Modes of Vibration of Air-driven Free Reeds in Transient and Steady State Oscillation

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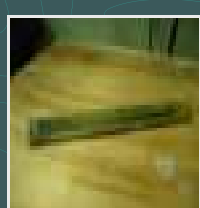
Background



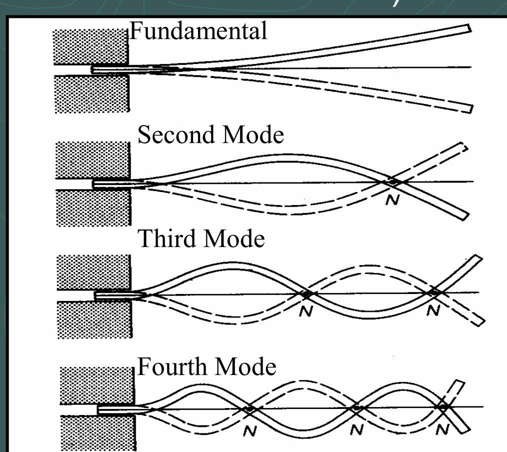
- Research done in the summer of 2002 by Blake Dirksen on mechanically driven reeds observed and identified modes of vibration, primarily higher transverse modes and torsional modes [Ref 2].
- Spectra from earlier research done in 1998 by Christopher Reed show the second transverse mode of vibration in air-driven reeds, primarily blown at higher pressures, and hint at the presence of torsional modes [Ref 3].

Current Research

- Using instruments to measure the vibrational response of the reed we have collected data on the motion of air-driven free-reeds of the type used in the American reed organ.
- At least the first three transverse modes and the first torsional mode are present and can be detected when an organ reed is played.
- There is evidence of the second mode and first torsional mode in transient waveforms

Modes of Vibration

- An organ reed can be modeled as a cantilever beam (though the reed cross section is not uniform).



- Modes of vibration observed include the fundamental, second, and third transverse modes, and the first torsional mode.

How to Observe Reed Motion

- Reeds are placed on a wind chest in which the pressure difference could be controlled by a variable transformer and an air supply.
- For measurements of transients a valve was constructed to simulate the operation of an American reed organ.

- Steady-state and transient waveforms and spectra are collected with a Fast Fourier Transform Spectrum Analyzer (FFT). Waveforms are further analyzed in computational programs like *Igor Pro*

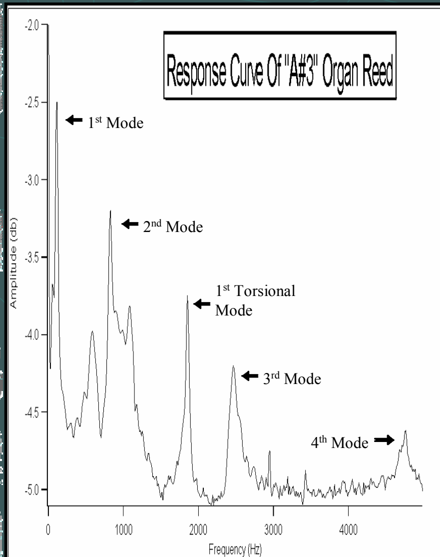
How to Observe Modes of Reed Vibration

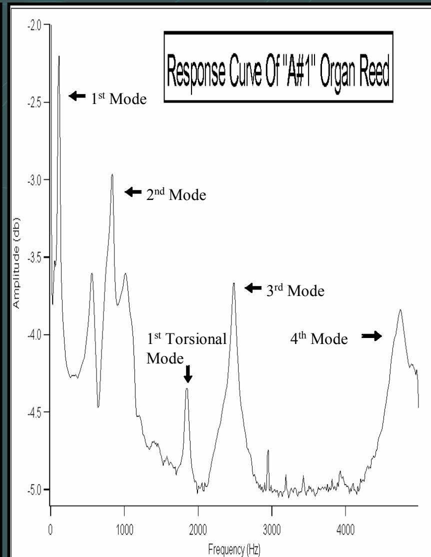
- **Reed Motion was measured along the reed tongue with:**
  - A Variable Impedance Transducer (VIT) sensor is a proximity sensor that outputs a voltage proportional to the distance from a conductor (the reed tongue).
  - A Laser Vibrometer uses the Doppler shift of light to accurately measure the velocities of reflective surfaces.

