COLLECTED DATA FOR TESTS ON AN AHAVAW AEROFOIL

VOLUME III: Pressure data relevant to the study of large-scale vertical-axis wind-turbines.

by

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M.W.GRACEY

and

R.GILMOUR

March 1992
COLLECTED DATA FOR TESTS ON AN AHAVAW AEROFOIL

Herein is presented the collected data for tests in which an AHAVAW aerofoil was subjected to a variety of oscillatory displacements in pitch about the quarter-chord location at low Reynolds numbers.

VOLUME III
PRESSURE DATA RELEVANT TO THE STUDY OF LARGE-SCALE VERTICAL-AXIS WIND-TURBINES.

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</table>
NOMENCLATURE

- c: chord
- \( C_m \): pitching-moment coefficient
- \( C_n \): normal force coefficient
- \( C_p \): pressure coefficient
- \( C_t \): "thrust" force coefficient
- D.P.: dynamic pressure \( (pV^2/2) \)
- k: reduced frequency \( (\omega c/2V) \)
- r: reduced pitch-rate \( (c/2V)d\alpha/dt \)
- TSR: tip speed ratio
- Re: Reynolds number
- V: velocity
- x/c: chordwise dimension
- \( \alpha \): angle of attack
- \( \omega \): rotational velocity

VOLUME II Pressure data from oscillatory tests.

VOLUME III Pressure data relevant to the study of large-scale vertical-axis wind turbines.

Each volume also includes the pressure data from tests in steady conditions and a brief description of the experimental apparatus and techniques.

2 DESCRIPTION OF TEST FACILITY

2.1 Aerofoil and Wind Tunnel

The general arrangement of the aerofoil in the wind tunnel was as shown in Figure 1. The aerofoil, of chord length 0.55m and span 1.61m, was constructed of fibre glass mounted on an aluminium spar and filled with an epoxy resin foam. The hand-finished surface was very smooth, and the profile accurate to better than 0.1mm. The instrumented model was fitted vertically into the University of Glasgow's "Handley Page" wind tunnel.

The "Handley Page" low-speed wind tunnel is an atmospheric-pressure closed-return type with a 1.61x2.13 octagonal working section (Figure 2) in which a wind velocity of 61ms\(^{-1}\) can be attained. The model was pivoted about its quarter-chord axis on two tubular steel shafts connected to the main support via two self-aligning bearings. A single thrust bearing on the top support beam took all the weight. The dynamic and aerodynamic loadings from the aerofoil were reacted to the tunnel framework by two transversely mounted beams.

2.2 Pitch Drive Mechanism

2.2.1 Actuator

Angular movement of the model was obtained using a linear hydraulic actuator and crank mechanism. The actuator was mounted horizontally below the tunnel working section on the supporting structure, with the crank rigidly connected to the tubular part of the spar by a welded sleeve and keyway. The actuator was a UNIDYNE 907/1 type with a normal dynamic thrust of 6.1KN operated from a...
supply pressure of 7.0MNm⁻². A MOOG 76 series 450 servo valve was used via a UNIDYNE servo controller unit to control the movement of the actuator. A suitable feedback signal for the controller was provided by a precision linear angular displacement transducer geared to the main spar of the model.

2.2.2 Command Signal

The model's angle of attack was incremented by the actuator controller. The input signal during the static tests was provided under software control by the data acquisition unit's own digital-to-analogue converter. This was possible because, during the sampling, the angle of attack was fixed and sufficient time was available between sampling to set the model at the required angle of attack. The two activities were separate and were performed sequentially.

Such was not the case during the unsteady tests, however, where sampling and control of the model's motion were required simultaneously. Therefore, during these tests, the input signal was provided by a separate function generator, comprised of an AMSTRAD 1512 microcomputer equipped with an ANALOG DEVICES RT815 multi-function input/output board. The required output function was digitised into equal time steps in 2's complement code and the frequency of the function was controlled using the internal interrupts of the AMSTRAD microcomputer. The code was written in TURBO PASCAL.

2.3 Instrumentation and Data Logging

2.3.1 Pressure Transducers

To provide the chordwise pressure distribution at mid-span, thirty KULITE XCS-093-5 PSI G ultra-miniature pressure transducers were installed just below the surface of the centre section of the model. The transducers were of vented gauge type with one side of the pressure sensitive diaphragm open to the ambient pressure outside the wind-tunnel (via tubes in the model). Each transducer was fitted with a temperature compensation module, which minimised the change in zero-offset and sensitivity with temperature. The locations of the pressure transducers in the model are illustrated in Figure 3.

The low voltage outputs from the thirty pressure transducers were suitably amplified and conditioned by a bank of differential amplifiers. The conditioned signals were passed to a "sample and hold" unit to overcome the time-skew problem arising from the sequential conversion of the analogue signals into digital form.

2.3.2 Dynamic Pressure

The dynamic pressure in the wind tunnel working section was determined by measuring the difference between the static pressure in the working section, 1.2m upstream of the leading edge, and the static pressure in the settling chamber. The pressure tappings were connected to a FURNESS FC012 micromanometer, which provided an analogue signal suitable for the data acquisition unit's analogue-to-digital converter. This dynamic pressure was recorded as the sample-and-hold unit was triggered to sample the output from the pressure transducers.

2.3.3 Incidence

The instantaneous angle of attack of the aerofoil was determined by an angular displacement transducer geared to the model's main spar. The signal voltage from the transducer was fed into an amplifier/splitter to produce three signals for the following purposes:

i) connection of the multiplexer for recording the aerofoil's angle of attack;

ii) connection of the Schmitt trigger for initiation of data sampling when a preset incidence (voltage) was attained;

iii) a feedback signal to the hydraulic actuator controller.

2.3.4 Acquisition Unit

The actual data acquisition unit was a DEC MINC-11 microcomputer, configured with an LSI-11/32 16-bit microprocessor and laboratory modules which included:
i) an analogue-to-digital converter module, with a 16-channel multiplexer incorporated. The converter was a 12-bit successive approximation type with a conversion time of of 30μs, but the multiplexer's settling time and the need to transfer the data from the analogue-to-digital converter into system memory increased the conversion time to 44μs;

ii) a multiplexer module, of 16 single-ended channels, which increased the number of channels that could be sampled to 32;

iii) a real-time clock module, with two Schmitt triggers. This was used as a time-base generator to accurately set the sampling frequency. The sampling frequency was determined at run time from the frequency of oscillation and the requirement that 128 sample sweeps should be obtained during each cycle. One of the Schmitt triggers was used to initiate data sampling, by setting its reference voltage to a value corresponding to the angular displacement transducer's output for the required mean angle of attack;

iv) a digital-to-analogue converter module which housed four independent 12-bit digital to analogue converters. This was used to provide the command signal for the hydraulic actuator during static tests.

The path of data flow and system layout is shown diagrammatically in Figure 4. The main control programs for the tests were written in FORTRAN IV, as described by Murray-Smith and Galbraith. The programs prompt the user for specific run information before calling a specialised subroutine written in MACRO-11 assembly language to receive and store the digitised data. The timing and control of the analogue-to-digital converter and associated circuitry was performed by the processor's hardware, but channel selection and data management were achieved under software control.

3 TEST SERIES AND PROCEDURE

3.1 Static Experiment

A number of experiments were performed under steady conditions. Once the wind velocity had reached the required value, the aerofoil was rotated about its quarter-chord axis until it was positioned at the incidence at which the first set of data were to be recorded. Usually, this was approximately -2°. The model's angle of attack was then increased in steps of approximately 0.5°. After each increment in incidence, the flow was allowed to stabilise for a few seconds before each transducer's output was sampled 100 times and the mean value for each was stored. After 64 sweeps of data had been recorded, the model was returned to its starting position. Data sampling was maintained at the same rate on the return arc in order to record any delay in the reattachment of flow.

3.2 Sinusoidal Experiment

For this experiment, the model was rotated about its quarter-chord axis so that its angle of attack varied sinusoidally with time. The amplitude and frequency were controlled by the AMSTRAD function generator. During each oscillatory cycle 128 data sweeps were recorded and logged, with data being sampled during ten cycles.

3.3 VAWT Experiment

The VAWT experiment was designed to emulate the incidence time histories encountered by the blade of a vertical-axis wind turbine. A computer algorithm, coded in FORTRAN 77, has been developed at the University of Reading to calculate the blade's angle of attack as a function of its azimuth position. The program can use both single and multiple streamtube models based on SANDIA data for the NACA series of aerofoil characteristics.
At low tip-speed ratios the time history for the single streamtube model is a skewed sine function, but this tends toward a true sine as the tip-speed ratio is increased. The upwind (positive) and downwind (negative) sections of each cycle attain identical peak values of incidence. Tip-speed ratio and amplitude are related as follows:

<table>
<thead>
<tr>
<th>TSR</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.00</td>
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<td>4.00</td>
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<td>3.50</td>
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<td>3.25</td>
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<td>2.33</td>
<td>22.6°</td>
</tr>
<tr>
<td>1.75</td>
<td>32.8°</td>
</tr>
</tbody>
</table>

The AMSTRAD function generator reproduced the angle of attack histories based upon the NACA 0015 aerofoil's characteristics. Data acquisition was performed in an identical manner to that for sinusoidal tests.

In addition, a number of non-standard VAWT experiments were performed. Each is described in Table 5.

