27th ITTC Propulsion Committee Report Presentation (2011 – 2014)

Frechou D., Borusevich V. , Ceccio S., Dinham-Peren T., Grabert R., Kim M.C., Korkut E., Ohmori T., Yang C.J.

27TH ITTC • COPENHAGEN

Outline of the presentation

- Members – Meetings – Main objectives
- Report on Task 1 : State of art update review
- Report on Task 2 : Review of ITTC recommended procedure
- Report on Task 3 up Task 10 : Specific tasks for the present comittee
- Recommendations to the 28th ITTC & Conclusions

Committee Members

Meeting at Michigan University

Chen-Jun YANG (Shanghai Jiao Tong University)

Valery BORUSEVICH (Krylov State Research Center)

Takuya OHMORI (Japan Marine United Corporation)

Emin KORKUT, (Istanbul Technical University)

Rainer GRABERT (Schiffbau-Versuchsanstalt Potsdam)

Steven CECCIO (University of Michigan)

Didier FRECHOU (DGA Hydrodynamics)

Moon Chan KIM (Pusan University)

Thomas DINHAM-PEREN (BMT Defence Services Ltd)

Propulsion Committee working organisation

5 Meetings organized :

- DGA Hydrodynamics, France, 30-31 January 2012
- Krylov Institute, Russia, 8-9-10 October 2012
- Pusan University, Korea, 22nd and 23rd January 2013
- University of Michigan, USA, 23-25 October, 2013.
- BMT Defence Services Ltd, UK, 13-14 March 2014.

Storage platform to share information between members

Review of the major International Journals and Conferences (1/2)

- Journal of Ship research
- Journal of marine science and technology
- The Naval Architect, Royal Institution of Naval Architects
- RINA Conference Proceedings
- Journal of Fluid mechanics
- International shipbuilding progress
- Journal of Naval Architect and ocean engineering
- Journal of Ocean engineering
- Journal of Ship research
- International shipbuilding progress
- Computers & Fluids

Propulsion Committee working organisation

Review of the major International Journals and Conferences (2/2)

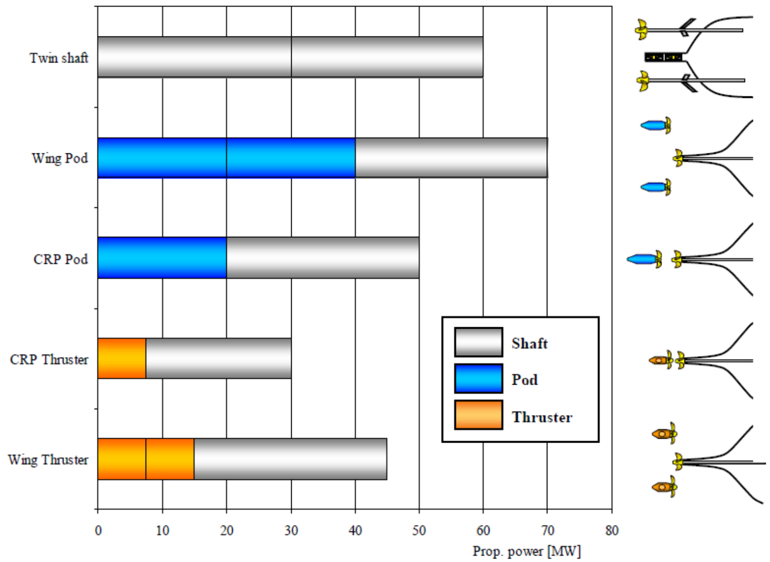
- 9th Symposium on Particle Image Velocimetry, 21-23 July 2011, Kobe.
- ICOMIA's 1st International Hybrid Marine Propulsion Conference, November 2011, The RAI, Amsterdam.
- SMP11 International Symposium on Marine Propulsors and Workshop, June 2011, Hamburg.
- IWSH 2011: 7th International Workshop on Ship Hydrodynamics 16-19 September 2011, Shanghai.
- MARINE 2011- IV International Conference on computational methods in marine Engineering, 28-30 September, Lisbon.
- IMDC 2012-11th International Marine Design Conference, June 2012, Glasgow.
- ICHD 2012- The 10th International Conference on Hydrodynamics, 1 - 4 October, 2012, St Petersburg.
- Voith Hydrodynamic conference, June 2012.
- CAV2012- 8th Symposium on Cavitation, 14-16 August, 2012, Singapore.
- ICMT 2012- International Conference on Maritime Technology, 25-28 June 2012, Harbin.
- ONR 29th symposium on Naval Hydrodynamics, 24 August 2012, Goteborg.
- Journées de l'Hydrodynamique 2012, 21-22-23 Nov 2012, Paris.
- NAV'2012 - 17th International conference on Ships and Shipping Research 17- 19 October 2012, Naples.
- ICETECH 2012, International Conference and Exhibition on Performance of Ships and Structures in Ice, September 17-20, 2012, Banff,
- 13th Propeller/Shafting Symposium September 11 – 12, 2012, Norfolk.
- ONR Naval S&T Partnership Conference event, October 22-24, 2012, Washington D. C.
- IWSH'2011, The 7th International Workshop on Ship Hydrodynamics, 16-19 September, 2011, Shanghai.
- ISOPE 2012 Conference: 22nd international Ocean and Polar Eng, 17-23 June, Rhodes.
- HIPER, 28-29 Sept 2012, Duisburg.
- ISOPE 2013 Anchorage Conference: 22nd international Ocean and Polar Eng, 30 June – 4 July, Anchorage.
- PRADS 2013: The 12th International Symposium on Practical Design of Ships and Other Floating Structures, 20-25 October 2013, Changwon.
- FAST 2013, 12th International Conference on Fast Sea Transportation, 2-5 Dec 2013, Amsterdam.
- AMT 2013, The 3rd International Conference on Advanced Model Measurement Technology for the EU Maritime Industry, 17-19 September 2013, Gdansk.
- OMAE 2013, The 32nd International Conference on Ocean, Offshore and Arctic Engineering, June 9 to 14, 2013, Nantes.
- IWSH 2013: The 8th International Workshop on Ship Hydrodynamics, 23- 25 September, 2013, Seoul.
- SMP'13, The Third International Symposium on Marine Propulsors, 5 – 8 May, 2013, Launceston.

Task 1a : State of the art Update on new technological developments

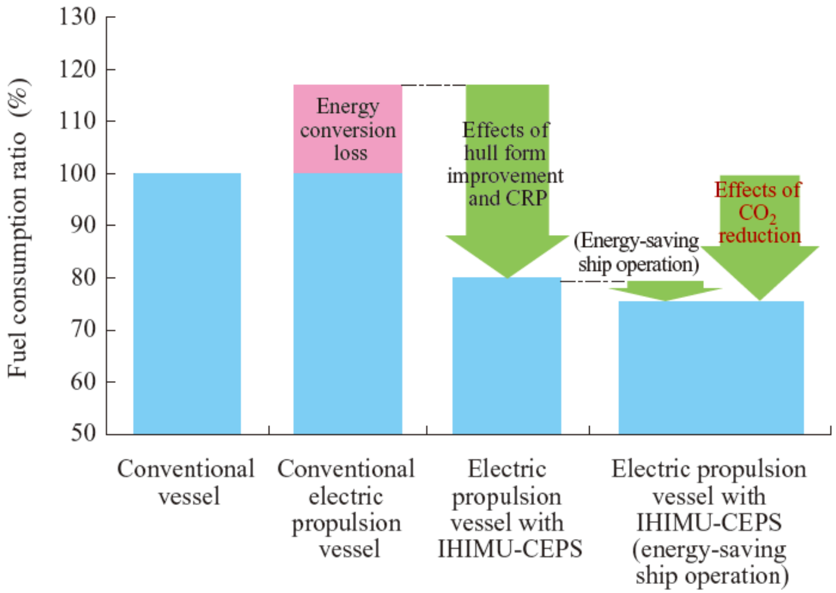
Still a tremendous interest in **Contra-Rotating Propeller concepts** because of :

- more electric propulsion vessels
- flexibility in engine room arrangement and possible optimisation of the hull form

and a substantial gain in energy consumption can be achieved.



Recommended power range for different propulsion concepts applied to a large displacement ferry (Levander, 2008)

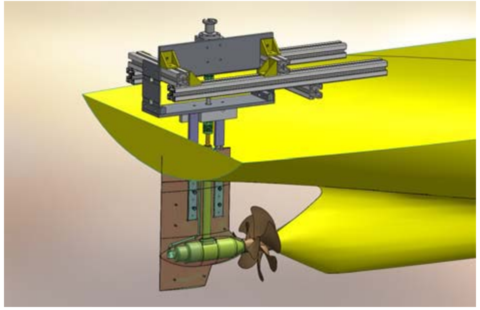


Comparison of fuel consumption between conventional (diesel) vessel and electric propulsion vessel with IHIMU-CEPS (Contra-rotating propeller Electric Propulsion System) for a 1,230 m3 type chemical tanker used as an example (Hideki et al., 2011)

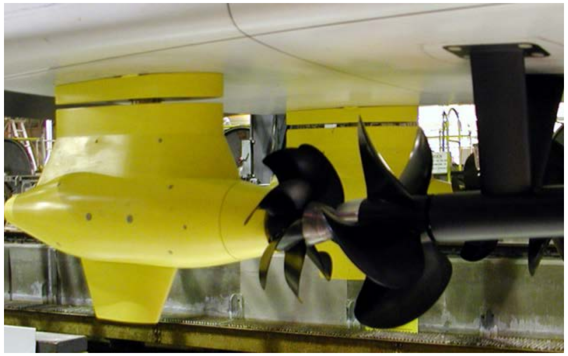
Task 1a : State of the art Update on new technological developments

The **Contra-Rotating Propeller** concept based on combination of POD unit and Single propeller appears to be one of the most investigated among the new propulsions systems.

The main propeller (right) with counter rotating, 360 degree azimuthing, ABB Azipod thruster on 200 TEU Container Feeder vessel (Henderson, 2013)



CRP Combination of a Rudder Pod unit and a single propeller (Sánchez-Caja, *et al.*, 2013)



Hybrid Shaft-Pod propulsor for a High Speed Sealift Ship (Black & Cusanelli, 2009)

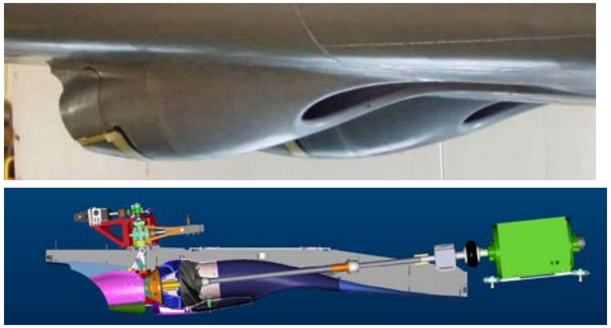
There is a need for a guideline / procedure for self-propulsion test for this concept.

