Manoeuvring Committee
Report & Recommendations

Andrés Cura Hochbaum

25th International Towing Tank Conference, 14-20 September 2008, Fukuoka

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  7. New experimental techniques
  8. Shallow and confined waters and ship-ship interactions
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  11. **Conclusions**
  12. **Recommendations**

Members

- Andrés Cura Hochbaum, HSVA, Germany, Chairman
- Frederick Stern, University of Iowa, USA, Secretary
- Kristian Agdrup, FORCE Technology, Denmark
- Riccardo Broglia, INSEAN, Italy
- Sun Young Kim, MOERI, Korea
- Pierre Perdon, Bassin d’essais des carènes, France
- Frans Quadvlieg, MARIN, The Netherlands
- Hironori Yasukawa, Hiroshima University, Japan
- Zao-Jian Zou, Shanghai Jiao Tong University, China

Meetings

- INSEAN, Italy, January 2006
- Shanghai Jiao Tong University, China, October 2006
- Bassin d’Essais des Carènes, France, April 2007
- MARIN, The Netherlands, January 2008

All members were present during the meetings

Tasks given to the 25th ITTC MC

1st Task: Update the state-of-the-art

- Potential impact of new developments
- New experimental techniques and extrapolation methods
- Practical application of computational methods
- Need of R&D for improving methods

State-of-the-art thoroughly described in the report

Tasks given to the 25th ITTC MC

2nd Task: Review procedures

7.5-02-06-01, 7.5-02-06-02, 7.5-02-06-03 and 7.5-02-05-05

- Needed changes
- Requirements for new procedures
- Support the SC on UA in reviewing procedures handling UA

3rd Task: Rewrite procedure

7.5-04-02-01

- IMO requirements, high speed crafts, pods, new technologies
- Limiting environmental conditions, corrections

Section 10 reviews the status of the MC procedures

Tasks given to the 25th ITTC MC

4th Task: Critically review examples of validation of manoeuvring prediction techniques. Identify and specify requirements for new benchmark data.

5th Task: Help to organise the workshop on verification and validation of ship manoeuvring simulation methods (SIMMAN).
Assist the workshop organisers in the collection of data for validation of ship manoeuvring simulation methods and make this available to ITTC Members.

Section 5 provides an overview of SIMMAN 2008

Tasks given to the 25th ITTC MC

6th Task: Monitor developments in manoeuvring criteria at IMO and clarify their implications on ITTC

Section 9 reviews the status of standards and safety

7th Task: Give support to the SC on APP in reviewing methods for the prediction of manoeuvring of ships with podded propulsion and investigating manoeuvring criteria for them

MC contacted SC on APP, no support required at this time

Tasks given to the 25th ITTC MC

8th Task: Continue review state-of-the-art for prediction methods and possible criteria for slow speed manoeuvring in shallow and confined water

Section 8 reviews the status of shallow and confined waters

9th Task: Investigate developments on manoeuvring and course keeping in waves. Report on developments and on how these should be taken into account by the ITTC in future

Section 6 reviews the status of manoeuvring in waves

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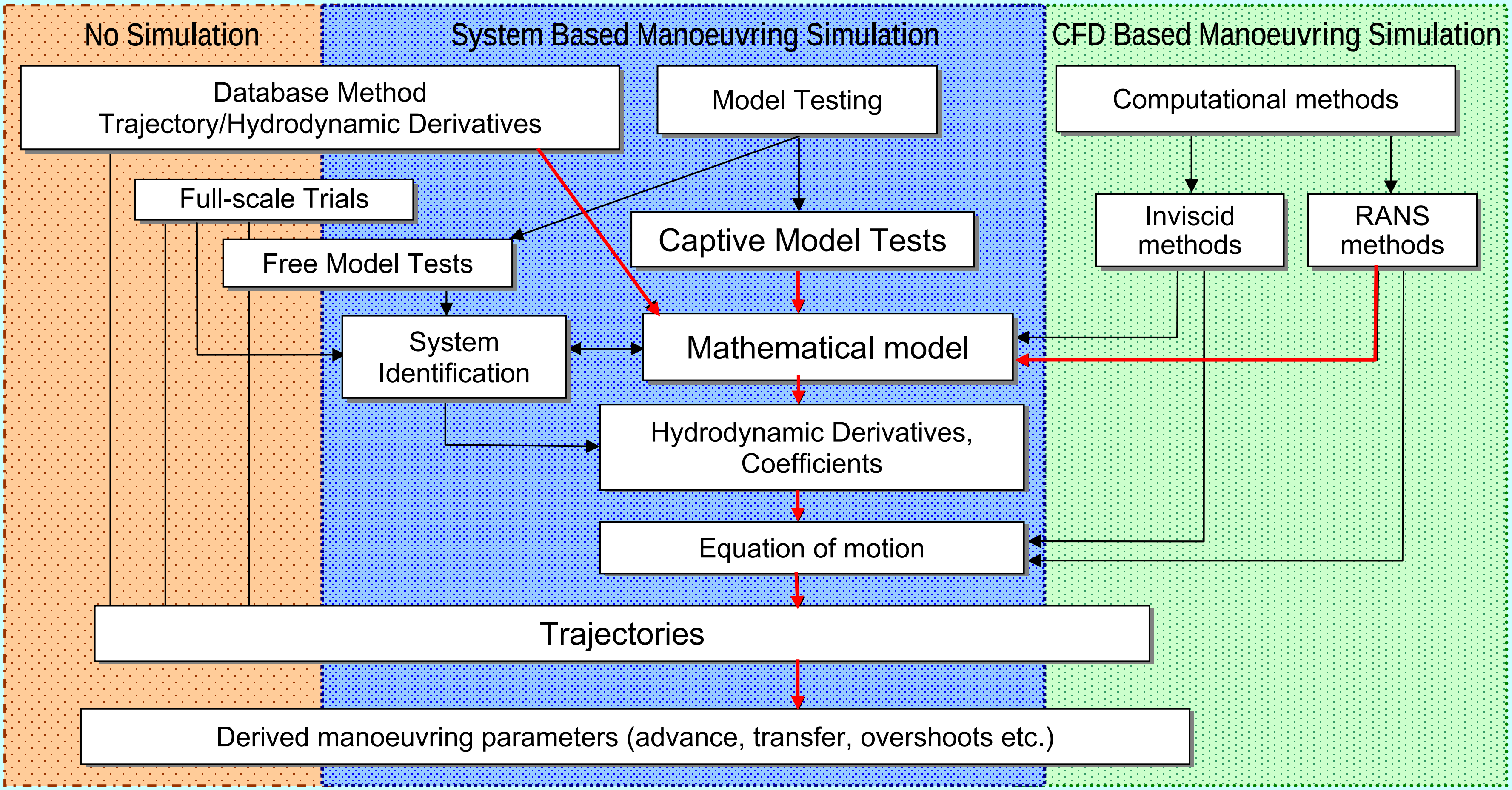
2. Overview of Manoeuvring Prediction Methods



