5-2001

Numerical Modeling of the Damping Effect of Fibrous Acoustical Treatments

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The Use of Poro-elastic Finite Elements to Model Fibrous Acoustical Treatments

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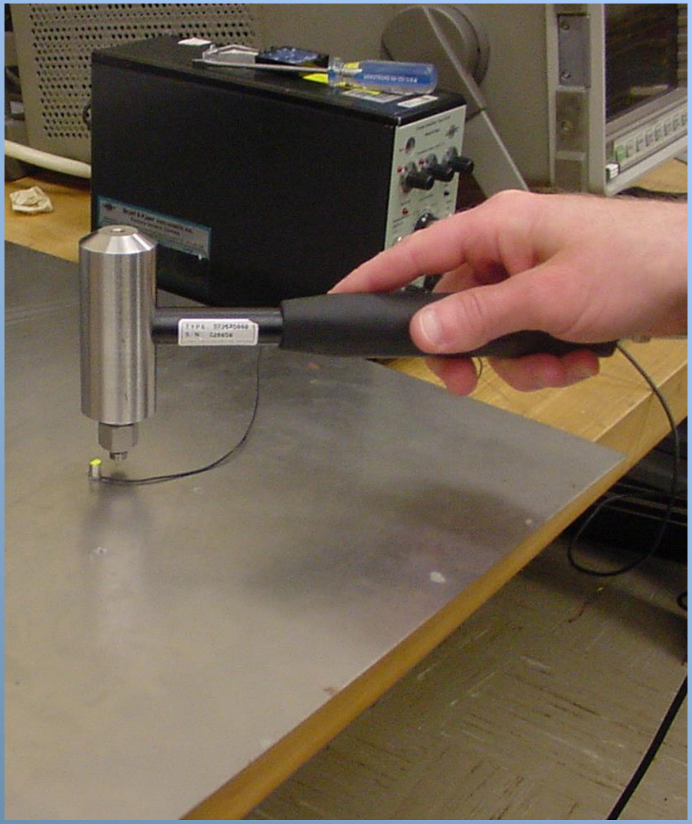
Introduction

- Modeling **structural damping** behavior.
- Comparison of three computational methods:
  - Poro-elastic FEA - Biot theory.
  - Equivalent fluid FEA - Limp mass formulation.
  - Modal expansion method - Limp mass.
- Based on Noise-Con 98 paper by Bolton, Lai, Gardner, et al.

Background

- Acoustic treatment is Thinsulate Acoustic Insulation (TAI), a fibrous material which provides both absorption and damping.
- Thinsulate Acoustic Insulation entered the automotive market in 1995.

Background - damping test



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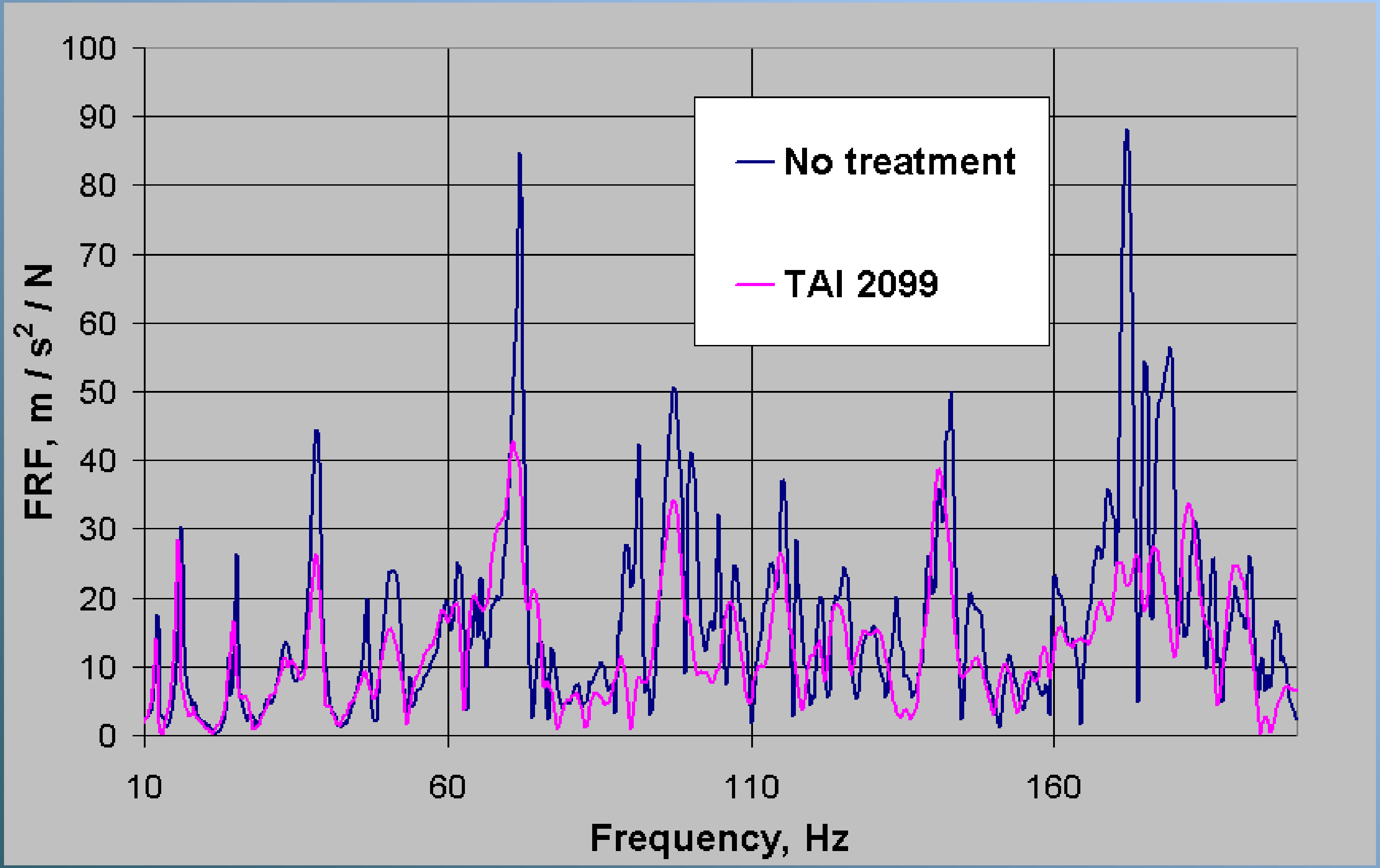
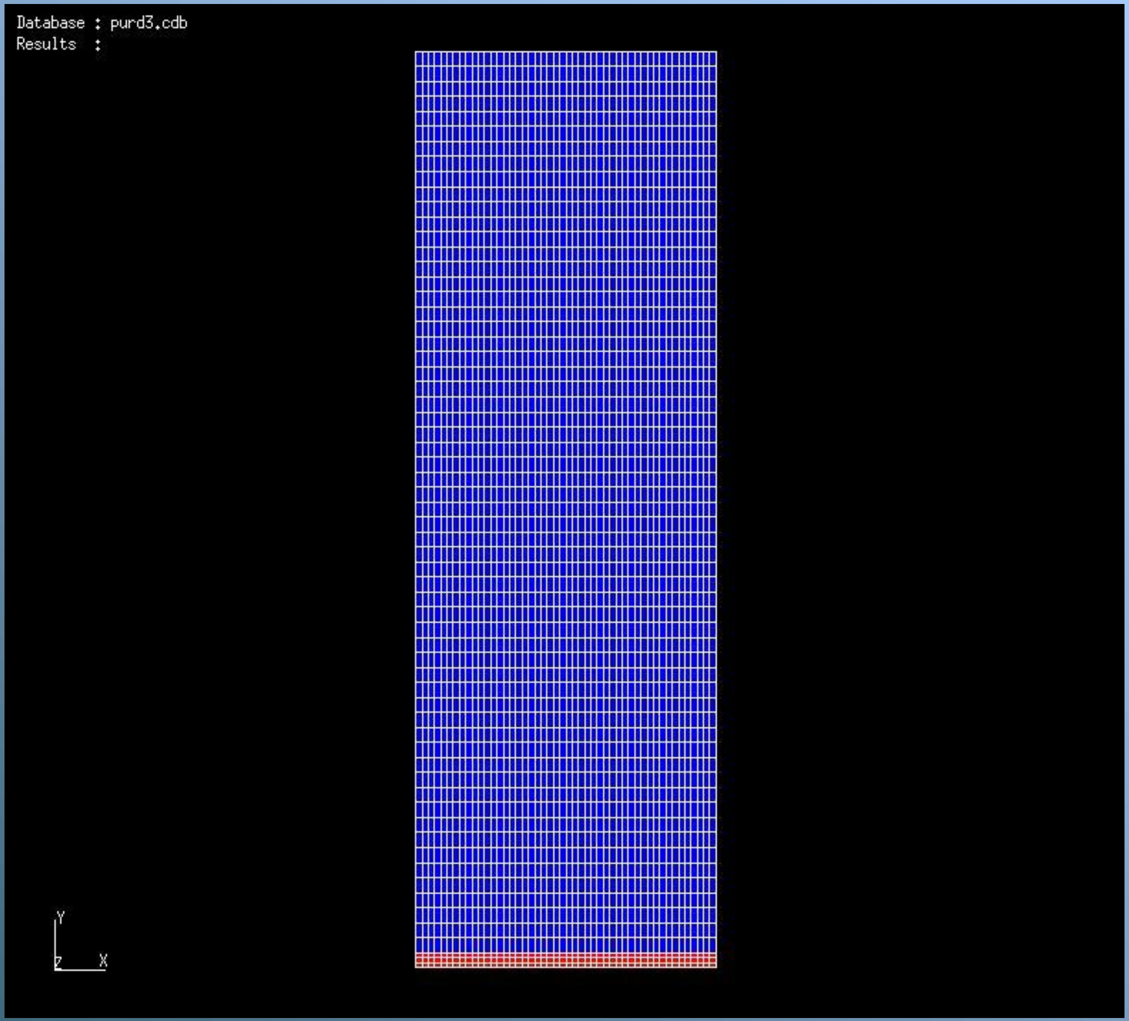
Background - test data



