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Cantilever Rod: Tutorial

GO-VIKING WP 6

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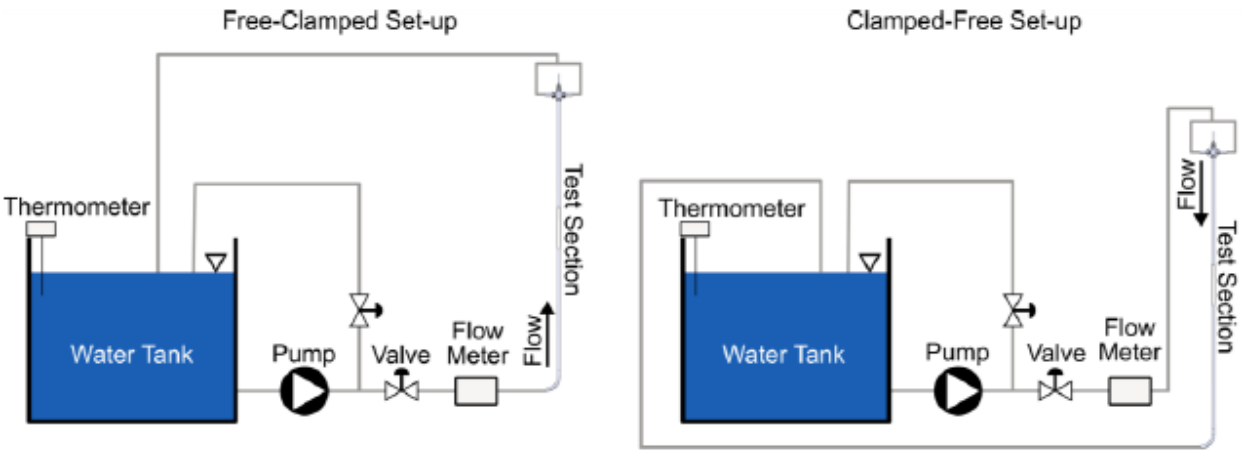
Outline

- Introduction
  - Test Section
- Modelling Assumptions
- CAD Geometry
- Interactive FSI tutorial using Simcenter STAR-CCM+ (V2306)
  - FSI Test
- FSI Test Results
- What have we learnt?

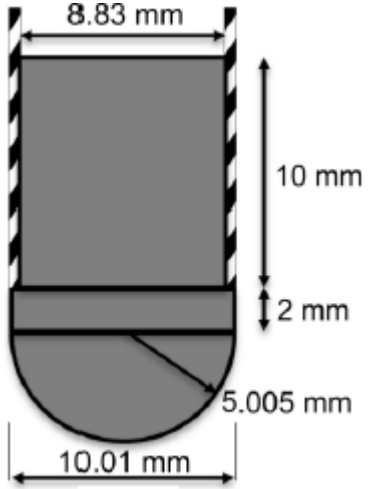
Introduction

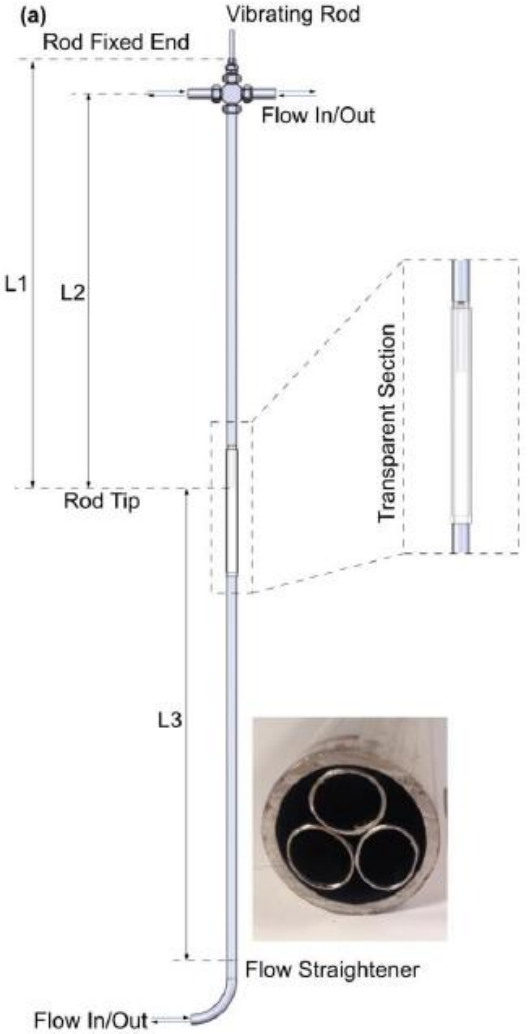
- Single Phase flow along Cantilevered Rod with Curved end considered
- Experiment carried out at UoM [1]
- Free-Clamped Configuration at Re_{ann}=21.2k