2. Overview of Manoeuvring Prediction Methods (cont.)

Predictions based on free model tests	Answers directly available No explanation for reasons of behavior
Predictions based on captive model tests, followed by simulations	Simulation of (almost) any manoeuvre Answers after post-processing and dependent on mathematical model
Predictions based on Empirical Methods	Very quick, low effort Accuracy, reliability and applicability of answers limited
Predictions based on system identification	Combines advantages of free & captive tests High data quality needed, mathematical model

2. Overview of Manoeuvring Prediction Methods (cont.)

Predictions using viscous flow CFD

Predictions using potential flow CFD

Hybrid methods

No model manufacturing. Physical insight.
Possible for full scale. Good results possible
Quality of answers strongly depend on user.
Required resources can be prohibitive

Faster answers
In general less accurate or even not suitable

Conclusions (Section 2)

Overview of Manoeuvring Prediction Methods

- Amount of methods has significantly grown over last decades
- Possibility to compare and select method depending on advantages and effort for given assignment
- Still difficult to quantify relative accuracy of each method
- Experience of expert remains necessary

3. Progress in System-based Simulation Methods

Conventional vessels

- Free model tests method

  Investigations for getting insight into specific cases reported
- Empirical calculations

  New formula for classical flow straightening coefficient, Aoki (2006)
- CFD calculation technique

  Some works using RANS as a means to increase insight in the coefficients and for improving cross flow drag technique
- Hybrid Methods

  Simulations based on slender body theory and empirical formula, Toxopeus (2006)

3. Progress in System-based Simulation Methods

Conventional vessels (cont.)

- Captive tests and mathematical modelling
  - Experimental technique for CPMC tests in shallow water, Eloot (2006)
  - 6 DOF oscillator, coefficients for seakeeping & manoeuvring, De Jong (2006)
  - Some investigations on the influence of often neglected degrees of freedom
- System identification
  - Some few works reported

High speed vessels / other vessels

More complex studies (often 6 DOF necessary)

Several papers reporting on particular problems, e.g. directional stability

Some new developments for special ships, e.g. tugs, and towed ships

Conclusions (Section 3)

Progress in System Based Simulation Methods

- For conventional vessels methods seem well established for standard manoeuvres
- For less conventional vessels new types of prediction methods reported. They need further development and validation for robust application
- Not much research reported on scale effects
- Validation and documentation needed for math. models used in ship simulators, especially at slow speed and shallow waters

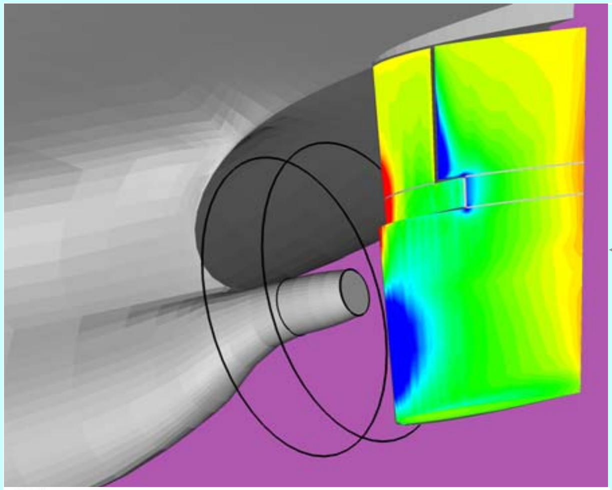
4. Progress in CFD-based Simulation Methods

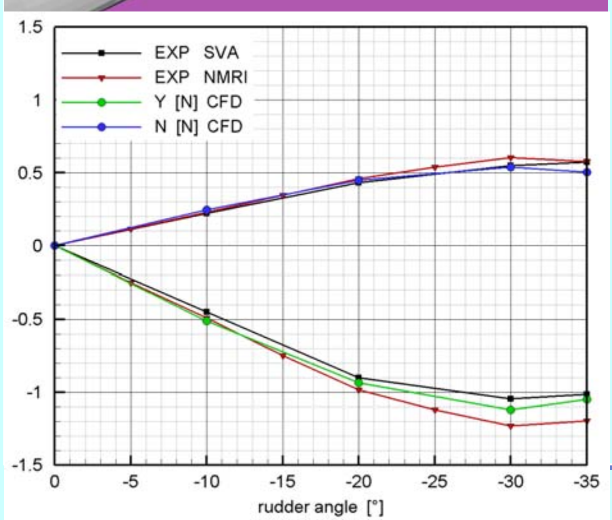
Inviscid Methods

RANS Methods

- Block-structured grids including non-matching interfaces
- Unstructured grids, sliding grids and/or dynamical overset grids
- More robust turbulence models
- Interface capturing techniques
- Moving grids or ship fixed grid and inertial forces for ship motions.
- Body Force models for propeller forces
- Control algorithms for direct manoeuvring simulations

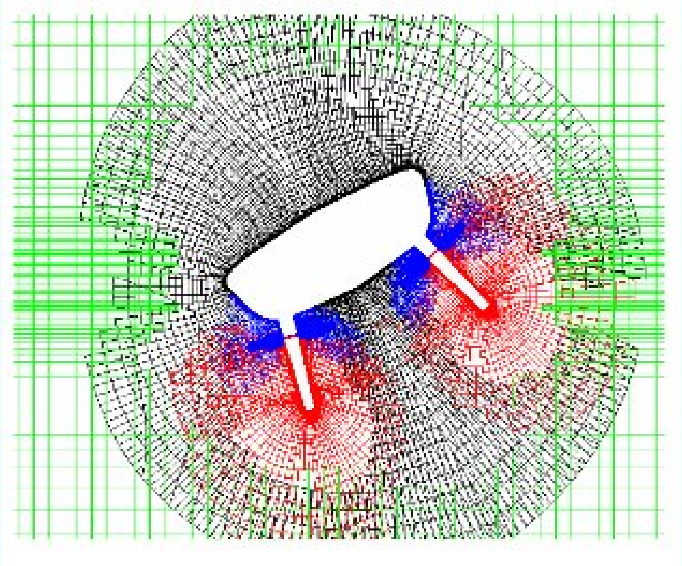
4. Progress in CFD-based Simulation Methods (cont.)