Analysis methods

- 3M commissioned Purdue University to study fibrous acoustical treatments.
- Modal expansion procedure was used at Purdue.
- Comet / Safe, a commercially available poro-elastic FEA code was used for 3M work.
- Comet / Safe was used for both poro-elastic and equivalent fluid models.

Comet/Safe FEA model



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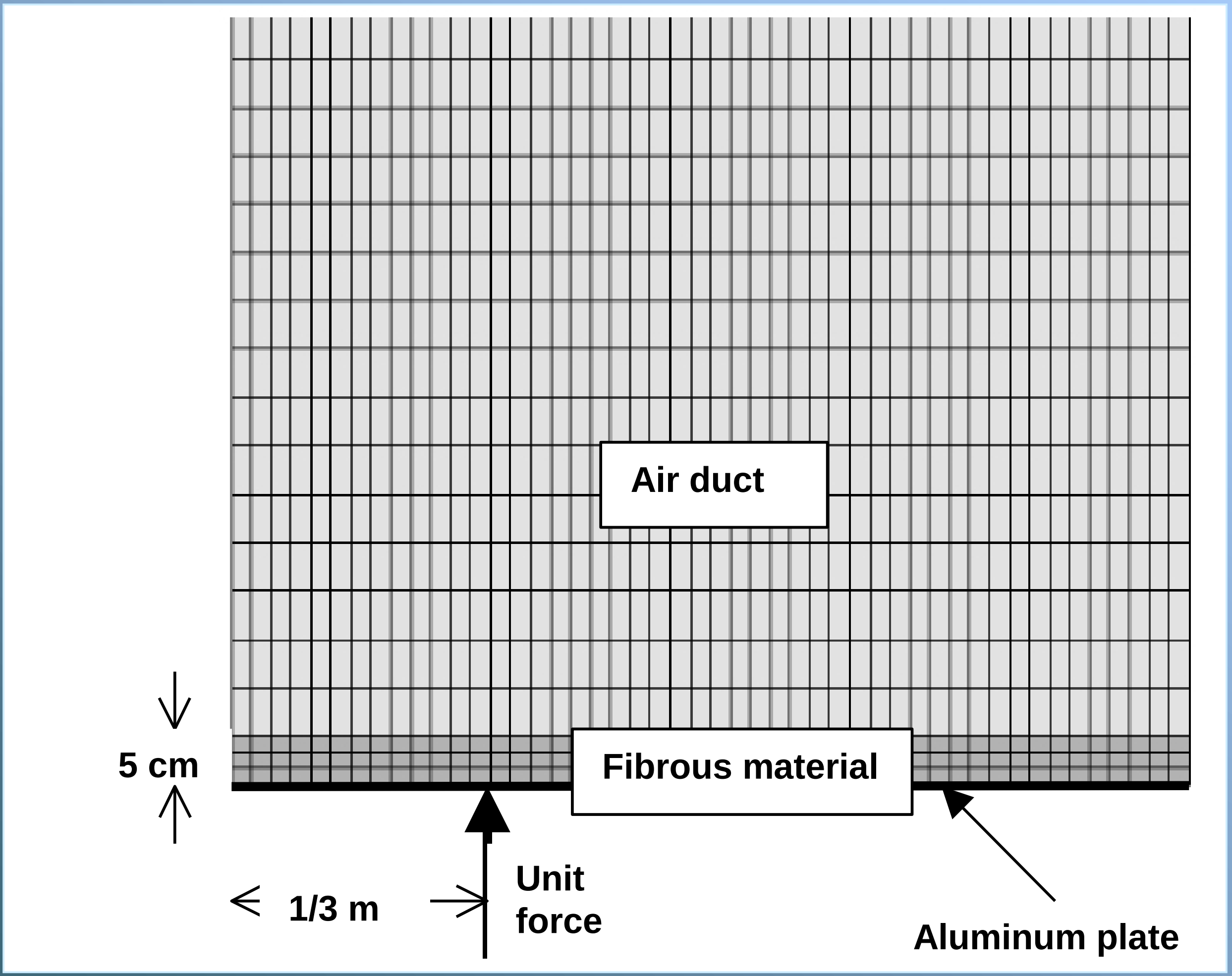
Comet/Safe FEA model- detail



