Data processing – directional and modal filtering

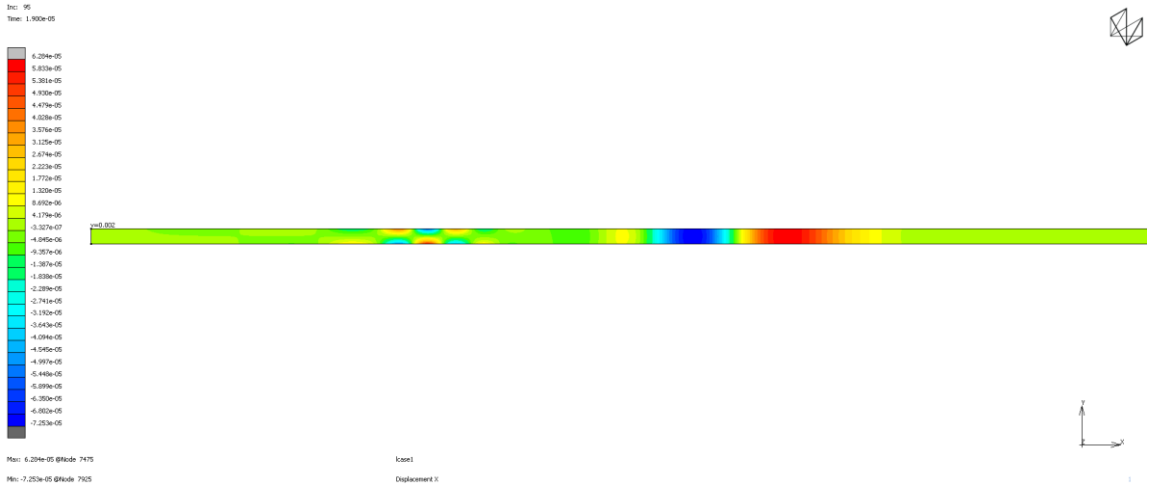
The laboratory's current research agenda prioritizes the development and implementation of directional and modal filters for the analysis of measured data. A solid understanding of the methods and techniques from previous classes on efficiently running simple transient simulations is essential.

A virtual experiment should be conducted, and measurement data should be collected using the MSC.Marc program or an alternative program deemed appropriate.

