Specialist Committee on Hydrodynamic Noise

2017-2021

Chairman :

Johan Bosschers [6] (MARIN, NL)

Secretary :

Bryce Pearce [3] (AMC, AU)

Members :

Romuald Boucheron [4] (DGA, FR)
Yezhen Pang [5] (CSSRC,CN)
Cheolsoo Park [9] (KRISO, KR)
Kei Sato [1] (MHI, JP)
Tuomas Sipila [2] (VTT, FI, until Feb. 2020)
Claudio Testa [8] (CNR/INM, IT)
Michele Viviani [7] (UNIGE,IT)

Meetings

Face-to-face:

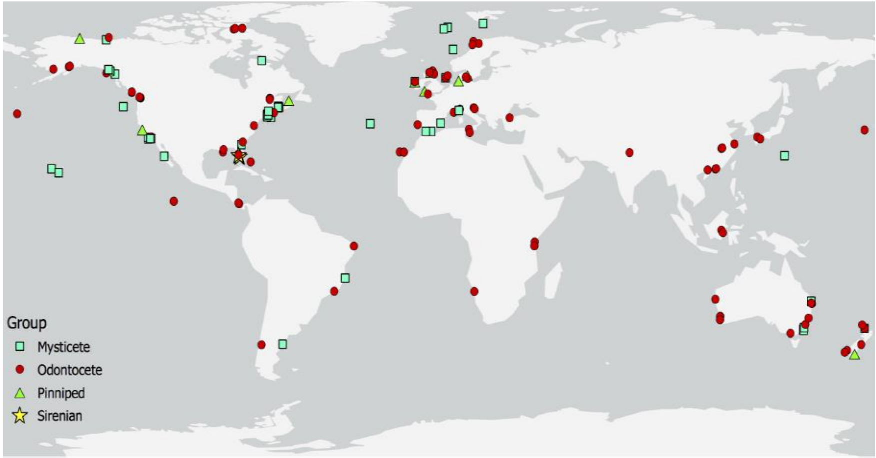
- Wageningen, Netherlands, February 2018
- Launceston, Australia, March 2019
- Rome, Italy, February 2020

Video Conferences:

- June 2018
- August 2019
- July 2020, September 2020, October 2020
- January 2021, March 2021

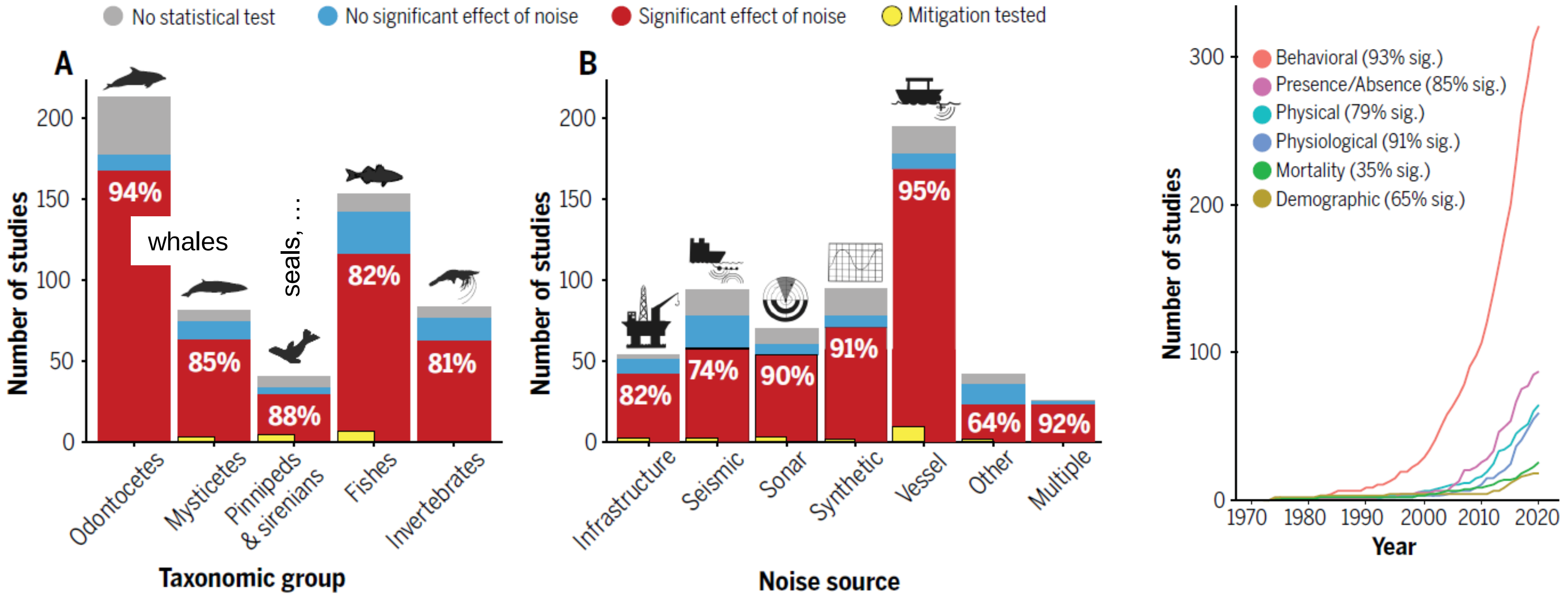
Introduction

- Sea life depends on sound for communication, food finding, orientation, …
- Increased anthropogenic noise levels mask the sound by sea life
  - Pile driving
  - Seismic research
  - Shipping
  - …



Map showing stations where effect of ship noise on sea life is studied (Erbe, 2019)
See also www.iqoe.org

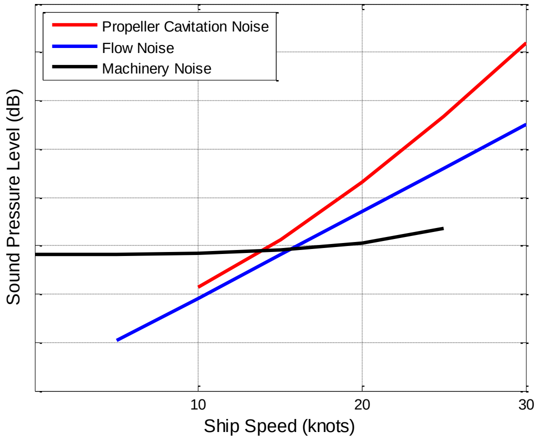
Introduction



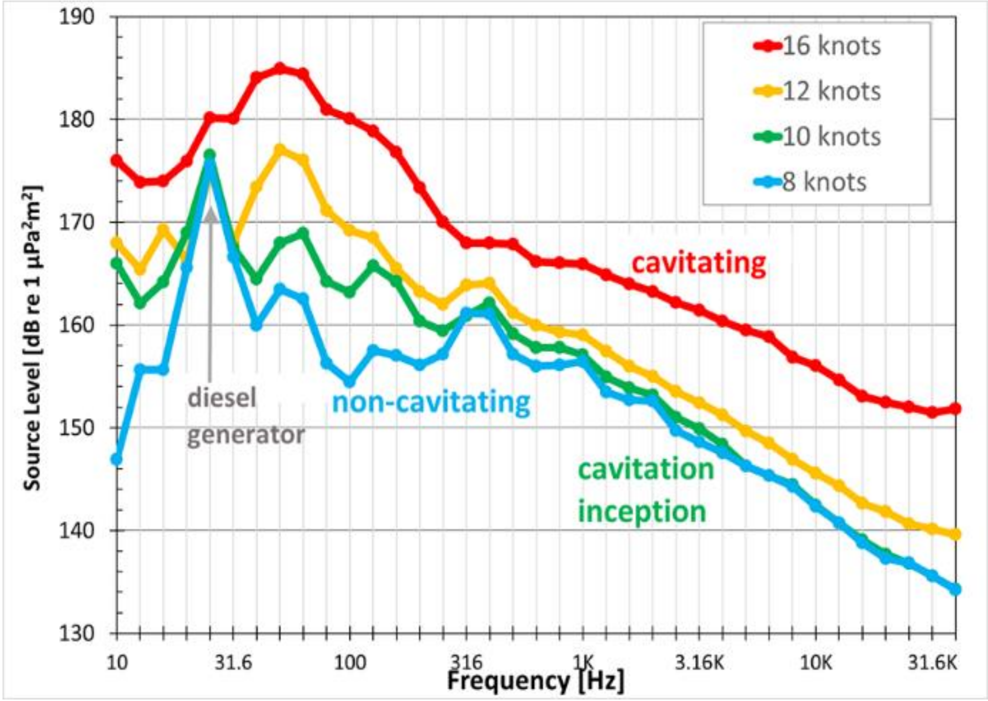
Duarte et al. (2021)