- Response Curves
  - To obtain a response curve a mechanical vibrator is positioned to vibrate the reed. A Function Generator makes a sweep of excitation frequencies.
  - An Oscilloscope and function generator set up to produce Lissajous Figures will accurately measure the frequencies of predicted modes.

Response Curves (Finding Mode Frequencies):

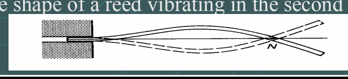
• One way to confirm the presence of modes of vibration is by comparing air-driven reed spectra to response curves generated with a mechanical oscillator.

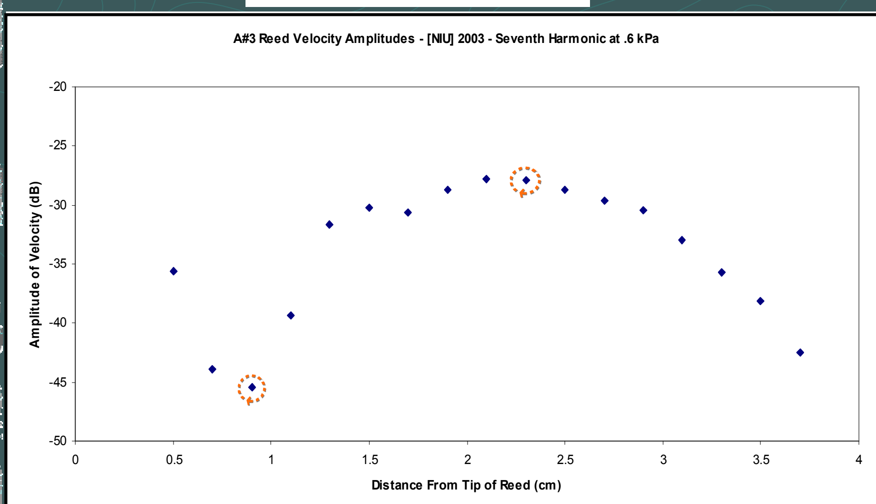




Second Transverse Mode in Air-Driven Reeds:

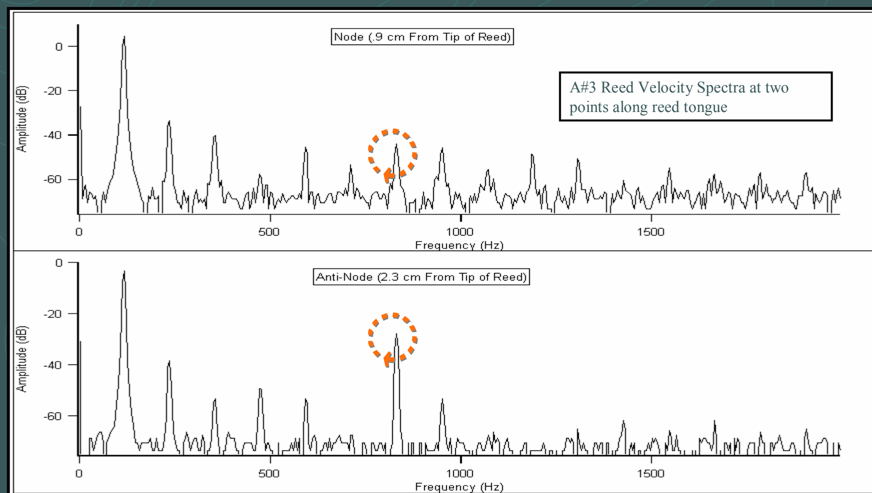
•Velocity spectra from the Laser Vibrometer give the peak amplitudes of the second mode frequency taken at points along the reed tongue. Highlighted are points near a node and anti-node on the reed to illustrate the shape of a reed vibrating in the second transverse mode.