### 3.4 Procedure

Before each individual set of tests, the tunnel was shut down and the air flow allowed to cease before the transducer offsets were logged. Immediately after these values were recorded, the appropriate data acquisition routine was initiated whilst the tunnel was brought up to speed and thence data gathered as per the software prompts. The tunnel was then shut down, offsets logged again and further tests were performed in the manner described above.

#### 3.5 Roughness Transition Strips

A number of the experiments were repeated with graded sand deposited at the aerofoil's leading edge. It was intended that this should trip the boundary layer in the leading-edge region. A direct comparison can be made between tests with and those without these roughness transition strips.

#### 3.6 Data Presentation

All data collected by the data acquisition routines were stored in unformatted form on magnetic tape. A library of programs (coded in FORTRAN 77) is available for the reduction, presentation and analysis of the data on a DEC MICROVAX 3400. By applying offsets, gains and calibrations, the data reduction programs convert the cycles of raw data into averaged or unaveraged non-dimensional pressure coefficients. As described by Leitch and Galbraith\(^9\), these data are stored on the University of Glasgow's aerofoil database. The airloads are determined by suitably integrating the pressure coefficient values.

### 4 RESULTS AND DISCUSSION

#### 4.1 Tunnel Performance

Assessment of the quality of the data can only be made with a clear insight of the tunnel effects. Unfortunately the tunnel performance was such that, for the time scales of the model motion, it was not possible to hold the dynamic pressure in the working section constant whilst altering the blockage due to the pitching of the aerofoil. During the static tests (i.e. k=0.0 and r=0.0), this variation was as illustrated in Figure 5, where it can be seen that there was approximately a 30% reduction in dynamic pressure as the angle of attack was increased from 0° to 30°. As illustrated in Figures 6 and 7, this reduction in dynamic pressure decreased as reduced frequency increased.

Figure 8 reveals that, during ramps, there was a drastic reduction and subsequent unsteadiness in the dynamic pressure during a test. The model was pitched to an incidence of 40° so that uniform ramp conditions existed at stall. Once the aerofoil had stalled, however,
all significant data had already been collected and the corresponding dynamic pressure reduction was only in the region of 10%. The subsequent data are of little relevance to the current work and is presented merely for completeness.

4.2 Averaging of the Data

The main data in this report are the average of a number of cycles. Individual cycles are presented in Figures 9 and 10 where it may be seen that, whilst minor random differences do exist from cycle to cycle, the salient features are highlighted by the averaging process. In addition, the sweep at which any event occurred did not vary. Therefore the given data may be considered as typical of aerofoil performance during any given individual cycle. This is particularly relevant when considering the detailed flow phenomena of separation and reattachment.

4.3 Test Data

The test data are grouped for each motion type with compact details of the specific tests listed in Tables 2 to 5.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the encouragement and support of their colleagues both academic and technical.

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REFERENCES


7Sharpe, D.J. Vertical axis WECS design procedures I. Department of Aeronautical Engineering, Queen Mary College, University of London.


### TABLE 1: AHAVAW AEROFOIL PROFILE AND COORDINATES

![Aerofoil Profile Image](image)

Coordinates in % Chord

<table>
<thead>
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<th>Upper Surface Ordinate</th>
<th>Lower Surface Station</th>
<th>Lower Surface Ordinate</th>
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<td>0.000</td>
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TABLE 2 : DETAILS OF STATIC TESTS

TABLE 2.1 : SUMMARY OF STATIC TESTS (nominal)

<table>
<thead>
<tr>
<th>Reynolds Number</th>
<th>$0.8 \times 10^6$</th>
<th>$1.1 \times 10^6$</th>
<th>$1.5 \times 10^6$</th>
<th>$2.0 \times 10^6$</th>
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</thead>
<tbody>
<tr>
<td>Angle of Attack</td>
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(all permutations)

TABLE 2.2 : LIST OF STATIC TESTS (actual)

<table>
<thead>
<tr>
<th>Run Number</th>
<th>Start ($\degree$)</th>
<th>Sweep ($\degree$)</th>
<th>Reynolds No. x $10^6$</th>
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</thead>
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<tr>
<td>*805741</td>
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<td>32</td>
<td>1.53</td>
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(*experiments with roughness transition strips)
TABLE 3 : DETAILS OF SINUSOIDAL EXPERIMENTS

TABLE 3.1 : SUMMARY OF SINUSOIDAL EXPERIMENTS AT FIXED REDUCED FREQUENCY (nominal)

<table>
<thead>
<tr>
<th>Mean Angle</th>
<th>0°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>5.4° 10.0° 12.2° 13.8° 17.4° 22.6° 32.8°</td>
</tr>
<tr>
<td>Reduced Frequency</td>
<td>0.05</td>
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<td>Reynolds Number</td>
<td>0.8x10^6 1.1x10^6 1.5x10^6 2.0x10^6</td>
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</tbody>
</table>

(all permutations)

TABLE 3.2 : SUMMARY OF SINUSOIDAL EXPERIMENTS AT FIXED REYNOLDS NUMBER (nominal)

<table>
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<tr>
<th>Mean Angle</th>
<th>0°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>5.4° 10.0° 12.2° 13.8° 17.4° 22.6° 32.8°</td>
</tr>
<tr>
<td>Reduced Frequency</td>
<td>0.02 0.04 0.05 0.06 0.075</td>
</tr>
<tr>
<td>Reynolds Number</td>
<td>1.5x10^6</td>
</tr>
</tbody>
</table>

(all permutations; tests at reduced frequency of 0.075 were repeated with roughness transition strips)

TABLE 3.3 : LIST OF SINUSOIDAL EXPERIMENTS (actual)

<table>
<thead>
<tr>
<th>Run Number</th>
<th>Mean (°)</th>
<th>Amplitude (°)</th>
<th>Reduced Frequency</th>
<th>Reynolds No. x 10^-6</th>
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</thead>
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<td>0.047</td>
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<td>0.87</td>
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<td>17.4</td>
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<td>0.87</td>
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*experiments with roughness transition strips
TABLE 4: DETAILS OF SINGLE STREAMTUBE VAWT EXPERIMENTS

TABLE 4.1: SUMMARY OF VAWT EXPERIMENTS AT FIXED REDUCED FREQUENCY (nominal)

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TABLE 4.3: LIST OF VAWT EXPERIMENTS (actual)
TABLE 4.3 : LIST OF VAWT EXPERIMENTS (concluded)

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<td>0.069</td>
<td>1.60</td>
</tr>
</tbody>
</table>
TABLE 5: LIST OF NON-STANDARD VAWT EXPERIMENTS

<table>
<thead>
<tr>
<th>Run Number</th>
<th>Mean Angle (°)</th>
<th>Amp'ude Angle (°)</th>
<th>Reduced Frequency</th>
<th>Reynolds No. x 10⁻⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>a55482</td>
<td>0</td>
<td>12</td>
<td>0.045</td>
<td>2.00</td>
</tr>
<tr>
<td>b55492</td>
<td>0</td>
<td>12</td>
<td>0.045</td>
<td>1.99</td>
</tr>
<tr>
<td>c55502</td>
<td>0</td>
<td>20</td>
<td>0.045</td>
<td>1.98</td>
</tr>
<tr>
<td>d55512</td>
<td>0</td>
<td>20</td>
<td>0.045</td>
<td>1.97</td>
</tr>
<tr>
<td>e55521</td>
<td>0</td>
<td>30</td>
<td>0.046</td>
<td>1.96</td>
</tr>
<tr>
<td>f55531</td>
<td>0</td>
<td>30</td>
<td>0.046</td>
<td>1.94</td>
</tr>
</tbody>
</table>

*angle of attack trace from simulation of the VAWT 260 at a wind speed of 7.89 m s⁻¹ (structural dynamic effects not included)

b*angle of attack trace from simulation of the VAWT 260 at a wind speed of 7.89 m s⁻¹ (structural dynamic effects included)

c*angle of attack trace from simulation of the VAWT 260 at a wind speed of 10.57 m s⁻¹ (structural dynamic effects not included)

d*angle of attack trace from simulation of the VAWT 260 at a wind speed of 10.57 m s⁻¹ (structural dynamic effects included)

e*angle of attack trace from VAWT 260

f*equivalent angle of attack trace for wind tunnel to reproduce airloads from VAWT 260
FIGURE 3: PRESSURE TRANSDUCER LOCATIONS FOR THE AHAYAV.

\[
\begin{array}{c}
X(1)/C = 0.98000 \\
X(2)/C = 0.95000 \\
X(3)/C = 0.83000 \\
X(4)/C = 0.70000 \\
X(5)/C = 0.59000 \\
X(6)/C = 0.50000 \\
X(7)/C = 0.26000 \\
X(8)/C = 0.17000 \\
X(9)/C = 0.10000 \\
X(10)/C = 0.05000 \\
X(11)/C = 0.02500 \\
X(12)/C = 0.01000 \\
X(13)/C = 0.00250 \\
X(14)/C = 0.00025 \\
X(15)/C = 0.00025 \\
X(16)/C = 0.00025 \\
X(17)/C = 0.00025 \\
X(18)/C = 0.00025 \\
X(19)/C = 0.00025 \\
X(20)/C = 0.00025 \\
X(21)/C = 0.00025 \\
X(22)/C = 0.00025 \\
X(23)/C = 0.00025 \\
X(24)/C = 0.00025 \\
X(25)/C = 0.00025 \\
X(26)/C = 0.00025 \\
X(27)/C = 0.00025 \\
X(28)/C = 0.00025 \\
X(29)/C = 0.00025 \\
X(30)/C = 0.00025
\end{array}
\]
FIGURE 4: SYSTEMATIC ARRANGEMENT OF DATA ACQUISITION AND CONTROL SYSTEM
FIGURE 5: REDUCTION OF DYNAMIC PRESSURE WITH INCREASING ANGLE OF ATTACK.