See after Task 9 report

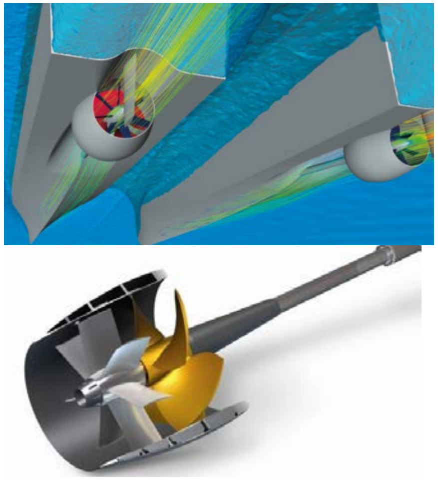
Task 1a : State of the art Update on new technological developments

Few projects on immersed pump-jet

- For reduced vessel draft
- Higher efficiency at high speed (>24 -26 Kts)



WaterJet Propulsor (Giles, et al. 2011)



VOITH's New Propulsion System: The Voith Linear Jet (Pospiech, 2012)

- Special procedure is required for Self-propulsion performance test

Increasing interest in energy saving devices

- This is reported further in Task 5

Task 1a : State of the art Update on new technological developments

Research studies on composite blade propellers are still going on because of their interest s for:

- Light weight and cost
- Maintenance cost reduction
- Potential improvement of performances via 3-D passive control of the blade deformation (pitch adaptating)

Rim-Driven Hubless Composite Props (Büchler and Erdman, 2006)

Elastic blade deformation on a composite propeller (Young, 2012)

Composite propeller to the RNLN minehunter. (Black, 2011)

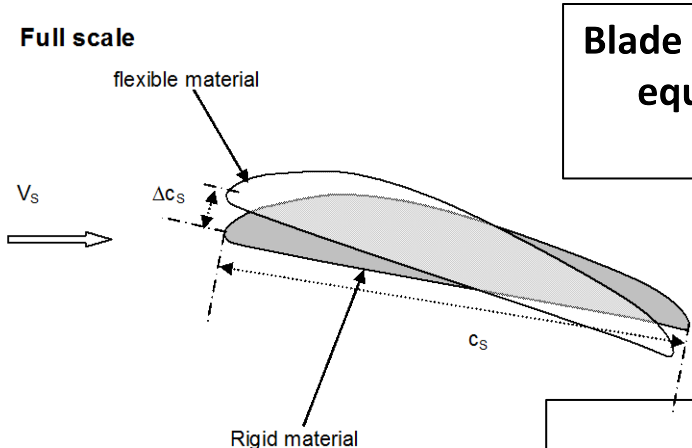
German Submarine Props (Stauble, 2007)

The design of a composite blade propellers compel to use **Fluid-Structure Interaction Computation** to take care of the blade deformation

(**see Young, 2007; Young, 2010; Young, 2012; Motley & Young 2012**)

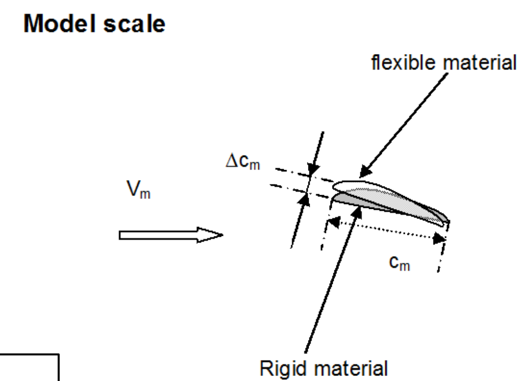
Task 1a : State of the art Update on new technological developments

Beside the interests, the main question that remains is : **what kind of similarity rules are required to perform model scale propulsion test for composite propeller ?**



Blade section strain at model scale equal Blade section strain to model scale

Same blade material
+ same full scale speed (flow, ship)



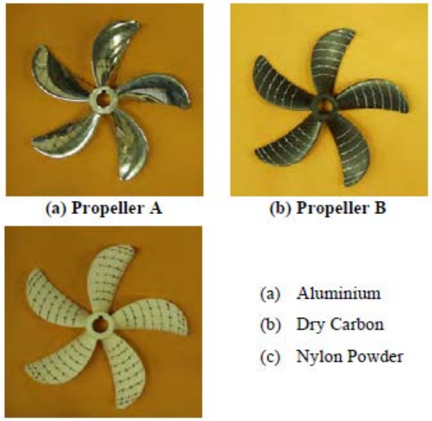
These requirements are difficult to achieve at standard model scale propellers (Ø≈250mm)

more reasonable to use CFD but with EFD validation
on specific model test (large scale model propeller with blade deformation meast.)

Task 1b : State of the art Update on new experimental techniques and extrapolations methods

- Propeller manufacturing using sintering nylon powders
  - The Nylon powder is too flexible to be representative of a NAB or SS propeller.
  - Geometry accuracy is still an issue.

Model composite propeller (Taketani et al., 2013)



(a) Propeller A (b) Propeller B (c) Propeller C

(a) Aluminium
(b) Dry Carbon
(c) Nylon Powder

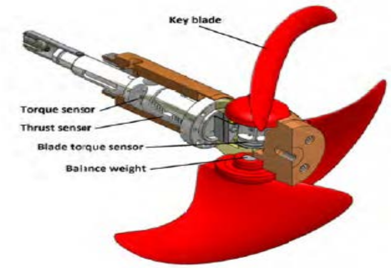
- Propeller blade geometry control using digital photogrammetry => meast. accuracy about 20µm

Optical scan on a CP propeller (deviation from its theoretical geometry, pressure side –suction side) (Dang et al., 2012)

Task 1b : State of the art Update on new experimental techniques and extrapolations methods

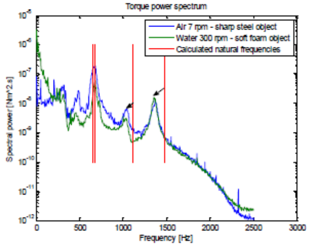
- Non stationary blade force measurements sensor

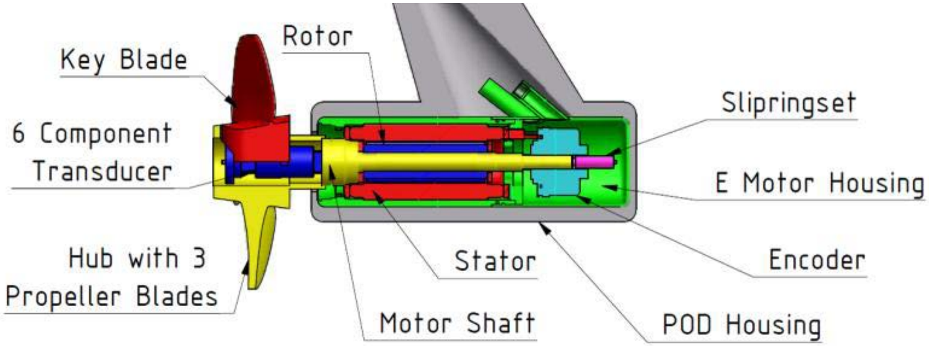
Propeller shaft thrust and torque sensor and the blade spindle sensor (Funeno, 2013)



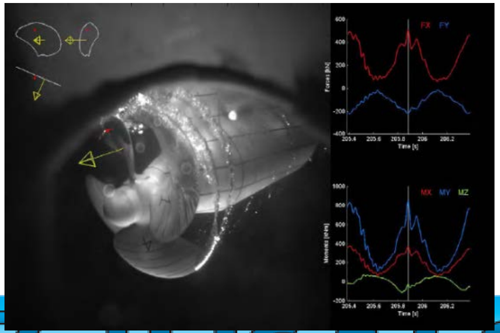
6DOF blade load measurement setup in a pod for measuring propeller-ice impact (Hagesteijn, 2012)

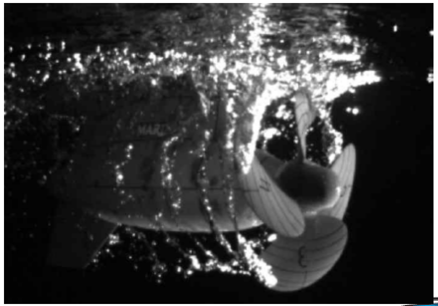
Bandwidth up 350 Hz





Brouwer & Hagesteijn, 2013





Dang et al, 2013

Task 1c : State of the art Update on new benchmark data

Benchmark on Podded propeller (so-called ABB case)

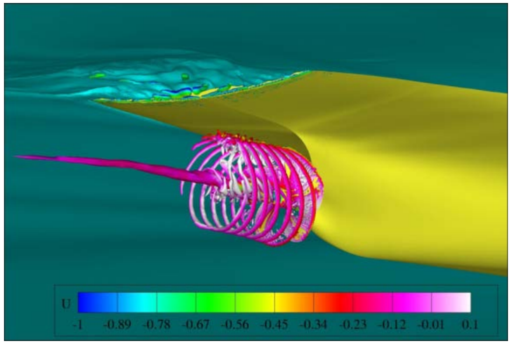
- A first benchmark launched by the Hydro-Testing Alliance (Veikonheimo, 2006) has lead to a sensitivity study of the testing parameters for propeller alone and Pod unit open water test (Glodowski et al, 2013).

- The final conclusions of this benchmarking test program were in line with the recommendations given in the 7.5-02-03-01.3 Podded Propulsor Tests and Extrapolation. The authors recommend having a aft fairing cone to rotate with the propeller and having a separate pre-test with a dummy hub to correct with the propeller open water test results which is a first alternative recommended in the 7.5-02-03-01.3 Podded Propulsor Tests and Extrapolation .

CFD simulation of self-propulsion

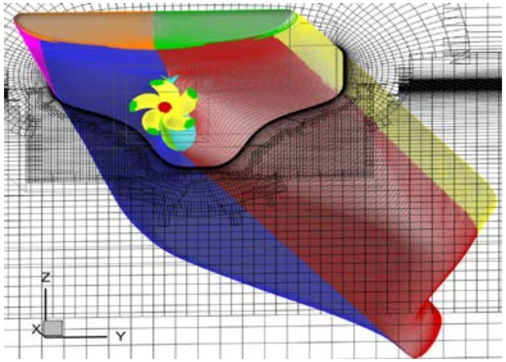
RANS – BEM approach

- Villa, *et al.* (2012):
  - KCS
  - RANS for hull
  - BEM-based body force model for propeller
- Sakamoto, *et al.* (2013a):
  - Twin-skeg container ship
  - RANS for hull
  - Body force model for propeller



RANS – LES or RANS DES hybrid approach

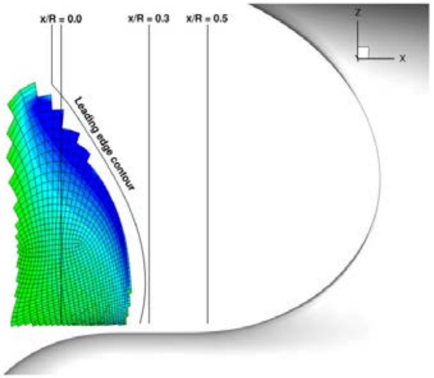
- Castro, *et al*. (2011):
  - KCS (Kriso Container Ship)
  - DES for hull & propeller
  - Dynamic overset grids



The overset grid system for KCS (Castro, *et al.*, 2011)

Effective wake field

- Rijpkema, *et al.* (2013)
  - RANS (hull) + BEM (propeller)
  - Body forces were distributed in the space otherwise occupied by the blades
  - Effective wake field was obtained by extrapolating BEM-based induced velocities at upstream locations to the propeller disk
- Sánchez-Caja, *et al.* (2014b)
  - RANS (hull) + lifting-line (propeller)
  - An correction factor approach was proposed based on comparison of the lifting-line- and RANS-based induced velocities for the body forces in open water



The axial locations used to compute the effective wake field. The contours represent the body force distribution in the RANS simulation. (Rijpkema, *et al.*, 2013)

Task 1d : State of the art Update on application of computational methods

Energy-Saving Devices

- Wake-Equalizing Ducts (WED)
  - Heinke *et al*. (2011) - Differences were identified between RANS & ITTC'78 predicted scale effects.
  - Huang *et al*. (2012) - Asymmetric arrangement of port and starboard half-ducts was found to be important through RANS and model tests.
- Mewis Duct® / Pre-Swirl Duct (PSD)
  - Guiard *et al*. (2013) - Model & full-scale RANS computations were used to account for scale effect on fin settings, as well as the impact of surface roughness on predicted wake.
  - Huang S.-Q, *et al.* (2012) - RANS simulations for the PSDs indicated that stator pitch angle was a key parameter for the gain in efficiency.

