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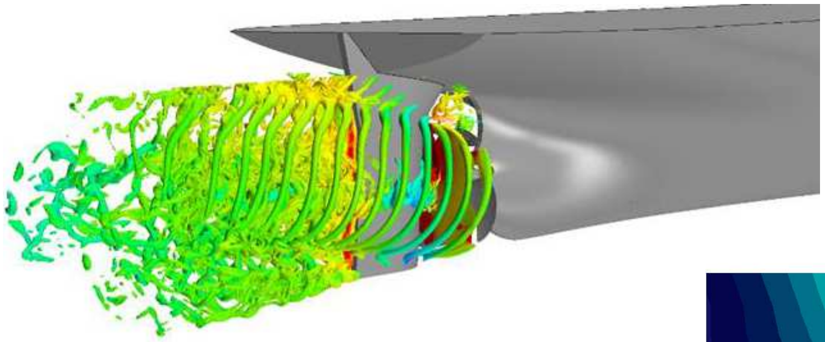
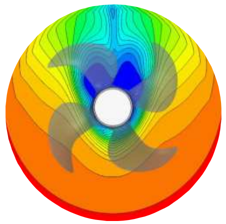
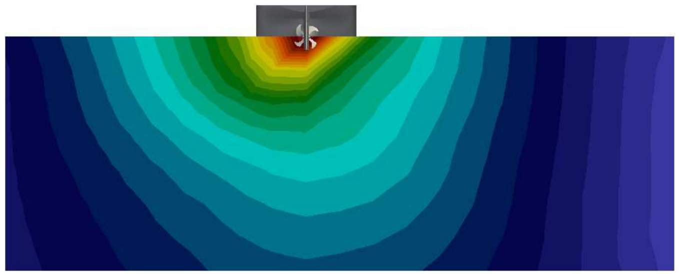
Numerical prediction of non-cavitation noise from marine propeller

Frédérique Chevalier, Hydro-acoustics Engineer, Naval Group







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1. Introduction

Context

- **It is always a necessity to assess and improve the radiated acoustic footprint of ships at the design stage**
- **At high speed, main noise contributions from hydrodynamic flow and propeller**
- **Evaluation and optimisation of the propeller radiated noise mainly achieved with high level propeller experiments in the Large Hydrodynamic Tunnel (GTH), a very specific facility of DGA Hydrodynamics**
- **Necessity to invest in numerical approaches to design ships with shorter delays**

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1. Introduction

Objectives:

- **Set up numerical approaches to estimate the propeller main contributions to noise and to reduce the number of model tests**
- **Develop and adapt aeronautical models for marine applications**
- **Get numerical approaches complementary to model test in their capability to provide additional information not available in the tunnel experiments (seabed effect, etc.)**

⇒ **To design quieter propellers**

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2. Non-cavitation noise from marine propeller

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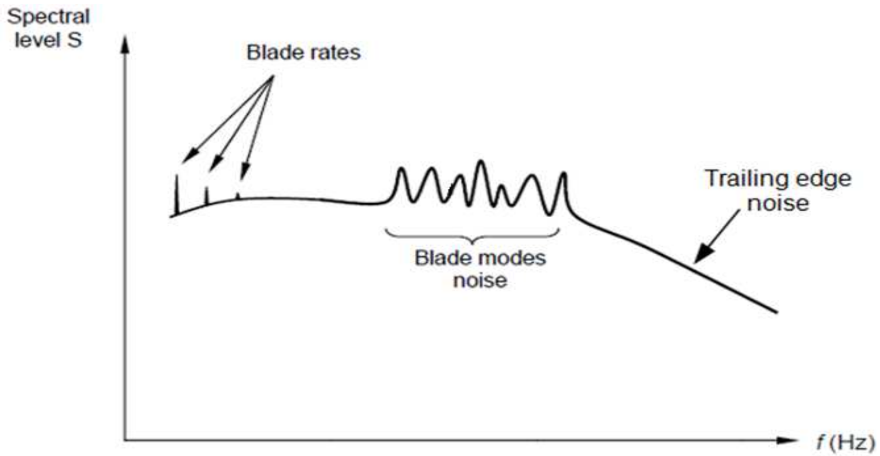
Propellers are designed in order to:

- **Push away far enough cavitation inception**
- **Reduce noise contribution without cavitation**

Main propeller direct noise contributions without cavitation:



⇒ **Each of these contributions requires specific modelling approaches**

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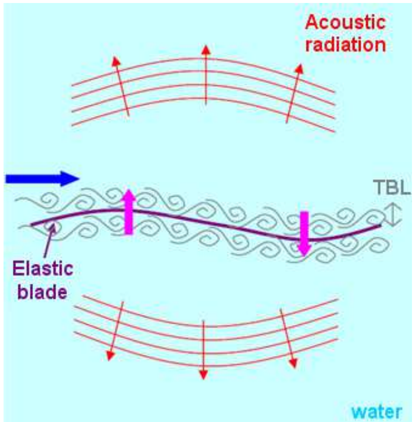
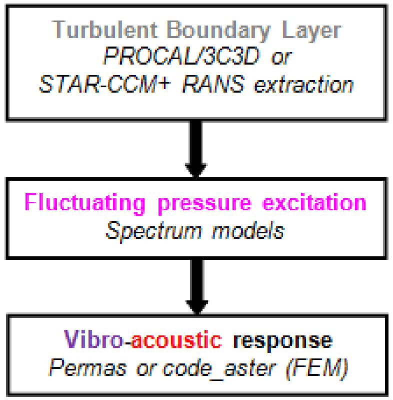
3. Numerical approaches and results

Blade modes noise prediction:

- **Improvement of a previous numerical approach [1]:**





- Turbulent boundary layer parameters directly extracted from RANS simulations
- Several pressure spectrum models available (Chase [2], Rozenberg [3]…)
- Spatial evolution of the turbulent boundary layer parameters taken into account in the fluctuating pressure excitation [4]

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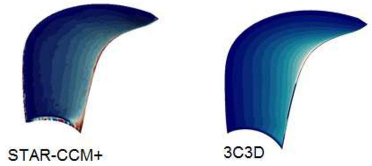
3. Numerical approaches and results

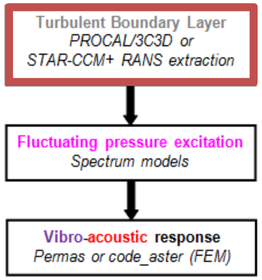
Blade modes noise prediction:

- **Validation of numerical results:**
  - Specific test case considered: two projects of propeller with a close structural behavior generate a very different blade modes noise level measured at model scale

  - Turbulent boundary layer parameters calculations:

⇒ STAR-CCM+ & 3C3D results in good agreement





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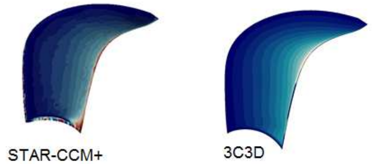
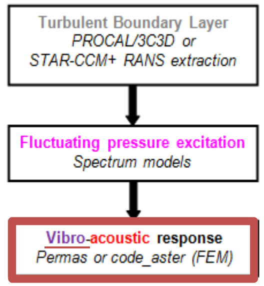
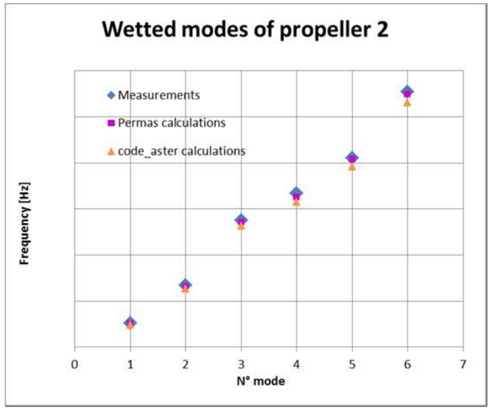
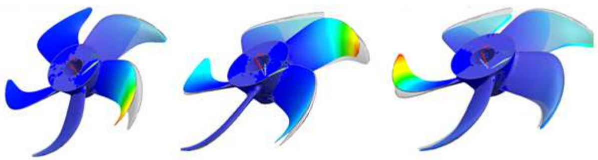




  - Vibration behavior calculations:

  ⇒ Blade wetted modes calculated by code_aster & PERMAS in good agreement with measurements





