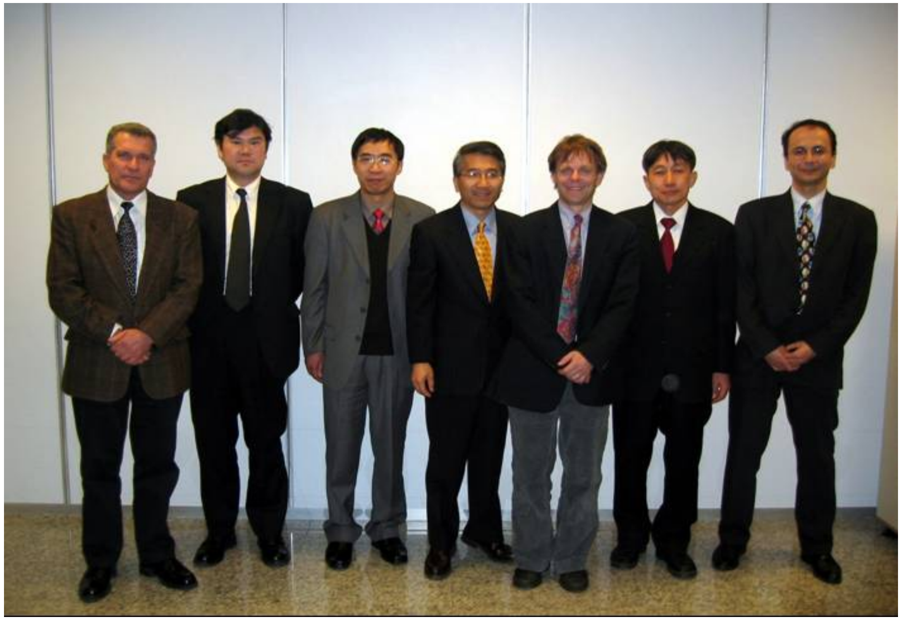
The 25th ITTC
Propulsion Committee
(2005 – 2008)

Final Report

Fukuoka, Japan
14-20 September 2008

25th ITTC Propulsion Committee Members


David Taylor Model Basin, 2007


Technical University of Istanbul, 2006

- Dr. Ki-Han Kim (Chairman), Office of Naval Research (ONR), U.S.A.
- Dr. Stephen Turnock (Secretary), University of Southampton, U.K.
- Professor Jun Ando, Kyushu University, Japan
- Dr. Paolo Becchi, CETENA, Italy
- Professor Emin Korkut, Technical University of Istanbul, Turkey
- Dr. Anton Minchev, FORCE Technology, Denmark
- Ms. Elena Ya Semionicheva, Krylov Shipbuilding Research Institute, Russia
- Dr. Suak-Ho Van, Maritime and Ocean Engineering Research Institute (MOERI), Korea
- Dr. Wei-Xin Zhou, China Ship Scientific Research Center (CSSRC), China.

Committee Meetings

- Technical University of Istanbul, Turkey (1-3 February 2006)
- CETENA, Italy (25-27 September 2006)
- David Taylor Model Basin, USA (18-20 April 2007)
- FORCE Technology, Denmark (23-25 October 2007)

Recommendations of the 24th ITTC

1. Update the state-of-the-art for propulsion systems emphasizing developments since the 2005 ITTC conference.

   (a) Comment on the potential impact of new developments on the ITTC,

   (b) Emphasize new experimental techniques and extrapolation methods and the practical application of computational methods to performance prediction and scaling,

   (c) Identify the need for R&D for improving methods of model experiments, numerical modelling and full-scale measurements.

Recommendations of the 24th ITTC

2. Review the following ITTC recommended procedures:

- 7.5-01-02-01: Terminology and Nomenclature of Propeller Geometry (Harmonize with ISO standard)
- 7.5-02-03-01.1: Propulsion Test
- 7.5-02-03-02.1: Propeller Open Water Test
- 7.5-02-03-02.3: Guide for Use of LDV
- 7.5-02-05-02: High Speed Marine Vehicles Propulsion Test.

Recommendations of the 24th ITTC

(a) Determine if any changes are needed in the light of current practice.

(b) In the review and update of the existing propeller open water test procedure 7.5-02-03-02.1 its applicability to new types of propulsors should be taken into account.

(c) Identify the requirements for new procedures.

(d) Support the Specialist Committee on Uncertainty Analysis in reviewing the procedures handling uncertainty analysis.

Recommendations of the 24th ITTC

3. Critically review examples of validation of prediction techniques. Identify and specify requirements for new benchmark data.
4. Review the development and progress in unconventional propulsors such as tip-rake, transcavitating and composite propellers (hydroelasticity and cavitation erosion susceptibility taken into account).
5. Review propulsion issues in shallow water and formulate recommendations for research.
6. Review the methods for predicting the performance of secondary thrusters and compare with operational experience.
7. Finalise the benchmark tests for waterjets and analysis of the data.

Task 1. Update the state-of-the-art for propulsion systems emphasizing developments since the 2005 ITTC conference

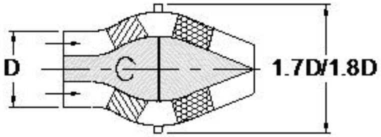
Major Sources for this Report

- CAV2006 (Sep. 2006, the Netherlands)
- Propellers/Shafting '06 (Sep. 2006, U.S.A.)
- 26th Symposium on Naval Hydrodynamics (Sep. 2006, Italy)
- T-POD 2006 (Oct. 2006, France)
- 9th International Conference on Numerical Ship Hydrodynamics (Aug. 2007, U.S.A.)
- FAST 2007 (Sep. 2007, China)
- Other technical journals and related conferences

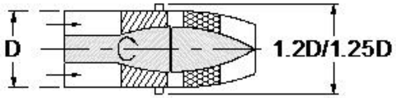
New Developments and Advancements in Propulsion Systems

- Axial-flow waterjets
- Advanced blade sections
  - Dual-cavitating blade sections
- Full-scale measurements
- Advances in CFD
  - Self-propulsion predictions using CFD
  - Propeller-rudder-hull interactions
  - Bubble-propeller interaction
- Anti-fouling paints

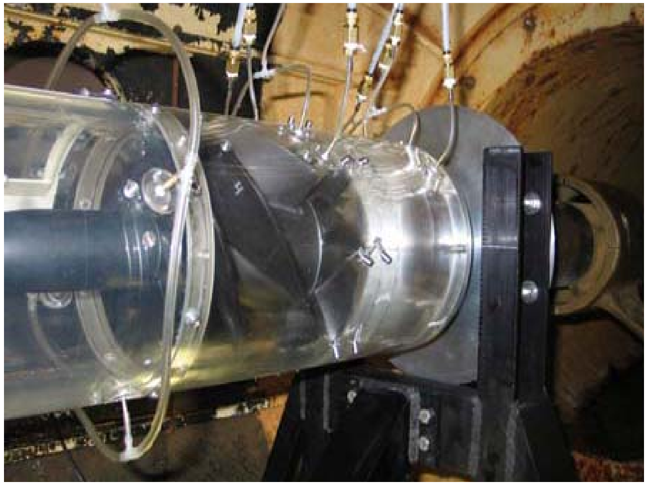
Axial-Flow Waterjet



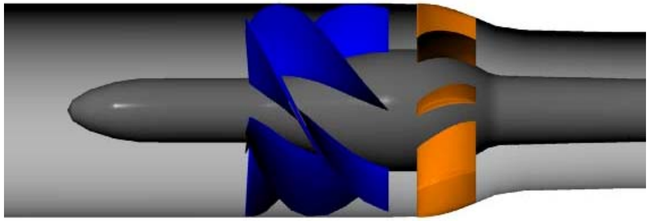
Mixed Flow WJ

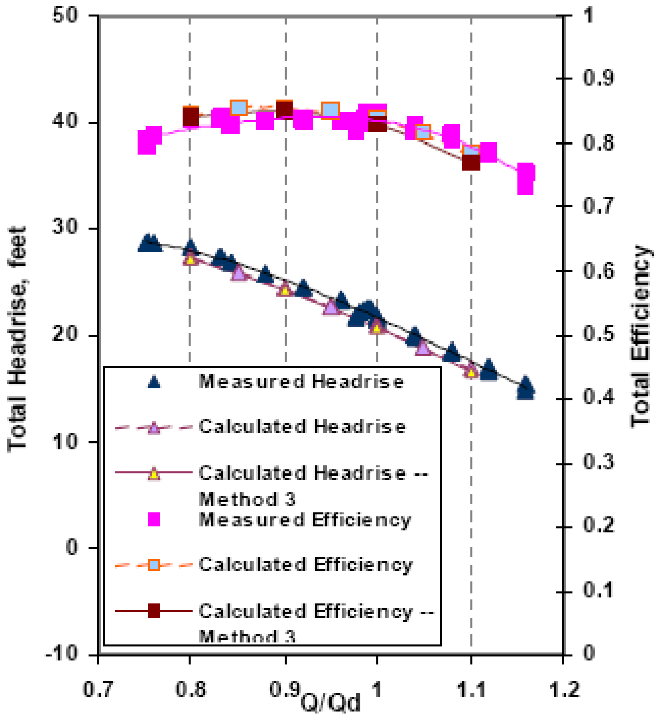


Axial Flow WJ



(Lavis, et al. 2007)

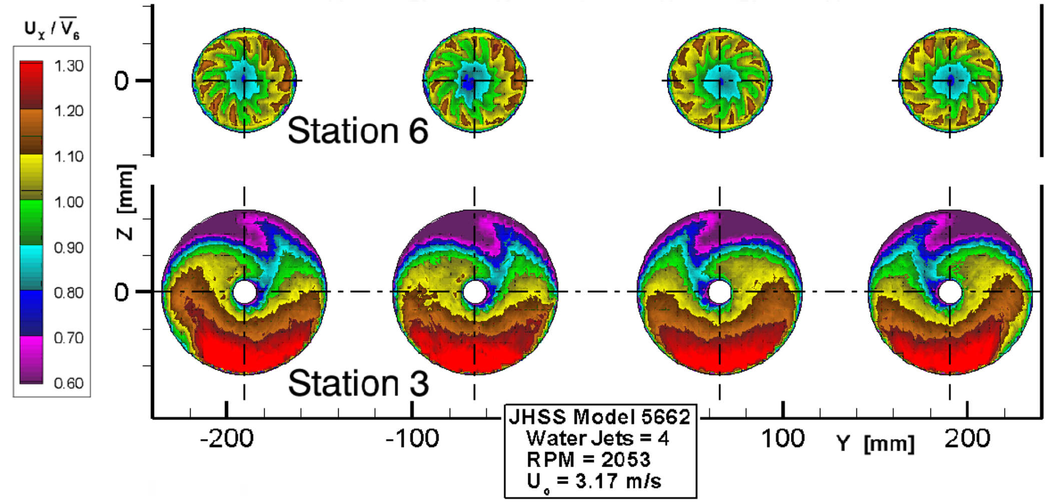




RANS Computation (Brewton, et al. 2006)

- Bulten and Verbeek (2007): axial-flow waterjet at Wärtsila company, LJX and WLD series. Better cavitation performance than equivalent mixed-flow WJ for similar efficiency.

