Underwater Radiated Noise from Vessels (SATURN)

Dr. Johan Bosschers
MARIN, Netherlands

Dr. Christ de Jong
TNO, Netherlands

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Cavitation noise by ship propellers

Johan Bosschers (MARIN)
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• Prediction during ship design stage
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Introduction to cavitation

cavitation requires nuclei (small gas bubbles, solid particles)
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. $V^2$)
Cavitation types

- **Bubble**
- **Sheet**
- **Vortex**

**Bubble**

- Franc & Michel (2004)
- Kuiper (1981)

**Sheet**

- Cavitating tip vortex
- Bosschers (2018)

**Vortex**

- (total) pressure

- Bosschers (2018)
The propeller operates in the wake of the hull -> loading variation

Cargo vessel

Contour plots of longitudinal velocity field

Cruise vessel

Hamalainen (2009)
Example full-scale cavitation observation with high-speed camera

- 182 m bulk carrier
- Propeller diameter 5.8 m
- Design speed 14.8 knots
Spectrum of propeller cavitation noise

Data taken from Arveson & Vendittis (2000)

Cavitation noise rapidly increases with ship speed
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

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

Bosschers (2018)

Lidtke et al. (2022)
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)
Significant improvements in fuel efficiency and URN can be obtained with modern (automated) design methods.
URN reduction using air bubbles (EU SATURN project)

URN reduction

Potential gain in energy efficiency if combined with

Air-lubrication systems

Prairie-like system

(reducing machinery noise)
Masker belts positioned around the hull

(reducing cavitation noise)
Bubbles injected in propeller inflow

Preswirl fins and ducts

DAMEN air cavity system

Becker Mewis duct twisted

Potential gain in energy efficiency if combined with
URN mitigation measures using air bubbles

Lloyd et al. (2024)
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
Thank you!

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@Saturn_H2020
@SaturnH2020
Linkedin.com/company/SaturnH2020
j.bosschers@marin.nl
cchrist.dejong@tno.nl