Effect of stochastic deformation on the vibration characteristics of a tube bundle in axial flow

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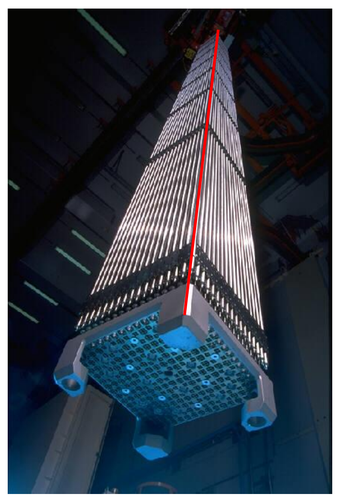
Introduction

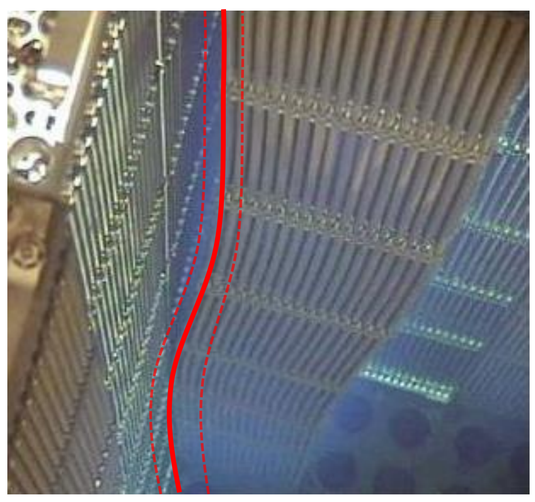
- **Flow-induced vibrations (FIV)** of nuclear power plant components
- Novel reactor design cooled with liquid lead → research needed
- FIV more and more investigated using computer simulations
- Geometry & operating conditions ≠ design on drawing table
  - **Bow deformation** fuel during stay in core
- Need to understand FIV and safety at these more realistic conditions too
  →Paradigm shift from purely deterministic simulations toward **simulations involving uncertainty** proposed

Objective

Evaluating statistics of uncertain FIV characteristics of a deformed fuel assembly by considering its bow deformation as a stochastic process



