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Model to Full Scale Numerical Considerations in the Context of Cavitation

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Introduction: Scaling Dilemma

Froude Similarity

Reynolds Similarity

$$F_n = \frac{V}{\sqrt{gL}}$$

$$R_e = \frac{VL}{\nu}$$

Introduction: Scaling Dilemma

⊘ Scaling effects

✓ Scaling procedures have been developed (ex: ITTC 78 method)

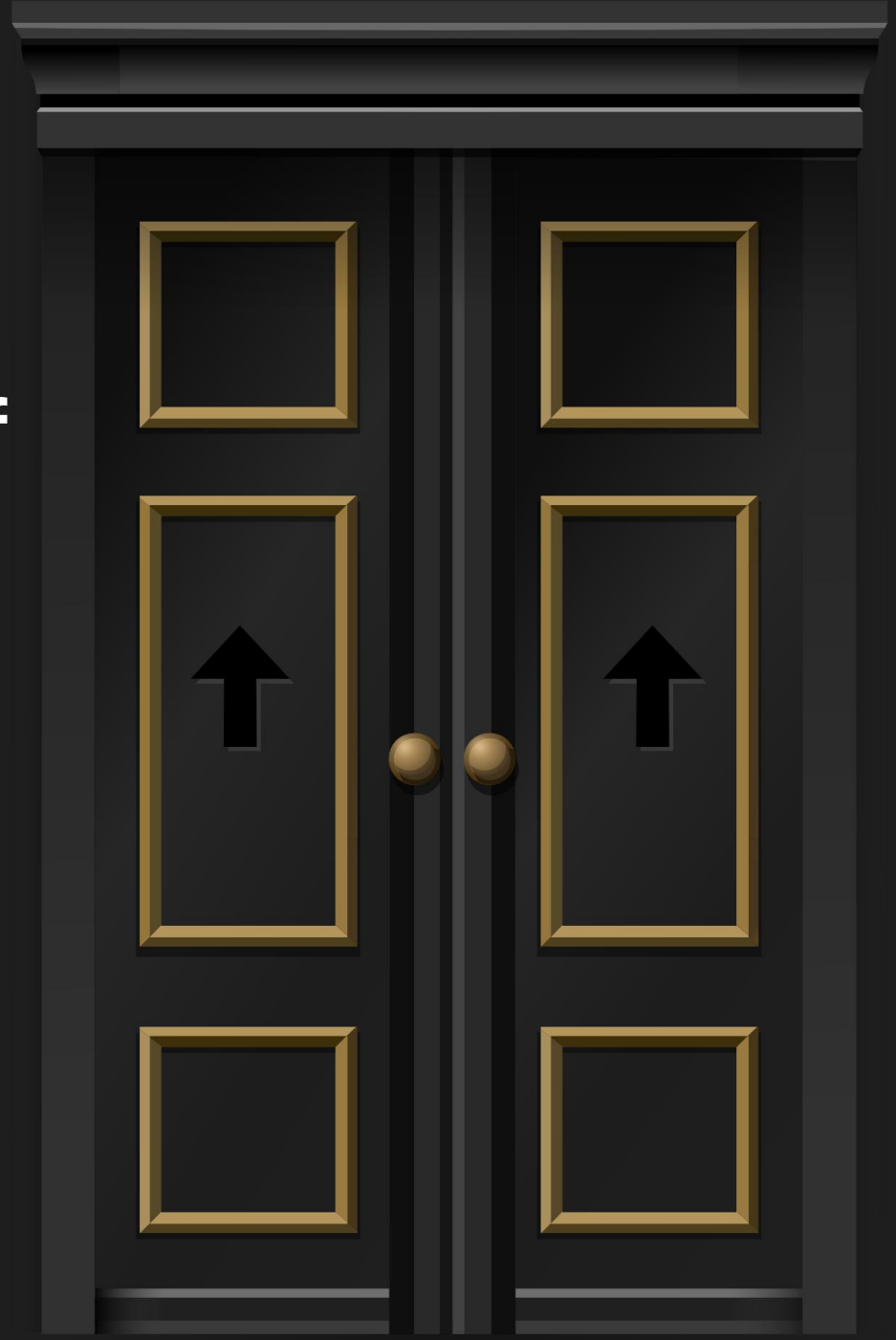
Motivation & Objective

Need for Full Scale Numerical Exploration:

- ✓ Efforts to reduce radiated noise from a cavitating propeller.
- ✓ A lack of insight on cavitation dynamics at full scale conditions.

Evaluate numerical considerations to properly resolve cavitation dynamics at full scale condition.

The Beginning of a Journey on model to full scale cavitation modeling



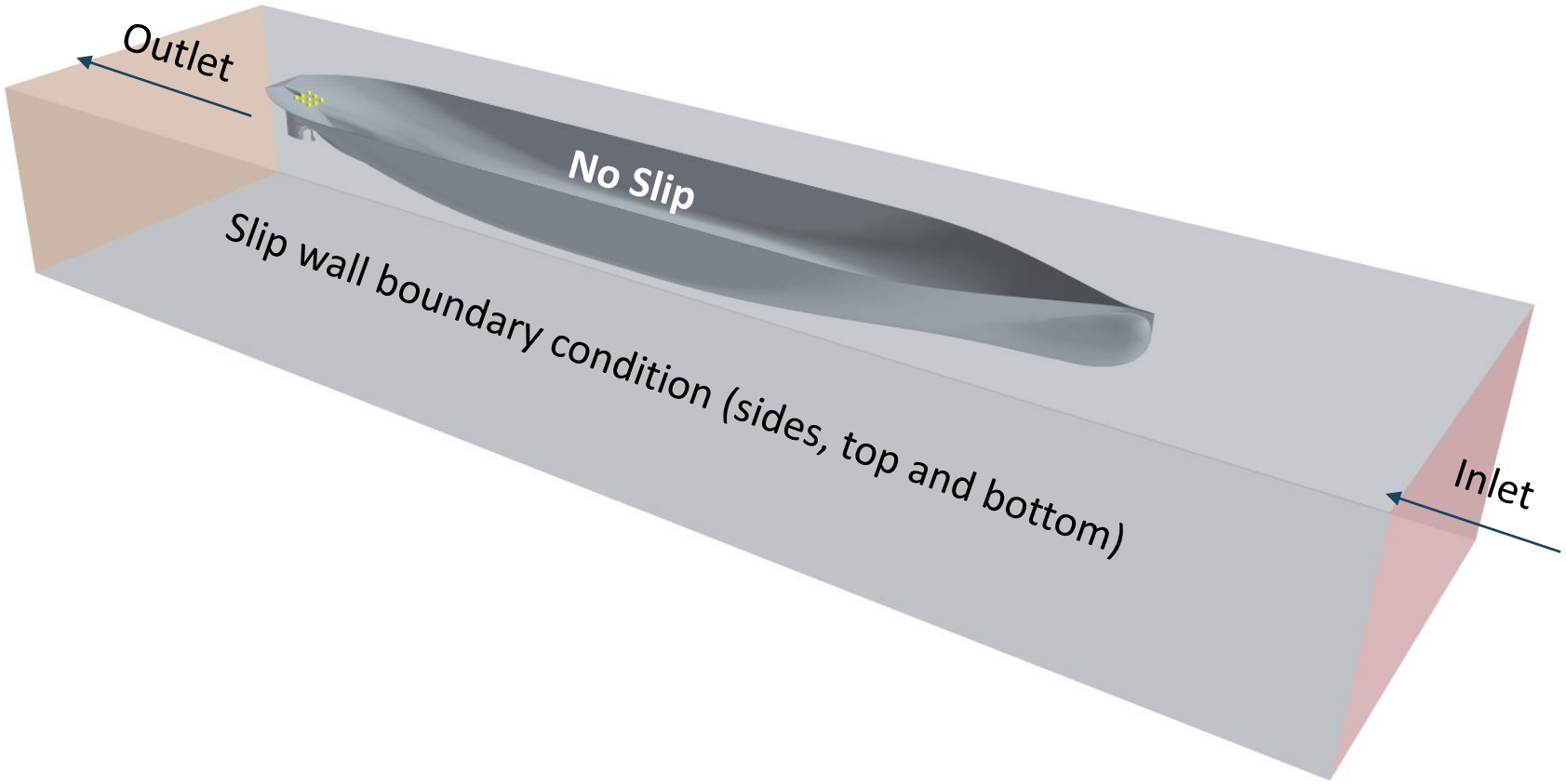
Numerical Considerations for Full Scale Simulations

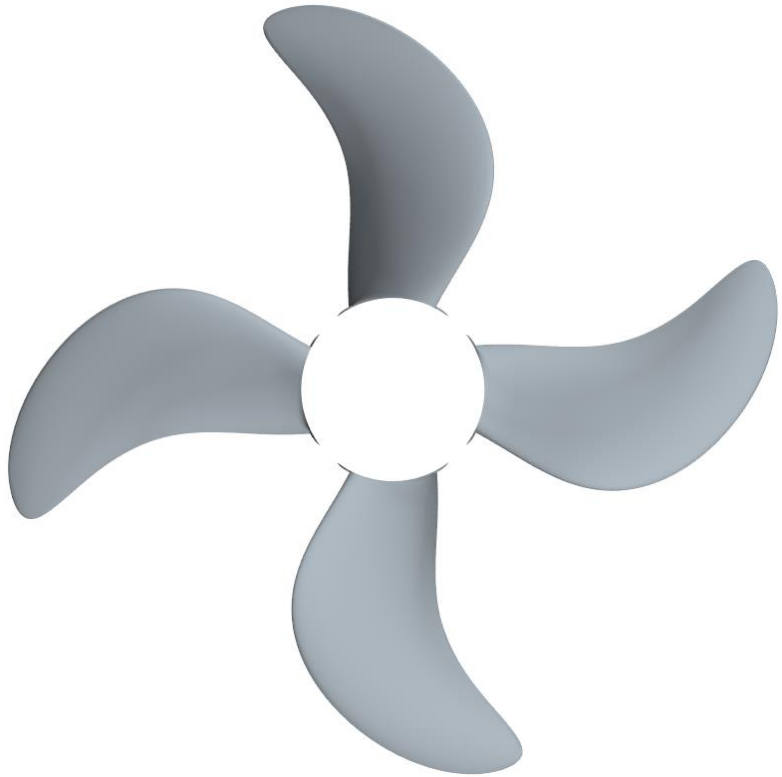
- ✓ **Boundary layer treatment**
- ✓ **Roughness Effects**
- ✓ **Domain Size**
- ✓ **Grid Resolution**
- ✓ **Time-step level**
- ✓ **Gravity effects**