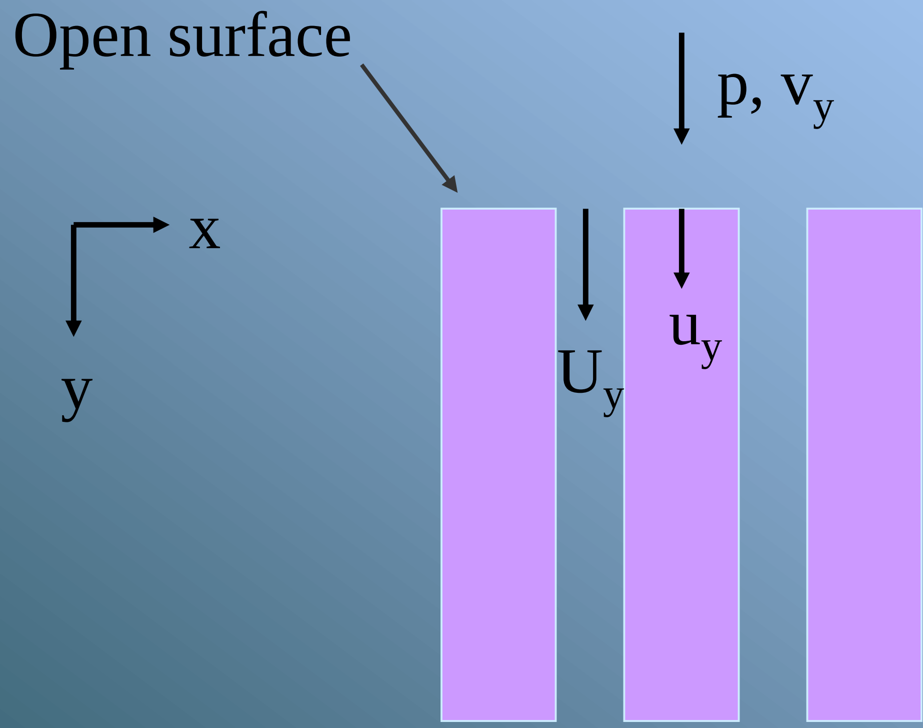
Aluminum plate properties

Thickness	1.27 mm
Length	1.0 m
Young's modulus	71,000 MPa
Poisson's ratio	0.33
Density	2700 kg/m^3

Material properties, poro-elastic

Porosity	.99
Tortuosity (Structure factor)	1.2
Flow resistivity	8882 Rayls/m
Young's modulus of solid	1000 Pa
Poisson's ratio of solid	0
Solid bulk density	11.43 kg/m^3
Fluid density	1.21 kg/m^3
Speed of sound in fluid	343 m/s
Prandtl number in fluid	.71
Specific heat ratio in fluid	1.4

Boundary conditions - Treatment/air interface



Volume velocity : $v_y = j\omega[(1-h)u_y + hU_y]$

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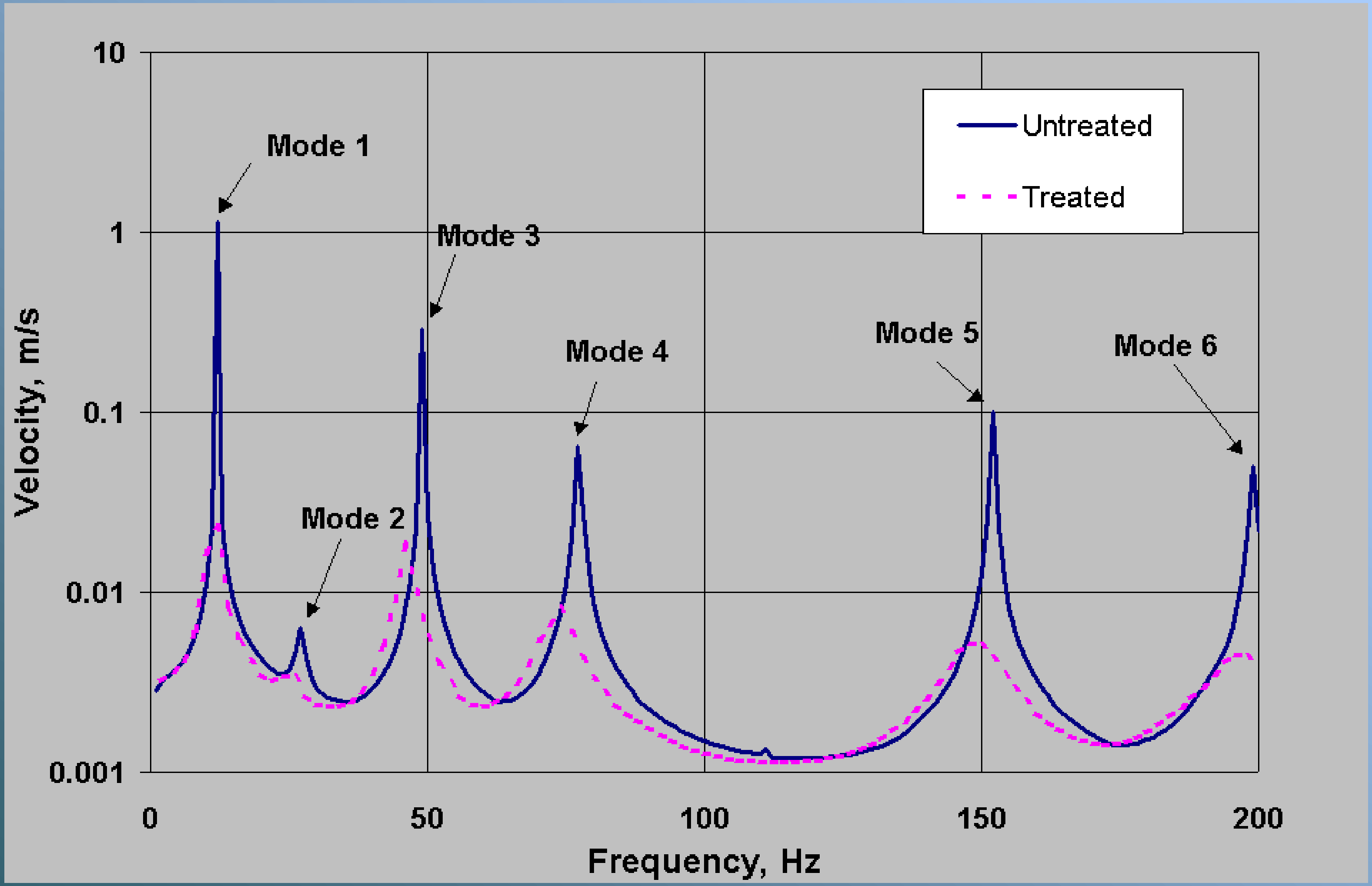
Velocity results - Treated and untreated aluminum plate