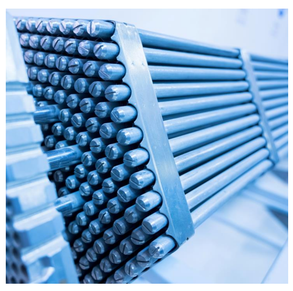
Months



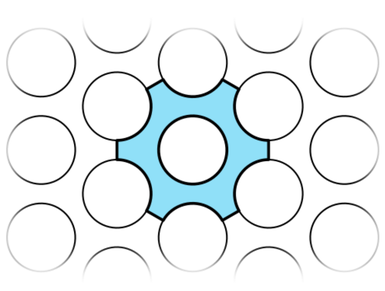
Methods

FIV obtained through coupled CFD-FEM simulation

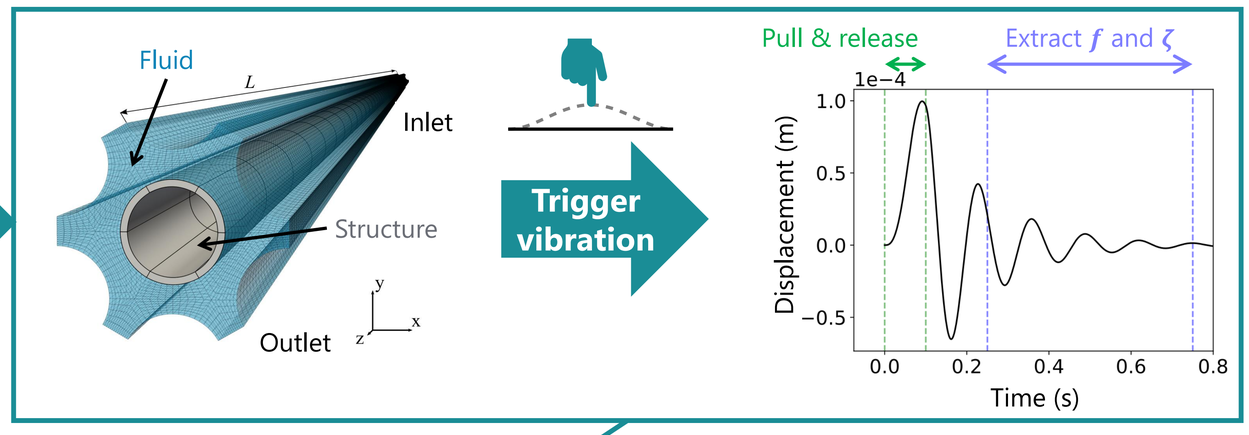
- Fluid-structure interaction (FSI): simultaneously simulating flow with computational fluid dynamics (CFD) solver and structure using finite element method (FEM)
- **Free vibration** triggered to characterize vibration by **frequency** f and **damping** ratio ζ



Simplify

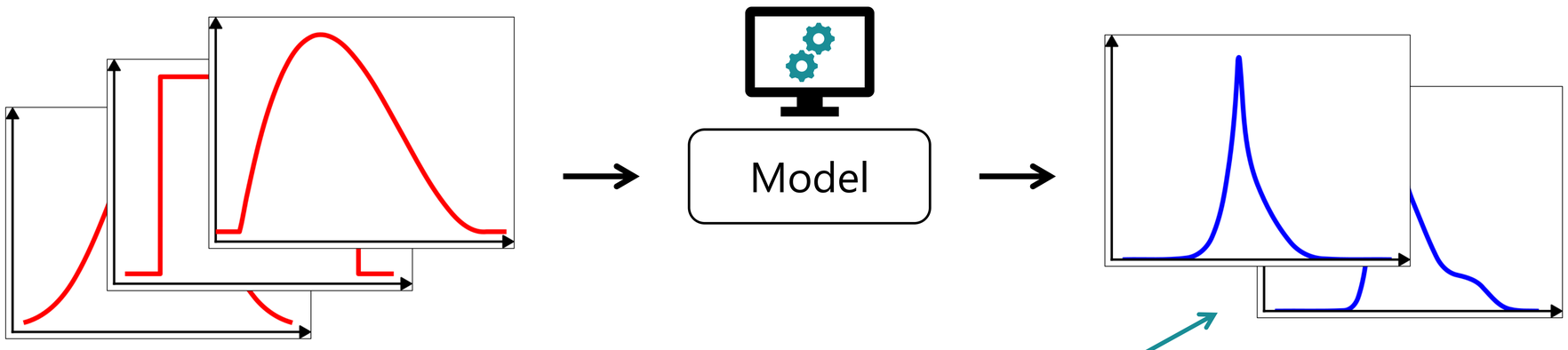


Model



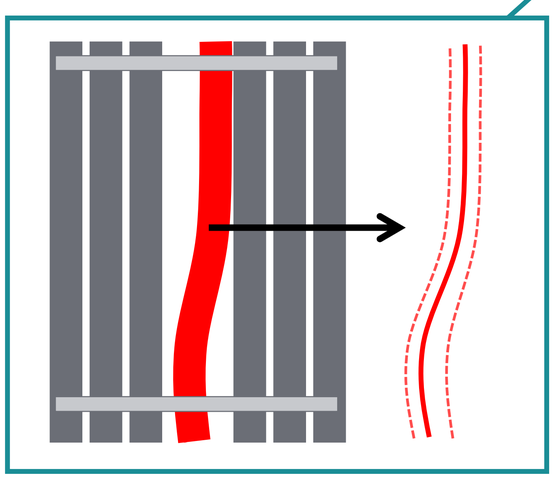
Statistical characterization of FIV using uncertainty quantification (UQ) method