Multi-component propulsors

- RANS models were used to investigate component interaction, cavitation, and scale effects. For example,
  - Ducted propeller/thruster
    - Kinnas *et al*. (2013)
    - Bulten *et al*. (2011, 2013)
    - Xia *et al*. (2012)
    - Maciel *et al*. (2013)
  - Podded propulsor
    - Sakamoto *et al*. (2013b)
  - Contra-rotating propellers
    - Fujisawa (2013)

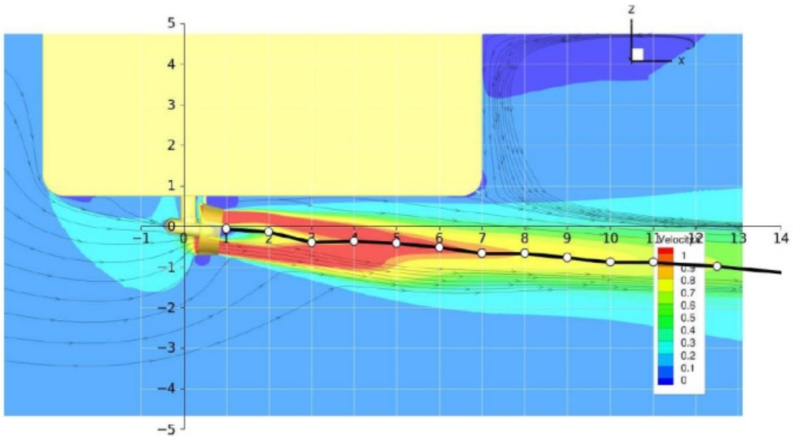
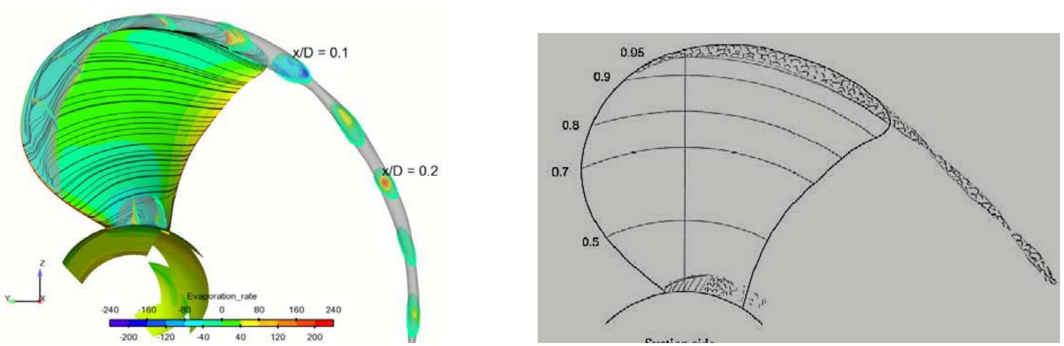


Figure 29: Comparison of RANS-simulated axial velocity contours with the wake trajectory measured by PIV for the tilted thruster working under the barge with bilge keel. (Maciel *et al*., 2013)

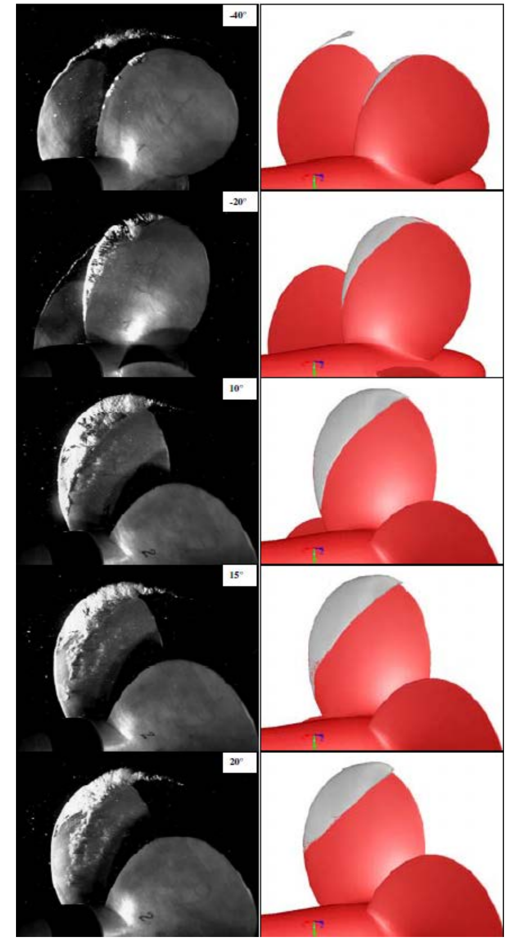
Task 1e : State of the art Update on experimental and CFD methods for prediction of cavitation

- Methods to predict cavitation on marine propeller blades has been classified by the 26th CFD Committee as:
  - interface tracking (lifting surface method)
  - discrete bubble dynamics (more for inception, bubble cavitation)
  - interface capturing methods (RANS / URANS code with multiphase flow and cavitation model solver, LES code).
- RANS code with mass transfert model



Stationary cavitation on PPTC propeller
Sipila & Siikonen, 2012

- LES codes begin to be also investigated



Stationary and non stationnary cavitation on Virtue propeller
Li et al, 2012

Task 1e : State of the art Update on experimental and CFD methods for prediction of cavitation

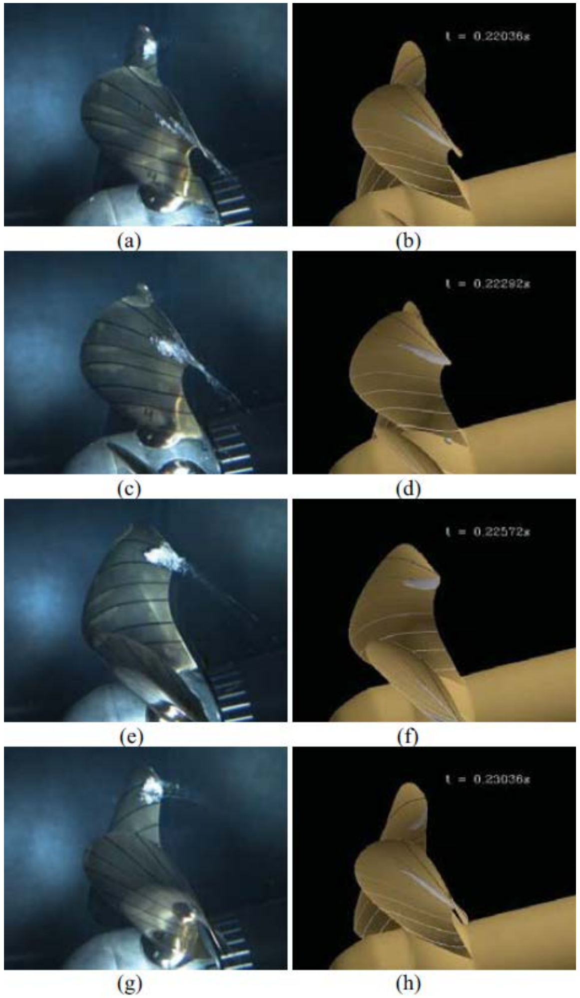
- Comparison of three methods (potential flow solver / RANS code / LES code)

  Lu et al 2012 made a comparative study on dynamic cavitation of RoPax vessel propeller

  - Potential flow solver can predict fairly well the thrust and torque coefficient, and usually captures simple types of sheet cavitation, it is not suitable for neither prediction of more complex sheets, nor the prediction of root cavitation.

  - RANS did captured the dynamic evolution of the sheet close to the tip region, and root cavitation,
    however it has mispredicted a leading edge sheet that is not present in the experiment. The missing of the vortices structure on blade limits also the use of RANS in analysis of some of the hydrodynamics that is crucial for understanding and controlling the cavitation and related noise and erosion.

  - The LES computation shows the tendency in filling in this gap by capturing the correct location and dynamic behavior of the vortices structure mentioned above.



**LES dynamic cavitation calculation
Lu et al 2012**

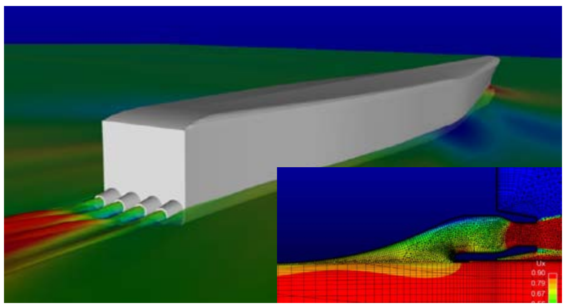
Task 1f : State of the art Update on the need for R&D

Specific areas needing improvement are the following:

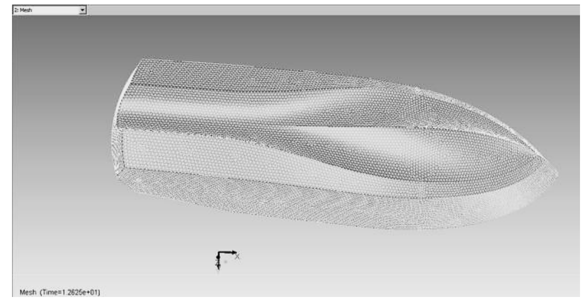
- model and full scale measurements of propulsors in off-design conditions
- full scale measurements of ship propulsive gain due to the use of Energy Savings Devices (ship configurations with and without)
- propulsive performances on composite propeller at full scale and model scale with possible measurement of blade deformation and torque
- full-scale measurements on Hybrid Contra-Rotating Shaft Pod propulsors
- EFD and CFD (*e.g.* RANS) simulation of the effect of varying Reynolds number on the performace of blade sections.
- full scale measurement of waterjet inlet flow velocity fields

Task 1g : State of the art Update on high-speed marine vehicle

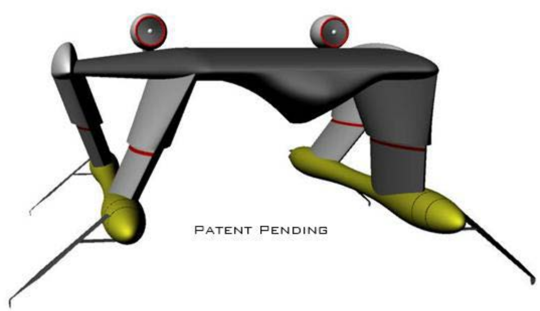
Propulsion for High speed marine vehicle remains an active domain. This include ships like deep V monohull, Y shape hybrid hull , Trimaran hull, SWATH, WIG craft



Aft view of the powered JHSS. Axial velocity contours inside the waterjet inlets . Delaney *et al.* (2011)



Y-shape hybrid hull. Bono *et al.* (2012)

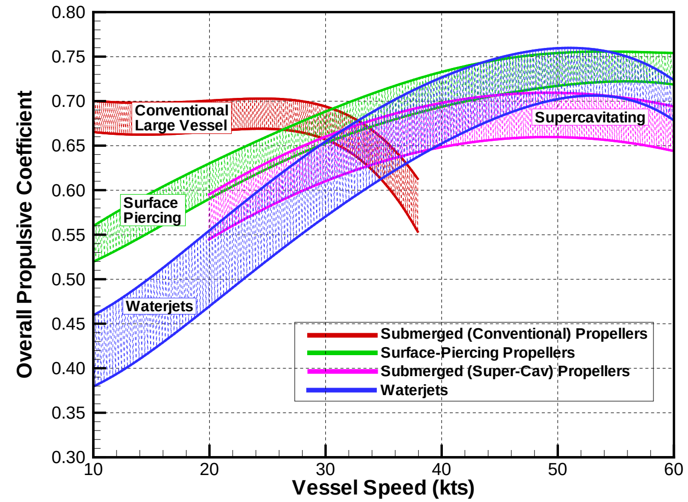


3D view of the concept design of the Ultrafast USV. Brizzolara *et al.* (2011)

Task 1g : State of the art Update on high-speed marine vehicle

Propulsion for high speed marine vehicle includes :

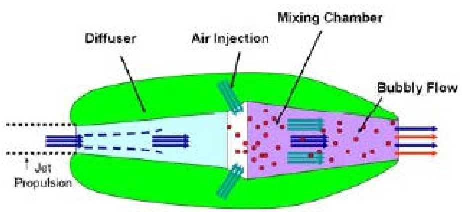
- Waterjet,
- super cavitating,
- surface piercing propeller



High speed marine vehicle Propulsors performances. Black *et al.* (2006)

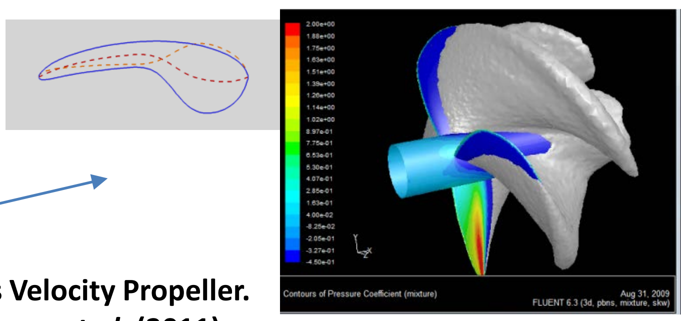
Design is often done using RANS code.