FIGURE 6: VARIATION OF DYNAMIC PRESSURE DURING OSCILLATORY TESTS.
FIGURE 7: VARIATION OF DYNAMIC PRESSURE FOR VARIOUS MEAN ANGLES OF ATTACK AT A REDUCED FREQUENCY OF 0.10.

FIGURE 8: VARIATION OF DYNAMIC PRESSURE FOR VARIOUS PITCH RATES DURING RAMP TESTS.
FIGURE 9: EFFECT OF AVERAGING ON THE NORMAL FORCE AND PITCHING MOMENT FOR OSCILLATORY TESTS.
FIGURE 10: TYPICAL UNAVERAGED DATA FOR RAMP TESTS.
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PRESSURE DATA FROM

STATIC EXPERIMENTS
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 11
REYNOLDS NUMBER = 1599672.
DYNAMIC PRESSURE = 1121.96 N/m²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 4/11/91
MACH NUMBER = 0.127
AIR TEMPERATURE = 18.5°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

Non-dimensional time (tx/V/c)

Non-dimensional time (tx/V/c)

Non-dimensional time (tx/V/c)

Cp at LE, TE, 30°

Non-dimensional time (tx/V/c)

ANGLE OF ATTACK

ANGLE OF ATTACK

Cp

Angle

Ct

Ct
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 491
REYNOLDS NUMBER = 1535410
DYNAMIC PRESSURE = 1029.75 Nm⁻²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 5/11/91
MACH NUMBER = 0.121
AIR TEMPERATURE = 20.0°C
SAMPLING FREQUENCY = 100.00 Hz
AVERAGED DATA OF 1 CYCLES

Cps at LE, TE, 30%
Non-dimensional time (txV/c)

Non-dimensional time (txV/c)

Non-dimensional time (txV/c)

ANGLE OF ATTACK

Cmψ

Cmψ

Cmψ

Cmψ

Non-dimensional time (txV/c)

ANGLE OF ATTACK

Ct

Ct

Ct

Ct

Cps at LE, TE, 30%
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 751
REYNOLDS NUMBER = 1040063.
DYNAMIC PRESSURE = 449.33 Nm^-2
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 6/11/91
MACH NUMBER = 0.080
AIR TEMPERATURE = 14.0°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES
**DYNAMIC CHARACTERISTICS FOR THE AHAVA W - VAWT Model**

**RUN REFERENCE NUMBER:** 3541  
**RUN LDS NUMBER:** 1100086.  
**DYNAMIC PRESSURE:** 489.62 Nm⁻²  
**NUMBER OF CYCLES:** 1  
**MOTION TYPE:** STATIC

**DATE OF TEST:** 10/11/91  
**MACH NUMBER:** 0.004  
**AIR TEMPERATURE:** 10.5°C  
**SAMPLING FREQUENCY:** 100.00 Hz.  
**AVERAGED DATA OF:** 1 CYCLES

---

**Graphs and Data**

- **Cp** distribution vs. angle of attack
- **Cn** distribution vs. angle of attack
- **Ct** distribution vs. angle of attack
- **Cmp** distribution vs. angle of attack
- **Non-dimensional time (t) vs. V/c**

---

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DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 3711
REYNOLDS NUMBER = 1588319.
DYNAMIC PRESSURE = 1040.48 Nm^-2
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 10/11/91
MACH NUMBER = 0.122
AIR TEMPERATURE = 12.4°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

Non-dimensional time (txV/c)

Cn

Non-dimensional time (txV/c)

ANGLE OF ATTACK

Cm

Non-dimensional time (txV/c)

ANGLE OF ATTACK

Ct

Non-dimensional time (txV/c)
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 3961
REYNOLDS NUMBER = 2023112.
DYNAMIC PRESSURE = 1768.50 N/m²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC
DATE OF TEST: 11/11/91
MACH NUMBER = 0.159
AIR TEMPERATURE = 17.3°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

C_n Non-dimensional time (t/V/c)

C_n Non-dimensional time (t/V/c)

C_m Non-dimensional time (t/V/c)

C_m Non-dimensional time (t/V/c)

C_l Non-dimensional time (t/V/c)

C_l Non-dimensional time (t/V/c)

C_p Cp at LE, TE, 30°

C_p Cp at LE, TE, 30°

C_p Cp at LE, TE, 30°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 4211
REYNOLDS NUMBER = 1213904
DYNAMIC PRESSURE = 659.00 N/m²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 11/11/91
MACH NUMBER = 0.097
AIR TEMPERATURE = 21.2°C
SAMPLING FREQUENCY = 100.00 Hz
AVERAGED DATA OF 1 CYCLES

Non-dimensional time (txV/c)

Cp

Non-dimensional time (txV/c)

Angle of attack

Cn

Non-dimensional time (txV/c)

Cm

Non-dimensional time (txV/c)

Cp

Non-dimensional time (txV/c)

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DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 4291
REYNOLDS NUMBER = 1631961.
DYNAMIC PRESSURE = 1191.95 Nm⁻²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 11/11/91
MACH NUMBER = 0.131
AIR TEMPERATURE = 21.3°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

ANGLE OF ATTACK

Non-dimensional time (txV/c)

\[
\begin{align*}
\text{C}_n & \quad 2.0 \\
& \quad 1.5 \\
& \quad 1.0 \\
& \quad 0.5 \\
& \quad 0.0 \\
& \quad -0.5 \\
& \quad -1.0 \\
& \quad -1.5 \\
& \quad -2.0 \\
\end{align*}
\]

\[
\begin{align*}
\text{C}_m & \quad 0.1 \\
& \quad 0.0 \\
& \quad -0.1 \\
& \quad -0.2 \\
& \quad -0.3 \\
& \quad -0.4 \\
& \quad -0.5 \\
\end{align*}
\]

\[
\begin{align*}
\text{C}_t & \quad 0.2 \\
& \quad 0.1 \\
& \quad 0.0 \\
& \quad -0.1 \\
& \quad -0.2 \\
& \quad -0.3 \\
& \quad -0.4 \\
\end{align*}
\]

Cps at LE, TE, 30°

Non-dimensional time (txV/c)

\[
\begin{align*}
\text{C}_n & \quad 2.0 \\
& \quad 1.5 \\
& \quad 1.0 \\
& \quad 0.5 \\
& \quad 0.0 \\
& \quad -0.5 \\
& \quad -1.0 \\
& \quad -1.5 \\
& \quad -2.0 \\
\end{align*}
\]

\[
\begin{align*}
\text{C}_m & \quad 0.1 \\
& \quad 0.0 \\
& \quad -0.1 \\
& \quad -0.2 \\
& \quad -0.3 \\
& \quad -0.4 \\
& \quad -0.5 \\
\end{align*}
\]

\[
\begin{align*}
\text{C}_t & \quad 0.2 \\
& \quad 0.1 \\
& \quad 0.0 \\
& \quad -0.1 \\
& \quad -0.2 \\
& \quad -0.3 \\
& \quad -0.4 \\
\end{align*}
\]
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 4801
REYNOLDS NUMBER = 860708.
DYNAMIC PRESSURE = 331.45 Nm⁻²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 18.8°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES
DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAWT Model

RUN REFERENCE NUMBER: 4881
REYNOLDS NUMBER = 1200616.
DYNAMIC PRESSURE = 655.01 N/m²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 20.8°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

Cₓ

Non-dimensional time (txV/c)

Cᵧ

Non-dimensional time (txV/c)

Cᵧₚ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₚₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

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Non-dimensional time (txV/c)

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Non-dimensional time (txV/c)

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Non-dimensional time (txV/c)

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Non-dimensional time (txV/c)

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Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cₓₒ

Non-dimensional time (txV/c)

Cᵧₒ

Non-dimensional time (txV/c)

Cxyz

Non-dimensional time (txV/c)
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 5031
REYNOLDS NUMBER = 2087112
DYNAMIC PRESSURE = 2996.46 Nm⁻²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 13/11/91
MACH NUMBER = 0.175
AIR TEMPERATURE = 27.3°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

![Graphs showing dynamic characteristics of the AHAVAW VAWT Model]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 5181
REYNOLDS NUMBER = 1661090.
DYNAMIC PRESSURE = 1205.29 Nm⁻²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 16.9°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

\[ C_n \]

\[ C_m \]

\[ C_p \]

\[ C_r \]

\[ \alpha \]

\[ x/c \]

\[ \frac{\text{Non-dimensional time (t/Vc)}}{\text{ANGLE}} \]

\[ \frac{\text{Non-dimensional time (t/Vc)}}{\text{ANGLE OF ATTACK}} \]

\[ \frac{\text{Cps at LE, TE, 30°}}{\text{ANGLE}} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAN – VAWT Model

REFERENCE NUMBER: 805541
REYNOLDS NUMBER = 1567557.
DYNAMIC PRESSURE = 1059.40 N/m²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 4/1/92
MACH NUMBER = 0.122
AIR TEMPERATURE = 18.6°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

Cp and Cm at LE, TE, 30°
Non-dimensional time (t/νc)

