Saturn
Developing Solutions for Underwater Radiated Noise

SATURN has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101006443.

Underwater Radiated Noise from Vessels (SATURN)

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TNO innovation for life

DOSITS webinar, 24 April 2024

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Cavitation noise by ship propellers

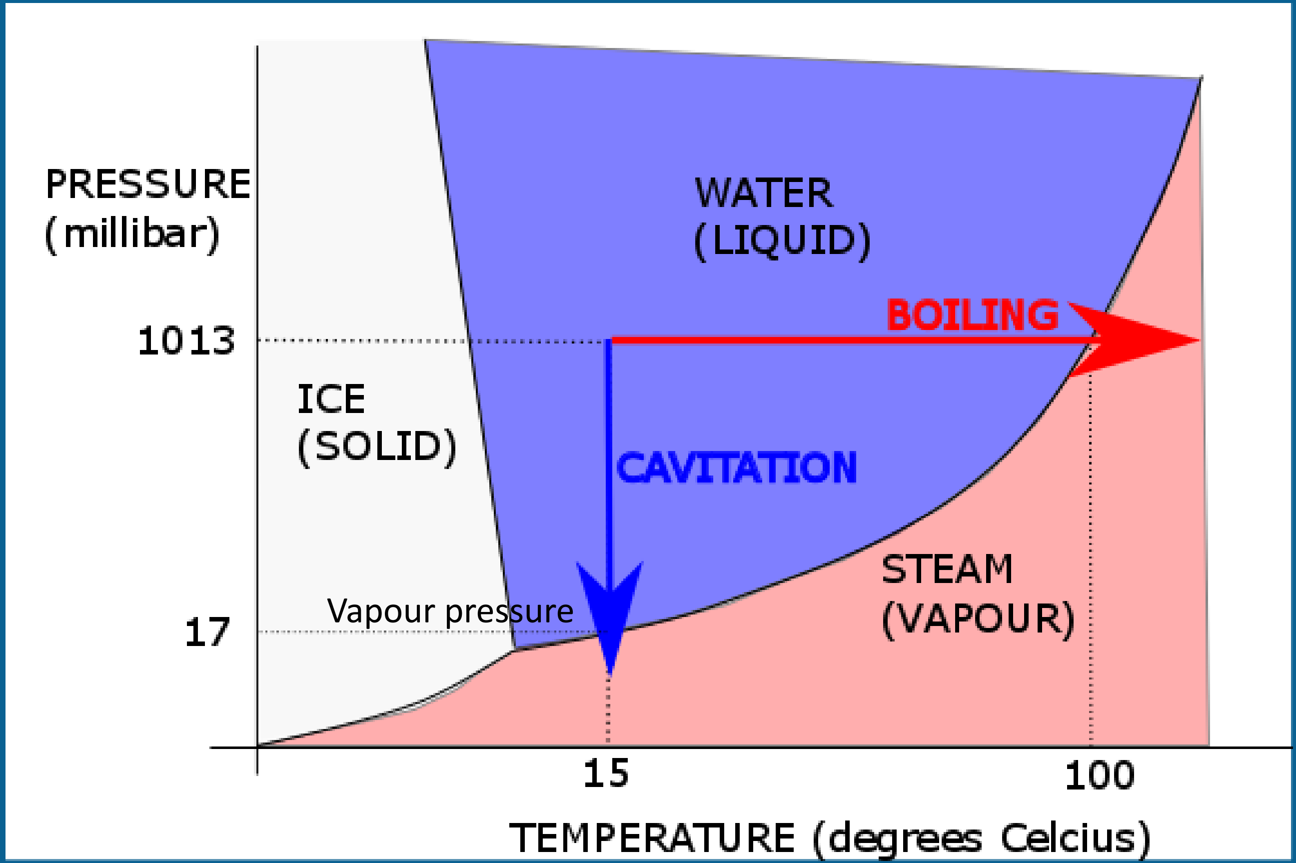
Johan Bosschers (MARIN)

DOSITS seminar; April 24, 2024

Contents:

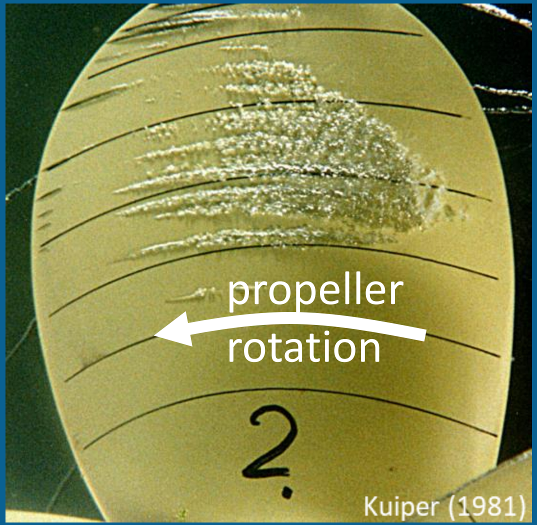
- Introduction
- Prediction during ship design stage
- Examples of technical mitigation measures (EU SATURN project)
- Concluding remarks

Introduction to cavitation



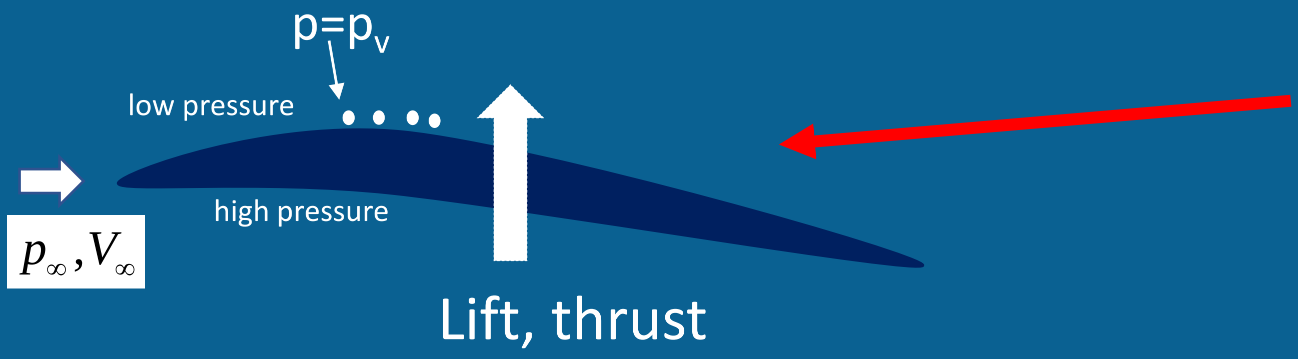
cavitation requires nuclei (small gas bubbles, solid particles)

