# High Head Francis Turbines

Background, research and findings

Competence and Innovation combo project

HydroCen Summit, 6. February 2020

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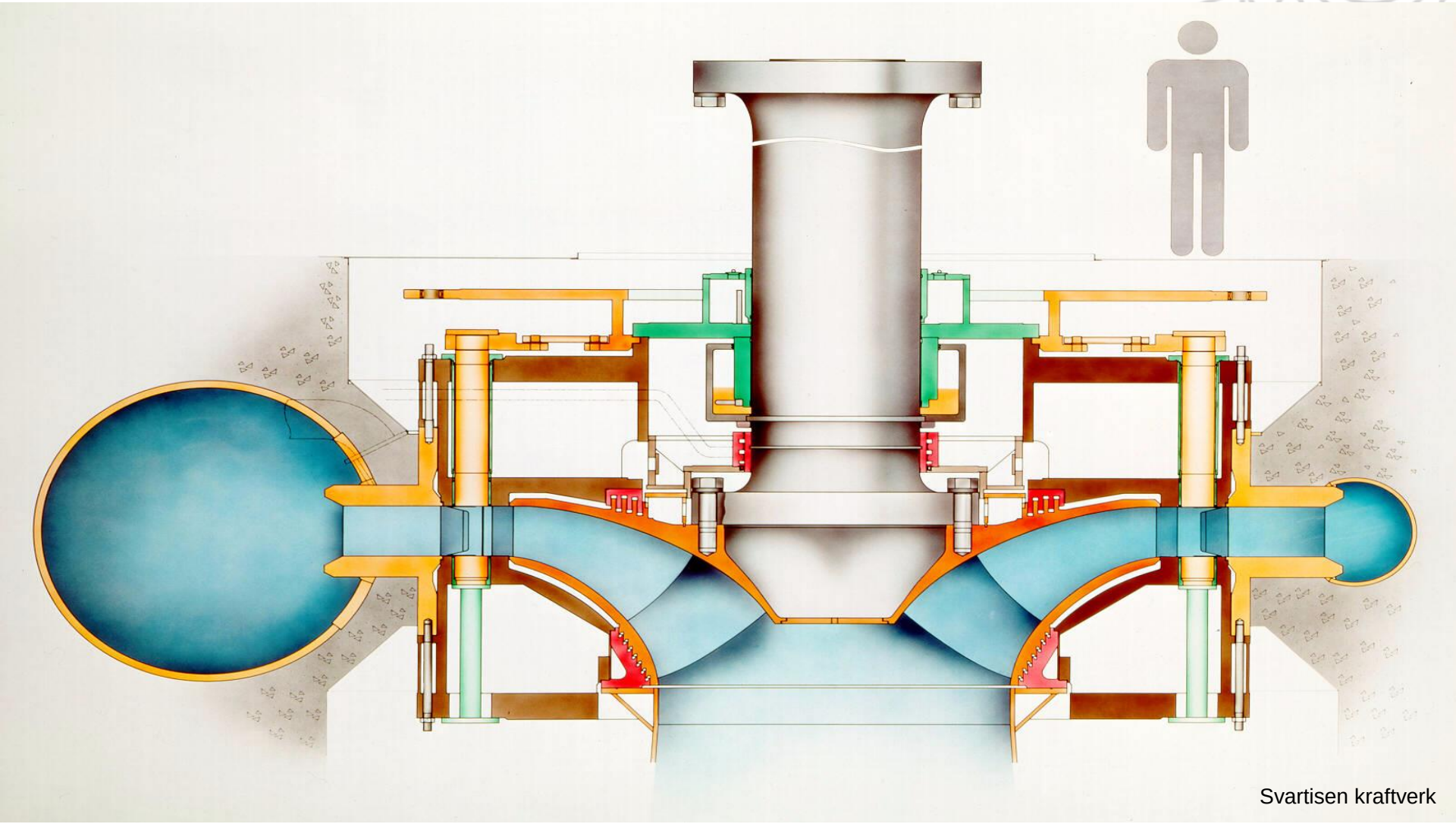
Post Doctoral Fellow
(Associate Professor)

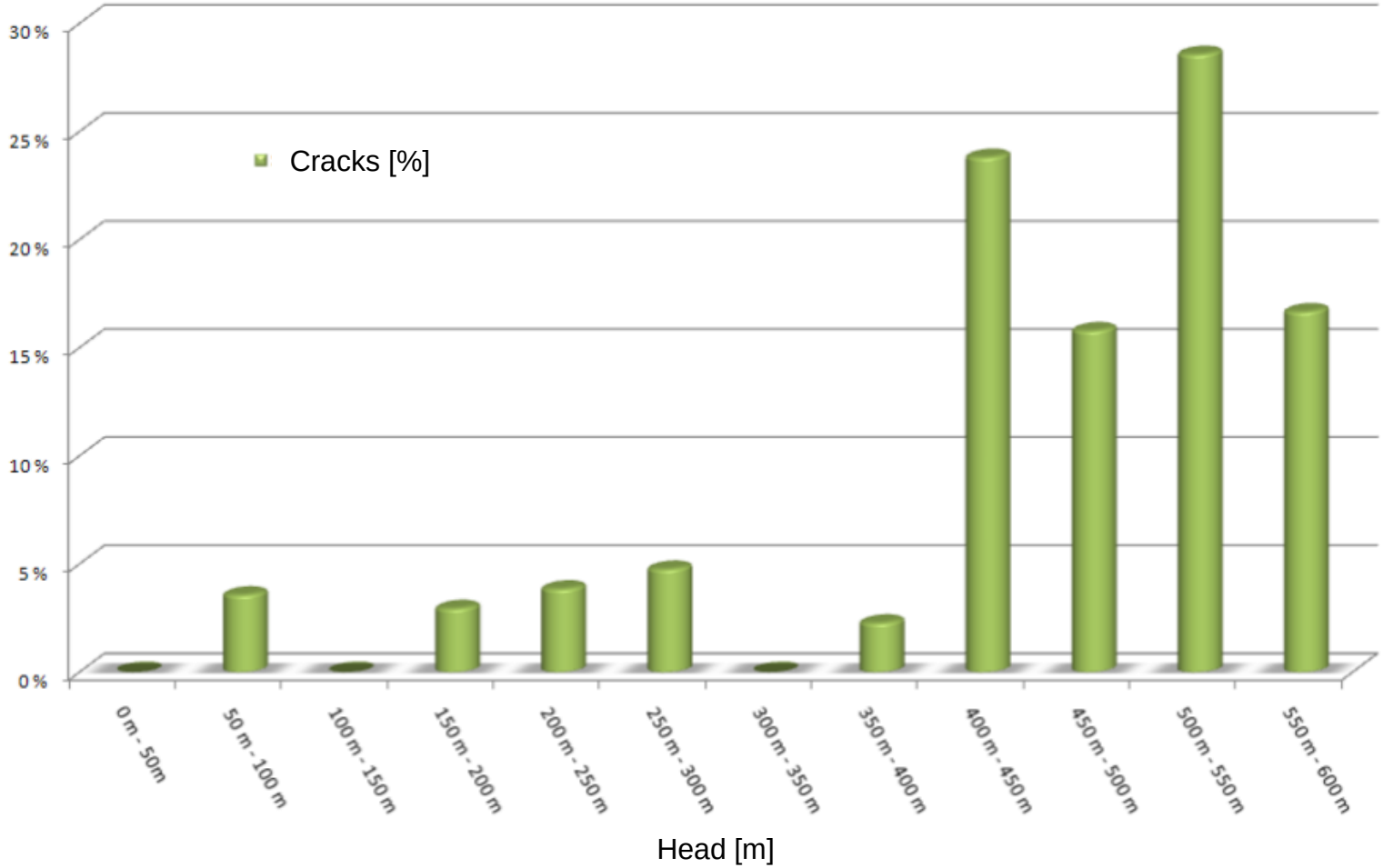
# High head turbines in Norway

| Turbine type | Head | Number of turbines | Number of power plants | Power | Energy |
|---|---|---|---|---|---|
| | [m] | [ - ] | [ - ] | [MW] | [GWh] |
| Francis | 300--> | 122 | 66 | 10.250 | 34.960 |
| Francis | 200-300 | 75 | 45 | 3.372 | 14.280 |
| Francis | 100-200 | 60 | 36 | 1.564 | 6.960 |
| Pelton | | 107 | 48 | 6.757 | 25.601 |



Svartisen kraftverk

# Cracks in High Head Francis runner




Ref. Bjarne Børresen "*Sprekker i løpehjul. Analyser, forebygging og erfaringer*" PTK 2009