Axial-Flow Waterjet

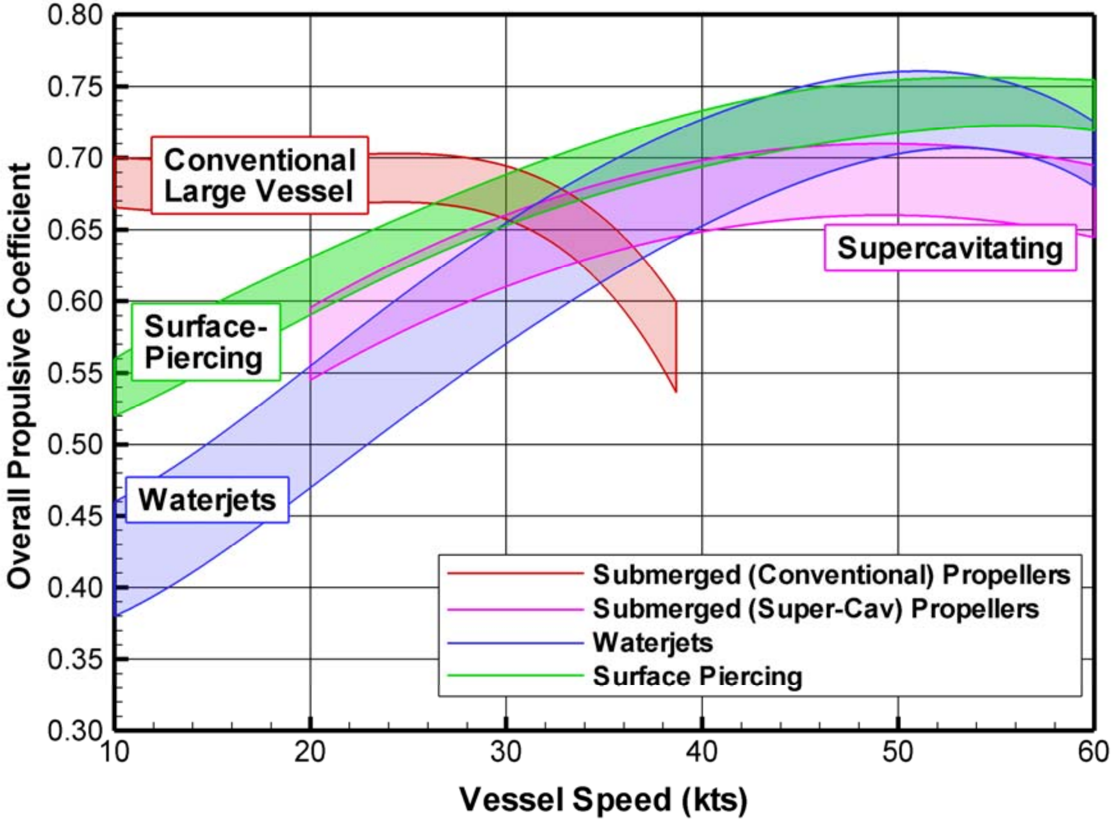


LDV Measurements of flow inside the Waterjet Duct (Jessup, et al. 2008)

Cusanelly, *et al*., (2007)

- Cusanelly, *et al*., (2007): comparative evaluation of powering performance of large high-speed sealift ship with conventional shafts and struts, mixed-flow WJ, and axial-flow WJ
- Jessup, et al. (2008): detailed performance analysis and archival-quality LDV flow measurements inside the waterjet ducts.

Advanced Blade Sections

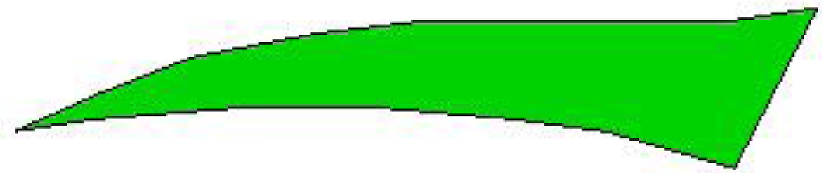


Black, et al. (2006)

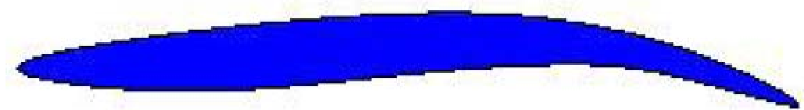
Can we design a propeller to operate ***efficiently*** at low and mid speed range where cavitation is of no concern (like conventional sub-cavitating propellers) but can transition to super-cavitating mode for high speed ***without thrust breakdown***?

Dual-Cavitating Blade Section

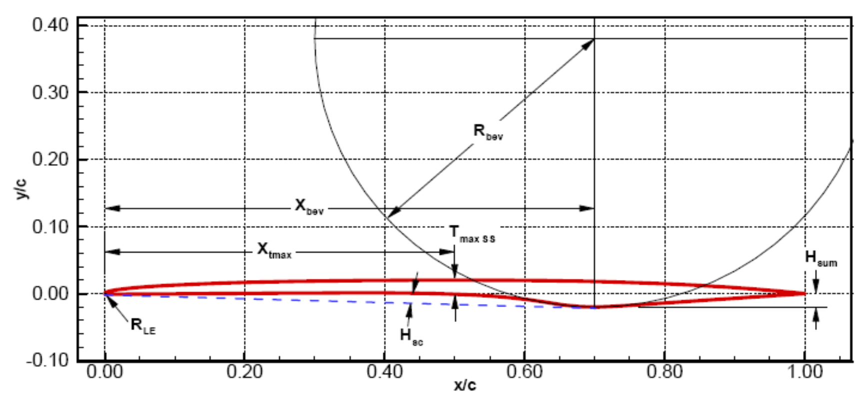
- Newton-Rader (1961)
- Shen (1966)
- Black, et al. (2006)
- Young & Shen (2007): BEM to predict the hydrodynamic and hydro-elastic response of dual-cav. propellers in subcavitating, partially cavitating, and supercavitating conditions.



Typical SCP Blade Section



Dual-Cavitating Blade Section
(Young and Shen, 2007)



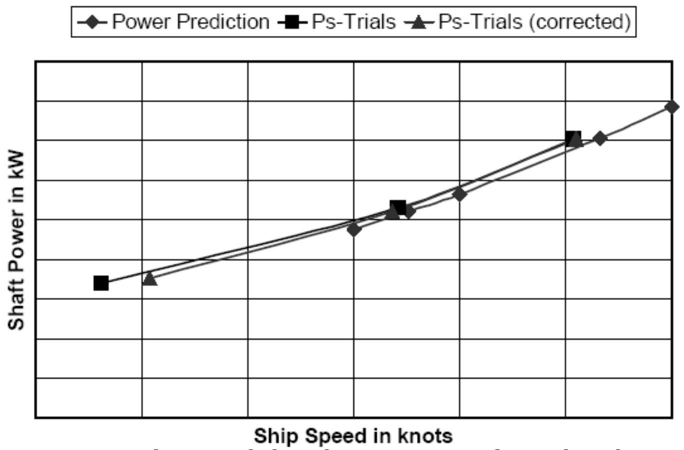
Black, et al (2006)

Full Scale Measurements

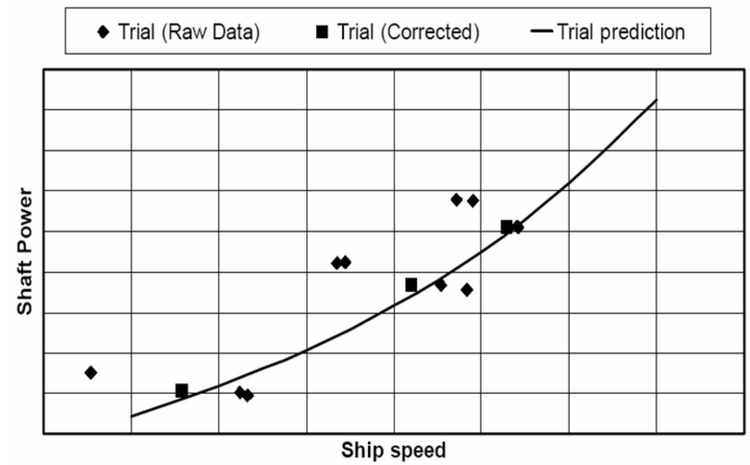
- EROCAV (Erosion on Ship Propellers and Rudders - the Influence of Cavitation on Material Damages) project.
- Ligtelijn, *et al*. (2004): presented a three-year research project, named CoCa (Correlation of Cavitation)
  - Five different ships used in this project
  - All model tests were performed in MARIN
  - Correlation of propulsive performance, propeller cavitation and propeller-induced hull-pressure fluctuations

Full Scale Measurements

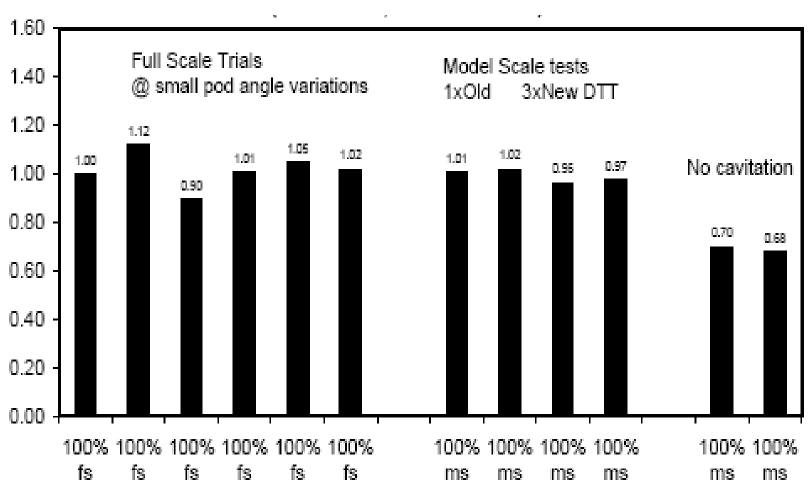
(From Ligtelijn, *et al*., 2004)



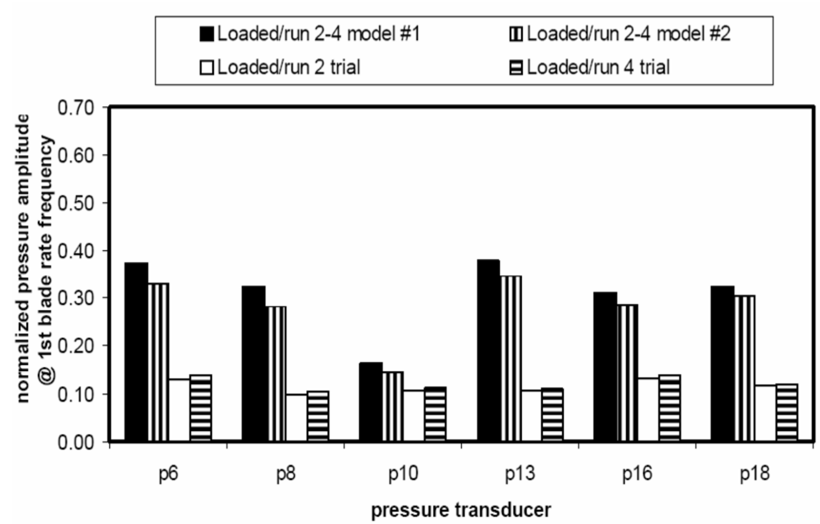
Cruise Ship (Costa Atlantica)