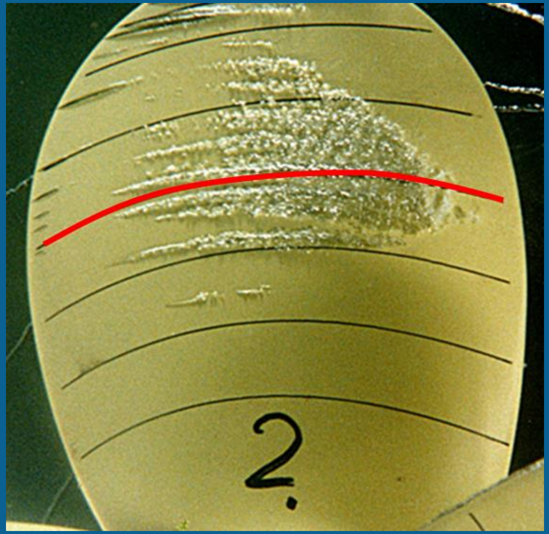
boiling



cavitation

Cavitation on propellers





Pressure reduction scales with V^2 (square of ship speed)

Low speed : no cavitation (minimum pressure higher than vapour pressure)
Inception speed : minimum pressure = vapour pressure
speed above inception : cavitation (length increases with approx. V^2)

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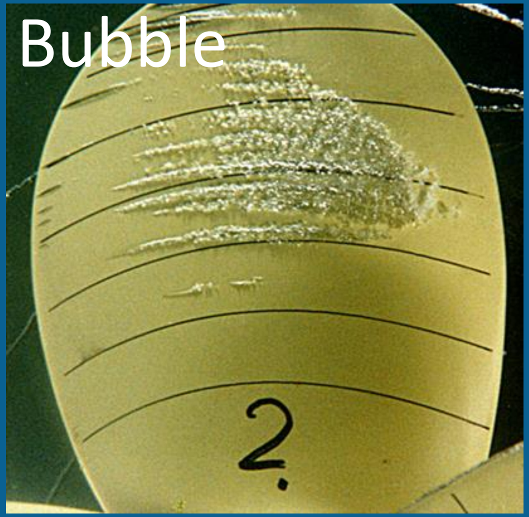
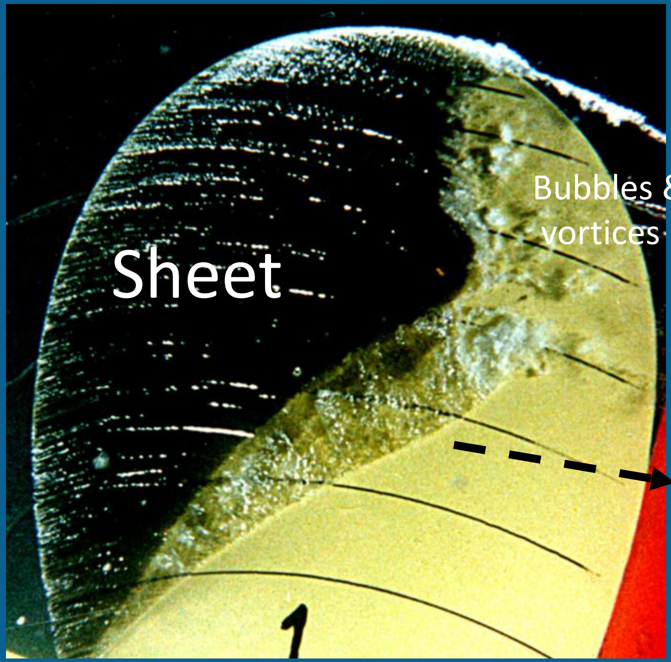
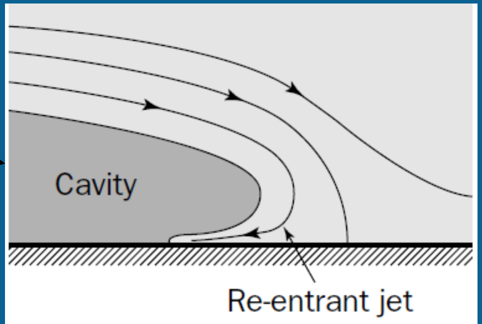
Cavitation types

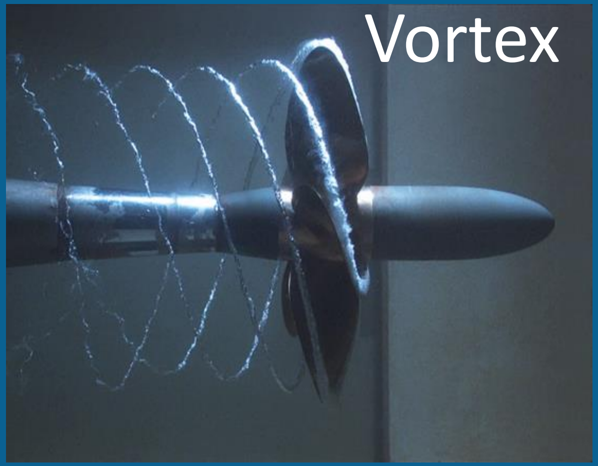
Kuiper (1981)

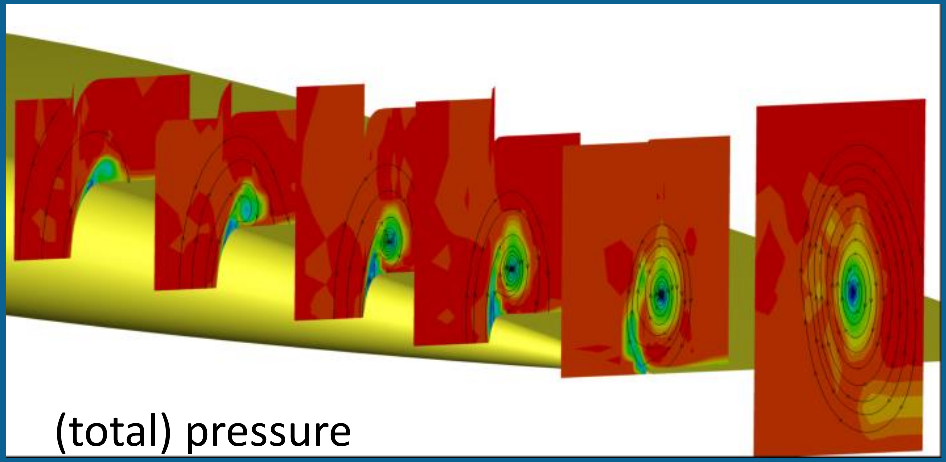


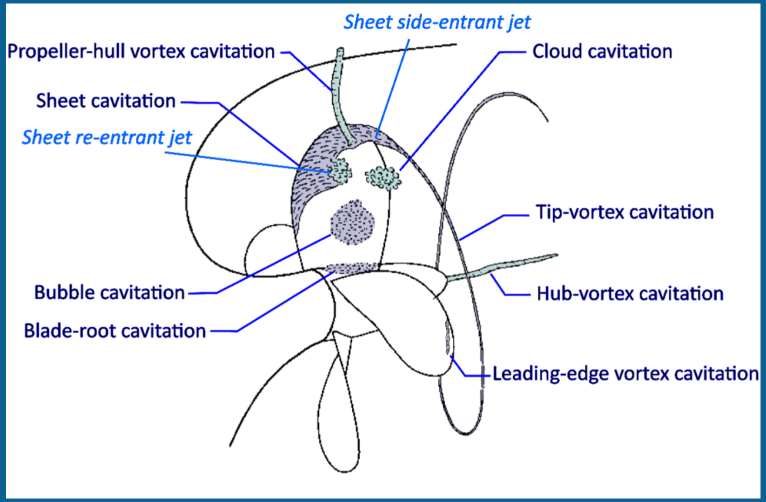




Franc & Michel (2004)