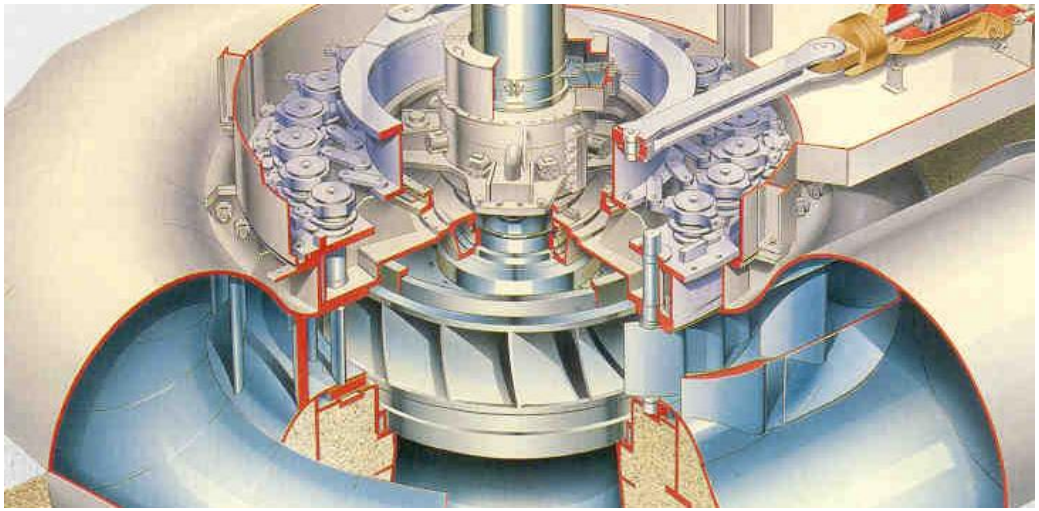
# Partners

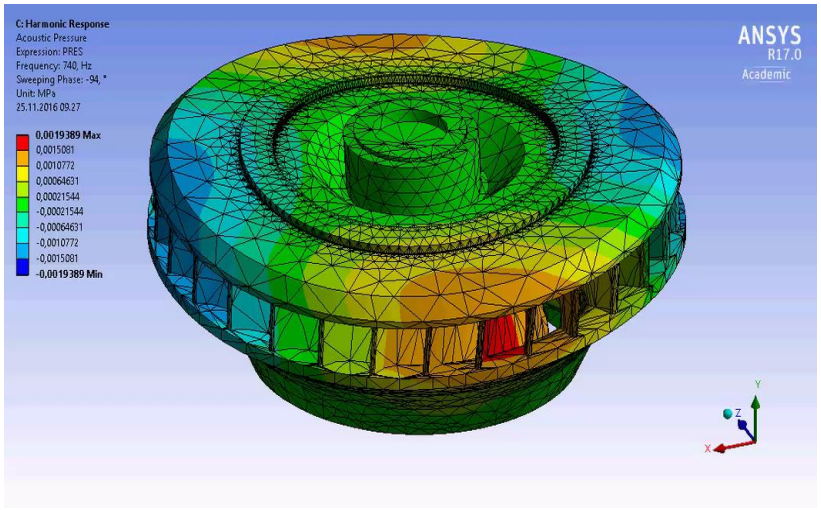
Forskningsrådet

- NTNU
- Norsk Vannkraftsenter
- Voith Hydro
- Andritz Hydro
- Rainpower
- GE Renewable Norway
- EDR Medeso
- Norconsult
- Sweco Norge
- Multiconsult

- Energi Norge
- Statkraft Energi
- Sira Kvina Kraftselskap
- E-CO Energi
- Hydro Energi
- BKK Produksjon
- Eidsiva Vannkraft
- Otra Kraft
- Agder Energi
- Skagerak Kraft

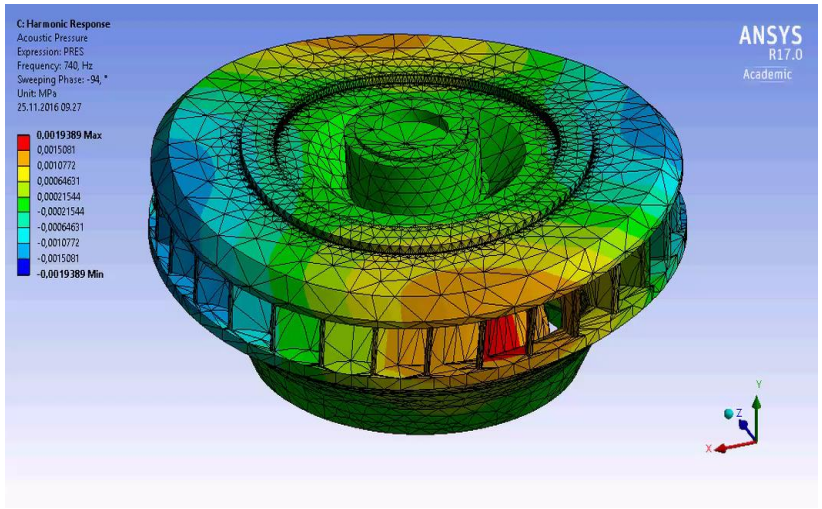
# Rotor-Stator Interaction, RSI, and deflection pattern of the runner

