Bending Vibration Analysis of Pipes and Shafts Arranged in Fluid Filled Tubular Spaces Using FEM

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Introduction: FSI

Fluid Dynamics

Structural Dynamic

ASSUMPTIONS!

- Compressible and Irrotational flow
- No body and viscous forces (inviscid)
- Mean density and pressure are uniform
- Small disturbances
- Medium at rest and Homogeneous

Acoustic Fluid

Fluid Structure Interface

Methods To Solve FSI

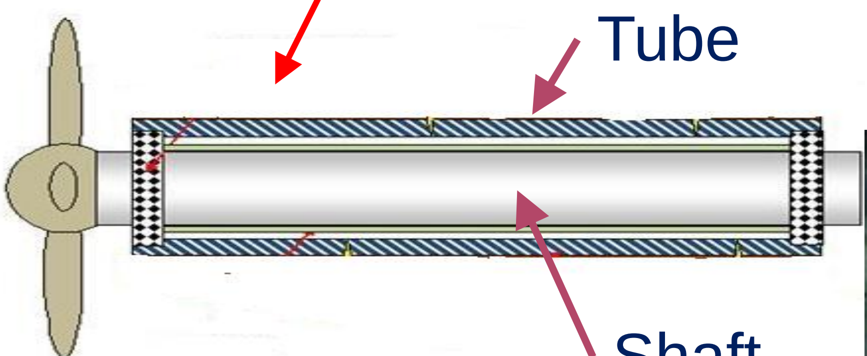
Monolithic approach:

Partitioned approach:

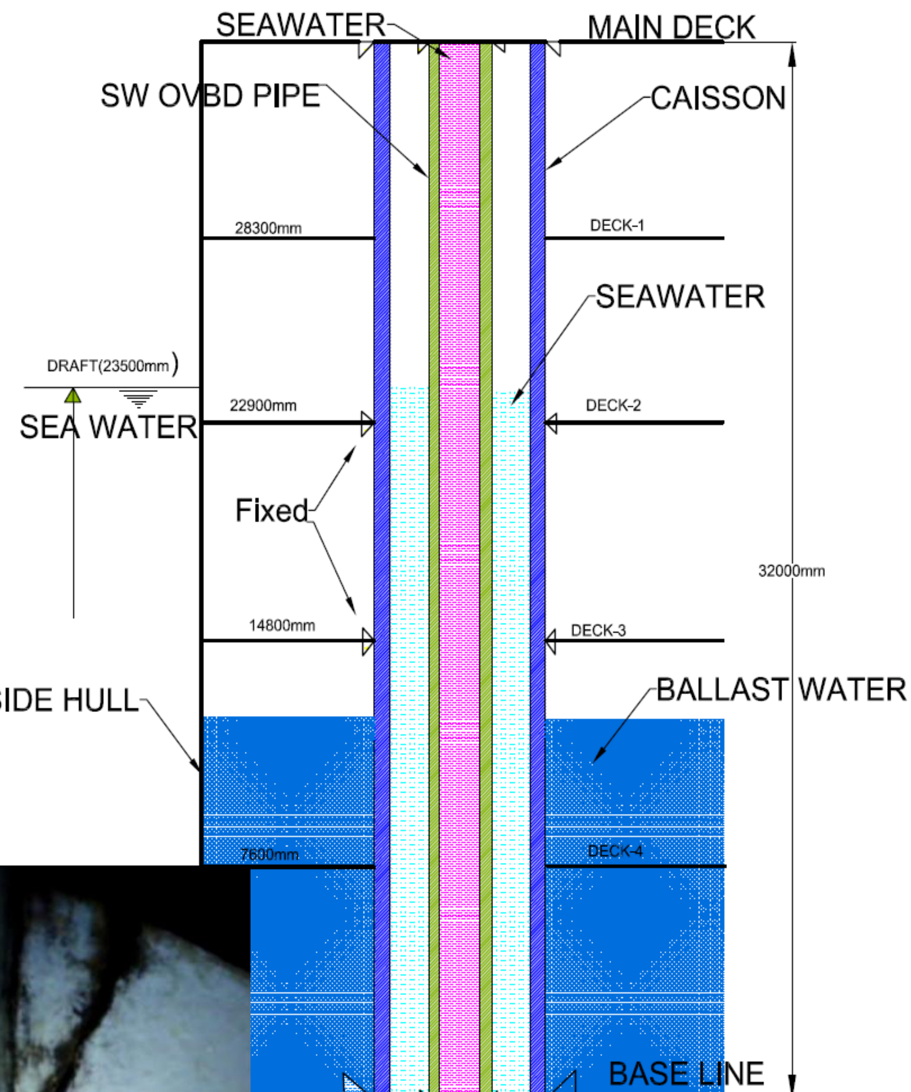
Engineering Applications

EMship Advanced Design

1. Ship stern Tube



2. Overboard discharge line



Video

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Objective and Scientific Contribution

Objective

- ➢ Develop acoustic FSI-FEM using ANSYS.
- ➢ Perform vibration analysis, parametric study and mesh adaptation.
- ➢ Determine shaft, and pipes vibration characteristic.
- ➢ Determine added mass coefficient of the components
- ➢ Finally to propose quick and simple formulae for added mass.

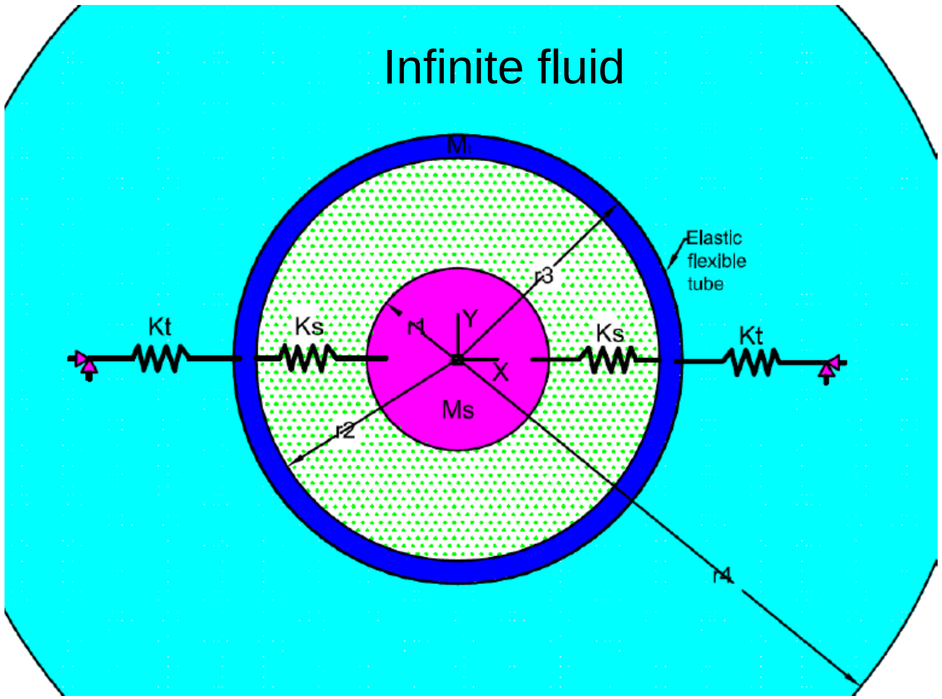
Contribution

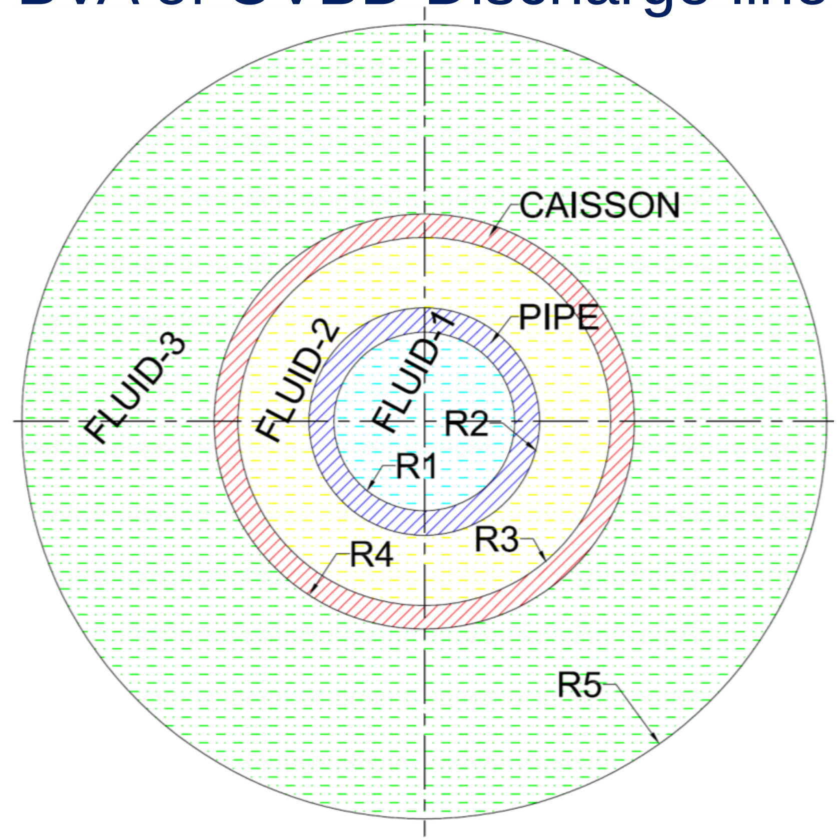
- ✓ Determine the effect of surrounding fluid on important construction members.
- ✓ Make known important design parameters for complex FSI of concerned problems.

Bending Vibration Analysis Of Shaft And Tube Coupled With Fluids

Part-1 BVA of stern tube

Part-2 BVA of OVBD Discharge line





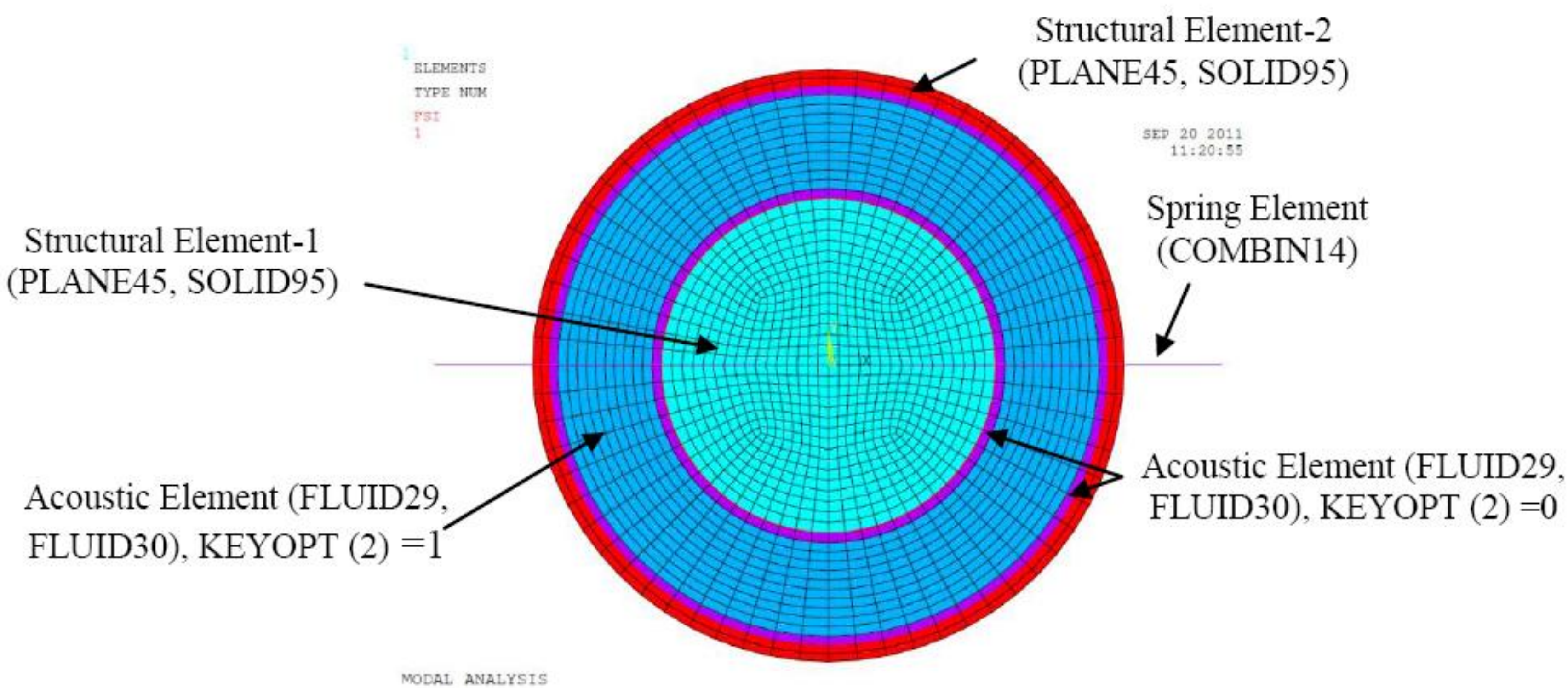
Assumptions

Material: Steel (shaft, tube, and caisson) and Fiber reinforced pipe

Fluid part : Acoustic fluid

Boundary cond. : Simply supported for part-1 and rigidly fixed for part-2

Acoustic FSI FE Model Techniques (ANSYS)