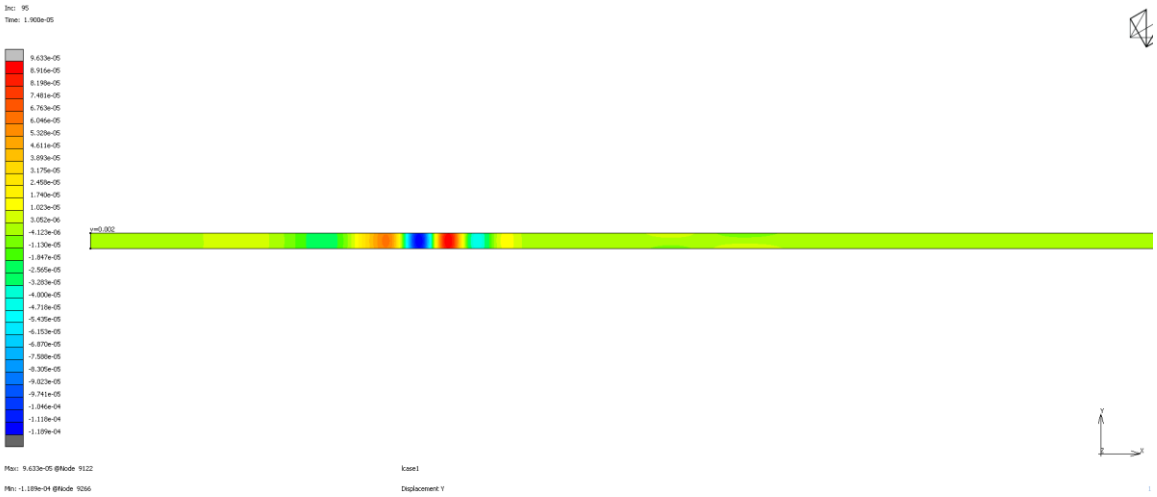
Test case no. 1

1. Create a 2D rectangular plate (***Planar analysis***) with dimensions of **300 x 2 mm**. Discretize your model using square quadrilateral elements (***Quad 4***). Use 8 elements to discretize the plate thickness. Specify the material properties for aluminum.
2. Apply an in-plane **(X)** excitation signal (***Point Load***) to the upper left corner. The signal should have a center frequency of 300 kHz, a sampling frequency of 10 MHz, and consist of one cycle. Multiply the sine wave by a Hanning window to mitigate discontinuities.
3. Create a ***Dynamic Transient*** load case and run your simulation for **0.1 ms** with a constant time step of **0.2 µs**.
4. Once the simulation is finished, compare elastic wave propagation in **out-of-plane (Y)** and **in-plane (X)** directions.

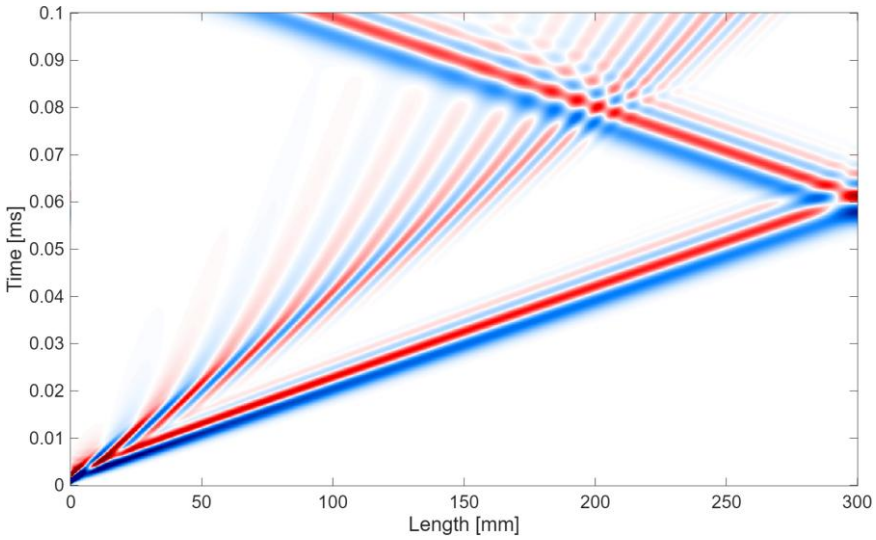
In-plane



Out-of-plane



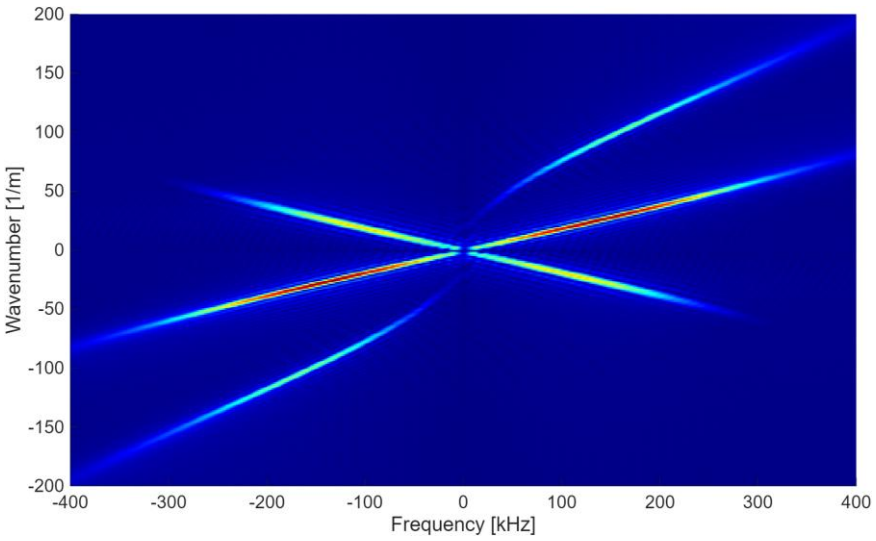
5. Collect wave motion data in the in-plane direction from the top surface of the model. Import the data into a .TXT file and plot it in MATLAB as a 2D map (space vs time). Sample results for particle displacement measured in the in-plane direction (Displacement X) are shown in the figure below.