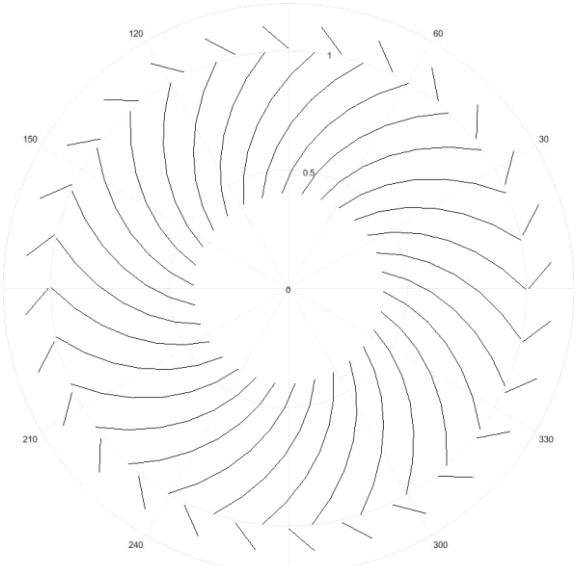




# Rotor-Stator Interaction, RSI, and deflection pattern of the runner

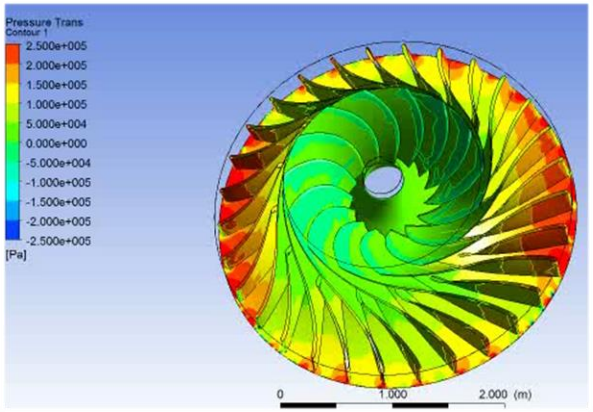
Francis 99 Turbine



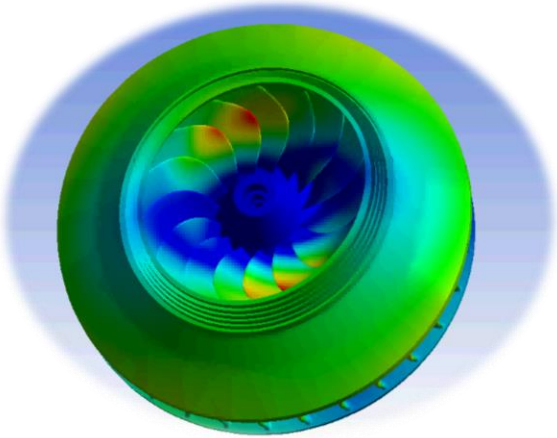



# Main focus of research

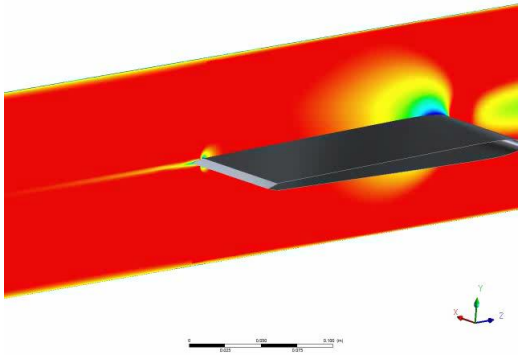
Fluid load



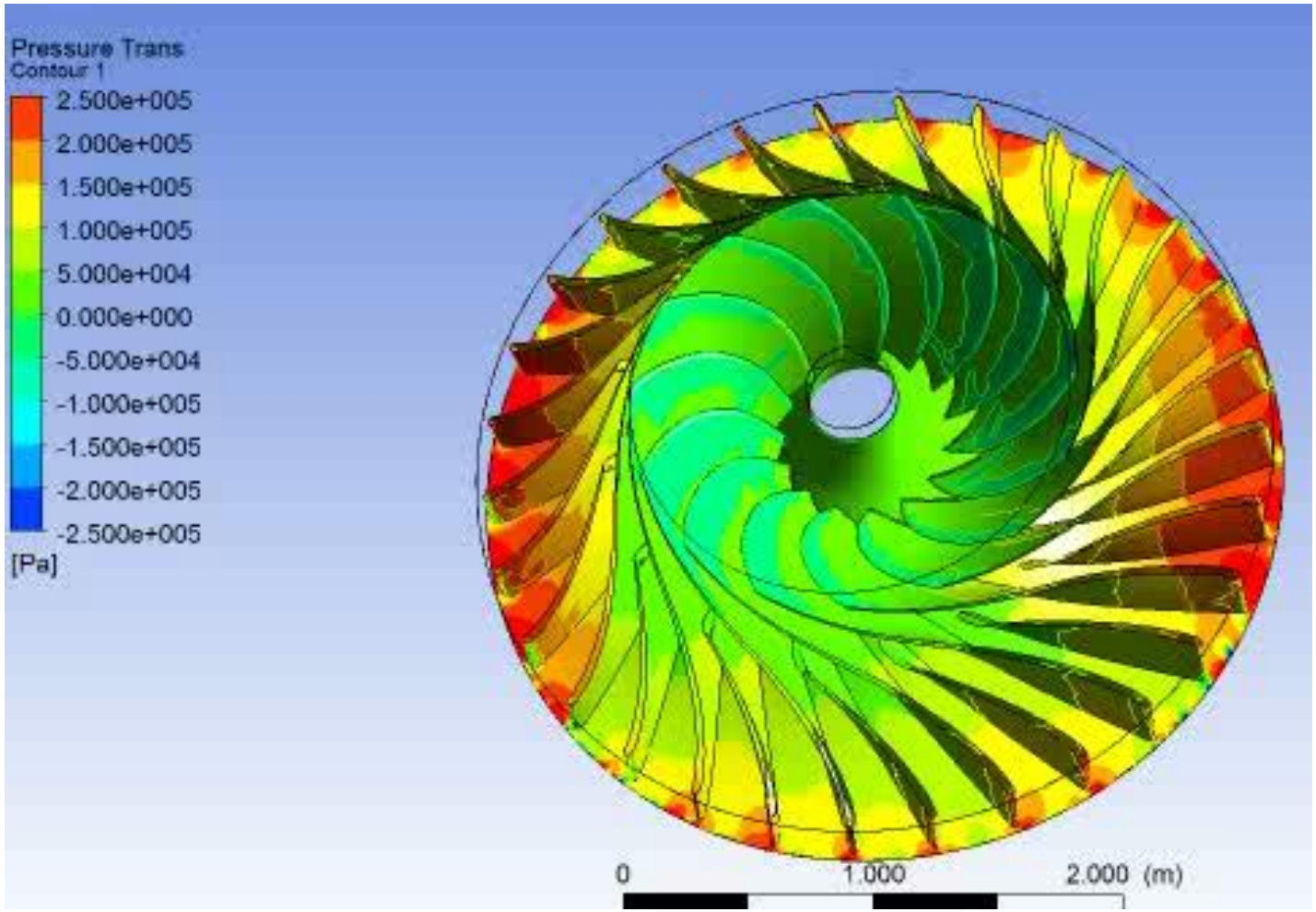

Natural Frequency



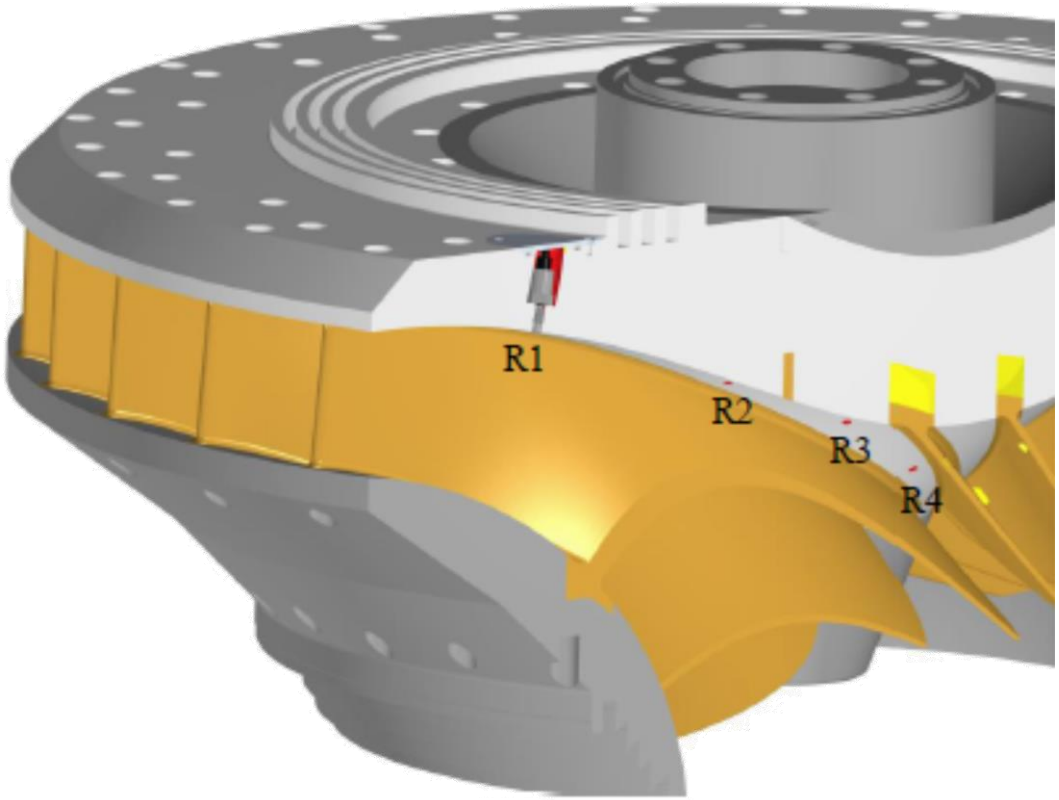
Damping

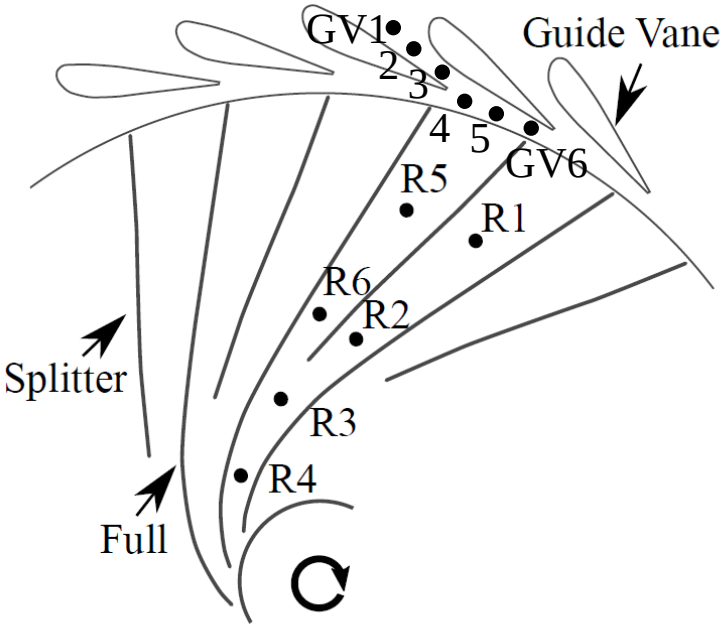


# Fluid Load


Pressure Trans
Contour 1
2.500e+005
2.000e+005
1.500e+005
1.000e+005
5.000e+004
0.000e+000
-5.000e+004
-1.000e+005
-1.500e+005
-2.000e+005
-2.500e+005
[Pa]
0
1.000
2.000 (m)