Full vs Model Scale: Test Case

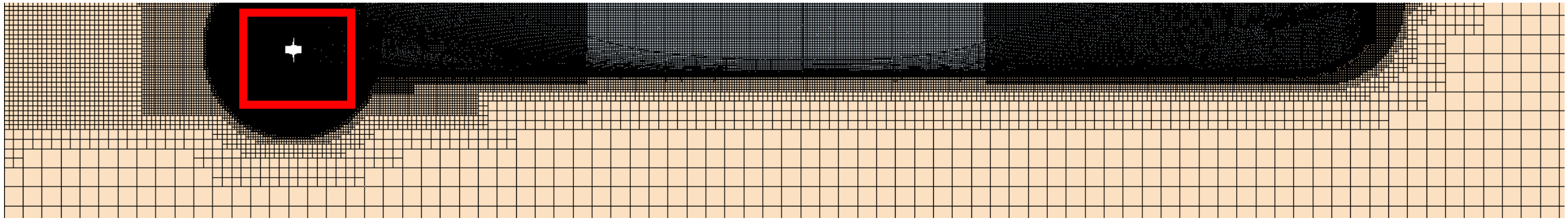
Chemical Tanker	
Length between perpendiculars [Lpp]	144.3 m
Ship draught [T]	8.7 m
Propeller diameter	5.7 m
Number of propellers	1
Number of blades	4
Model Scale	
Scaling ratio	**27.143**

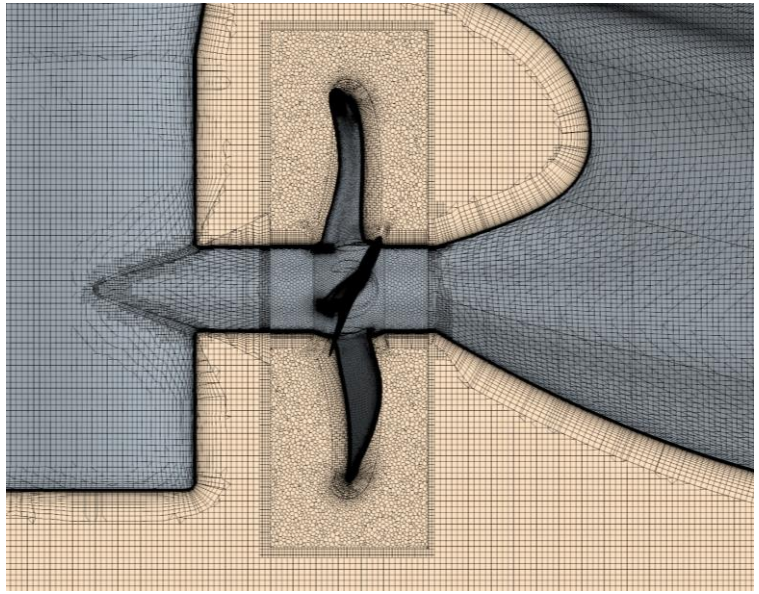
Full vs Model Scale: Domain





Full vs Model Scale: Grid





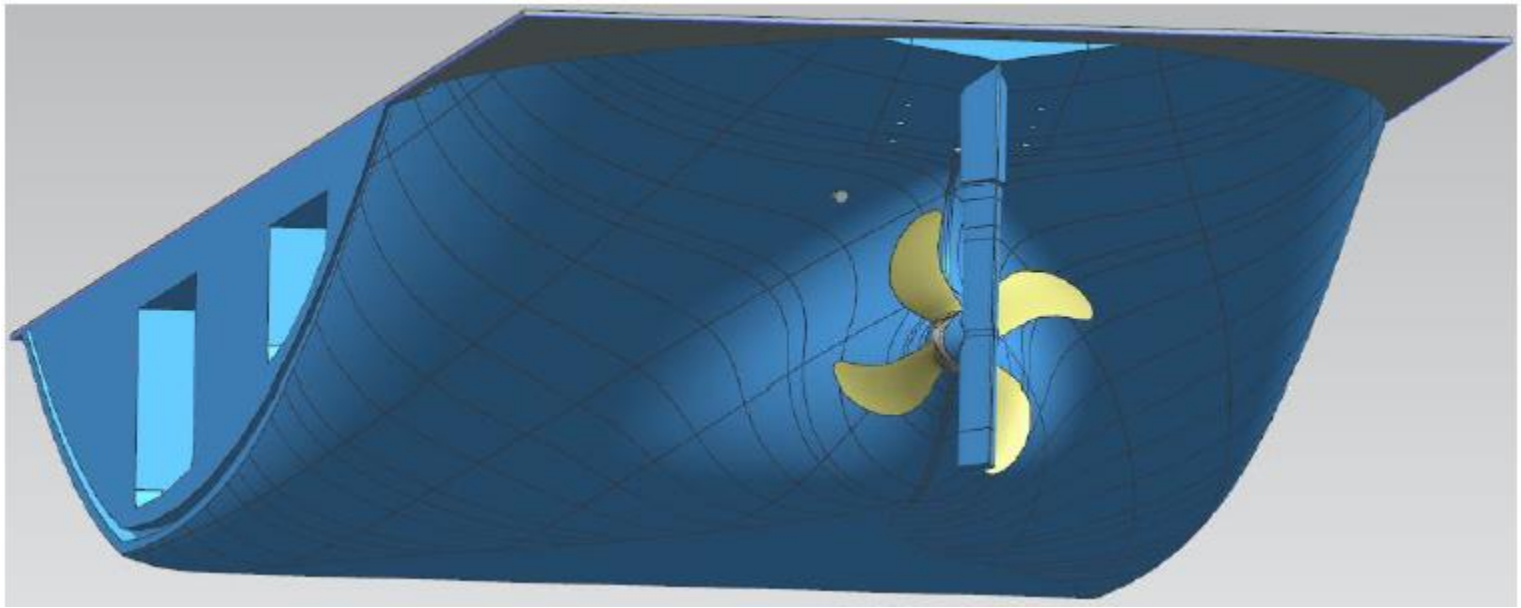
	Model Scale	Full Scale
Cell count (10^6)	55.0	27.8
Mean Y+ (Hull)	0.56	84.2
Mean Y+ (Propeller)	0.39	0.28

Full vs Model Scale: Numerical Methods

- ✓ Software: STARCCM+.
- ✓ RANS k-ω SST, 2nd order schemes
- ✓ Solution initialized steady state with MRF approach before switching to transient sliding mesh.
- ✓ Time step: 1024 time-steps per revolution.
- ✓ At model scale experiments, KQ similarity was achieved by adjusting the inlet velocity.
- ✓ Schnerr-Sauer Cavitation model

Experiments: Dummy Hull Cavitation Test

Kongsberg Cavitation Tunnel



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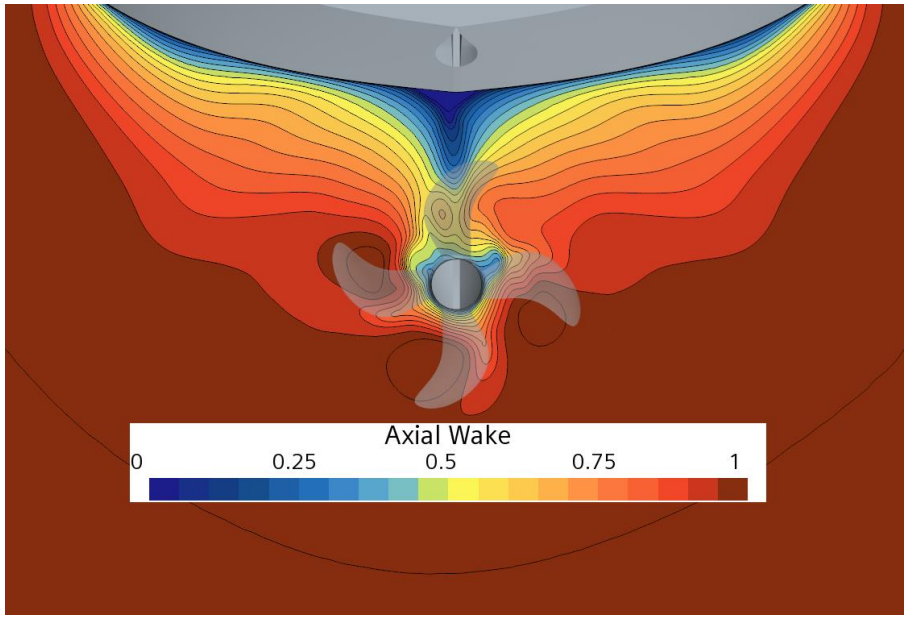
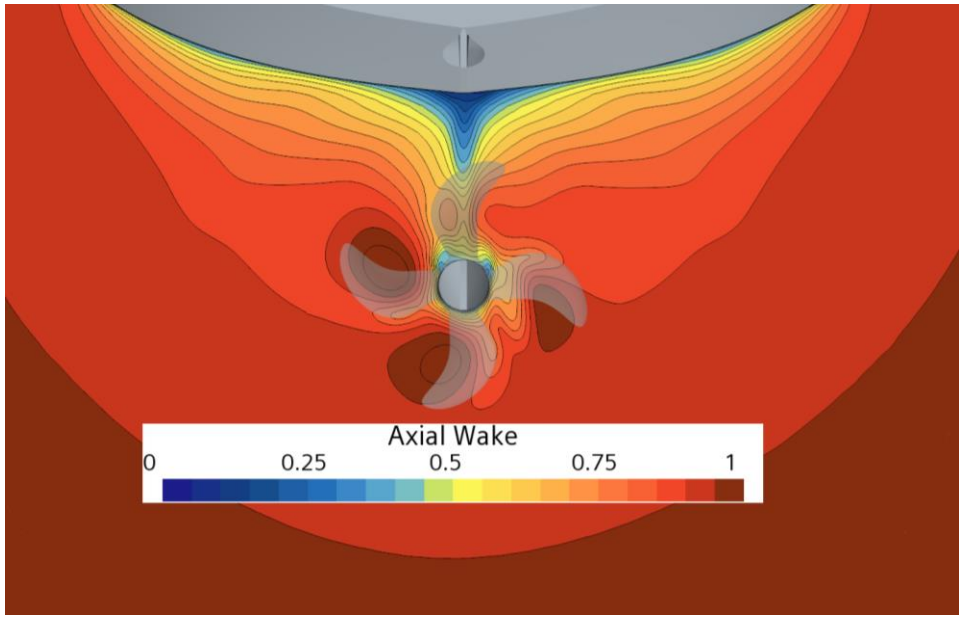
Predicted Wake & Cavitation