- Waterjet with air injection [see Wu *et al.* 2012 & Gowing *et al*. 2011] that significantly increase the thrust



Concept sketch of bubble augmented jet propulsion. Wu *et al.* (2012)

- New blade geometry to extend the use of conv. Propeller at high ship speed



Trans Velocity Propeller. Hwang *et al.* (2011)

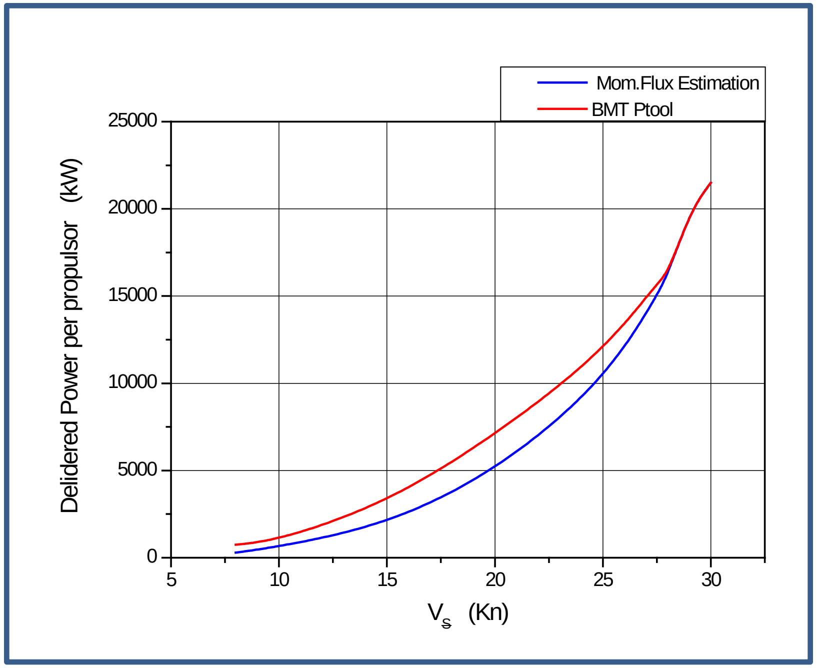
WATER JETS DESIGN, TESTING AND SCALING

Giles, *et al.* (2013)

WJ delivered power calculations

- ITTC "momentum flux" method
- Empirical method based on conventional WJ theory (van Terwisga, 1997)

Significant differences for submerged type WJ
The need to develop a robust and mature procedure.



Delivered power curves.
Giles, *et al.* (2013)

WATER JETS DESIGN, TESTING AND SCALING

Flush intake and mixed flow type WJ . Model test for fast river ferry

Dang, *et al.* (2012)

<u>Conclusions</u>

Blade tip chord
Rn = 4÷5×10^6

Duct Rn up to 10^6
CFD may provide better solutions on duct losses.

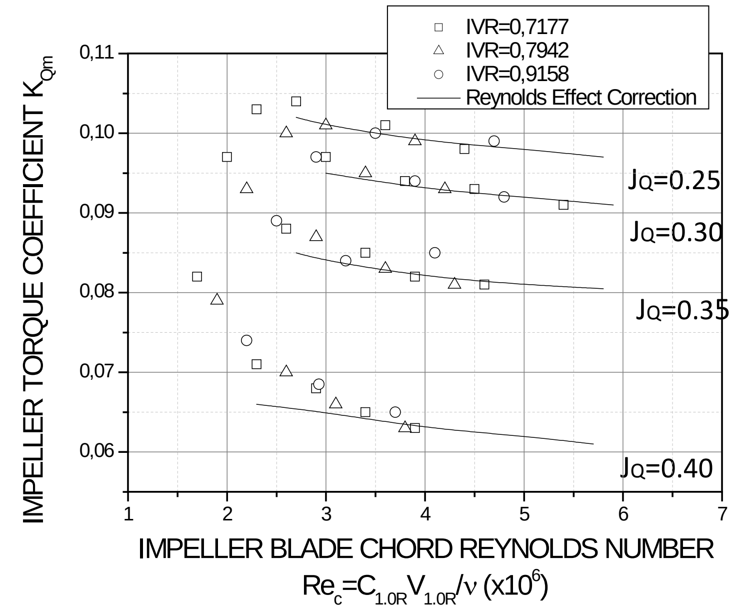
Power loading coefficient Cp to find the operating point

<u>ITTC procedure</u>

To test at more than one Rn

CFD to study Rn influence on inlet duct losses.

Thrust loading coefficient to find the operating point



Reynolds effect on impeller torque coefficient
Dang, *et al.* (2012)

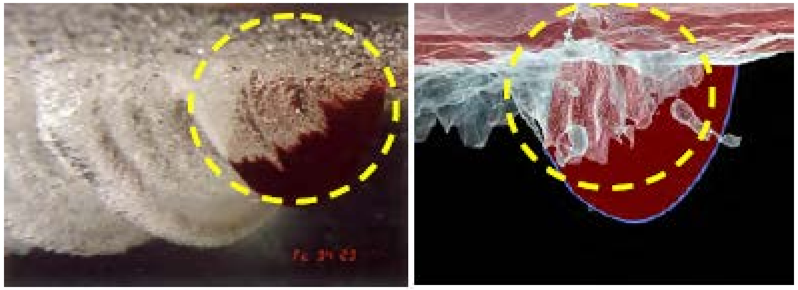
SURFACE PIERCING PROPELLERS

Himei *et al.* (2013)
Numerical analysis on SPP analysis by two methods and compared with experimental results from Olofsson 1996:

- Vortex Lattice method
- RANS / VOF method

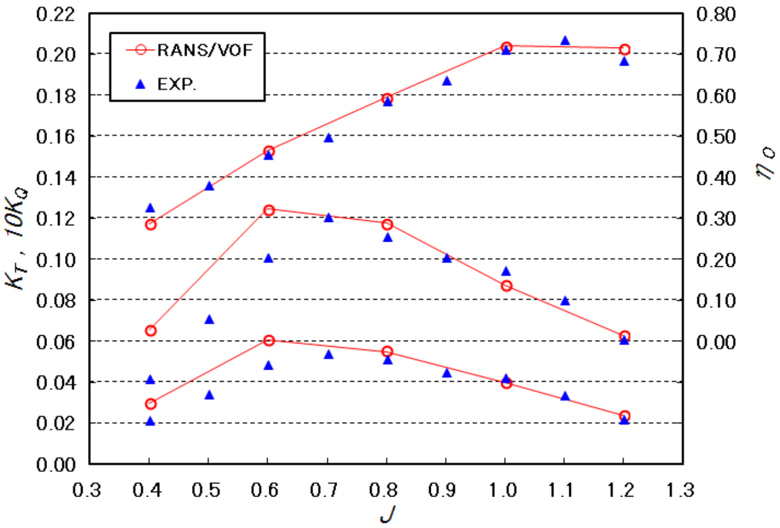
The RANS-VOF did catch the decrease of thrust and torque at lower value of J, but an over estimate of the coefficient was found.

Good agreement is found on ventilated cavity extent compared to experimental data.



(b) J=1.0, Angular position=150deg.

Comparison of ventilated cavity between CFD and EFD Himei *et al.* (2013)



Comparison between CFD and EFD Himei *et al.* (2013)

Task 2. Review ITTC recommended procedures

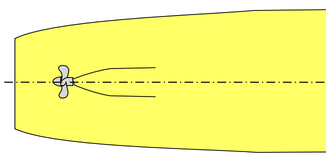
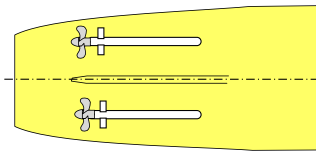
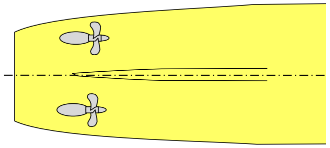
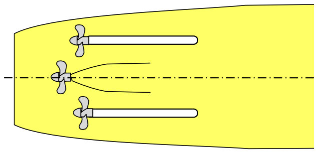
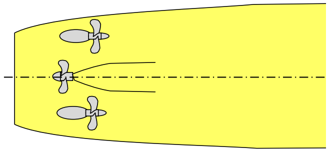
Updates of the following procedures have be proposed:

- ITTC Procedure 7.5-02 03-01.4 Performance, Propulsion 1978 ITTC Performance Prediction Method (**minor correction on Propulsive efficiency definition**)
- ITTC Procedure 7.5-02 03-02.3 Propulsor Nominal Wake Measurement by LDV Model Scale Experiments (**minor correction on calibration procedure of signal analyser and of fringe spacing**)
- ITTC Procedure 7.5-02 03-03.2 Testing and extrapolation Methods Propulsion: Cavitation Description of Cavitation Appearances (**minor correction for addition of sketches of cavity extend as a function of blade angular position**)
- Update to ITTC Procedure 7.5-02 03-03.3 Cavitation Induced Pressure Fluctuations Model Scale experiments) (**minor correction on pressure signal analysis based on harmonic analysis in the blade angular position domain and time domain**)
- ITTC Procedure 7.5-02-03-03.4 Cavitation Induced Pressure Fluctuations: Numerical Prediction Methods (**minor correction for potential use of RANS code to be included**
- ITTC Procedure 7.5-02-03-01.2 Propulsion, Performance Uncertainty Analysis, Example for Propulsion Test (**small correction**)
- ITTC Procedure 7.5-02-03-02.1 Testing and Extrapolation Methods Propulsion, Propulsor Open Water Test. (**small correction**)
- ITTC Procedure 7.5-02-03-02.2 Propulsion, Propulsor Uncertainty Analysis, Example for Open Water Test (**small correction**)

Task 2. Review ITTC recommended procedures

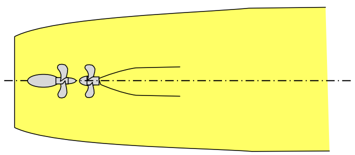
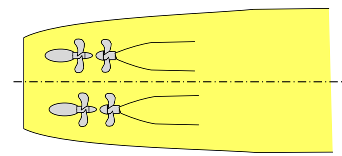
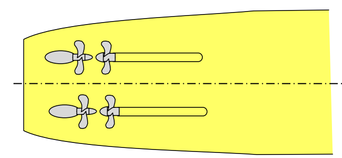
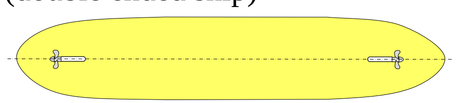
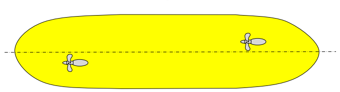
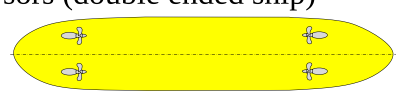
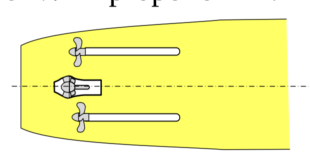
Need for new procedures have been found because of the increasing number of propulsion types.