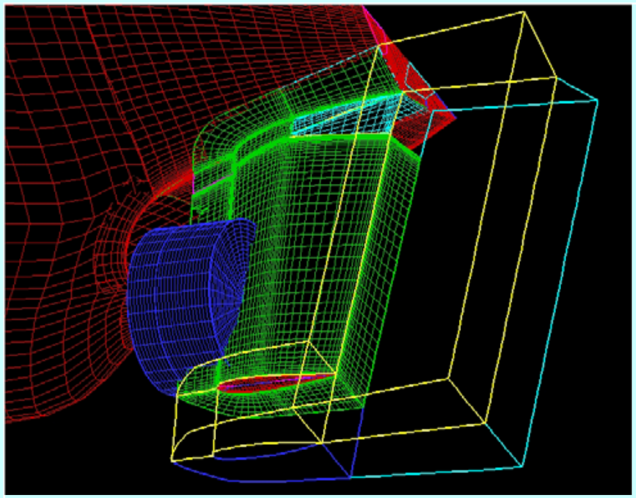
Some examples of RANS simulations

Virtual static rudder angle tests for KCS

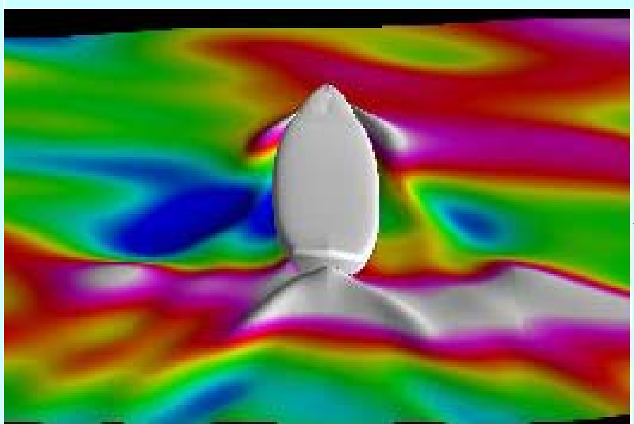


Overlapping grids for simulation of roll motion

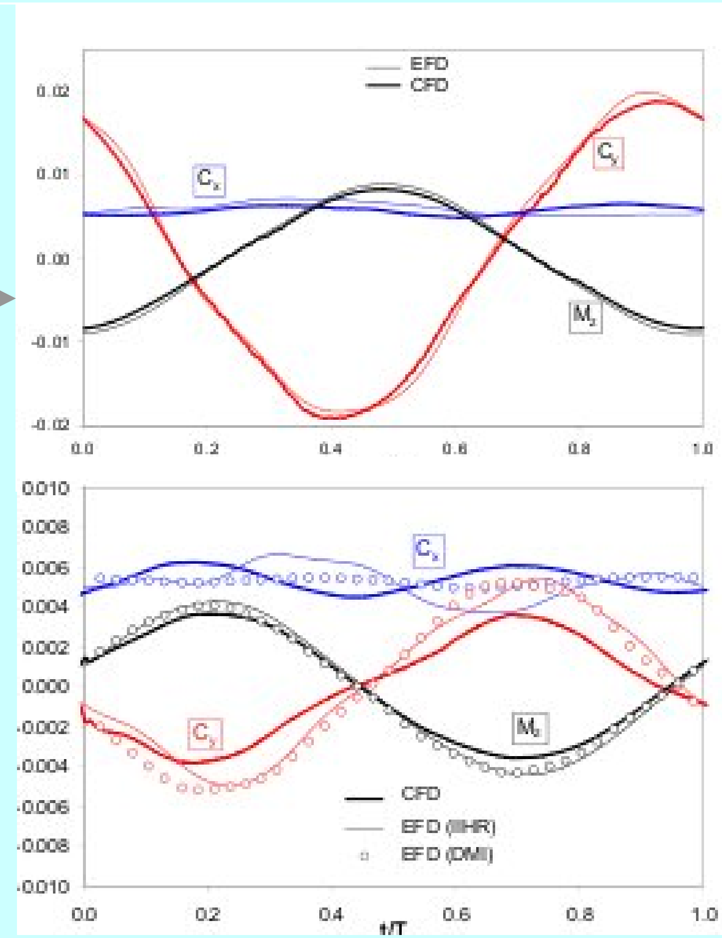
4. Progress in CFD-based Simulation Methods (cont.)



Virtual pure sway and pure yaw test for 5415



Simulation of roll, heave and pitch motion in oblique waves



Conclusions (Section 4)

Progress in CFD Based Simulation

- Rapid development & application has continued. New techniques enable simulations for practical relevant problems
- Prediction based on virtual captive model tests has reached a state which allows practical application
- More development still necessary for accurate predictions in some cases
- Required resources, lack of trained users / user-friendly codes and need for V&V still set the pace for widespread use of CFD in practice
- Codes have to be much faster to make CFD useful for industrial application

5. Validation of Simulations & Benchmark data: SIMMAN 2008

New benchmark ships:

KVLCC 1 & 2

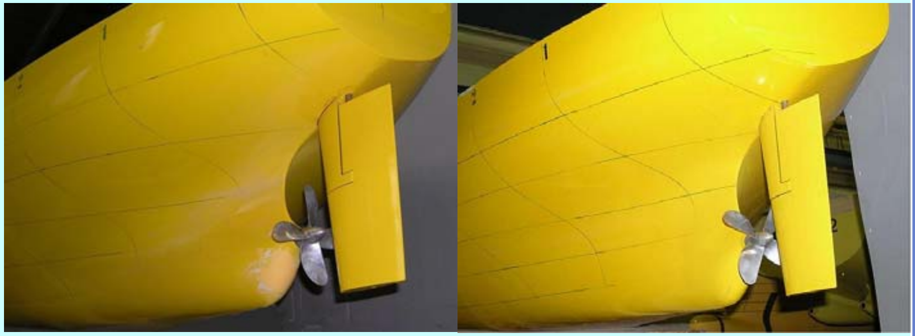
L_{PP} = 320 m

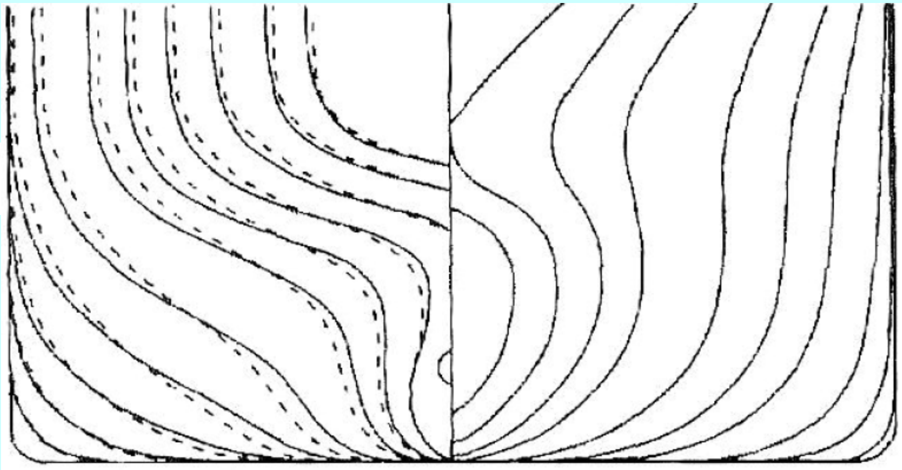
B = 58 m

T = 20.8 m

C_B = 0.81

V = 15.5 kn





Aft body shape influences manoeuvrability

5. Validation of Simulations & Benchmark data: SIMMAN 2008

KCS

L_{PP} = 230 m

B = 32.2 m

T = 10.8 m

C_B = 0.651

V = 24 kn

DTMB 5415

L_{PP} = 142 m

B = 19.06 m

T = 6.15 m

C_B = 0.507

V = 30 kn

No full scale ships have been built for these three hull forms.
However, all relevant ship data and also model test data available to everybody

All information www.simman2008.dk

SIMMAN 2008

Models and model tests overview

Benchmark ship	Model Scale	Model Scale	Model Scale
KVLCC 1 & 2	45,71 (INSEAN)	58,00 (MOERI)	110,00 (NMRI)
KCS	31,60 (MOERI)	52,67 (SVA)	75,50 (NMRI)
5415	35,48 (MARIN)	24,83 (INSEAN)	46,59 (IIHR)