Bosschers (2018)

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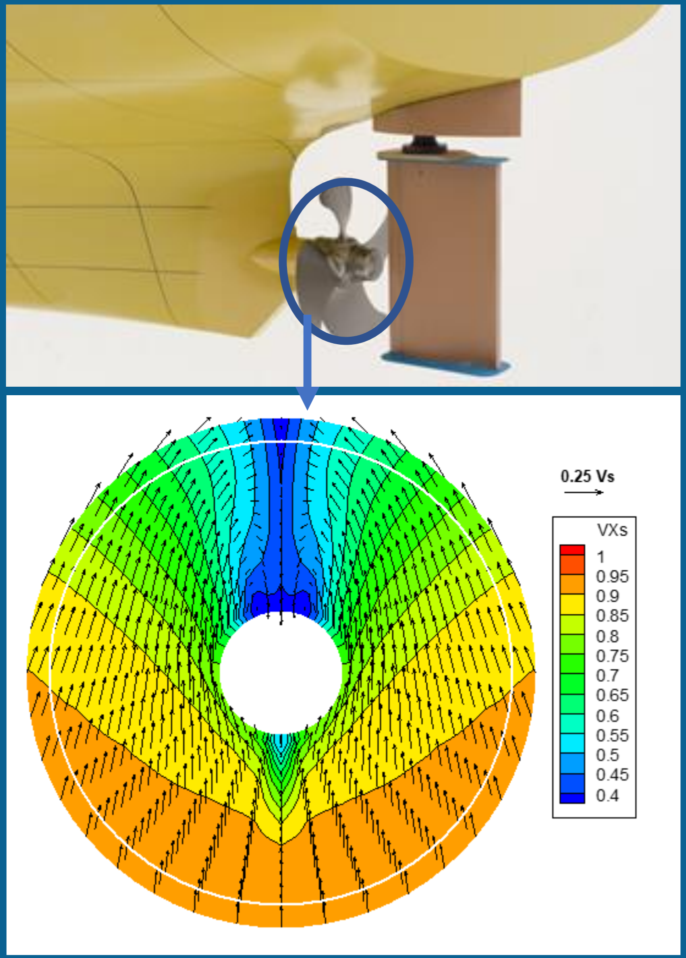
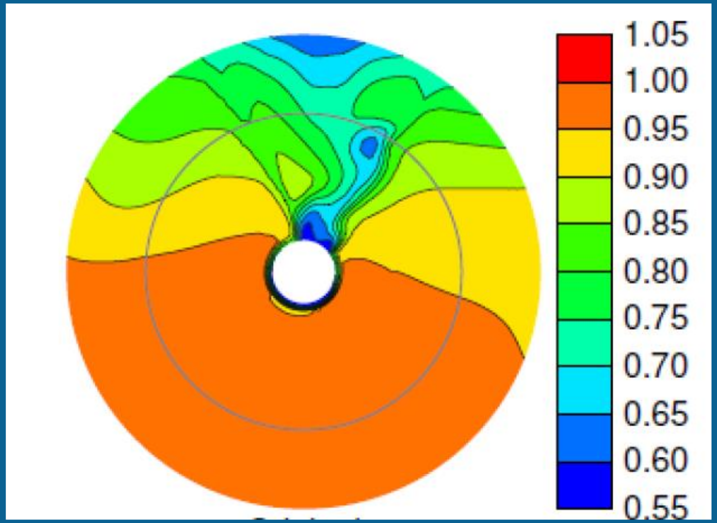
The propeller operates in the wake of the hull -> loading variation



Cargo vessel

Contour plots of longitudinal velocity field



Cruise vessel

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Example full-scale cavitation observation with high-speed camera