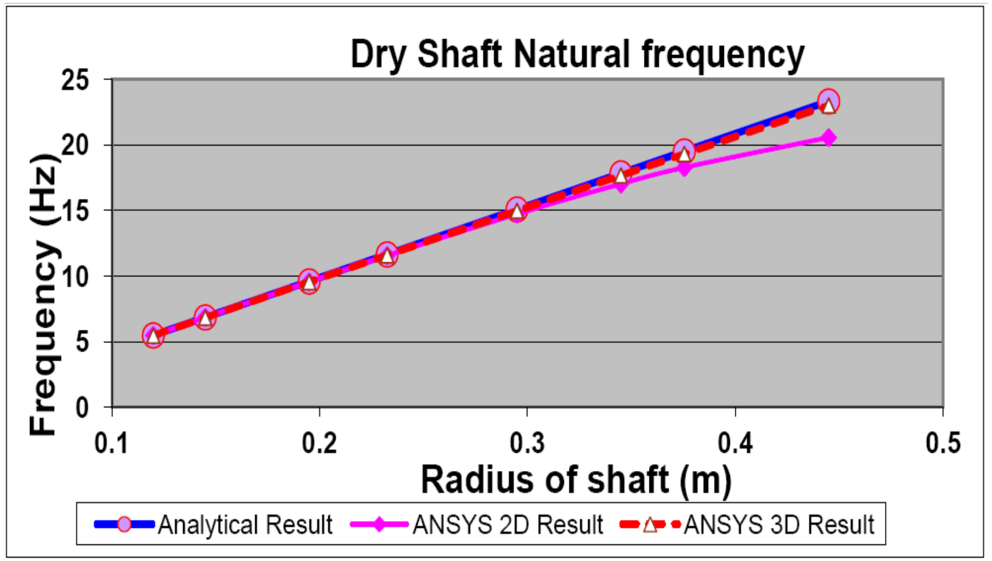
Boundary Conditions and Interfaces Definitions

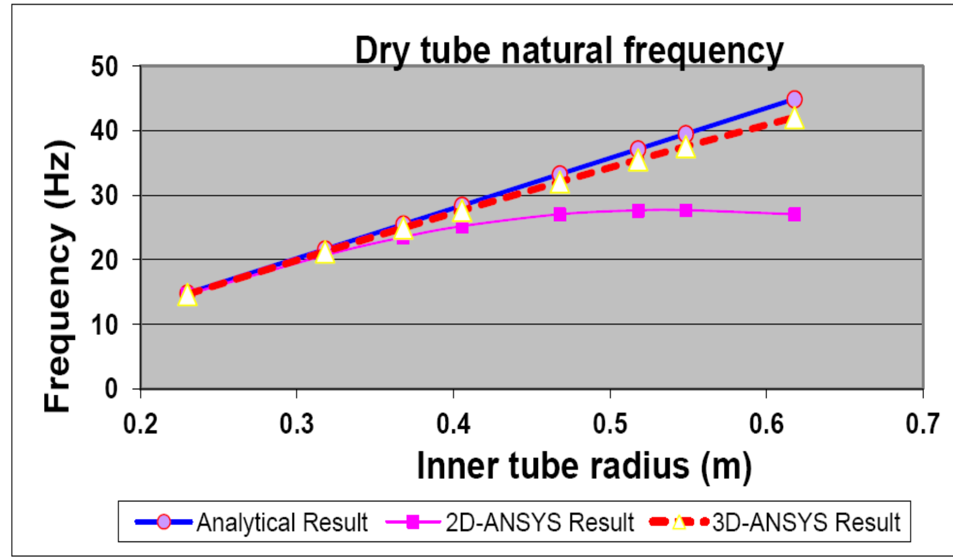
- Displacement (U_x, U_y, U_z) and pressure DOF for fluid in contact
- Only pressure DOF for other domain (KEYOPT(2)=1)

CASE-1 Bending Vibration of Solid Elastic Dry Shaft and Elastic Tube

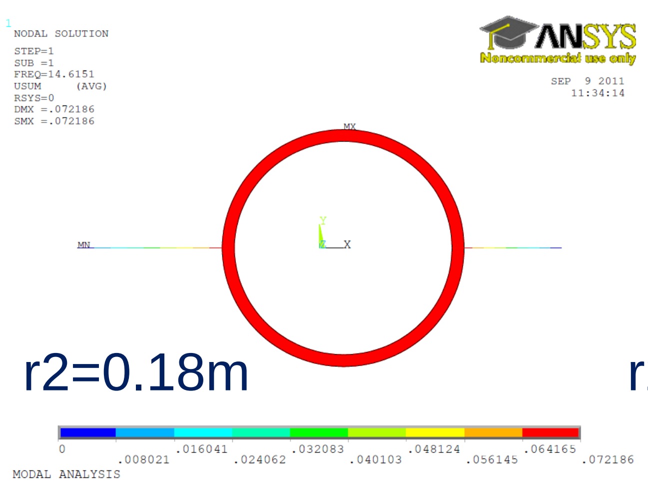
EMship Advanced Design

Validation with analytical result

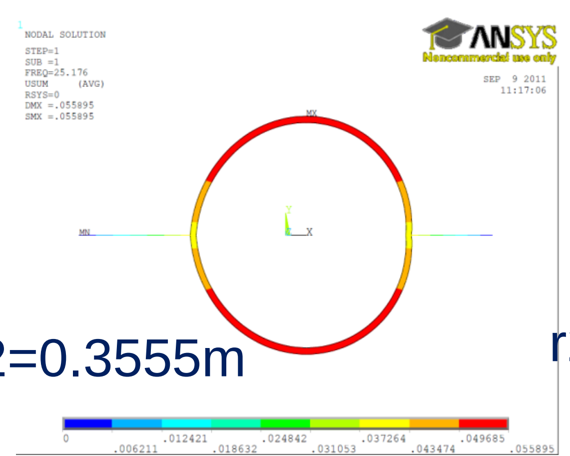




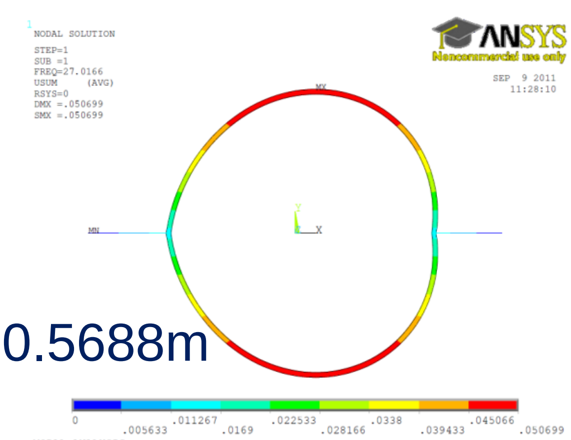
Problems with 2D models



r2=0.18m



r2=0.3555m



r2=0.5688m

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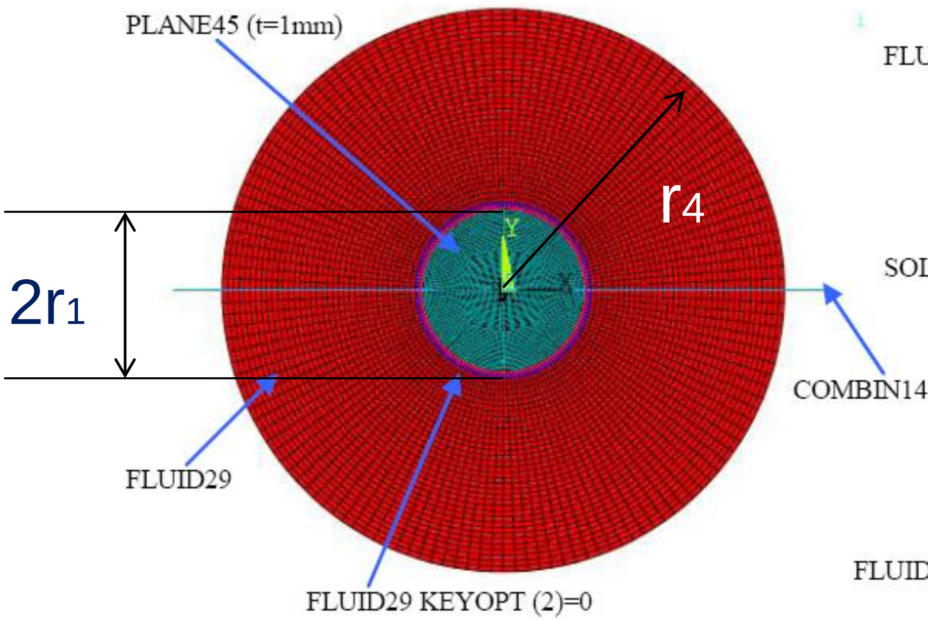
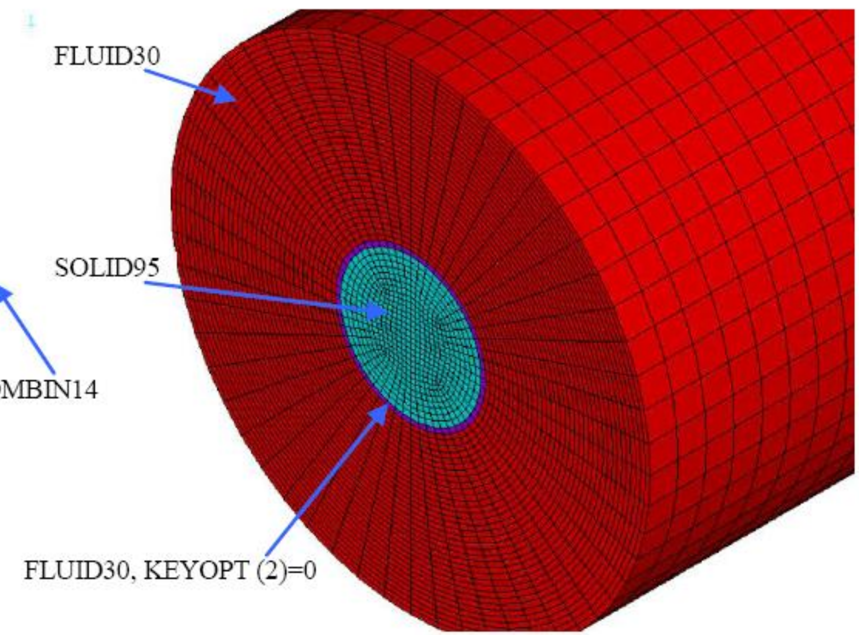
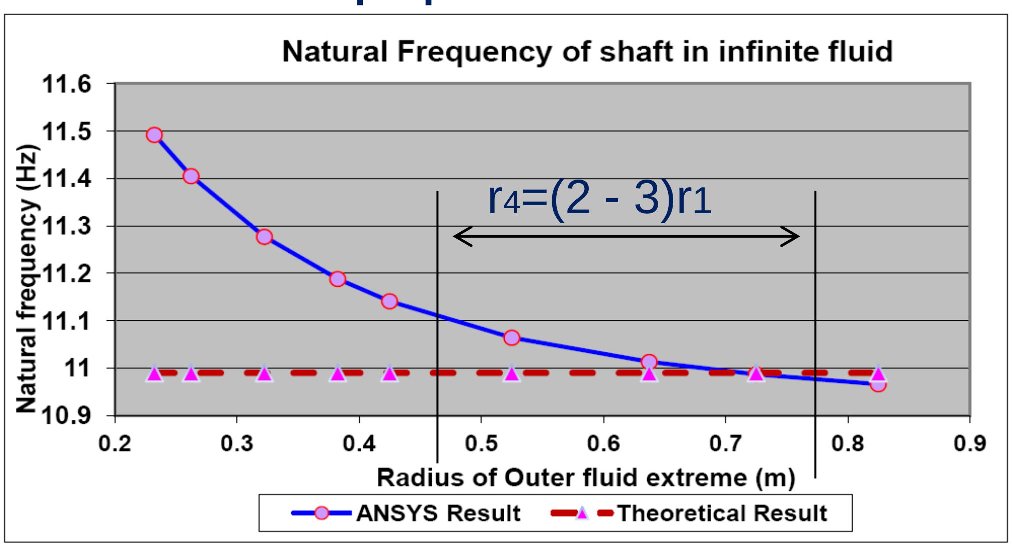
CASE-2 BVA of Solid Elastic Shaft in Infinite Fluid