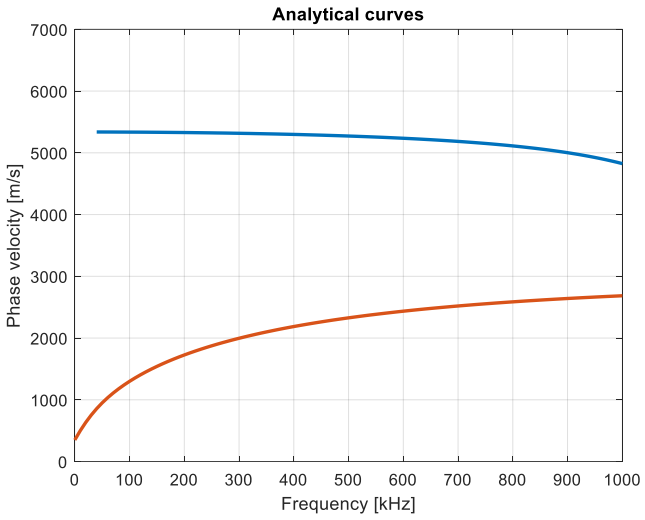
6. Based on the 2D wave motion data calculate dispersion curves using the following formula

$$U(k,f) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} u(x,t) e^{i(2\pi f t - kx)} dx dt$$

The final dispersion curves, ***U(k,f)***, for displacement X should resemble the figure below.

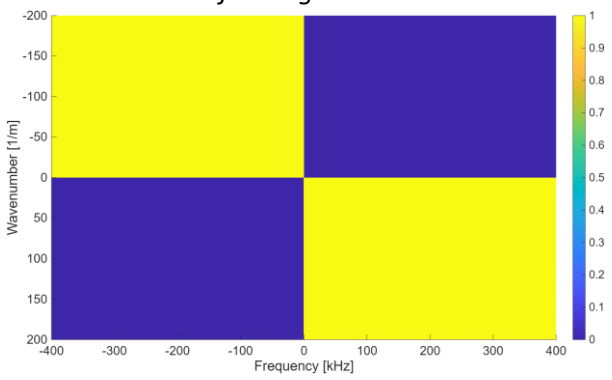


7. Based on the wavenumber-frequency plot, calculate the Lamb wave phase velocity for visible modes. Validate your results with analytical dispersion curves presented below.

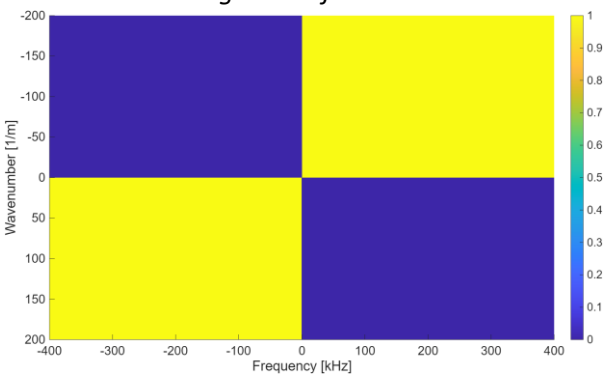


8. In the frequency domain, construct a direction filter (mask, which we can call ***m(k,f)***) to filter out left-to-right and right-to-left waves.