Model vs Full Scale: Wake

Model Scale

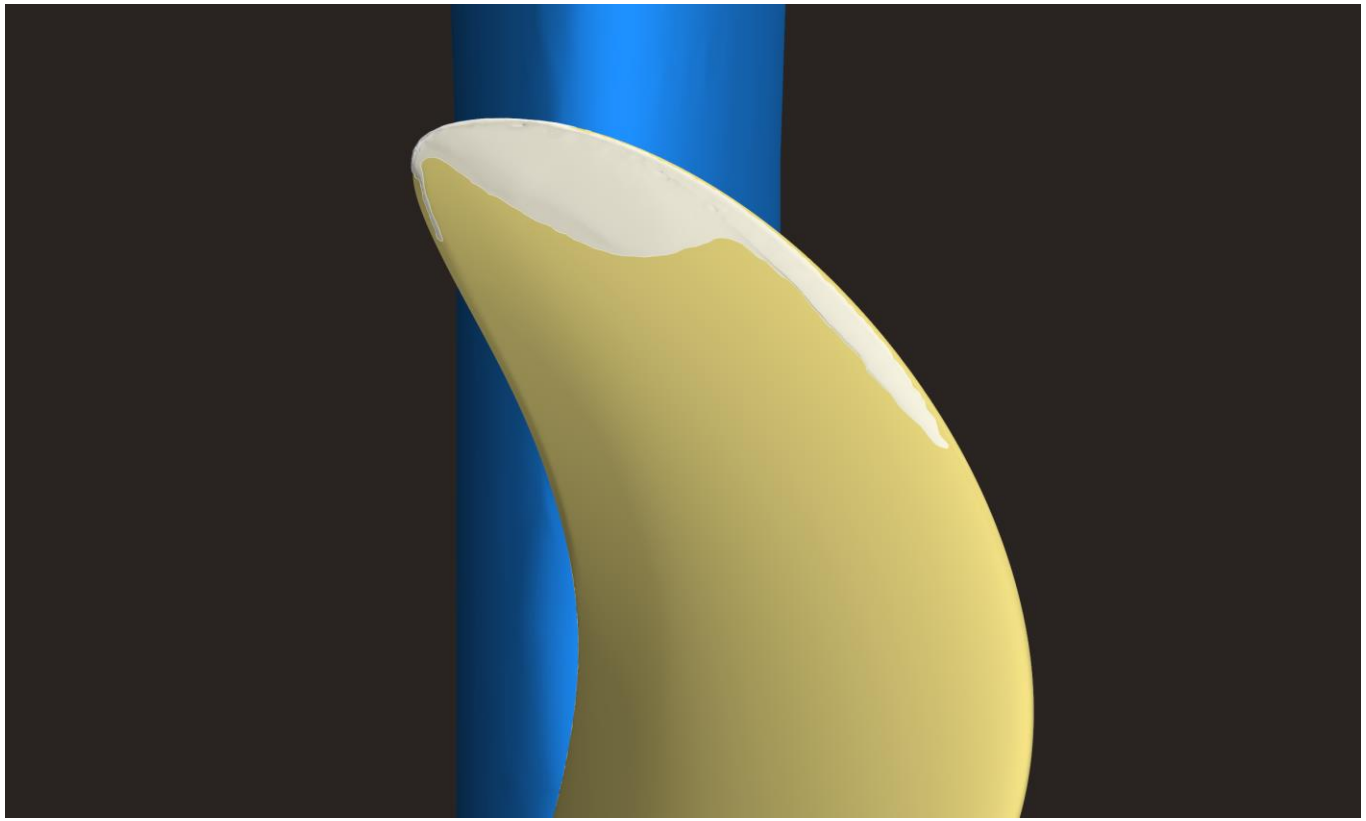


Full Scale (smooth wall)



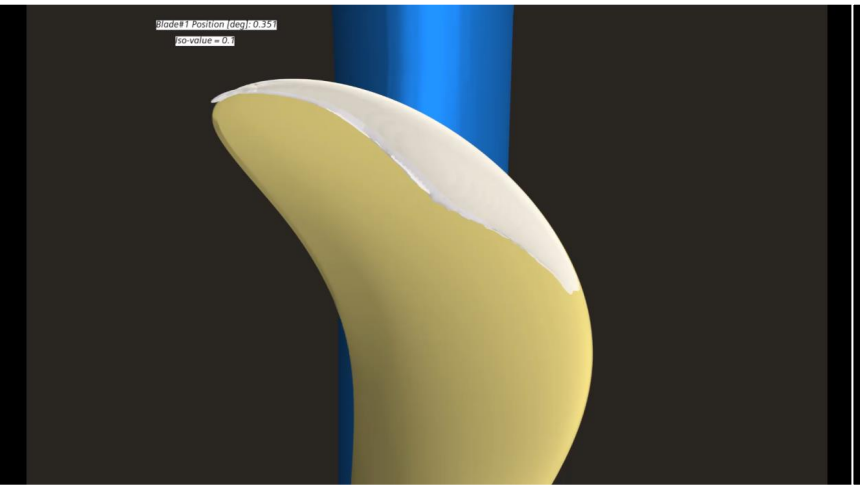
Results: Wall Function

- **Wall function does not resolve the re-entrant jet.**

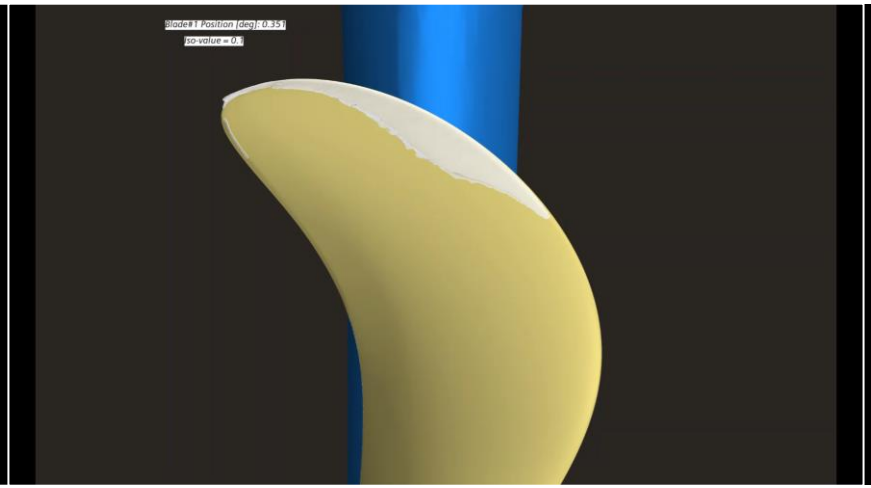


Results: Predicted Cavitation Pattern

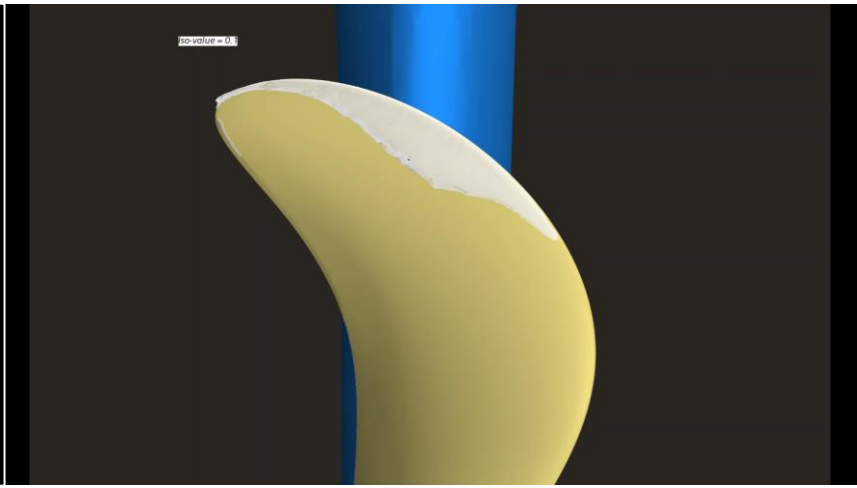
Model Scale



Full Scale (<u>smooth</u>)

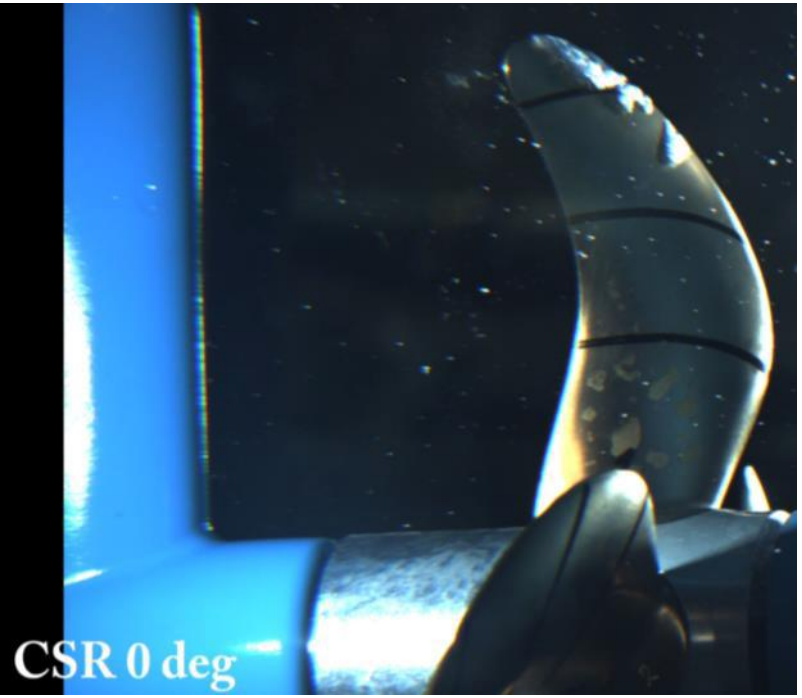


Full Scale (<u>rough</u>)