Introduction

Ship noise:
- Flow noise
- Machinery noise
- Propeller cavitation noise
    - usually dominates at design speed



28th ITTC SC Hydrodynamic Noise Report (2017)



Data of Arveson & Vendittis (2000): 173 m merchant vessel

Terms of References

1. Present ITTC procedures and our community's capabilities to predict emitted noise from ships to the IMO. Specifically, an informative submission shall be made to MEPC 72 (Spring, 2018) of Guideline 7.5-02-01-05 Model-scale propeller cavitation noise measurements.
2. Monitor progress on shipping noise measurement procedures for shallow water and regulations as developed by ISO, classification societies and regulatory agencies.
3. Monitor progress on model-scale noise measurements with emphasis on facility reverberation and scaling of vortex cavitation noise.
4. Monitor progress on computational prediction of propeller noise with emphasis on methods using the acoustic analogy such as coupling CFD with FWHE.
5. Identify a benchmarking case for model-scale noise measurements that has, full-scale underwater radiated noise measurements available, that is a representative merchant vessel, and of which geometry and measurement data can be shared with the ITTC community.
6. Maintain and update ITTC guideline 7.5-02- 01-05: Model-Scale Propeller Cavitation Noise Measurements and guideline 7.5-04-04-01: Underwater Noise from Ships, Full-Scale Measurements.

ToR #1: IMO submission

Present ITTC procedures and our community's capabilities to predict emitted noise from ships to the IMO. Specifically, an informative submission shall be made to MEPC 72 (Spring, 2018) of Guideline 7.5-02-01-05 Model-scale propeller cavitation noise measurements.

- Specialist Committee has communicated to AC that it does not consider this useful (yet) as, among others, URN was not on MEPC72 agenda.
- ITTC secretary has send informative submission to IMO, no input from Specialist Committee
- To date, URN still not on agenda of MEPC, hence informative submission by ITTC on this topic not considered to be of added value to IMO community by Specialist Committee

ToR #2: Measurement procedures and regulation

Monitor progress on shipping noise measurement procedures for shallow water and regulations as developed by ISO, classification societies and regulatory agencies.

- Review of literature on
  - Regulatory agencies
  - ISO working groups
  - Classification societies

ToR #2: Measurement procedures and regulation

- IMO:
  - Transport Canada Workshop in IMO building, London, 2019: identify possibilities and priorities for URN regulation
  - Submission MEPC/75/14 (2020) by Australia, Canada, US, supported by EU:
    - Proposal to review IMO guidelines document
    - Identify next steps
    - EU: Proposal to put URN on agenda of MEPC76
  - MEPC75 organized as virtual meeting in November 2020, submission on URN not discussed due to time limitations, postponed to MEPC76.

ToR #2: Measurement procedures and regulation

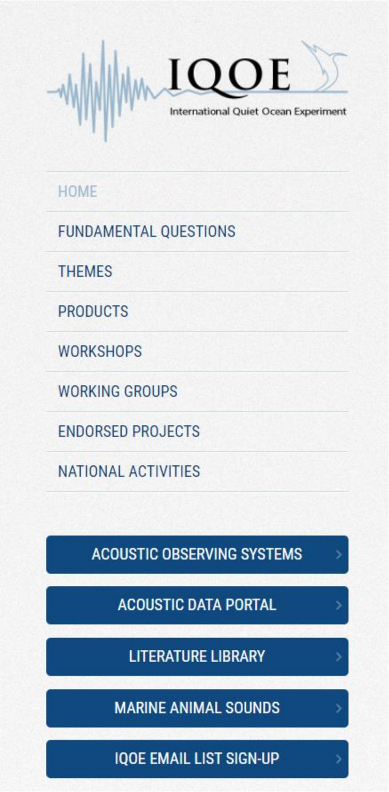
- Australia: follows and endorses developments at IMO
  - Concern for Great Barrier Reef
  - Legislation for Particular Sensitive Sea Area allows for setting speed limits
- EU: Marine Strategy Frameword Directive 2008/56/EC which aims to achieve good environmental status, includes continuous URN
  - Focus on assessment of current levels in EU waters
    - North Sea: JOMOPANS; Mediterranean: QuietMED2; Atlantic: JONAS; and others
- US: noise monitoring campaigns in seven national marine sanctuaries and one marine national monument

ToR #2: Measurement procedures and regulation

- Canada:
  - Both Transport Canada and Port of Vancouver very active in promoting research on shipping URN and effect on sea life
  - Workshop TC (2019)
  - Echo program Port of Vancouver
  - Reduction harbor fees Port of Vancouver when ship has URN class

ToR #2: Measurement procedures and regulation

- International Quiet Ocean Project IQOE, www.iqoe.org
- promotes research, observations, and modelling to improve understanding of ocean soundscapes and effects of sound on marine organisms
- Provides references to
  - Sound monitoring programs
  - Literature
  - …



ToR #2: Measurement procedures and regulation

- Standards full-scale noise measurements:

  - ANSI-ASA (2009) : Deep water measurements
  - ISO 17208-1:2016: Deep water measurements (comparison purposes)
  - ISO 17208-2:2019: Deep water measurements (source level determination)
  - ISO/NP 17208-3 : Shallow water measurements, in development

  - ISO 18405:2017 : Underwater acoustics - terminology

ToR #2: Measurement procedures and regulation

- Classification societies
  - DNV-GL (2010, 2019)
  - BV (2014, 2017, 2018)
  - CCS (2016, 2018)
  - RINA (2017)
  - LR (2018)
  - ABS (2018)

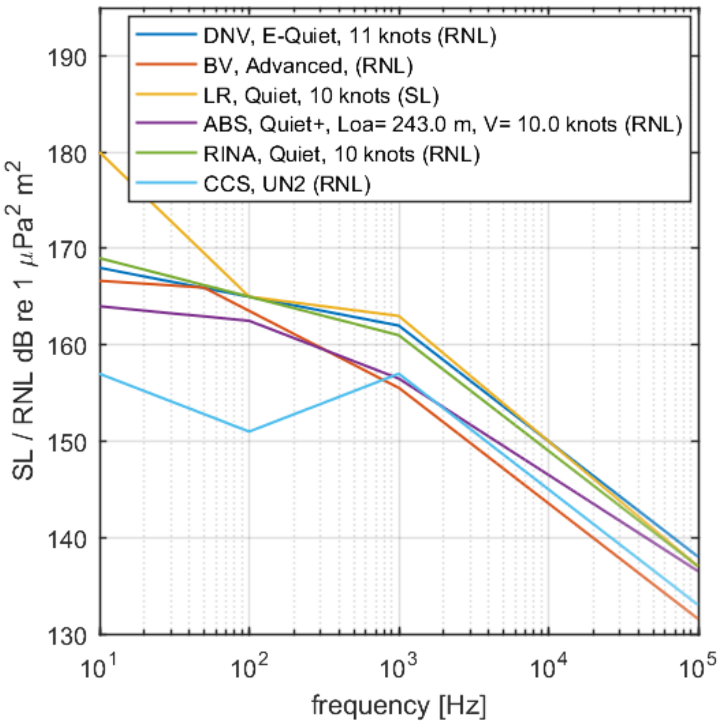
Describe both measurement procedure and provide noise limits (spectra)