Cp

Cm

Non-dimensional time (t/νc)
ANGLE OF ATTACK

Cn

Non-dimensional time (t/νc)
Cn

Non-dimensional time (t/νc)
Ct

Non-dimensional time (t/νc)
Ct

Non-dimensional time (t/νc)
Cmα0

Cmα0

Non-dimensional time (t/νc)
Cmα0

Non-dimensional time (t/νc)
Cmα0
DYNAMIC CHARACTERISTICS FOR THE AVAN - VAWT Model

RUN REFERENCE NUMBER: 805741
REYNOLDS NUMBER = 1530799.
DYNAMIC PRESSURE = 994.80 Nm⁻²
NUMBER OF CYCLES = 1
MOTION TYPE: STATIC

DATE OF TEST: 5/1/92
MACH NUMBER = 0.118
AIR TEMPERATURE = 17.4°C
SAMPLING FREQUENCY = 100.00 Hz.
AVERAGED DATA OF 1 CYCLES

Cp

Cp

Non-dimensional time (t/V/c)

Non-dimensional time (t/V/c)

Cn

Cn

Non-dimensional time (t/V/c)

Non-dimensional time (t/V/c)

Non-dimensional time (t/V/c)

Non-dimensional time (t/V/c)

ANGLES

ANGLES

ANGLES

ANGLES

ANGLES
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DEPARTMENT OF AEROSPACE ENGINEERING

PRESSURE DATA FROM

OSCILLATORY EXPERIMENTS
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14141  DATE OF TEST: 11/11/91
REYNOLDS NUMBER = 869347.  MACH NUMBER = 0.069
DYNAMIC PRESSURE = 335.88 N/m²  AIR TEMPERATURE = 20.5°C
NUMBER OF CYCLES = 10  SAMPLING FREQUENCY = 83.20 Hz.
MOTION TYPE: SINUSOIDAL  REDUCED FREQUENCY = 0.047
MEAN ANGLE = 0.00°  AMPLITUDE = 5.40°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

Cp vs. angle of attack

Cn vs. angle of attack

Cm vs. angle of attack

Ct vs. angle of attack

Angular velocity vs. Time (rads.)

Cps at LE, TE, 30°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 54811
REYNOLDS NUMBER = 863195.
DYNAMIC PRESSURE = 334.25 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 19.1°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 5.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14151
REYNOLDS NUMBER = 868967.
DYNAMIC PRESSURE = 335.88 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.069
AIR TEMPERATURE = 20.6°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 10.00°

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DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14161
REYNOLDS NUMBER = 868967.
DYNAMIC PRESSURE = 335.88 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.069
AIR TEMPERATURE = 20.6°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 12.20°
DYNAMIC CHARACTERISTICS FOR THE ANAVAN - VANT Model

RUN REFERENCE NUMBER: 54031
REYNOLDS NUMBER = 862057.
DYNAMIC PRESSURE = 334.25 Ns²
NUMBER OF CYCLES = 10
MOTION TYPE: VANT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 19.4°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 12.20°

AVERAGED DATA OF 10 CYCLES

\begin{align*}
\text{ANGLE OF ATTACK} & \\
\text{ANGLE OF ATTACK} & \\
\text{ANGLE OF ATTACK} & \\
\text{ANGLE OF ATTACK} & \\
\end{align*}
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14171
REYNOLDS NUMBER = 868587.
DYNAMIC PRESSURE = 335.88 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.069
AIR TEMPERATURE = 20.7°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54841
REYNOLDS NUMBER = 862057
DYNAMIC PRESSURE = 334.25 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 19.4°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14181
REYNOLDS NUMBER = 868587.
DYNAMIC PRESSURE = 335.88 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.069
AIR TEMPERATURE = 20.7°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 17.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 54851
REYNOLDS NUMBER = 861679.
DYNAMIC PRESSURE = 334.25 Nm^{-2}
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 19.5°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 17.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14191
REYNOLDS NUMBER = 868587.
DYNAMIC PRESSURE = 335.88 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.069
AIR TEMPERATURE = 20.7°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54861
REYNOLDS NUMBER = 861679.
DYNAMIC PRESSURE = 334.25 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT Function
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 19.5°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14201
REYNOLDS NUMBER = 868207.
DYNAMIC PRESSURE = 335.88 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.069
AIR TEMPERATURE = 20.8°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 32.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54871
REYNOLDS NUMBER = 860922.
DYNAMIC PRESSURE = 334.25 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.650 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.070
AIR TEMPERATURE = 19.7°C
SAMPLING FREQUENCY = 83.20 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14221
REYNOLDS NUMBER = 1204218.

DYNAMIC PRESSURE = 648.44 Nm⁻²
AIR TEMPERATURE = 21.2°C

NUMBER OF CYCLES = 10
SAMPLING FREQUENCY = 114.43 Hz.

MOTION TYPE: SINUSOIDAL
REduced FREQUENCY = 0.047

MEAN ANGLE = 0.00°
AMPLITUDE = 5.40°

OSCILLATION FREQUENCY = 0.894 Hz.

AVERAGED DATA OF 10 CYCLES

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\[ C_{\text{mup}} \]

\[ C_{\text{p}} \]

\[ C_{\text{T}} \]

\[ \Omega \times T (\text{rads.}) \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{Cps at LE, TE, 304} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54891
REYNOLDS NUMBER = 1197490.
DYNAMIC PRESSURE = 656.17 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 21.6°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 5.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14231
REYNOLDS NUMBER = 1202120.
DYNAMIC PRESSURE = 648.44 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.096
AIR TEMPERATURE = 21.6°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 10.0°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT MODEL

AVERAGED DATA OF 10 CYCLES

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References:
- DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT MODEL
- Data provided by project number: 54901
- Dynamic reference number: 1195527
- Dynamic pressure = 656.17 N/m²
- Number of cycles = 10
- Mean angle = 0.00
- Oscillation frequency = 0.20 Hz
- Average data of 10 cycles

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Notes:
- Date of test: 13/11/91
- Mach number = 0.998
- Air temperature = 21.9°C
- Reduced frequency = 0.046
- Amplitude = 10.00

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Graphical representations:
- Graph showing angle of attack vs. time
- Graph showing oscillation frequency vs. time
- Graph showing mean angle vs. time
- Graph showing dynamic characteristics with x/c ratio and alpha values

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Further analysis and discussion may be required for a comprehensive understanding of the data presented.
DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAWT Model

RUN REFERENCE NUMBER: 14241
REYNOLDS NUMBER = 1201596.
DYNAMIC PRESSURE = 648.44 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.094 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.096
AIR TEMPERATURE = 21.7°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 12.2°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 54911
REYNOLDS NUMBER = 1194887.
DYNAMIC PRESSURE = 656.17 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 22.1°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 12.20°

Cp at LE, TE, 30°

ANGLE OF ATTACK
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14251
REYNOLDS NUMBER = 1201073.
DYNAMIC PRESSURE = 648.44 N/m^2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 21.8°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 13.80°

\(\text{OMEGA x T (rads.)}\)

\(\text{ANGLE OF ATTACK}\)

\(\text{Cp} -\)

\(\text{x/c} \quad 0.4 \quad 0.6 \quad 0.8 \quad 1.0\)

\(\alpha \quad -1.75 \quad 3.66 \quad 13.25 \quad 13.50 \quad 13.80 \quad 9.57 \quad 5.61 \quad 10.82 \quad -13.78 \quad -11.95 \quad -7.30 \quad -0.93 \quad -8.43 \quad -12.50 \quad -3.04 \)

\(\text{ANGLE OF ATTAC_k}\)

\(\text{Ct} -\)

\(\text{x/c} \quad 0.4 \quad 0.6 \quad 0.8 \quad 1.0\)

\(\alpha \quad -0.2 \quad 0.2 \quad -0.2 \quad -0.1 \quad 0.1 \quad 0.2 \quad 0.1 \quad -0.1 \quad -0.2 \quad -0.3 \quad -0.2 \quad -0.1 \quad -0.0 \quad 0.0 \quad 0.1 \quad 0.2 \quad 0.3 \quad 0.4 \quad 0.5 \quad 0.6 \quad 0.7 \quad 0.8 \quad 0.9 \quad 1.0\)

\(\text{Cm}_{\alpha} \quad -0.2 \quad 0.2 \quad -0.2 \quad -0.1 \quad 0.1 \quad 0.2 \quad 0.1 \quad -0.1 \quad -0.2 \quad -0.3 \quad -0.2 \quad -0.1 \quad -0.0 \quad 0.0 \quad 0.1 \quad 0.2 \quad 0.3 \quad 0.4 \quad 0.5 \quad 0.6 \quad 0.7 \quad 0.8 \quad 0.9 \quad 1.0\)

\(\text{Cm} \quad -0.2 \quad 0.2 \quad -0.2 \quad -0.1 \quad 0.1 \quad 0.2 \quad 0.1 \quad -0.1 \quad -0.2 \quad -0.3 \quad -0.2 \quad -0.1 \quad -0.0 \quad 0.0 \quad 0.1 \quad 0.2 \quad 0.3 \quad 0.4 \quad 0.5 \quad 0.6 \quad 0.7 \quad 0.8 \quad 0.9 \quad 1.0\)
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54921
REYNOLDS NUMBER = 1193849.
DYNAMIC PRESSURE = 656.17 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 22.3°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 13.80°

Cn

C Aw

C M0

C L

OMEGA x T (rads.)

OMEGA x T (rads.)