The committee has proposed the following classification of propulsion types:

CASE I	Single shaft line Propeller 	Twin shaft lines Propellers or Pods  	Already existing ITTC self-propulsion procedures
CASE II	Center line Propeller + wing conventional shafl line propeller 	Center line Propeller + wing Pods / Thrusters / Z drives 	Need for self-propulsion procedure that should include differentiation of wake fraction and thrust deduction factor for wing and centre propellers and issues on power distribution. Possible extension of the existing procedure

Task 2. Review ITTC recommended procedures

Classification of propulsion types :

CASE III	Single Shaft Line CRP Concept Conventional Propeller / Pod combination 	Twin shaft lines CRP Concept Conv. Propeller behind skeg / Pod Combination  Conv. Propeller open shaft / Pod Combination 	A new guideline is proposed by the present committee for Hybrid Contra-Rotating Shaft Pod Propulsors (HCRSP) Model Test.
CASE IV	Single Forward and aft propulsors (double ended ship)  	Twin Forward and aft propulsors (double ended ship)  Water jet(s) combined with conv. propeller / Pods 	Need for self-propulsion procedure that should include issues on power distribution optimization

Guideline proposed (Task 9)

Task 2. Review ITTC recommended procedures

A part from these needs regarding self propulsion procedure, the committee is recommending to focus updating existing procedure or developing new procedure for scaling issues on Energy Saving Devices

Task 3. Liaison with the performance of ships in service committee

EEDI index prediction

$$EEDI = \frac{\text{Im}\,pact\ to\ environment}{Benefit\ \ to\ \ society} = \frac{CO_2\ \ emission}{transport\ \ work}$$

measured in gCO_2 per ton mile

$$\frac{\overbrace{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} \boxed{P_{ME(i)}} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right)}^{\text{Main engine(s) } CO_2 \text{ emissions}} + \overbrace{(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right)}^{\text{Auxiliary engine(s) } CO_2 \text{ emissions}} - \overbrace{\left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}^{CO_2 \text{ emission reduction due to Innovative technology(s)}}}{f_i \cdot Capacity \cdot \boxed{V_{ref} \cdot f_w}}$$

Correction factor for power for ice-classed ships

Benefit to society:
- Deadweight for cargo vessels
- GT for ferrys / cruise

Reference speed:
- 75%MCR
- Deepest draught
- No waves

Loss of speed in sea conditions (Beaufort Scale 6)

From model test, P_{MEI} (V_{ref}) and f_w can be predicted from model tests following the existing ITTC procedures :

- 7.5-02-07-02.2 Testing and Extrapolation Methods Loads and Reponses, Seakeeping Prediction of Power Increase in Irregular Waves from Model Tests
- 7.5-04-01-01.1, 7.5-04-01-01.2 Speed and Power Trials Parts 1 and 2
- 7.5-02-03-01.5 Testing and extrapoltaion methods, Propulsion, Performance, Predicting Powering margins : need to review power margins for calm water in service performance

Status of relevant developments

- There's a growing interest in applying viscous CFD tools for hydrodynamic and cavitation performances, in particular Reynolds scale effects. For example,
  - Effective wake field and wake scaling
  - Scale effects on CLT, podded, ducted, and CR propellers
  - Reverse and crash astern simulations by DES/LES
  - Flexible propellers
- Full RANS or combined viscous/inviscid tools are being used as complements to model experiments by providing data that are difficult or impossible to measure.

The need for hybrid procedures

- The Committee finds that it is still too early to recommend a new hybrid procedure because
  - The numerical models and data in public domain bring about many options and make it difficult to judge their applicable extent.
  - Full-scale validation is necessary for any numerical approach that is to be incorporated into an existing procedure - but there's a lack of full scale data.
- Potentially CFD and EFD can be combined to perform
  - scaling of resistance and powering
  - simulation of full scale and effective wake field
  - scaling for ducted and podded propellers, as well as ESDs
  - scaling for flexible propellers

Task 5. Modelling and scaling of unconventional propulsion and wake improving devices

Unconventional propulsion and wake improving devices have been first reviewed by :

- **the unconventional Propulsion committee of the 22nd ITTC (1996)**
- **Carlton (1994 - 2007)**

The classification used :

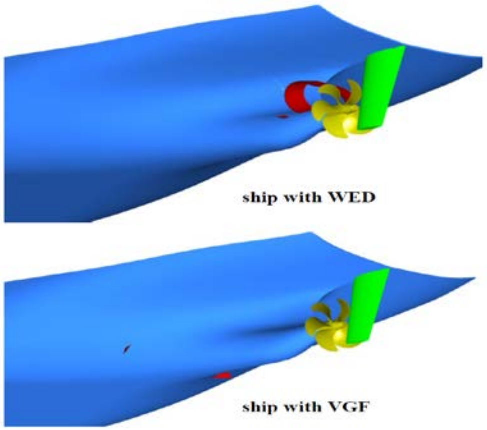
- **Devices before the propeller (WED, pre-swirl duct, pre-swirl stator, Flow regulating front fins)**
- **Special propeller (Tip rake propeller, CRP propellers, hybrid propulsion system)**
- **Devices within the propeller (Propeller Boss Cone Fins, divergent propeller boss cap) and after the propeller (Rudder with rudder bulb, Rudder thrust fins, Twisted rudder with rudder bulb, High Efficiency Rudders)**

The energy saving figures reported hereafter for every ESD are taken from different recently published sources :

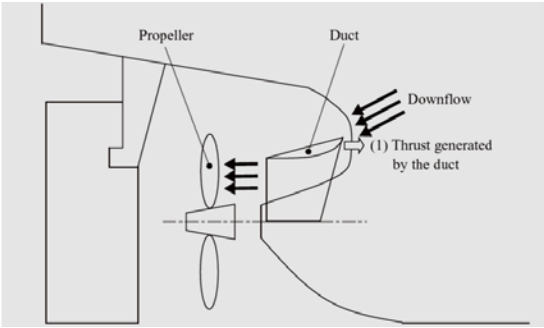
- **Hollenbach and Friesch, 2007**
- **Choi (DSME) energy savings devices, 2008**
- **Quadvlieg, 2009**
- **ABS report on Ship Energy efficiency, 2013**

Task 5. Modelling and scaling of unconventional propulsion and wake improving devices

Devices before the propeller (WED, Pre-swirl stator, Pre-swirl duct, Fins)



Appendage profiles
(Heinke *et al.*, 2011)



Basic energy-saving principles of the semi-circular duct
(Yasuhiko et al. , 2011)

Daewoo Ship and Marine Engineering asymmetric pre-swirl stator

The CFD calculations at the model and full scale show that the change in the propulsion coefficients, such as the thrust deduction fraction, wake fraction and hull efficiency of ships with a WED or VGF can be predicted with good accuracy using the ITTC 1978 propulsion method.

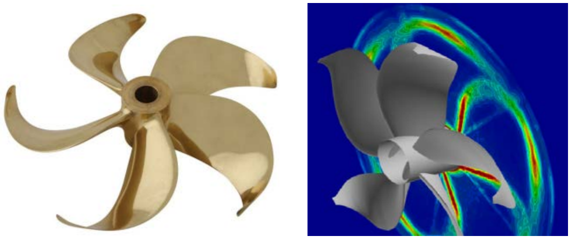
Devices before the propeller	Gain
Grothues wake equaling spoiler	3%
Schneekluth wake equaling duct	4%
Sumitomo Integrated Lammeren duct (SILD)	6%
Single pre-swirl fin (Peters / Mewis)	3%
Pre-swirl fin system (DSME, Korea)	4%

Hollenbach and Friesch, 2007
ABS report on Ship Energy efficiency (2013)

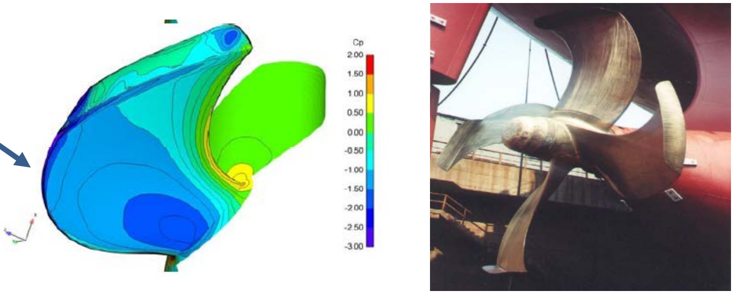
Task 5. Modelling and scaling of unconventional propulsion and wake improving devices

Special propellers

- Contracted and Loaded Tip Propeller
  - Forward tip rake propeller (Kappel)
  - Backward tip rake propeller (Sistemar)
- Contra-rotating Propeller
- Combination of CRP and CLT



Forward tip rake propeller (Kappel)
Bertetta et al (2012) ; Cheng et al. (2010)

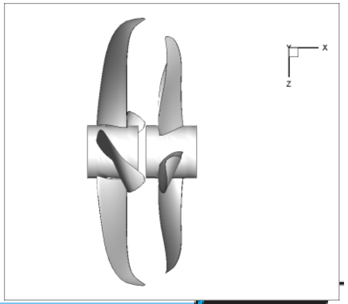


Backward tip rake propeller (Sistemar)
Sanchez-Caja et al. (2012) ; Inuakai (2013)

Special Propeller	Gain
CLT forward rake Propeller	> 6%
CLT backward rake Propeller	3% - 6%
CRP Propeller	5 % - 10 %
CRP + CLT Propeller	? %

CFD showed larger scale effect than standard extrapolation from model scale
Sanchez-Caja et al. (2012)
Cheng et al. (2010)

Combined CRP and CLT Propeller
Inuakai (2011)

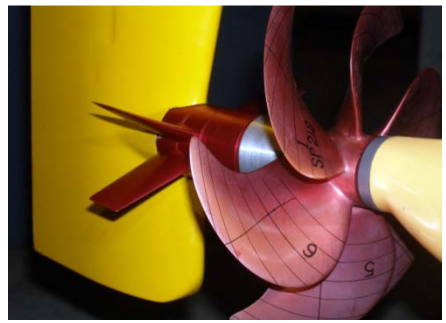


Task 5. Modelling and scaling of unconventional propulsion and wake improving devices

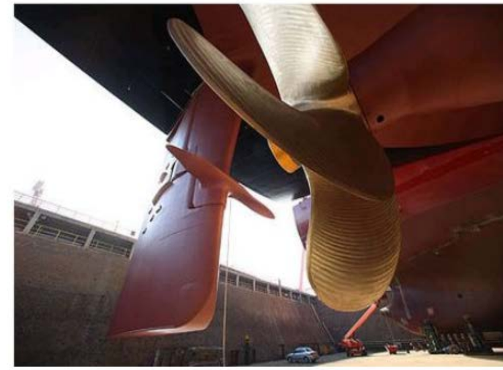
Devices at and after the propeller

- **To reduce the losses of rotational energy**
- **to optimize the flow on the rudder to delay cavitation)**

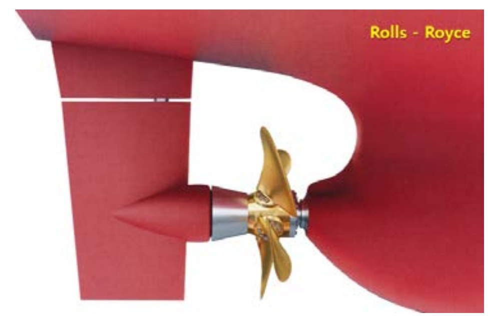
PBCF to a full scale ship (Hansen *et al.*, 2011)



SHI Post stator Hollenbach & Reinholz , 2011



Thrust fin (HHI)



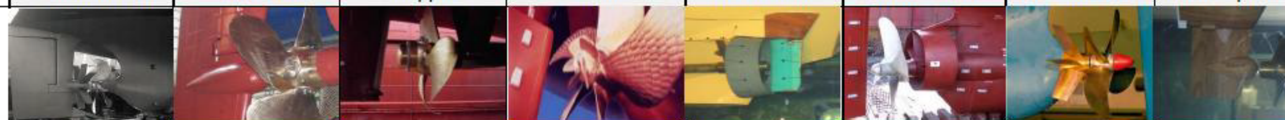
Rudder bulb (Rolls-Royce brochure)

Reducing Rotational and Hub Vortex Losses	Gain
Divergent propeller boss cap	2%
Rudder with rudder bulb	2%
Propeller boss cap fins (PBCF)	3%
Rudder thrust fins (HHI, Korea)	4%
Twist rudder with rudder bulb (BMS / HSVA)	2%
High Efficiency Rudders (Wartsila, Rolls Royce)	6%
Post stator (SHI)	4%

(Hollenbach and Friesch, 2007)

Task 5. Modelling and scaling of unconventional propulsion and wake improving devices

Possible combination of different Energy Saving Devices (as reported by Nielsen, 2012)



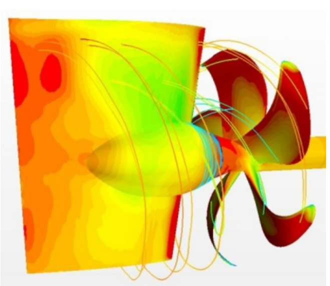
SOLUTIONS	Post swirl Fins	Rudderbulb	Kappel	PBCF	AHT Nozzle	Mewis Duct	Pre Swirl Fins	Rudder profile
Post swirl fin	2-3%							
Rudder bulb		2-5%						
Kappel propeller			3-6%					
PBCF				2-5%				
AHT Nozzle					6-8%			
Mewis duct						3-8%		
Pre swirl fins							3-5%	
Efficeincy rudders								2-6%