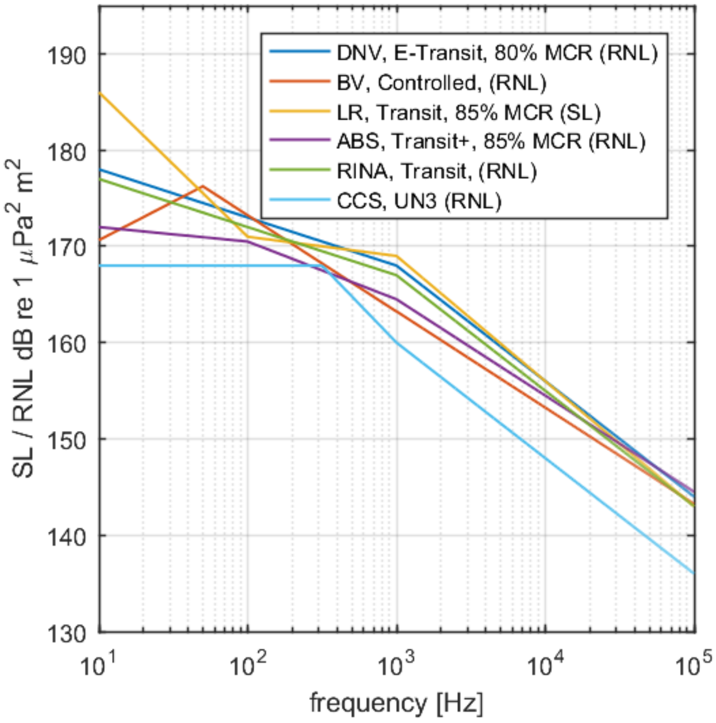
- but measurements procedures differ
- post-processing procedure differ
- (definition of) spectra noise limits differ

Table with comparison presented in appendix of Committee report

Efforts ongoing to harmonize the class rules

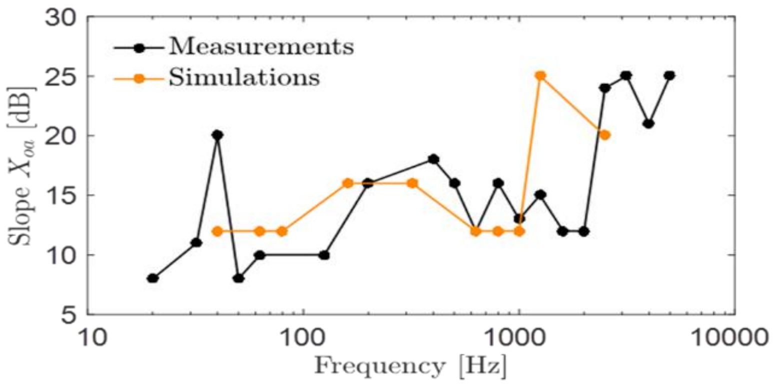
ToR #2: Measurement procedures and regulation



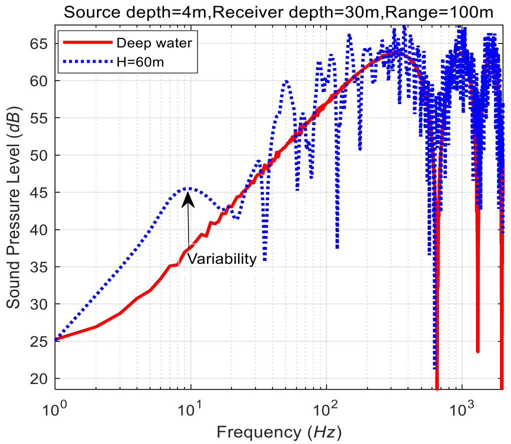


ToR #2: Shallow water measurements

- Noise propagation models: developed for long range ~ 1 km - 10 km
- Nowdays also applied for ship noise trials in shallow water
- BV rule allows for use of computational methods for computing propagation loss in shallow water



Sipila et al (2019), propagation X $\log_{10}$ R
25 m water depth, CPA= 150 m.



Simulations by Pang et al. (2020)

ToR#3: Model-scale noise measurements

Monitor progress on model-scale noise measurements with emphasis on facility reverberation and scaling of vortex cavitation noise

- Topics addressed in report:
  - Acoustic measurements techniques in general
  - Pressure measurements, calibration
  - Facility reverberation
  - Tip-vortex scaling
  - Water quality
  - Uncertainties
  - Review HTF benchmarking study
  - Validation studies

ToR#3: Facility reverberation

- Tunnel walls reflect sound waves which lead to interference patterns and standing waves
- Below Schroeder frequency noise field dominated by standing waves leading to large variability in transfer function with position of source and hydrophone
- Formulation for cavitation tunnels derived by Boucheron (2019, 2020)
- Acoustic field reconstruction at low frequencies in progress

Varying positions of acoustic source and hydrophone

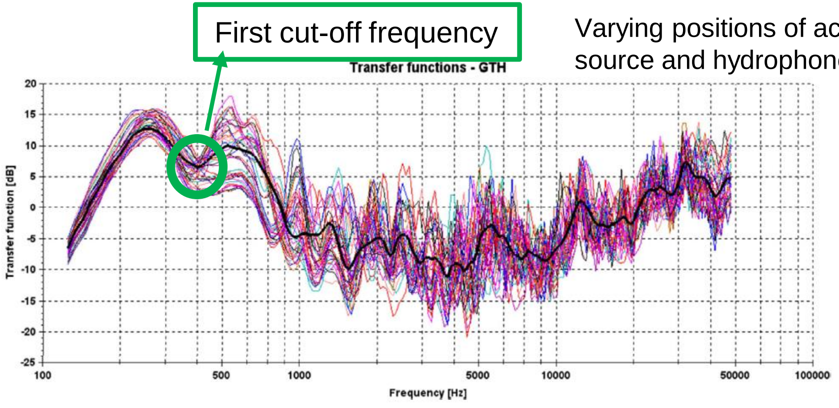
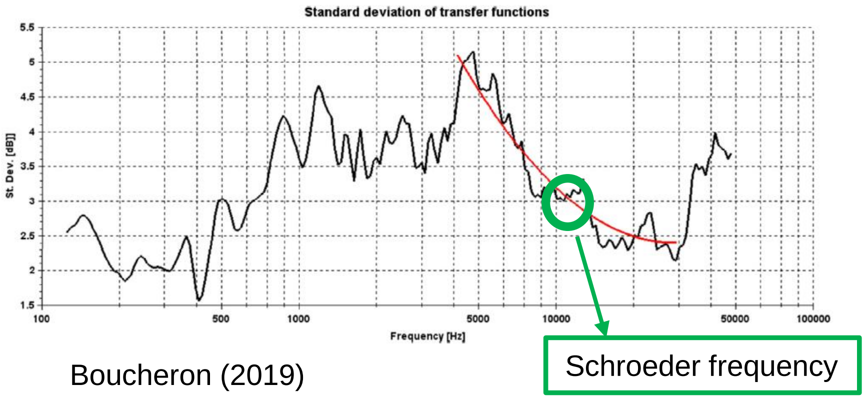


Fig. 13. Example of forty individual Transfer Functions measured in the GTH.

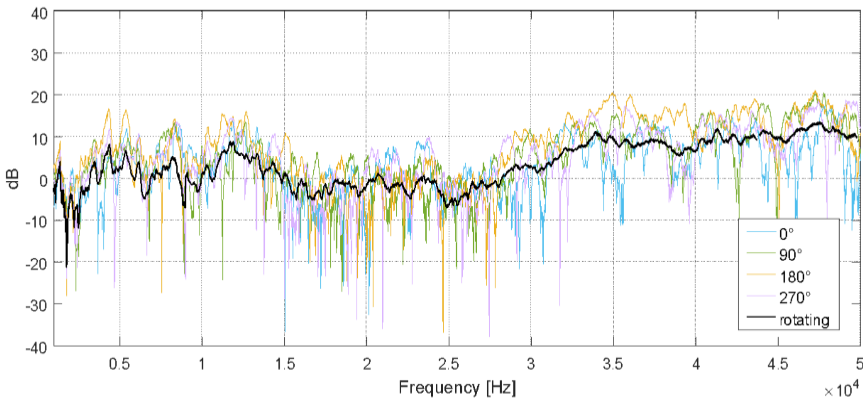


Boucheron (2019)

ToR#3: Facility reverberation

- Transfer function measurements depend on
  - Type sound projector
  - Type signal
  - Position projector and hydrophone
  - Air content
  - …
- Averaging required