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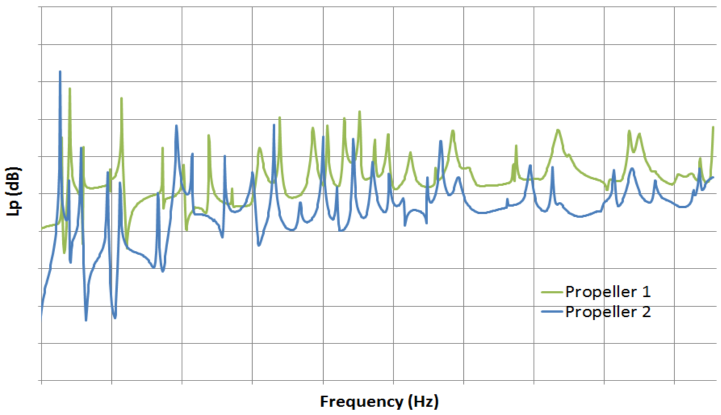
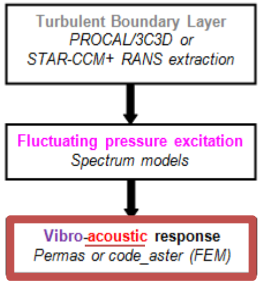
3. Numerical approaches and results

Blade modes noise prediction:

- **Validation of numerical results:**
  - Blade modes noise calculations:

  ⇒ Numerical approach enables to well reproduce the vibro-acoustic phenomenon





- **Approach improvements:**
  - Turbulent boundary layer excitation: test other models like Slama [5]
  - Excitation implementation in the vibro-acoustic response

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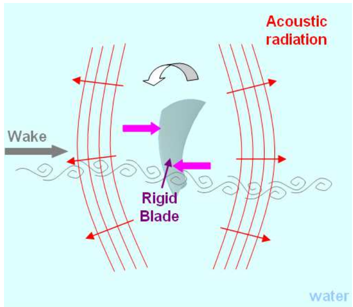
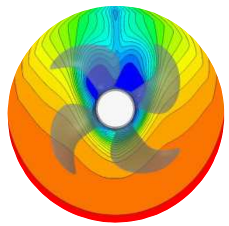
3. Numerical approaches and results

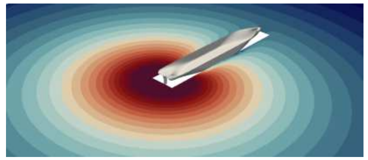
Blade rates noise prediction:

- **Improvement of an already available numerical approach [6]:**



Incoming flow
STAR-CCM+ (URANS)
↓
Surface fluctuating pressure
STAR-CCM+ extraction
↓
Hydro-acoustic response
Virtual.Lab Acoustics [7]





⇒ **Enable to take into account free surface and installation effects**

- **Validation of numerical results on model measurements:**
  - Noise level prediction for the first BR frequency close to the model measurements
  - Noise level underestimated for the other BR frequencies

⇒ **Benchmark with other commercial software in process to keep improving predictions**

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3. Numerical approaches and results

Trailing edge noise prediction:

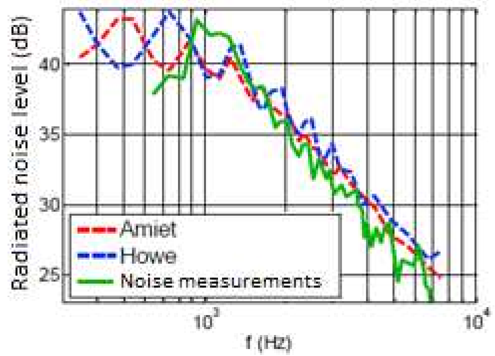
- **Implemented models** :
  - Far field radiated noise model: Howe [8], Amiet [9]
  - Parietal pressure spectrum model: TNO Blake [10], « Scaling law » [11]

- **Validation of numerical results:**
  - On NACA0012 into the air [12]:

  ⇒ Results in good agreement with measurements
  - On blade into the water:

  ⇒ Experimental noise slope well predicted

  ⇒ Main noise contribution associated to the blade tip one



- **Approach improvements:**
  - Use parietal pressure excitation extracted from CFD calculations
  - Take trailing edge vibration into account
  - Predict tip vortex noise

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4. Conclusions and perspectives

The developed numerical approaches give valuable results for the propeller design process

Some improvements remain to be included to get a more accurate noise prediction

Moreover, ongoing validation tests will bring useful data to refine these approaches

Implementation of these numerical approaches will enable:

- **To predict the radiated noise from marine propellers before model tests**
- **To accelerate the design process of silent propellers within a numerical optimisation loop**
- **To design quieter propellers**

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