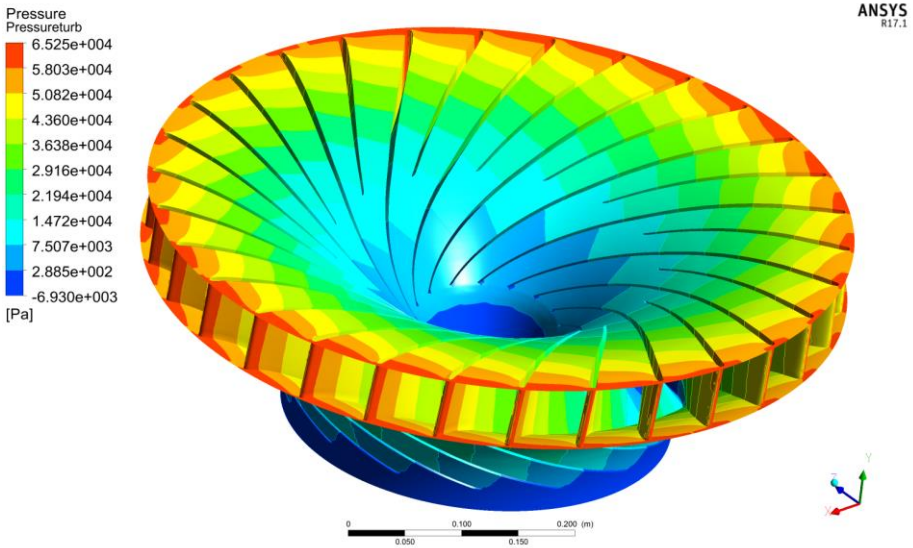
# Fluid Load - Experiment

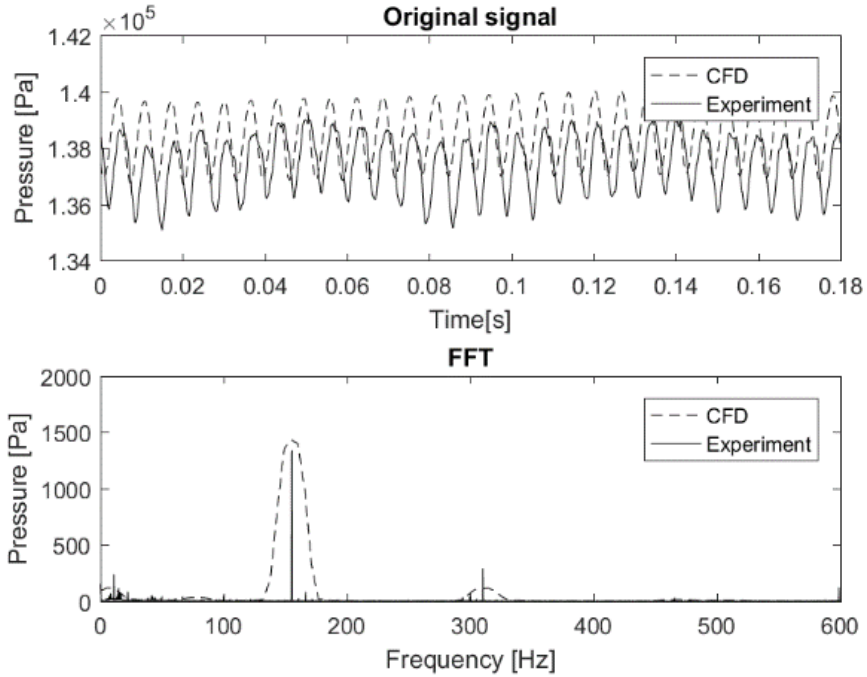


# Fluid Load - Validation

## Full-wheel simulations

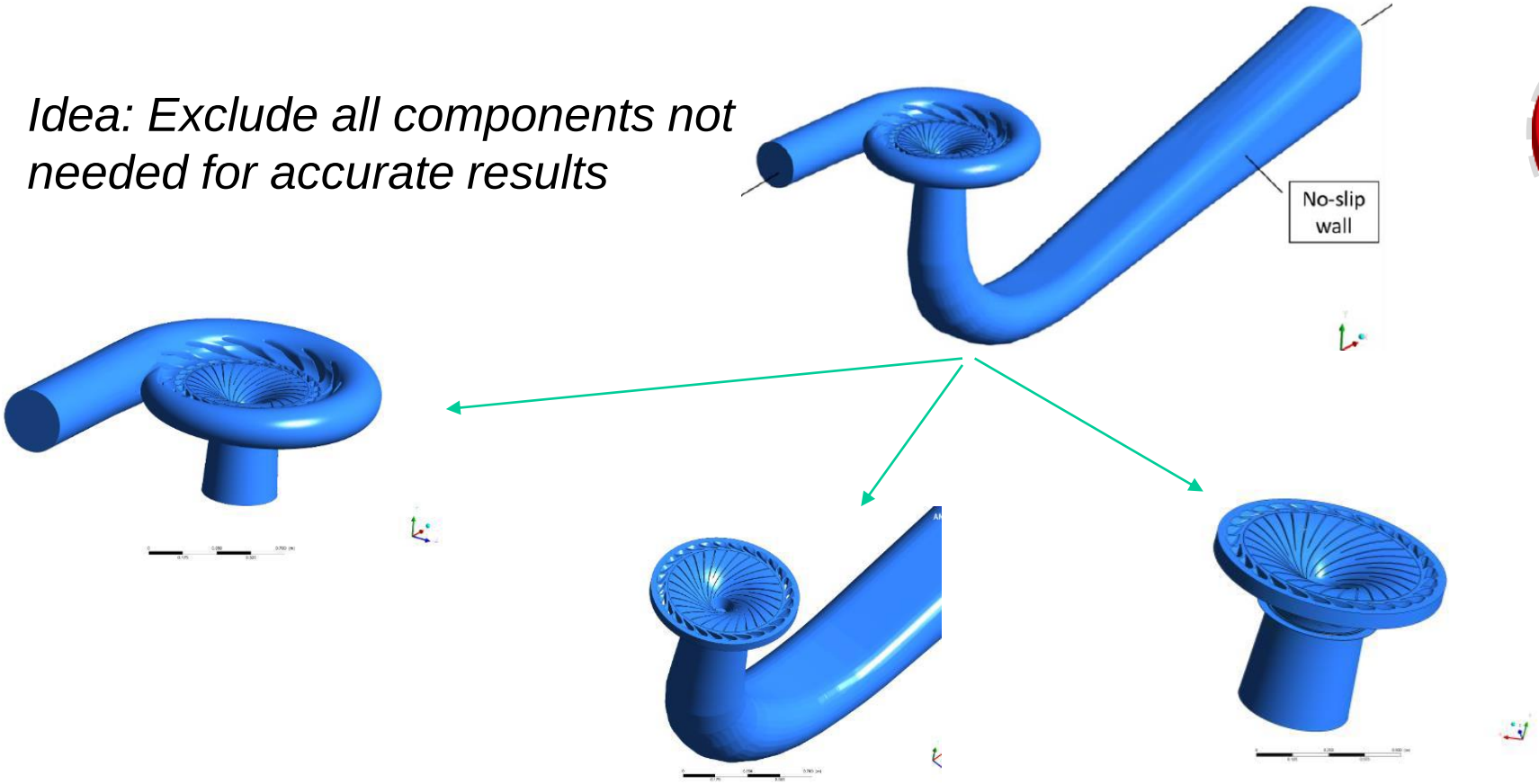


# Fluid Load - Simulation

## Reduced modeling

*Idea: Exclude all components not needed for accurate results*

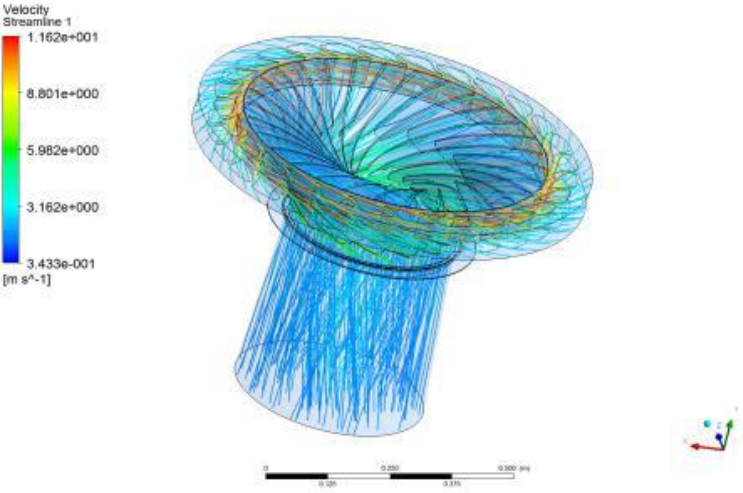


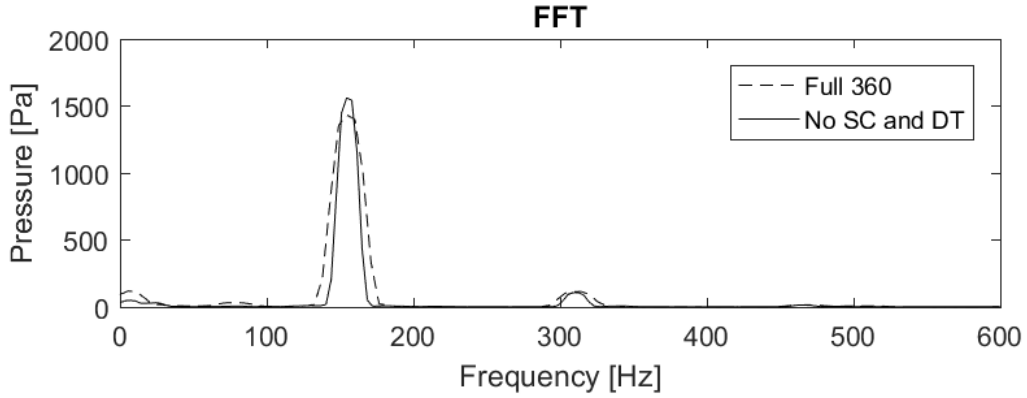
# Fluid Load - Simulation

## Reduced modeling

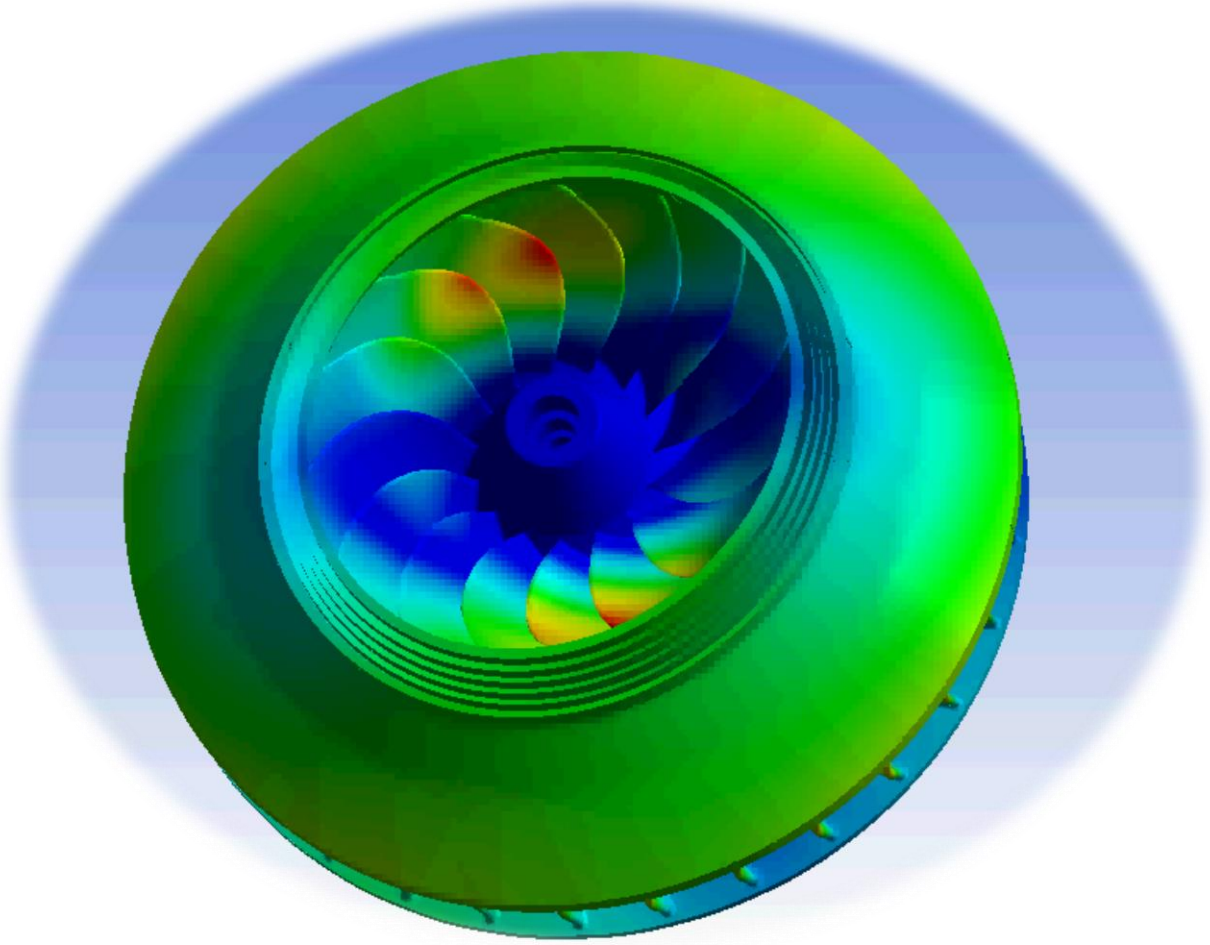
*Table 1 – Simulation time per period*

| Method | Relative speedup |
|---|---|
| Full 360 | 1 |
| No volute | 1.2 |
| Short draft tube | 1.7 |
| Combined | 2.2 |