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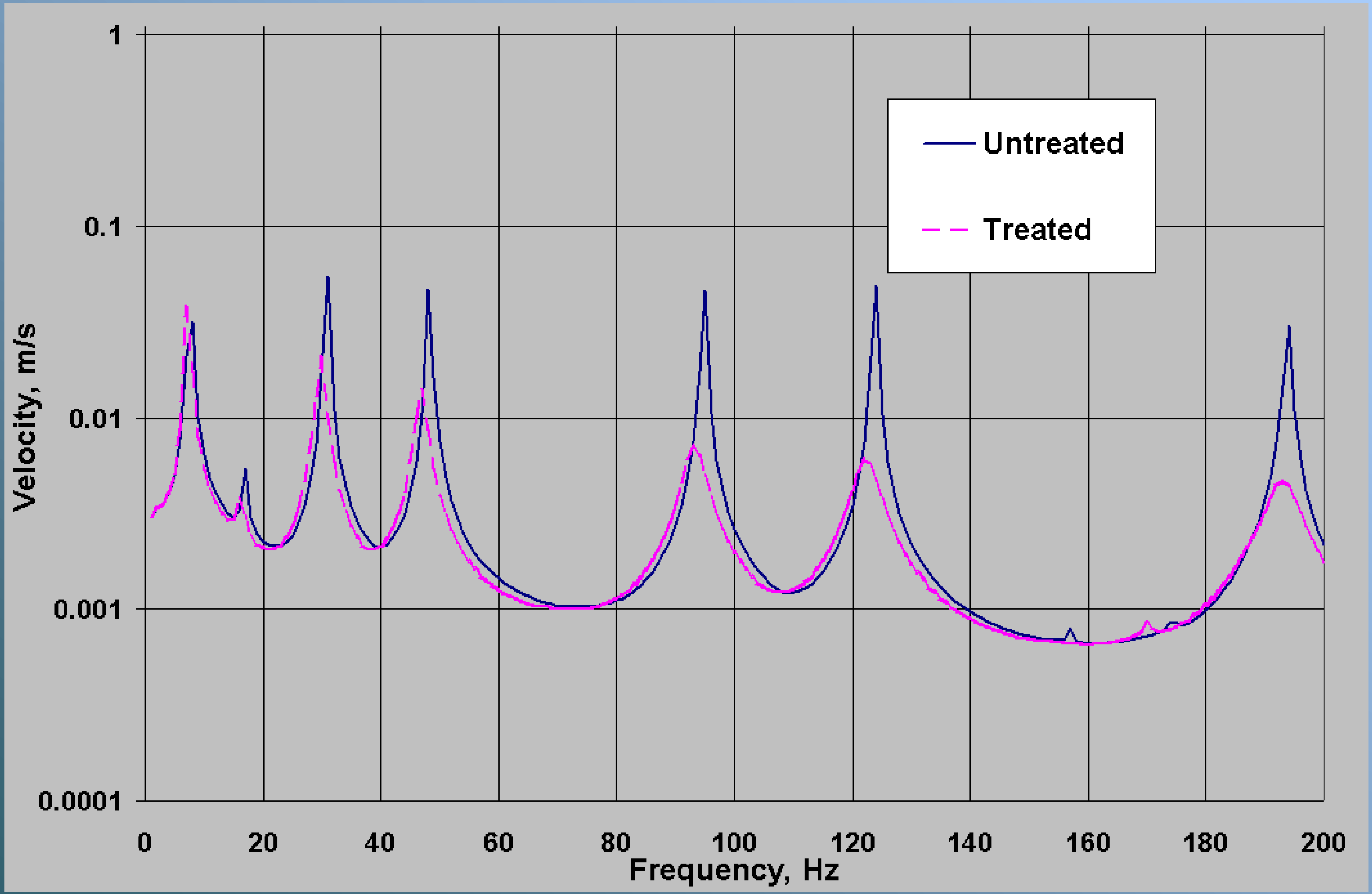
Velocity results - Treated and untreated steel plate