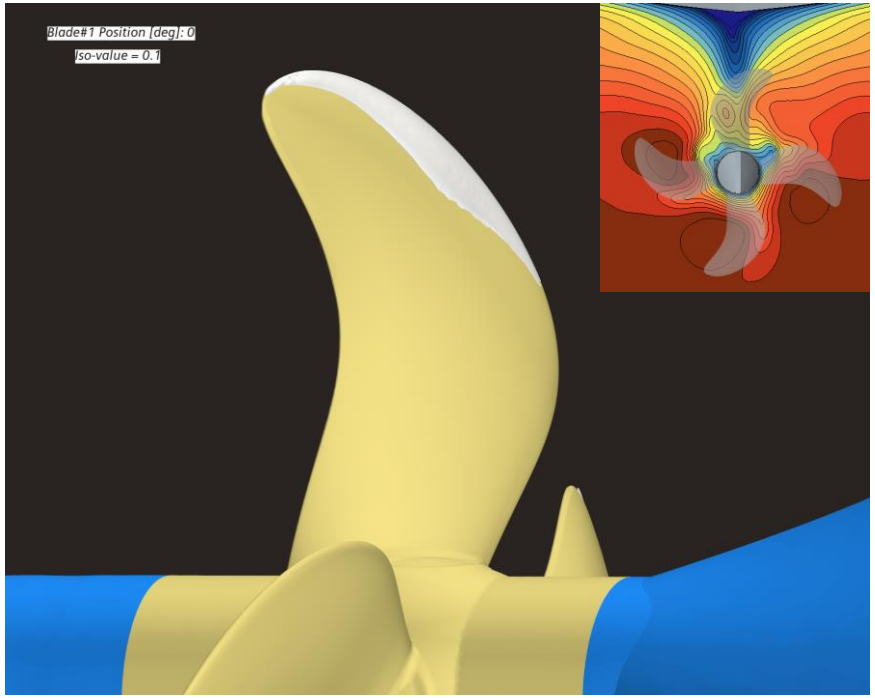


Results: Cavitation Pattern [0 deg]

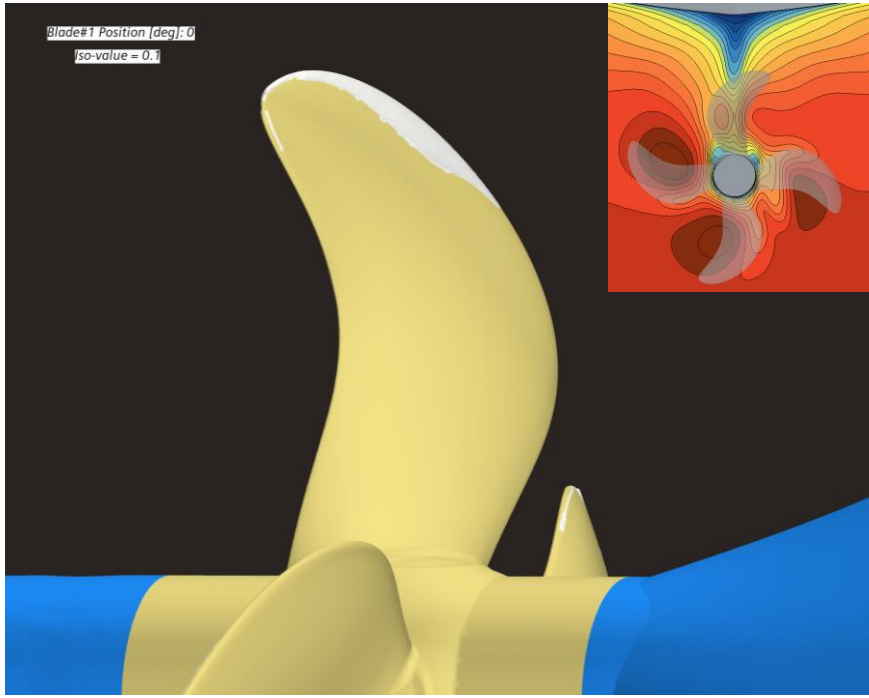
Experiment



Model scale

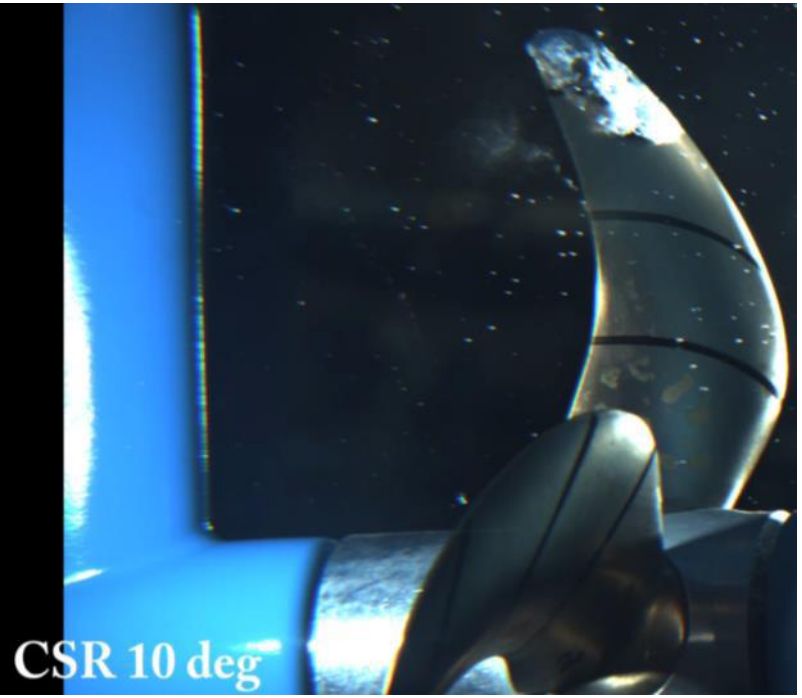


Full scale (smooth)

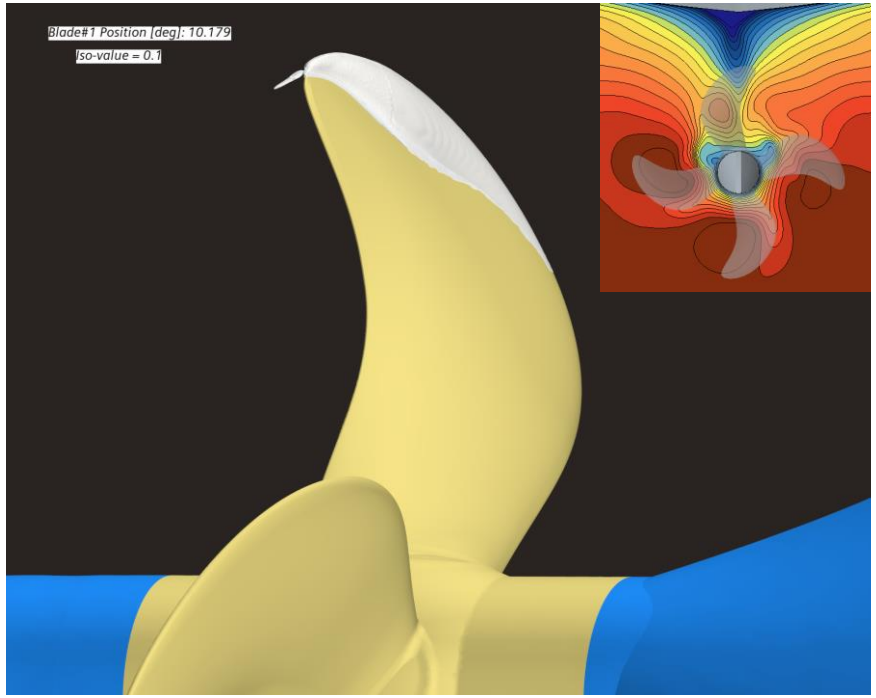


Results: Cavitation Pattern [10 deg]

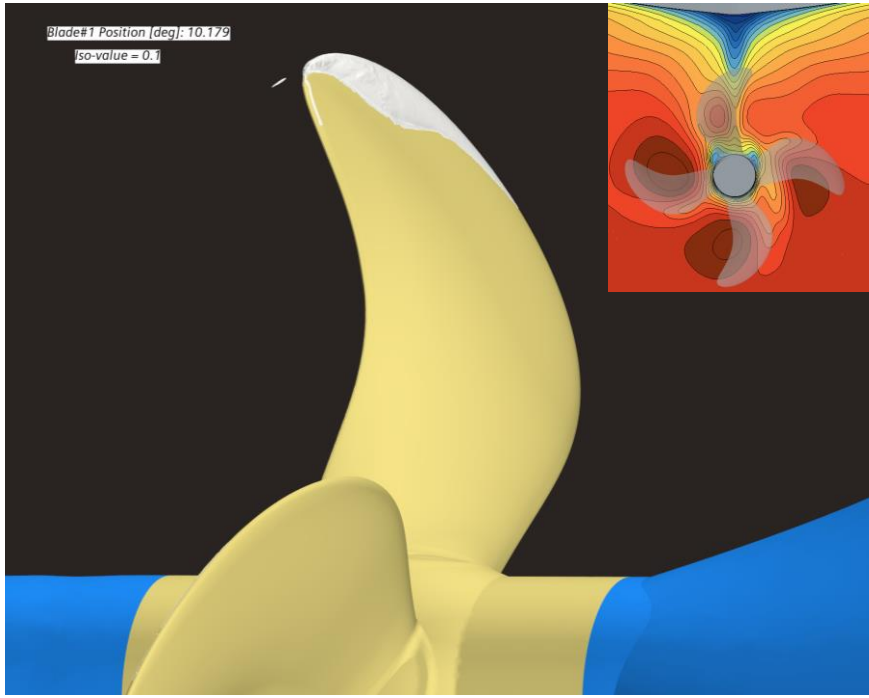
Experiment



Model scale

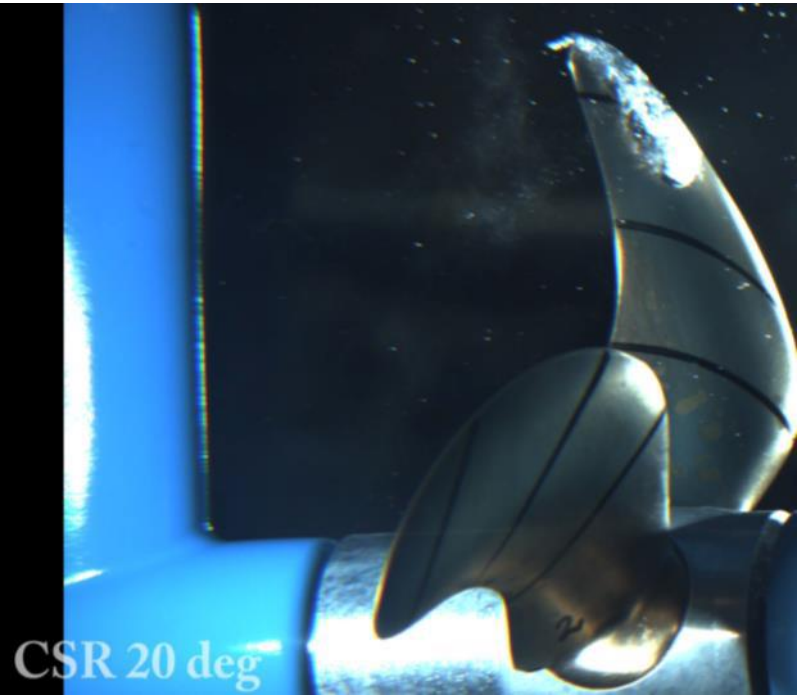


Full scale (smooth)