- Lafeber et al. (2015), Briancon et al. (2013), Park et al. (2018), Tani et al. (2019), Boucheron (2019, 2020)



Tani et al. (2019)

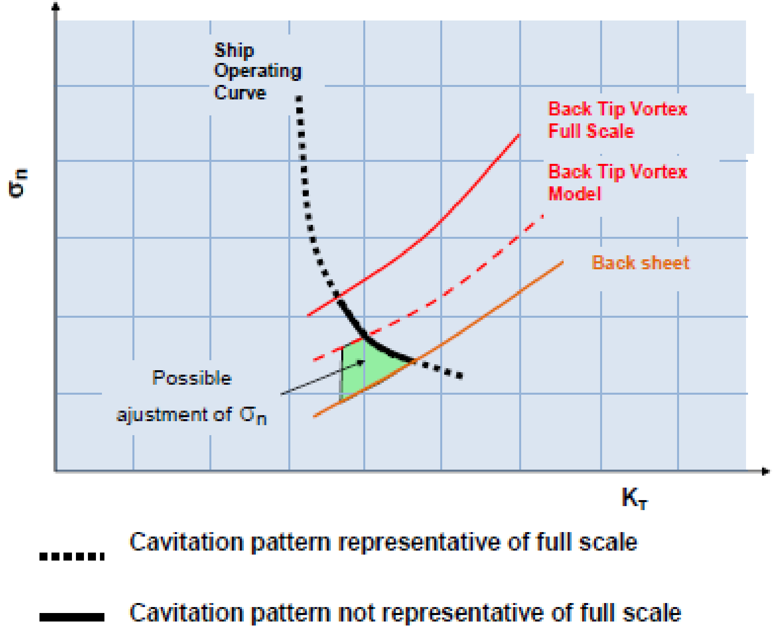
ToR#3: Tip-Vortex Cavitation (TVC) scaling

- Inception of TVC depends on Reynolds number

$$\frac{\sigma_m}{\sigma_s} = \left(\frac{Re_m}{Re_s}\right)^n$$

- Typical value for inception, n~ 0.35
- Adjust cavitation number to get correct noise prediction for TVC:
  - Oshima (1990), n= 0.15
- Or scale noise levels
  - Park & Seong (2017) n= 0.32
  - Park et al. (2019), n= 0.1

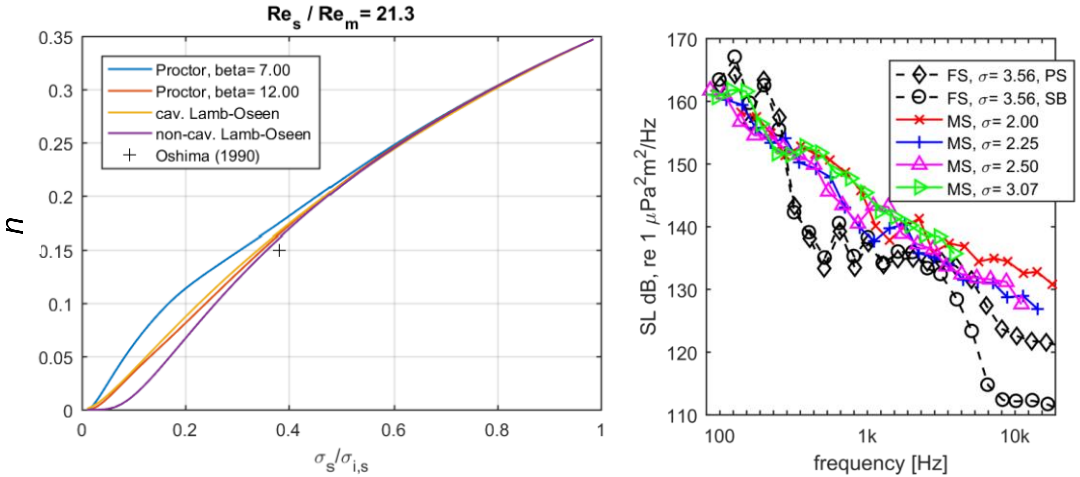
$$\Delta L_p = \left(\frac{Re_s}{Re_m}\right)^{2.5\,n}$$



28th ITTC SC Hydrodynamic Noise Report (2017)

ToR#3: Tip-Vortex Cavitation (TVC) scaling

- Bosschers (2018, 2020):
  - Adjust cavitation number to obtain equal cavity size
    - Vortex model in non-dimensional form
  - Leads to variation of *n* depending on cavity size
  - Or correct noise levels for difference in cavity size using empirical formulation

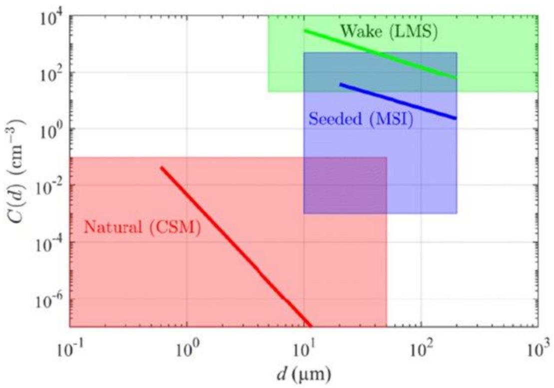


Bosschers (2020), *making use of exp. data of Oshima (1990)*

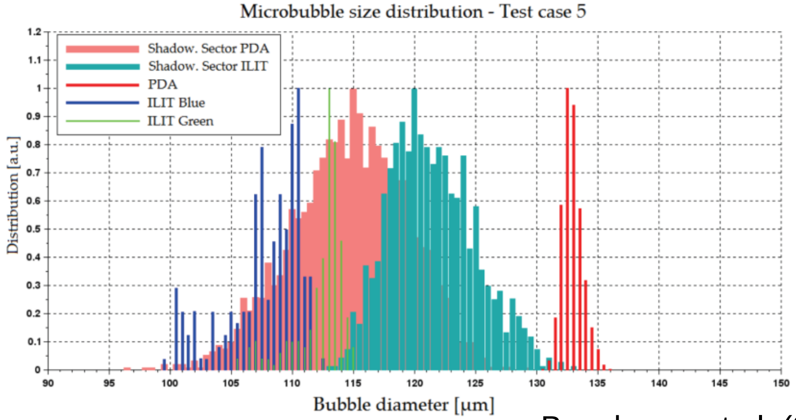
ToR#3: Water quality

- Known to affect cavitation extents, hull pressure tests and URN tests
  - Nucleii + non-condensable gas
- No recent literature on URN
- But progress made in nuclei measurements
  - Cavitation susceptibility meter
  - Shadowgraphy
  - Phase Doppler anemometry
  - Holography
  - Defocus technique

    used by a.o. Birvalski & van Rijsbergen (2018), Boucheron et al. (2018), Ebert et al. (2018), Russell et al. (2020)



Russell et al. (2020)

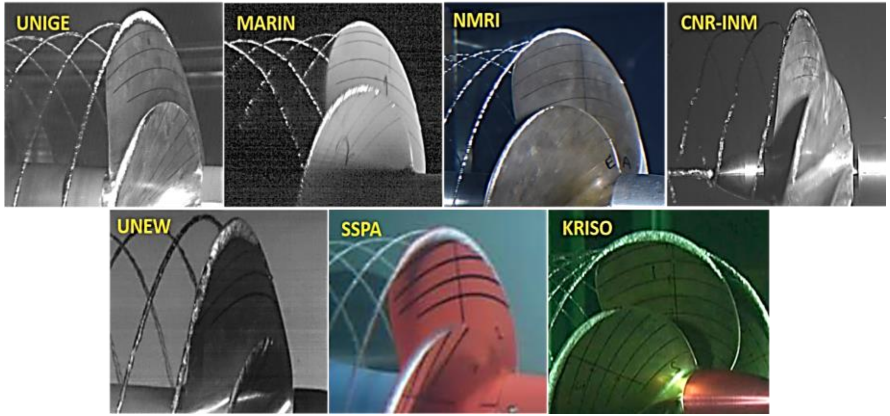


Boucheron et al. (2018)

ToR#3: HTF benchmarking study

- HydroTesting Forum has organized a round robin test-case for URN
- Propeller in open water with shaft inclination angle