Can be combined
Can sometimes partly be combined
Should not be combined

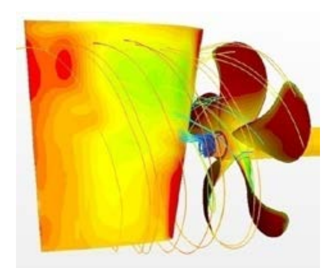
Example of combination of Tip rake propeller and rudder bulb (Nielsen et al, 2012)

Power reduction [%]	Without rudder bulb	With rudder bulb
Conventional propeller	Reference	4.50%
Kappel propeller	5.20%	9.30%

Kappel with ruder bulb



Conventional propeller without ruder bulb



27TH ITTC • COPENHAGEN

Wake simulation test to better simulate cavitation

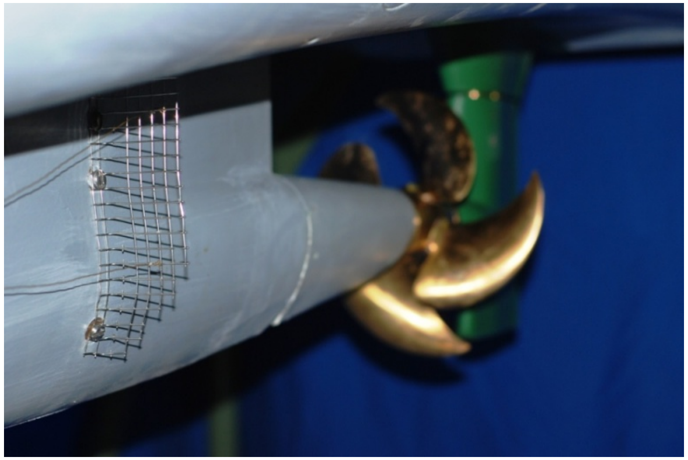
- **Full scale wake fields can be calculated using RANS Code**
- **Use of dummy model with wire grids (starting KonKav II Project in Germany)**
- **Use of simple shortening and narrowing dummy model (Schuiling et al. 2011)**
- **Use of smart dummy model (Schuiling et al. 2011, Bosschers et al. 2012 and Johannsen et al. 2012)**

This become possible by using iterative computation of different hull geometries or by using an optimisation process of the RANS computation with wake objective function (Stück *et al.* (2010), Kröger *et al.* (2011), and Rung *et al*. (2012))

German joint research project KonKav II

"Correlation of Cavitation Effects Under Consideration of the Wake Field"

- Flensburger Schiffbau-Gesellschaft (FSG)
- Hamburgische Schiffbau-Versuchsanstalt (HSVA)
- Schiffbau-Versuchsanstalt Potsdam (SVA)
- Technische Universität Hamburg-Harburg (TUHH)
- Universität Rostock (UniHRO)

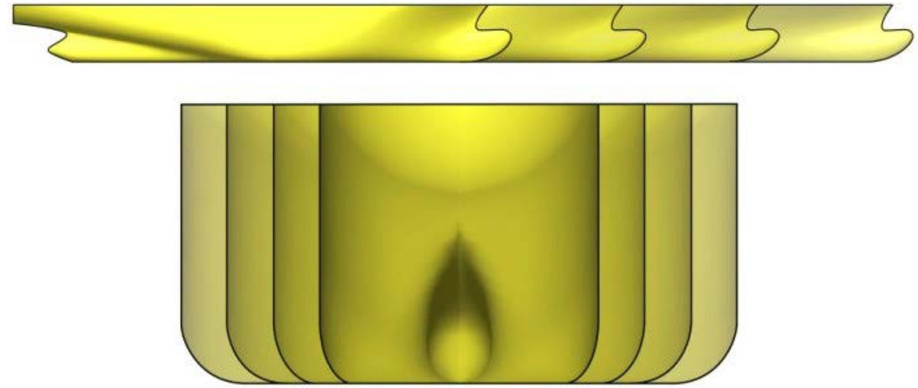


Additional grids used on the conventional dummy

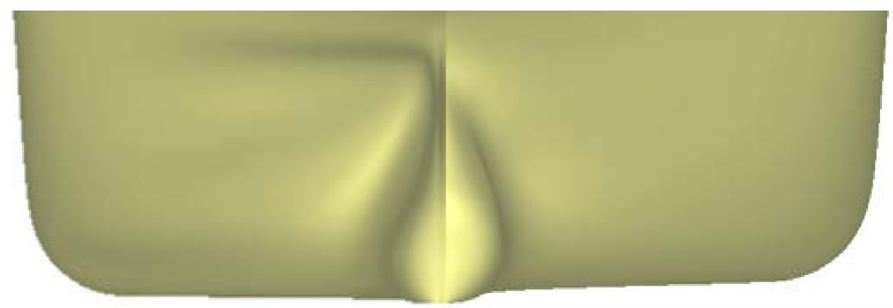
Dummy model, optimized on the base of an adjoint sensitivity analysis

Task 6. Examine methods of wake simulation

Simple shortening and narrowing the model did not lead to the expected Full Scale wake fields. (Schuiling *et al.* 2011), for the magnitude of the axial velocity in the top position was significantly lower than the one at full scale.



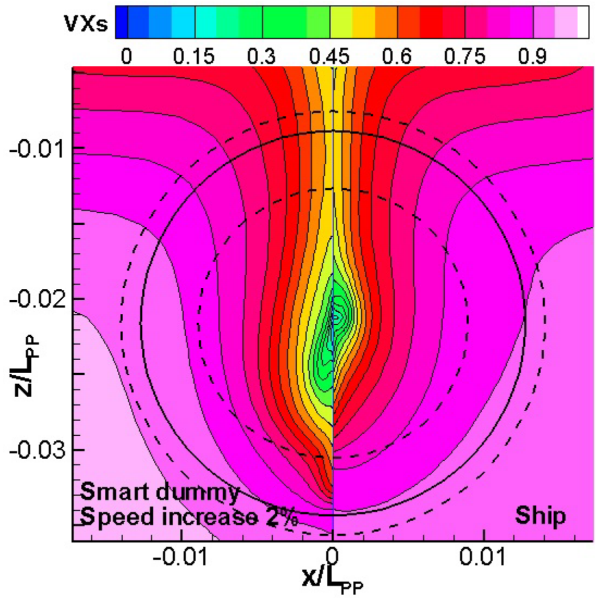
Use of a smart dummy model -non geomsim model - (Schuiling *et al.* 2011)



Smart dummy Geosim hull

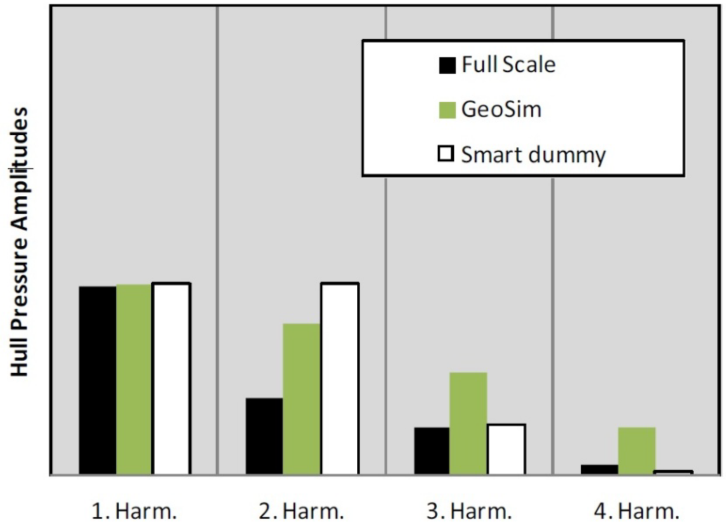
Task 6. Examine methods of wake simulation

Smart Dummy Wake : comparison of CFD / EFD Results in cavitation tunnel



Smart dummy wake

Full scale wake

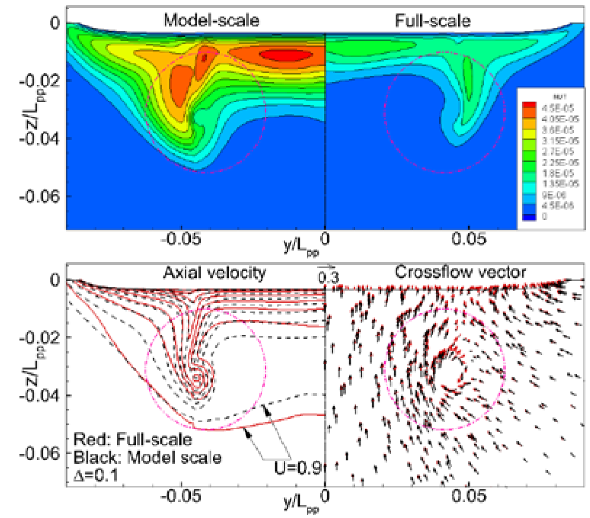


Pressure Pulses

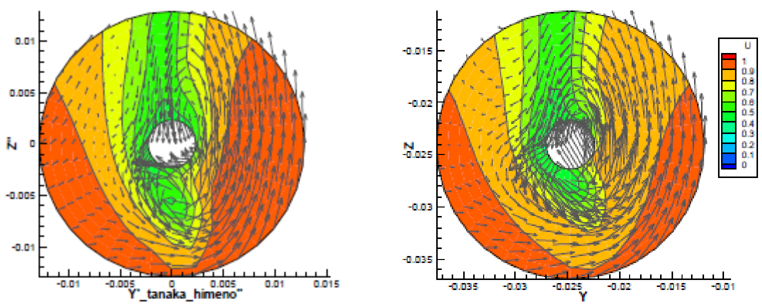
Wake fraction scaling (related to the 1978 Performance prediction method)

- For Twin screw ship with shaft supported by A-bracket : using $w_{TS}=w_{TM}$ is still advised

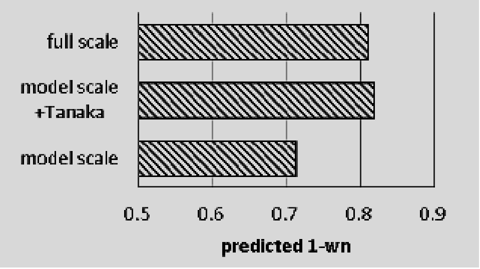
- For Twin skeg vessels, the wake field is similar to the wake field of a single skeg vessel. Thus the normal single screw wake scaling should be used.