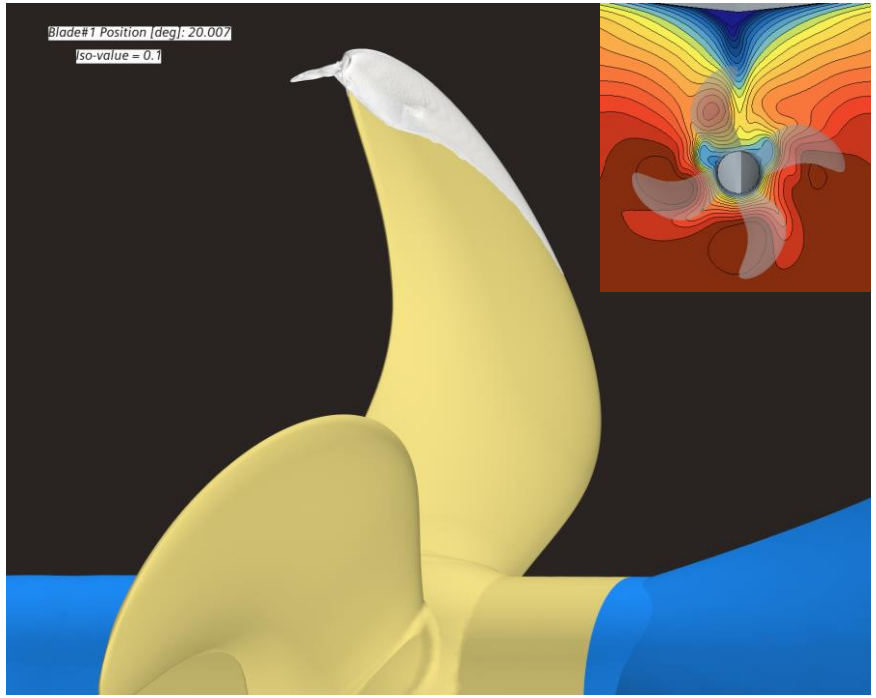


Results: Cavitation Pattern [20 deg]

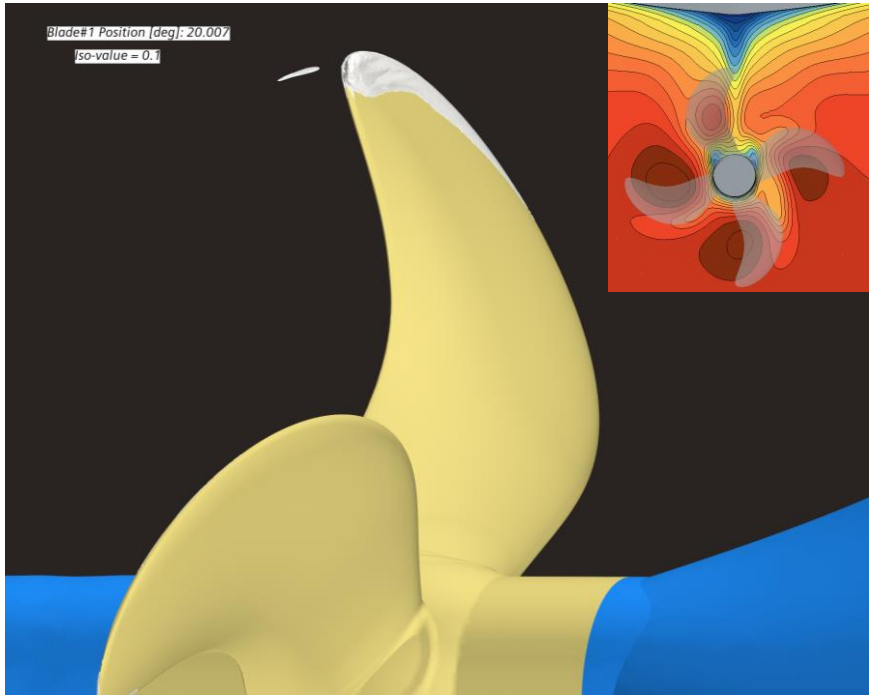
Experiment



Model scale

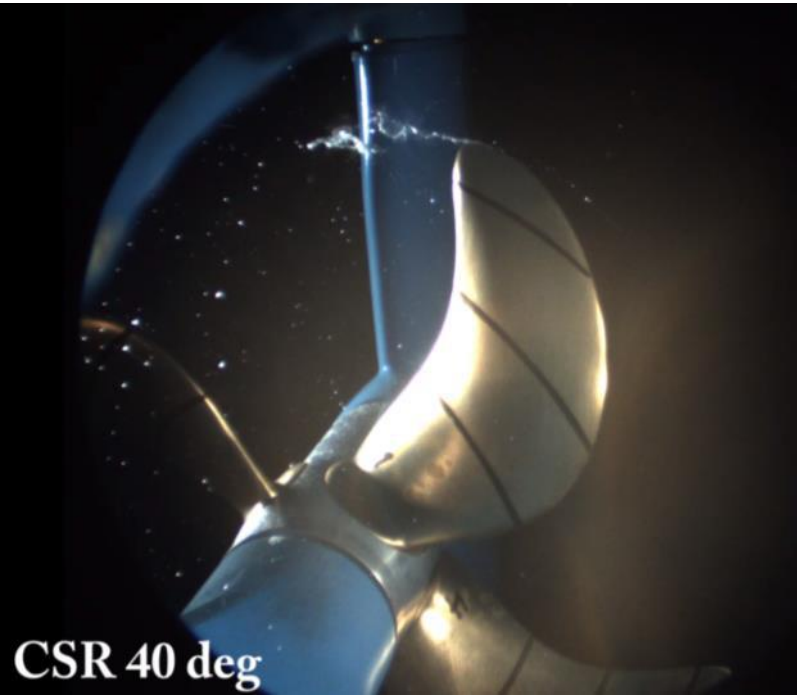


Full scale (<u>smooth</u>)

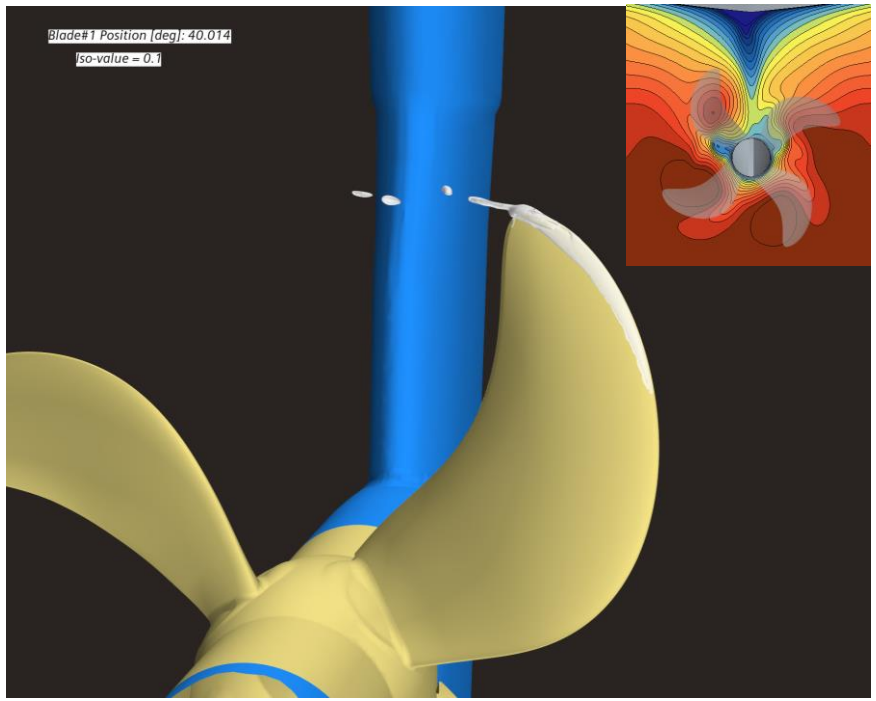


Results: Cavitation Pattern [40 deg]