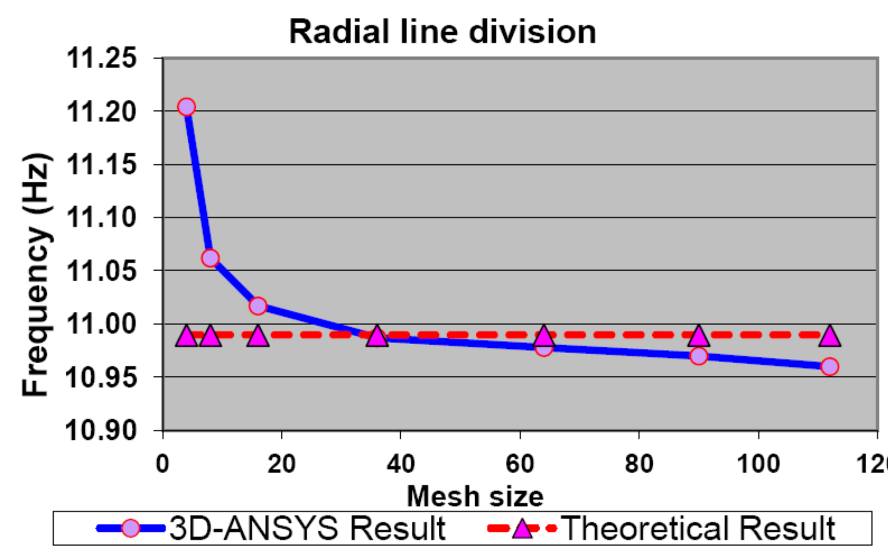




Determination of proper infinite fluid outer extreme



Identification of proper mesh size



- Set pressure zero at 2 to 3 times of outer diameter (error <1%)

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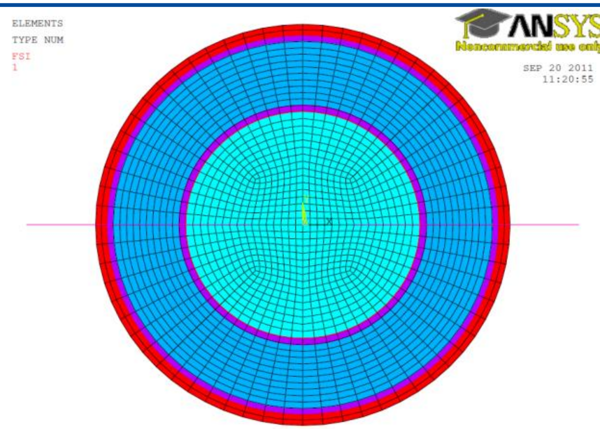
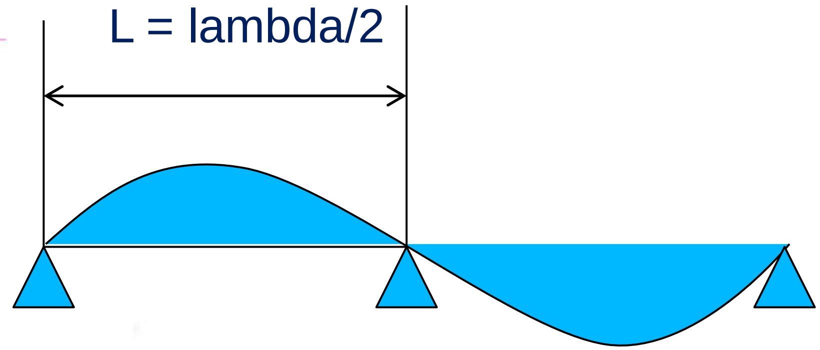
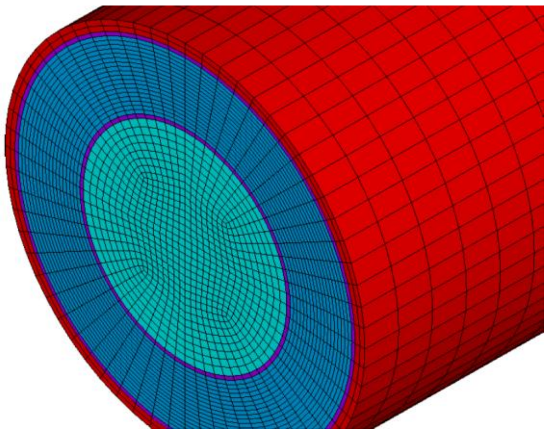
CASE-3 BVA of Solid Elastic Shaft in Fluid Filled Rigid Tube

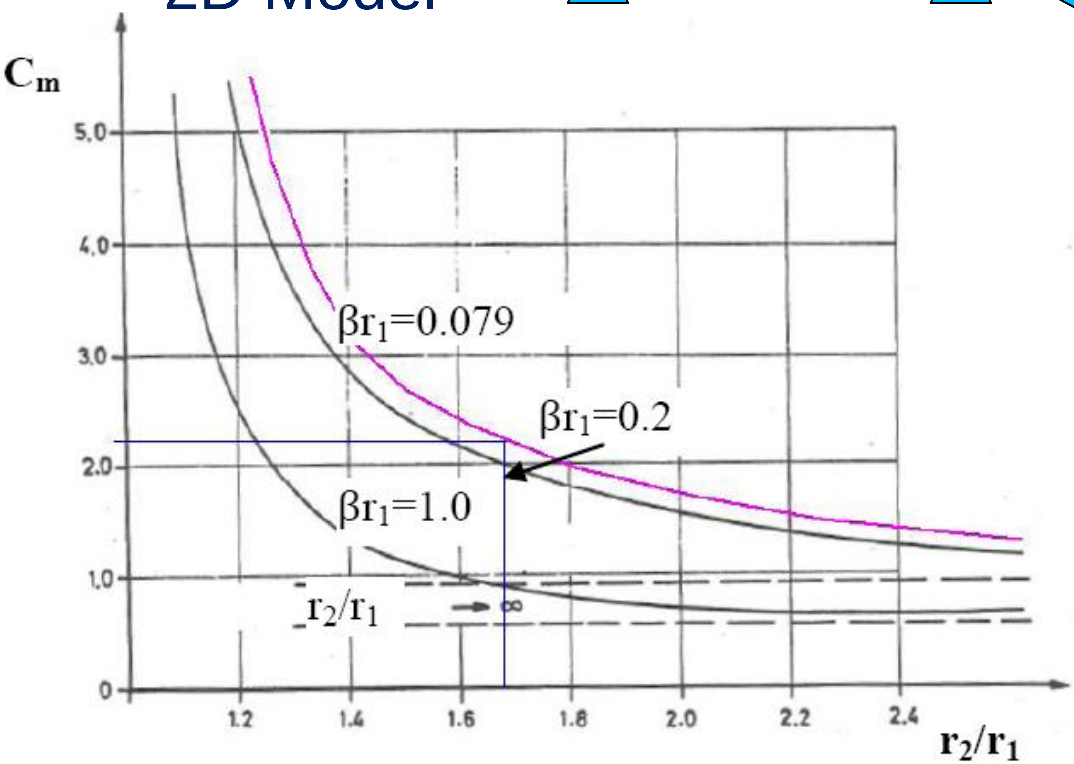


2D Model





3D Model



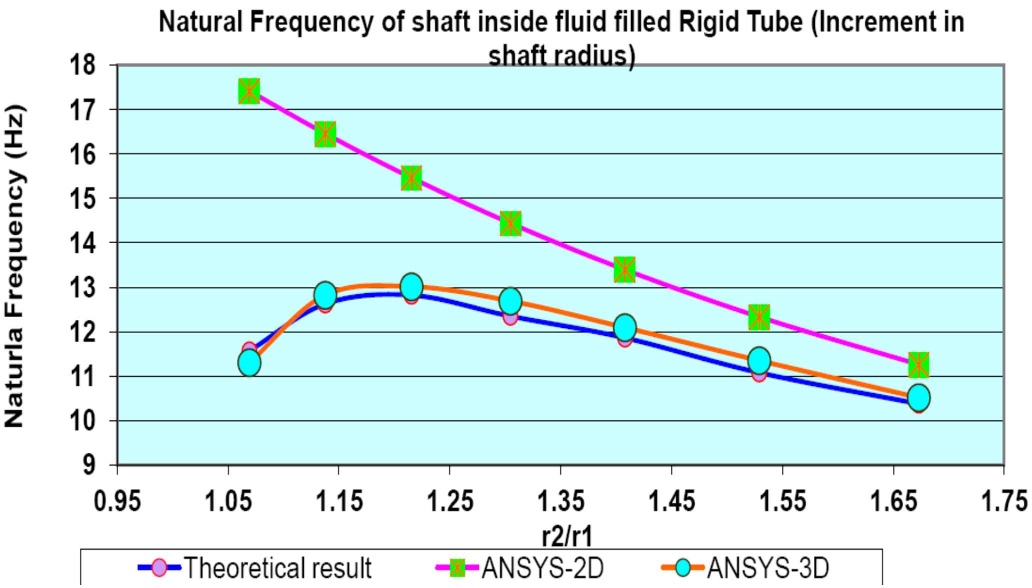
Theoretical added mass

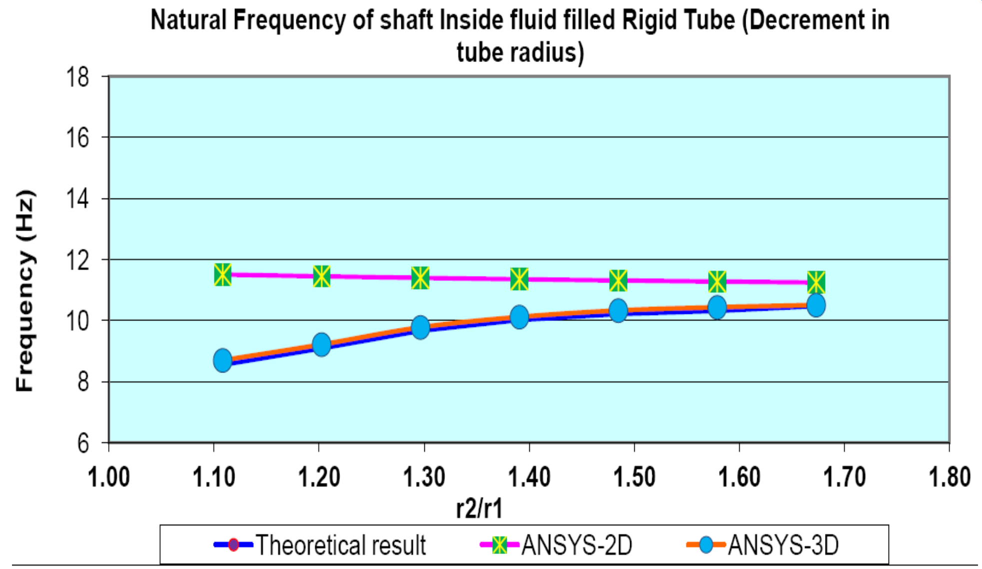
$$M_a = \rho_f C_m A$$

This result will be compared with ANSYS 2D and 3D

Graph used to determine Cm (Grim O., 1975)

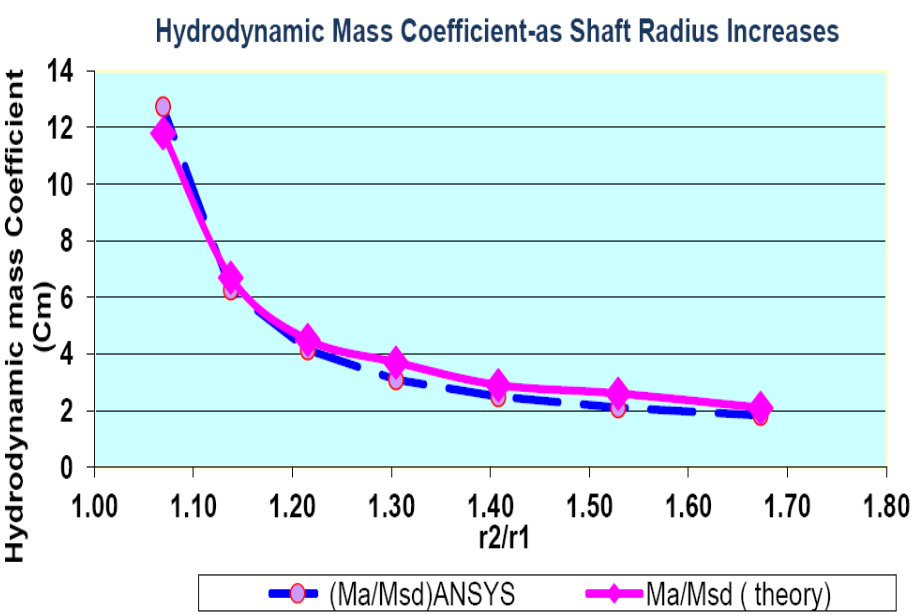
CASE-3 Models Validation with Theoretical results