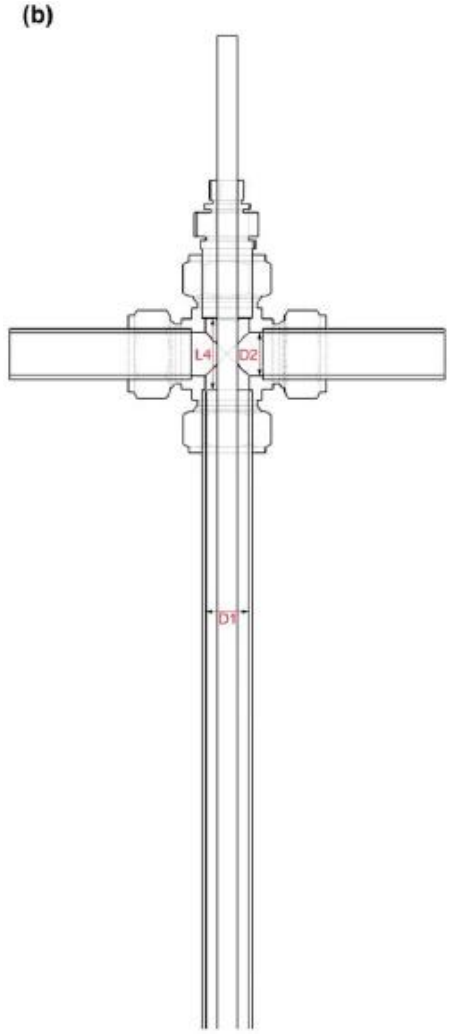


Test Section

- Rods are filled with lead shots (d = 0.3-1.6 mm)
- Rod is made of AISI 316 SS with an aluminum end plug
- Mass density of rod = 588 g/m
- Measurements:
  - L1 = 1045 mm
  - L2 = 944 mm
  - L3 = 1100 mm
  - D1 = 20.86 mm
  - D2 = 21.80 mm







Modelling Assumptions

- Only the test section will be considered
- The lead shots are absent, the effective density of AISI 316 SS will be increased to respect the mass density
- The flow straighteners are absent, a uniform velocity will be provided at the inlet
- The union cross and the two outlet pipes will be present
- Roughness of the rod will be considered
- The working fluid will be taken as water at 20^{o}C
- Gravity will be considered
- Since the Rod is slender and hollow, the nonlinear geometry solver will be used
- The FSI coupling will be two-way
- URANS governing equations will be solved for the fluid side

CAD Geometry

- Can be created externally on any CAD tool and imported into STAR-CCM+
- Can be created using ‘3D-CAD Modeler’ of STAR-CCM+ via creation of 2D sketches and extrusions and then create ‘Parts’ from the geometry
- Can be created via Boolean operations on primitives such as cylinders and spheres in STAR-CCM+ directly as ‘Parts’