- 182 m bulk carrier
- Propeller diameter 5.8 m
- Design speed 14.8 knots

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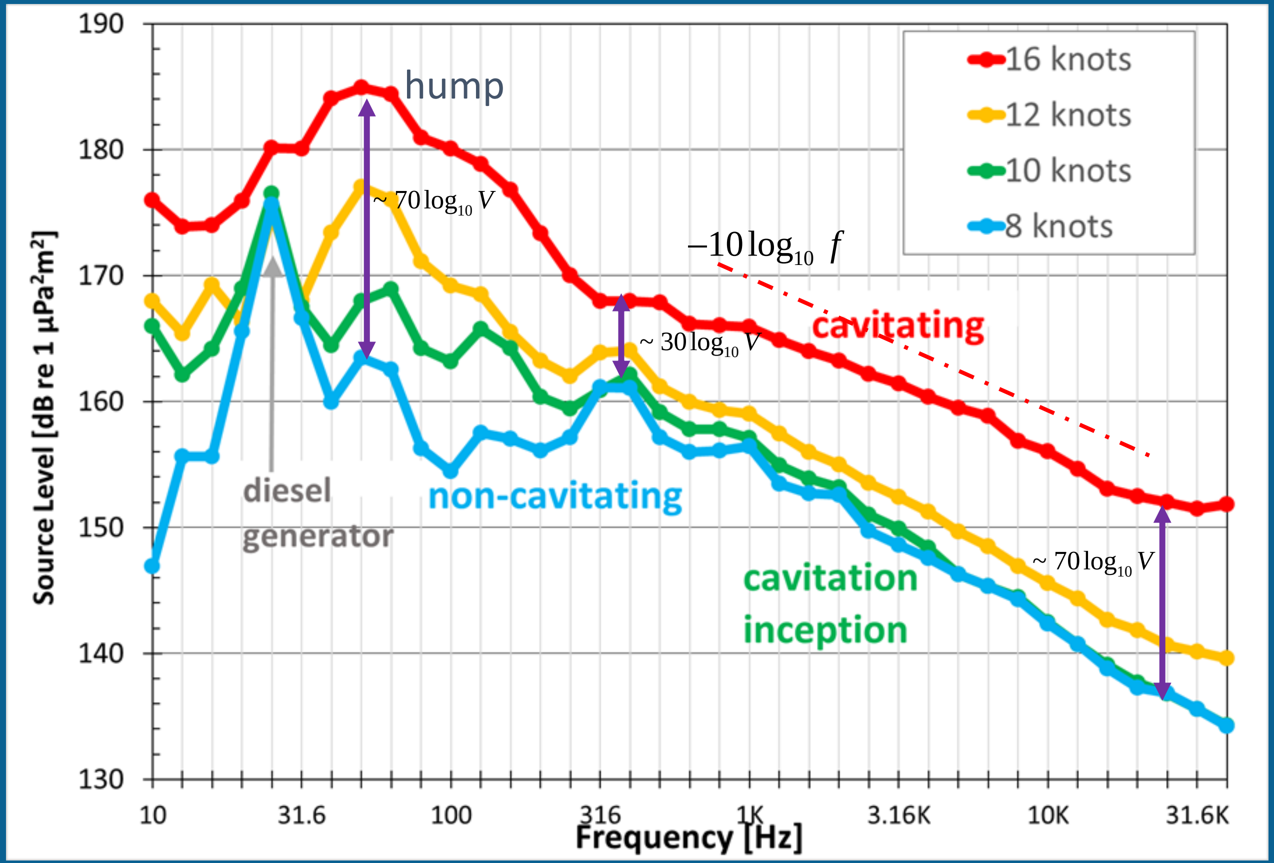
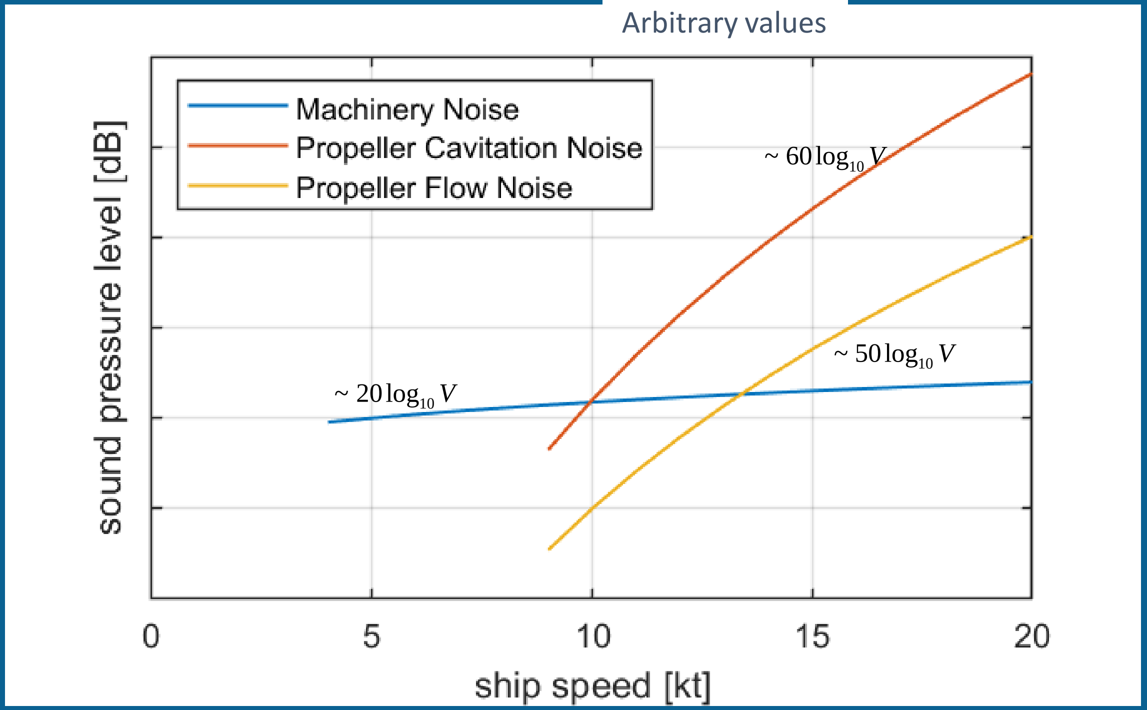
Spectrum of propeller cavitation noise



Data taken from Arveson & Vendittis (2000)



Cavitation noise rapidly increases with ship speed

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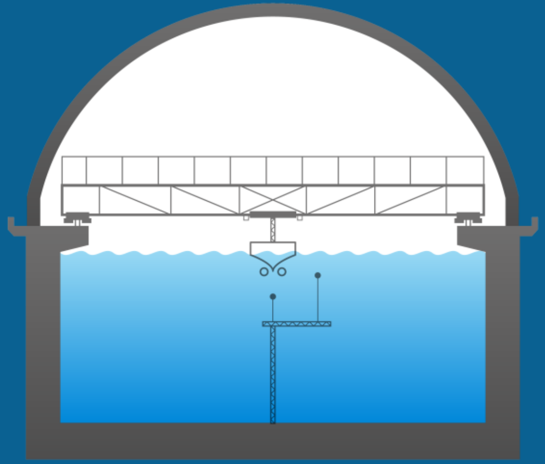
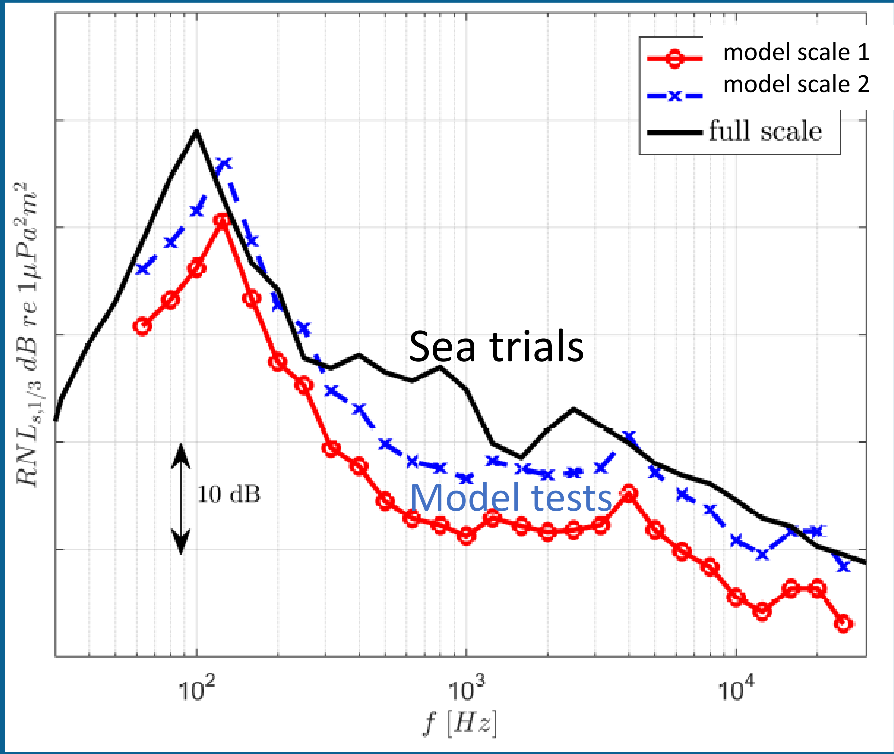
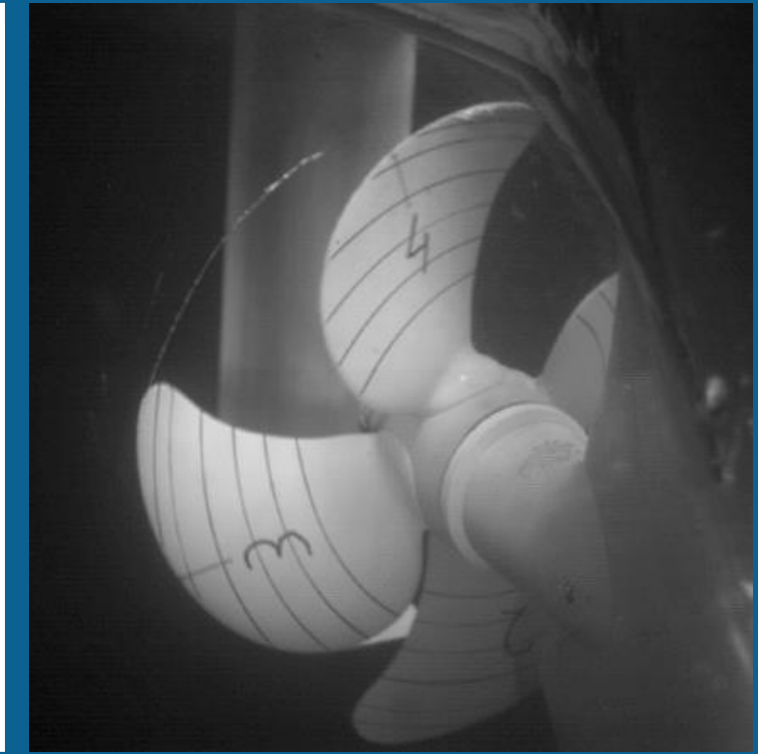
Prediction and assessment of propeller cavitation noise (experiments)