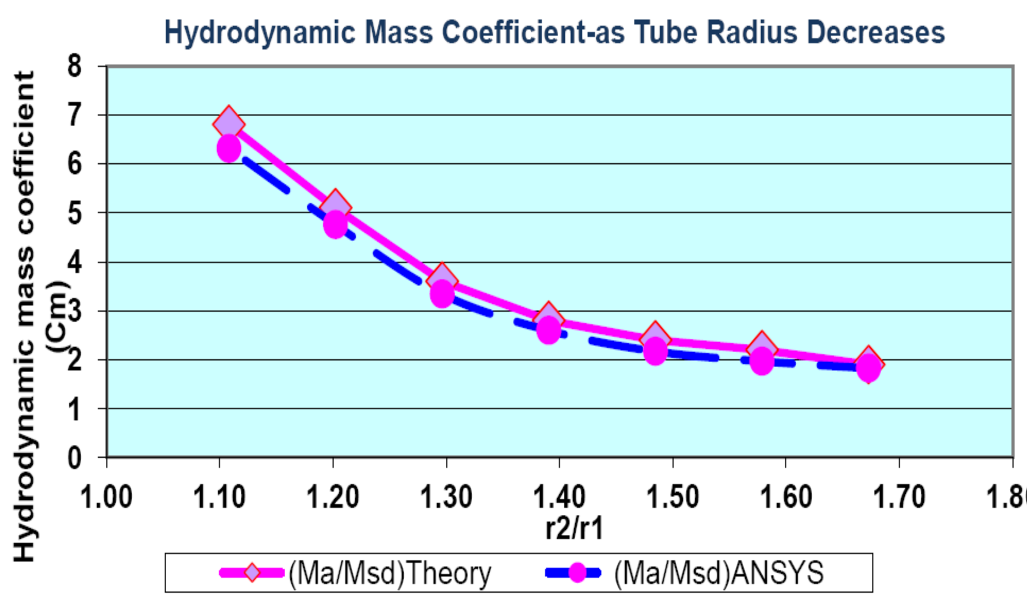




As shaft radius increases

As tube radius decreases

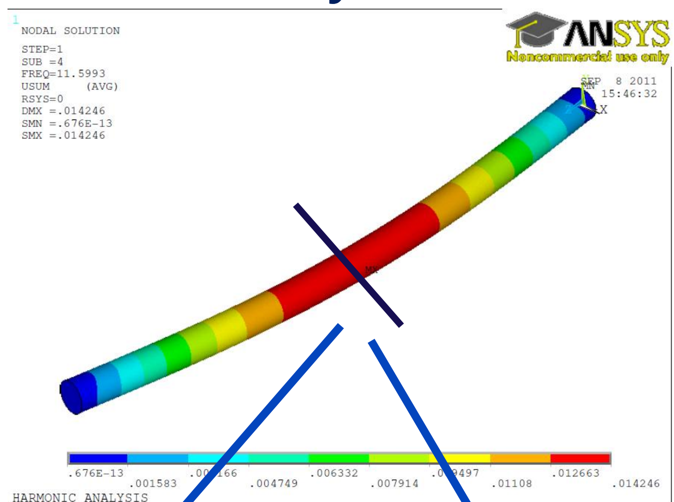


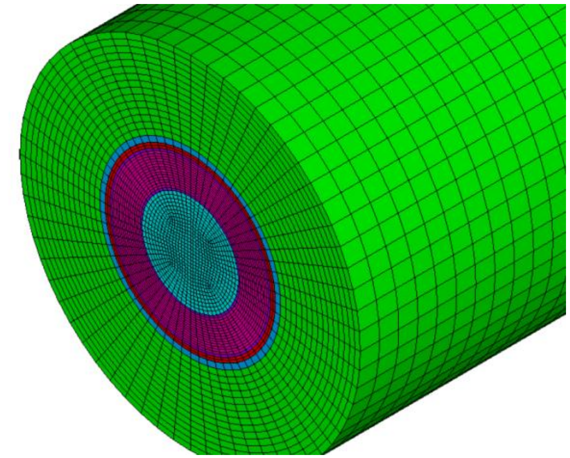


CASE-4 BVA of Solid Elastic Shaft in Fluid Filled Elastic Flexible Tube Immersed in Infinite Fluid