Interactive Tutorial

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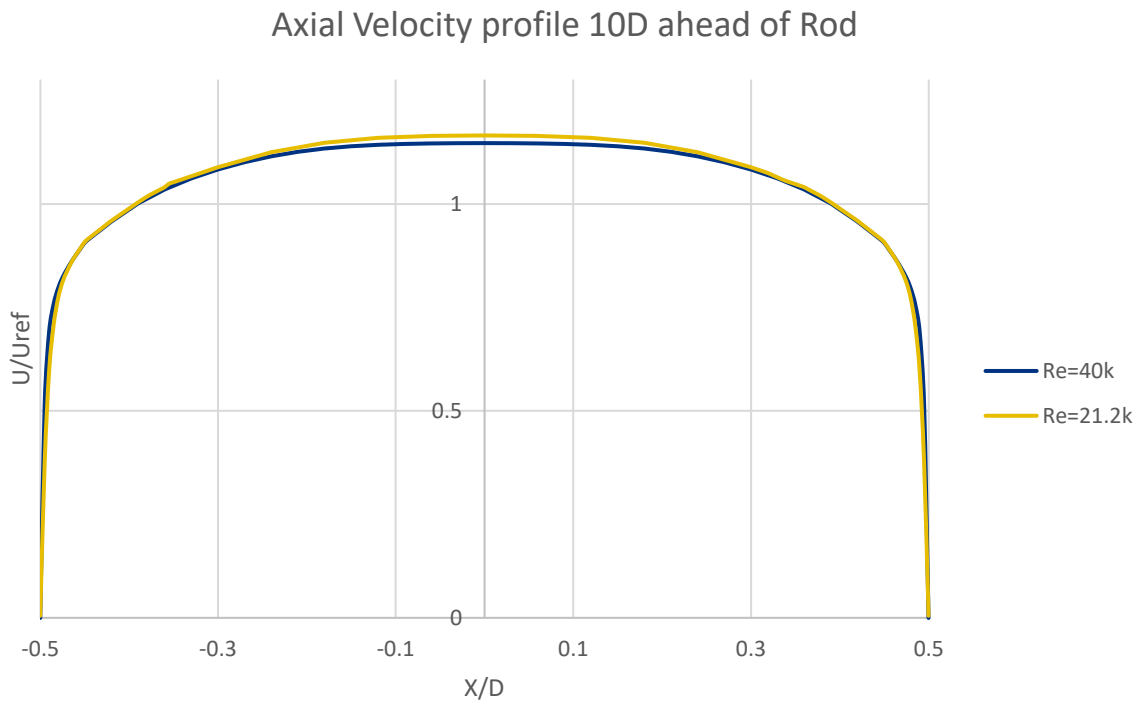
- Regions --> Apply your boundary conditions
- Continua --> Describe your solid and fluid properties
- Meshing --> Spatial Discretization of your domain
- Interfaces --> Exchange kinematic & dynamic boundary conditions for FSI or contacts
- Solvers & Stopping Criteria --> Set the solver settings
- Parameters & Field Functions --> Handy for automation
- Derived Parts, Reports, Monitors, Plots & Scenes--> Post processing

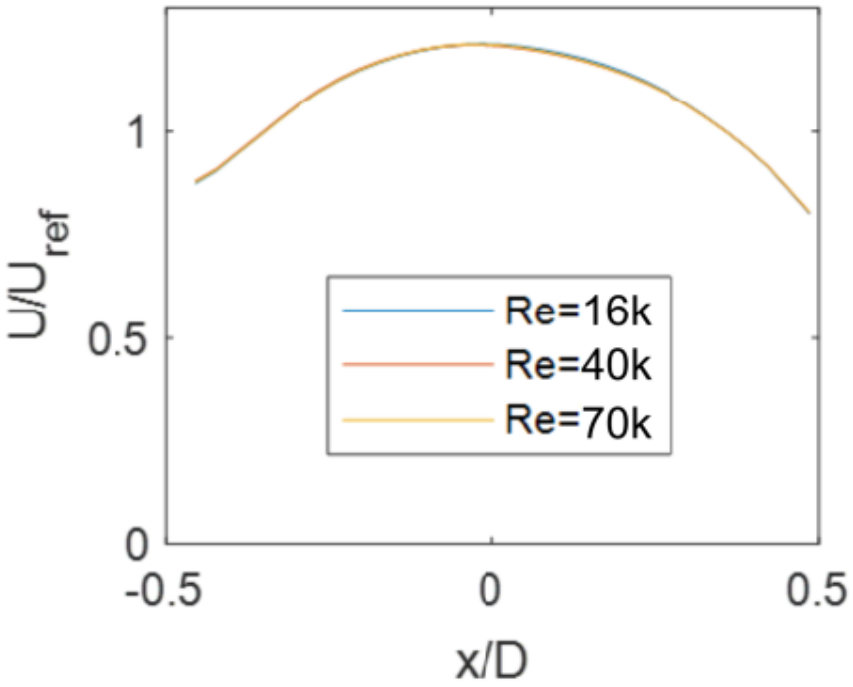
Interactive Tutorial: FSI Test

- Free to Clamped flow
- Re_{ann} = 21.2k (V_{in} = 1.510 m/s)
- Simulation run for 12.08 Flow Passes (1FP = 1.376s)
- Time step size = 0.1 ms with 25 inner iterations/time step
- Standard K-Epsilon Low Re Turbulence model
- First 3.5FP ignored for Vibration statistics, first 4.5FP ignored for PIV statistics

FSI Test results

- Results: Left Simulation, Right Expt.