- Model-scale tests in Cavitation Tunnels or MARIN's Depressurized Wave Basin (DWB)
- Various scale effects need to be accounted for (see e.g. ittc.info)





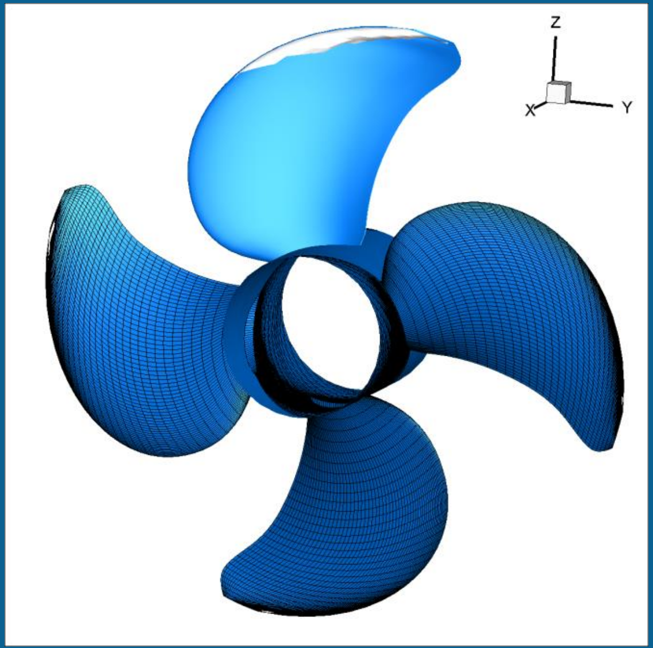


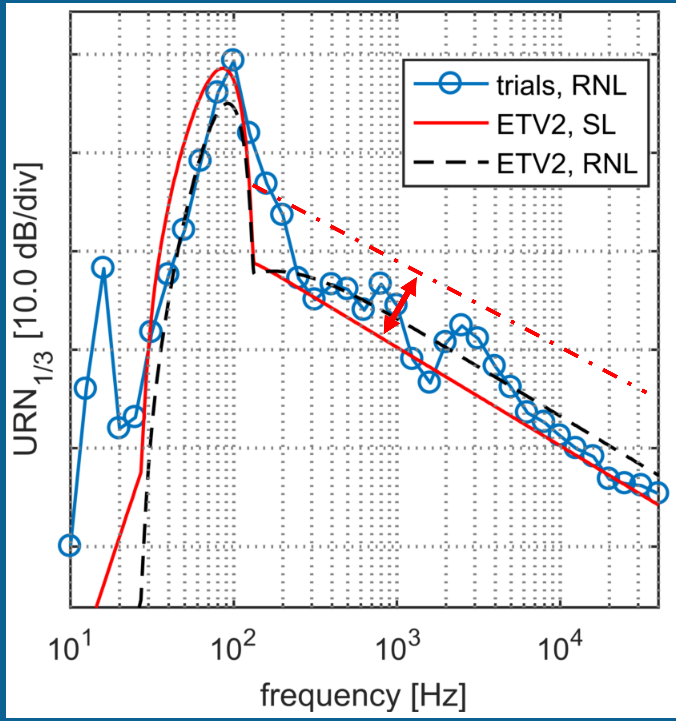
Lloyd et al. (2018)

Prediction and assessment of propeller cavitation noise (computations)

- Ship propeller cavitation noise involves large range of length and time scales!

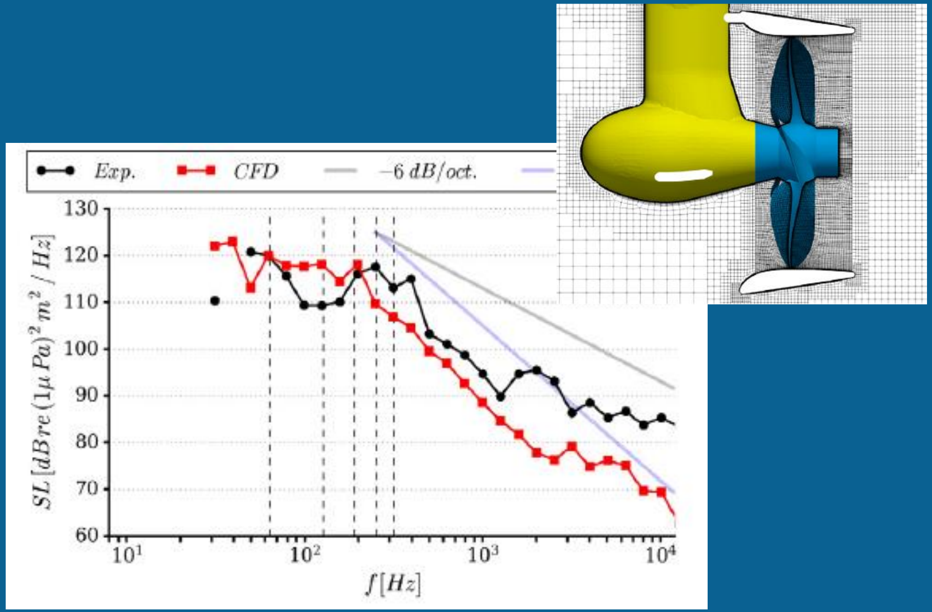
- Boundary Element Method (viscous effects not captured)
- Semi-empirical models for broadband URN