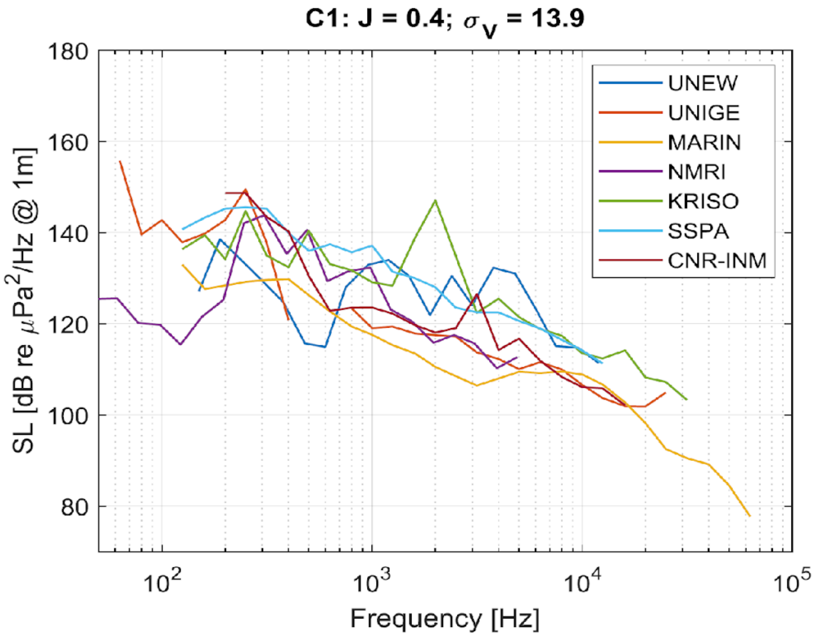
Loading Condition	J [-]	σ_V [-]
C1	0.4	13.9
C2		8.1
C3		4.5
C4	0.5	13.9
C5		8.1
C6		4.5



Tani et al. (2020)

ToR#3: HTF benchmarking study

- URN results scaled to reference condition
- Max-min difference is 10-20 dB
- HF slope very similar
  - Offset present
- Differences expected to be due to
  - Difference in operational condition
  - Water quality
  - Facility reverberation
  - …



Tani et al. (2020)

ToR#3: Validation studies

- Summary of comparison between model-scale URN predictions and sea trials for 9 vessels
- Report describes
  - Cavitation observations sea trials
  - Propagation loss for sea trials
  - Type of facility
  - Ship wake field
  - Propeller loading model test
  - Propagation loss for model test
  - Scaling
  - Comparison of levels

Ship type	Validation studies
Crude Oil Tanker	Lee *et al.* (2012)
Product Carrier	Seol *et al.* (2015)
Oil/Chemical Tanker	Tani *et al.* (2016b), Li *et al.* (2018)
LNG carrier	Park *et al.* (2020)
Container Ship (3,600 TEU)	Kleinsorge *et al.* (2017)
Container Ship (14,000 TEU)	Park *et al.* (2020)
Combi-Freighter	Lloyd *et al.* (2018)
Research vessel (Princess Royal)	Aktas *et al.* (2016a), Gaggero *et al.* (2016), Labefer & Bosschers (2016), Tani *et al.* (2019a)
Research vessel (Nawigator XXI)	Traverso *et al.* (2017)

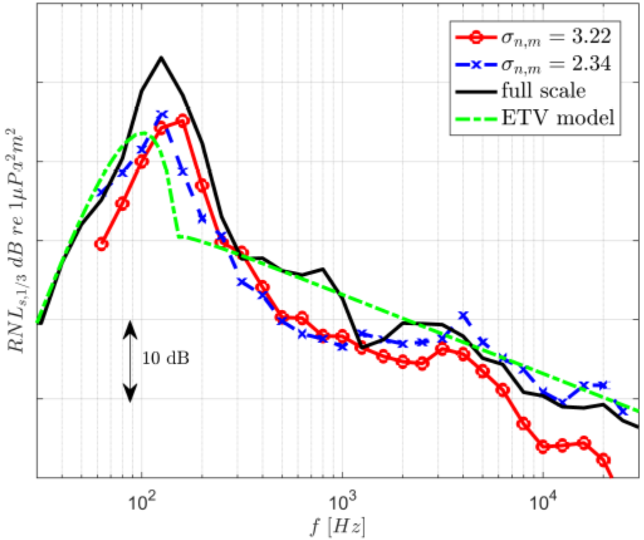
ToR#3: Validation studies

Propagation loss (full-scale)	Validation studies
Spherical spreading	Lee *et al*. (2012), Seol *et al*. (2015), Traverso *et al*. (2017), Park *et al*. (2020)
Spherical spreading & Lloyd mirror	Aktas *et al*. (2016b), Labefer & Bosschers (2016), Tani *et al*. (2019a)
Spherical spreading & bottom reflection	Lloyd *et al*. (2018)
Surface & bottom reflection	Kleinsorge *et al*. (2017)
Transmission loss (measured)	Tani *et al*. (2016b), Li *et al*. (2018)
Transmission loss (calculated)	Gaggero *et al*. (2016)

Propagation loss (model-scale)	Validation studies
Transfer function (measured)	Seol *et al*. (2015), Gaggero *et al*. (2016), Tani *et al*. (2016b), Tani *et al*. (2019a), Park *et al*. (2020)
Spherical spreading	Lee *et al*. (2012), Aktas *et al*. (2016b), Traverso *et al*. (2017), Li *et al*. (2018), Tani *et al*. (2016b),
Transfer function & Spreading	Kleinsorge *et al*. (2017)
Lloyd mirror & spherical spreading	Labefer & Bosschers (2016), Lloyd *et al*. (2018)

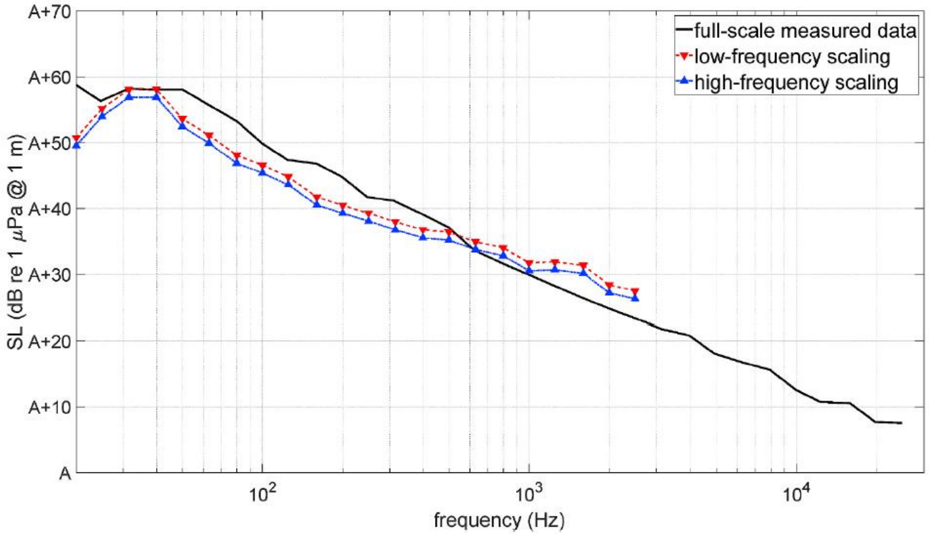
ToR#3: Validation studies

Model scale tests are, in general, able to predict full scale URN within 5 to 10 dB



(b) run F2 ($\sigma_{n,s} = 3.22$)

Lloyd et al. (2018)