Status April'08

<table>
<tr><th>Hull</th><th>PMM app. deep</th><th>PMM app. shallow</th><th>PMM bare deep</th><th>PMM bare shallow</th><th>CMT app. deep</th><th>CMT bare deep</th><th>Free app. deep</th></tr>
<tr><td rowspan="3">KVLCC1</td><td>MOERI (1999)</td><td rowspan="3">INSEAN (2006)</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">NMRI (2006)</td><td rowspan="3">-</td><td>HSVA (2006)</td></tr>
<tr><td rowspan="2">INSEAN (2006)</td><td>CTO (*) (2007)</td></tr>
<tr><td>MARIN (2007)</td></tr>
<tr><td rowspan="3">KVLCC2</td><td>MOERI (1999)</td><td rowspan="3">INSEAN (2006)</td><td rowspan="3">INSEAN (2006)</td><td rowspan="3">INSEAN (2006)</td><td rowspan="3">NMRI (2006)</td><td rowspan="3">-</td><td>HSVA (2006)</td></tr>
<tr><td rowspan="2">INSEAN (2006)</td><td>CTO (*) (2007)</td></tr>
<tr><td>MARIN (2007)</td></tr>
<tr><td rowspan="2">KCS</td><td rowspan="2">CEHIPAR (2006)</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">NMRI (2005)</td><td rowspan="2">-</td><td>SVA (2007)</td></tr>
<tr><td>BSHC (2007)</td></tr>
<tr><td rowspan="3">5415</td><td>FORCE (2000)</td><td rowspan="3">-</td><td>FORCE (2004)</td><td rowspan="3">-</td><td rowspan="3">MARIN (2007)</td><td rowspan="3">BEC (2006)</td><td rowspan="3">MARIN (2000)</td></tr>
<tr><td rowspan="2">MARIN (2007)</td><td>IIHR (2005)</td></tr>
<tr><td>INSEAN (2005)</td></tr>
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SIMMAN 2008

Test cases for free simulations

Hull	Test type	Approach speed	Helm rate
KVLCC1 KVLCC2	10/10 zig-zag	15.5 kn	2.32 deg/s
	20/20 zig-zag		
	5, 10, 20, 35 deg turning circle		
KCS	10/10 zig-zag	24.0 kn	2.32 deg/s
	20/20 zig-zag		
	5, 10, 20, 35 deg turning circle		
5415	10/10 zig-zag	30.0 kn	9.0 deg/s
	20/20 zig-zag		
	5, 10, 20, 35 deg turning circle		

Validation of manoeuvring simulation methods

SIMMAN 2008

Test cases for forced motion simulations

Hull form	Simulation conditions	Test type	Test condition
KVLCC1, KVLCC2	Appended Heave and pitch free; roll fixed	Static rudder	$\delta = 0°$
			$\delta = 10°$
		Static drift	$\beta = 12°$
		Pure sway	$v' = 0.0852$
		Pure yaw	$r' = 0.30$
KCS	Appended Heave and pitch free; roll fixed	Static rudder	$\delta = 0°$
			$\delta = 10°$
		Static drift	$\beta = 8°$
		Pure sway	$v' = 0.140$
		Pure yaw	$r' = 0.40$
5415	Bare Hull Fixed	Static drift	$\beta = 10°$
		Pure sway	$v' = 0.174$
		Pure yaw	$r' = 0.30$
	Appended Heave and pitch free; roll fixed	Static drift	$\beta = 10°$
		Pure sway	$v' = 0.174$
		Pure yaw	$r' = 0.410$

Validation of CFD based methods

SIMMAN 2008 — Submissions

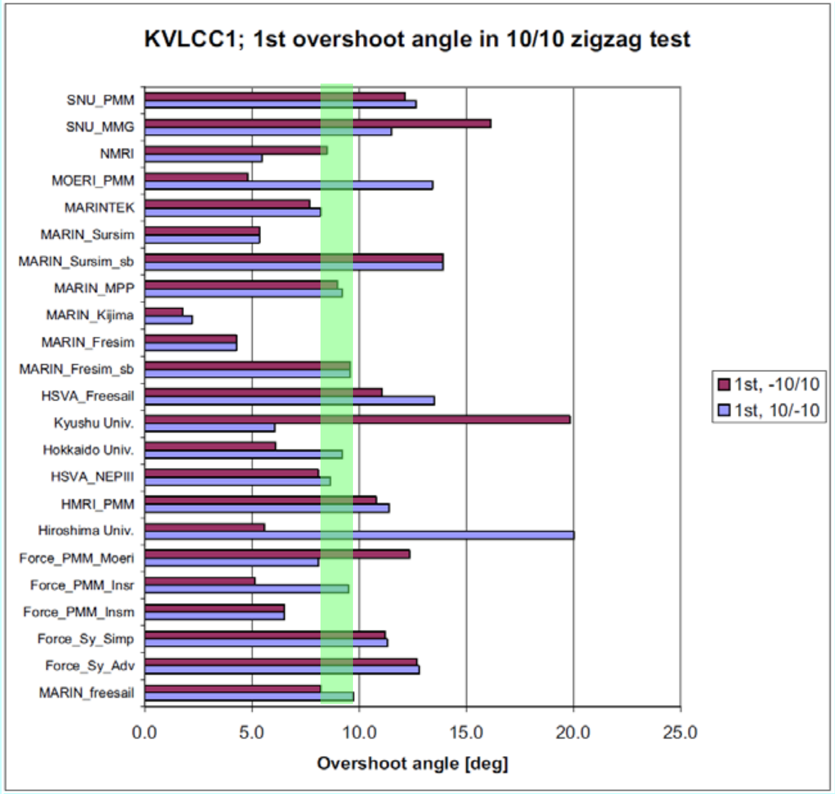
	Free manoeuvres	Captive motions
KVLCC1	22	3
KVLCC2	21	6
KCS	11	2
5415	10	5
total	64	16