ANGLE OF ATTACK

ANGLE OF ATTACK

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DYNAMIC CHARACTERISTICS FOR THE AHAUAN - VAWT Model

RUN REFERENCE NUMBER: 14261
REYNOLDS NUMBER = 1200551.
DYNAMIC PRESSURE = 648.44 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.096
AIR TEMPERATURE = 21.9°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 17.40°
DYNAMIC CHARACTERISTICS FOR THE ANAVAV - VAWT Model

RUN REFERENCE NUMBER: 54931
REYNOLDS NUMBER = 1192295.
DYNAMIC PRESSURE = 656.17 m/s²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 22.6°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 17.40°

- ANGLE OF ATTACK
- C_{pm}
- C_{m0}
- C_{n}
- C_{pT}
- C_{nT}

- OMEGA x T (rads.)
- OMEGA x T (rads.)
- OMEGA x T (rads.)
- ANGLE OF ATTACK
- ANGLE OF ATTACK
- ANGLE OF ATTACK

493
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54941
REYNOLDS NUMBER = 1191777.
DYNAMIC PRESSURE = 656.17 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 22.7°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14281
REYNOLDS NUMBER = 1199507.
DYNAMIC PRESSURE = 648.44 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.096
AIR TEMPERATURE = 22.1°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 54951
REYNOLDS NUMBER = 1191261.
DYNAMIC PRESSURE = 656.17 Pa
NUMBER OF CYCLES = 10
MOtion TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.894 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.098
AIR TEMPERATURE = 22.8°C
SAMPLING FREQUENCY = 114.43 Hz.
REDUced FREQUENCY = 0.046
AMPlITUDE = 32.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAWT Model

RUN REFERENCE NUMBER: 14301
REYNOLDS NUMBER = 1603725.
DYNAMIC PRESSURE = 1167.19 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 22.9°C
SAMPLING FREQUENCY = 155.9 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 5.40°

\[ C_n \]

\[ C_{m0} \]

\[ C_{mH} \]

\[ C_{T} \]

\[ \omega \times T (\text{rads.}) \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{Cps at LE TE, 30°} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VANT Model

RUN REFERENCE NUMBER: 54961
REYNOLDS NUMBER = 1601500.
DYNAMIC PRESSURE = 1195.20 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VANT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 23.7°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 5.40°

\[ \text{Graphs showing \( \Omega \times T \) (rads.) for different cases.} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14311
REYNOLDS NUMBER = 1600950.
DYNAMIC PRESSURE = 1167.19 N/m^2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 23.3°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 10.00°

\[ C_p \times T \ (\text{rads.}) \]
\[ C_n \times T \ (\text{rads.}) \]
\[ \text{ANGLE OF ATTACK} \]
\[ C_{m_{\alpha}} \times T \ (\text{rads.}) \]
\[ \text{ANGLE OF ATTACK} \]
\[ C_{m_{\beta}} \times T \ (\text{rads.}) \]
\[ C_t \times T \ (\text{rads.}) \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 54971
REYNOLDS NUMBER = 1598047.
DYNAMIC PRESSURE = 1195.20 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14321
REYNOLDS NUMBER = 1599565.
DYNAMIC PRESSURE = 1167.19 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 23.5°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 12.20°
DYNAMIC CHARACTERISTICS FOR THE AIRCRAFT - VAWT MODEL

- RUN REFERENCE NUMBER: 54981
- REFERENCE WIND SPEED: 135.5 m/s
- DYNAMIC WIND SPEED: 110.5 m/s
- NUMBER OF CYCLES: 10
- MEAN WIND SPEED: 0.00 m/s
- OSCILLATION FREQUENCY: 1.218 Hz
- REDUCED FREQUENCY: 0.046
- AMPLITUDE: 12.20
- AVERAGE DATA OF 10 CYCLES
**DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model**

**RUN REFERENCE NUMBER:** 14331  
**REYNOLDS NUMBER:** 1597492.  
**DYNAMIC PRESSURE:** 1167.19 Nm^-2  
**NUMBER OF CYCLES:** 10  
**MOTION TYPE:** SINUSOIDAL  
**MEAN ANGLE:** 0.0°  
**OSCILLATION FREQUENCY:** 1.218 Hz.  
**AVERAGED DATA OF 10 CYCLES**

**DATE OF TEST:** 11/11/91  
**MACH NUMBER:** 0.129  
**AIR TEMPERATURE:** 23.8°C  
**SAMPLING FREQUENCY:** 155.91 Hz.  
**REDUCED FREQUENCY:** 0.047  
**AMPLITUDE:** 13.8°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 54991
REYNOLDS NUMBER = 1569817.
DYNAMIC PRESSURE = 1195.20 Nm^{-2}
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25.4°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 13.8°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14341
REYNOLDS NUMBER = 1594737.
DYNAMIC PRESSURE = 1167.19 Na^2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.2°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 17.40°

C_p vs Cp at LE, TE, 30°

OMEGA x T (rads.)

C_a

OMEGA x T (rads.)

ANGULAR VELOCITY

C_m

OMEGA x T (rads.)

C_m

OMEGA x T (rads.)

C_m

OMEGA x T (rads.)

C_m

ANGULAR VELOCITY

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DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55001
REYNOLDS NUMBER = 1568453.
DYNAMIC PRESSURE = 1195.20 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25.6°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 17.40°

\[ C_{p} \]

\[ C_{n} \]

\[ C_{m} \]

\[ C_{p} \]

\[ C_{n} \]

\[ C_{m} \]

\[ C_{t} \]

\[ C_{p} \]

\[ C_{n} \]

\[ C_{m} \]

\[ C_{t} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14351
REYNOLDS NUMBER = 1594049.
DYNAMIC PRESSURE = 1167.19 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.3°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55011
REYNOLDS NUMBER = 1585053.
DYNAMIC PRESSURE = 1195.20 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 26.1°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14361
REYNOLDS NUMBER = 1591990.
DYNAMIC PRESSURE = 1166.19 N/m²
NUMBER OF CYCLES = 10
OTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 11/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.6°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RIM REFERENCE NUMBER: 55021
REYNOLDS NUMBER = 1583021.
DYNAMIC PRESSURE = 1195.20 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 26.4°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 32.8°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14381  DATE OF TEST: 12/11/91
REYNOLDS NUMBER = 2067046.  MACH NUMBER = 0.167
DYNAMIC PRESSURE = 1925.38 Nm⁻²  AIR TEMPERATURE = 20.7°C
NUMBER OF CYCLES = 10  SAMPLING FREQUENCY = 208.12 Hz.
MOTION TYPE: SINUSOIDAL  REDUCED FREQUENCY = 0.049
MEAN ANGLE = 0.0°  AMPLITUDE = 5.40°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 550441
REYNOLDS NUMBER = 2673131.
DYNAMIC PRESSURE = 2123.51 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.176
AIR TEMPERATURE = 30.4°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 5.4°

\[ \text{C_n} \]
\[ \text{C_m} \]
\[ \text{C_p} \]
\[ \text{C} \]

\[ \text{OMEGA x T (rads.)} \]
\[ \text{ANGLE OF ATTACK} \]

\[ \text{C_p at LE, TE, 30%} \]
\[ \text{OMEGA x T (rads.)} \]
\[ \text{ANGLE OF ATTACK} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14391
REYNOLDS NUMBER = 2058046.
DYNAMIC PRESSURE = 1925.38 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.167
AIR TEMPERATURE = 21.7°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 10.00°

ANGLER x T (rads.)

Cn

2.0

1.5

1.0

0.5

0.0

-0.5

-1.0

-1.5

-2.0

-2.5

0

1.0

2.0

3.0

4.0

5.0

6.0

OMEGA x T (rads.)

ANGLE OF ATTACK

Cp at LE, TE, 30°

Cp

8

7

6

5

4

3

2

1

0

-1

-2

-3

-4

-5

-6

-7

-8

0

10

20

30

40

OMEGA x T (rads.)

ANGLE OF ATTACK

Ct

0.2

0.1

0.0

-0.1

-0.2

-0.3

-0.4

-0.5

-0.6

-0.7

-0.8

-0.9

0

10

20

30

40

Ct

0.2

0.1

0.0

-0.1

-0.2

-0.3

-0.4

-0.5

-0.6

-0.7

-0.8

-0.9

0

10

20

30

40
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55051
REYNOLDS NUMBER = 2064170.
DYNAMIC PRESSURE = 2123.51 m
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.176
AIR TEMPERATURE = 31.2°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 10.00°

\[ C_n \]
\[ C_{mu} \]
\[ C_p \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW – VAWT Model

RUN REFERENCE NUMBER: 14401
REYNOLDS NUMBER = 2052682.
DYNAMIC PRESSURE = 1925.38 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.167
AIR TEMPERATURE = 22.3°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 12.20°

Cp 2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

Cn 2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

CM
0.1
0.0
0.1
0.2
0.3
0.4
0.5

ANGLE OF ATTACK

GREEK NOTATION

\(\omega_t\)
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55061
REYNOLDS NUMBER = 2060115.
DYNAMIC PRESSURE = 2123.51 N m⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.176
AIR TEMPERATURE = 31.9°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 12.20°