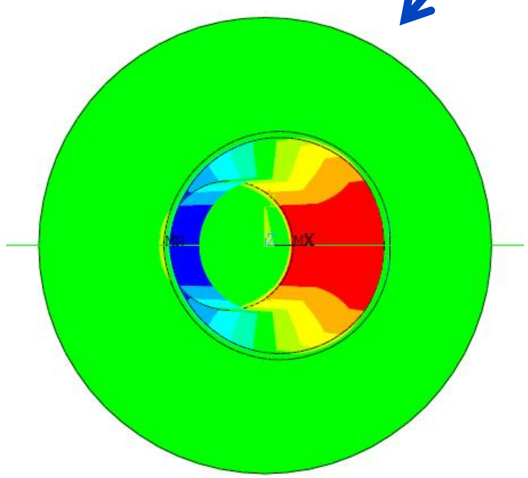
Main assumptions

- Simply supported
- Acoustic fluid and initially at rest

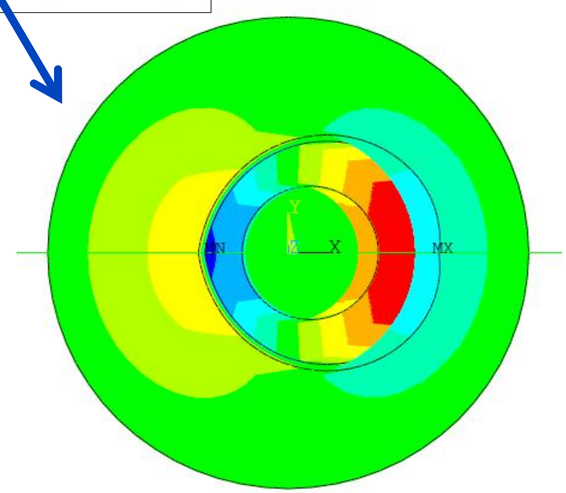




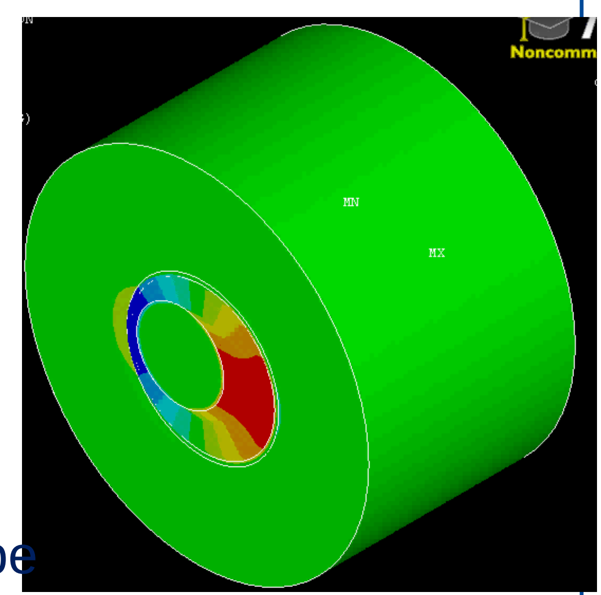
Acoustic FSI-3D Model



Pressure distribution for shaft resonance

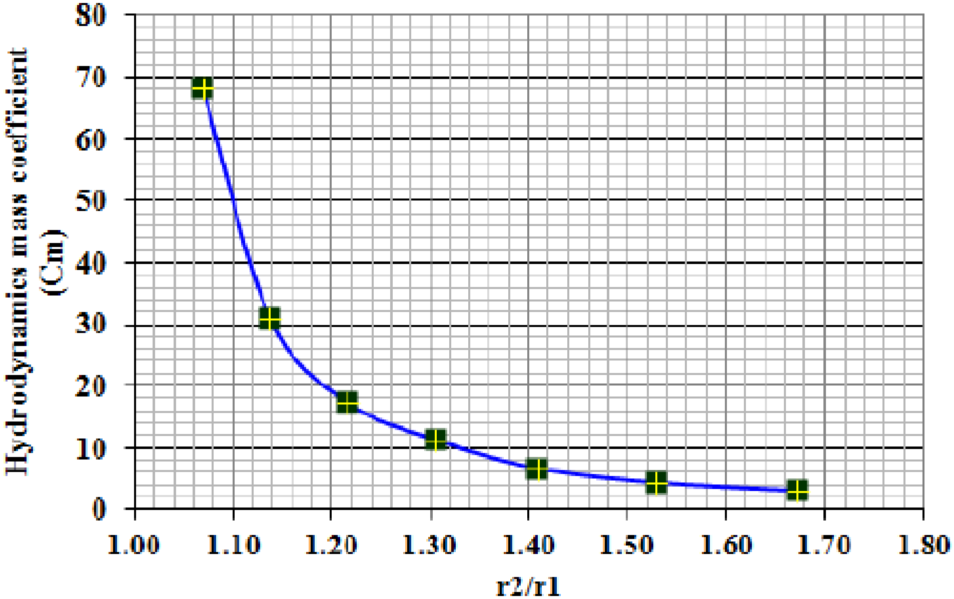


Pressure distribution for tube resonance

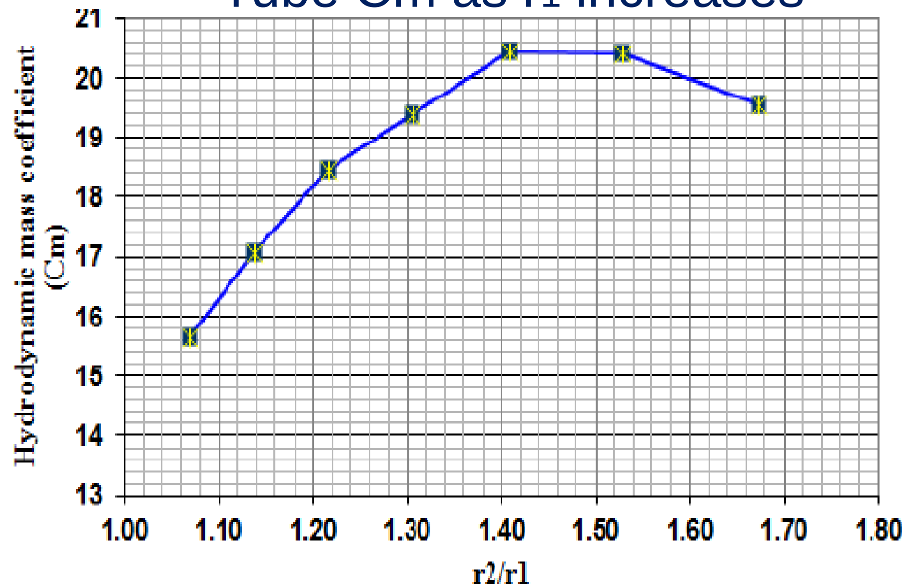


Added Mass Coefficient of Stern Tube

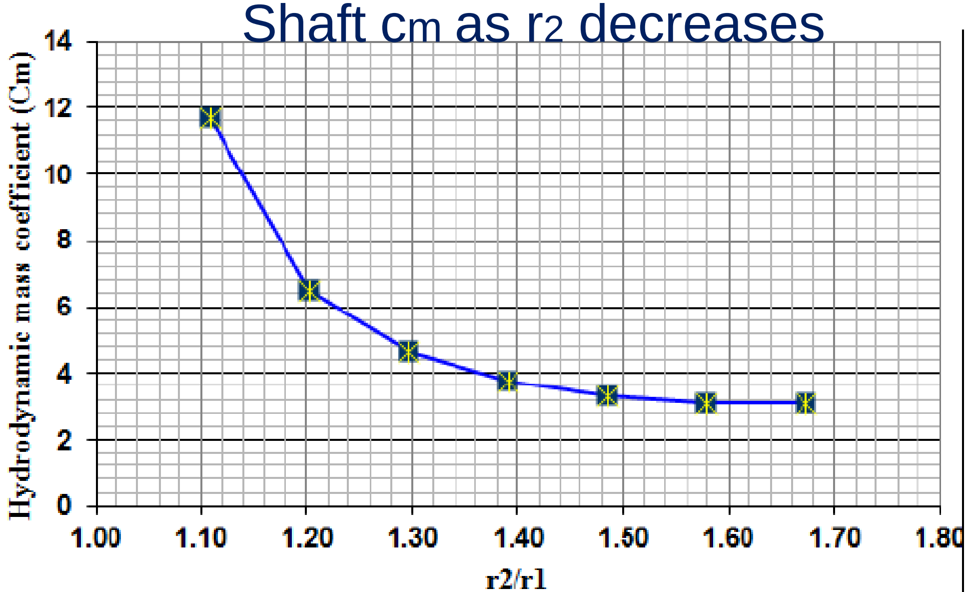
Shaft cm as r1 increases



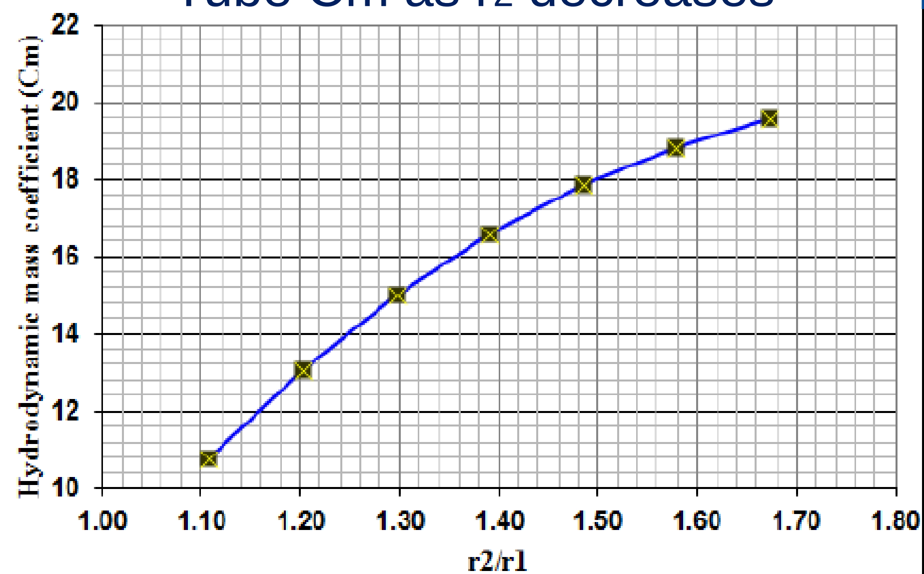
Tube Cm as r1 increases



Shaft cm as r2 decreases

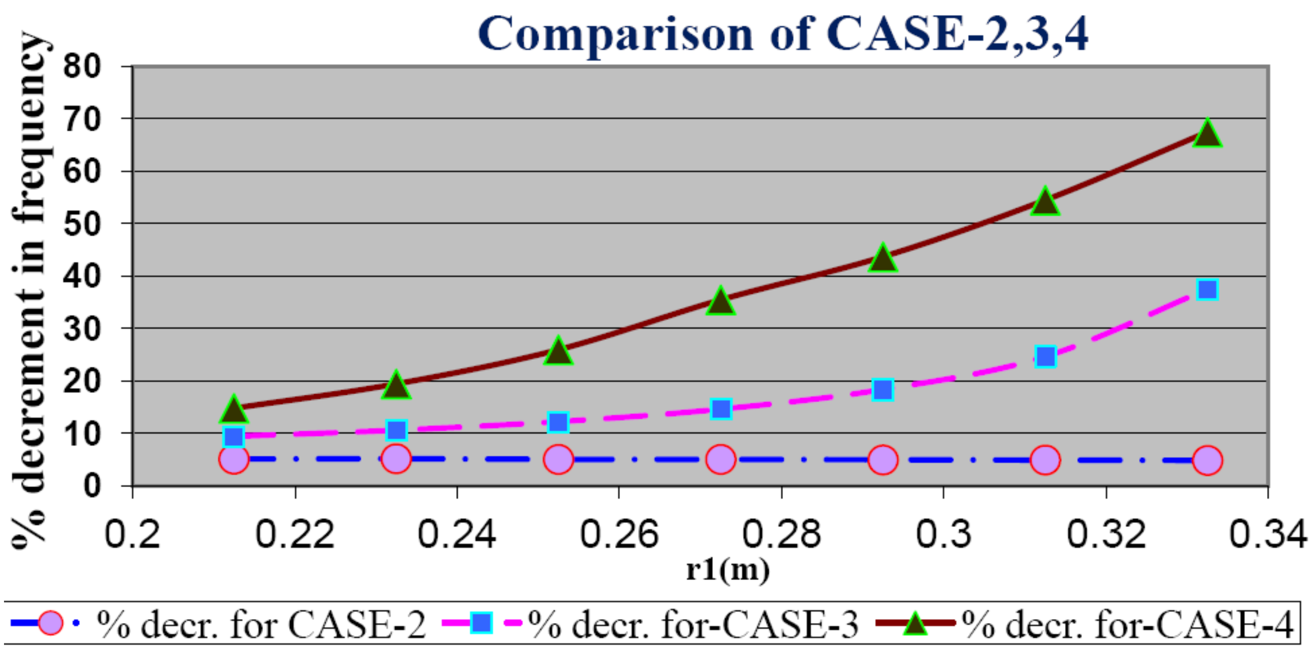


Tube Cm as r2 decreases

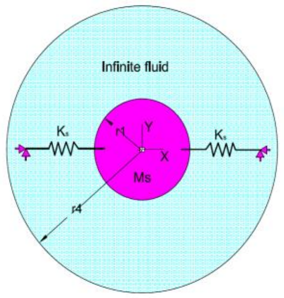


Added mass $M_a = \rho_f C_m A$

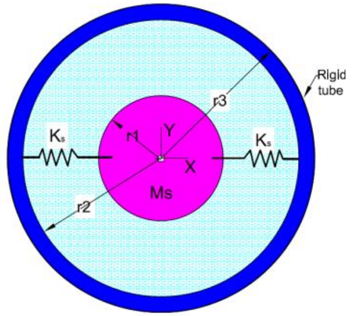
Comparison of Different CASES



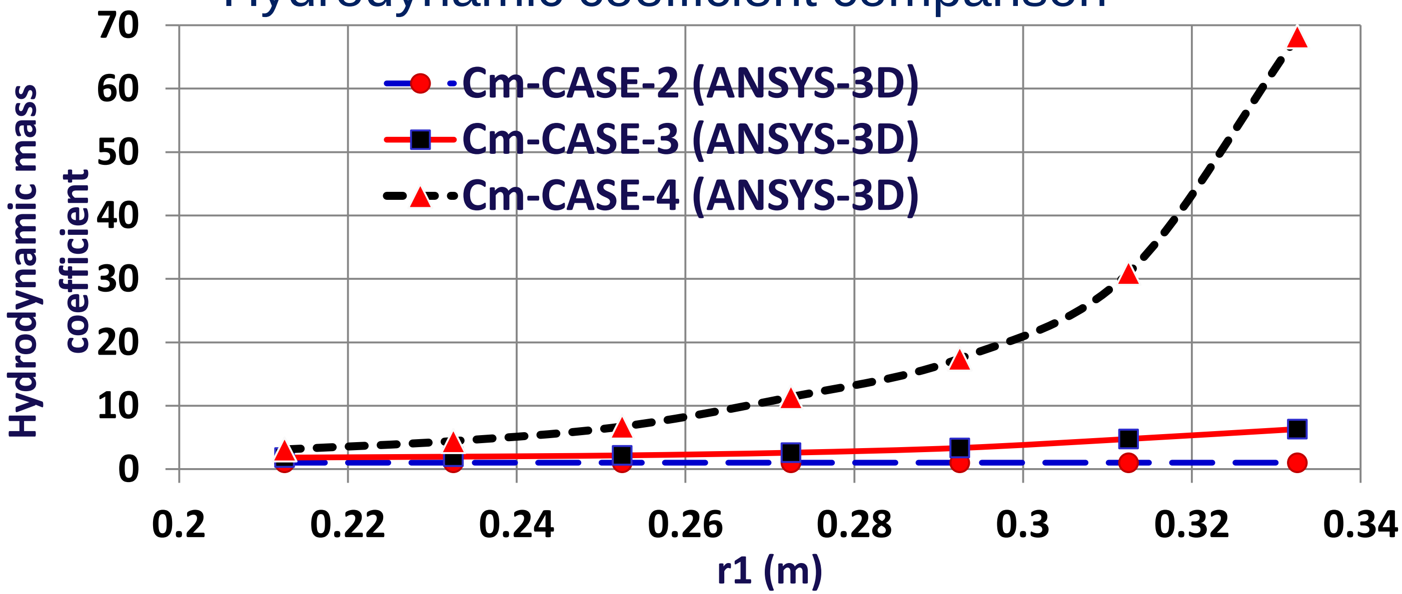
CASE-2



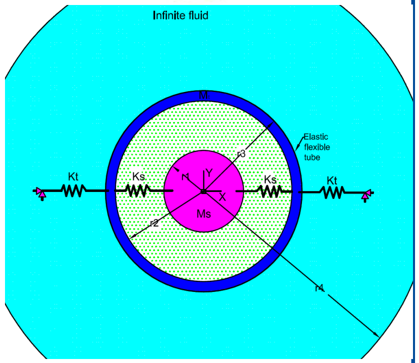
CASE-3



Hydrodynamic coefficient comparison



CASE-4



CASE-4 50% more affected as compared to CASE-3

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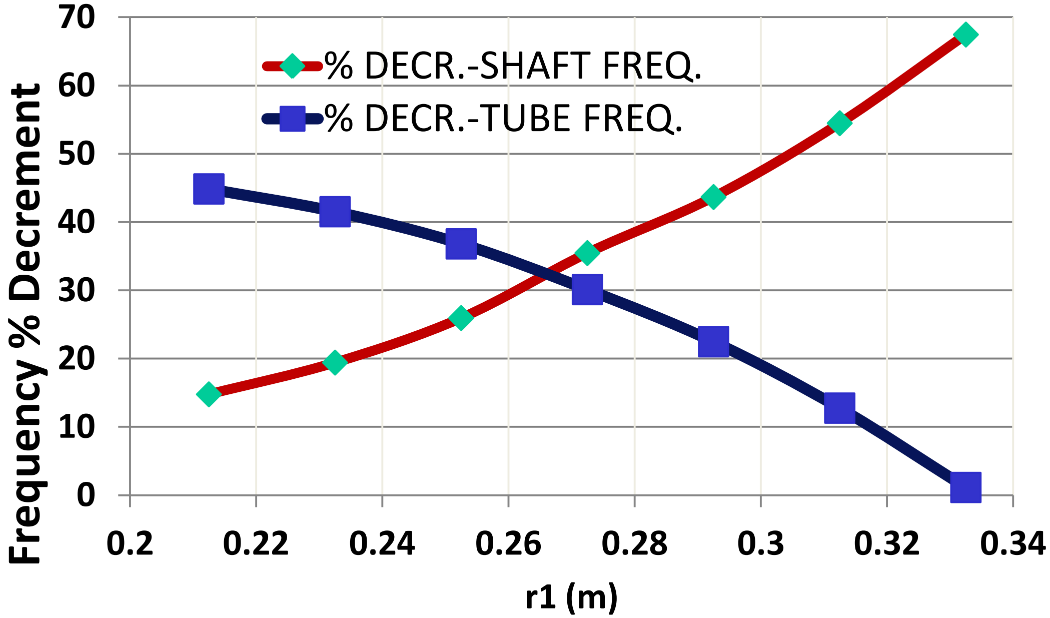
Comparison of Percentage Decrement in Shaft and Tube Natural Frequency

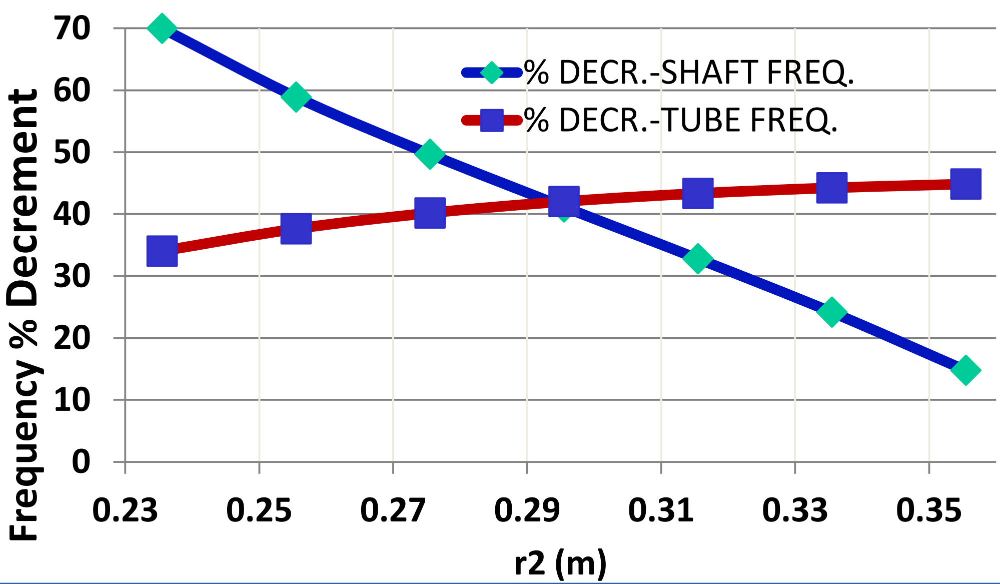
EMship
Advanced Design

As r1 increases



-Shaft frequency affected much as with change in its radius.