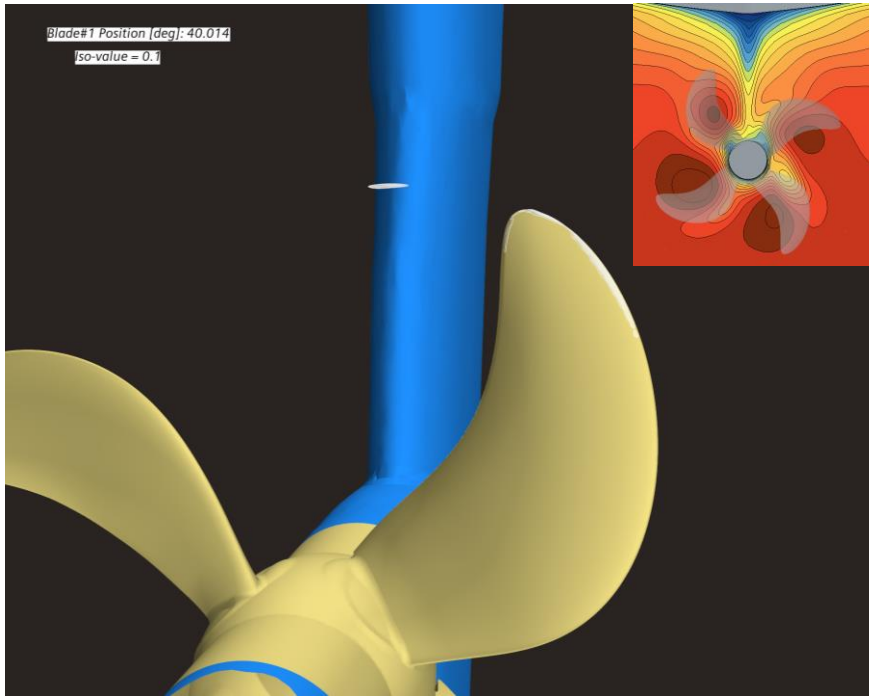
Experiment



Model scale



Full scale (smooth)



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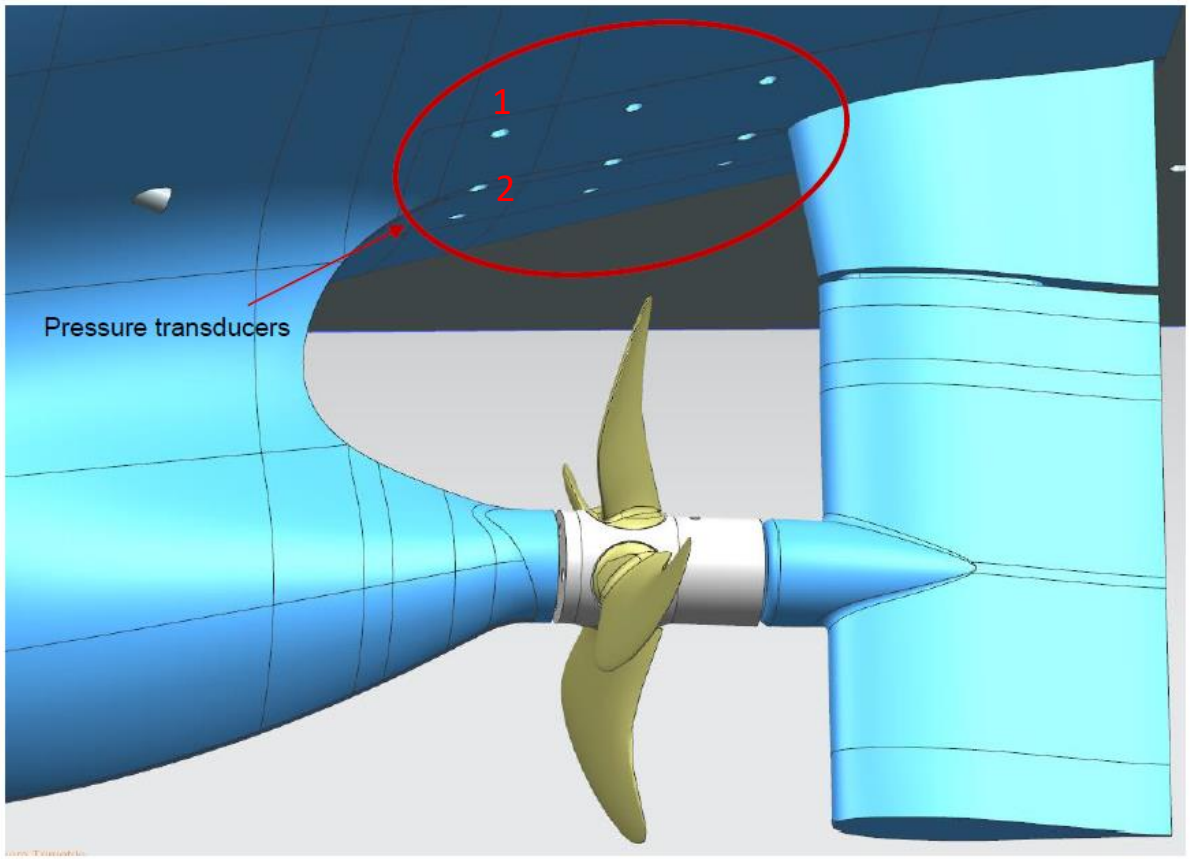
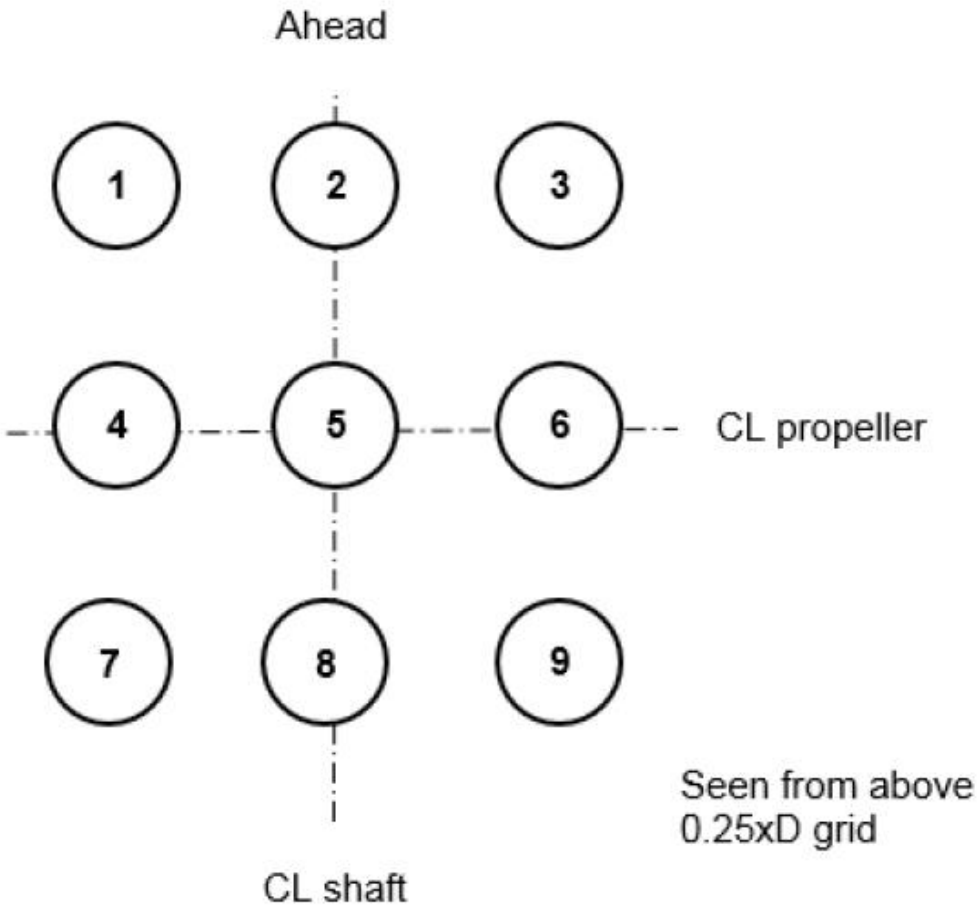
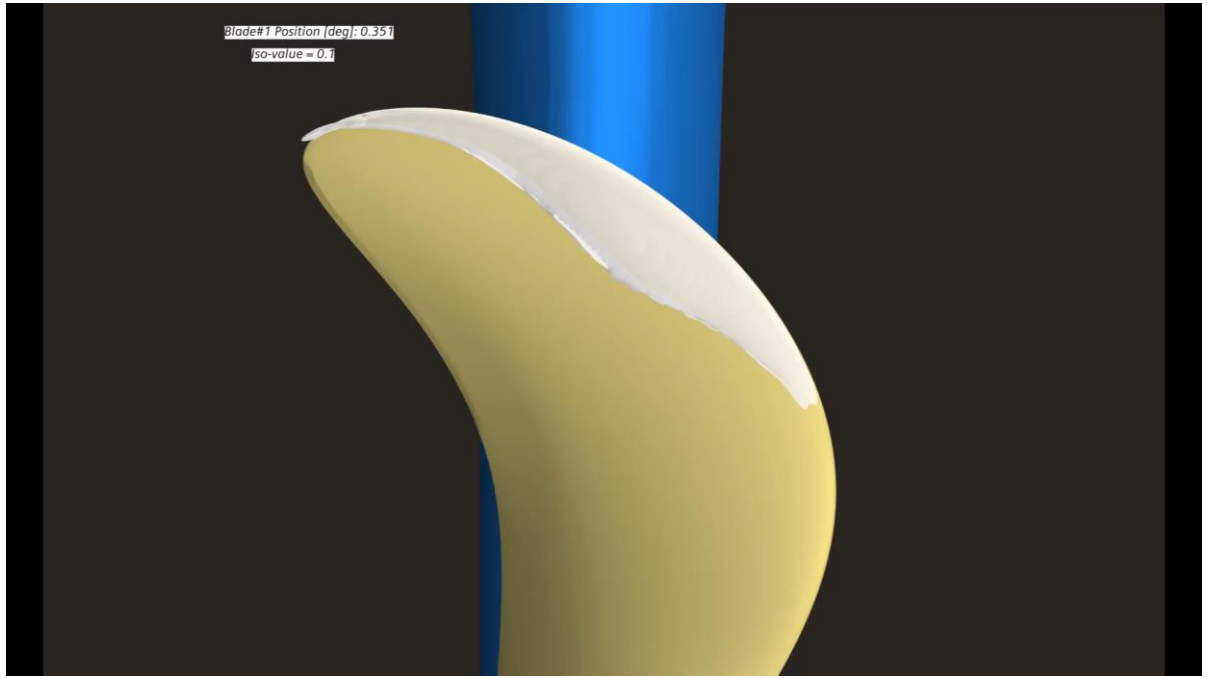
Predicted Pressure Pulses