506
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14411
REYNOLDS NUMBER = 2048232.
DYNAMIC PRESSURE = 1925.38 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.167
AIR TEMPERATURE = 22.8°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 13.8°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55071
REYNOLDS NUMBER = 2054094.
DYNAMIC PRESSURE = 2123.51 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.176
AIR TEMPERATURE = 32.6°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.045
AMPLITUDE = 13.8°

\[ \text{Cp} \]
\[ \text{Cn} \]
\[ \text{Cm} \]
\[ \text{Ct} \]

\[ \text{OMEGA} \times T \text{ (rads.)} \]
\[ \text{ANGLE OF ATTACK} \]

\[ \text{OMEGA} \times T \text{ (rads.)} \]
\[ \text{ANGLE OF ATTACK} \]

\[ \text{OMEGA} \times T \text{ (rads.)} \]
\[ \text{ANGLE OF ATTACK} \]
DYANMIC CHARACTERISTICS FOR THE AHAVAN - VANT Model

RUN REFERENCE NUMBER: 14421
REYNOLDS NUMBER = 2044685.
DYNAMIC PRESSURE = 1925.38 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.167
AIR TEMPERATURE = 23.2°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 17.40°

\[ \text{Cp} \]

\[ \text{Cn} \]

\[ \text{Cm} \]

\[ \text{Cl} \]

\[ \text{OMEGA x T (rads.)} \]

\[ \text{ANGLE OF ATTACK} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55081
REYNOLDS NUMBER = 2049814.
DYNAMIC PRESSURE = 2123.51 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.176
AIR TEMPERATURE = 33.1°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.045
AMPLITUDE = 17.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14431
REYNOLDS NUMBER = 2040268.
DYNAMIC PRESSURE = 1925.30 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.147
AIR TEMPERATURE = 23.7°C
SAMPLING FREQUENCY = 208.1 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 22.0°
DYNAMIC CHARACTERISTICS FOR THE AHAVV - VAWT Model

RUN REFERENCE NUMBER: 55091
REYNOLDS NUMBER = 2041304.
DYNAMIC PRESSURE = 2123.51 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MASS NUMBER = 0.176
AIR TEMPERATURE = 34.1°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.045
AMPLITUDE = 32.80°

\[ C_n \]
\[ C_m \]
\[ C_p \]
\[ \alpha \]
\[ \theta \]
\[ \Omega \times T \text{ (rads.)} \]
\[ \text{ANGLE OF ATTACK} \]
\[ \text{OMEGA} \times T \text{ (rads.)} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14442
REYNOLDS NUMBER = 1978656.
DYNAMIC PRESSURE = 1871.52 Nm^-2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.165
AIR TEMPERATURE = 27.7°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 32.0°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55102
REYNOLDS NUMBER = 1971107.
DYNAMIC PRESSURE = 1871.52 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.626 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.165
AIR TEMPERATURE = 28.6°C
SAMPLING FREQUENCY = 208.12 Hz.
REDUCED FREQUENCY = 0.049
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14451
REYNOLDS NUMBER = 1578970.
DYNAMIC PRESSURE = 1146.97 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 23.0°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.019
AMPLITUDE = 5.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 55111
REYNOLDS NUMBER = 1566814.
DYNAMIC PRESSURE = 1212.93 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 30.4°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.018
AMPLITUDE = 5.4°

- COV

-0.68
-4.11
2.81
-4.90
-0.69
5.44
-0.72

- Cn

1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

- Cn

2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

- Cn

2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

- Cn

0.1
0.05
0.0
-0.05
-0.1

- Cn

0.2
0.1
0.0
-0.1
-0.2

- Cn

0.2
0.1
0.0
-0.1
-0.2

- Cn

0.2
0.1
0.0
-0.1
-0.2

- Cn

0.2
0.1
0.0
-0.1
-0.2

- Cn

0.2
0.1
0.0
-0.1
-0.2

- Cn

0.2
0.1
0.0
-0.1
-0.2

- Cn

0.2
0.1
0.0
-0.1
-0.2
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14461
REYNOLDS NUMBER = 1575556.
DYNAMIC PRESSURE = 1146.97 Nm^-2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 23.5°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.019
AMPLITUDE = 10.00°

\[ C_B \]
\[ C_{mB} \]
\[ C_{\alpha} \]
\[ \alpha \]
\[ \frac{\Omega \times T}{\text{rads.}} \]
\[ \frac{\Omega \times T}{\text{rads.}} \]
\[ \text{ANGLE OF ATTACK} \]
\[ \text{ANGLE OF ATTACK} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55121
REYNOLDS NUMBER = 1565495.
DYNAMIC PRESSURE = 1212.93 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 30.6°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.018
AMPLITUDE = 10.00°

ANGLE OF ATTACK

OMEGA x T (rads.)

ANGLE OF ATTACK

OMEGA x T (rads.)

OMEGA x T (rads.)
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14471
REYNOLDS NUMBER = 1572836.
DYNAMIC PRESSURE = 1146.97 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 23.9°C
SAMPLING FREQUENCY = 62.34 Hz.
REduced FREQUENCY = 0.019
AMPLITUDE = 12.20°

角度与力矩

角度与力矩

角度与力矩

角度与力矩

角度与力矩

角度与力矩

角度与力矩

角度与力矩

角度与力矩
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14481
REYNOLDS NUMBER = 1570801.
DYNAMIC PRESSURE = 1146.97 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.2°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.019
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14491
REYNOLDS NUMBER = 1568095.
DYNAMIC PRESSURE = 1146.97 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.6°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.019
AMPLITUDE = 17.40°
DYNAMIC CHARACTERISTICS FOR THE AIRVAN - VAT Model

Sampled Data:
- Date of Test: 13/11/91
- Dynamic Pressure: 1212.93 Pa
- Number of Cycles: 10
- Mean Angle = 60°
- Oscillation Frequency = 0.487 Hz
- Averaged Data of 10 Cycles
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 14561
REYNOLDS NUMBER = 1566746.
DYNAMIC PRESSURE = 1146.97 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.8°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.019
AMPLITUDE = 22.60°

Cp vs z/ct

Cp vs angle

Cp at LE, TE, 30°
DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAWT Model

RUN REFERENCE NUMBER: 55161
REYNOLDS NUMBER = 1560898.
DYNAMIC PRESSURE = 1212.93 N\(\text{m}^{-2}\)
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 31.3°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.018
AMPLITUDE = 22.6°
DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAWT Model

RUN REFERENCE NUMBER: 14511
REYNOLDS NUMBER = 1564726.
DYNAMIC PRESSURE = 1146.97 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 9.00°
OSCILLATION FREQUENCY = 0.407 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.1°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.019
AMPLITUDE = 32.00°

\[ C_n \quad 2.0 \]
\[ C_n \quad 1.5 \]
\[ C_n \quad 1.0 \]
\[ C_n \quad 0.5 \]
\[ C_n \quad 0.0 \]

[Graph showing \( C_n \) vs. angle]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55171
REYNOLDS NUMBER = 1559588
DYNAMIC PRESSURE = 1212.93 Ns⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLOSTION FREQUENCY = 0.487 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 13/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 31.5°C
SAMPLING FREQUENCY = 62.34 Hz.
REDUCED FREQUENCY = 0.018
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14521
REYNOLDS NUMBER = 1563269.
DYNAMIC PRESSURE = 1138.94 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 24.5°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 5.40°

Cp at LE, TE, 30°
DYNAMIC CHARACTERISTICS FOR THE AH10VAN - VAWT Model

DYNAMIC REFERENCE NUMBER: 55191
RUN NUMBER: 1644553
DATE OF TEST: 14/11/91
AIR DENSITY: 1.237 kg/m³
DYNAMIC PRESSURE = 123.17 N/m²
REYNOLDS NUMBER = 0.343
NUMBER OF CYCLES = 10
DYNAMIC PRESSURE = 124.80 Hz
SAMPLED FREQUENCY = 0.037
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz
HUMIDITY = 5.40°
AVERAGED DATA OF 10 CYCLES

\[
\begin{align*}
C_p & = \text{Pressure Coefficient} \\
\theta & = \text{Angle of Attack} \\
\omega & = \text{Angular Frequency} \\
\phi & = \text{Phase Angle}
\end{align*}
\]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW – VAWT Model

RUN REFERENCE NUMBER: 14531
REYNOLDS NUMBER = 1558569.
DYNAMIC PRESSURE = 1138.94 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.2°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 10.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55201
REYNOLDS NUMBER = 1641677.
DYNAMIC PRESSURE = 1217.37 m/s^2
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 20.7°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.037
AMPLITUDE = 10.00°

\[ C_{p} \]
\[ C_{d} \]
\[ \text{Omega} \times T (\text{rads.}) \]
\[ \text{Angle of Attack} \]
\[ \text{Omega} \times T (\text{rads.}) \]
\[ \text{Omega} \times T (\text{rads.}) \]
\[ \text{Angle of Attack} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 14541
REYNOLDS NUMBER = 1557900.
DYNAMIC PRESSURE = 1138.94 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.3°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 12.20°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55211
REYNOLDS NUMBER = 1642042.
DYNAMIC PRESSURE = 1217.37 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 20.9°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.037
AMPLITUDE = 12.20°

Graphs showing:
- OMEGA x T (rads.)
- ANGLE OF ATTACK
- C_p vs. Angle of Attack
- C_m vs. Angle of Attack
- C_n vs. Angle of Attack
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14551
REYNOLDS NUMBER = 1556563.
DYNAMIC PRESSURE = 1138.94 N/m^2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.5°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER:  55221  DATE OF TEST:  14/11/91
REYNOLDS NUMBER =  1638095.  MACH NUMBER =  0.133
DYNAMIC PRESSURE =  1217.37 Nm⁻²  AIR TEMPERATURE =  21.2°C
NUMBER OF CYCLES =  10  SAMPLING FREQUENCY =  124.80 Hz.
MOTION TYPE:  VAWT FUNCTION  REDUCED FREQUENCY =  0.037
MEAN ANGLE =  0.0°  AMPLITUDE =  13.80°
OSCILLATION FREQUENCY =  0.975 Hz.
AVERAGED DATA OF 10 CYCLES
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14561
REYNOLDS NUMBER = 1555228.
DYNAMIC PRESSURE = 1138.94 N/m^2
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.7°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 17.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 55231
REYNOLDS NUMBER = 1636667.
DYNAMIC PRESSURE = 1217.37 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 21.4°C
SAMPLING FREQUENCY = 124.8 Hz.
REDUCED FREQUENCY = 0.037
AMPLITUDE = 17.40°

C_n

OMEGA x T (rads.)