Container Ship (Tasman)



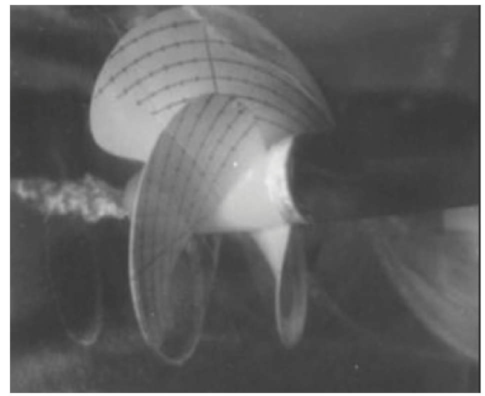
Cruise Ship (Costa Atlantica)



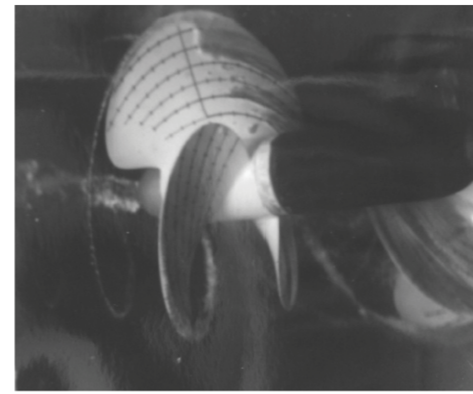
Container Ship (Tasman)

Full Scale Measurements (Cont.)
(From Bobanac, *et al*., 2005)

Cavitation Observation
On Fast Small Ship

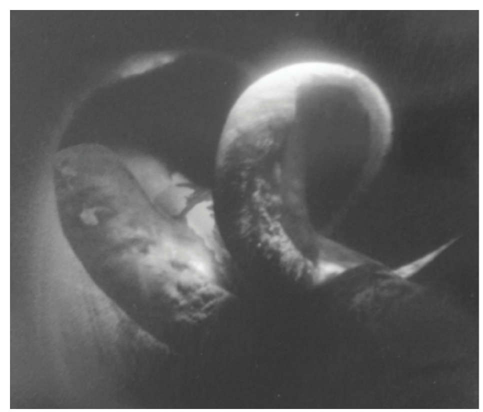


Model (1500 rpm)

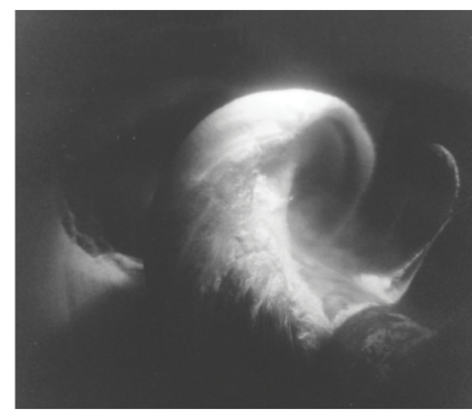


Model (1800 rpm)

- Sampaio, *et al*. (2005): full scale trials for three different hull/propeller roughness conditions on Brazilian patrol vessel Guaporé.



Full Scale



Full Scale

Advances in CFD

- CFD Workshop Tokyo 2005
  - Calm water resistance
  - Self-propulsion performance

KRISO Container Ship Self-Propulsion Characteristics

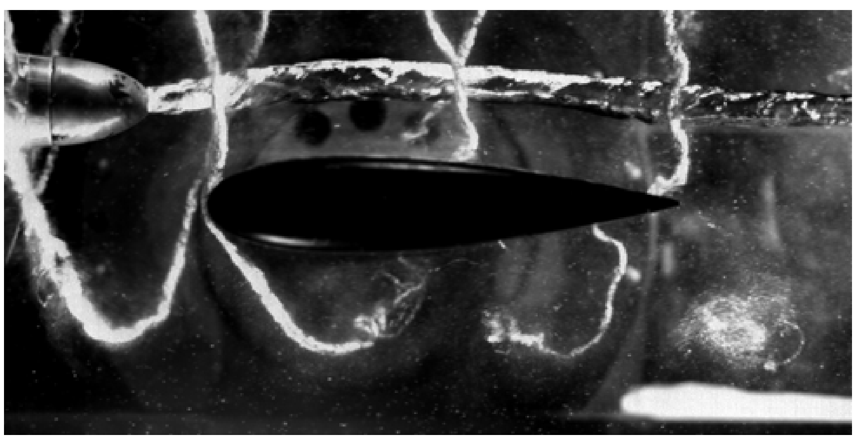
	1-t	$1-w_t$	η_o	η_r	J	n (rps)	η
Exp.	0.853	0.792	0.682	1.011	0.728	9.5	0.74
HSVA	0.865	0.789	0.667	0.981	0.725	9.56	0.717
SVA	0.91	0.765	0.614	1.007	0.708	9.5	0.735
KRISO	0.846	0.779	0.671	1.023	0.729	9.38	0.746
OPU	0.852	0.789	0.631	1.074	0.718	9.53	0.732
NMRI	0.85	0.81	0.659	1.01	-	-	0.77
Mean	0.865	0.786	0.648	1.019	0.72	9.49	0.732
S.D.	0.026	0.016	0.025	0.034	0.009	0.08	0.02

(from Kim, et al (2006) and Hino (2006))

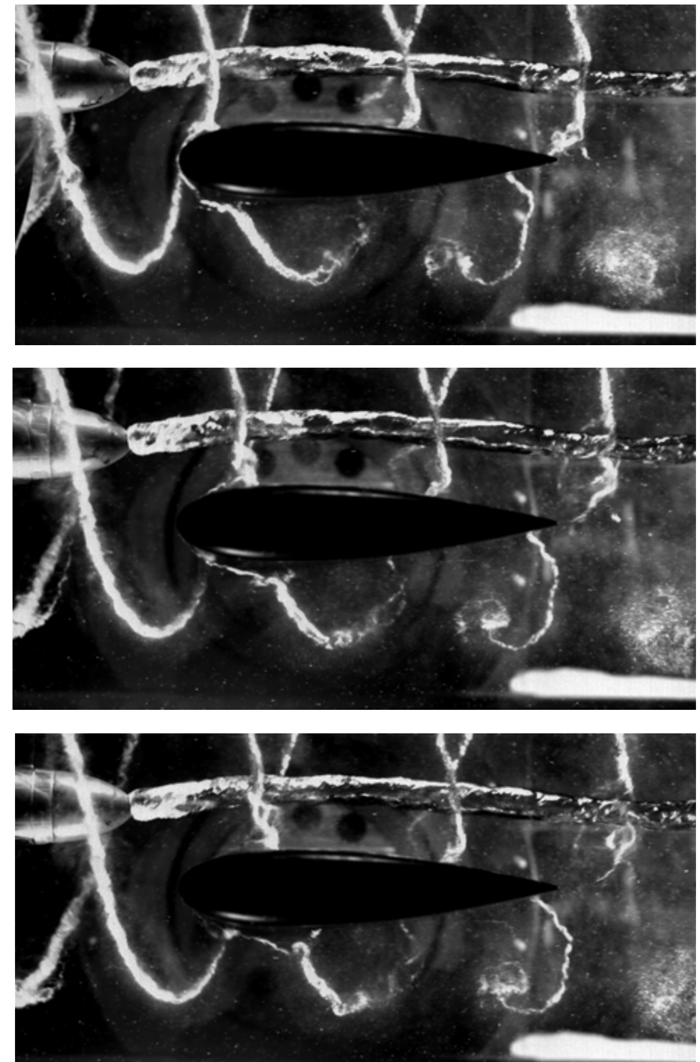
Hull-Propeller-Rudder Interaction

Experiments: Felli, *et al.* (2006): 26th Symp. on Naval Hydro.

Italian Navy Cavitation Tunnel (CEIMM)

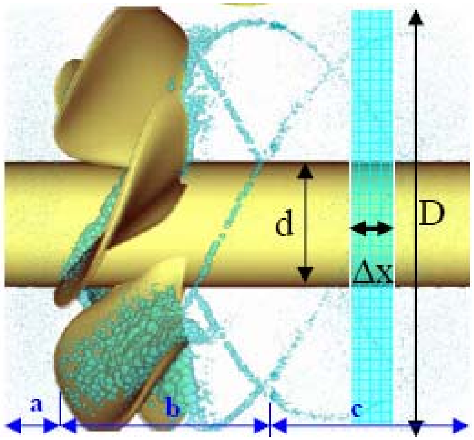


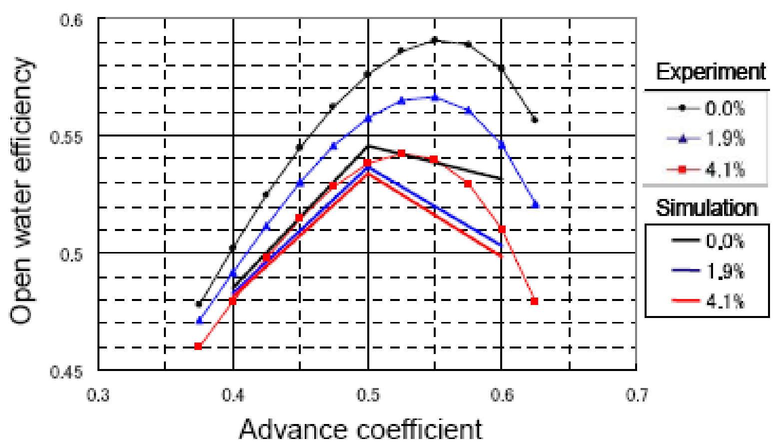
Evolution of Prop Tip Vortex



Bubble-Propeller Interaction

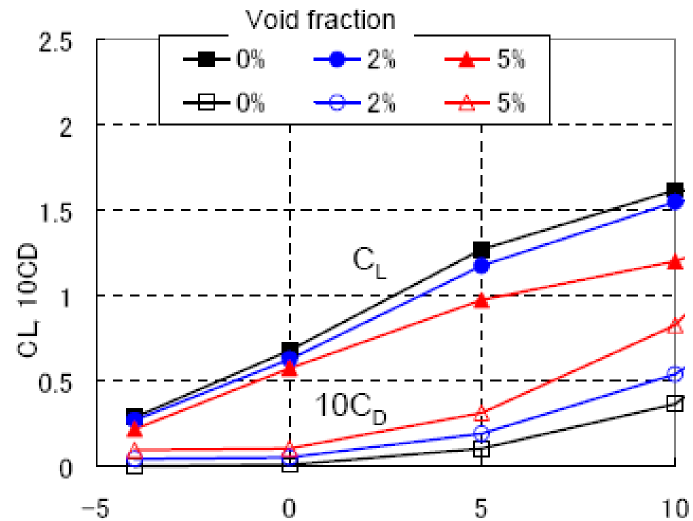
(Hsiao, *et al*. (2006): 26th Symp. on Naval Hydro. Rome)