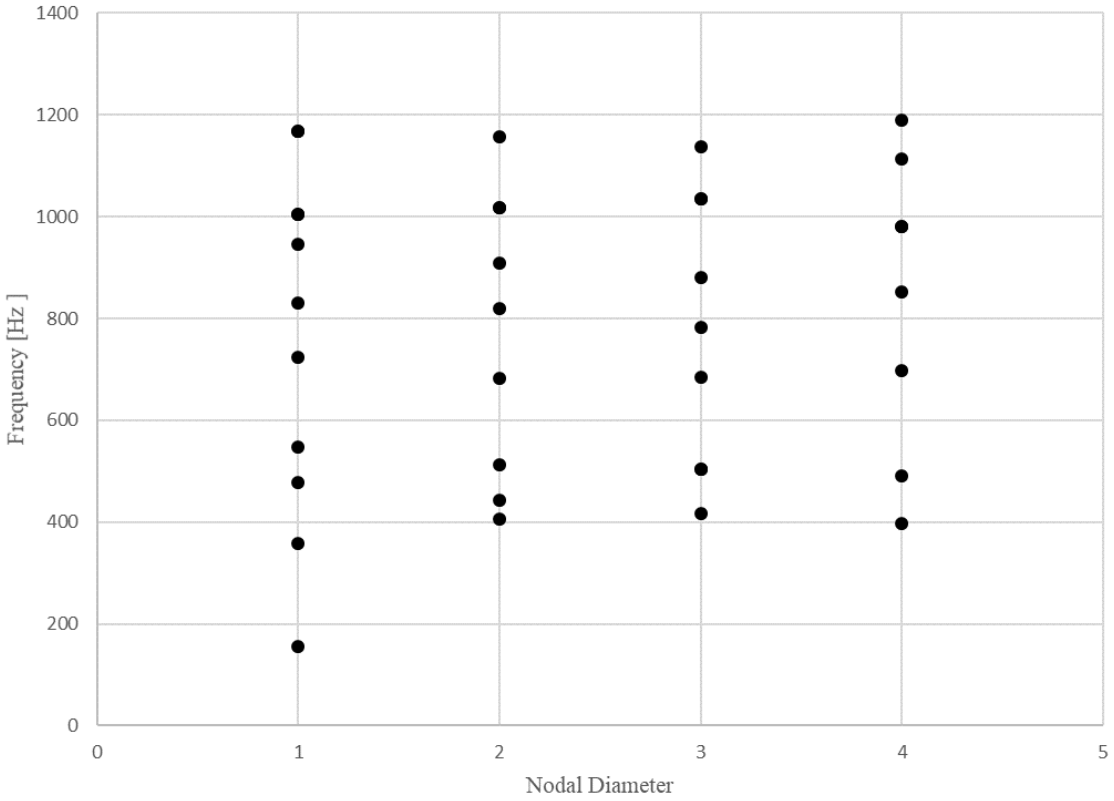


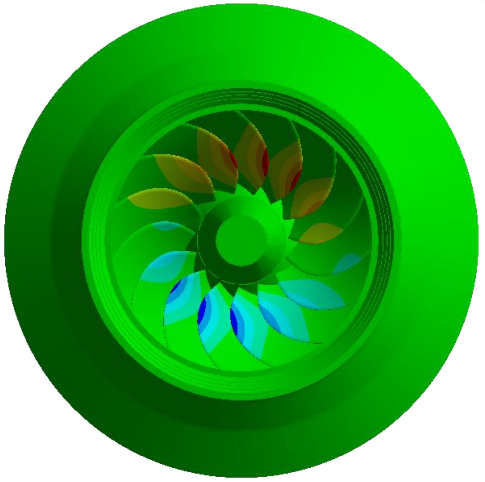



# Natural Frequency

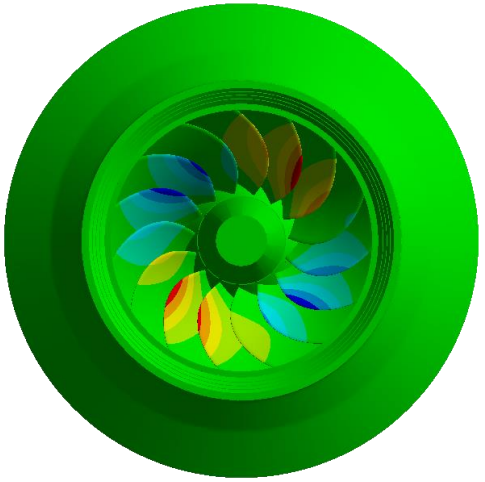


# Natural Frequency - Simulation



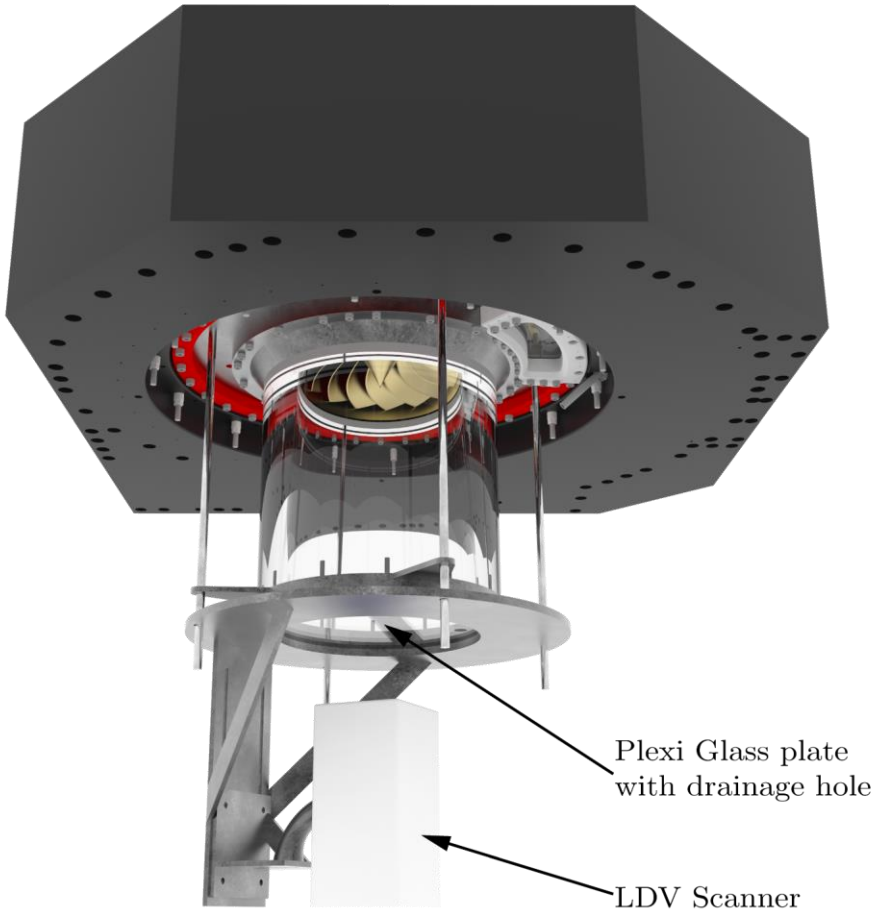



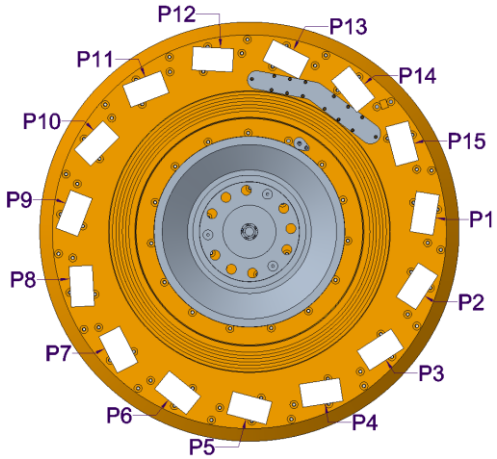
ND1

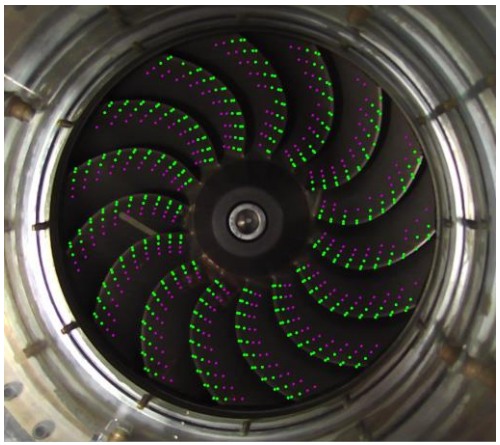


ND2

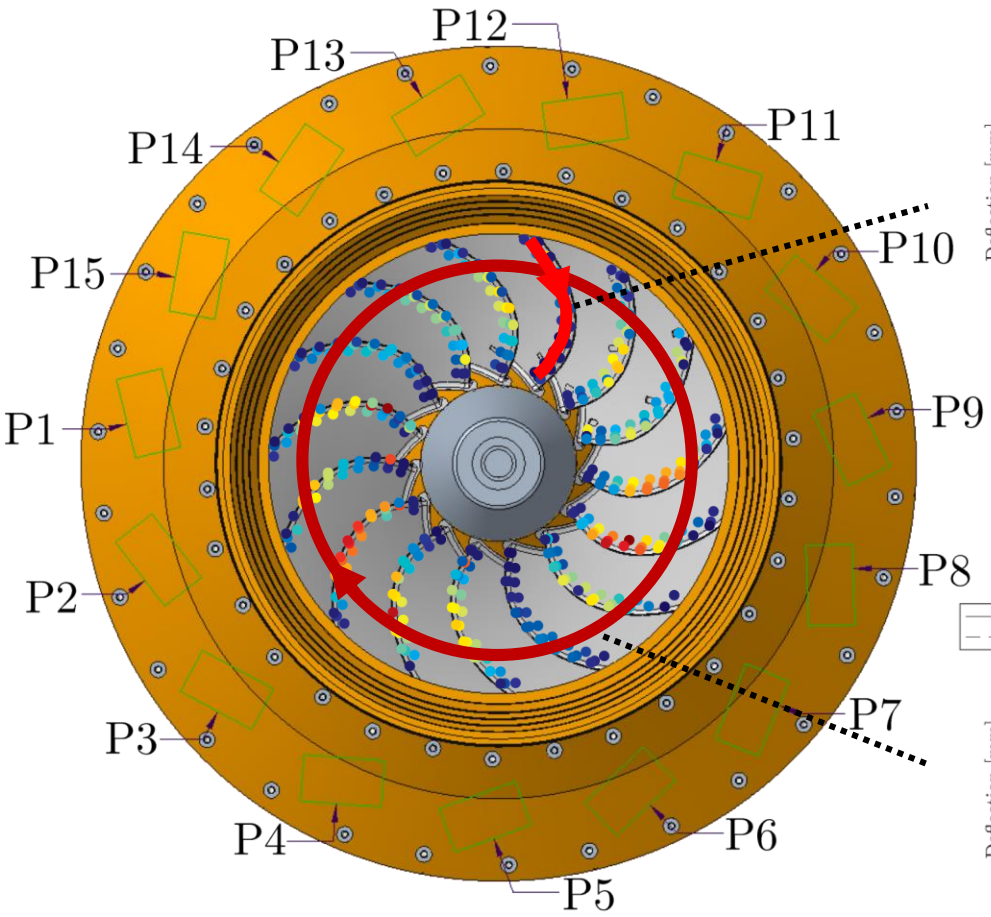
# Natural Frequency – Experiments

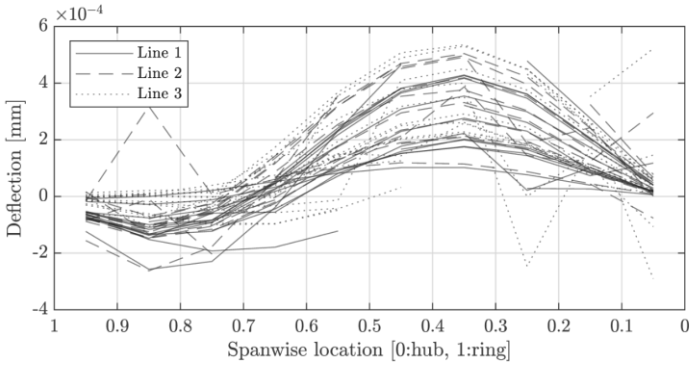


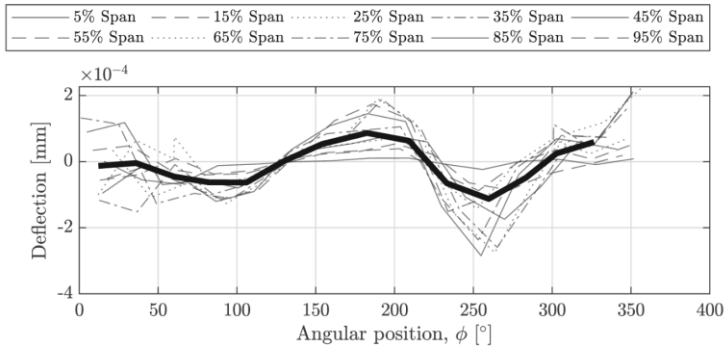



# Natural Frequency – Experiments



# Natural Frequency – Experiments

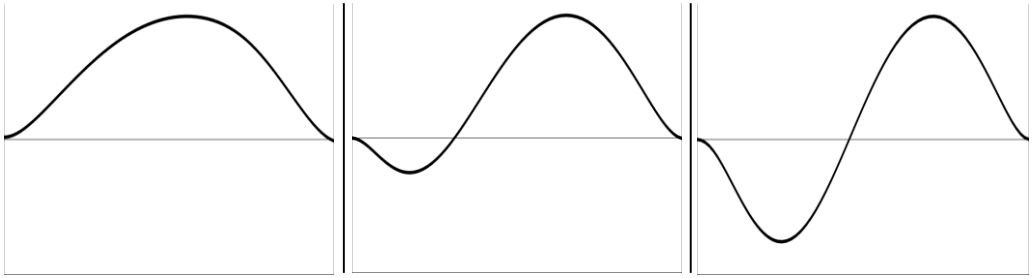
ND2
$f_w = 340$ Hz

ND1
$f_w = 457$ Hz