C_m0

OMEGA x T (rads.)

ANGLE OF ATTACK

C_m0

ANGLE OF ATTACK

C_t

ANGLE OF ATTACK
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14571
REYNOLDS NUMBER = 1554562.
DYNAMIC PRESSURE = 1138.94 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.8°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 22.60°

Cps at LE, TE, 30°

OMEGA x T (rads.)

Cn

OMEGA x T (rads.)

ANGLE OF ATTACK

Cmα

OMEGA x T (rads.)

ANGLE OF ATTACK

Ct
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55241
REYNOLDS NUMBER = 1634528.
DYNAMIC PRESSURE = 1217.37 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 21.7°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.037
AMPLITUDE = 22.60°
DYNAIFIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14581
REYNOLDS NUMBER = 1553230.
DYNAMIC PRESSURE = 1138.94 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.0°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.038
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55251
REYNOLDS NUMBER = 1631846.
DYNAMIC PRESSURE = 1217.37 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 0.975 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 22.1°C
SAMPLING FREQUENCY = 124.80 Hz.
REDUCED FREQUENCY = 0.037
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VANT Model

RUN REFERENCE NUMBER: 14591
REYNOLDS NUMBER = 1558826.
DYNAMIC PRESSURE = 1139.29 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.0°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 5.40°

Cp at LE, TE, 30°

OMEGA x T (rads.)

OMEGA x T (rads.)

Cn

Cn

Oomega x T (rads.)

ANGLE OF ATTACK

Cmα

Cmα

Oomega x T (rads.)

ANGLE OF ATTACK

Cl

Cl
DYNAMIC CHARACTERISTICS FOR THE AHAVAII - VAWT MODEL

RUN REFERENCE NUMBER: 55261
REYNOLDS NUMBER = 1639648.
DYNAMIC PRESSURE = 1225.00 kN/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 21.7°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 5.40°

ANGLE OF ATTACK

OMEGA x T (rads.)

ANGLE OF ATTACK

OMEGA x T (rads.)

OMEGA x T (rads.)

526
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14601
REYNOLDS NUMBER = 1556820
DYNAMIC PRESSURE = 1139.29 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.3°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 10.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT MODEL

RUN REFERENCE NUMBER: 55271
REYNOLDS NUMBER: 1636085.
DYNAMIC PRESSURE = 1225.00 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 22.2°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 10.00°

\[ \text{OMEGA} \times \text{T (rads.)} \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{OMEGA} \times \text{T (rads.)} \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{Cn} \]

\[ \text{C_m0} \]

\[ \text{C_mw} \]

\[ \text{Ct} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55281
REYNOLDS NUMBER = 1631329.
DYNAMIC PRESSURE = 1225.00 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 22.8°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 12.20°
DYNAMIC CHARACTERISTICS FOR THE AHAVA W - VAWT Model

RUN REFERENCE NUMBER: 14621
REYNOLDS NUMBER = 1553484.
DYNAMIC PRESSURE = 1139.29 Pa
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.8°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14631
REYNOLDS NUMBER = 1552153.
DYNAMIC PRESSURE = 1139.29 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.0°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 17.4°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 55301
REYNOLDS NUMBER = 1626187.
DYNAMIC PRESSURE = 1225.00 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 23.6°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 17.4°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14641
REYNOLDS NUMBER = 1550825.
DYNAMIC PRESSURE = 1139.29 m/s²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.2°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 22.60°

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- Chart 1: Cn vs. Ω (rads.)
- Chart 2: Cm vs. Ω (rads.)
- Chart 3: ANGLE OF ATTACK
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55311
REYNOLDS NUMBER = 1623379.
DYNAMIC PRESSURE = 1225.00 m/s^2
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 24.0°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 22.60°

![Graphs showing dynamic characteristics](image)

Cn

OMEGA x T (rads.)

Cn

ANGLE OF ATTACK

C_m

OMEGA x T (rads.)

C_m

ANGLE OF ATTACK

C_t

OMEGA x T (rads.)

C_t
DYNAMIC CHARACTERISTICS FOR THE ANAHAVW - VAWT Model

RUN REFERENCE NUMBER: 14651
REYNOLDS NUMBER = 1550162.
DYNAMIC PRESSURE = 1139.29 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.3°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.047
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55321
REYNOLDS NUMBER = 1620581.
DYNAMIC PRESSURE = 1225.00 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.218 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.133
AIR TEMPERATURE = 24.4°C
SAMPLING FREQUENCY = 155.91 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 32.0°

Oversight in the document text:
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14661
REYNOLDS NUMBER = 1554665.
DYNAMIC PRESSURE = 1139.07 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.6°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 5.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55331
REYNOLDS NUMBER = 1611746.
DYNAMIC PRESSURE = 1205.43 N/a^2
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 23.8°C
SAMPLING FREQUENCY = 107.13 Hz.
REDUCED FREQUENCY = 0.055
AMPLITUDE = 5.40°

C_n

OMEGA x T (rads.)

ANGLE OF ATTACK

C_m

OMEGA x T (rads.)

C_p

OMEGA x T (rads.)

C_L

ANGLE OF ATTACK
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14471
REYNOLDS NUMBER = 1552667.
DYNAMIC PRESSURE = 1139.07 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 25.9°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 10.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55341
REYNOLDS NUMBER = 1608273.
DYNAMIC PRESSURE = 1205.43 Nm²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 24.3°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.055
AMPLITUDE = 10.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14681
REYNOLDS NUMBER = 1551336.
DYNAMIC PRESSURE = 1139.07 Ns⁻¹
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.1°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 12.2°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55351
REYNOLDS NUMBER = 1605504.
DYNAMIC PRESSURE = 1205.43 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 24.7°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.055
AMPLITUDE = 12.20°
DYNAMIC CHARACTERISTICS FOR THE ANHAVAN - VANT Model

RUN REFERENCE NUMBER: 14691
REYNOLDS NUMBER = 1550011.
DYNAMIC PRESSURE = 1139.07 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.3°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55361
REYNOLDS NUMBER = 1602744.
DYNAMIC PRESSURE = 1205.43 MN⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25.1°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.055
AMPLITUDE = 13.80°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14701
REYNOLDS NUMBER = 1549348.
DYNAMIC PRESSURE = 1139.07 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.4°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 17.40°

\[ \text{C}_{\text{p}}(\omega T) \]
\[ \text{C}_{\text{n}}(\omega T) \]
\[ \text{C}_{\text{m}_{\text{n}}} \]
\[ \text{C}_{\text{m}_{\text{u}}} \]
\[ \text{C}_{\text{t}} \]

\[ \text{OMEGA x T (rads.)} \]
\[ \text{OMEGA x T (rads.)} \]
\[ \text{OMEGA x T (rads.)} \]

\[ \text{ANGLE OF ATTACK} \]
\[ \text{ANGLE OF ATTACK} \]

\[ \text{x/c} \]
\[ \text{alpha} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55371
REYNOLDS NUMBER = 1599993.
DYNAMIC PRESSURE = 1205.43 Nm^-2
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25.5°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.055
AMPLITUDE = 17.40°

\[ \text{OMEGA x T (rads.)} \]

\[ \text{C_n} \]

\[ \text{C_m(a) - 0.2} \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{C_m} \]

\[ \text{C_t} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 14711
REYNOLDS NUMBER = 1540024.
DYNAMIC PRESSURE = 1139.07 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 3.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.6°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 22.60°
CD in n^i &

DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAMT Model

RUN NUMBER: 55311
REYNOLDS NUMBER = 1,894,950
DYNAMIC FREQUENCY = 1,605.4 Hz
NUMBER OF CYCLES = 10
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1,462 Hz
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25°C
REDUCED FREQUENCY = 0.035
AMPLITUDE = 22.6°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VANT Model

RUN REFERENCE NUMBER: 14721
REYNOLDS NUMBER = 1546702.

DYNAMIC PRESSURE = 1139.07 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00º
OSCILLATION FREQUENCY = 1.462 Hz.

AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.129
AIR TEMPERATURE = 26.8°C
SAMPLING FREQUENCY = 187.13 Hz.
REDUCED FREQUENCY = 0.057
AMPLITUDE = 32.00º

\[
\begin{align*}
\text{C}_n & = 2.0 \\
\text{C}_m & = 0.2 \\
\text{C}_\alpha & = 0.0 \\
\text{C}_t & = 0.2
\end{align*}
\]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55391
REYNOLDS NUMBER = 1596568.
DYNAMIC PRESSURE = 1205.43 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.462 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 26.0°C
SAMPLING FREQUENCY = 107.13 Hz.
REDUCED FREQUENCY = 0.055
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14731
REYNOLDS NUMBER = 1547059.
DYNAMIC PRESSURE = 1131.83 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 55401
REYNOLDS NUMBER = 1609922
DYNAMIC PRESSURE = 1207.90 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 24.3°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.069
AMPLITUDE = 5.40°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14741
REYNOLDS NUMBER = 1545074.
DYNAMIC PRESSURE = 1131.83 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.128
AIR TEMPERATURE = 26.3°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.071
AMPLITUDE = 10.00°

\[ C_D \]
\[ U_3 \]
\[ n \]
\[ \omega \]
\[ I \]
\[ TISNY \]
\[ d \]
\[ in \]
\[ b0ih \]
\[ c\]
\[ 0 \]
\[ « \]
\[ M \]
\[ W \]
\[ g \]
\[ CD \]
\[ r- \]
\[ LD \]
\[ in \]
\[ ^ \]

\[ \text{Cp at LE,TE, 30°} \]

\[ OMEGA x T (rads.) \]

\[ ANGLE OF ATTACK \]

\[ OMEGA x T (rads.) \]

\[ ANGLE OF ATTACK \]

\[ OMEGA x T (rads.) \]

\[ ANGLE OF ATTACK \]

\[ OMEGA x T (rads.) \]

\[ ANGLE OF ATTACK \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55411
REYNOLDS NUMBER = 1664659.
DYNAMIC PRESSURE = 1207.90 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 24.8°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.069
AMPLITUDE = 10.00°

C_n

OMEGA x T (rads.)

ANGLER OF ATTACK

C_m

OMEGA x T (rads.)

ANGLE OF ATTACK

C_r

OMEGA x T (rads.)

541
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14751
REYNOLDS NUMBER = 1543753.
DYNAMIC PRESSURE = 1131.83 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.128
AIR TEMPERATURE = 26.5°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.071
AMPLITUDE = 12.20°

\[ C_n x T \text{ (rads.)} \]

\[ \text{C}_{m0} x T \text{ (rads.)} \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{ANGLE OF ATTACK} \]

\[ \text{ANGLE OF ATTACK} \]
DYNAMIC CHARACTERISTICS FOR THE AHAVAM - VAWT Model

RUN REFERENCE NUMBER: 55421
REYNOLDS NUMBER = 1604387.
DYNAMIC PRESSURE = 1207.90 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.027 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25.1°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.069
AMPLITUDE = 12.20°

Graphs showing OMEGA x T (rads.) and Cp at LE, KE, 30°.
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VANT Model

RUN REFERENCE NUMBER: 14761
REYNOLDS NUMBER = 1542434.
DYNAMIC PRESSURE = 1131.83 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.128
AIR TEMPERATURE = 26.7°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.071
AMPLITUDE = 13.80°

Cp Vs Alpha

Cp at LE, TE, 30°

Omega x T (rads.)

Cn

Omega x T (rads.)

Angle of Attack

Cmwy

Omega x T (rads.)

Angle of Attack
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55431
REYNOLDS NUMBER = 1602322.
DYNAMIC PRESSURE = 1207.90 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 25.4°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.069
AMPLITUDE = 13.80°

\begin{align*}
C_T & = 0.02 \\
C_L & = 0.12 \\
C_D & = 0.05 \\
C_M & = 0.00 \\
C_N & = 0.01
\end{align*}

\begin{align*}
\text{ANGLE} & \text{ VERSUS AZIMUTH} \\
\text{OMEGA} \times T \text{ (rads.)} & \text{ Cps at LE, TE, 30%}
\end{align*}
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14771
REYNOLDS NUMBER = 1541776.
DYNAMIC PRESSURE = 1131.83 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.126
AIR TEMPERATURE = 26.8°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.071
AMPLITUDE = 17.40°

Cn vs. Omega x T (rads.)

Angie OF ATTACK

Cmp at LE, TE, 30°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14781
REYNOLDS NUMBER = 1540460.
DYNAMIC PRESSURE = 1131.83 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.128
AIR TEMPERATURE = 27.0°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.071
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 14791
REYNOLDS NUMBER = 1539147.
DYNAMIC PRESSURE = 1131.83 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 12/11/91
MACH NUMBER = 0.128
AIR TEMPERATURE = 27.2°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.071
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55461
REYNOLDS NUMBER = 1597520.
DYNAMIC PRESSURE = 1207.90 Nm$^{-2}$
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 14/11/91
MACH NUMBER = 0.132
AIR TEMPERATURE = 26.1°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.069
AMPLITUDE = 32.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVA - VAWT Model

RUN REFERENCE NUMBER: 815671
REYNOLDS NUMBER = 1486123.
DYNAMIC PRESSURE = 978.49 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 4/1/92
MACH NUMBER = 0.118
AIR TEMPERATURE = 21.7°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.078
AMPLITUDE = 5.4°

Cp vs. t (rads.)

Cn

ANGLE OF ATTACK

OMEGA x T (rads.)

ANGLE OF ATTACK

OMEGA x T (rads.)

Cm

x/c

alpha

567
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 915561
REYNOLDS NUMBER = 1484184.
DYNAMIC PRESSURE = 978.49 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.0°
OCCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 4/1/92
MACH NUMBER = 0.118
AIR TEMPERATURE = 22.0°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.078
AMPLITUDE = 10.0°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 815691
REYNOLDS NUMBER = 1482894.
DYNAMIC PRESSURE = 978.49 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 4/1/92
MACH NUMBER = 0.130
AIR TEMPERATURE = 22.2°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.078
AMPLITUDE = 12.20°
Dynamic Characteristics for the Ahava - VAWT Model

Run Reference Number: 815701
Reynolds Number = 1482250
Dynamic Pressure = 978.49 N/m²
Number of Cycles = 10
Motion Type: Sinusoidal
Mean Angle = 0.00°
Oscillation Frequency = 1.827 Hz.
Averaged Data of 10 Cycles

Date of Test: 4/1/92
Mach Number = 0.118
Air Temperature = 22.3°C
Sampling Frequency = 233.86 Hz.
Reduced Frequency = 0.078
Amplitude = 13.8°

Cps at LE, TE, 30°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 815711
REYNOLDS NUMBER = 1480563.
DYNAMIC PRESSURE = 978.49 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 4/1/92
MACH NUMBER = 0.116
AIR TEMPERATURE = 22.5°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.078
AMPLITUDE = 17.40°

Cn x T (rads.)

OMEGA x T (rads.)

Cp at LE, TE, 30°

OMEGA x T (rads.)

ANGLE OF ATTACK

Cn

OMEGA x T (rads.)

ANGLE OF ATTACK

Ct
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 815721
REYNOLDS NUMBER = 1479037.
DYNAMIC PRESSURE = 978.49 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: SINUSOIDAL
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.827 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 4/1/92
MACH NUMBER = 0.118
AIR TEMPERATURE = 22.8°C
SAMPLING FREQUENCY = 233.86 Hz.
REDUCED FREQUENCY = 0.078
AMPLITUDE = 22.60°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55452
REYNOLDS NUMBER = 2002221.
DYNAMIC PRESSURE = 1661.37 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.36 Hz
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 10/12/91
MASS NUMBER = 0.152
AIR TEMPERATURE = 15.5°C
SAMPLING FREQUENCY = 174.69 Hz
REDUCED FREQUENCY = 0.035
AMPLITUDE = 12.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAW - VAWT Model

RUN REFERENCE NUMBER: 55492
REYNOLDS NUMBER = 1989011
DYNAMIC PRESSURE = 1646.84 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.360 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 10/12/91
MACH NUMBER = 0.152
AIR TEMPERATURE = 16.0°C
SAMPLING FREQUENCY = 174.09 Hz.
REDUCED FREQUENCY = 0.045
AMPLITUDE = 12.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAV - VAWT Model

RUN REFERENCE NUMBER: 55502
REYNOLDS NUMBER = 1976699.
DYNAMIC PRESSURE = 1648.33 N/m²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.0°
OSCILLATION FREQUENCY = 1.360 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 10/12/91
MACH NUMBER = 0.152
AIR TEMPERATURE = 17.5°C
SAMPLING FREQUENCY = 174.09 Hz.
REDUCED FREQUENCY = 0.045
AMPLITUDE = 20.0°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN REFERENCE NUMBER: 55512
REYNOLDS NUMBER = 1973912.
DYNAMIC PRESSURE = 1658.28 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.360 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 10/12/91
MACH NUMBER = 0.152
AIR TEMPERATURE = 18.5°C
SAMPLING FREQUENCY = 174.09 Hz.
REDUCED FREQUENCY = 0.045
AMPLITUDE = 20.00°
DYNAMIC CHARACTERISTICS FOR THE AHAVAN - VAWT Model

RUN NUMBER: 55531
REYNOLDS NUMBER = 1944123.
DYNAMIC PRESSURE = 1604.03 Nm⁻²
NUMBER OF CYCLES = 10
MOTION TYPE: VAWT FUNCTION
MEAN ANGLE = 0.00°
OSCILLATION FREQUENCY = 1.360 Hz.
AVERAGED DATA OF 10 CYCLES

DATE OF TEST: 29/1/92
MACH NUMBER = 0.149
AIR TEMPERATURE = 19.5°C
SAMPLING FREQUENCY = 174.09 Hz.
REDUCED FREQUENCY = 0.046
AMPLITUDE = 30.00°

\[ \Omega \times T \text{ (rads.)} \]

\[ C_n \]

\[ C_{m\alpha} \]

\[ C_{t} \]