Effects of Vehicle Weight and True Versus Indicated Airspeed on BVI Noise During Steady Descending Flight

Presented by:

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Motivation

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Background
- Motivation
- Analysis Technique

Experiment Description
- Vehicle Characteristics
- Flight Conditions

Results
- BVI Extraction vs BVISPL
- Average BVI
- BVI Standard Deviation

Conclusions

High-Speed Impulsive

Thickness

Tail Rotor

Blade Vortex Interaction

Loading
Aerodynamics Affecting BVI Noise

– Inflow
– Blade Loading
– Advance Ratio

Flight Test Uncertainties

– Inconsistent Vehicle Flight Path
– Inconsistent Vehicle Velocity
– Atmospheric Effects (Wind, Temperature, Etc.)
– Blade-Blade Variations
– Variable Weight (Fuel burn)


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Wavelet Transform

\[ \tilde{p}(l, t) = \frac{1}{\sqrt{l}} \int_{-\infty}^{\infty} p(t') \psi_w^*(\frac{t' - t}{l}) dt' \]

Morlet Wavelet

\[ \hat{\psi}_M(l \omega, \omega_\psi) = \sqrt{\frac{2\pi l}{N}} \pi^{-\frac{1}{4}} H(\omega) e^{-(l \omega - \omega_\psi)^2 / 2} \]

Wavelet Energy

\[ E(f, t) = \frac{1}{C_\psi} \frac{|\tilde{p}(f, t)|^2}{l^2} \]

Inverse Wavelet Transform

\[ p(t') = \frac{1}{C_\psi} \int_{-\infty}^{\infty} \int_{l}^{\infty} \tilde{p}(l', t) \psi_w(\frac{t' - t}{l'}) \frac{dl'}{l'2} \text{dt} \]
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**BVI Filter**

\[
\tilde{p}(f_j, t_i) = \begin{cases} 
\tilde{p}(f_j, t_i) & \text{if } f_j > f_{cut} \text{ and } E(f_j, t_i) > E(f_{MR}, t_i) - A_{cut} \\
0 & \text{otherwise}
\end{cases}
\]

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**Analysis Technique**

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• (28) Wireless Acoustic Microphone Systems
  ½” B&K 4189 – 25 kHz sampling
  15” Diameter ground board
  GPS Receiver

• Weather Systems
  – Tethered Weather Balloon
    • Weather Sonde (200’)
    • (up to 4) Temperature, Humidity, Pressure Sensors (~50’)
  – ZephIR 300 LIDAR System
    • Wind velocity at 12 altitudes up to 1000’
  – (5) Ground Weather Stations
    • Located near Mics 1,11,21,24,27
Vehicle Characteristics

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- Aircraft Navigation and Tracking System (ANTS) (20 Hz sampling)
  - GPS Receiver
  - Inertial Navigation Data

- Air-Data Boom (5 Hz)
  - Outside Air Temperature
  - Static and Dynamic Pressures
  - Wind Velocities

<table>
<thead>
<tr>
<th></th>
<th>MR</th>
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<tbody>
<tr>
<td>Number of Blades</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Radius (R)</td>
<td>10.69</td>
<td>1.86 [m]</td>
</tr>
<tr>
<td>Blade Pass Frequency (f)</td>
<td>19.5</td>
<td>104 [Hz]</td>
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6° Descent Condition

<table>
<thead>
<tr>
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<th>KIAS</th>
<th>KTAS</th>
<th>Nom.</th>
<th>Takeoff Wgt</th>
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<td>80 KIAS</td>
<td>80</td>
<td>87 (Typ)</td>
<td>11</td>
<td>13</td>
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<tr>
<td>80 KTAS</td>
<td>73 (Typ)</td>
<td>80</td>
<td>12</td>
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</table>
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\[ f_{cut} = 11 f_{MR} \]

\[ A_{cut} = -6 \text{ [dB]} \]
Results

Guides to阅读文本

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\[ f_{cut} = 11 \ f_{MR} \quad A_{cut} = -6 \ [\text{dB}] \]
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\[ f_{cut} = 11 \, f_{MR} \quad \text{and} \quad A_{cut} = -6 \, [\text{dB}] \]
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\[ \Delta W_{\text{nom}} = 11\% \rightarrow -1.5 \text{ Pa} \approx 1.0 \text{ dB} \]
\[ \Delta W_{\text{max}} = 17\% \rightarrow -2.4 \text{ Pa} \approx 1.3 \text{ dB} \]

\[ \alpha_{\text{TPP}} = - \frac{D}{W} - \gamma? \]
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Average BVI

80 KTAS (~73 KIAS)

Peak to Peak [Pa]

4400 lb
(12 Runs)

\[ \Delta W_{nom} = 11\% \rightarrow -1.5 \text{ Pa} \approx 1.0 \text{ dB} \]

\[ \Delta W_{max} = 17\% \rightarrow -2.4 \text{ Pa} \approx 1.3 \text{ dB} \]

\[ \alpha_{TPP} = -\frac{D}{W} - \gamma \]
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• BVI noise can be **strongly** affected by weight
  – Vortex Strength + Tip-Path Plane?

• BVI noise highly variable
  – Up to 50% of normalized standard deviation
  – Can be used to identify secondary BVI events
Acknowledgements

- Mike Watts
- David Conner
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- Andrew McCrae
- Nikolas Zawodny
- Aris Helicopters
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