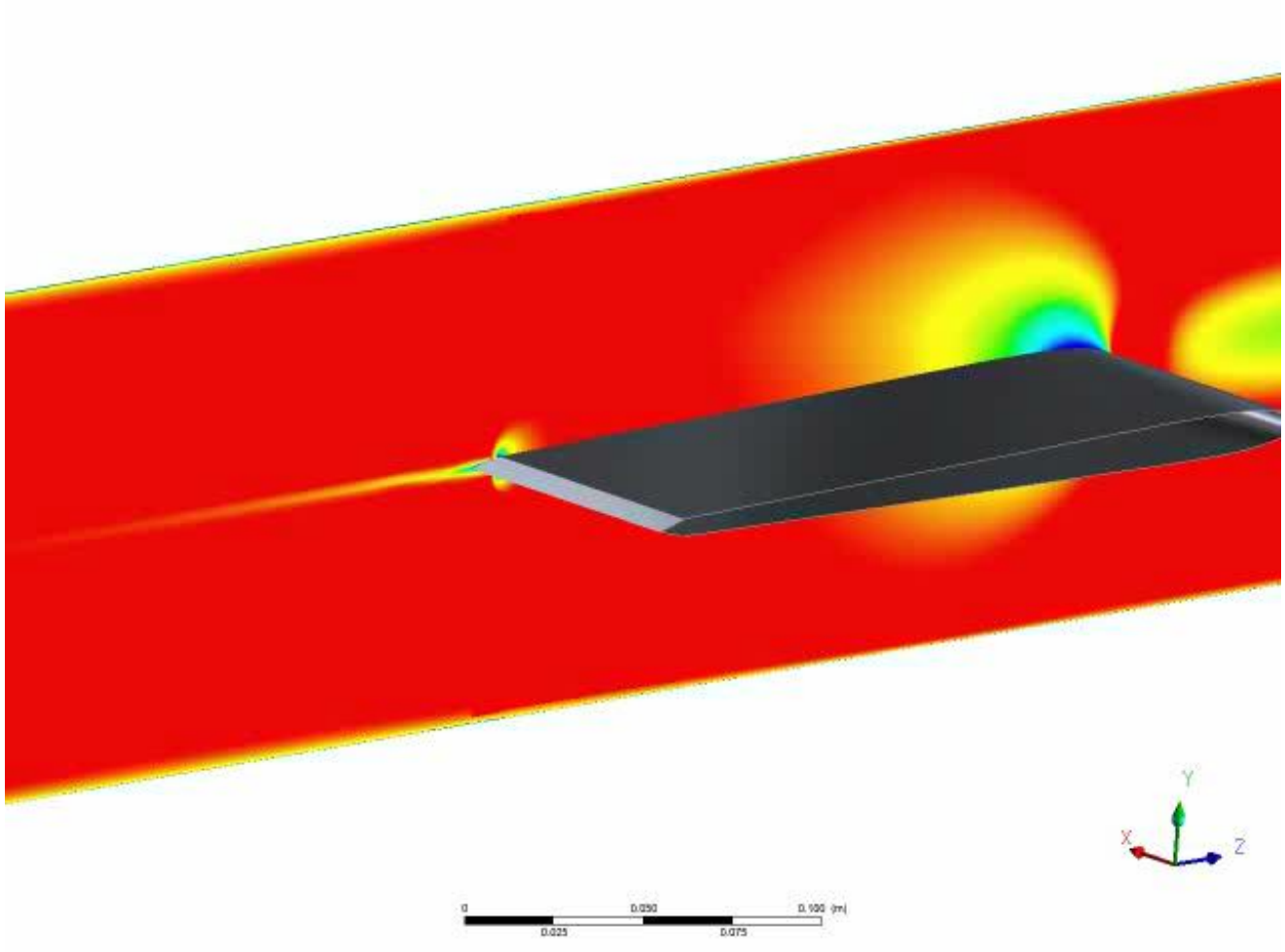
ND3
$f_w = 584$ Hz

Span

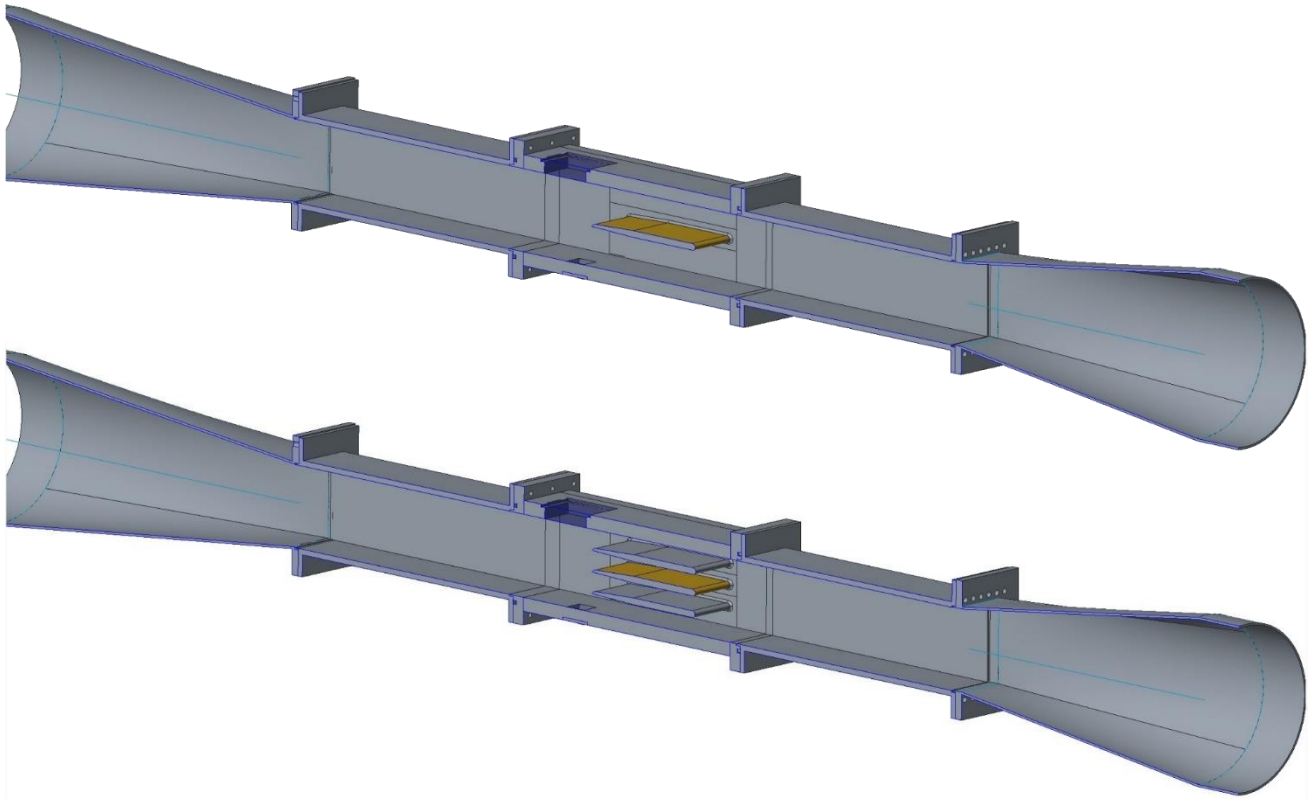
Rotations



# Damping



# Damping - Experiments



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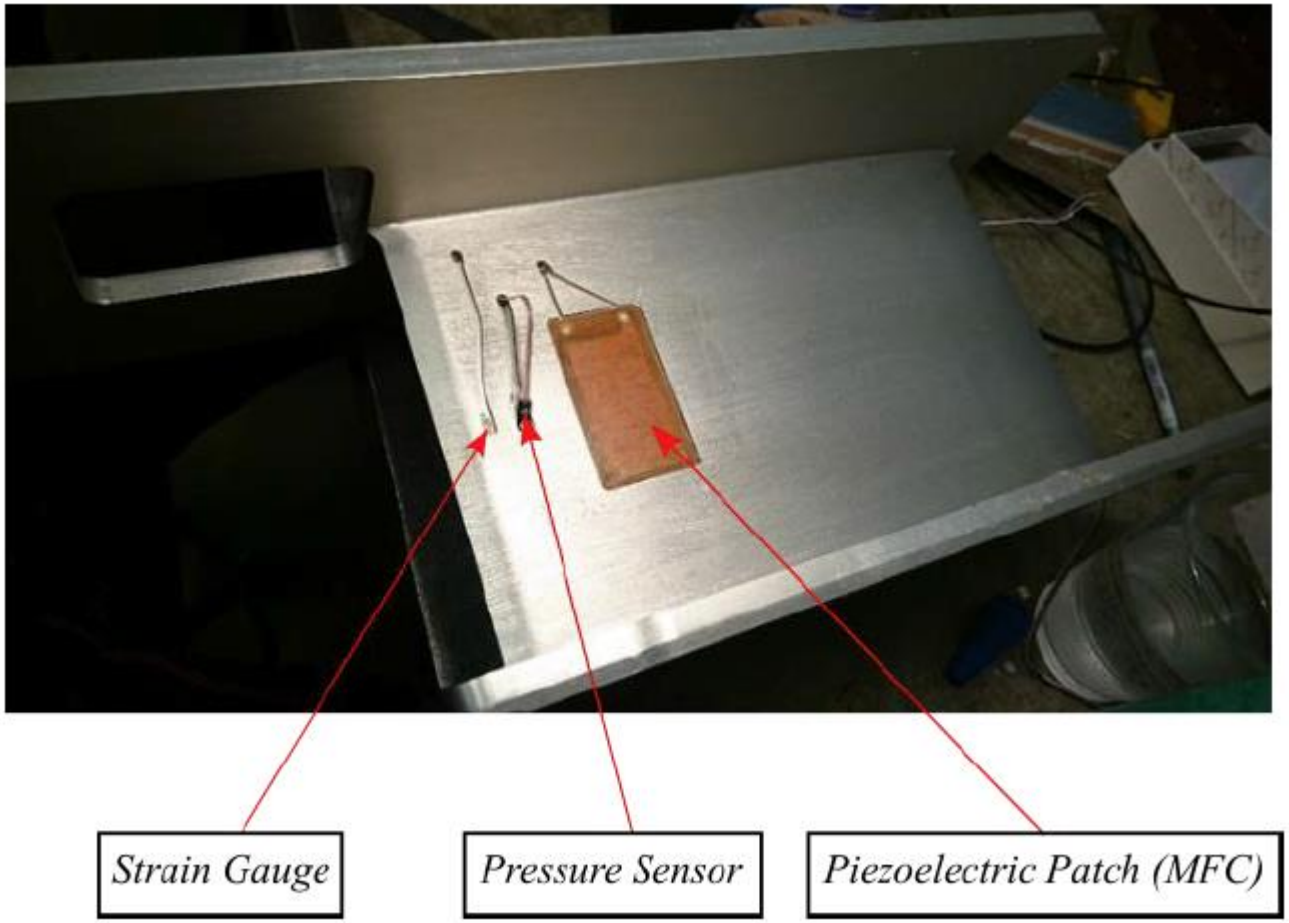
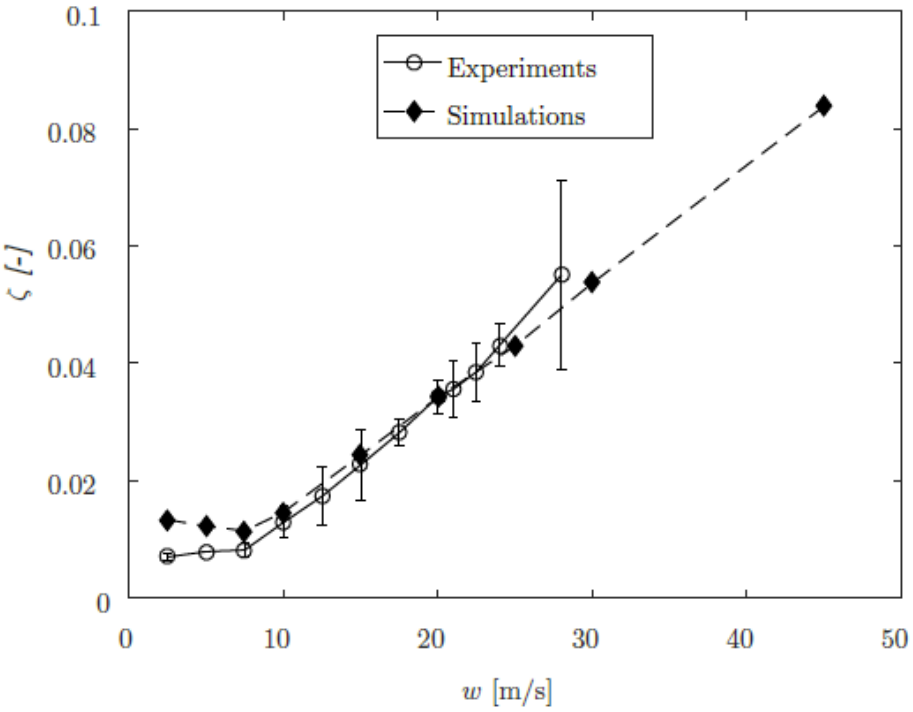
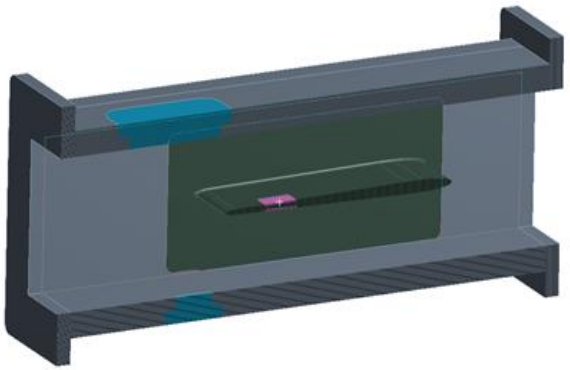


# Damping - Simulations







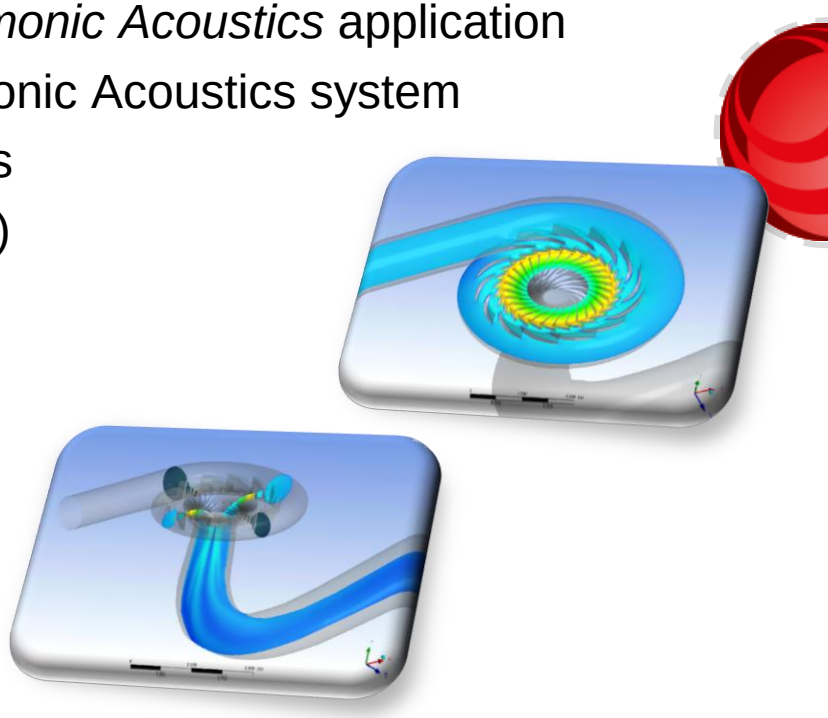
# Main public results

- QuickSolve Harmonic Acoustic app for Ansys
- Recommended Practice for CFD and FEA
- Buyers Guide for tendering and acquisition

# The *QuickSolve Harmonic Acoustics* app

EDRMedeso have developed the *QuickSolve Harmonic Acoustics* application