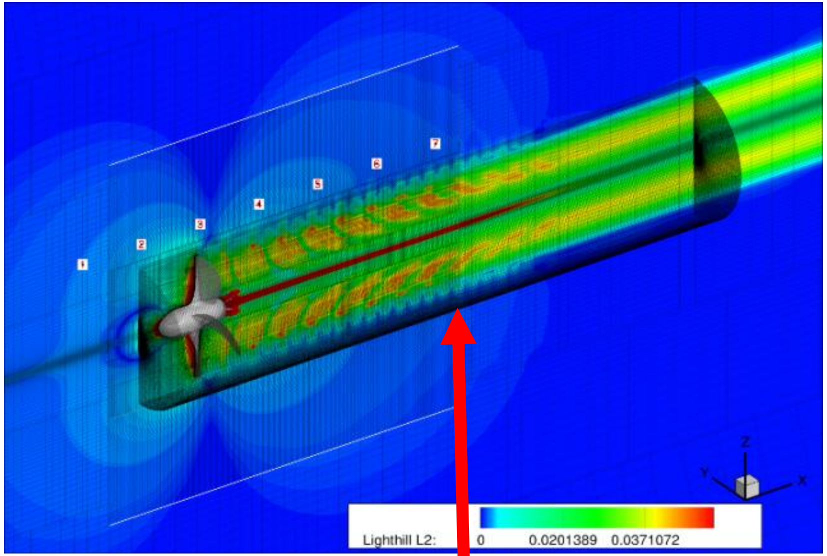


Park et al. (2020)

ToR#4 Computational prediction

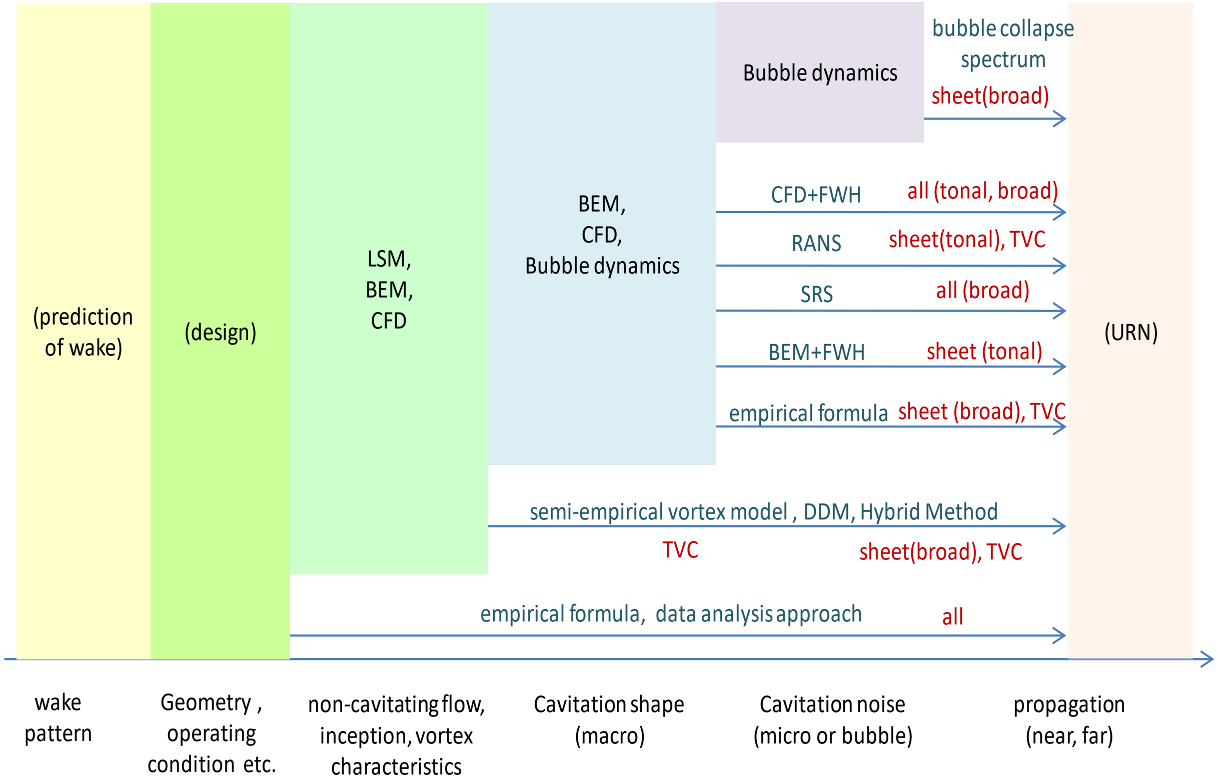
Monitor progress on computational prediction of propeller noise with emphasis on methods using the acoustic analogy such as coupling CFD with FWHE

- Various levels of modeling
  - Semi-empirical methods
  - Acoustic analogy:
    - Hydrodynamic source:
      BEM / CFD
    - Acoustic pressure:
      Ffowcs Williams & Hawkings



Surface for which hydrodynamic sources are integrated to compute far field acoustic pressure

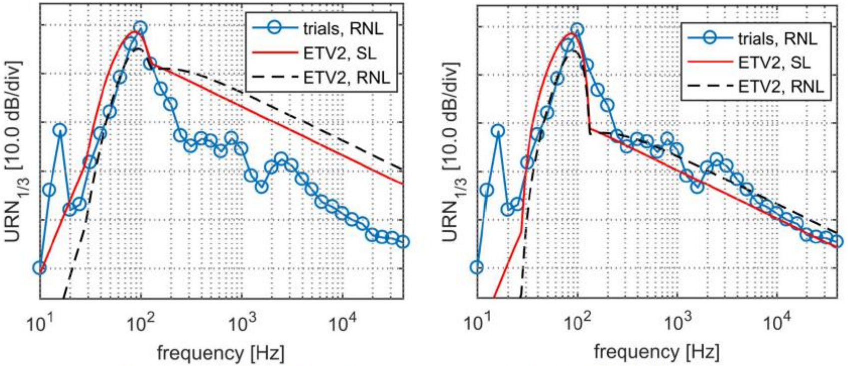
ToR#4 Computational prediction



ToR#4 Computational prediction

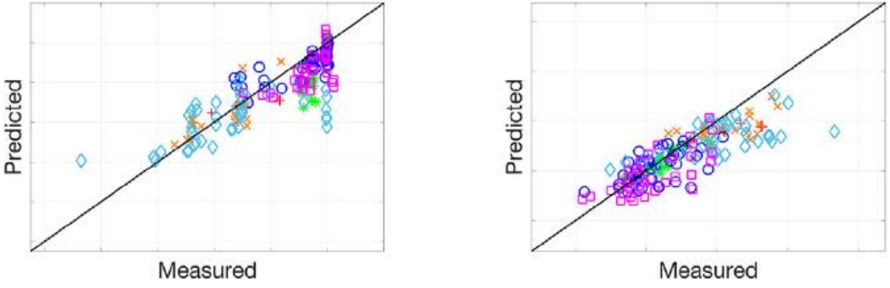
- BEM + Semi-empirical / data driven models

Test data-sets



(a) Default values for the ETV-method

(b) Adapted value for ΔL_{α}



(c) f_c $[0.2 \log_{10}(\mathrm{Hz})/\mathrm{div}]$

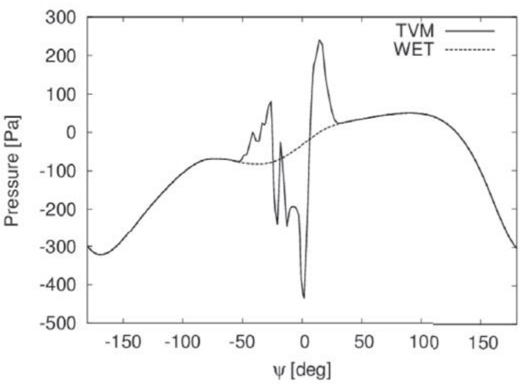
(d) RNL_c $[10\mathrm{dB}/\mathrm{div}]$

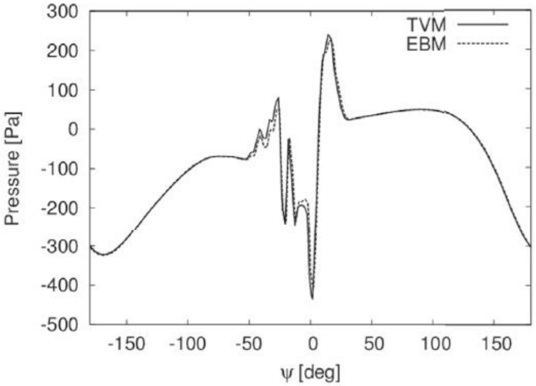
Bosschers (2018)

Hump centre prediction
Miglianti et al. (2019)