Bosschers (2018)

- Scale-resolving Computational Fluid Dynamics (CFD) for broadband URN
- Model-scale only, computationally expensive



Lidtke et al. (2022)

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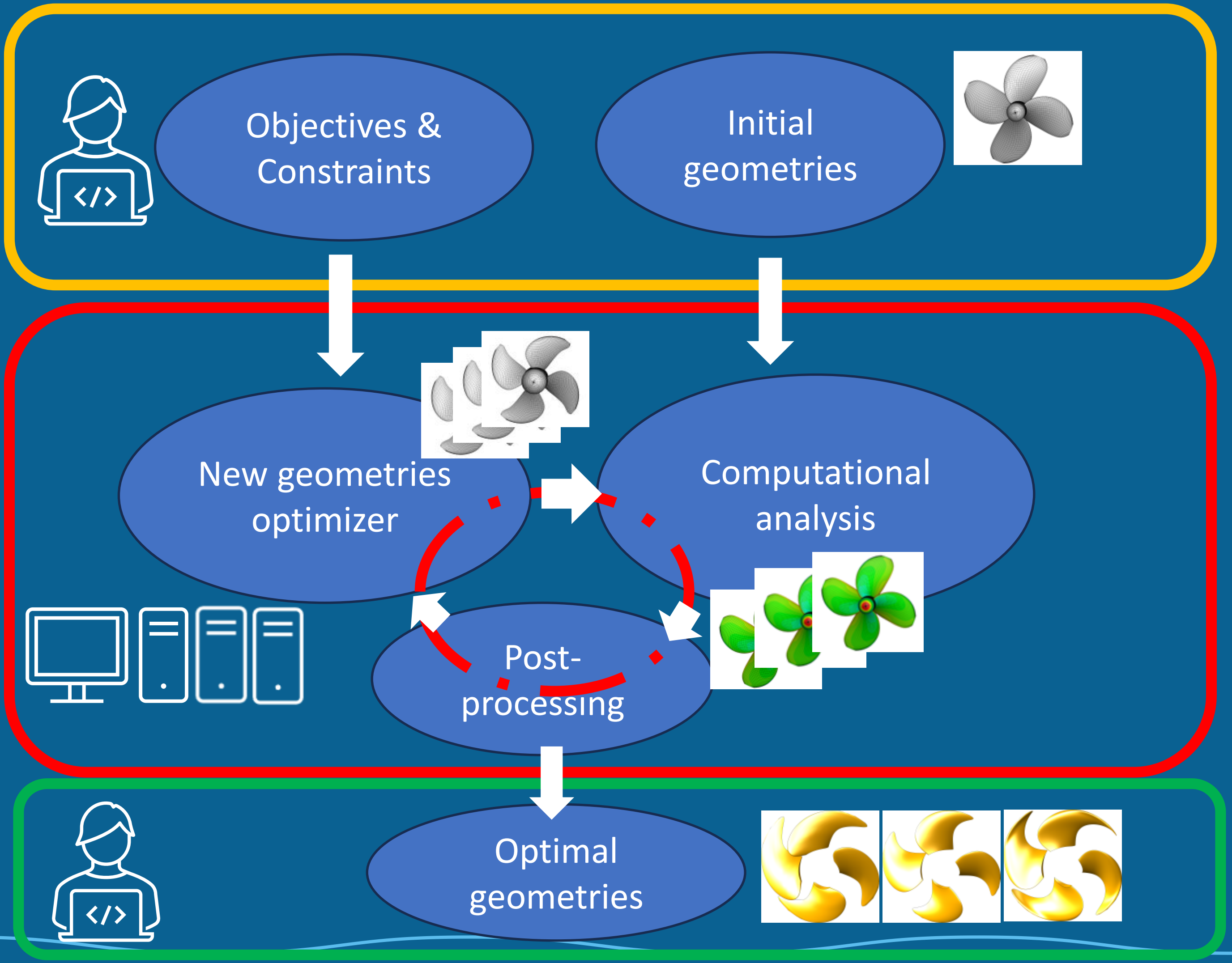
Automated propeller design optimization

- Objectives and constraints
  - Thrust, efficiency, URN, …
  - Cavitation erosion, strength, …

- Computational analysis of performance
- Optimizer: Genetic algorithm, Particle Swarm, …
  - Geometry generation

- Optimal geometries
  - Pareto front: series of propellers with best solutions showing trade-off between URN and efficiency



Huisman & Foeth (SMP 2017)

