The Specialist Committee on Cavitation and Noise

Presentation of the proposed Round Robin Test

The test proposed to the community is to perform cavitation tests with URN (Underwater Radiated Noise) measurements on an existing propeller. Institutes all around the world are encouraged to participate to this Round Robin Test. Results will be gathered by ITTC Specialist Committee on Cavitation and Noise and will be shared with all the participants. Institutes can be member of ITTC or not.

All the different details are given in this document. Additionally, to this document, one can download these files from the ITTC website (https://www.ittc.info/)

- the geometry files of the propeller
- a template file for the results

Others information about benchmark activities of ITTC can be found in the document Guidelines for Benchmarking v4.0-01 available on the ITTC website.

Proposed candidate ship

The ship chosen for the benchmarking activity is the Nawigator XXI, already considered in the European Projects EFFORT and AQUO (Ref.: Gaggero *et al*, 2016).

In the following, a brief outline of the ship characteristics and the measurements available in full scale is reported.

Ship characteristics

In Figure 1 a photograph of the ship is reported, while main ship characteristics are listed below.

Figure 1: Nawigator XXI Research Vessel

- Ship name: Nawigator XXI
- Type / Year of building: Research Vessel built in 1998
- Owner: Maritime University of Szczecin
- Length overall: 60.3 m (LOS)
- Beam: 10.5 m
- Draft: 3.15 m
- Displacement: about 1150 t
- Speed: 13 kn (max)

Propulsion plant and other machineries characteristics are listed below:

- 1 Controllable Pitch Propeller (CPP), D = 2.26 m, P/D (design) = 0.942, 4 blades
- Main Engine: SULZER Cegielski 8S20D (4 stroke, 8 cyl L) resilient mounted, 1120 kW, 900 RPM, reduction rate: 3.75
- Auxiliary Engines: Caterpillar SR4: (4 stroke, 8 cyl L) resilient mounted, 2 x 240 kW + 1 x 85 kW, 1500 RPM
- Bow thruster: 110 kW, abt. 500 RPM (propeller)

Full scale measurement campaign

URN measurements at sea have been carried out during the EU-FP7 AQUO project; the campaign took place in the Baltic Sea and the following data were recorded:

- Power, rpm, pitch, speed over ground

- Cavitation observations
- Vibrations
- URN
- Pressure pulses

Measurements have been performed at one ship draught (namely, 3.2 m at stern, 3.15 m at bow), mainly varying pitch at constant RPM (8 different pitch settings); in addition to this, two different propeller RPM have been considered at one pitch setting (navigation and maximum)

It has to be kept in mind that the measurement campaign presents some shortcomings. In particular, information on blade pitch angle is only obtained from the bridge, thus there is some uncertainty on the exact value. Moreover, cavitation photographs using hull windows are available but quality is not enough to capture correctly cavity extents. Finally, the URN measurements have been performed in shallow (24 m) water, requiring the use of a computational method to convert the radiated noise levels to source levels.

Proposed conditions for the benchmark activity

During the activity of the Committee, possible facilities interested in the benchmarking activities were asked to answer a questionnaire in order to define the propeller functioning conditions to be considered. Moreover, some numerical calculations were also carried out (see Final Report from the Noise Committee of the 29th ITTC). On the basis of these two activities, the Committee decided to propose the following conditions for the benchmark activity:

- Three “mandatory” conditions (condition A1 as indicated above, condition A2 obtained with higher loading at constant cavitation number, condition A3 with reduced cavitation, near inception)
- One “suggested” condition (condition A4 with reduced loading at fixed pitch)
- Possible “additional conditions”, such as:
  - tests at reduced pitch (31% in order to have reference full scale tests), with a dedicated FPP model (condition B1)
  - tests in open water: basic test with no shaft inclination (conditions C1-C4) plus additional test at large shaft inclination, suggested value 8° (conditions D1-D4)
  - for smaller facilities using wake screens, additional tests with model scale wake (conditions E1-E4)

The conditions are summarised in the following table

Condition	P/D	K_T	$\sigma_{N\,(tip)}$	Type
A1[1]	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
B1[2]	0.464	0.08	3.58	Additional (lower pitch)
C1	0.91	0.22	2.79	Additional (uniform flow, no shaft inclination)
C2	0.91	0.26	2.79	
C3	0.91	0.22	4.07	
C4	0.91	0.08	2.79	
D1	0.91	0.22	2.79	Additional (uniform flow, 8° shaft inclination)
D2	0.91	0.26	2.79	
D3	0.91	0.22	4.07	
D4	0.91	0.08	2.79	
E1	0.91	0.22	2.79	Additional (wake sensitivity study)
E2	0.91	0.26	2.79	
E3	0.91	0.22	4.07	
E4	0.91	0.08	2.79	