ToR#4 Computational prediction

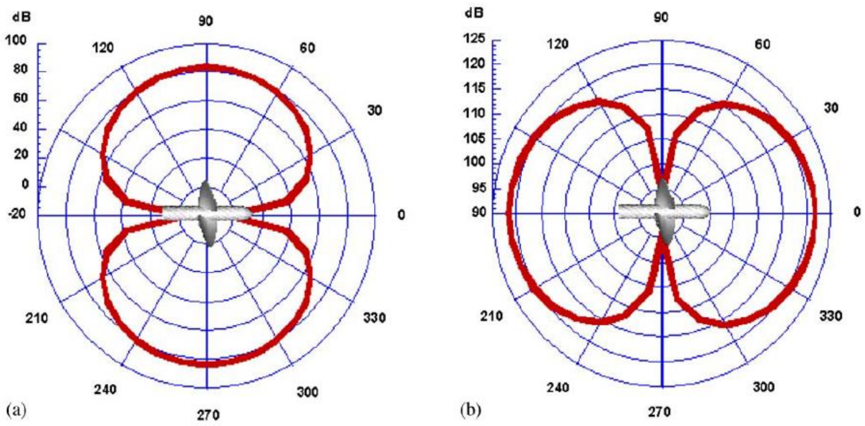
- BEM + FWH: mature from theoretical point of view
  - Tonals at blade passage frequency and harmonics
  - Non-cavitating flow: thickness and loading noise
  - Sheet cavitation: Transpiration Velocity Method / Equivalent Body Method





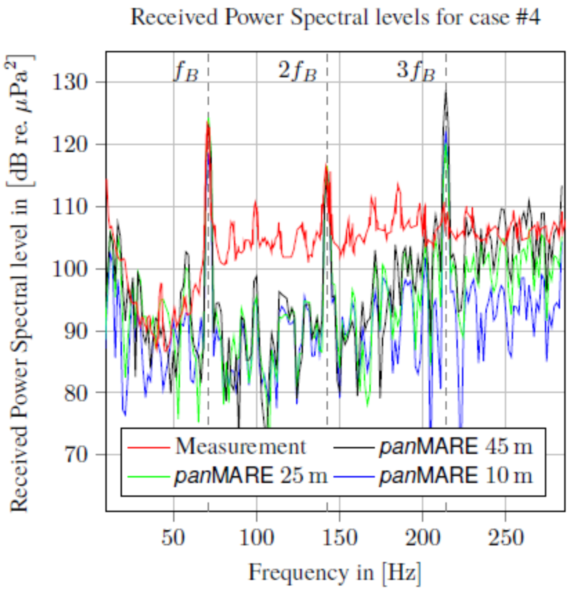
Testa et al. (2017)

ToR#4 Computational prediction: BEM + FWH



Thickness noise @10R   Loading noise @10R

Seol et al. (2005), propeller in three-cycle wake



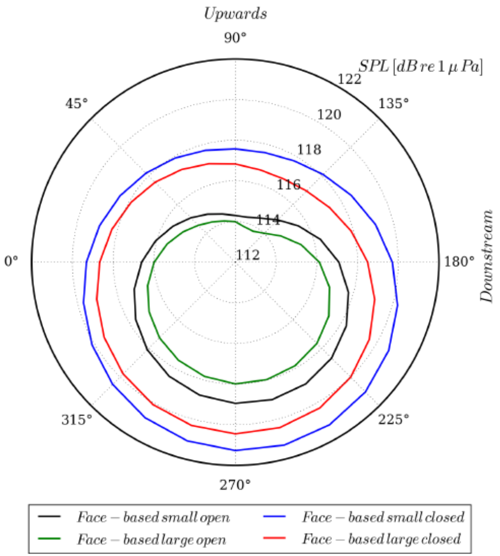
Gottsche et al. (2019),
Princess Royal test-case

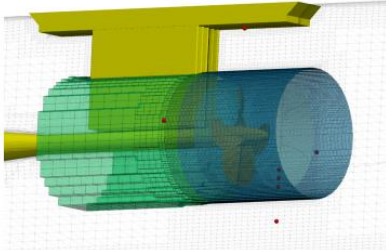
ToR#4 Computational prediction: CFD + FWH

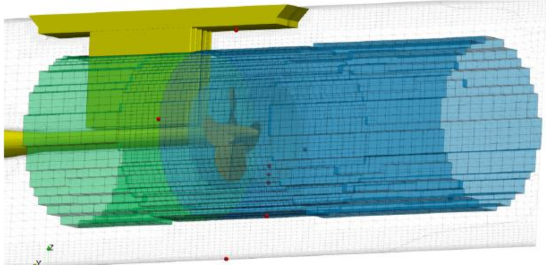
- CFD + FWH: requirements for accurate results being investigated
- Several studies for non-cavitating propellers

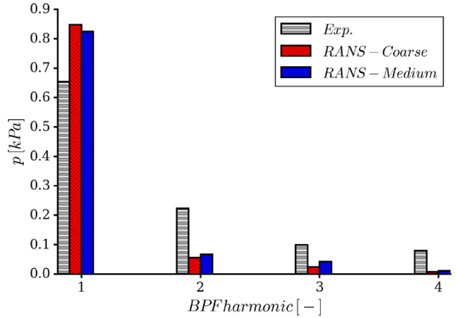
  e.g. Ianiello (2016), Testa et al. (2018), Cianferra et al (2019)
  - RANS and LES computations
    - RANS: tonals only, LES: tonals and broadband noise
  - Difference linear terms and non-linear terms using porous surface approach
    - Studies for open water conditions only
  - Effect of end cap on porous surface
    - Open versus closed
    - Proximity to propeller blade
- Results for cavitating propellers being published

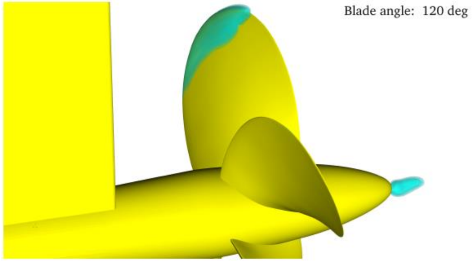
ToR#4 Computational prediction: CFD + FWH





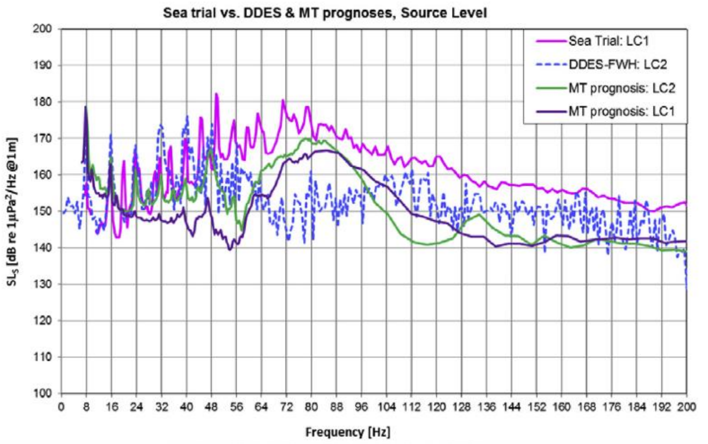


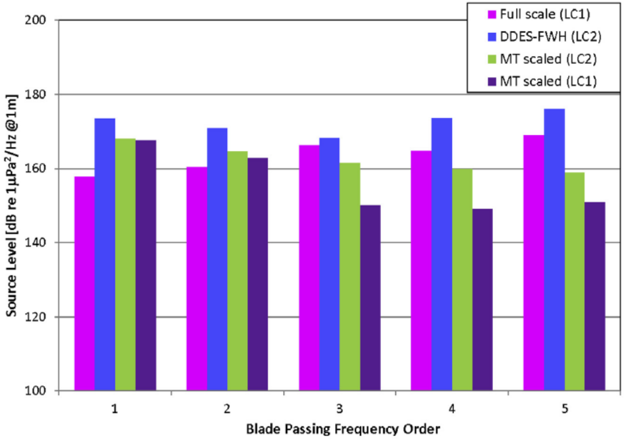


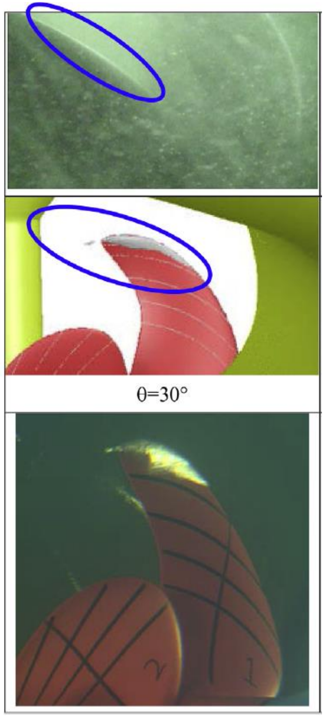


Lidtke et al. (2019), effect of porous surface, cavitating propeller, RANS

ToR#4 Computational prediction: CFD + FWH







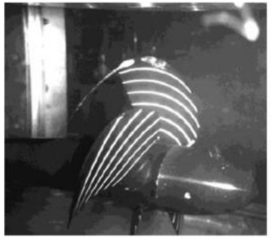
Li et al (2018), comparison between sea trials, CFD and model tests