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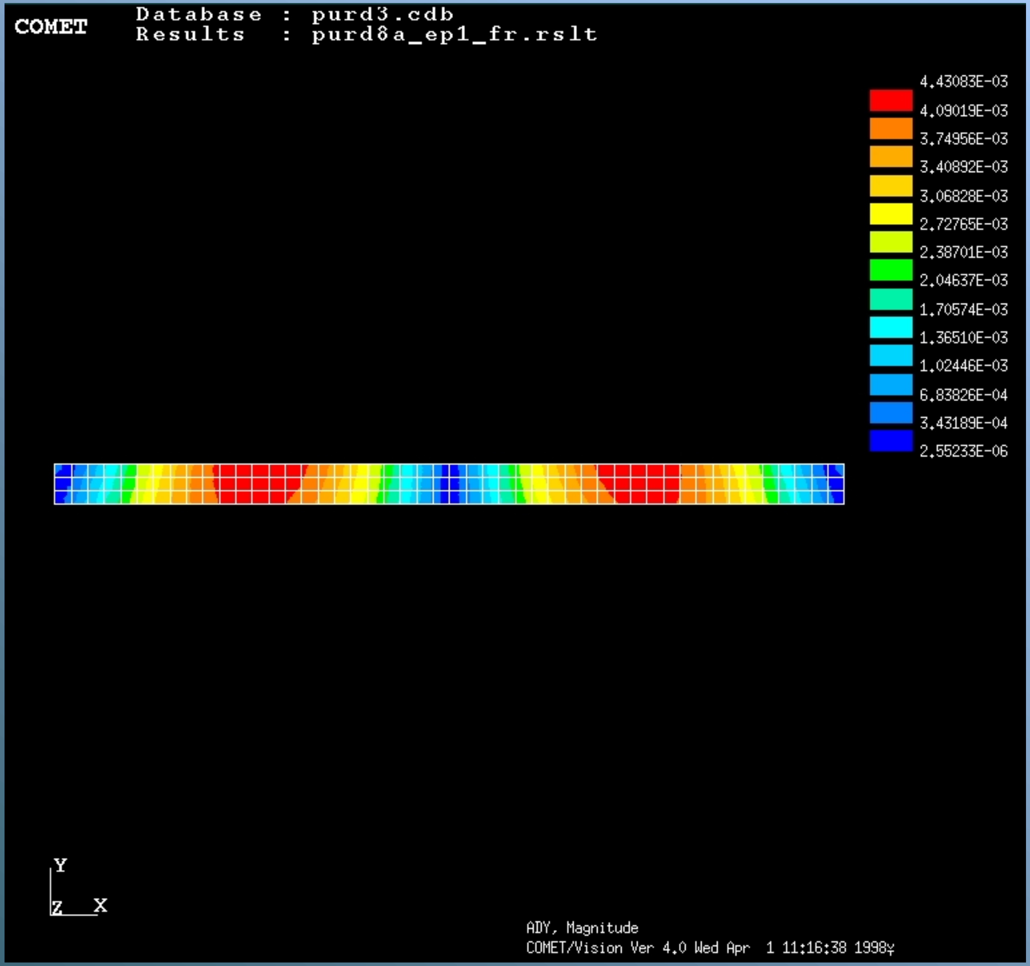
Results - Normal particle displacement in fibrous treatment - 11 Hz



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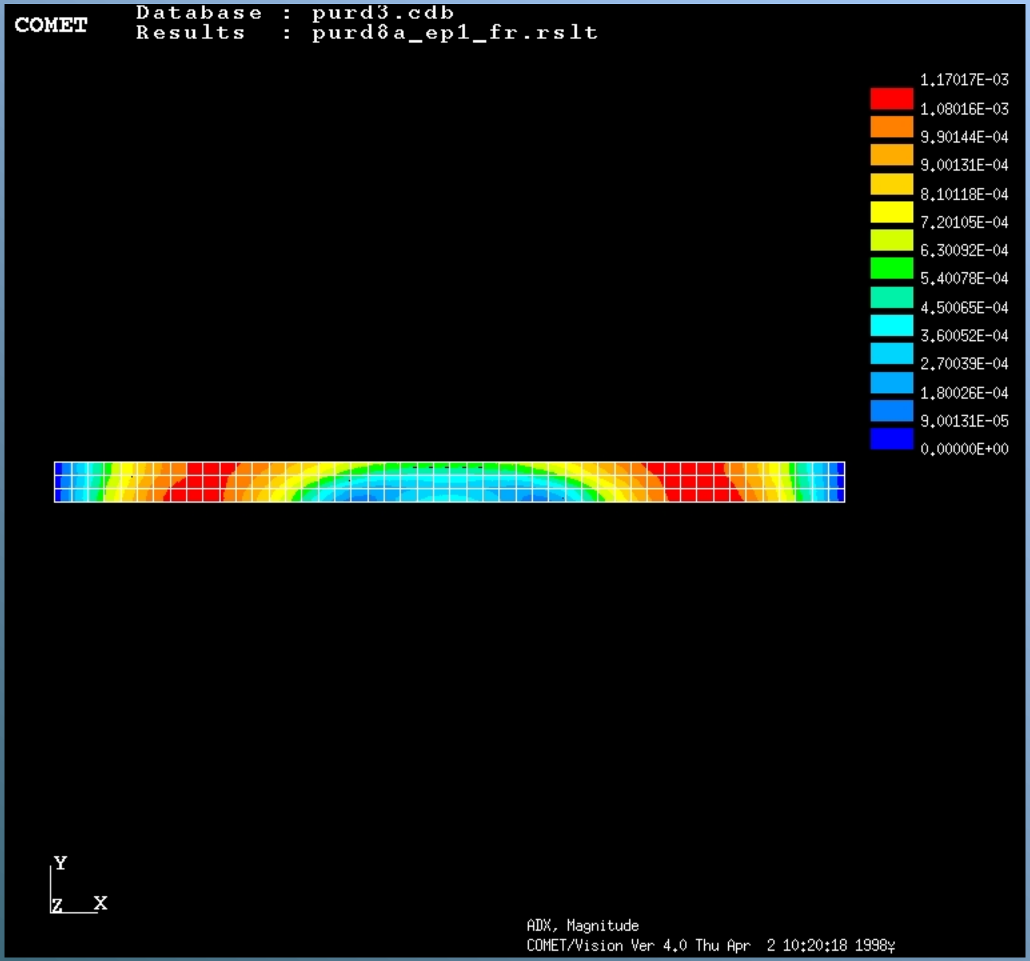
Results - Parallel particle displacement in fibrous treatment - 11 Hz



