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PHONONIC DISPERSION COUPLING AS FLOWMETER

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Abstract: Flow sensors are common features on the exterior of flight vehicles; however, for vehicles that face reentry or other harsh flight environments, a simple pitot tube may not survive with uninterrupted functionality. We present a method to employ interior sensors to the problem of detecting flow velocity in harsh environments by examining the excitation of A_0 modes of an instrumented test plate.

Introduction:

- Exterior sensors such as pitot tubes are vulnerable to harsh flow conditions.
- Knowledge of flow velocity is desirable for flight control and navigation
- What if this information could be obtained from internal sensors based on vibration information?

COMSOL 2-D Solid Mechanics Simulation:

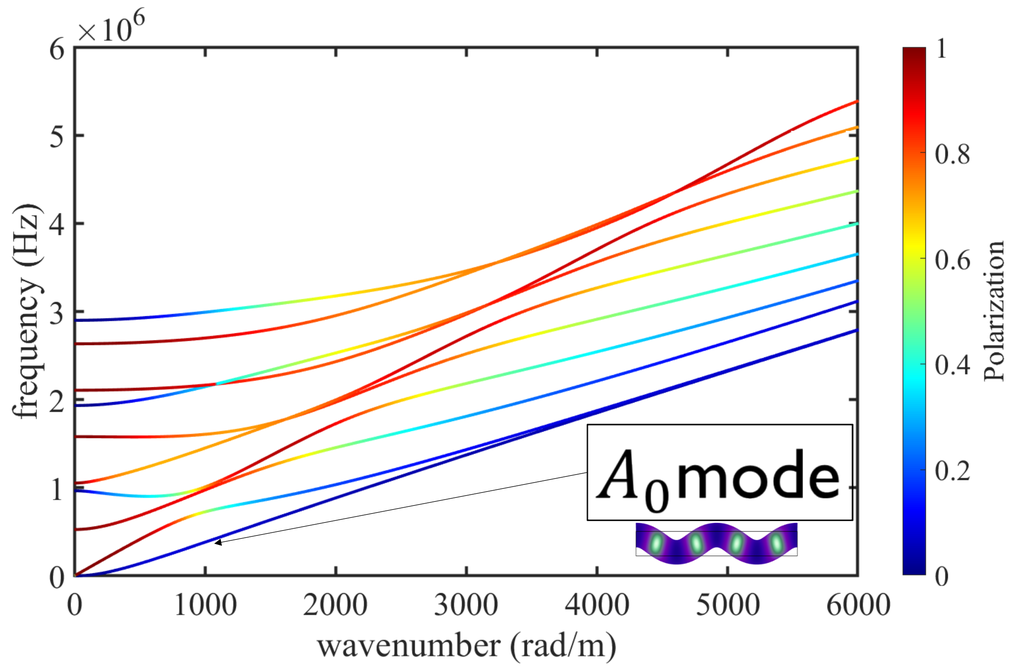
- 2-m x 3-mm steel plate with an imposed boundary load (top) with phase $-\frac{2\pi f x}{c_{air}} = -kx$ to simulate a rightward propagating boundary load
- Low-reflective boundary conditions on the left and right sides
- Displacement response evaluated along a cut line adjacent to the lower surface

MATLAB Post processing:

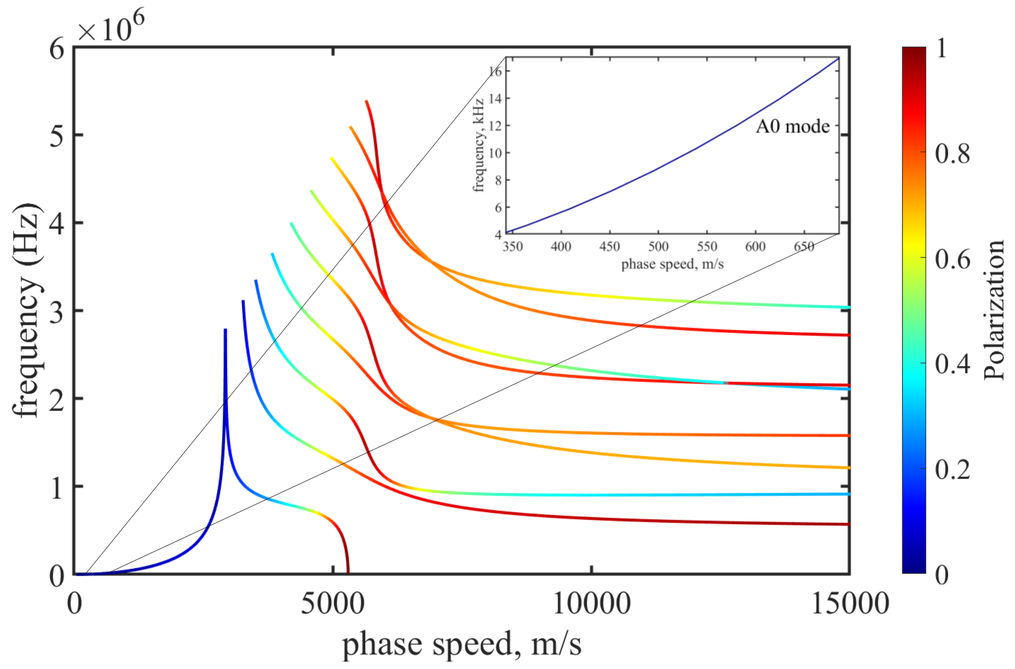
- Displacement across position is transformed for each frequency and velocity to obtain wavenumber spectra
- Hann window used to limit leakage
- Under 2,923 m/s, only A_0 mode is present → exactly one frequency couples best at each velocity
- Two wavenumber peaks are visible in each case: those associated with the A_0 mode and the boundary load

Conclusions/Consequences:

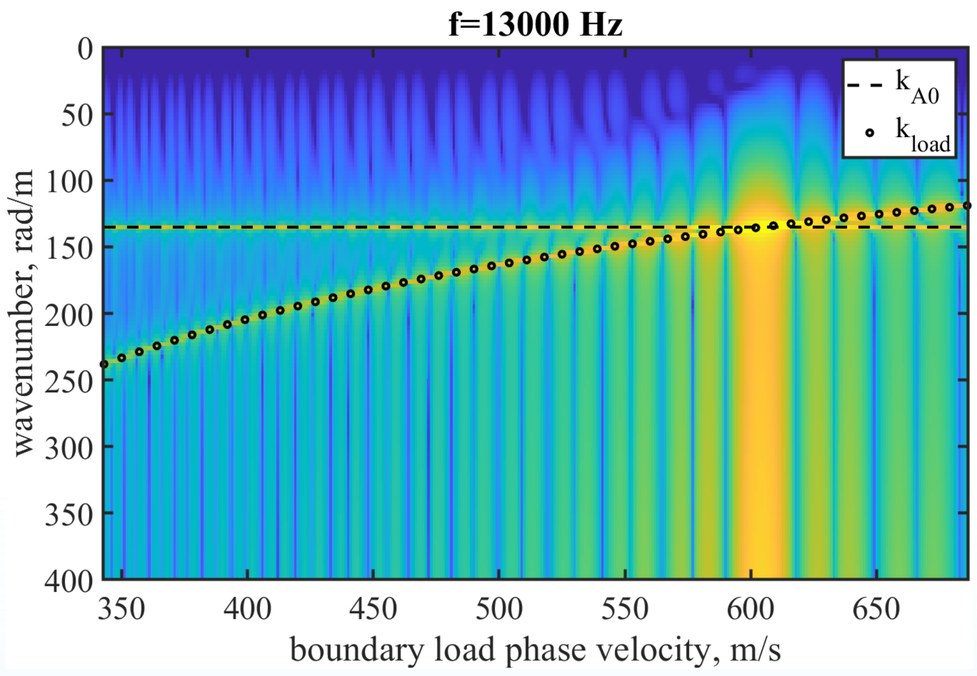
- By evaluating the peak of the spectrum the phase velocity of boundary loads can be determined
- Preliminary simulations suggest appropriate ***internal*** sensor arrays could be used to evaluate flow velocity in harsh environments!



- Dispersion (band structure) calculation for a 3-mm thick steel plate allows prediction of frequency as a function of wavenumber and mode



- Phase speed is determined from band structure
- A0 is the only mode affecting lower velocities



- The wavenumber spectrum reflects a combination of the A0 mode wavenumber and the boundary load wavenumber.
- The boundary load wavenumber can be used to determine convective velocity of the loads.
- Largest amplitudes result when $k_{A_0} = k_{load}$

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