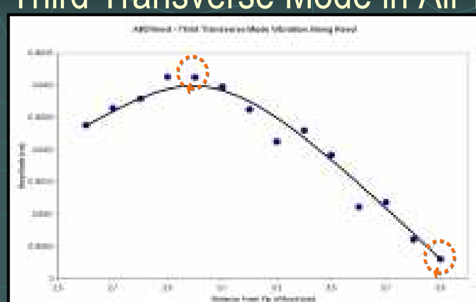


Spectra of Second Mode in Air-Driven Reeds:

•Typical reed spectra show a large fundamental frequency and its harmonics. These spectra show the presence of the second transverse mode frequency at its anti-node and its absence at the node.

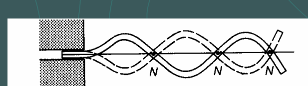


Third Transverse Mode in Air-Driven Reeds:

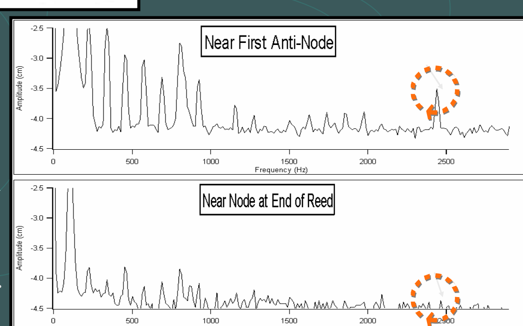


•The third transverse mode frequency appears on reed motion spectra, and is also verified by looking at nodes and antinodes.

•Amplitudes of vibration of the third mode are measured along the reed with the VIT

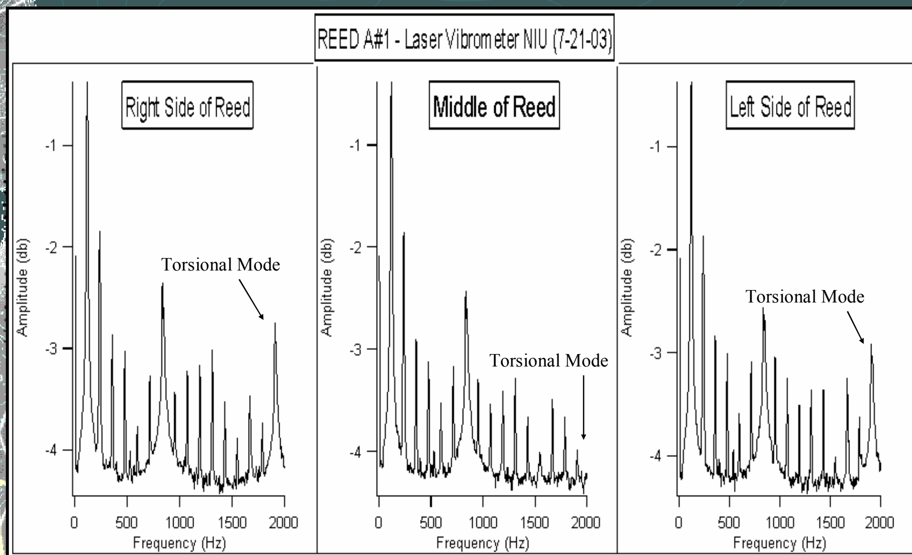


•The spectra near the clamped end and near an anti-node show the expected presence and absence of the third mode.