- UQ: **input uncertainty** propagated through model into **output uncertainty**
- 2 UQ methods considered:
- Monte Carlo method
  - Well-established ☺
  - Many model evaluations ☹
- Polynomial Chaos method
  - Feasible for FSI ☺
  - Less robust ☹

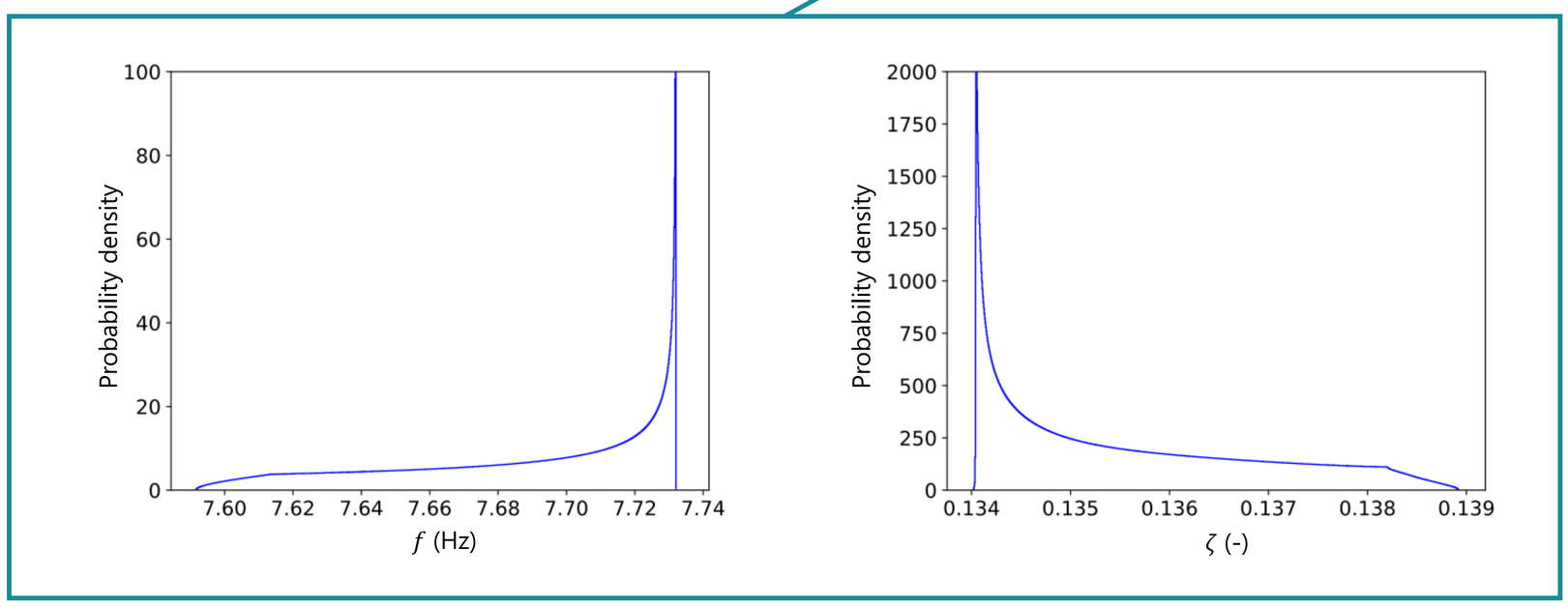


Results

Parametrized deformation propagated through model for FIV



UQ



Conclusion

Objective achieved

- Model to obtain FIV characteristics via a **coupled CFD-FEM** model simulating free vibration in liquid lead established
- Developed efficient procedure for UQ of FIV characteristics of **deformed fuel pin**, using validated methods
- **Statistics of frequency and damping ratio** characterizing FIV obtained

Outlook

Methods will be used in future work

- Vibration of steam generator tubes in gas-liquid flow