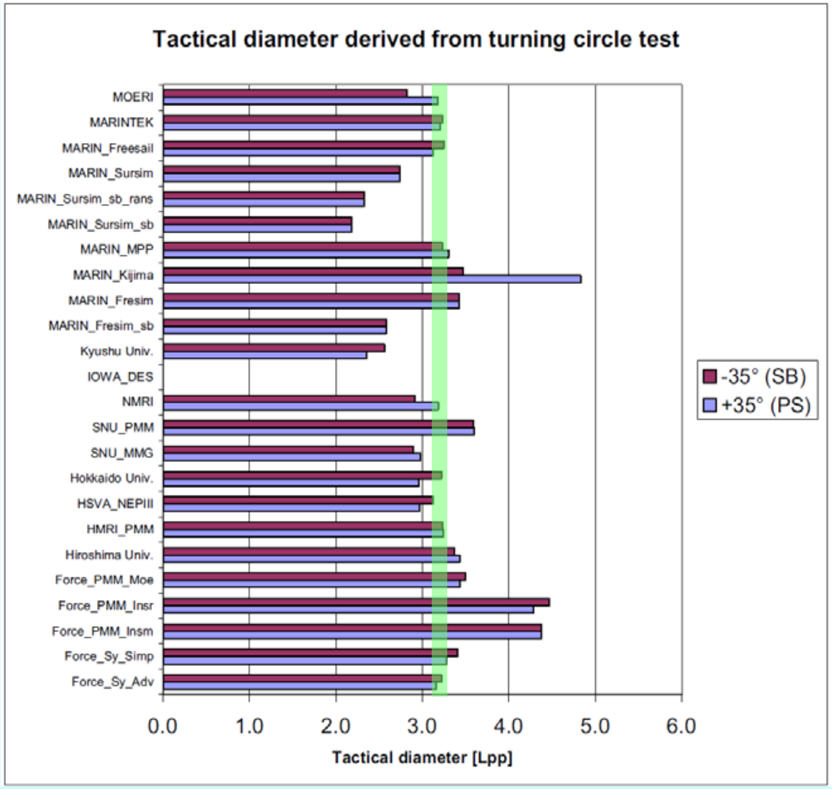
Very satisfactory participation

Number of submissions for CFD-based simulations less than expected

SIMMAN 2008

Some predicted results for KVLCC1



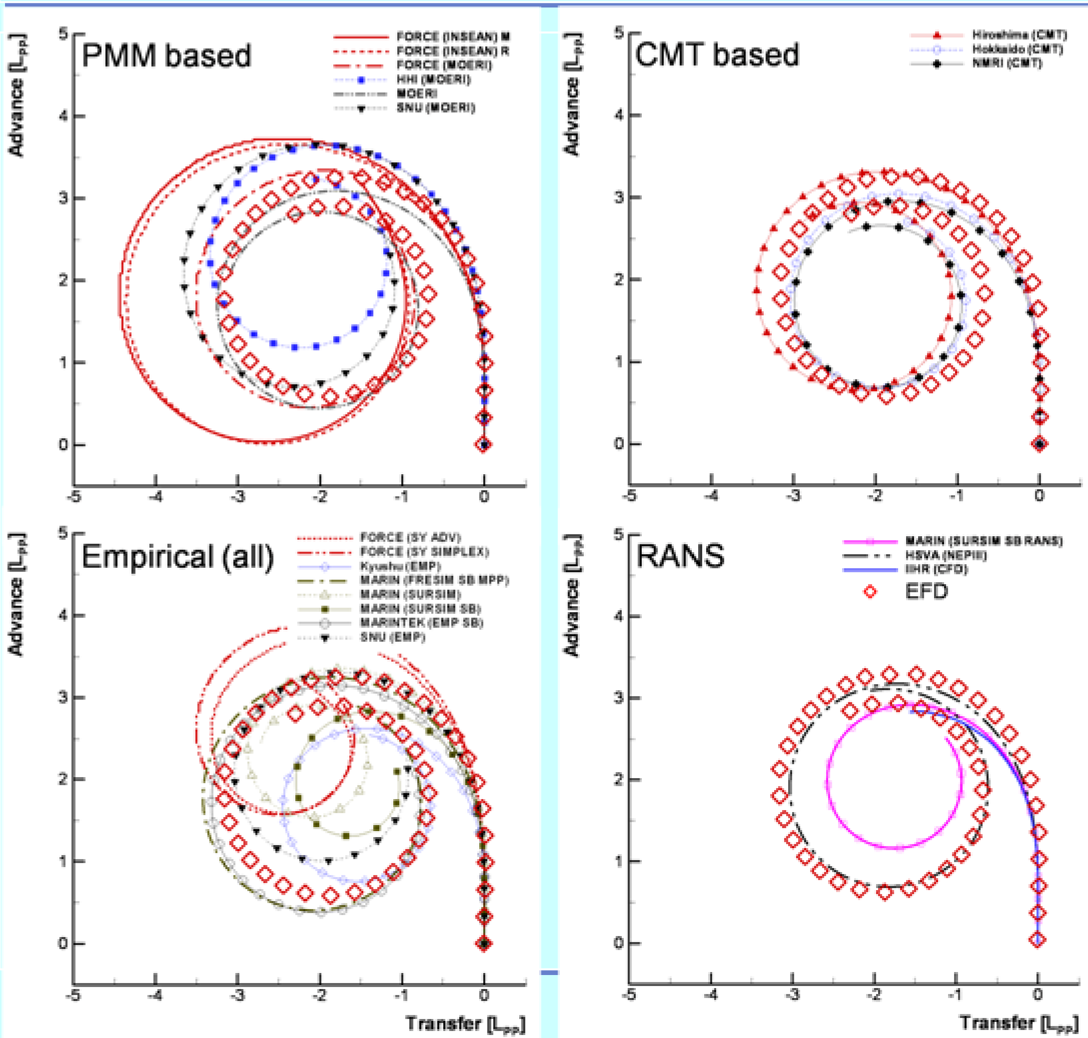


Predicted / measured 1st overshoot angle (all methods together)

Predicted / measured tactical diameter (all methods together)

SIMMAN 2008

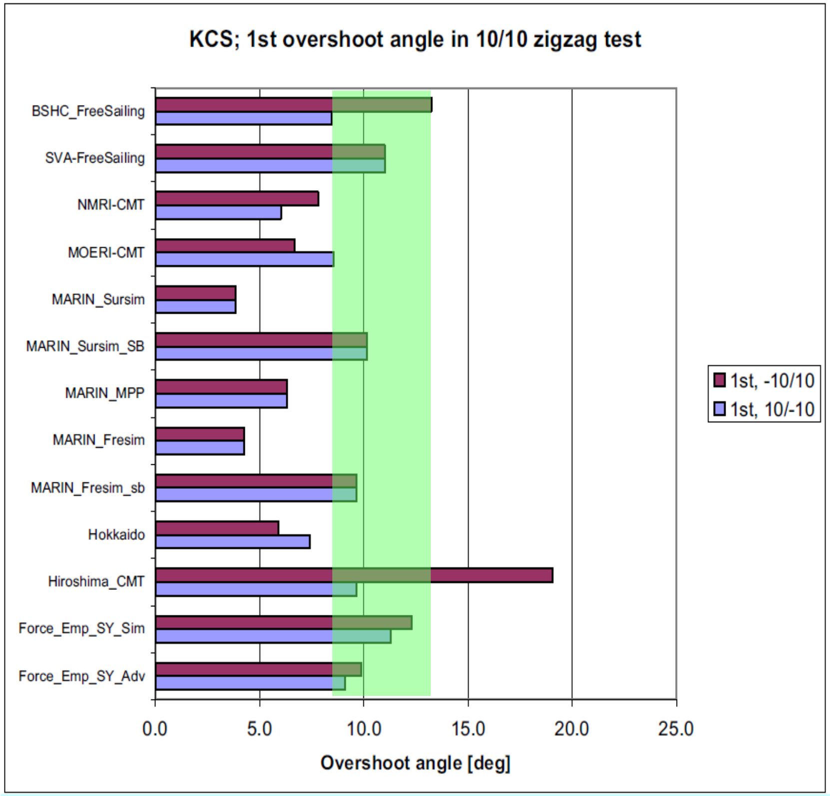
Predicted turning circle test for KVLCC1