As r2 decreases



As the gap decreases the natural frequency of shaft increase and of the tube decreases

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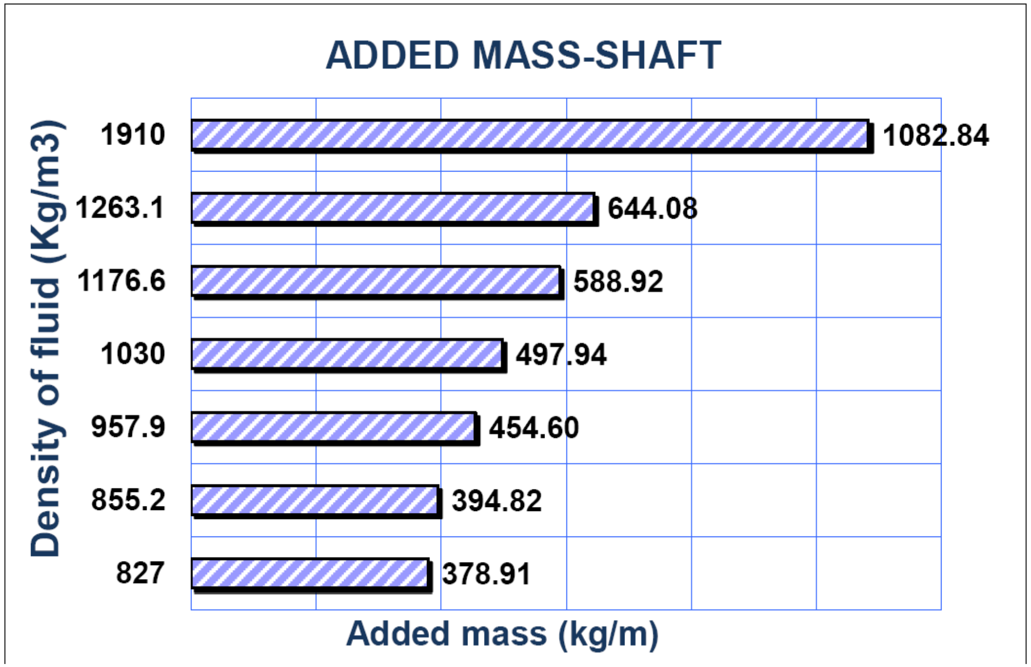
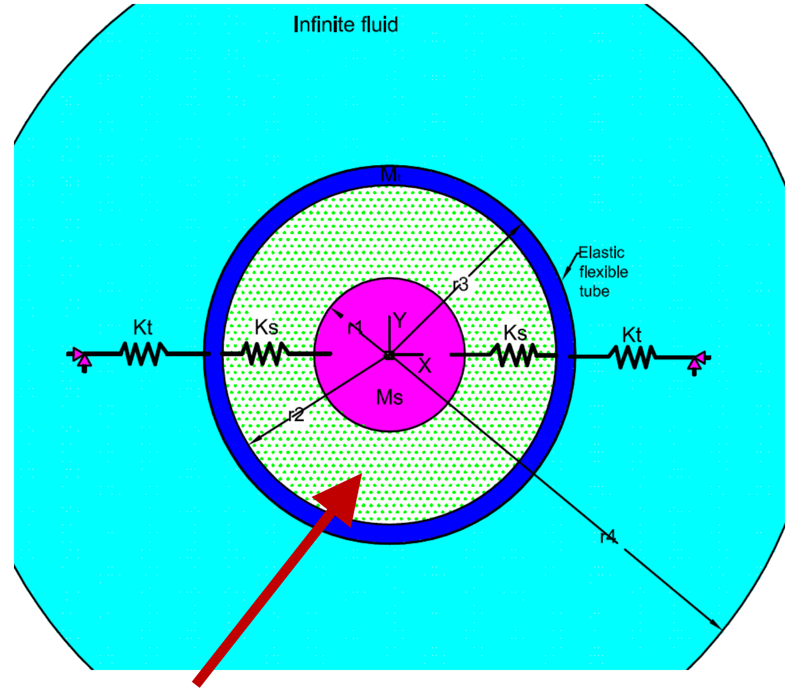
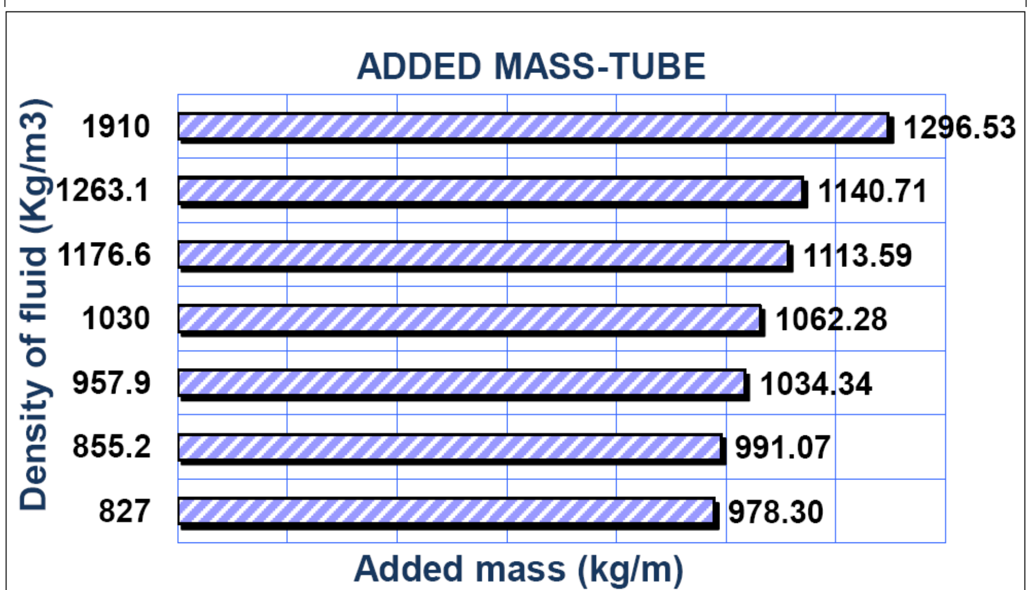
Influence of Density







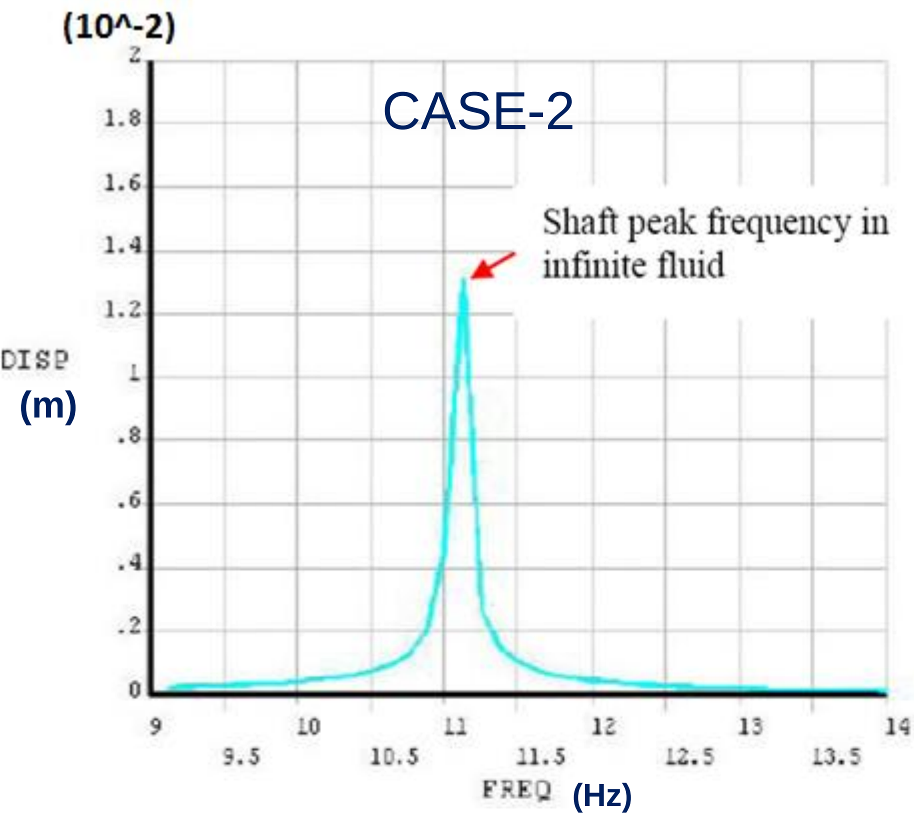
- Only fluid between shaft and tube changed

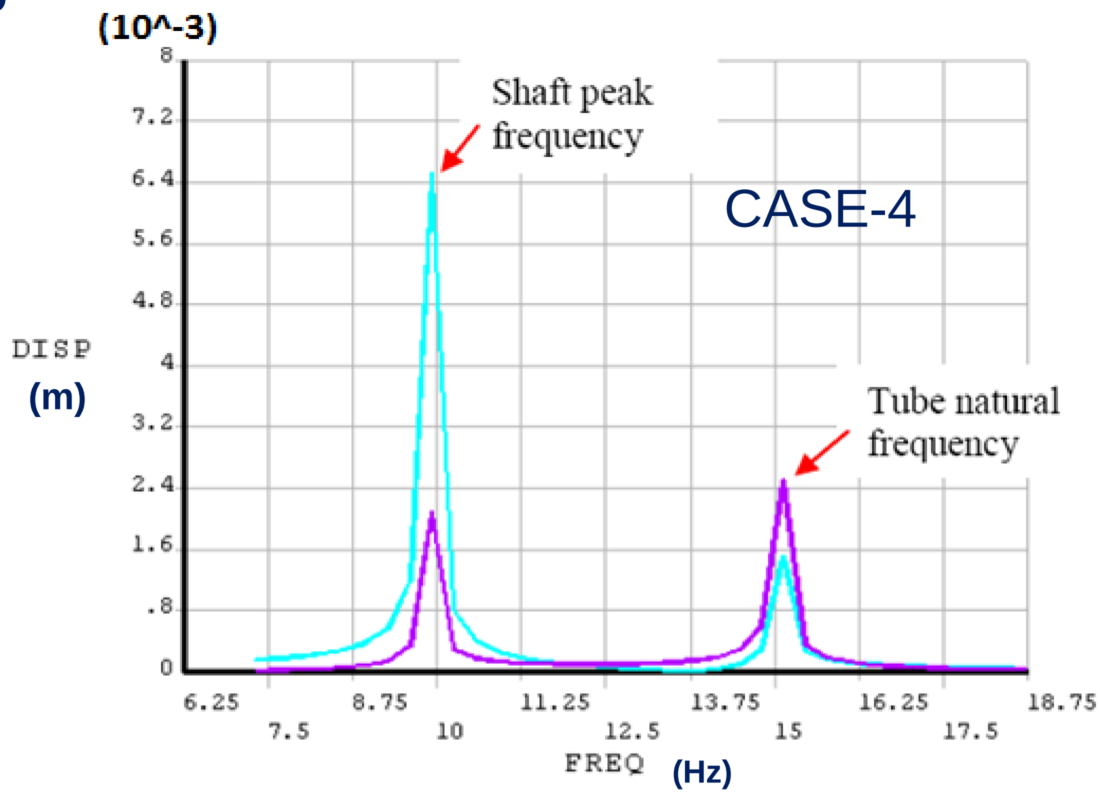
- Shaft natural frequency influenced more.

Harmonic Analysis

-2kN harmonic force applied at the center on shaft.

- To determine steady state response of shaft and tube.
- To validate modal analysis.
- To determine vibration transmission from shaft to tube and vice versa through fluid.