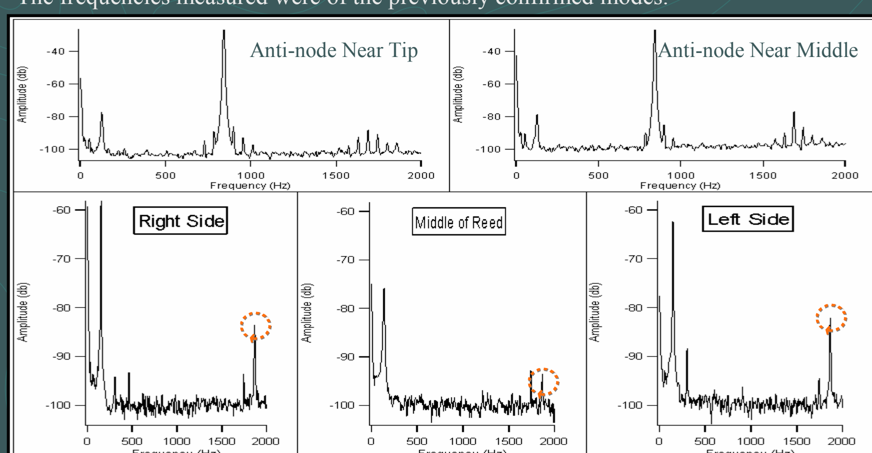
Torsional Modes in Air-Driven Reeds:

- Torsional modes are determined by comparing frequencies and by looking for nodes.
- The amplitude of the mode frequency is large at points measured near the edges of the reed and absent in the middle, at the node of its vibration.



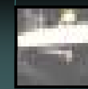
Induced Modes:

- After finding nodes for different modes of vibration we were able to induce specific modes of vibration in air-driven reeds being played on the windchest.
- The frequencies measured were of the previously confirmed modes.



- These modes were produced by suppressing other modes of vibration, much like producing a harmonic on a stringed instrument.

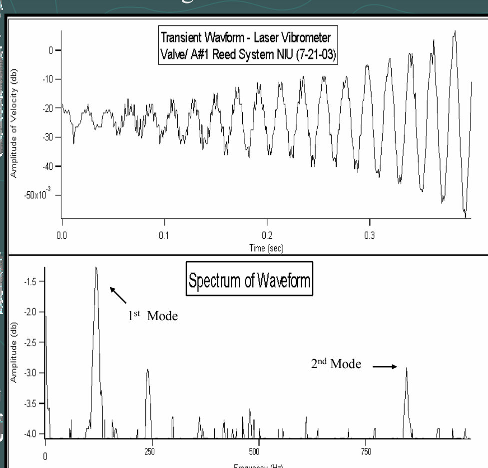
Attack Transients

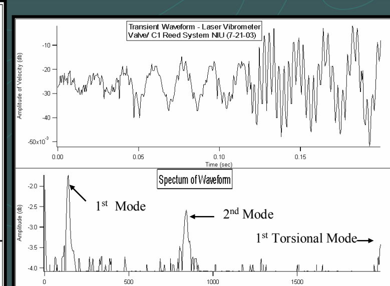


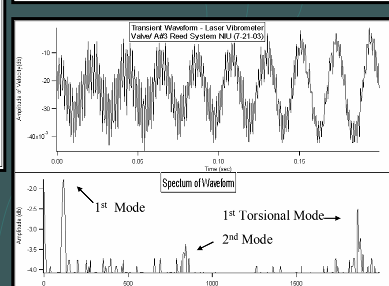
- The period in which the reed transitions from no vibration to steady-state, playing motion was analyzed.
- A valve was constructed to simulate the effect of pressing a key on an organ.
- Reed motion during transient periods was measured with the Laser Vibrometer and the VIT.
- The instantaneous spectra of these waveforms was analyzed to confirm the presence of modes of vibration, and the second and first torsional modes were confirmed frequently.

Attack Transients of Reed Motion:

•Obtained using the Laser Vibrometer to measure reed velocity.







•The second mode is present in the flat A# and C reeds, and less in the curved A# reed which in turn shows a large torsional mode.

Acknowledgments

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