Full-scale and model scale nominal wake on twin skeg container vessel Sakamoto et al, 2011



Tanaka scaling MS wake and FS CFD wake Ohmori et al 2013

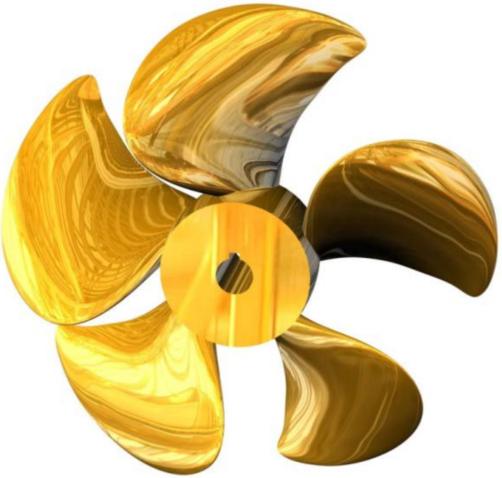


Initiating a comparative CFD calculation project

- 2 propellers
  - 1 conventional
  - 1 unconventional
- Started with the conventional propeller : **PPTC Propeller from SVA Potsdam**

- Still looking for an open unconventional propeller

PPTC conventional Propeller



- All data are on the web site of SVA Potsdam
- http://www.sva-potsdam.de/ittc-benchmark.html

9 Participants

- SVA Potsdam
- Hyundai Heavy Industries
- Krylov State Research Centre
- MARIC
- SJTU
- SSPA
- SSSRI
- DGA Hydrodynamics
- Technical Research Centre Japan Marine United Corporation (JMU)

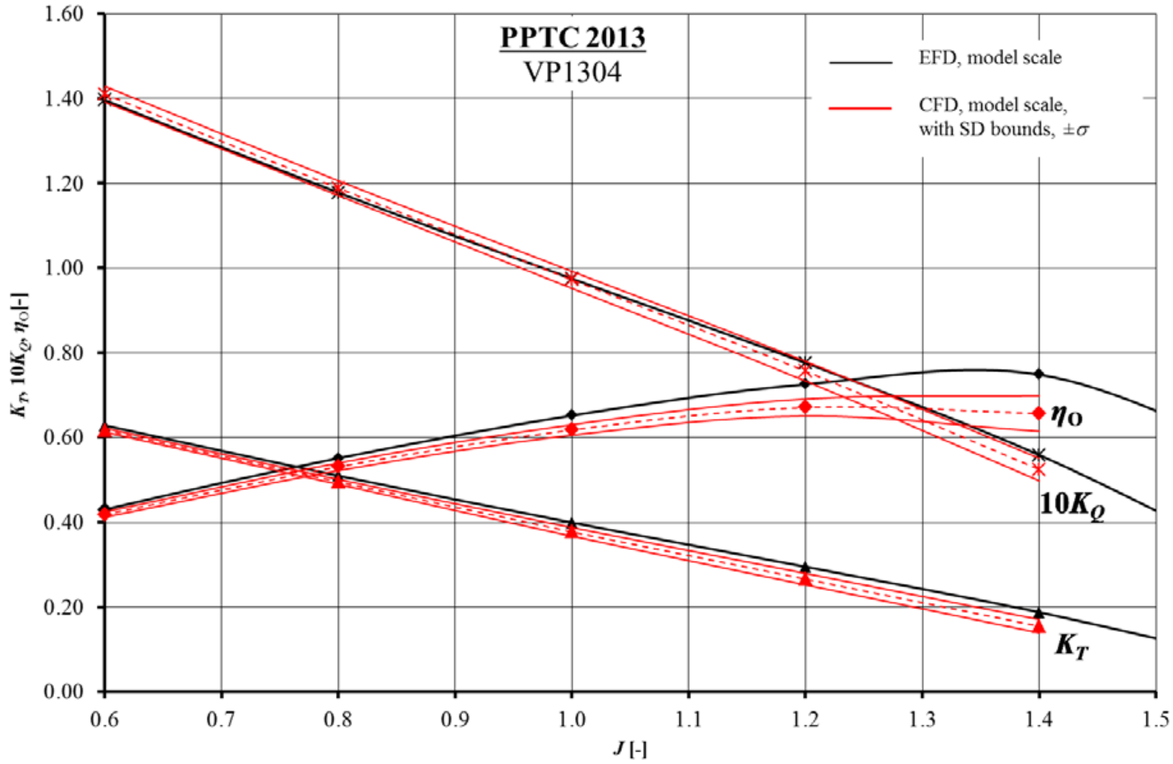
- Further participants are welcome

Details of Computations

- In general a single blade passage with periodic side boundaries is used
- The side boundaries are in general matching
- In general unstructured meshes consisting of tetrahedral elements with a prismatic boundary layer and local grid refinement are used
- In model scale the dimensionless wall distances ranges between 1 and approx. 50
- In full-scale the dimensionless wall distances ranges in general between 1 and approx. 30
- The number of cells on the blade surface is in the range between 9,800 and 80,000
- All participants use 2 equations turbulence models
- For the domain extent two groups can be distinguished
  1. Very large domain with the cross sectional area being 3600 times of the propeller disc area
  2. Very small domain extent having values of below 16
- The same applies for the upstream and downstream extent of the solution domain.

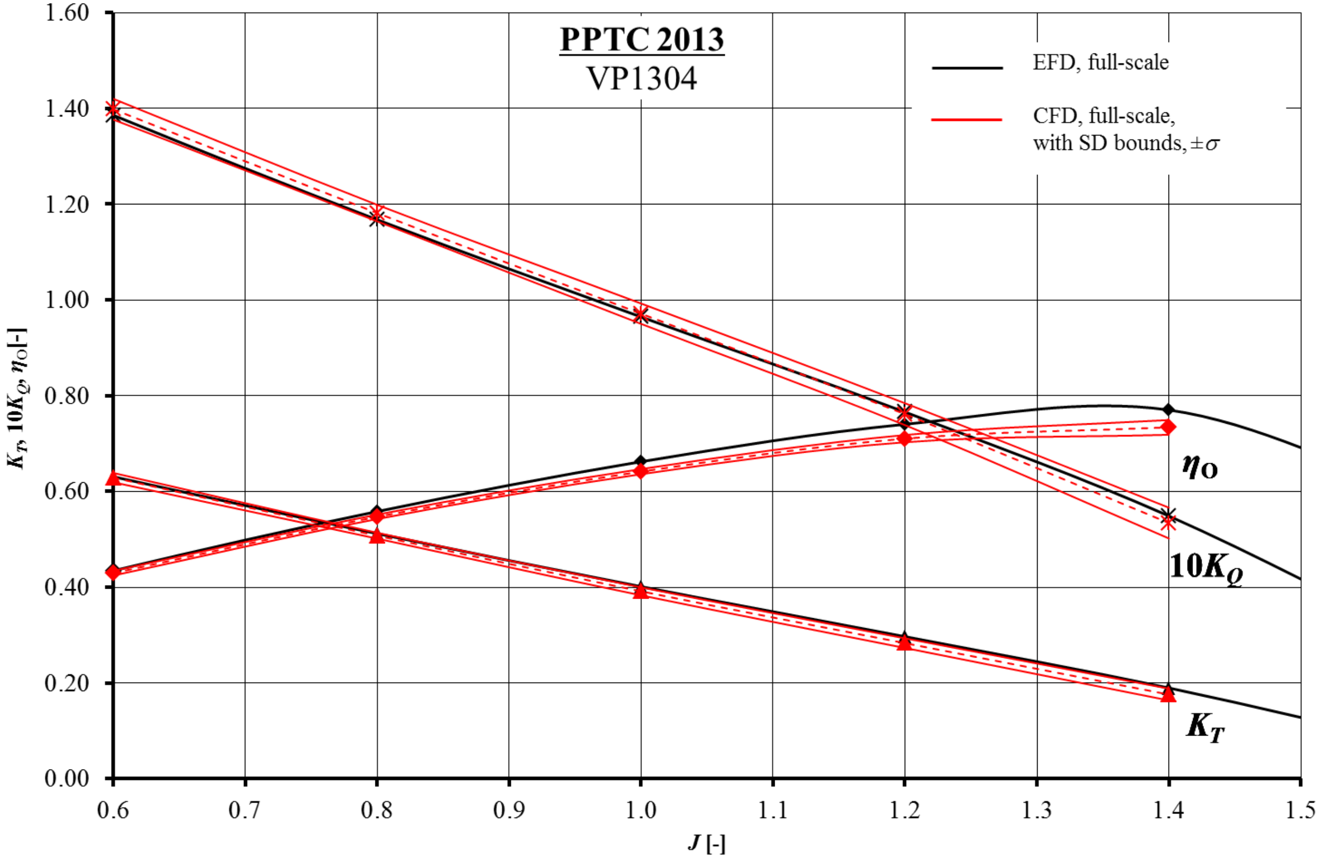
Task 8. Scaling of conventional and unconventional propeller open water data

Results at Model Scale



$K_{T\ \mathrm{EFD}} > K_{T\ \mathrm{CFD}}$ and $\eta_{0\ \mathrm{EFD}} > \eta_{0\ \mathrm{CFD}}$

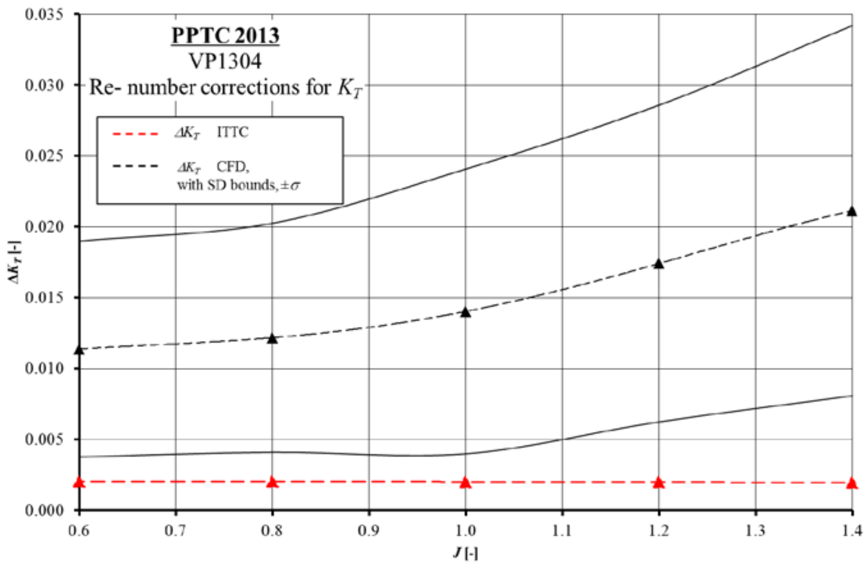
Results in Full Scale



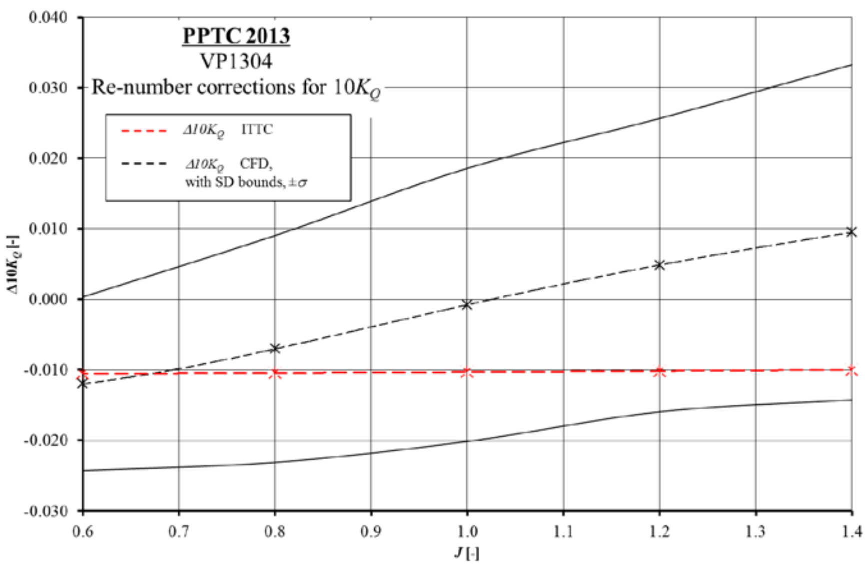
$K_{T\ \text{EFD extrapolated}} > K_{T\ \text{CFD extrapolated}}$ and $\eta_{0\ \text{EFD}} > \eta_{0\ \text{CFD}}$

Task 8. Scaling of conventional and unconventional propeller open water data

K_T-Corrections to full scale



K_Q-Corrections to full scale



CFD is showing larger scaling corrections but K_T and η_0 are closer at full scale

Task 8. Scaling of conventional and unconventional propeller open water data

Preliminary conclusions

- **It is difficult to conclude on the comparison of ITTC scaling method and the CFD scaling results, because CFD is showing larger scaling corrections but CFD and extrapolated EFD K_T and η_0 are closer at full scale**

- **The benchmark on the conventional propeller should continue.**

- **It would be helpful to have EFD results from some other ITTC organisations to have some idea of the uncertainties on the measurements of open water performances.**

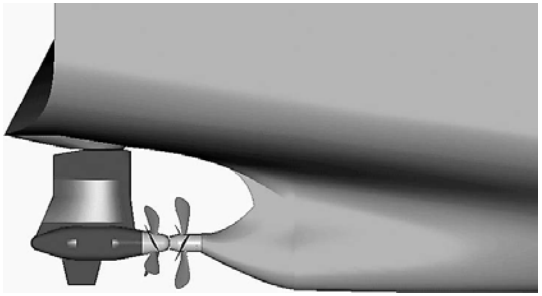
- **It will be also helpful to launch a similar open water experiment on an unconventionnal propeller (Pod unit or CLT propeller)**