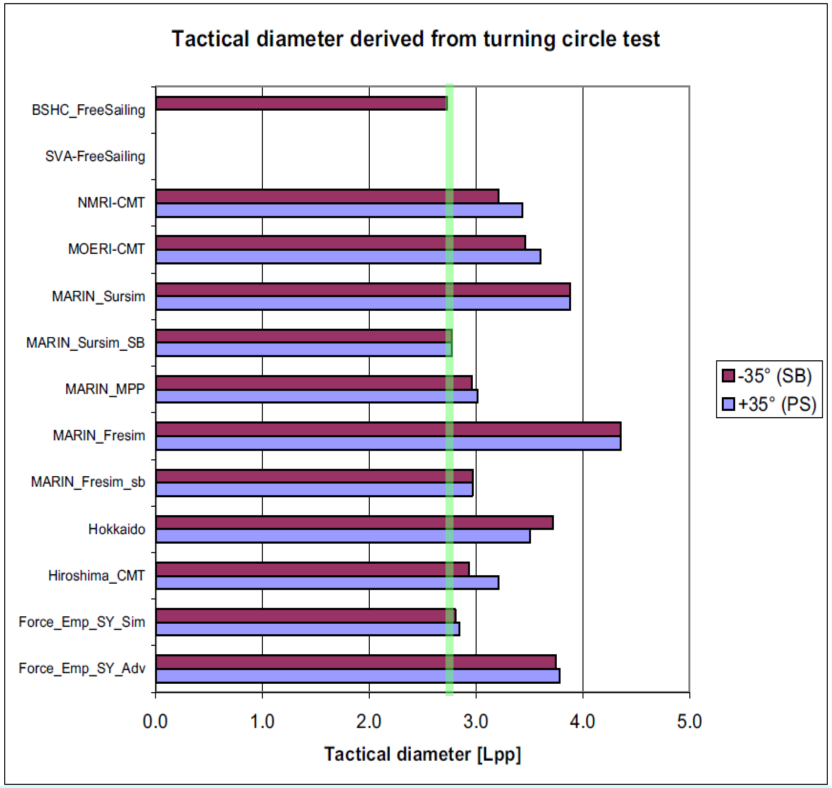


Grouping results by methods and further analysis will shed light on achievable accuracy of different strategies

SIMMAN 2008

Some predicted results for KCS

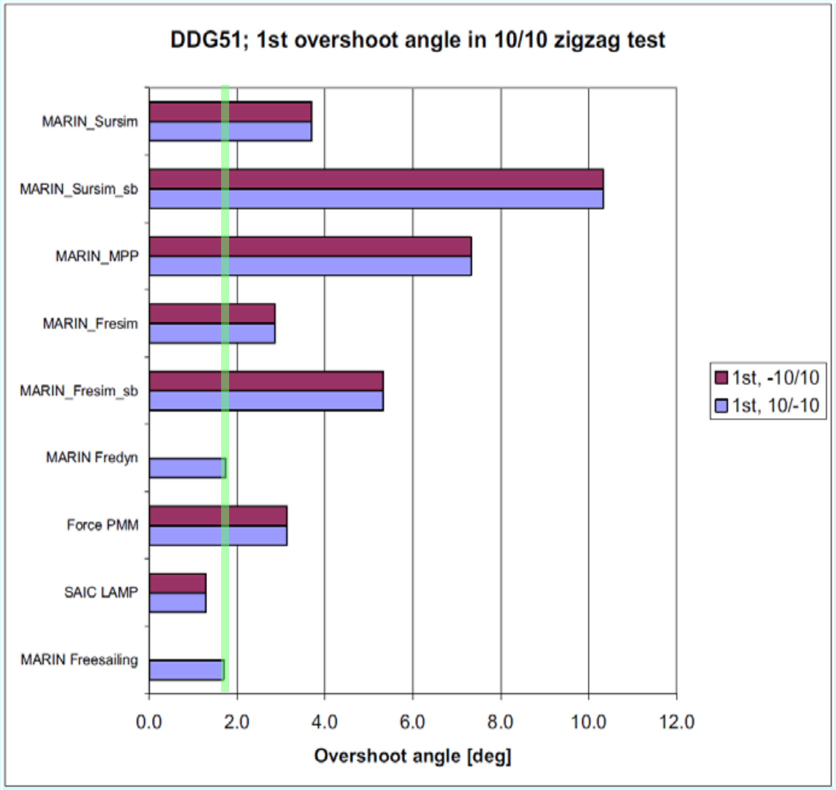


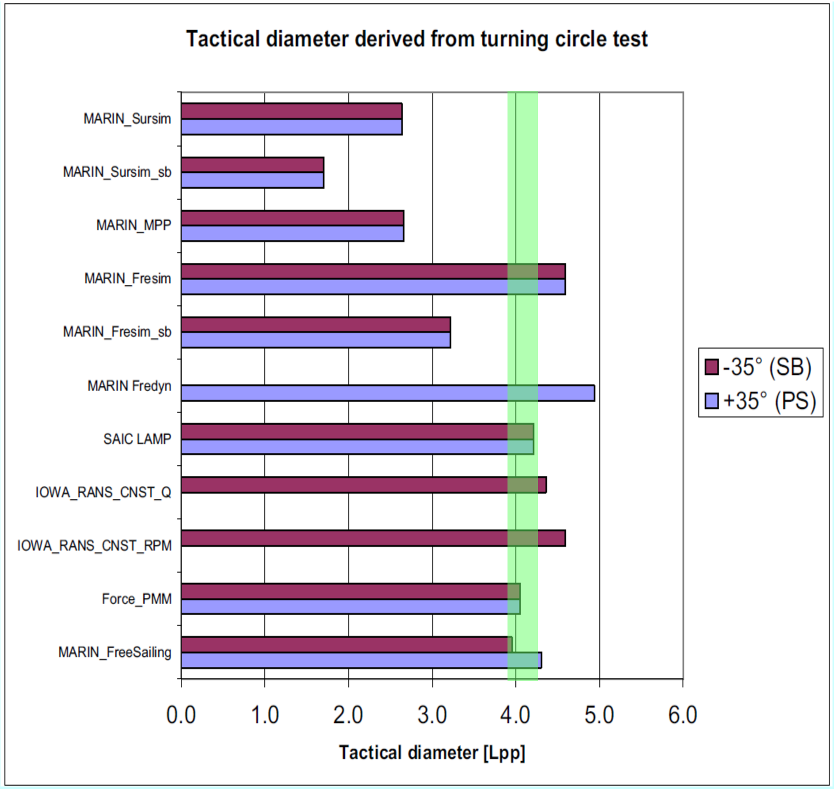


Predicted / measured 1st overshoot angle (all methods together)

Predicted / measured tactical diameter (all methods together)