left-to-right mask



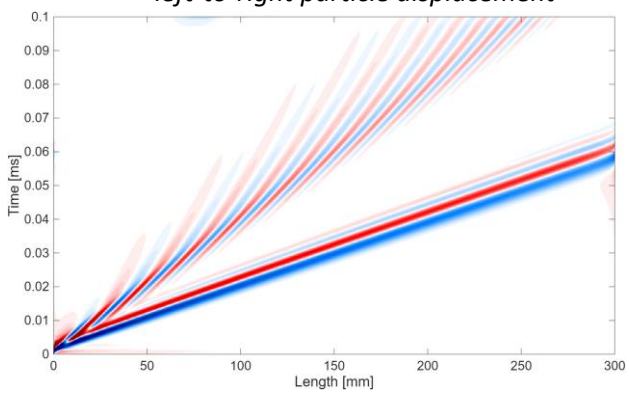
right-to-left mask



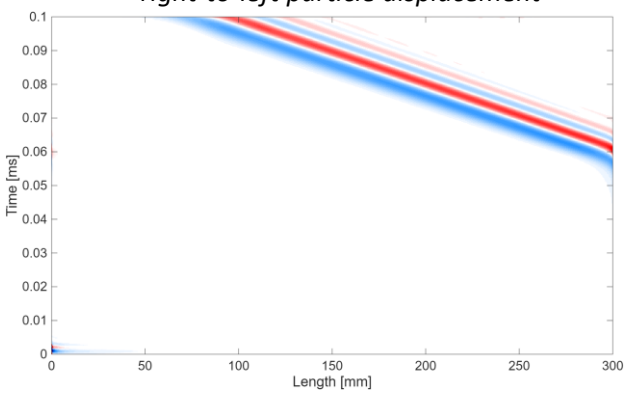
U'(k,f) = U(k,f) * m(k,f)

The resulting displacement profile after filtering should resemble the following:

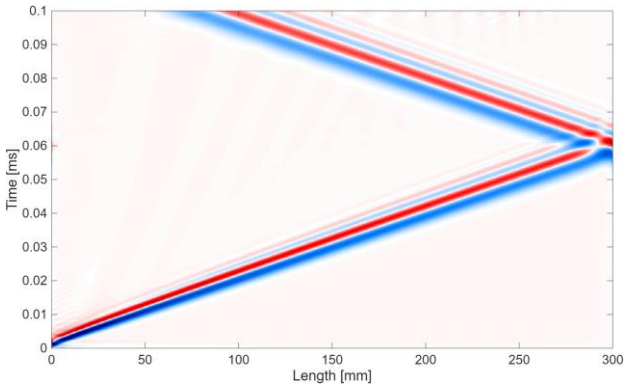
left-to-right particle displacement

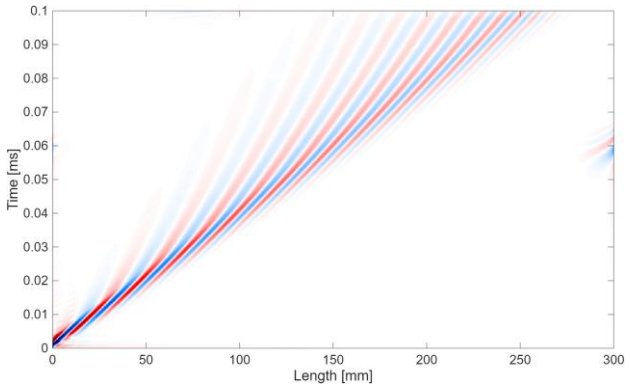


right-to-left particle displacement



9. Design a filter in the frequency domain that eliminates one of the wave modes (symmetric or antisymmetric), as shown below.





10. Calculate similar dispersion curves for particle displacement measured out-of-plane *(Displacement Y)*. What are the differences between *Displacement X* and *Displacement Y*? Name the appropriate wave modes.