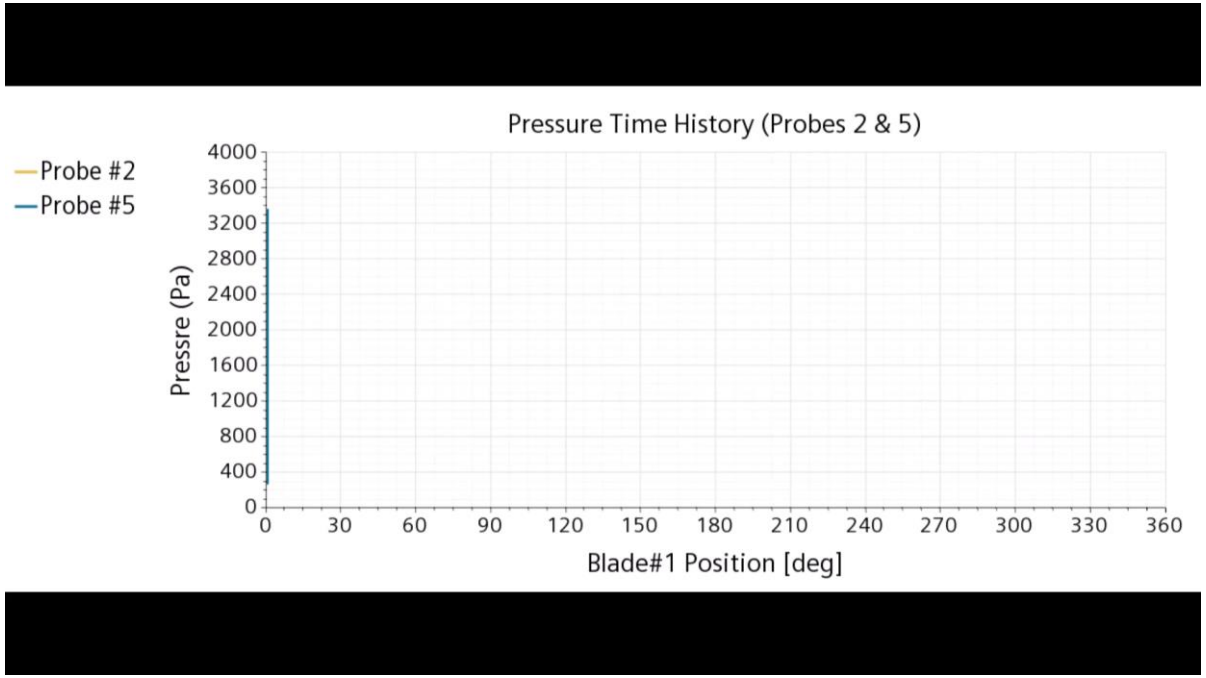
Results: Pressure Pulses (Transducers Location)



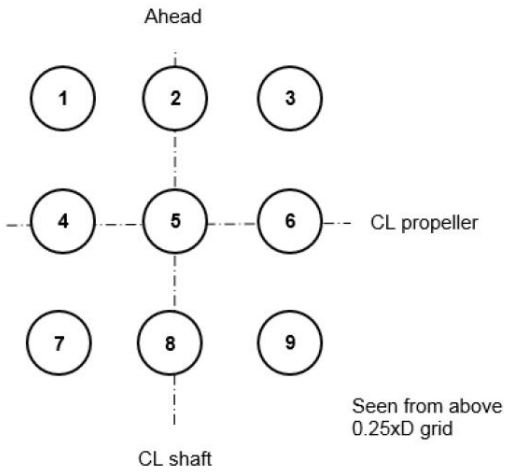


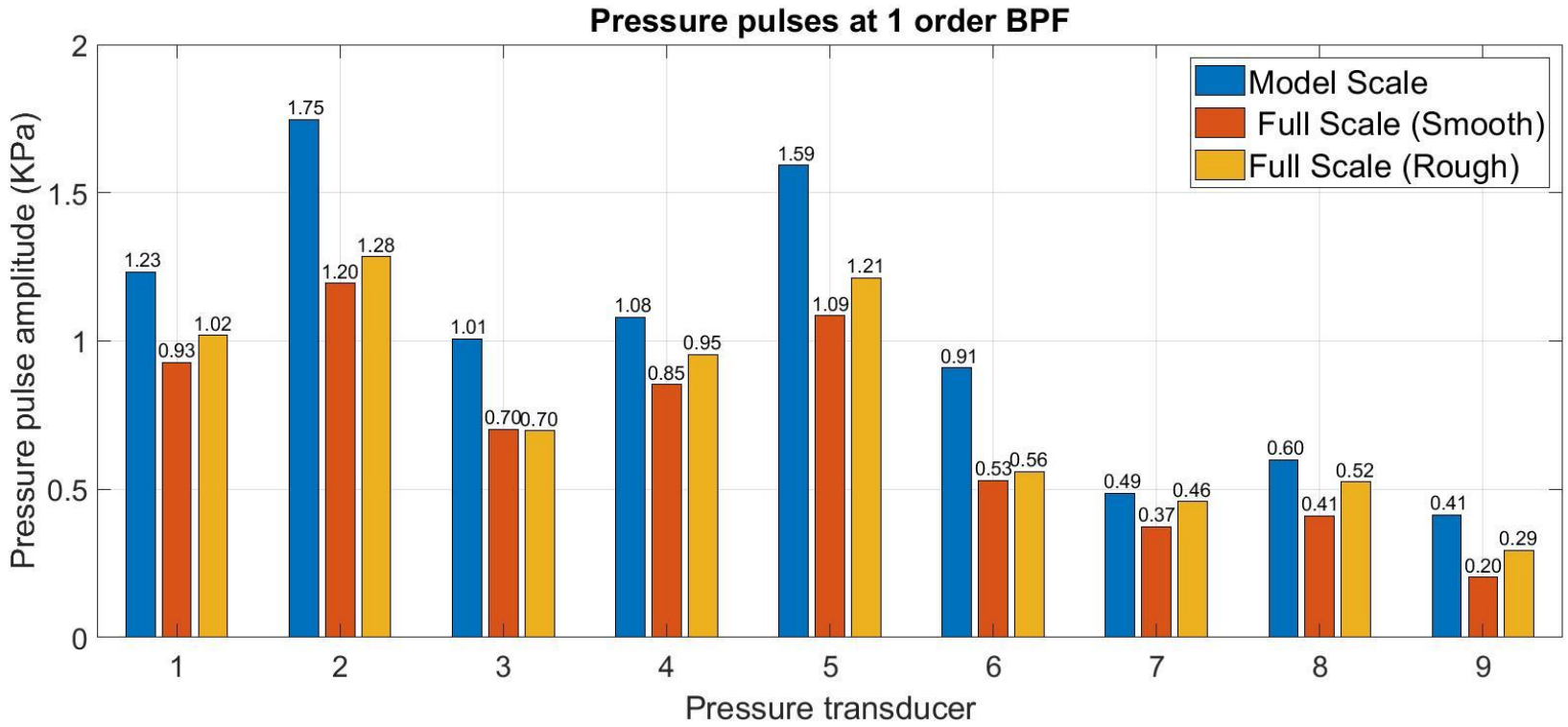
Results: Pressure Pulses From Cavitation



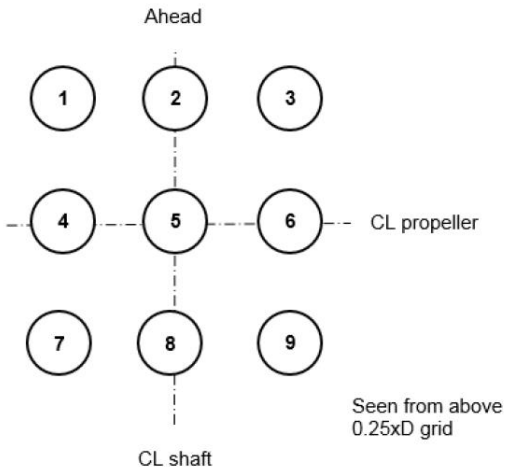


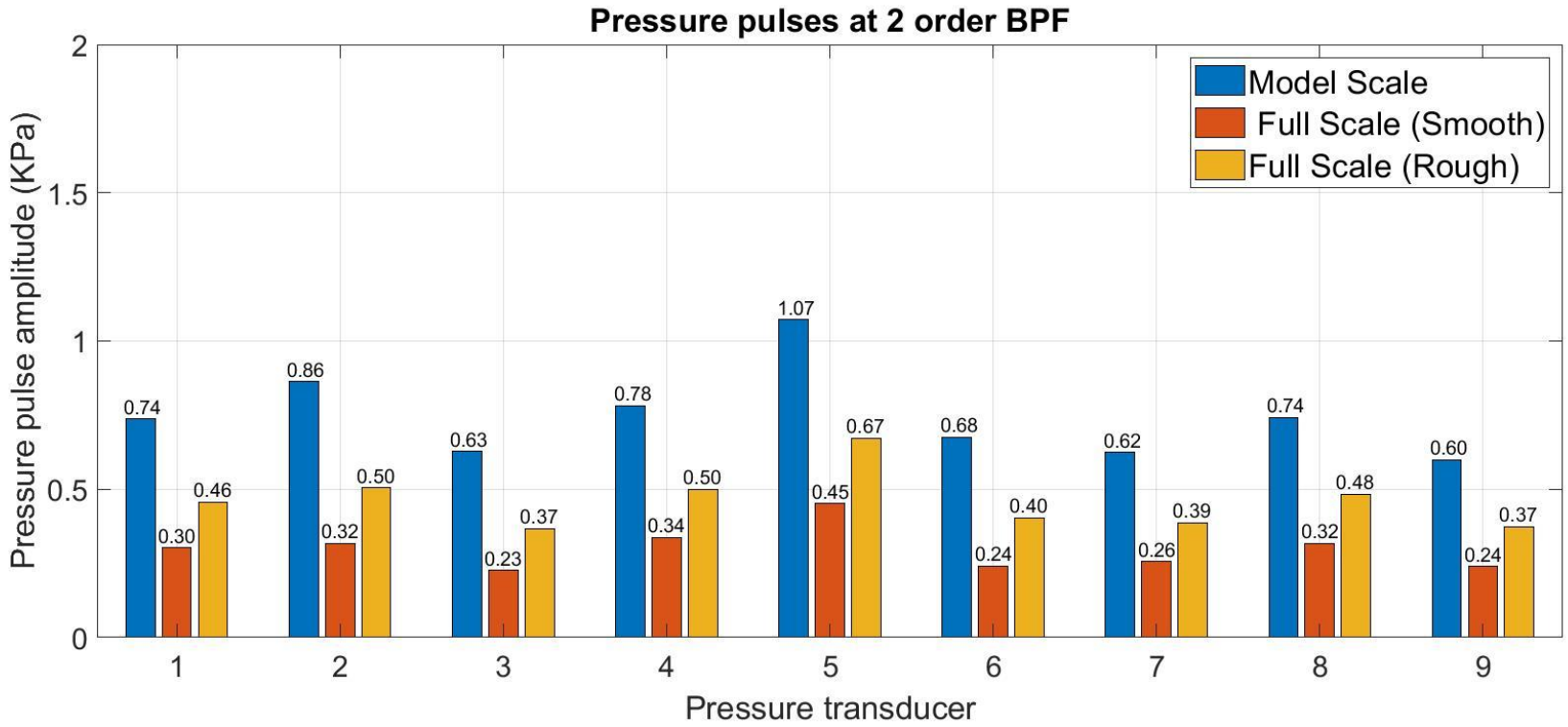
1st Order Blade Pass Frequency (BPF)