SIMMAN 2008 — Some predicted results for DTMB 5415





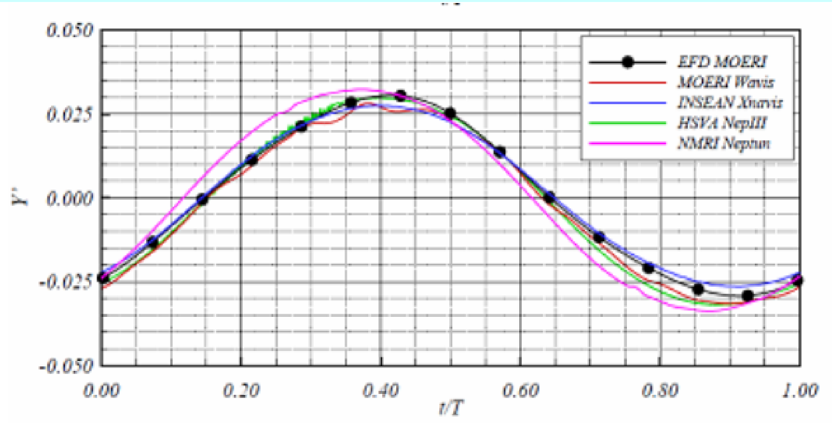
Predicted / measured 1st overshoot angle (all methods together)

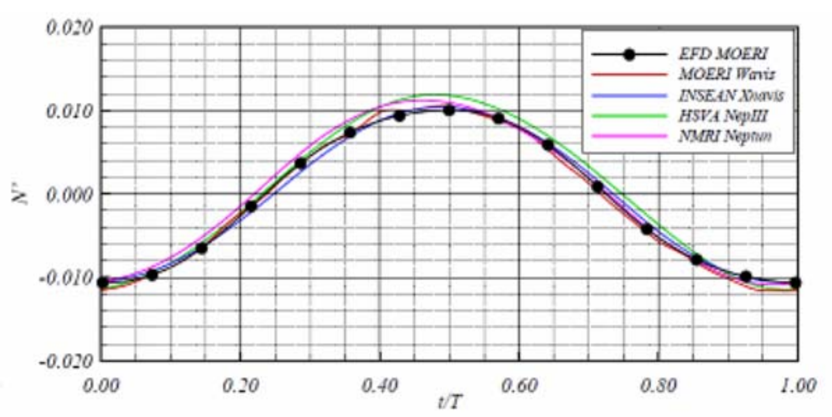
Predicted / measured tactical diameter (all methods together)

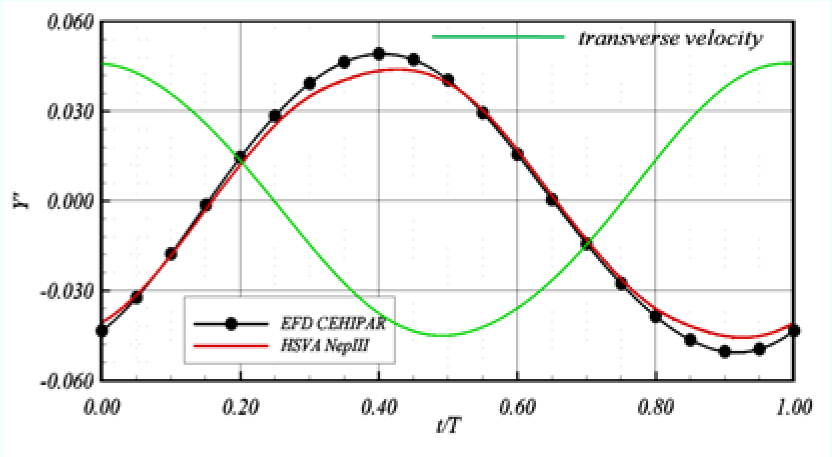
SIMMAN 2008

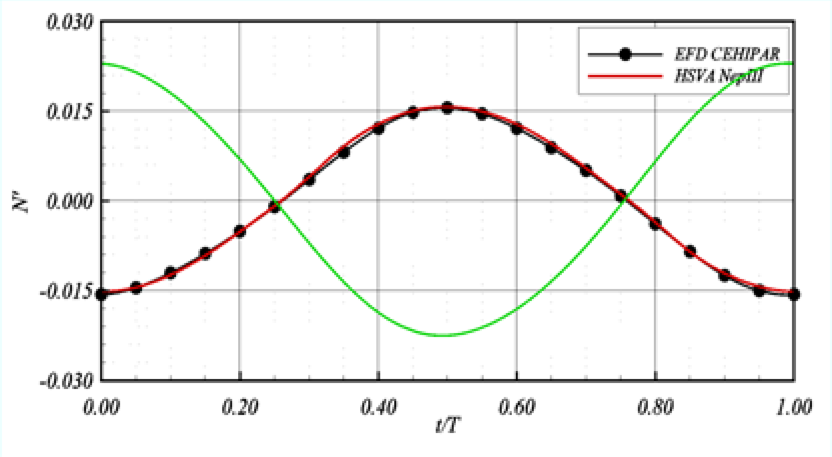
Some predicted results for KVLCC2

CFD simulation of forced motions









Conclusions (Section 5)

Validation of Simulations & Benchmark data

- SIMMAN 2008 successfully held in April this year
- Noteworthy international cooperation in obtaining data
- Blind submission of results
- Valuable insight into performance of different methods
- Final proceedings expected early 2009

Preliminary conclusions SIMMAN 2008

- Clarification of some tests needed (some are being repeated already)
- Many players and large scatter of results. Grouping / detailed analysis needed
- Homegrown methods with in-house procedures give better results
- 4 DOF / 3 DOF can be very important
- Empirical methods should be restricted to the ship types they are developed for
- CFD mostly for virtual captive model tests; it is possible to get very good results
- We have to compare derivatives or equivalent magnitudes
- Direct simulation of manoeuvres yields promising results (but time consuming)

There is a general need for a definition of how to validate a manoeuvring prediction method, i.e. which accuracy is acceptable? A “prediction quality index” should be defined

6. Manoeuvring and Course Keeping in Waves

- **Experimental methods for manoeuvring in waves**

  Still the most usual and reliable procedure

- **Manoeuvring in waves by system-based simulation methods**

  Several studies on system-based simulation methods where mean wave forces are calculated with strip methods or 3D panel codes.

