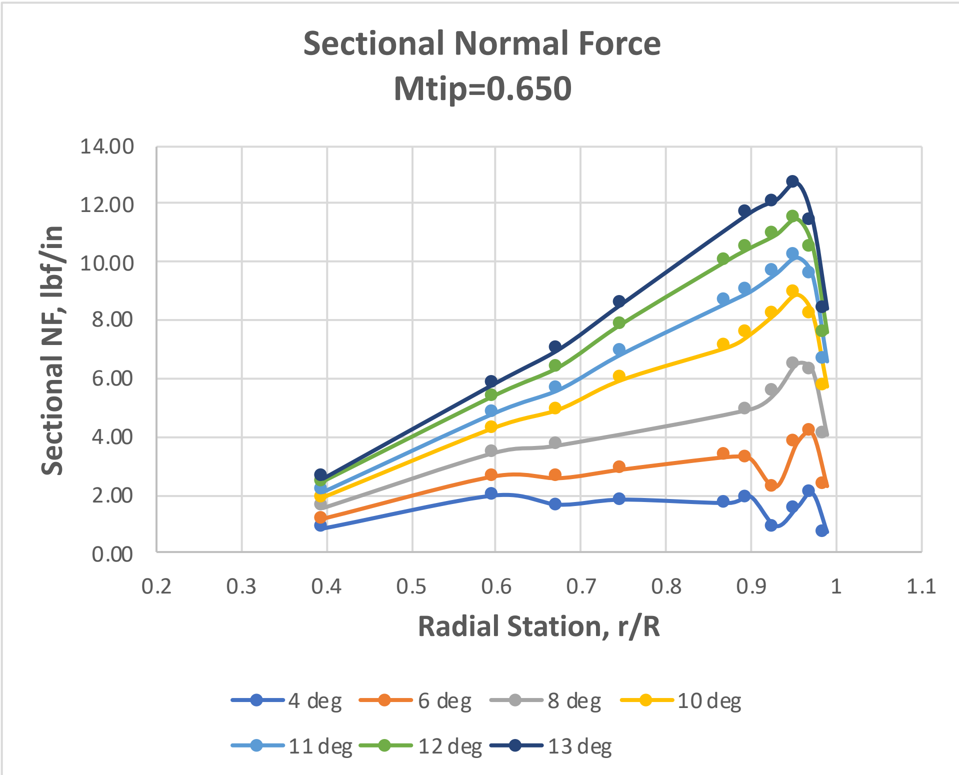

Figure 1. Sectional Normal Force, M_{tip} = 0.650

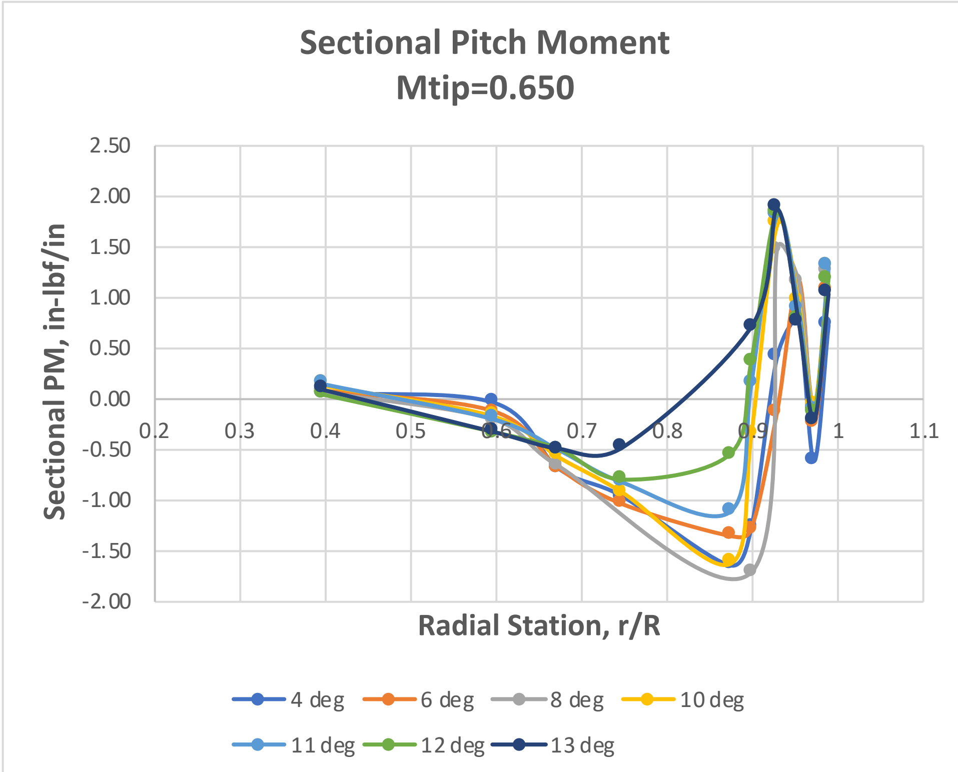

Figure 2. Sectional Pitch Moment, M_{tip} = 0.650

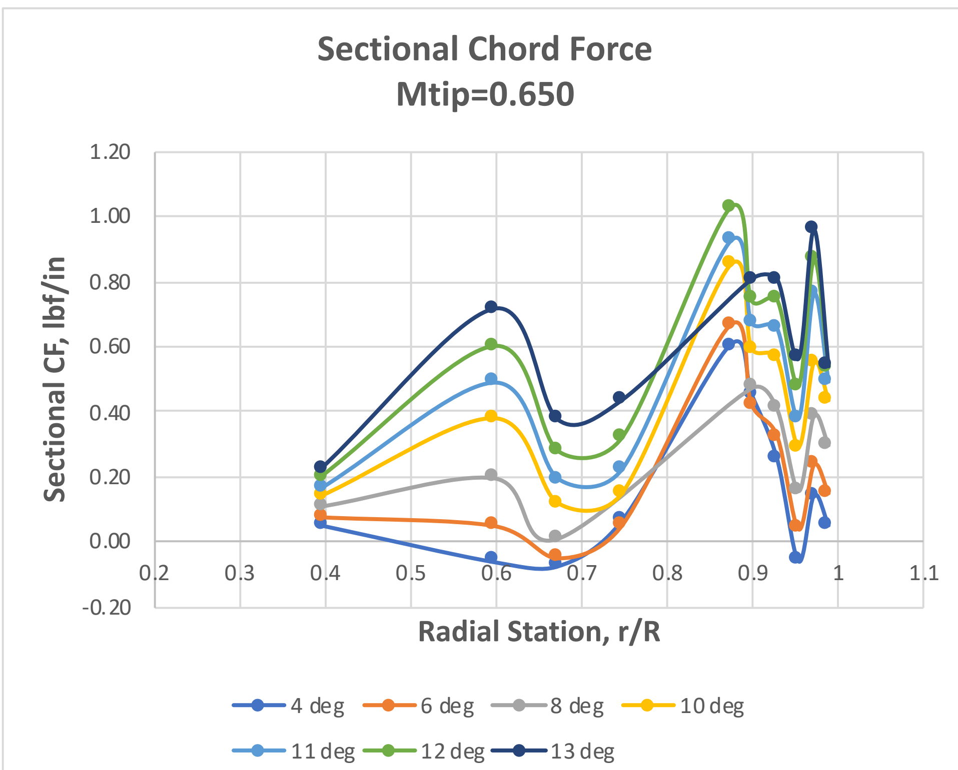

Figure 3. Sectional Chord Force, M_{tip} = 0.650