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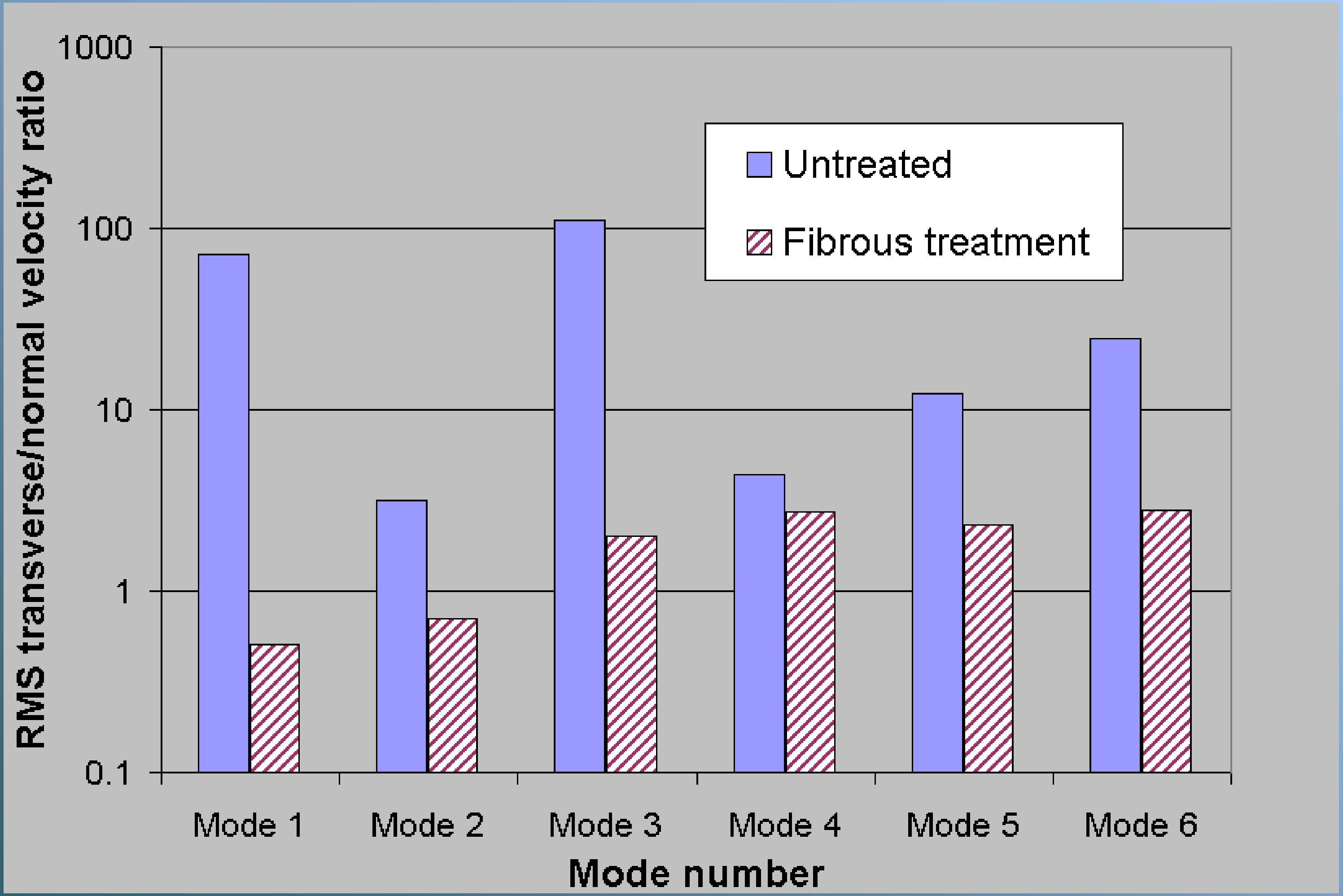
Results - Transverse / normal velocity ratio



Equivalent fluid - SAFE model

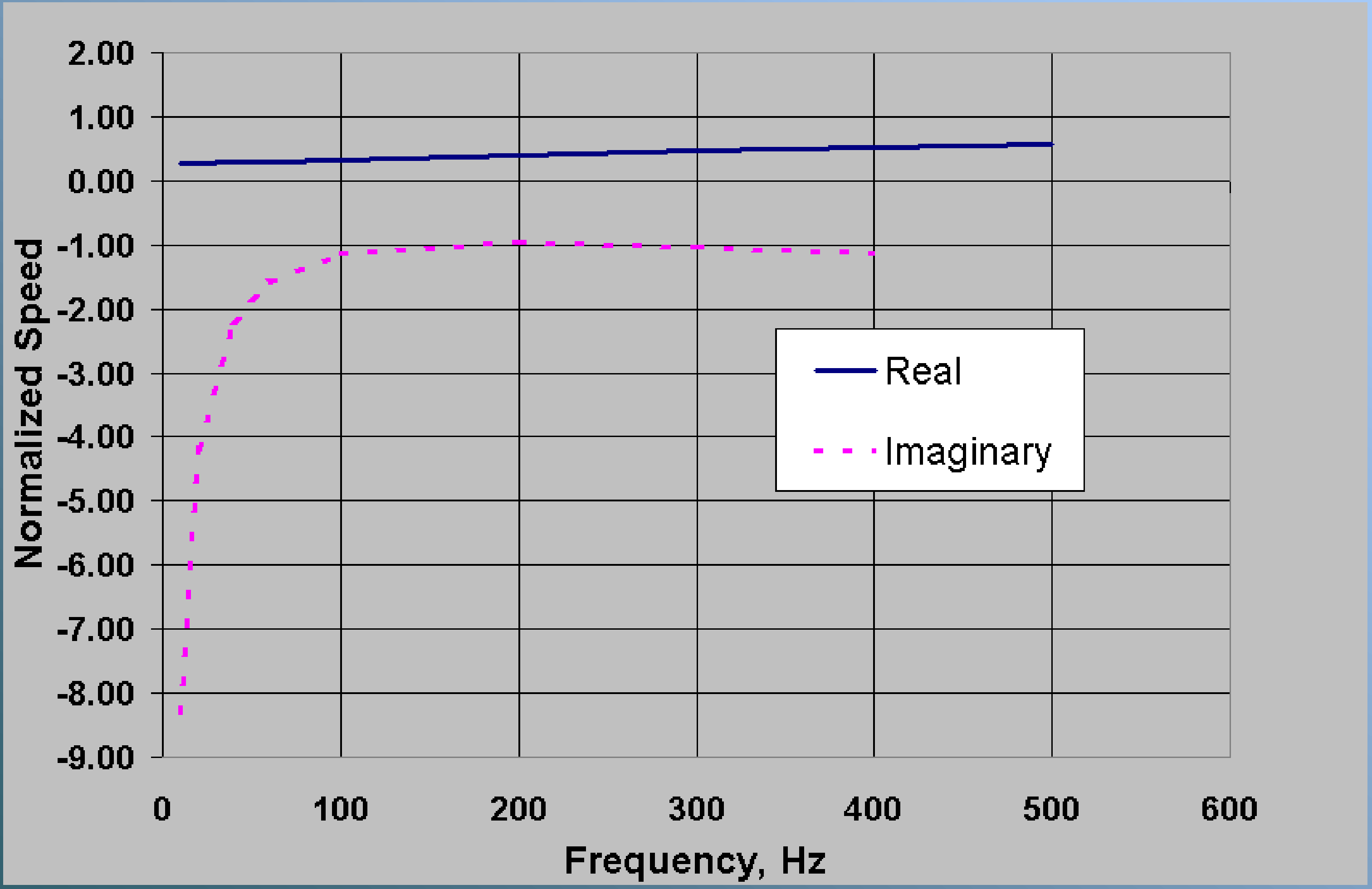
Motivation:

- Faster computations.
- Input measured complex ρ, c.