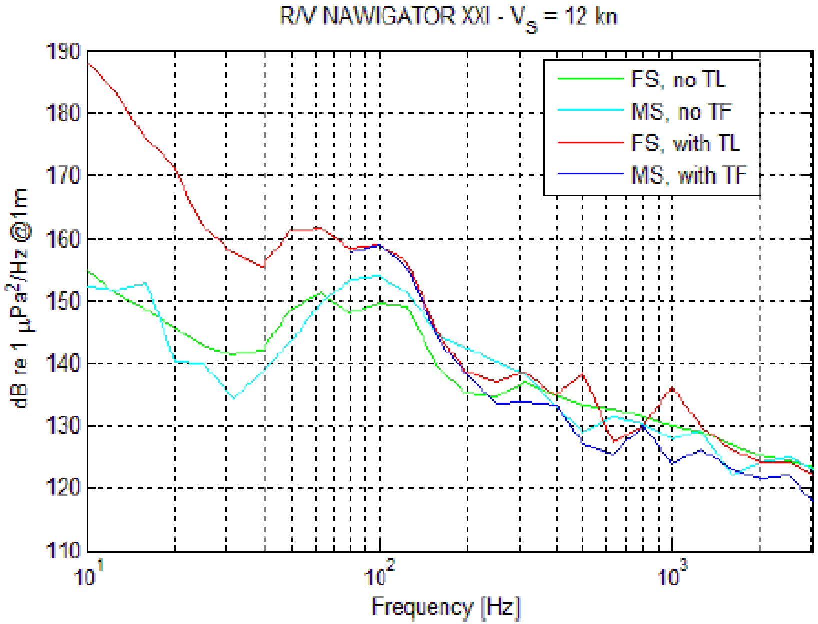
ToR #5: Benchmarking case

Identify a benchmarking case for model-scale noise measurements that has, full-scale underwater radiated noise measurements available, that is a representative merchant vessel, and of which geometry and measurement data can be shared with the ITTC community

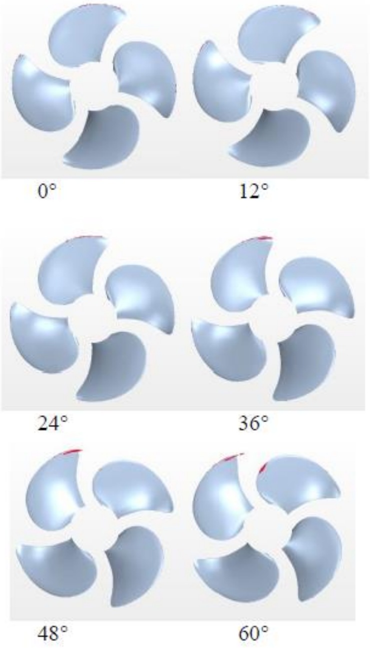
- Suitable candidate identified
  - Polish research vessel Nawigator XXI
  - Loa= 60.3 m
  - CPP, D= 2.26 m
  - Sea trials in EU Effort project (2005)
  - Noise trials in EU AQUO project (2014)
    - But in acoustic shallow water
    - Propeller pitch setting only from bridge
    - Poor cavity observations
    - Good signal to noise ratio for few conditions only
  - Model tests already performed by U. Genova

ToR #5: Benchmarking case

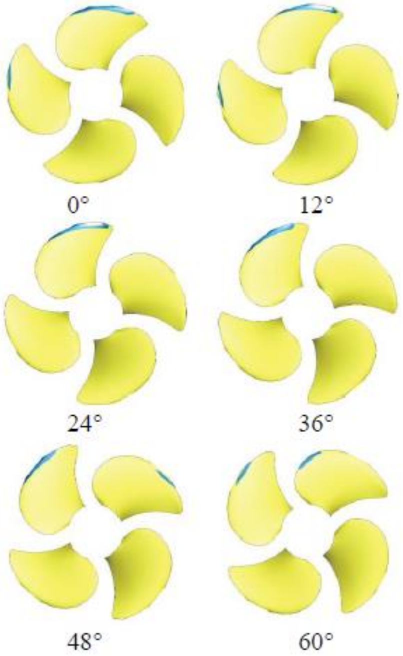




Model- and full-scale tests in AQUO project by UNIGE, Gaggero et al. (2016)



RANS, CSSRC



BEM, UNIGE

ToR #5: Benchmarking case

- Questionnaire
  - 19 organizations (potentially) interested for model tests
  - Also interest as benchmark for computational methods
- Test-conditions:
  - 'Mandatory':

Condition	P/D	K_T	σ_N (tip)	Type
A1[14]	0.91	0.22	2.79	Mandatory
A2	0.91	0.26	2.79	
A3	0.91	0.22	4.2	
A4	0.91	0.08	2.79	Suggested

A1: Full-scale URN available

  - Optional:
    - Tests at reduced pitch (12 - 63% interest)
    - Open water tests, incl. shaft inclination (12 - 63%)
    - For those using wake screens (14- 73%), test at model-scale wake (8 - 42%)

ToR #6: update guidelines

Maintain and update ITTC guideline 7.5-02- 01-05: Model-Scale Propeller Cavitation Noise Measurements and guideline 7.5-04-04-01: Underwater Noise from Ships, Full-Scale Measurements

- Guideline for model-scale noise measurements 7.5-02-01-05
  - Renumbered to guideline no 7.5-02-03-03.9 (chapter on cavitation tests)
  - Extended with descriptions of
    - Facility reverberation and transfer function
    - Reynolds number scaling of tip-vortex cavitation

- Guideline for full-scale noise measurements 7.5-04-04-01
  - Extended with description of new class rules
  - Extend with description of Lloyd-mirror effect

Conclusions (1/2)

- URN not yet on agenda of IMO, multiple noise monitoring programs ongoing
- URN measurement procedures for shallow water still in development
- Noise limits and measurements procedures of class societies differ
- Reduction of harbor fees by Port of Vancouver led to increase of ships with URN classes
- Progress made in model-scale URN measurements on facility transfer function, nuclei measurements, Reynolds scaling of TVC
- Open water benchmarking study on model-scale URN measurements shows significant differences between facilities
- Comparison model-scale URN predictions to sea trials gives better agreement than open water benchmarking study

Conclusions (2/2)

- Progress made in computational prediction of URN
  - Semi-empirical / data driven models
  - BEM + FWH
  - RANS/SRS + FWH
  - Propagation loss models applied to correct sea trial data
- Suitable benchmarking case identified, test-conditions proposed
  - 19 organizations (potentially) interested
- Guidelines for model-scale URN measurements and full-scale URN measurements updated

Recommendations

- Adopt guideline 7.5-02-01-05 and 7.5-04-04-01
- Organize round robin test
- Further monitor and investigate specific aspects of model-scale URN measurements including reverberation, tip-vortex scaling, water quality, and the effect on uncertainty
- Continue monitor progress on shipping noise measurements for shallow water and regulations as developed by ISO, class societies and regulatory agencies
- Continue monitor progress on ship noise prediction by computational methods for URN prediction and noise propagation modeling

Thank you for your attention