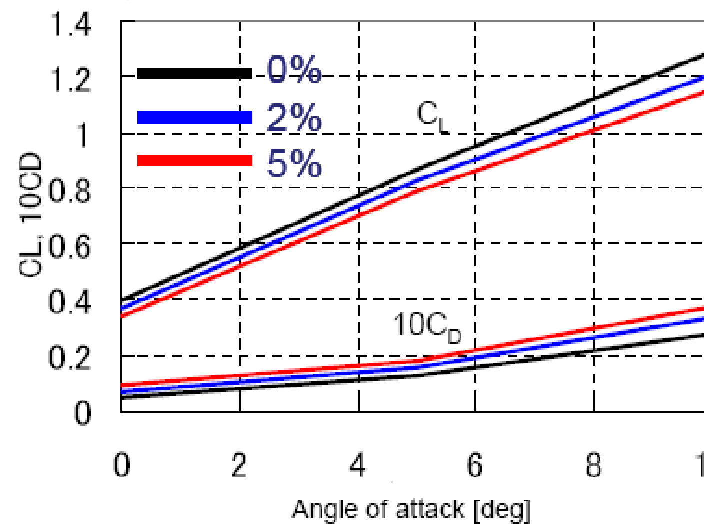




Kawamura, et al. (2007)

(Kawamura, et al. (2007), 5th Joint ASME/JSME Fluids Eng. Conf., San Diego)





Anti-Fouling Paints

- Current anti-fouling paints: toxic copper or Tri Butyl Tin (TBT – SPC)
- IMO & EC: complete ban of using TBT by 2008
- Non-toxic foul-releasing paints under development (silicon based)
  - Atlar, *et al*. (2005): ~150 full-scale props
  - Mutton, *et al*. (2005): R/V Bernicia prop almost intact after 37 months w/o cleaning
  - Atlar, *et al*. (2002, 2003): computations showed 6% efficiency increase with foul releasing paint on a tanker prop
  - Korkut (2007): effects on cavitation and noise, proper coating thickness (particularly trailing edge area) important (to avoid singing)

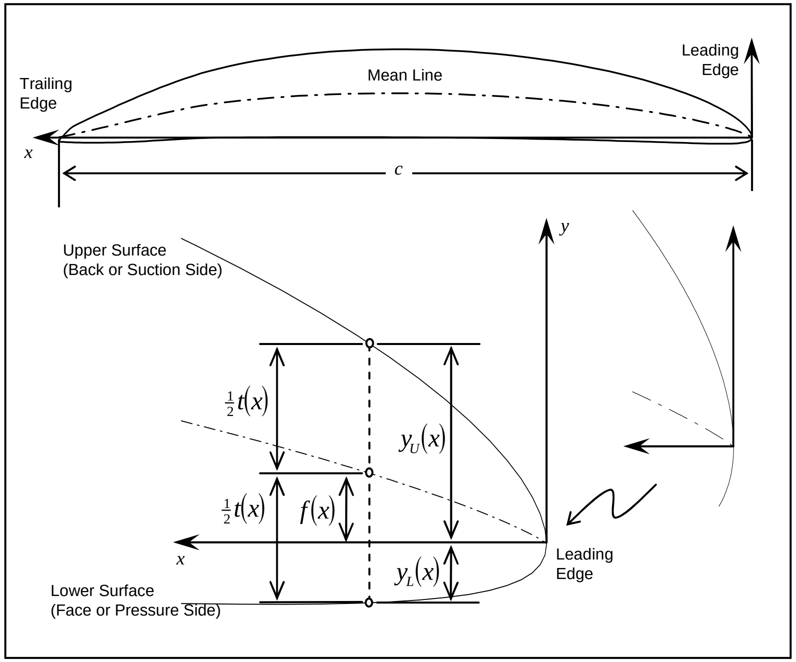
Task 2. Review the ITTC Recommended Procedures

- 7.5-01-02-01: Terminology and Nomenclature of Propeller Geometry (Harmonize with ISO standard)
- 7.5-02-03-01.1: Propulsion Test
- 7.5-02-03-02.1: Propeller Open Water Test
- 7.5-02-03-02.3: Guide for Use of LDV
- 7.5-02-05-02: High Speed Marine Vehicles Propulsion Test.

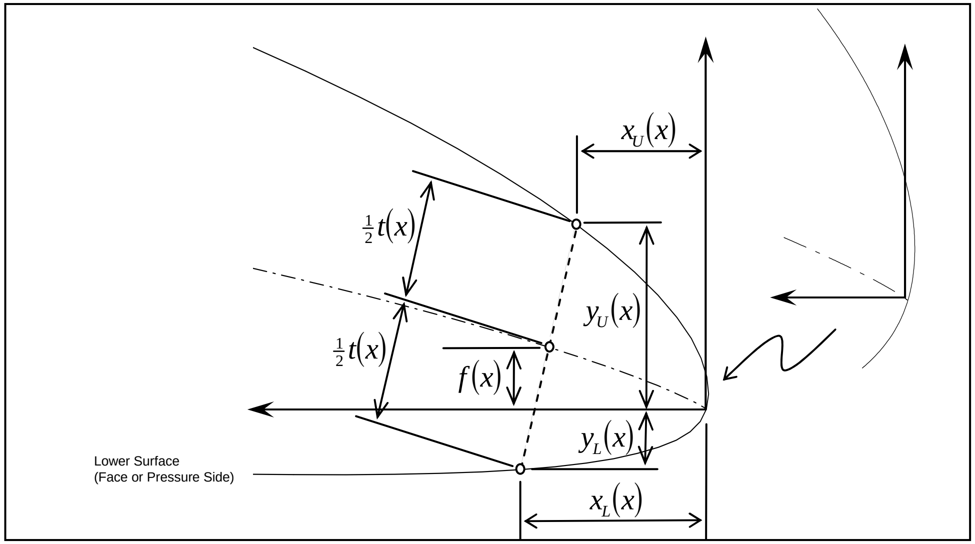
a. Determine if any changes are needed in the light of current practice.
b. In the review and update of the existing propeller open water test procedure 7.5-02-03-02.1 its applicability to new types of propulsors should be taken into account.
c. Identify the requirements for new procedures.
d. Support the Specialist Committee on Uncertainty Analysis in reviewing the procedures handling uncertainty analysis.

(a) 7.5-01-02-01: Propeller Geometry Terminology

- Reviewed and compared the ITTC Propeller Terminology and the ISO 3715-1: 2004 *Vocabulary for geometry of propellers*
  - Both documents contain thorough definitions of propeller geometry
  - ISO Standard: from manufacturing view point
  - ITTC Definitions: from hydrodynamic view point
- Recommended addition of the LE definition to the ITTC Terminology and Nomenclature



Thickness added normal to the nose-tail line



Thickness added normal to the mean line

(a) 7.5-01-02-01: Propeller Geometry Terminology

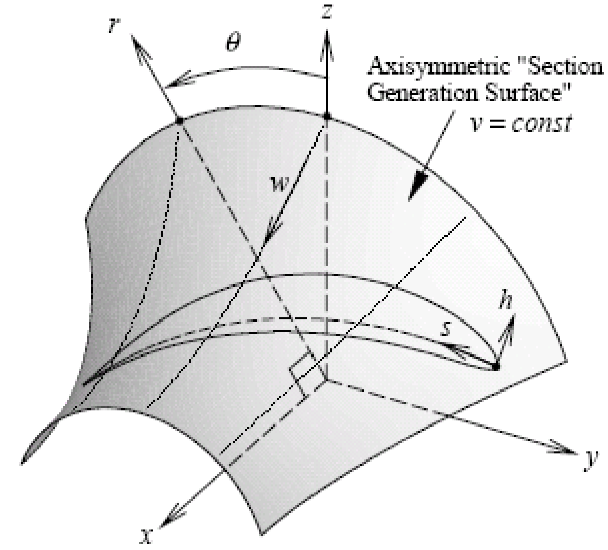
Prop Geometry for Non-Cylindrical Sections

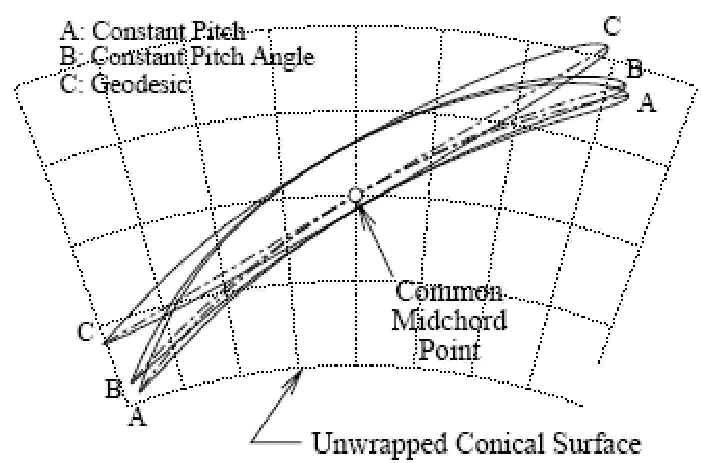
Prop Geometry on Cylindrical Sections not Adequate for

- Podded Propulsor: highly tapered hub
- Ducted Propeller: tapered tip boundary

Neely (1977) proposed:

- Constant Pitch Method: r tanϕ = const.
- **Constant Pitch Angle Method: ϕ = const.**
- Geodesic Method: r cosϕ = const.





Neely (1977): Prop/Shafting '97 Symp

(b) 7.5-02-03-01.1: Propulsion Test

Special Propulsion Test Cases

- Podded Propulsor
- CRP Pod Propulsor: conventional prop + Azipod
  - *Kawamani, et al. (2005) Japanese Eco-Ship project; Ukon, et al. (2006) TPOD; Sasaki, et al. (2006) TPOD; Veikonheimo (2006)*
- Unresolved Issues
  - *Should the pod be considered as part of the propulsor or as part of the hull?*
    - *E.g. Sasaki, et al. (2006) survey: 76% entire pod as propulsor, 24% pod as an appendage*
  - *Hybrid CRP Pod Propulsor:*
    - *67% prop open water boat for fwd prop, podded prop unit for aft prop*
    - *NMRI: open water test of entire unit (fwd & aft props)*
  - *Scaling the pod drag*
- More to come from the 25th ITTC Specialist Committees on Azimuthing Podded Propulsion

(b) 7.5-02-03-01.1: Propulsion Test (Cont.)

- Bollard pull test
  - Offshore supply vessels, cable laying vessels, escort and harbor tug boats, fishing trawlers, etc.
  - Bollard pull as part of self-propulsion test

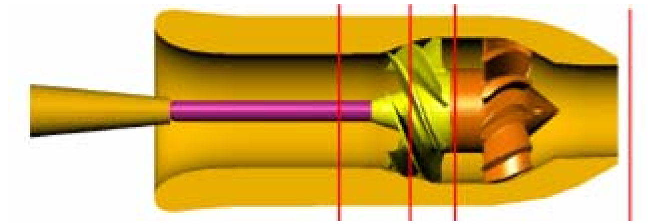
- Recommendation
  - Self-propulsion testing procedure be extended to include the bollard pull testing for open, CRP and ducted propulsors.