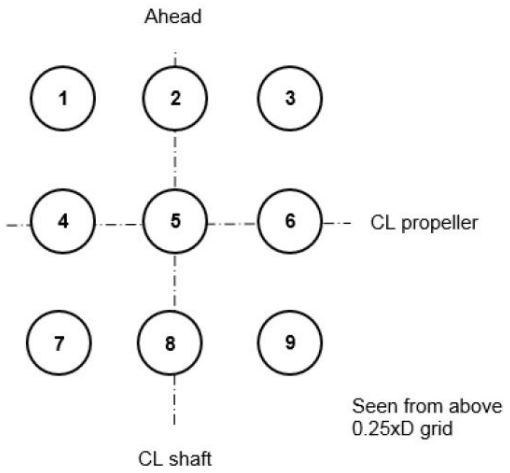


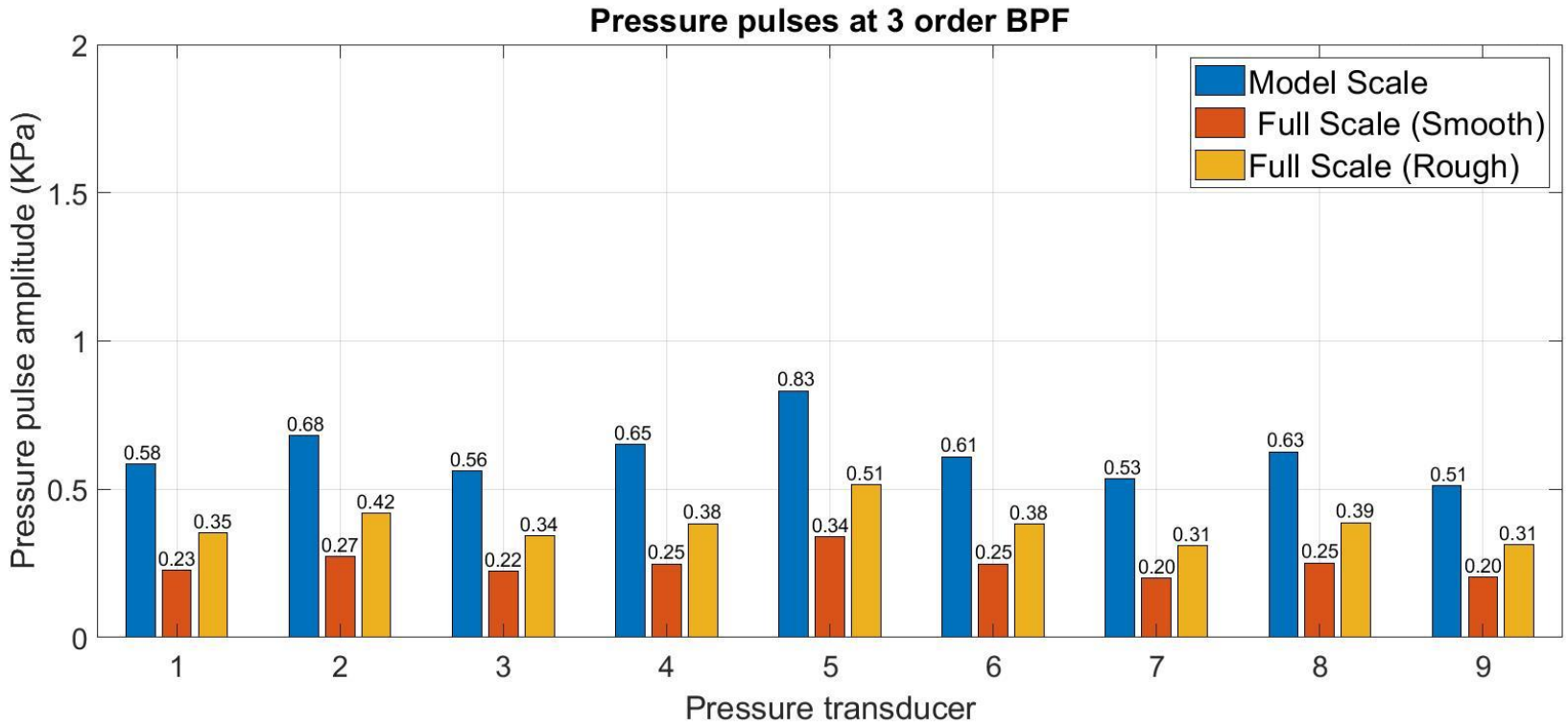
2nd Order Blade Pass Frequency (BPF)



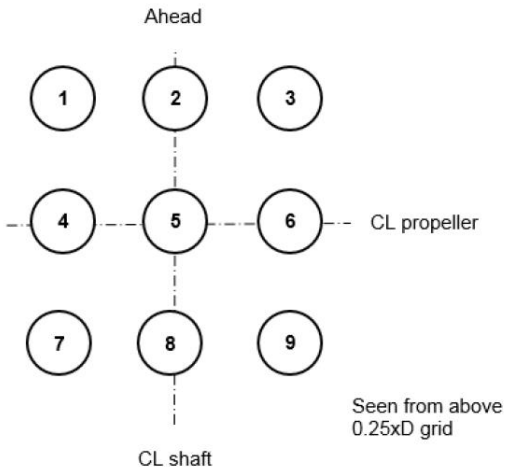


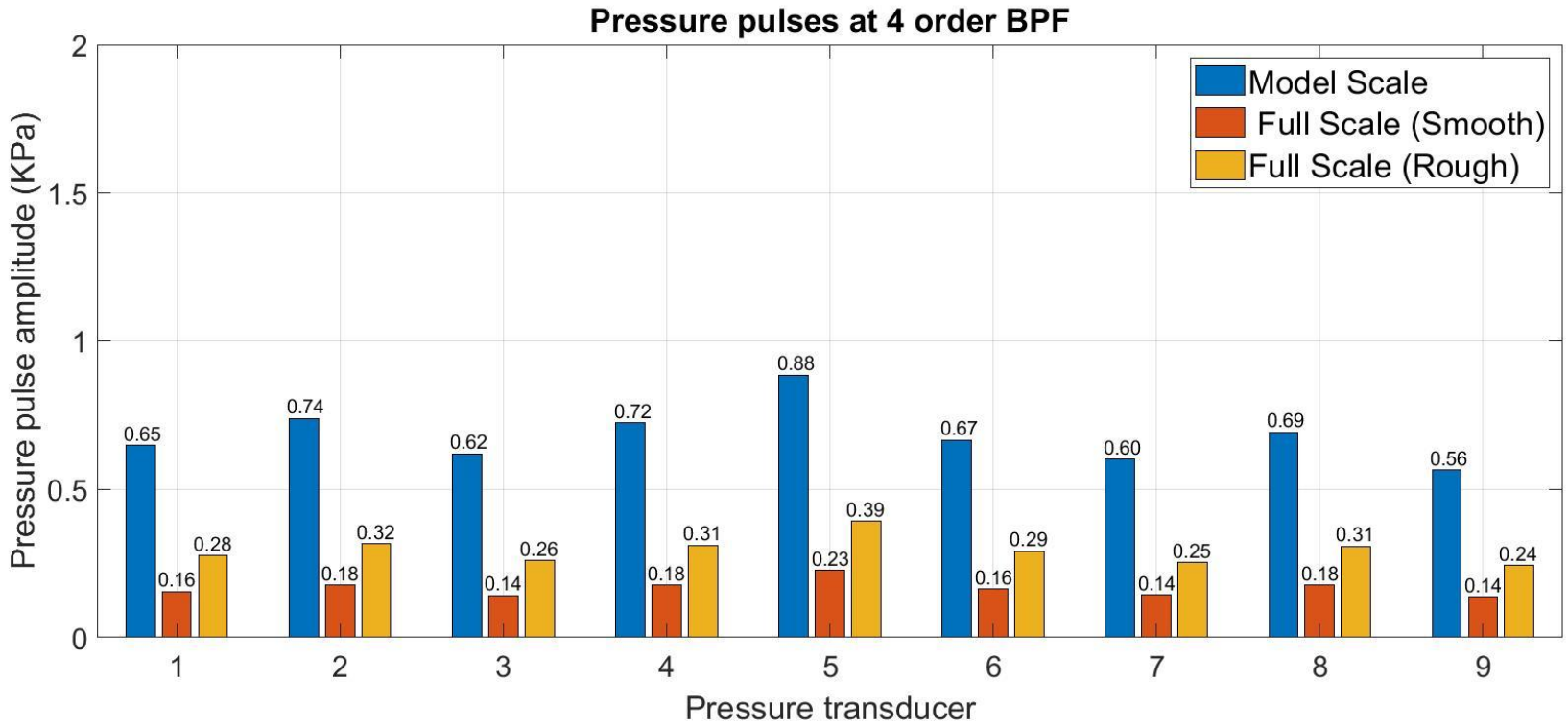
3rd Order Blade Pass Frequency (BPF)





4th Order Blade Pass Frequency (BPF)





Conclusions & Future Work

- Wall function is unable resolve the re-entrant jet.
- Wake in full scale condition has a narrow window which changes extent and dynamics the cavity.
- Predicted pressure pulse levels are observed to be higher in model scale.
- Future work will include (but not limited to) grid study, time-step level study, noise levels.

Acknowledgements

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