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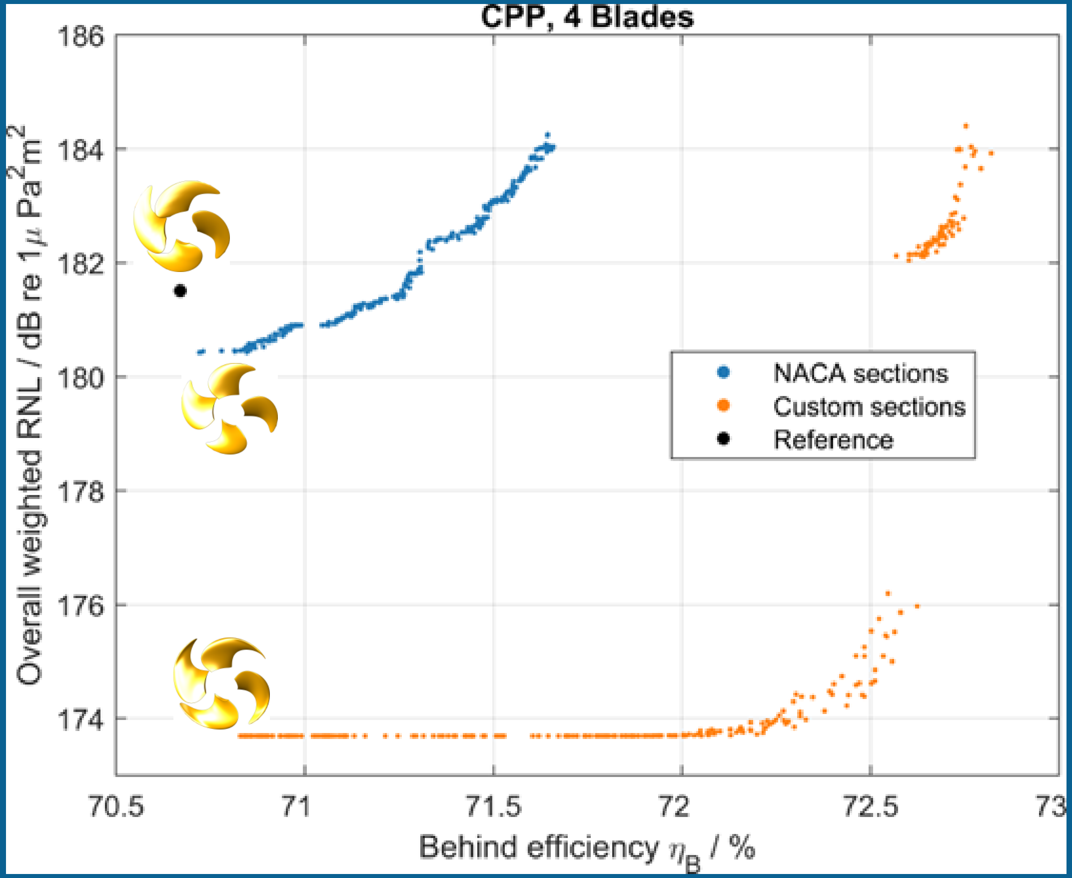
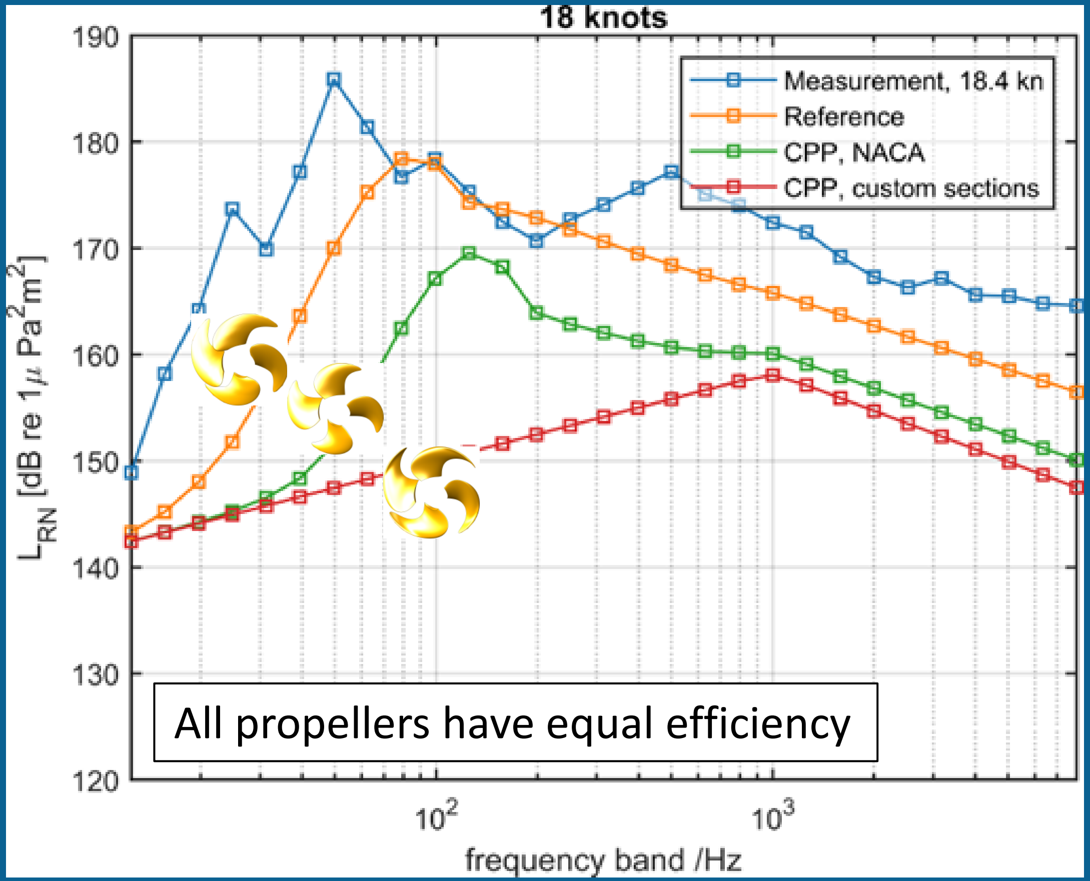
URN reduction using a propeller redesign (twin screw ferry, EU SATURN project)





Significant improvements in fuel efficiency and URN can be obtained with modern (automated) design methods

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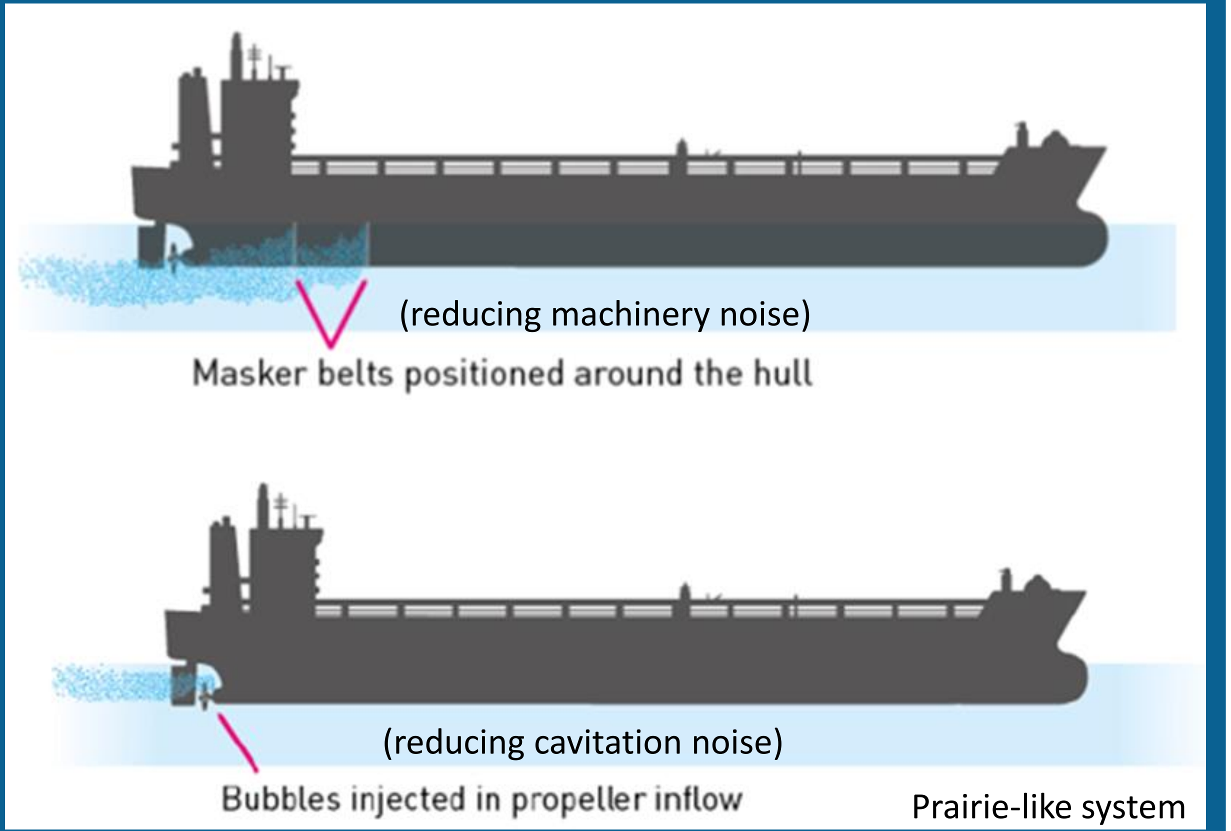
URN reduction using air bubbles (EU SATURN project)