(c) 7.5-02-03-02.1: Propeller Open Water Test

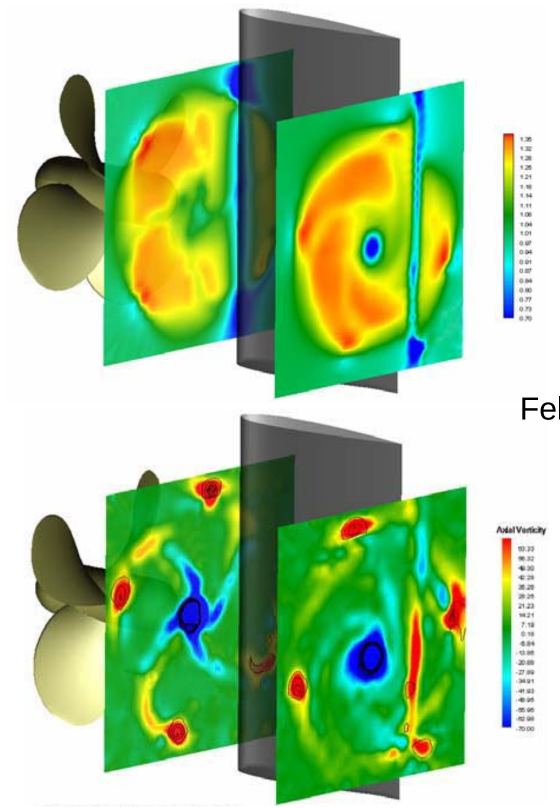
- Editorial changes
- Recommendations
  - Current OW test procedure is only for towing tank
  - Add a procedure for open water test in the water tunnel
    - Proper accounting for blockage effects

(d) 7.5-02-03-02.3: Guide for Use of LDV

- Current Propulsion Committee: no technical expertise to intelligently review the current procedure and provide guidance. Instead, reviewed major efforts using LDV and PIV
- LDV and PIV are widely used in both water tunnel and towing tank
- Michael and Chesnakas (2004): flow in the waterjet (LDV)
- Abdel-Maksoud, *et al*. (2004): hub vortex flow (LDV)
- Felli, *et al*. (2006): propeller-rudder wake flow (LDV)



Michael and Chesnakas (2004)



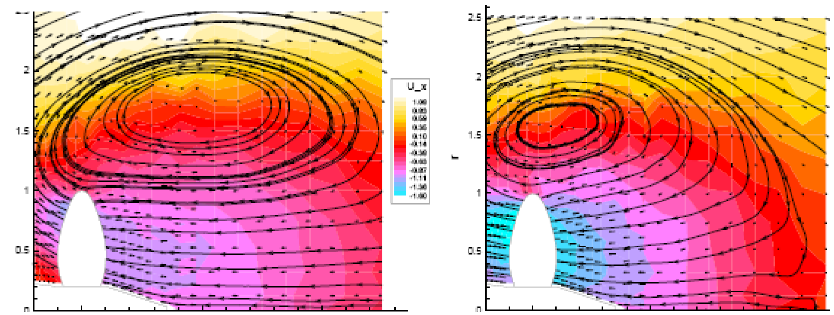
Axial Velocity

Felli, et al (2006)

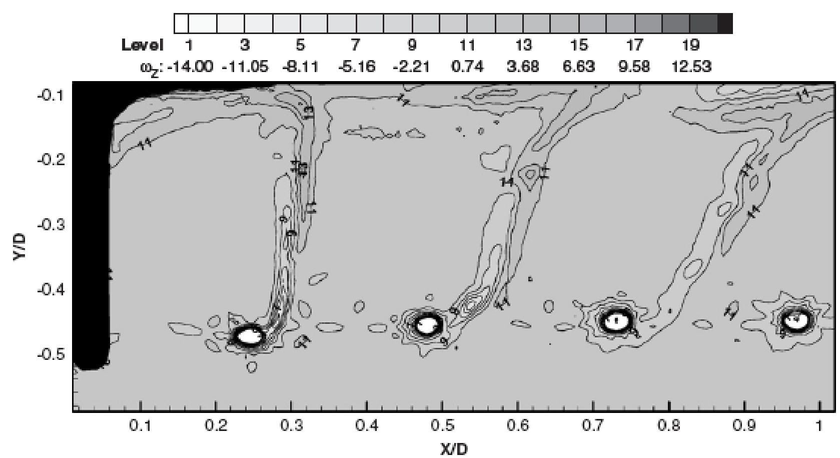
Vorticity

(d) 7.5-02-03-02.3: Guide for Use of LDV (cont.)

- Jessup, et al. (2004): open prop in extreme off-design condition & crashback flow (LDV/PIV)
- Atlar, *et al*. (2007): podded prop downstream flow (LDV)
- Lubke and Mach (2004): wake of the propelled KCS model (LDV)
- Jessup, et al. (2007): ducted prop crashback flow (LDV/PIV)
- Paik, et al. (2007): prop wake (PIV)
- Suggestion
  - Specialist Committee on advanced optical measurement techniques, including LDV/PIV



Jessup, et al. (2004)



Paik, et al. (2007)

(e) 7.5-02-05-02: High Speed Marine Vehicles (HSMV) Propulsion Test

- Details of procedure enhanced to match with other high speed test procedures
- Definition of HSMVs
  - Mono-Hull: planing vessels, round-bilge semi-displacement craft
  - Multi-Hull: SWATH, Catamarans, Trimarans
  - Hydrofoil
  - Air Cushion Supported Vehicles: ACV, SES
  - Excluded waterjet-propelled vessels
- Definitions of High Speed (for design speed)
  - $Fn > 0.45$
  - $Vs > 3.7 \nabla^{1/6}$ (m/s)
  - Qualitative: conditions where high trim angles are expected or for dynamically supported vessels
- More work required for effects of shaft inclination on actual effective wake analysis

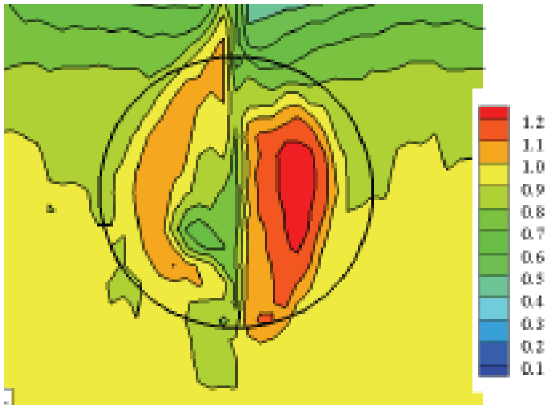
Task 3. Benchmark Validation Data

- Major International Workshops for CFD Validations
  - CFD Workshop Tokyo 2005: Hino (2005)
    - Calm water resistance and self-propulsion performance
  - SIMMAN Workshop 2008: Denmark
    - Maneuvering performance with and without propeller effects

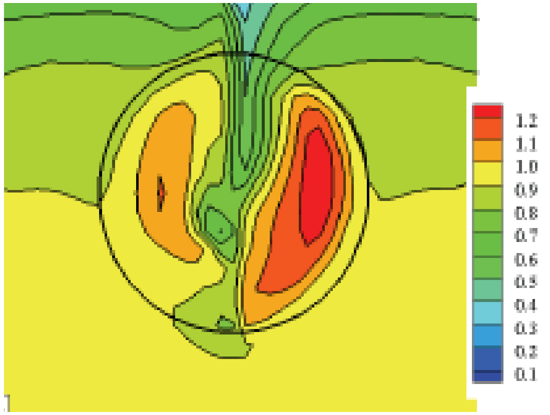
- Major ITTC Benchmark Data for CFD Validations
  - KRISO containership (KCS) self-propulsion test data: CFD Workshop Tokyo 2005
  - Collaborative ship maneuvering test data: SIMMAN Workshop (2008)
  - Propeller-rudder-hull Interactions data on MOERI 138K LNG Carrier (KLNG): Kim, et al. (2007)
  - PIV data for crashback flow for open and ducted propulsors: Jessup, et al. (2004, 2006)

Hull-Propeller-Rudder Interaction

MOERI (formerly KRISO) LNG Carrier (138,000 m^3)

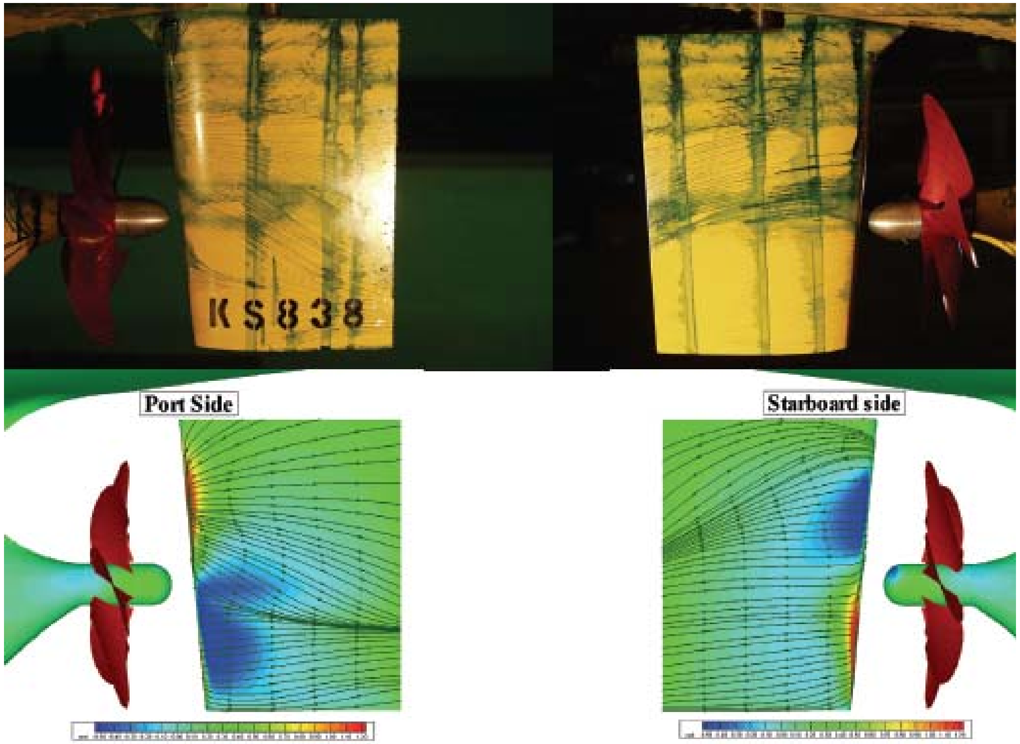


Experiments



Computations

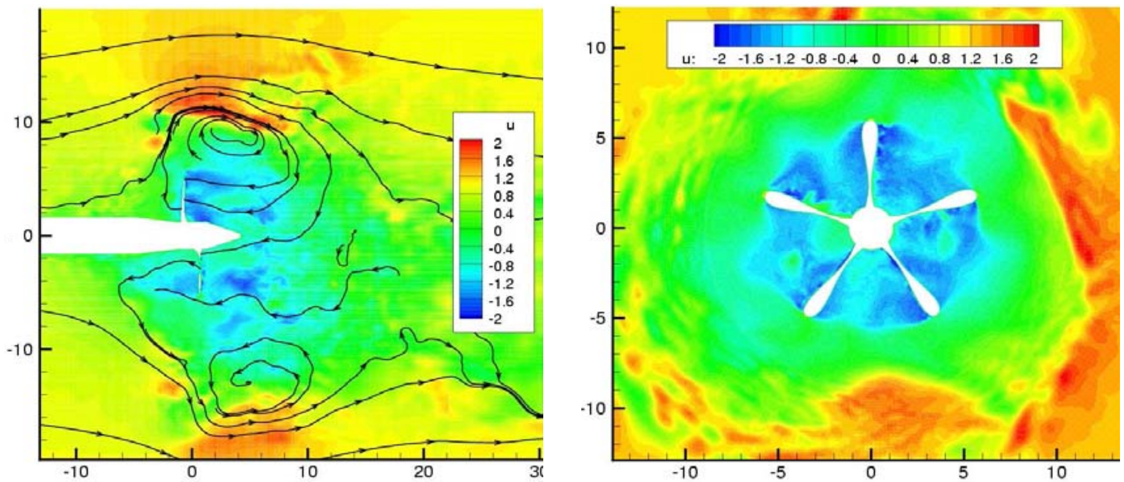
(Axial Velocity Right Behind Rudder)