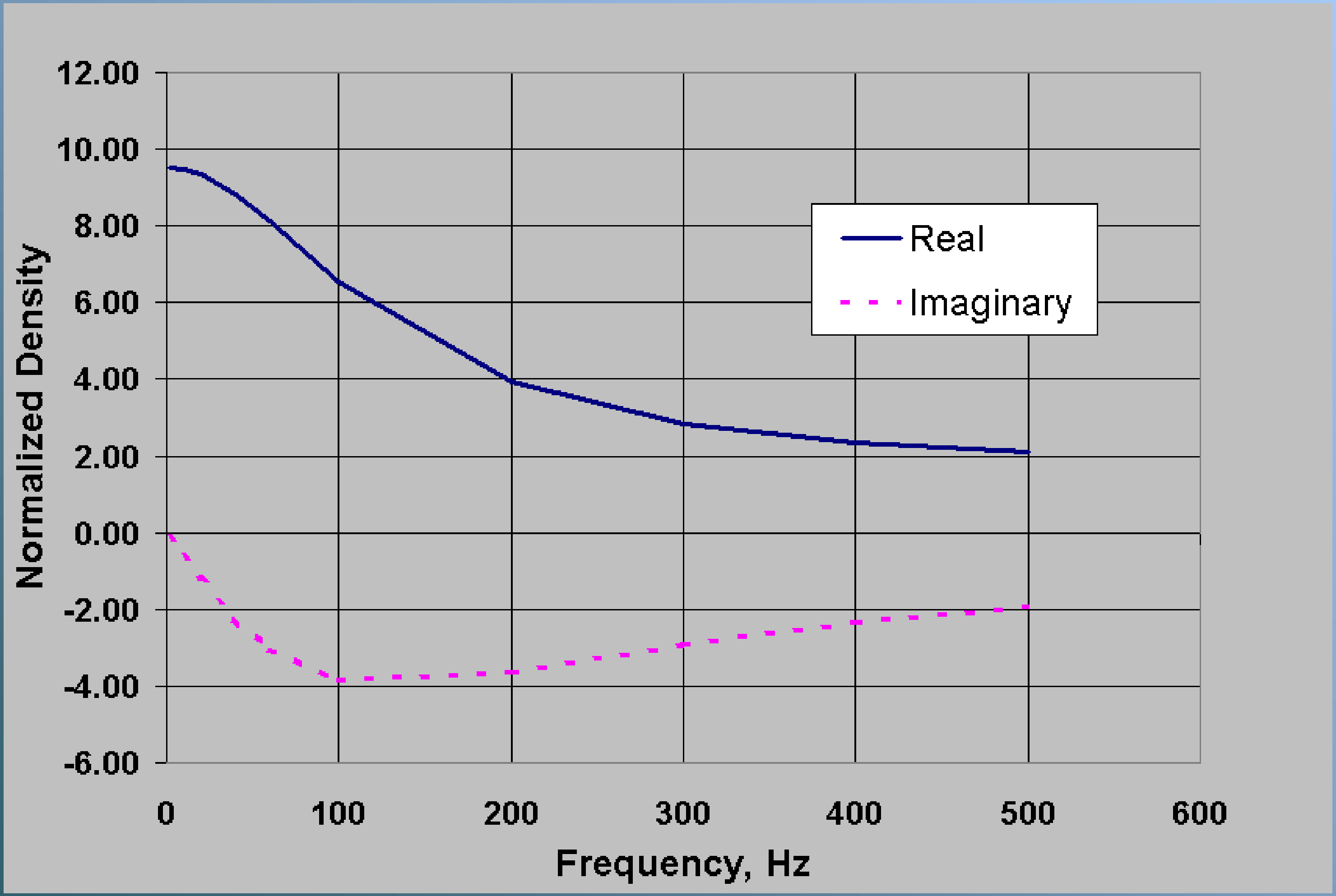
In this case, calculated ρ, c.

- Based on limp model formulation.