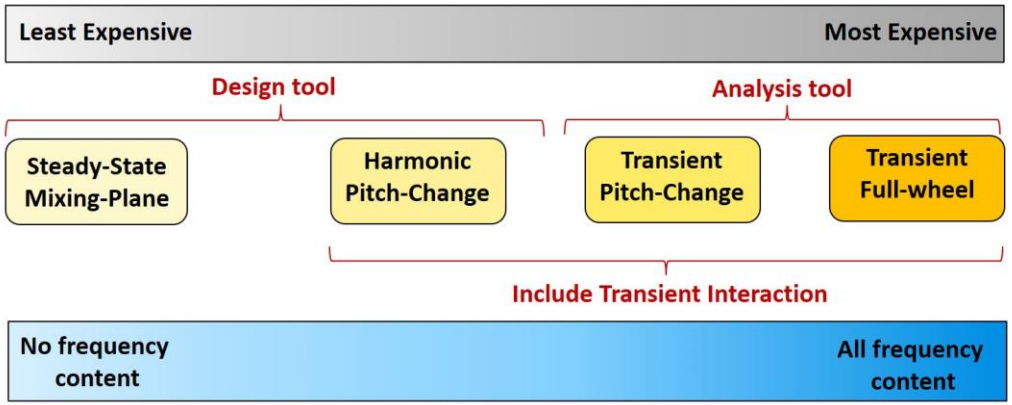
- Performs Model Order Reduction of a full Harmonic Acoustics system
- All applications of acoustic harmonic simulations
- Streamlined process (reduce human interaction)
- Verified with extremely promising results
- Time savings of 10x-100x

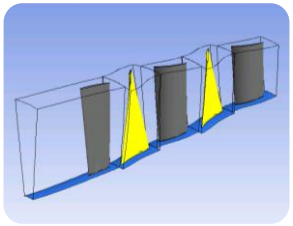


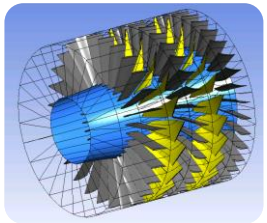
# Recommended Practice CFD and FEA

## Purpose of document

- Best practice guidelines.
- Combining existing CFD guidelines with findings from project.
- Basic CFD knowledge assumed.
- Separate RP for FEA





# Buyers Guide

- Support for tendering and acquisition of High Head Francis runners
- First version limited to research conducted within the project
- Workgroup to keep document relevant and updated

# Dissemination

- Peer-reviewed journal papers : 8
- Conference papers : 22
- Seminars/workshops : 6

# Main findings

## Fluid load

- Accurate results with experiments
- Lower CPU cost
- Detailed insight into RSI effects

## Natural Frequency

- Ambiguous results from experiments
- Similarities with simulations
- Validation in progress

## Damping

- Proportional to velocity
- Independent of amplitude
- Possible generalization