PART-2 Bending vibration Analysis of OVBD Line

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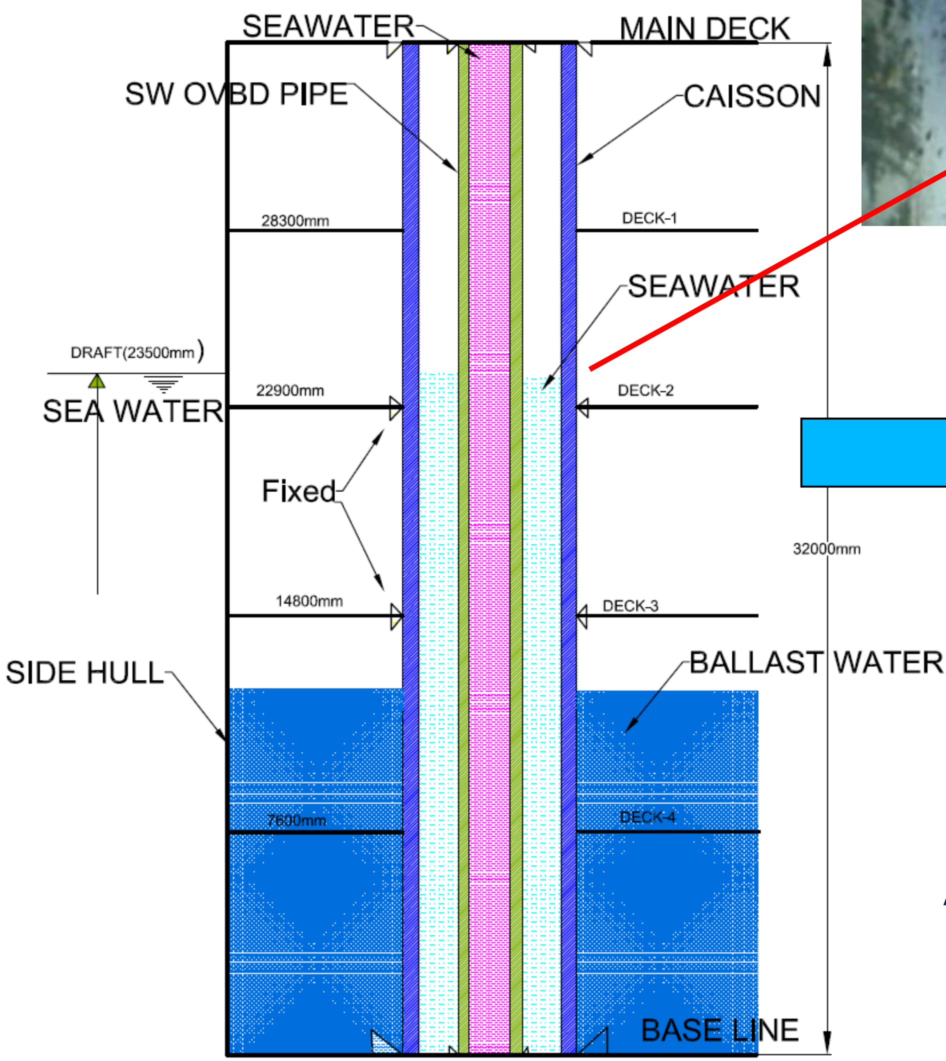
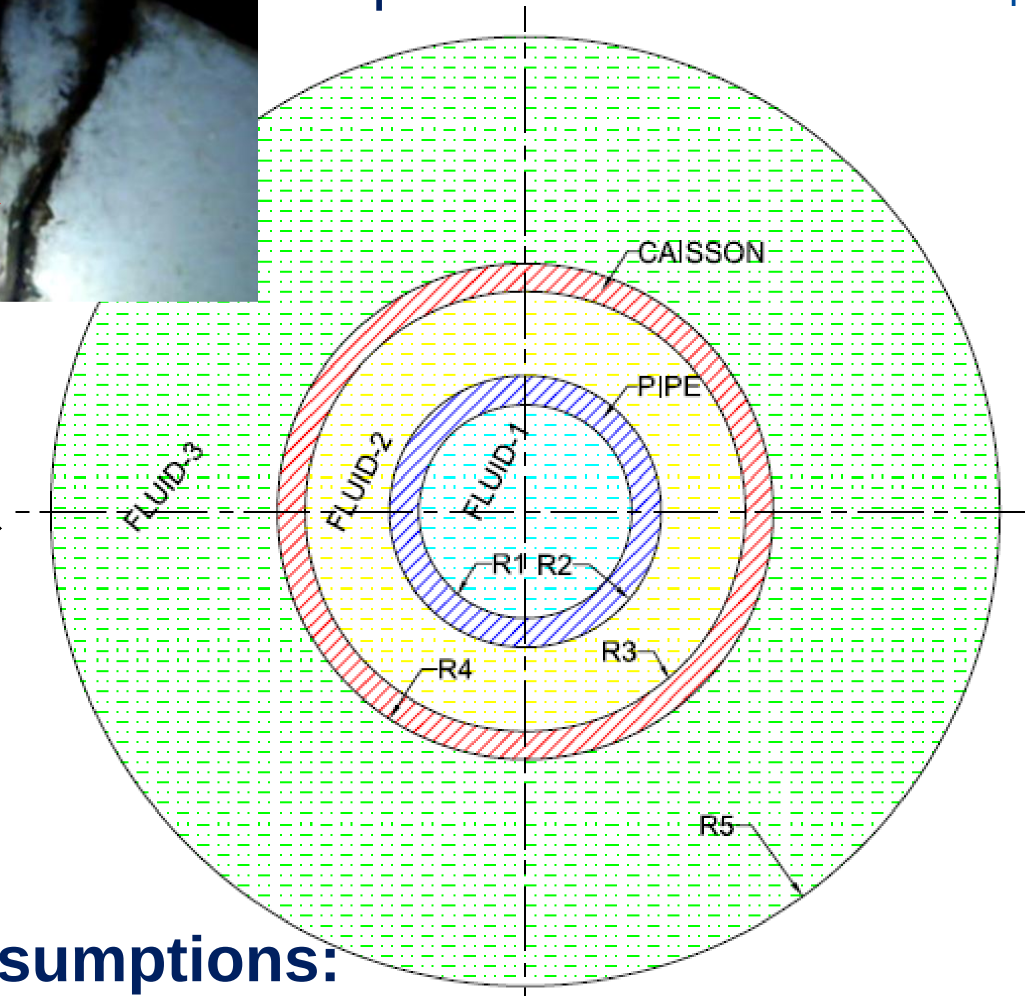
Real model



Simplified model



Assumptions:

- Ballast water considered as infinite fluid
- Caisson rigidly fixed at 4 points!
- Pipe rigidly fixed at two extremes

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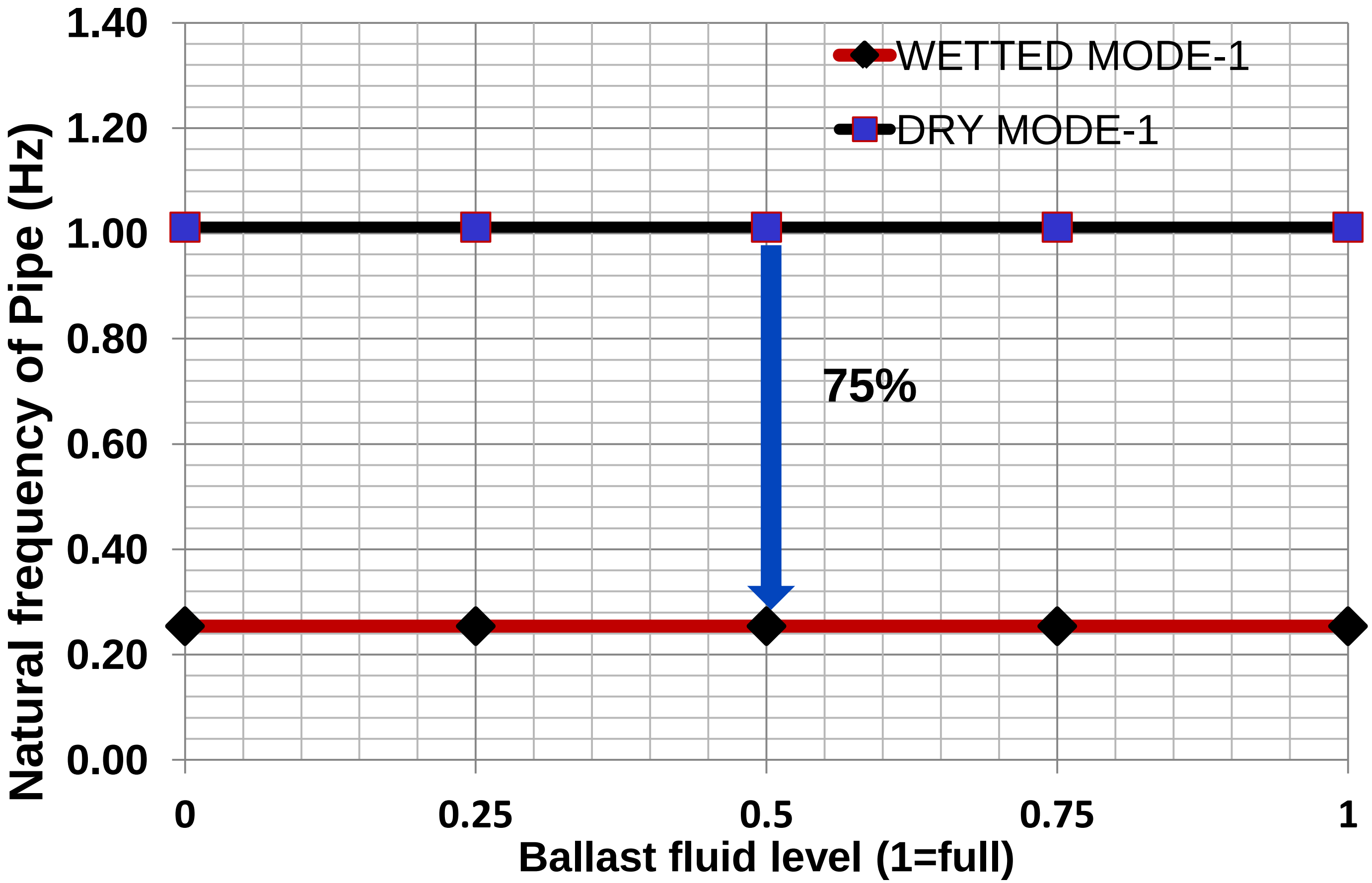
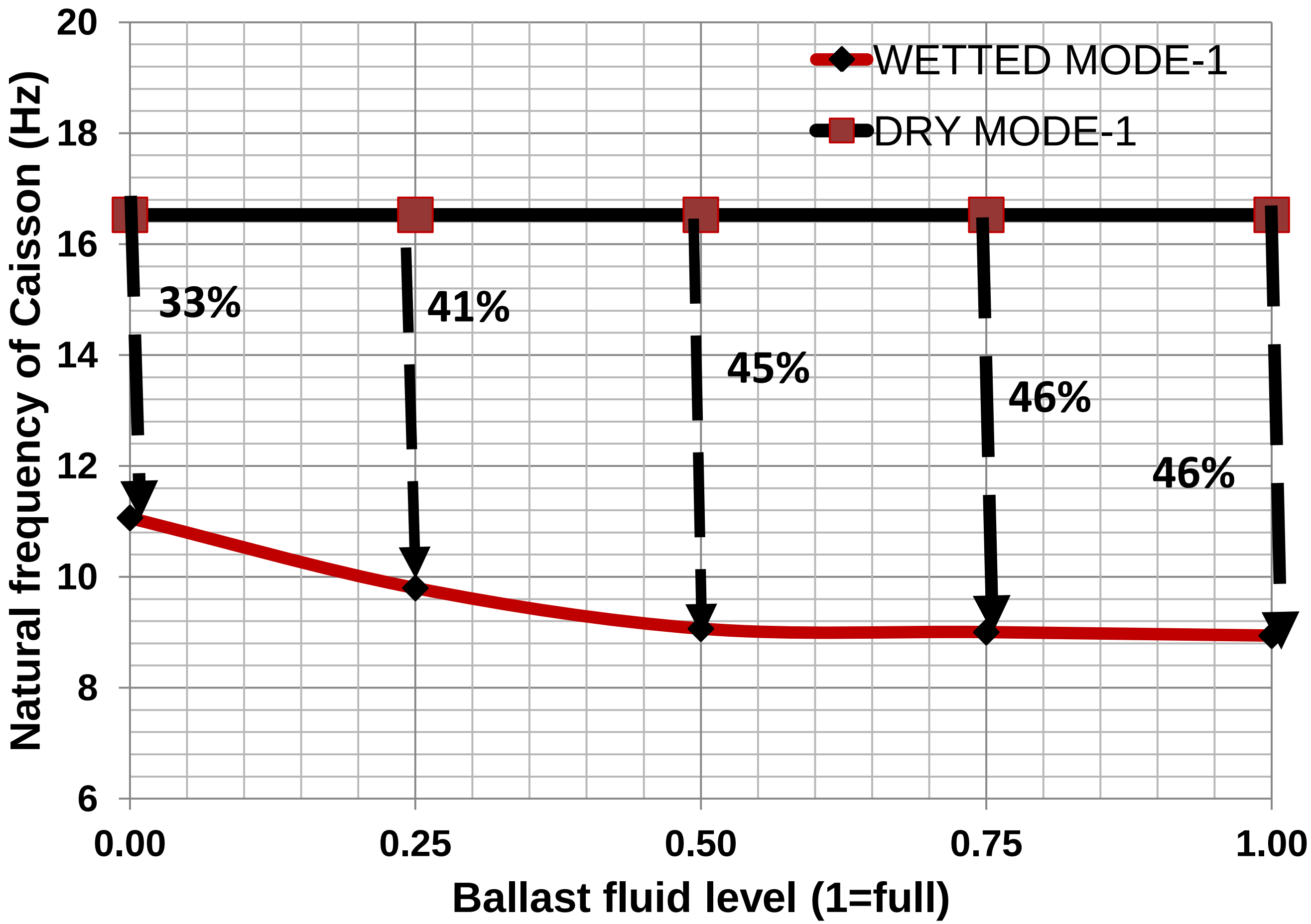
Pipe natural frequency



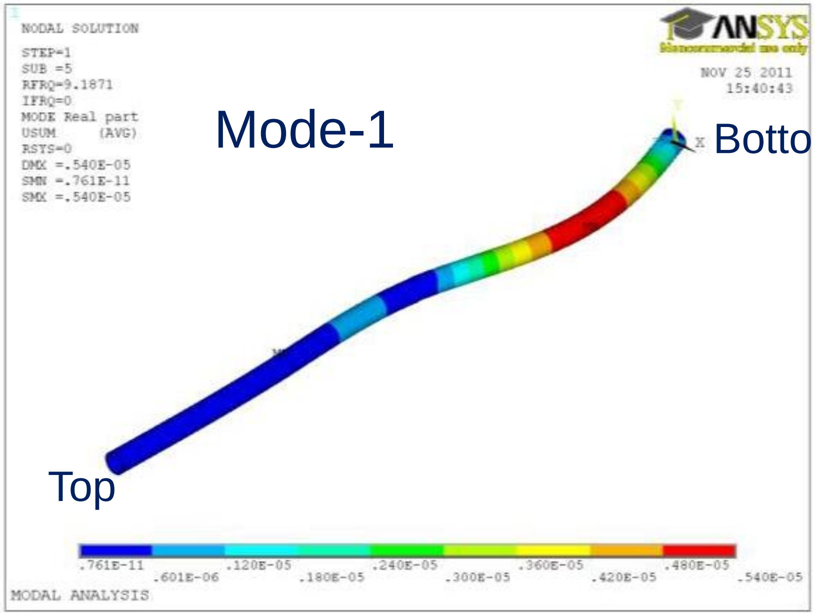
Mode-2 – 76% (3.9 - 0.9Hz)
Mode-3 – 74% (8.4 - 2. 2Hz)
-Almost no effect of ballast water