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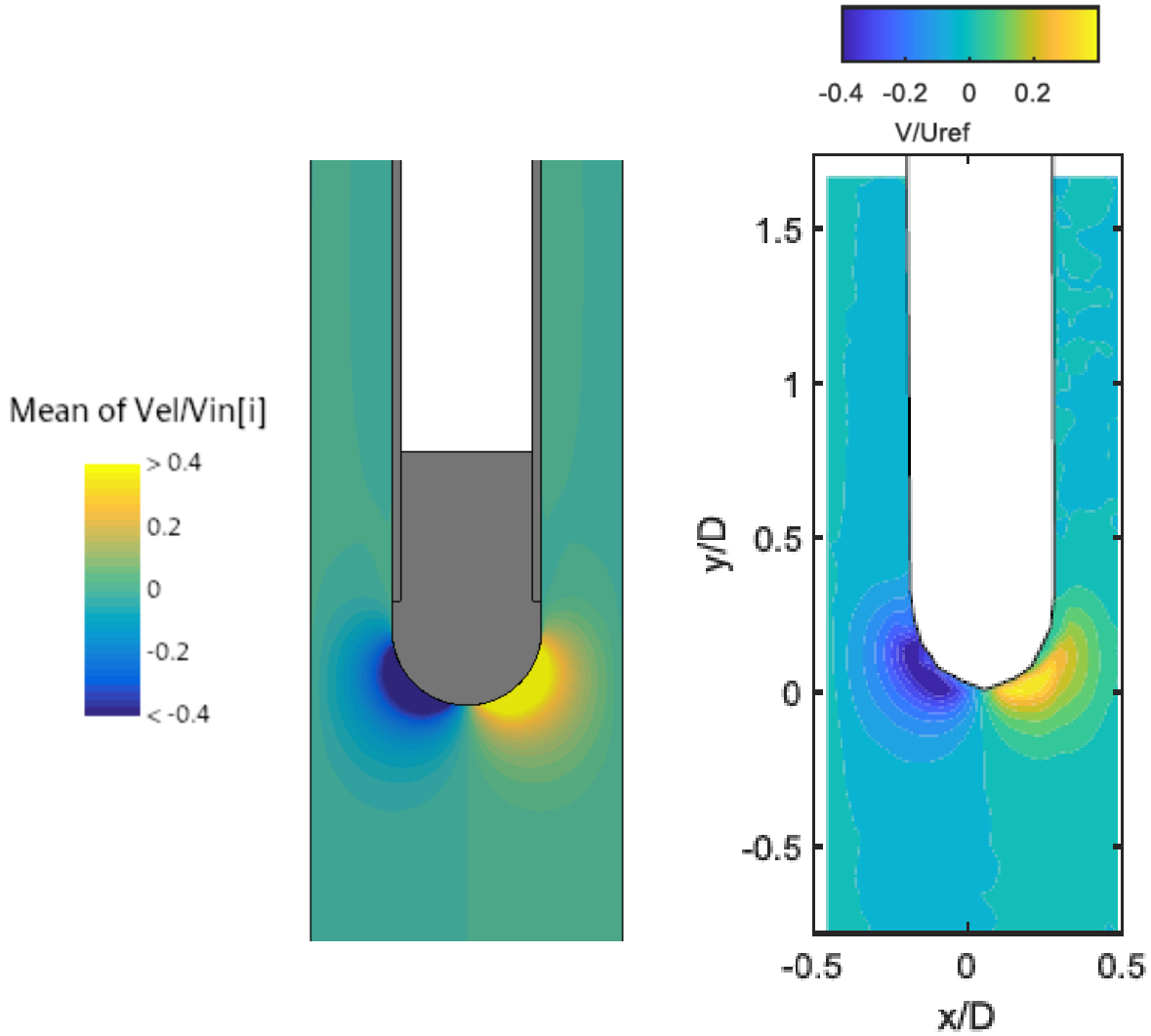