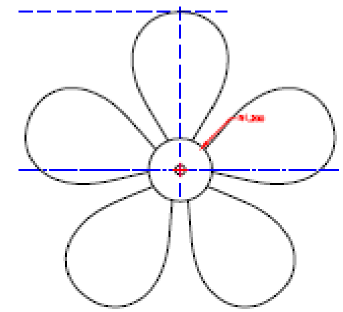
Streamlines on the Rudder Surface (Self-Propulsion Condition)

(Kim, et al. 2007: 9th Int'l Conf. on Num. Ship Hydro, Ann Arbor)

LES Simulation of Crashback (Open Prop)



Axis Velocity and Instantaneous Streamlines
(J = -0.7, Rn = 480,000)

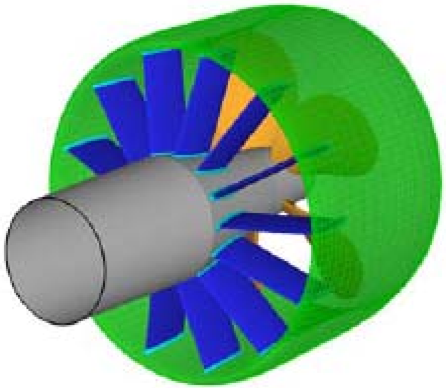


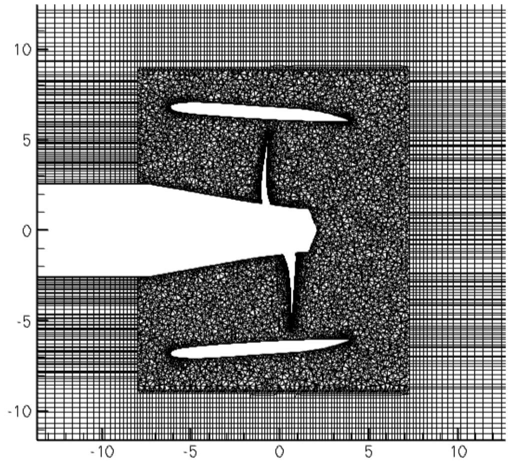
DTMB 36-in Water Tunnel

	K_T	K_Q	K_{fy}	K_{fz}
Mean (LES)	-0.38	-0.072	0.004	-0.002
Mean (Exp.)	-0.33	-0.065	0.019	-0.006
RMS (LES)	0.067	0.012	0.061	0.057
RMS (Exp.)	0.06	0.011	0.064	0.068

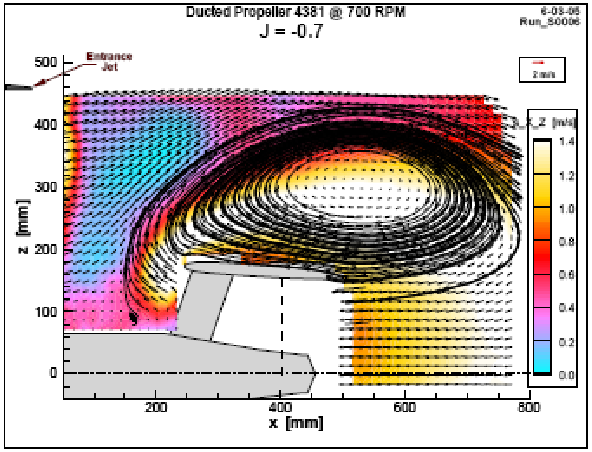
(Vysohlid & Mahesh, 2006
26th Symp. on Naval Hydro., Rome)

Crashback Flow around Ducted Prop

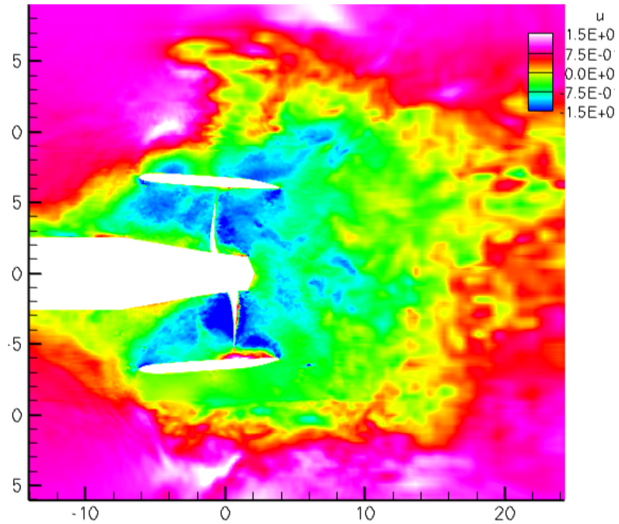




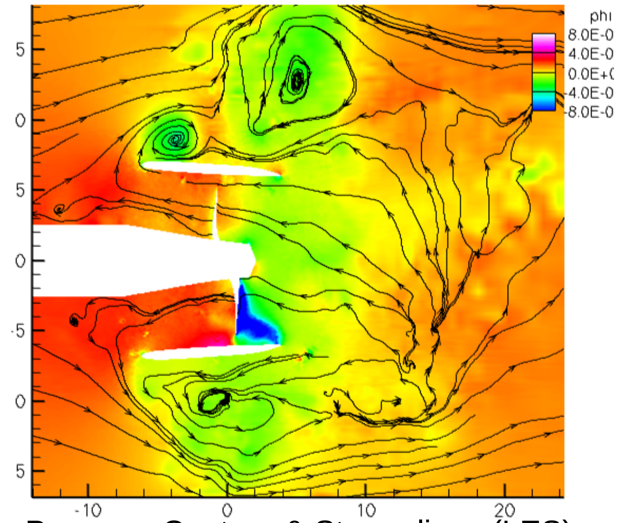
LES Mesh



Jessup, et al,



Axial Velocity (LES)



Pressure Contour & Streamlines (LES)

(J = -0.7, Rn = 480,000)

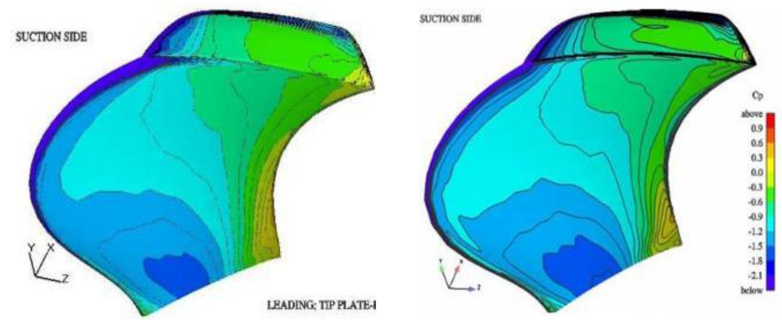
(Jang & Mahesh, 2008, 27th Symp on Naval Hydro, Seoul)

Task 4. Unconventional Propulsors

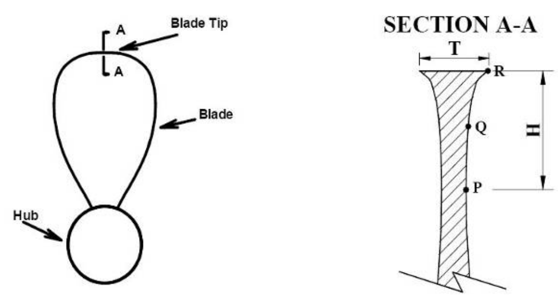
- Previous Reviews
  - *21st Propulsor Committee* (1996): CR prop, vane wheel, end plate prop, podded prop, boss cap fin, pre-swirl stator, ducted prop and ring prop
  - *22nd ITTC* (1999) Specialist Committee on Unconventional Propulsors: reviewed and evaluated propulsion tests and extrapolation methods for these unconventional propulsors
  - *23rd Propulsor Committee* (2002): composite prop
  - *24th Propulsion Committee* (2005): waterjets, podded prop, tip plate prop, rim-driven prop, trans-cavitating prop and composite
- *25th Propulsion Committee* (2008): tip-rake/plate prop, surface-piercing prop, super-cavitating prop, composite prop, bio-memetic propulsion

Tip Rake/Plate Propeller

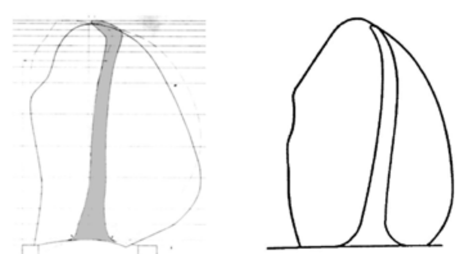
- Sánchez-Caja, *et al*. (2006a): flow around end-plate prop using RANS
- Chen, C.T. *et al*. (2006): tip fillet prop
- Yamasaki and Okazaki (2007): straight leading-edge prop (SLEP) & backward tip rake prop (BTRP)
- Kuiper, *et al*. (2006): parametric study of tip rake for tip vortex cavitation



Model & Full-Scale Pressure Distribution (Suction Side)
Sánchez-Caja, *et al*. (2006)



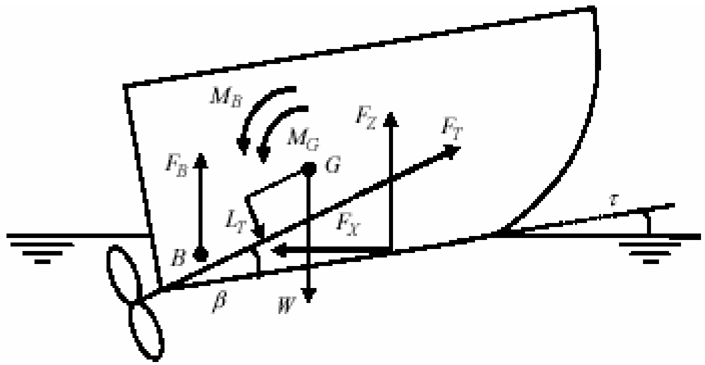
Tip Fillet Prop
(Chen, C.T. *et al*., 2006)