Equivalent fluid, normalized speed of sound



Equivalent fluid, normalized density



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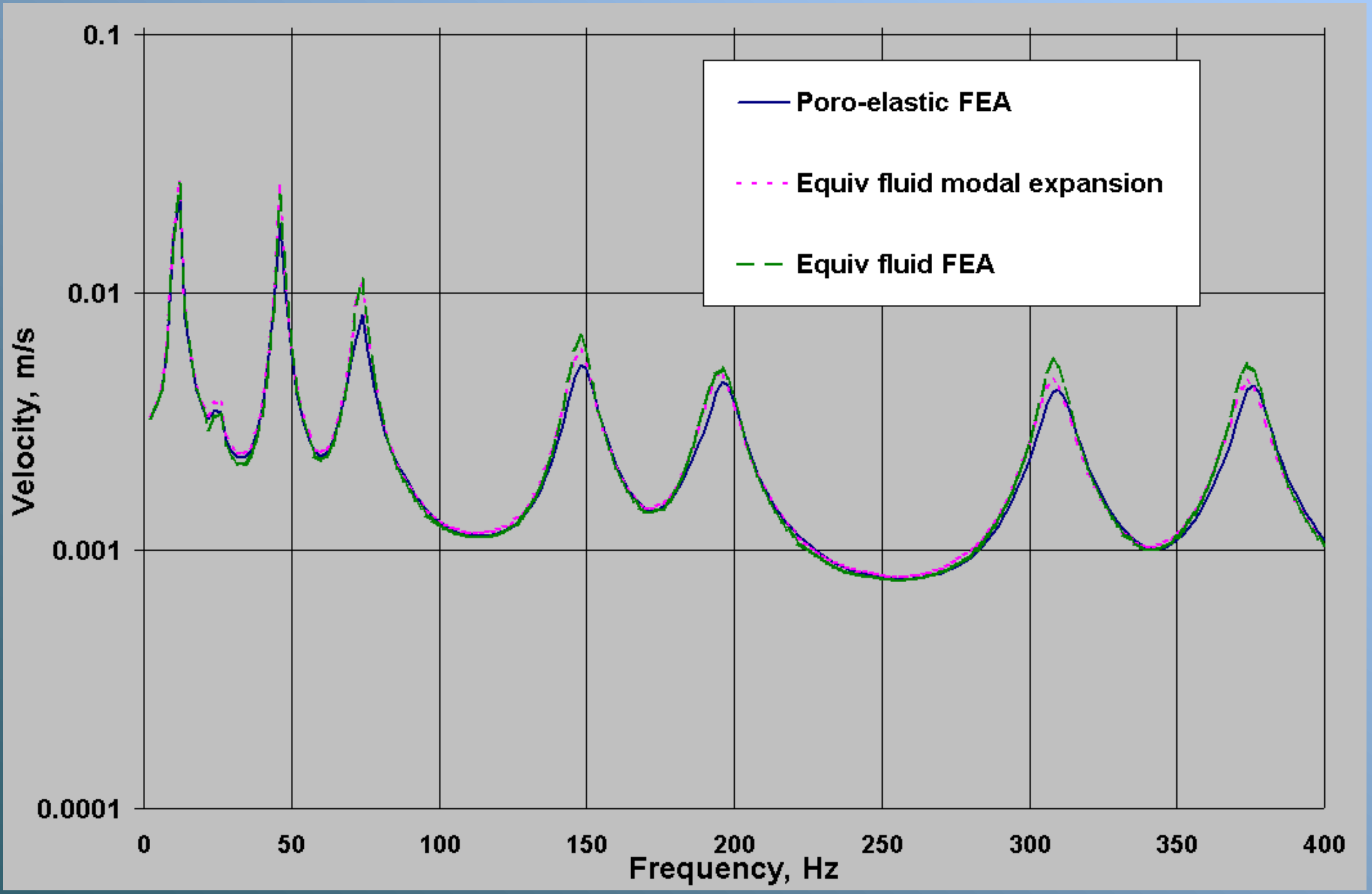
Spatially averaged velocity results



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Viscoelastic damper - FEA model

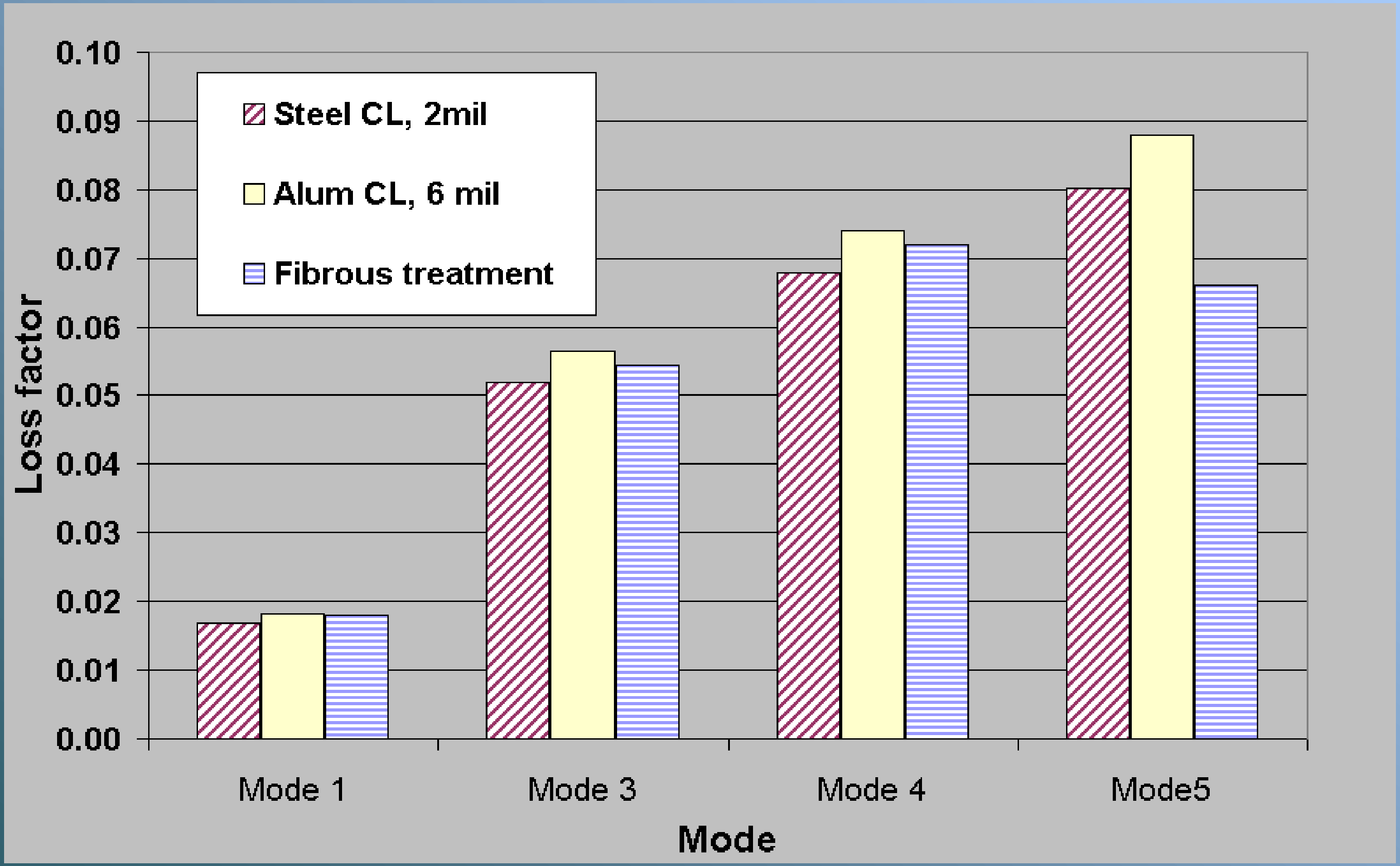
Modeled constrained layer damper with ANSYS.

Matched basis weights.

Used published viscoelastic material properties.

Used modal strain energy method to determine modal damping.

Viscoelastic damper comparison



Future work

Test data.

3D models with complex equivalent fluid.

Optimize fibrous treatment for damping effect.

Characterize damping effect.

Summary

- Successfully duplicated modal expansion results using two FEA methods.
  - Three independent methods predicted damping effect due to fibrous treatment.
- Damping effect seems to be on the order of constrained layer damper.
- Damping results from interaction of panel nearfield and fibrous material.