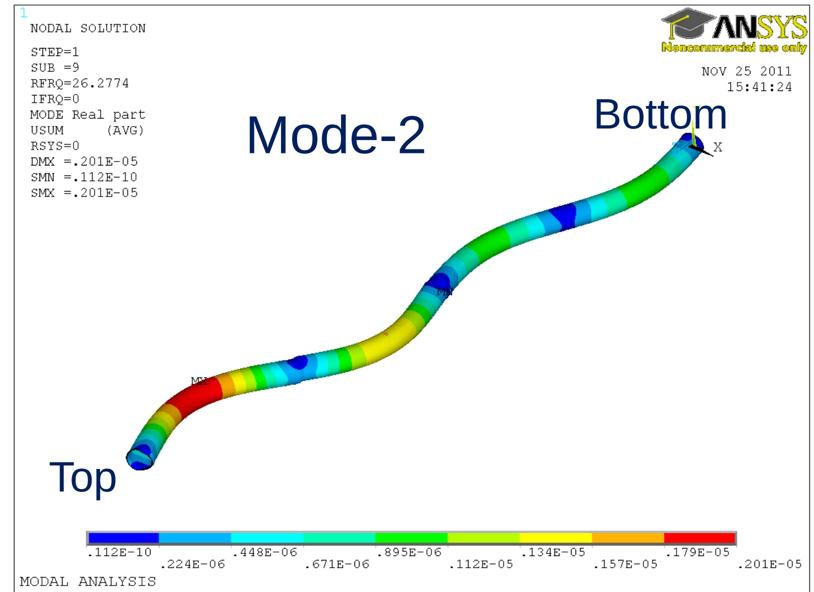
Caisson natural frequency



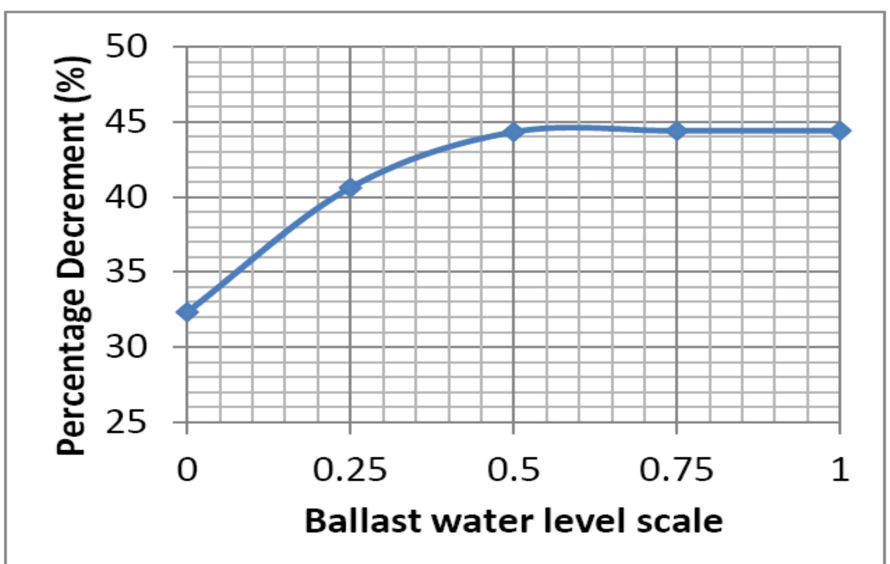
-Much affected by ballast water

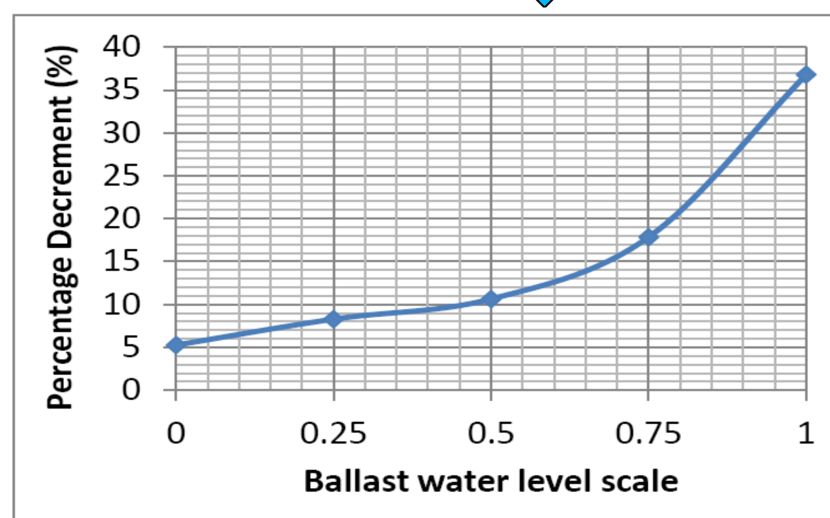
Effect of Ballast Water on Wetted In and Out Caisson



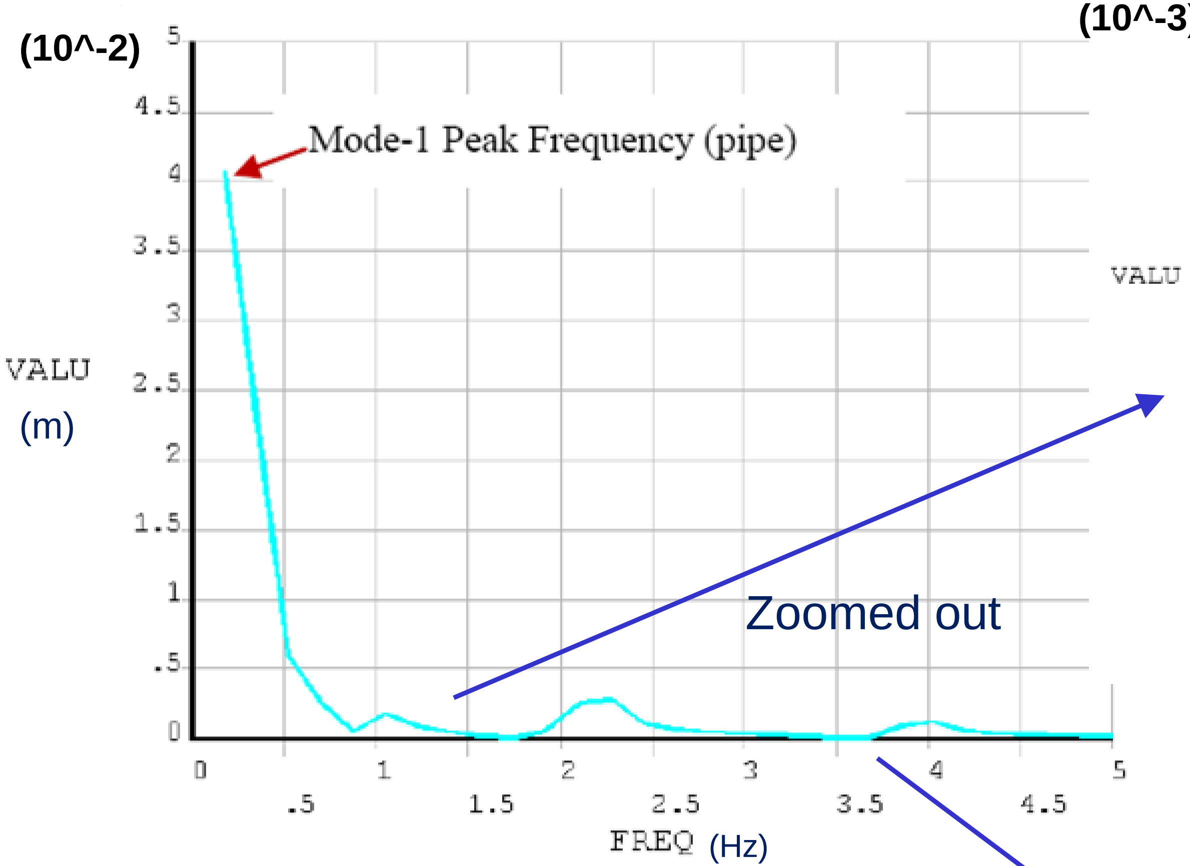


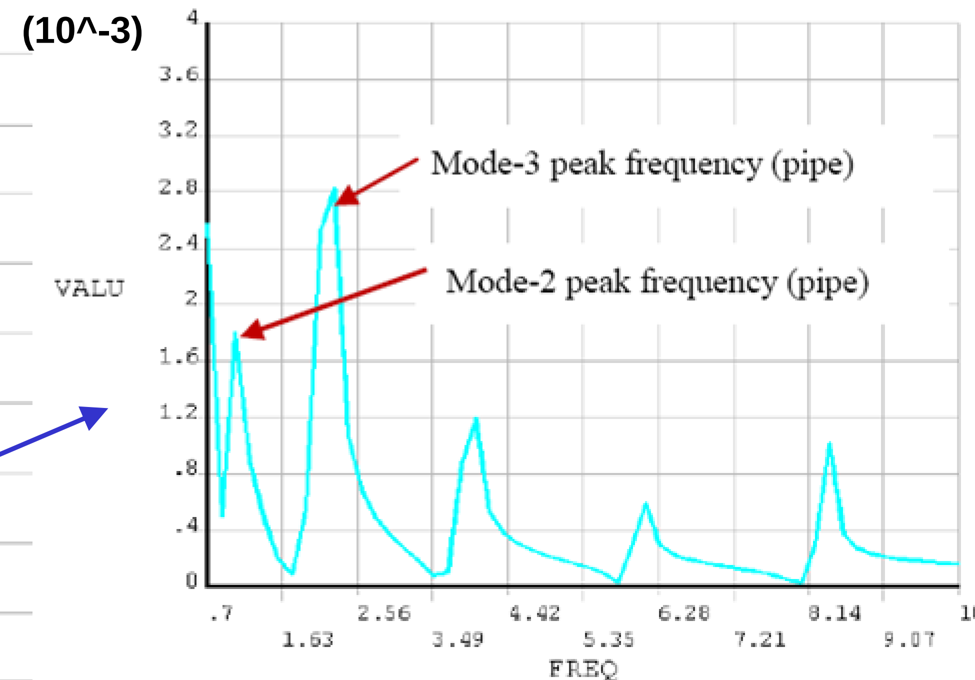
Frequency percentage decrement

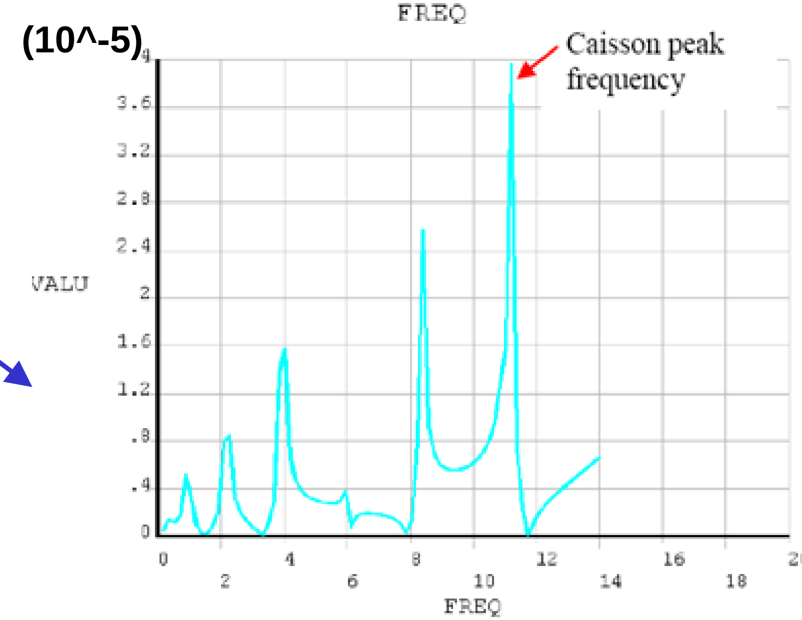




Forced OVBD System Without Ballast Water







2kN harmonic force applied to the pipe at the center

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Conclusion and Future Direction

- Acoustic FSI FEM can simulate BVA with minimum error.
- Stern tube BV much affected by added mass
- Added mass coefficient depend on absolute dimension of shaft and tube, not only on ratio.
- Added mass coefficient of shaft increase as gap decreases
- Added mass coefficient of tube decrease as the gap decreases
- Natural frequency and added mass of OVBD discharge line are much affected by surrounding fluid.
- No influence of ballast water on pipe natural frequency
- Caisson frequency depend on ballast water condition as well

THANK YOU
FOR YOUR ATTENTION!