Task 9. Develop guidelines for hybrid propulsor testing

Hybrid propulsor definition and new guideline proposed

- **Hybrid Propulsor is generally including**
  - **low interaction propulsors arrangement**
    - CL conv. propeller + wing pods/thrusters/Z-drives
    - CL pod/thruster unit + wing conv. propellers
    - Forward/Aft propulsion systems (typically double-ended ferries)
    - Water jet(s) combined with conv. propellers/pods
  - **and high interaction propulsor arrangement**
    - CRP concept - conv. propeller/pod combination

- **The committee focused the work on a guideline for high interaction propulsor as HCRSP (Hybrid Contra-Rotating Shaft Pod) propulsor**

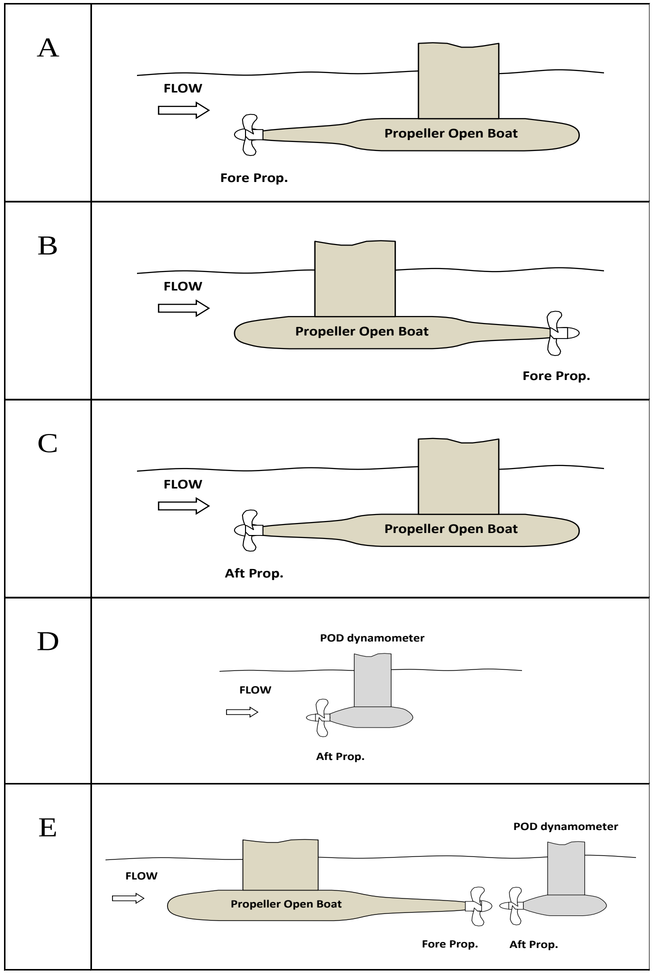


- **Guideline because the scaling issue is not discussed because of a lack of feedback from full scale data.**

Task 9. Develop guidelines for hybrid propulsor testing

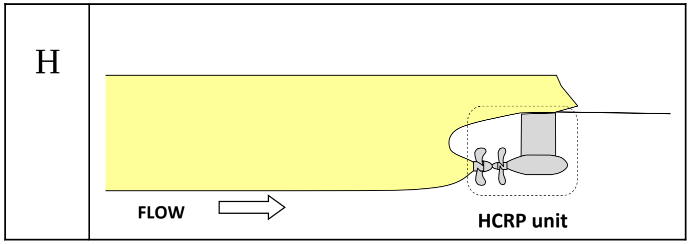
Models test procedure is based (1/2)

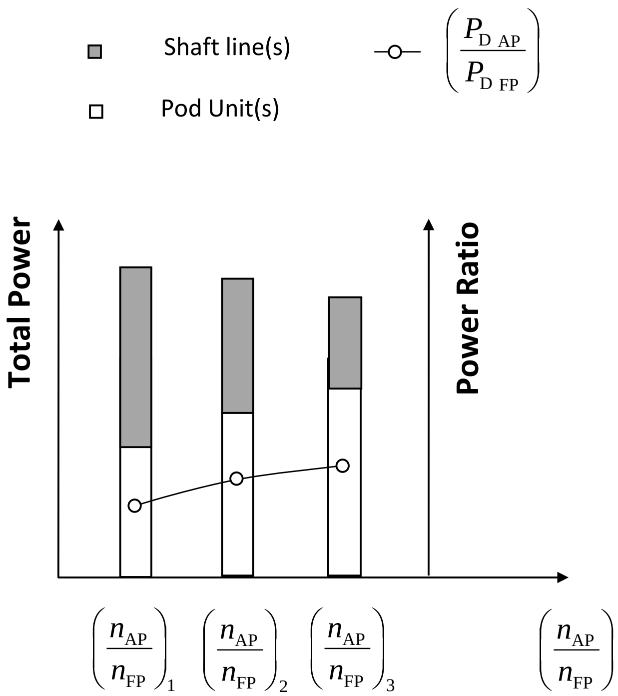
- The method is based on studies of Sasaki (2006-2009), Chang (2011), Quereda (2012), Sanchez-Caja (2013) and existing ITTC podded propulsor test procedure
- Different settings of fore prop. and aft prop. RPM ratio should be considered for the tests (OW and self propulsion)
- Open water test s include:
  - OW test of the fore propeller
  - OW test of the aft (Pod) propeller
  - OW of the Pod propeller
  - wake fraction of the propeller open boat



Models test procedure is based (2/2)

- **Self-propulsion test considering the HCRSP unit as one propeller (with a constant ratio of revolution rates between aft and fore propellers)**
- **The self-propulsion test is done at different revolution rate ratios.**
- **From the self propulsion tests, not only the total power is found but also the power ratio between the Pod Unit and the Shaft propeller**





Task 10. Monitoring of full scale data for Podded propulsion

Full scale data for Podded propulsion

- No new full-scale data has been published, the only known available example is the “ABB case”.
- Honninen, *et al.* (2007) mentionned that ABB has carried on extensive full-scale load measurements on four different types of ice-going and icebreaking vessels
- Possible available data in a near future from the “Norilsky Nickel” ship on which extensive measurements have been performed.

Conclusions

Recommendations to the Conference

- Adopt the revised procedure ITTC Procedure 7.5-02 03-01.4 1978 ITTC Performance Prediction Method
- Adopt the revised procedure ITTC Procedure 7.5-02 03-02.3 Propulsor Nominal Wake Measurement by LDV Model Scale Experiments
- Adopt the revised procedure ITTC Procedure 7.5-02 03-03.2 Testing and extrapolation Methods Propulsion : Cavitation Description of Cavitation Appearances
- Adopt the revised procedure Update to ITTC Procedure 7.5-02 03-03.3 Cavitation Induced Pressure Fluctuations Model Scale experiments
- Adopt the revised procedure ITTC Procedure 7.5-02-03-03.4 Cavitation Induced Pressure Fluctuations: Numerical Prediction Methods

- Adopt the new guideline 7.5-02-03-01.6 HCRSP (Hybrid Contra-Rotating Shaft Pod) Propulsors Model Test

Conclusions

Recommendations to the next committee (1/4)

1. Procedure Review/Update

- The Model test scaling for the HCRSP propuslor
- The new procedures Speed and Power Trials Parts 1 and 2
- the Water jet system Performance procedure (Monitor the Reynolds scale effect on impeller blade and intake duct of water-jet, to update)

Conclusions

Recommendations to the next committee (2/4)

2. New Procedures

– extension of existing procedure on self propulsion performance for triple shafts vessels

3. Technologies to monitor

– Model test and scaling procedures for energy saving devices (specially on Wake improving devices)

– Use of CFD to target the 3D FS wake field in cavitation testing

– Smart dummy model use for cavitation tests

Conclusions

Recommendations to the next committee (3/4)

3. Technologies to monitor next

- Continuing the PPTC benchmark on CFD
- Find a model test reference for CFD study of an unconventional propeller
- Monitor the way to handle composite propeller to predict propulsive performances through the use of validated CFD
- Monitor new experimental techniques (PIV, blade deformation for composite propeller, cavity surface or volume,…)

Conclusions

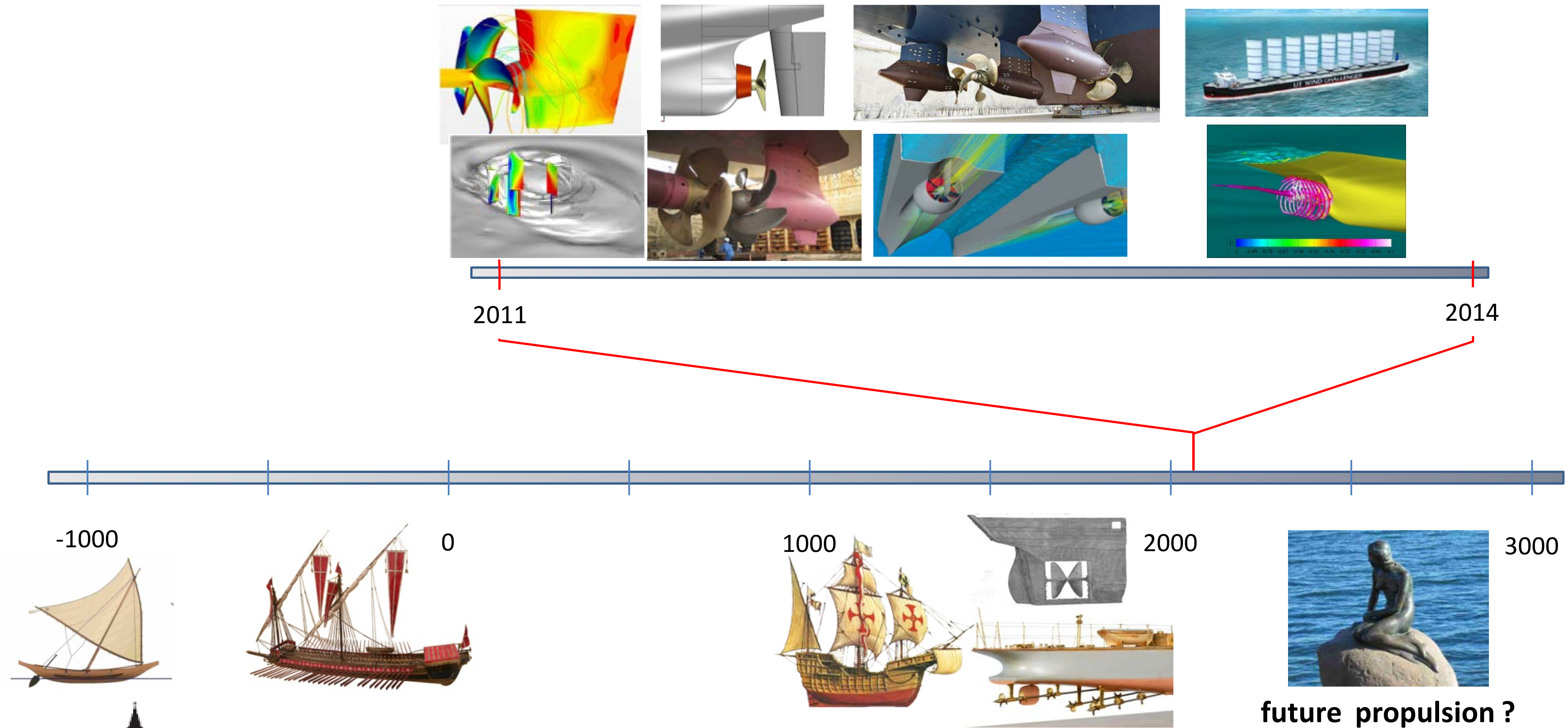
Recommendations to the next committee (4/4)

4. Scaling for propulsors

- Look for full scale data on Pod propulsor
- Scaling propulsor induced hull pressure
- Scaling ESD to increase the accuracy of power savings

Conclusions

To remain humble, the committee just focused over 3 years of the ship propulsion history.



Conclusions

Thank you very much for your attention.

Mange tak

(only for little mermaid citizens)