[1] For this condition full scale measurements are available; propeller revolution rate at full scale was 230 RPM, with a corresponding $\sigma_{N\,(shaft)} = 3.09$

[2] For this condition full scale measurements are available; propeller revolution rate at full scale was 203 RPM, with a corresponding $\sigma_{N\,(shaft)} = 3.96$

The tests have to be performed according to normal procedures by all participants. For conditions A1-A4 and B1 the complete hull model or smart dummy will be used for larger facilities, dummy models or wake screens for smaller facilities. In the case of wake screens, the full scale wake will be reproduced. For conditions E1-E4 (smaller facilities only), the model scale wake will be reproduced.

Some further remarks have to be considered when the benchmarking activity will be started:

- for the lower pitch condition B1, possible additional conditions might be tested;
- for cases “C”, “D”, “E”, all conditions proposed for case “A” are currently reproduced in the table, however the number of tests could be reduced.

Numerical calculations

As mentioned above, a series of numerical calculations have been carried out in order to propose the functioning conditions. In particular, Marin and UNIGE used BEM potential codes and CSSRC used a RANS code. In the following, some of the results obtained are reported with the aim of providing an idea of cavitation extent before testing the propellers.

CSSRC calculations:

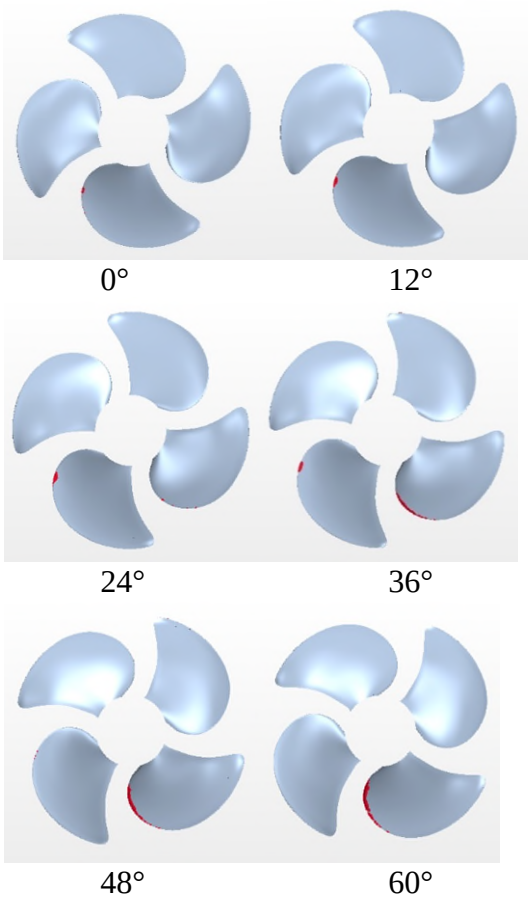
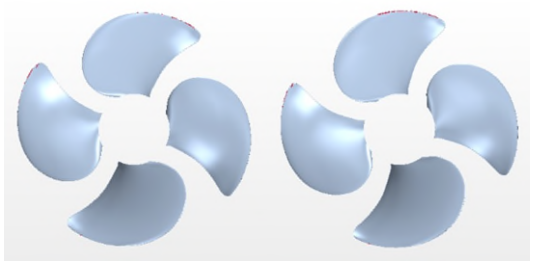
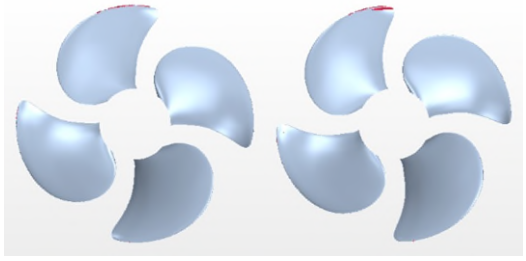


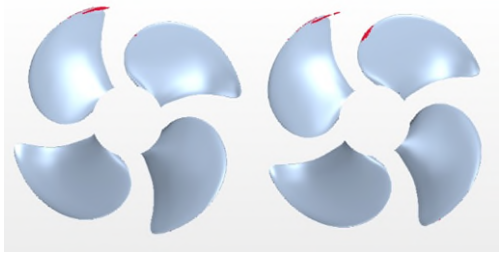
Figure 2: σ_{Nshaft} = 3.09, K_T = 0.08 (pressure side) Condition A4