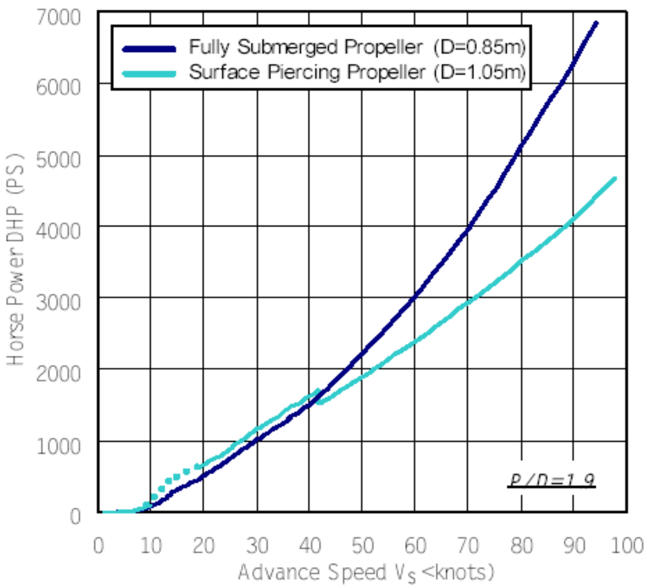


Kuiper, *et al*.
(2006)

Surface-Piercing Propeller (SPP) & Super-Cavitating Propeller (SCP)

- Young (2004): coupled BEM/FEM for time-dependent hydroelastic response of SPPs.
- Nozawa and Takayama (2005): running attitude of the high speed craft with SPP.

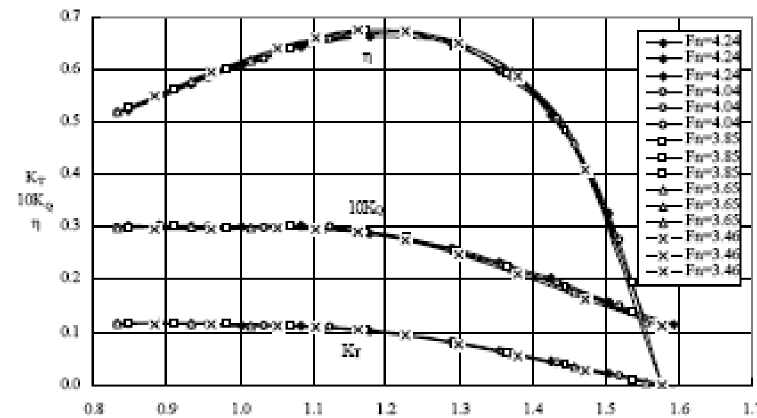




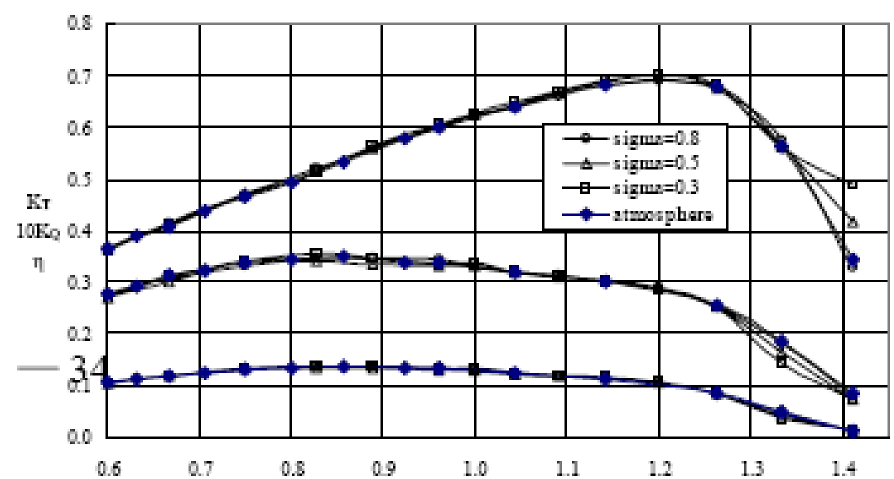
Nozawa and Takayama (2005)

Surface-Piercing Propeller (SPP) & Super-Cavitating Propeller (SCP) (cont.)

- Ding (2007): recent research on SPP at China Ship Scientific Research Center (CSSRC)
  - Methodical series of 6-bladed SPPs with varying P/D
  - Open water tests at depressurized tank for different tip submergence
  - Effects of Fn $(V/(gD)^{1/2})$on open water performance
  - Effects of cavitation number



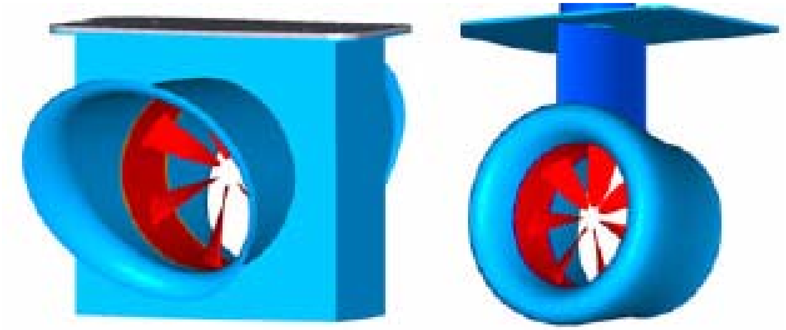
Effects of Fn (V/(gD)1/2)



Effects of σ

Composite Propeller

- Increased interests in composite props
- Surface ships (Büchler and Erdman, 2006) and submarines (Stauble, 2007)
- Advantages over conventional materials prop (e.g. NAB, SS)
  - Light weight
  - Potential cost savings (acquisition & maintenance)
  - High strength and stiffness
  - Tailorability
- Major Issues
  - Cavitation erosion
  - Structural integrity
  - Impact resistance
  - Repairability



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

German Submarine Props
(Stauble, 2007)

Composite Propeller (Cont.)

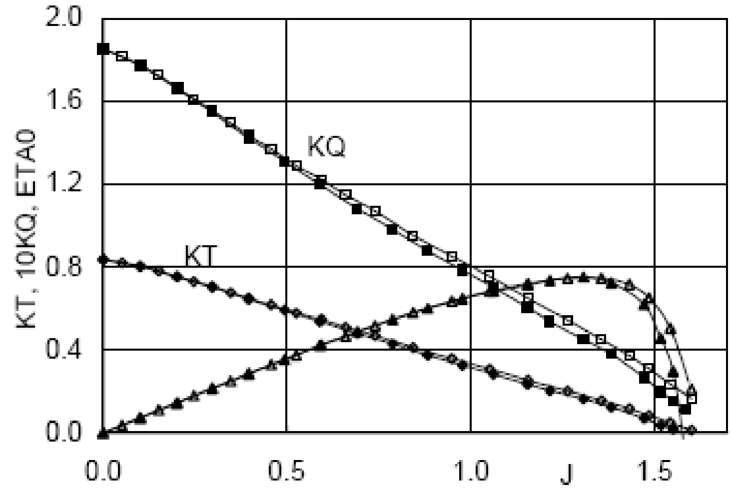
- Recent Papers
  - Büchler and Erdman (2006): various composite props developed by A.I.R. for surface ship applications
  - Stauble (2007): composite props for submarine applications (German 206A and 212A submarines)
  - Chen, et al. (2006): model experimental results of pitch-adapting composite propeller
  - Young (2006, 2007), Young, et al. (2006): coupling of BEM (fluid) and FEM (structure) to analyze fluid-structure interaction of the pitch-adapting composite propeller

Task 5. Propulsion Issues in Shallow Water

- 24th ITTC Propulsion Committee (2005) reviewed the issues
- Limited published activities since then
- Limited demand for operational/design improvements?
- Influence of depth on propulsor performance
  – Effective change in wake at the propulsor plane
  – Effect of wave field on the prop wake ($V/(gh)^{1/2} \sim 1$)
  – Effect of bank suction on trim (planing and semi-planing hulls)
  – Effect on thrust deduction

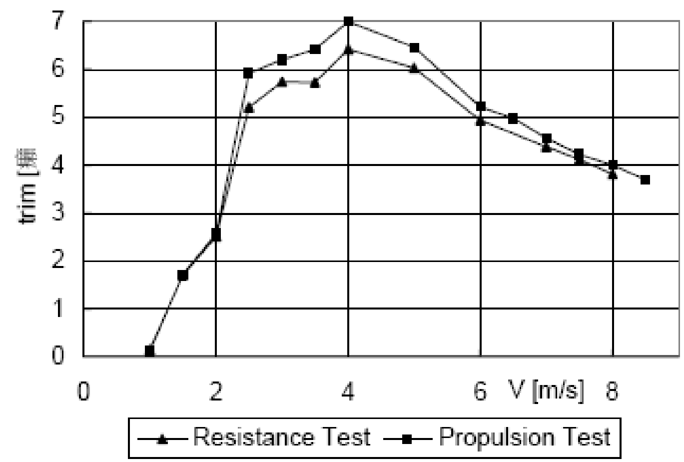
Task 5. Propulsion Issues in Shallow Water (Cont.)

- Self-propulsion testing in shallow water (Friedhoff, *et al*., 2007)
- Low speed maneuvering
- Seabed scour
  - Hamil, et al. (1999): jet effect on scour depth
  - Atlar, et al. (2007): impact of slipstream wash of a podded propulsor
  - Gorski, et al. (2005): prop performance in bollard conditions on shallow water
- Recommendation
  - For crafts exclusively operatign in shallow water, optimal design of hull and propulsor
  - CFD & EFD (LDV, PIV) for propulsor flow in shallow water



(Solid: zero Inclunation, Hollow: 10-deg Inclination)

(Friedhoff, *et al*., 2007)



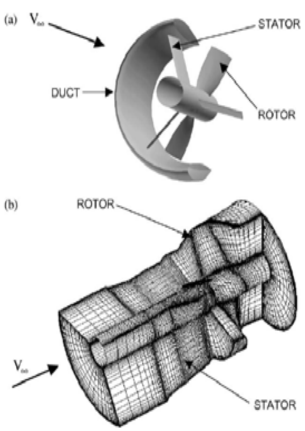
(Friedhoff, *et al*., 2007)

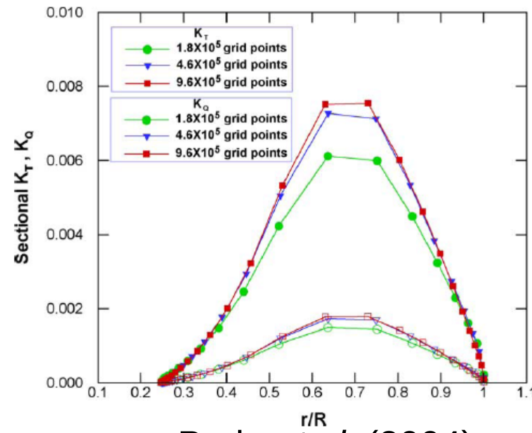
Task 6. Secondary Thrusters Performance and Operational Experience