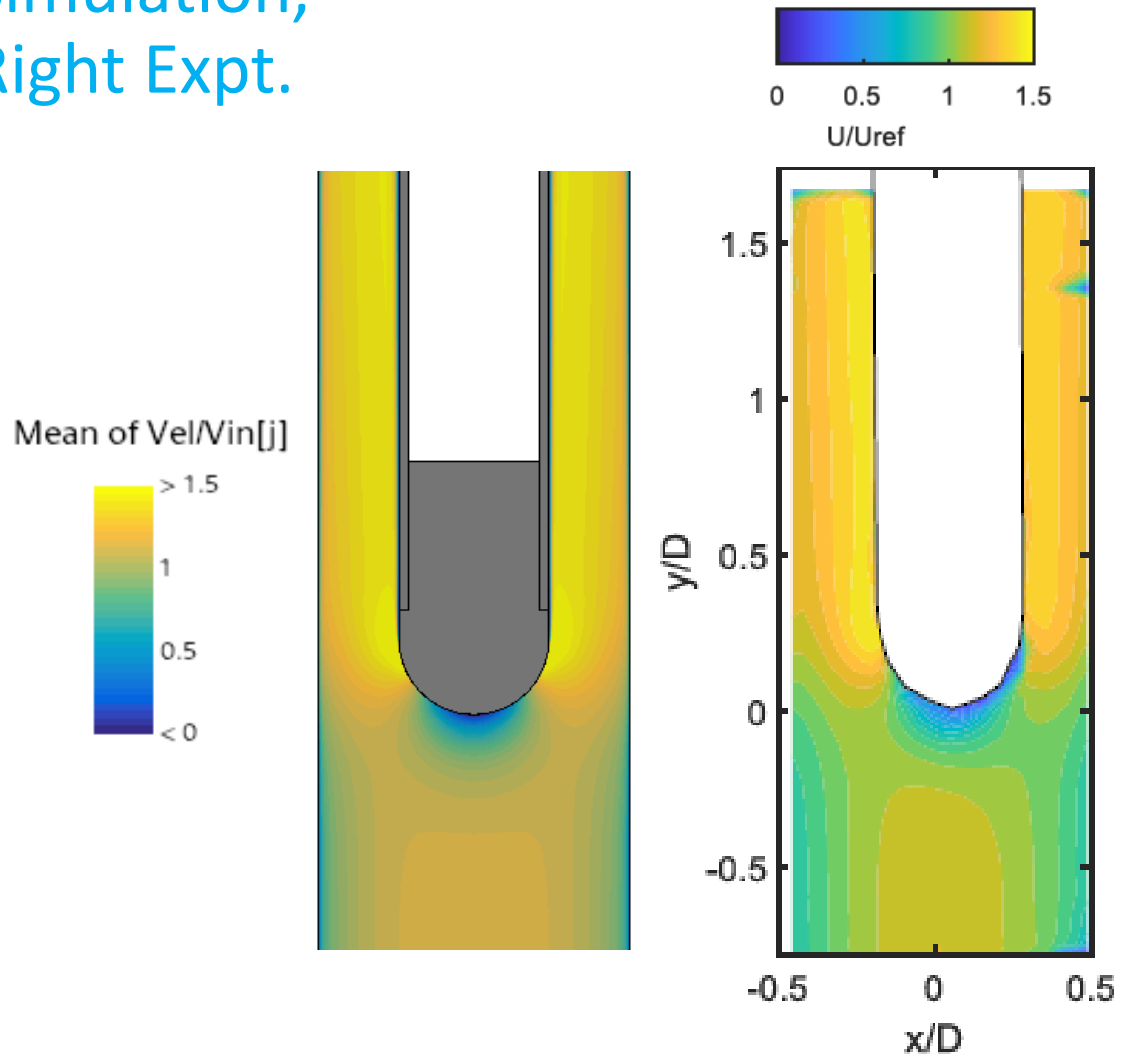

FSI Test results

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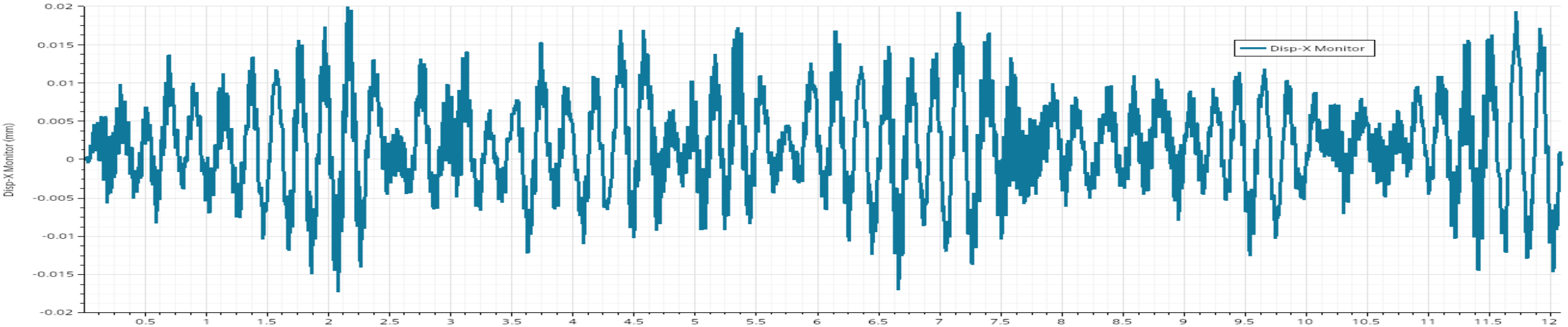

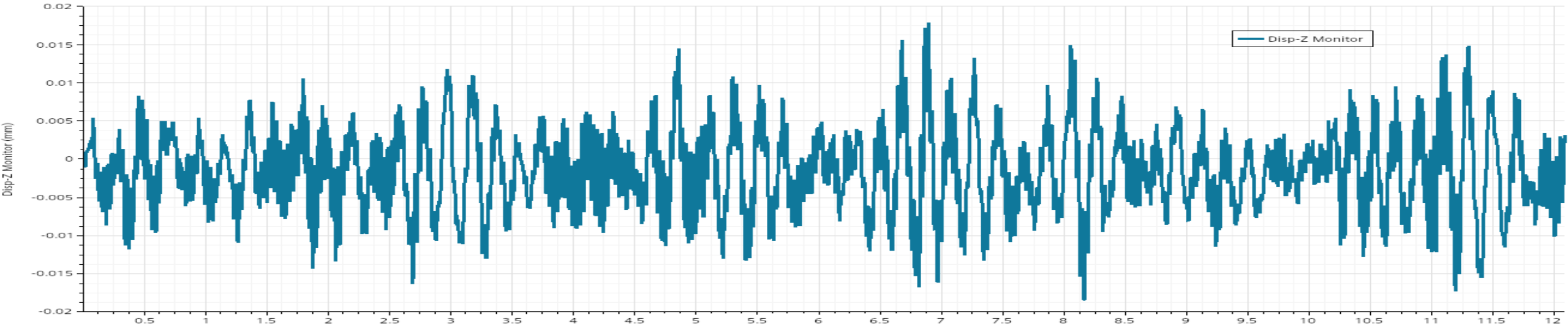

FSI Test results

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Vibration Results:

1. Polar displacement [Rho → sqrt([x-<x>]^2+ ([z-<z>]^ 2)]

- Expt. = 0.08 mm
- Numerical = 0.00816 mm (An order of magnitude less)

2. Vibrational frequency [F → 0.5*(F_z+F_x)]

- Expt. = 3.758 Hz
- Numerical = 3.601Hz [4% error]

What have we learnt?

- The Cantilevered Rod problem
- Modelling Assumptions for the FSI problem
- How to Setup the problem on the commercial code Simcenter STAR-CCM+ (V2306)
- FSI Test Results

Reference

- Cioncili, A. et. al. (2023). Experiments on axial-flow-induced vibration of free-clamped/clamped-free rod for light-water nuclear reactor applications. Annals of Nuclear Energy, 190, 109900. Doi: 10.1016/j.anucene.2023.109900
- Simcenter STAR-CCM+ User Guide: Available at Simcenter STAR-CCM+ - User Guide (HUGE pdf) (siemens.com)

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Thank you!

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