0° 12°

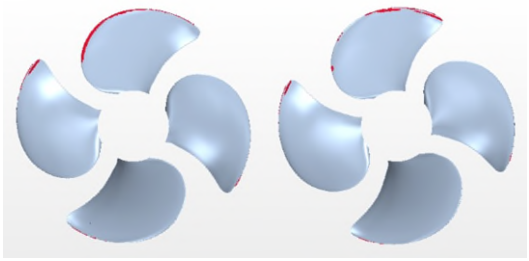


24° 36°

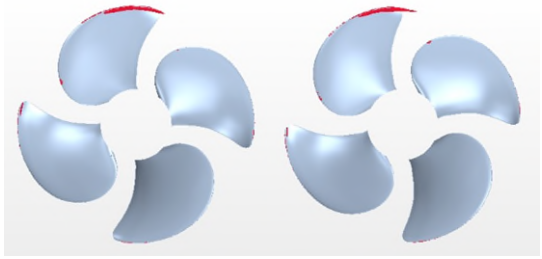


48° 60°

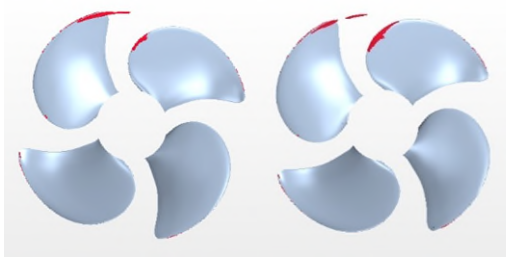
Figure 3: σ_{Nshaft} = 3.09, K_T = 0.22 (suction side)
Condition A1



0° 12°



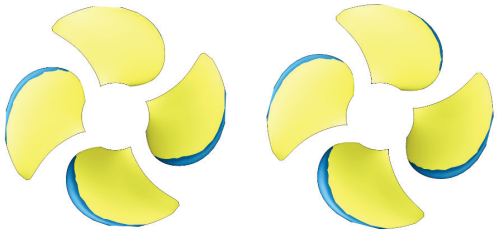
24° 36°



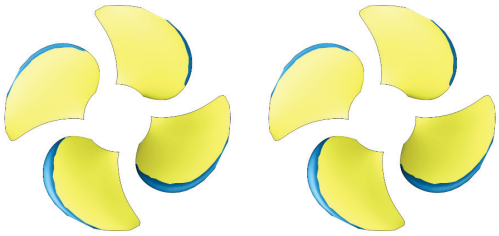
48° 60°

Figure 4: σ_{Nshaft} = 3.09, K_T = 0.26 (suction side)
Condition A2

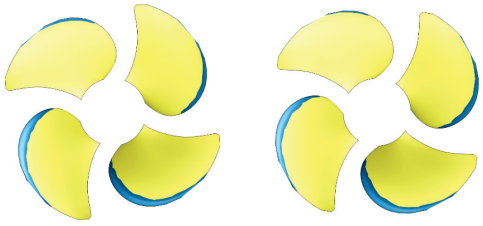
UNIGE calculations:



0° 12°

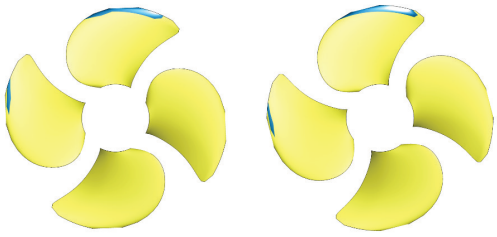


24° 36°



48° 60°

Figure 5: σ_{Nshaft} = 3.09, K_T = 0.08 (pressure side)
Condition A4



0° 12°

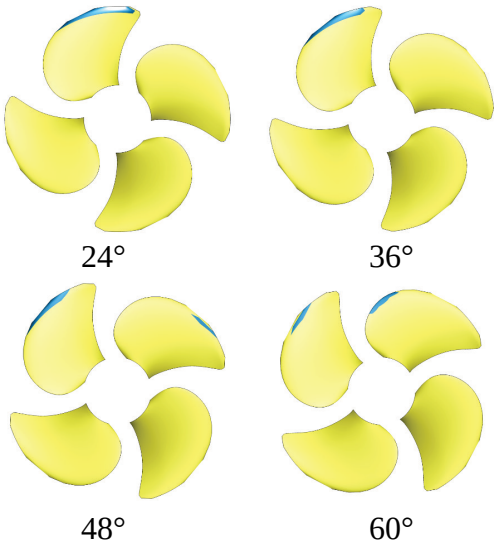


Figure 6: σ_{Nshaft} = 3.09, K_T = 0.22 (suction side)
Condition A1

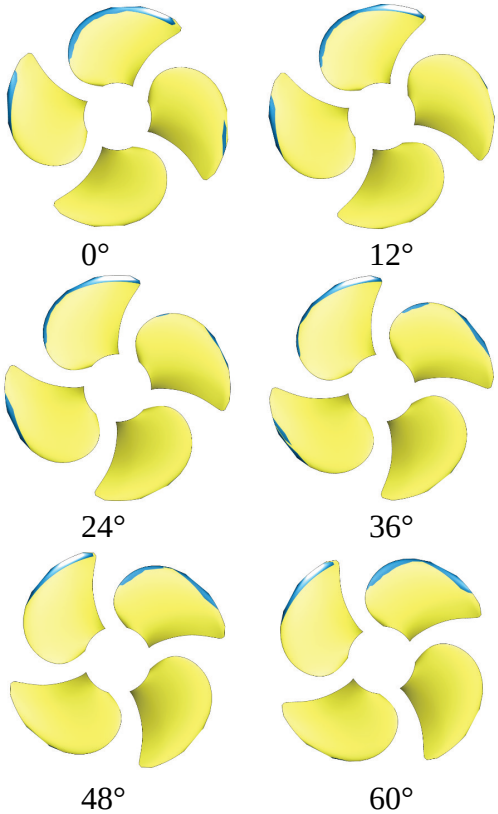


Figure 7: σ_{Nshaft} = 3.09, K_T = 0.26 (suction side)
Condition A2

Required measurements

For every condition selected for the benchmark activity, it will be required to perform the following measurements:

- Propeller geometry check, in order to allow for comparison of different models
- Propeller functioning conditions (V, N, p, K_T, σ_N) [3] and definition of parameters adopted
- Nominal wake at propeller disc (with indication of turbulence intensity level, if possible)
- Cavitation observations (sketches / photographs / videos) at different blade angular positions; these should to allow a good assessment of the extent of cavitation.
- URN measurements (it is strongly recommended to perform tests not only at the prescribed condition, but also at any complementary condition, with ±5% K_T and ±10% σ_N, at least for the mandatory conditions). Frequency band resolution is to be preferably adjusted to 1 Hz or better.
- Water quality (at least dissolved O2 content or air content, further measurements according to facility experience)
- Facility transfer function
- Background noise measurements[4]

Additional measurements could include pressure pulses; in this case, the typical "cross configuration with one probe above propeller tip plus 4 additional probes (2 shifted longitudinally by one propeller radius upstream and downstream, 2 shifted sidewards by one propeller radius port and starboard).

All URN results need to be converted to source levels by correcting for background noise and facility reverberation and need to be scaled to two specified reference conditions (propeller diameter and shaft RPM will be proposed by the organizers):

[3] These quantities should be measured during the actual noise tests in order to avoid uncertainties. For instance, if the load cell used during noise measurements is disconnected, this should be specified and other quantities should be provided to allow verifying the consistency of the measuring points (e.g. checking the advance ratio).

[4] Preferably background noise measurements should be carried out both by replacing the propeller with a dummy hub and with the propeller in cavitation suppression, in order to measure the shaft line noise with actual propeller loading.

- One model-scale condition (useful for CFD comparisons which will be carried out in model scale) for λ=1/10.
- One full-scale condition

The method to scale cavitation noise is the 'low-frequency' noise scaling method as given in the ITTC guidelines for model-scale noise measurements. If other scaling methods are preferred by the test facility, the method must be described and the results using this method have to be supplied as well.

Document to be uploaded

To facilitate the data processing by the Committee, a template in xls format is proposed. Each facility is asked to use as far as possible the template to present the results for the benchmark activity. A complete submission of this benchmark will comprise:

- The template file gathering all URN measurements (at least the mandatory conditions A1, A2, A3)
- A document with cavitation visualisation (images or videos) for the different conditions
- The document "Data Agreement" signed
- Any other document containing important features or results.

Please tag all documents with the name of your institute/facility as for example "INSTITUTE_Results.xls".

All the documents have to be sent to the ITTC Secretary.

REFERENCES

Gaggero S., Gaggero T., Rizzuto E., Tani G., Villa D., Viviani M., (2016), "Ship propeller side effects: pressure pulses and radiated noise", Noise Mapping Vol.3, pp.295-315