- Limited data published on secondary thruster performance, no published data to compare operational experience with performance prediction
- Thruster types
  - Tunnel thrusters using controllable-pitch (e.g. dynamic positioning (DP) system), fixed-pitch or rim-driven thrusters
  - AUV (Palmer, et al., 2008): control issues
- Performance issues
  - Conventional ships: only for a short period of time
  - Offshore vessels (DP system): higher duty cycles, thus overall efficiency is more important
- Focus on commercial industry
  - Practical installation issues
  - Reducing noise levels (passenger crafts)
  - Enhancing maneuvering forces

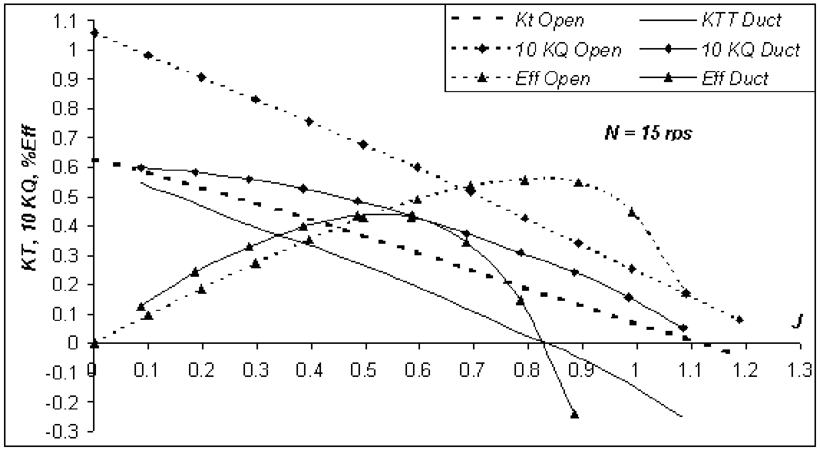
Task 6. Secondary Thrusters Performance and Operational Experience (cont.)

- Exp. & computations for thruster performance
  - Secondary thrusters typically employ two blade rows (stator and rotor)
  - Hydrodynamics: similar to ducted propulsor
  - Park, et al. (2004): ducted prop performance using 3D RANS (rotor-stator interactions)
  - Oweis, *et al*. (2006a,b): ducted prop tip-leakage flow cavitation
  - Lababidy, *et al*. (2006): DP thrusters with & without duct





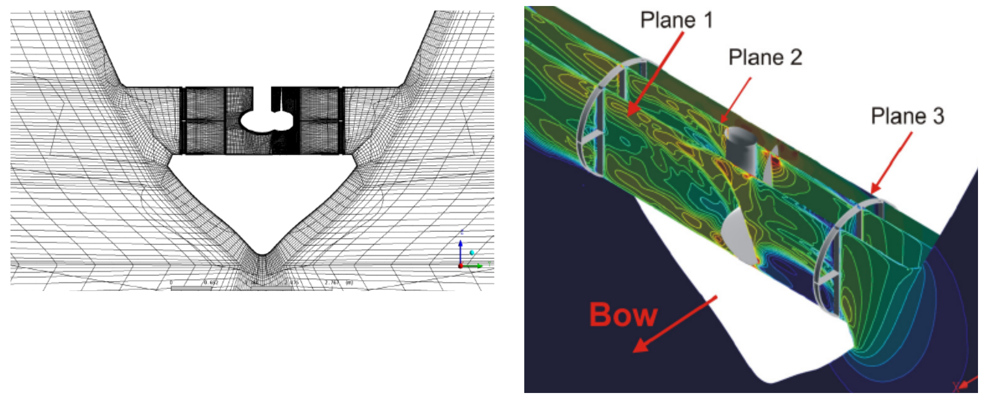
Park, *et al*. (2004)



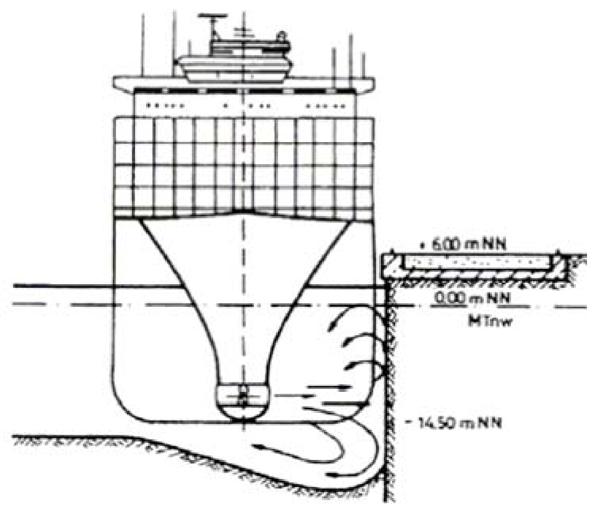
Lababidy, *et al*. (2006) 26th SNH

Task 6. Secondary Thrusters Performance and Operational Experience (cont.)

- Thomas and Schmode (2005): effect of bow thruster shapes (conical, sharp, round entrance) using RANS
- Muller and Abdel-Maksoud (2007): parametric study using RANS; entrance shape, tunnel length, inclination of the vessel side, shape and position of the protective grids.
- Nielsen (2005): exp. on effect of the flow induced by a bow thruster on a vertical quay wall
- **Recommendations**
  - Increased use of CFD for design and performance predictions of thrusters
  - Further research be done on scale effects



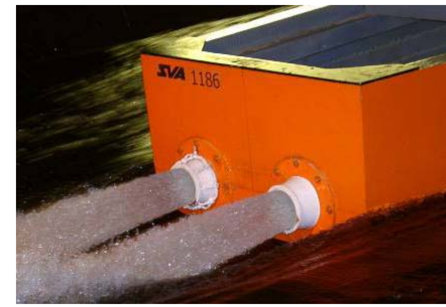
Muller and Abdel-Maksoud (2007)



Nielsen (2005)

Task 7. Finalise the benchmark tests for waterjets and analysis of the data

- Wrap-up of 24th ITTC Waterjet Committee
- 9 Participants: CEHIPAR, HMRI, INSEAN, KRISO (MOERI), KSRI, MARIN, DTMB, SSMB, SVA
- Two identical models were fabricated and circulated: one for European participants and the other for US and Asian participants
- Data from KSRI and SVA added in the current report

R/V Athena (LOW=46.9m), Model (LOW = 5.49m)

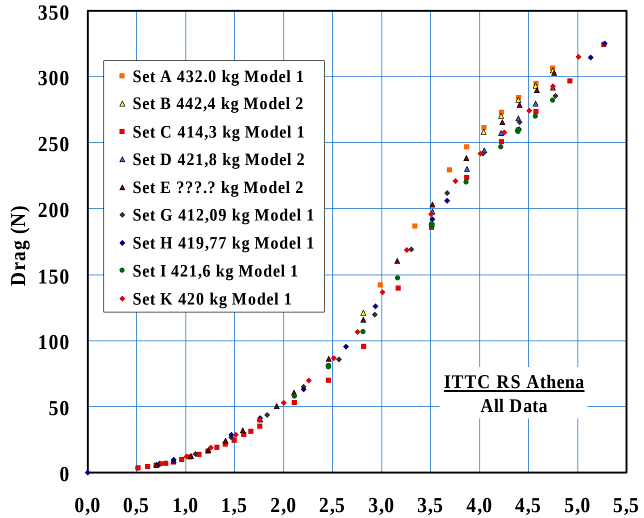
Tasks of the 24th ITTC WJ Committee

- Bare Hull Resistance Tests
- Bare Hull Inlet Velocity Survey
- Working Inlet Velocity Survey
- Jet Velocity Survey
- Momentum Flux Calculations
- Full Scale Predictions

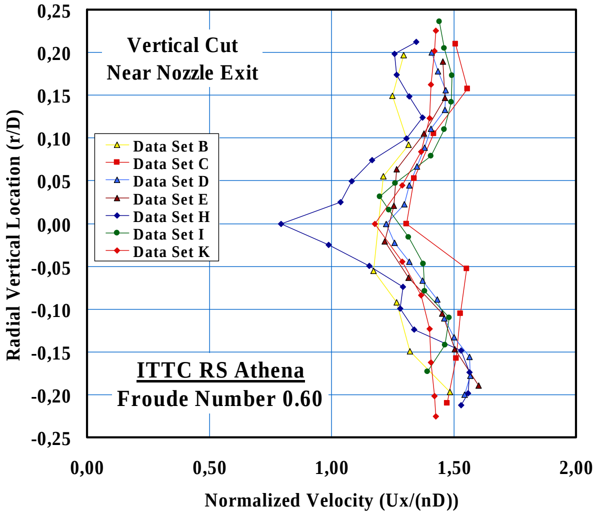
Task 7. Finalize Waterjet Benchmark Tests

- Bare Hull Resistance data
  - Two trend lines: smaller and larger tanks
  - Average resistance measured by smaller tanks is ~7% higher than that by larger tanks
  - Average 4.5% scatter band
  - Smaller basins: 1% scatter
  - Larger basins: 1.7% scatter

- Flow rate estimation by measured jet velocity
  - Large scatter in the measurements (LDV and pitot tubes)



Measured Bare Hull Resistance



Jet Velocity Profiles (at Nozzle Discharge)

Task 7. Finalize Waterjet Benchmark Tests (cont.)

- Effect of New Results from KSRI and SVA
  - Addition of the two new sets of data did not impact the previous conclusions
  - Importance of tow tank blockage effects on resistance test
  - Recommend to incorporate blockage effects in resistance tests
- Major Issues
  - Accurate measurements of flow rate critical to WJ powering performance prediction
    - Running condition at the nozzle exit at design Fn
    - Bollard pull condition
  - Determination of tow force
  - Determination of self-propulsion point
  - Reynolds number scaling
  - Effects of momentum and energy non-uniformity

Observations/Conclusions

- Continued improvements and new developments in advanced propeller concepts
  - axial-flow waterjets, podded propulsors, advanced blade sections, composite propellers and propeller blade coatings
- Rapid advancements in CFD enable predictions of
  - Resistance & self-propulsion characteristics (RANS)
  - Propeller-rudder-hull interactions (RANS)
  - Rn Scale effects (RANS)
  - Highly separated flow around props, e.g. crashback flow (LES)
- Advancements in measurement and flow visualizatioin techniques significantly enhanced our understanding of complex propulsor flow
  - LDV and PIV provide enhanced understanding of tip flow and highly separated flow
  - High-speed video and photography revealed better understanding of the propeller tip vortex evolution and its interaction with and the rudder
- More benchmark model and full-scale data highly desired

Recommendations

- Adopt the updated definitions 7.5-01-02-01: Terminology and Nomenclature of Propeller Geometry.
- Adopt the updated procedure 7.5-02-03-01.1: Propulsion Test.
- Adopt the updated procedure 7.5-02-03-02.1: Propeller Open Water Test.
- Adopt the updated procedure 7.5-02-05-02: High Speed Marine Vehicles Propulsion Test.

Thank you!

ありがとうございました!