URN reduction



Prairie-like system

Potential gain in energy efficiency if combined with

DAMEN air cavity system

Air-lubrication systems

Preswirl fins and ducts


Becker Mewis duct twisted

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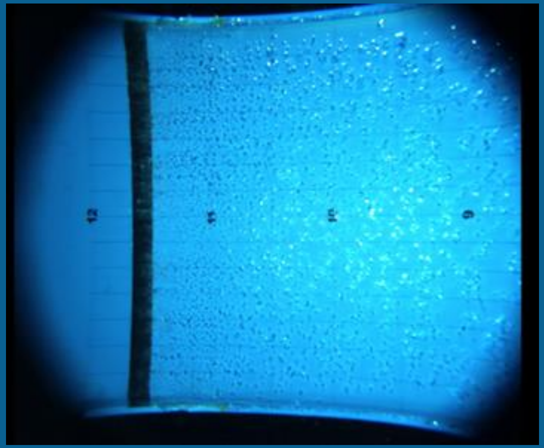
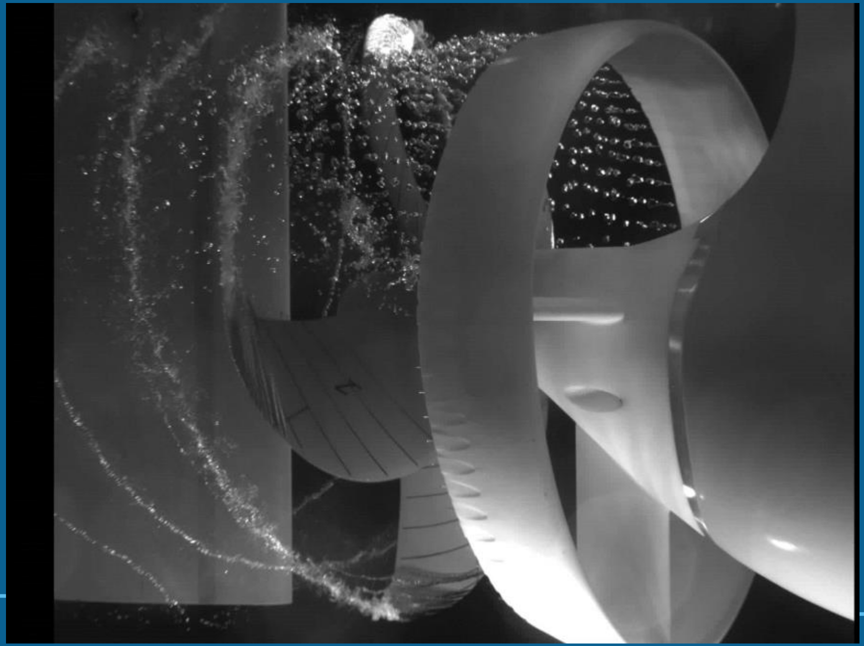
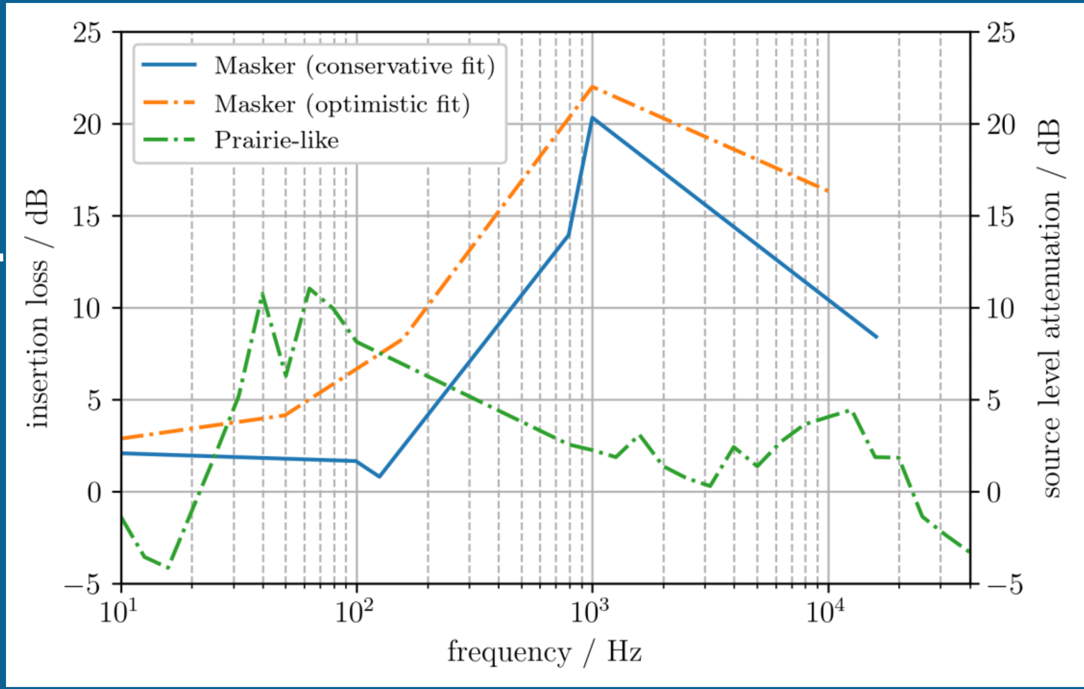
URN mitigation measures using air bubbles







Lloyd et al. (2024)

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Concluding remarks

- Technology for machinery noise control is available
- Standardized procedures for URN measurements for ships are being extended from deep to shallow water

- Early assessment of URN by ship propeller cavitation well possible
- Quantitative knowledge of mitigation measures for cavitation noise is growing

- Basic knowledge now available to perform steps in IMO URN Management Plan for individual ships
- Wider application of URN reduction requires experience building

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Thank you!

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