  Trend to unified theory, predicting manoeuvring & seakeeping with same code

- **Manoeuvring in waves by CFD-based methods**

  Some papers on RANS codes being extended for seakeeping & manoeuvring

- **Course keeping in waves**

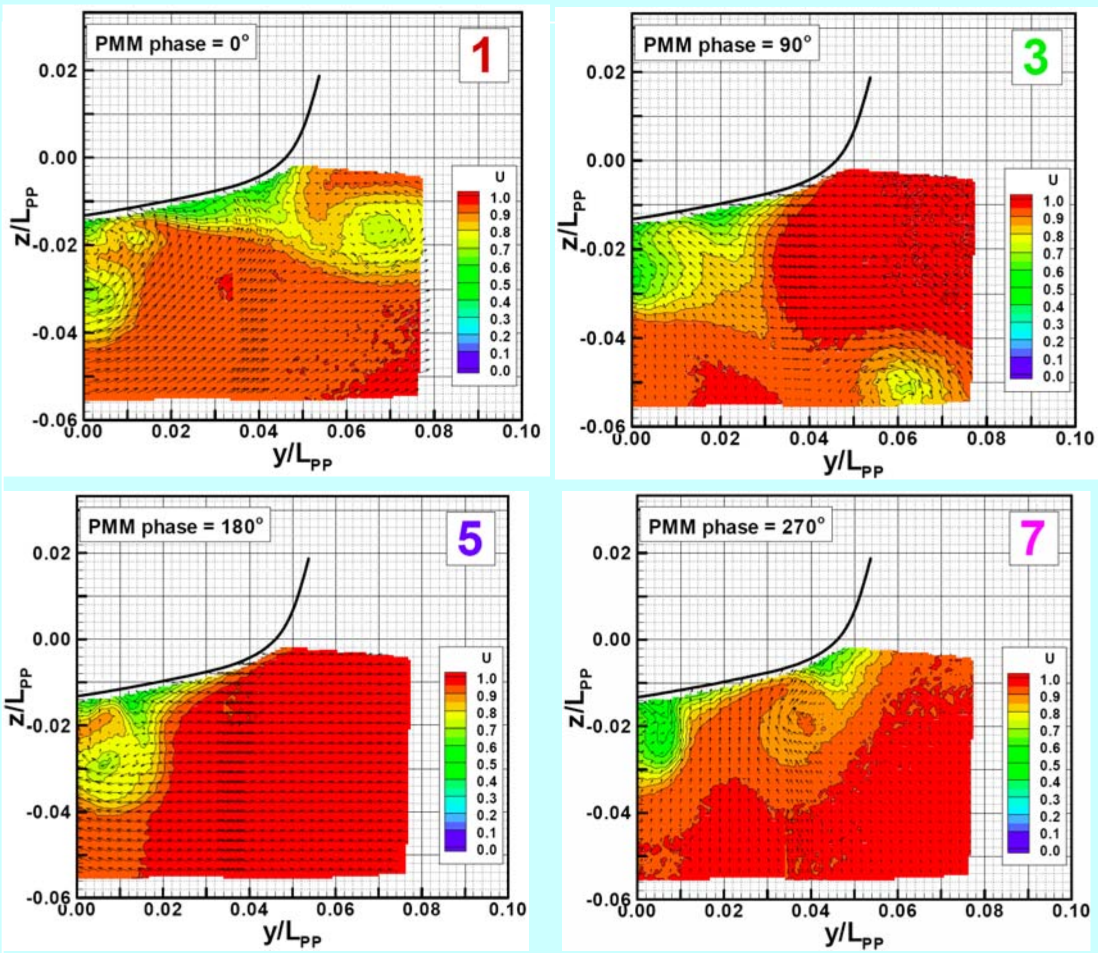
  Several papers on development of control algorithms and autopilots for course keeping in waves

Conclusions (Section 6)

Manoeuvring and Course Keeping in Waves

- Increasing attention to this subject in recent years
- Trend to common analysis of manoeuvring and seakeeping behaviour by means of unified theory
- Model tests and system-based simulations mostly used
- CFD-based methods becoming available and expected to play a more prominent role

7. New Experimental Techniques 3C Particle Image Velocimetry (PIV)

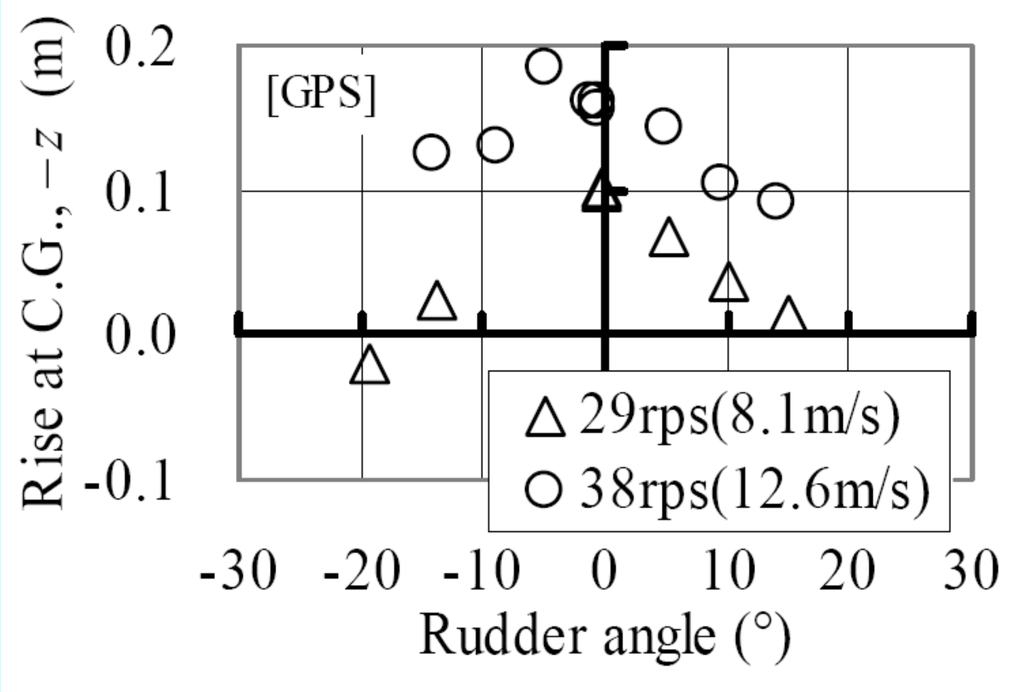


Velocity at cross section of surface combatant during pure sway test

(Longo et al. 2006)

- ⇨ Insight into flow details
- ⇨ Validation of CFD codes

7. New Experimental Techniques — GPS Measurements in full scale



Kinematic DGPS used to measure 6-DOF motions of planning craft during manoeuvring sea trials

(Ueno et al. 2006)

- ⇨ Improved accuracy by kinematic mode
- ⇨ Technique suitable for Squat measurement

Conclusions (Section 7)

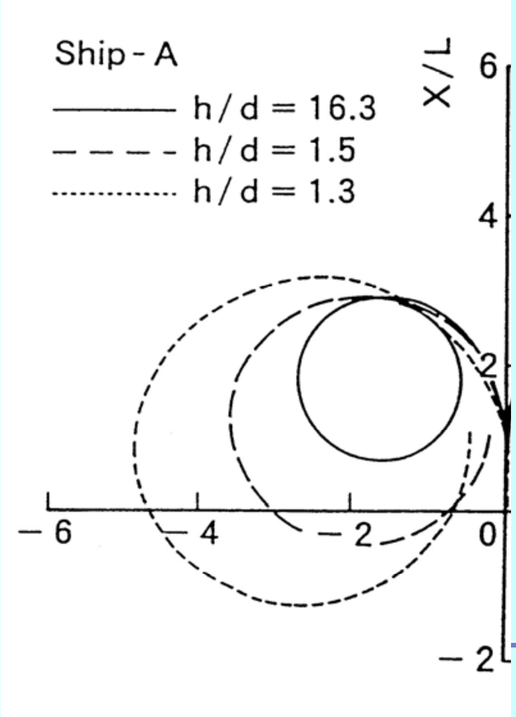
New experimental techniques

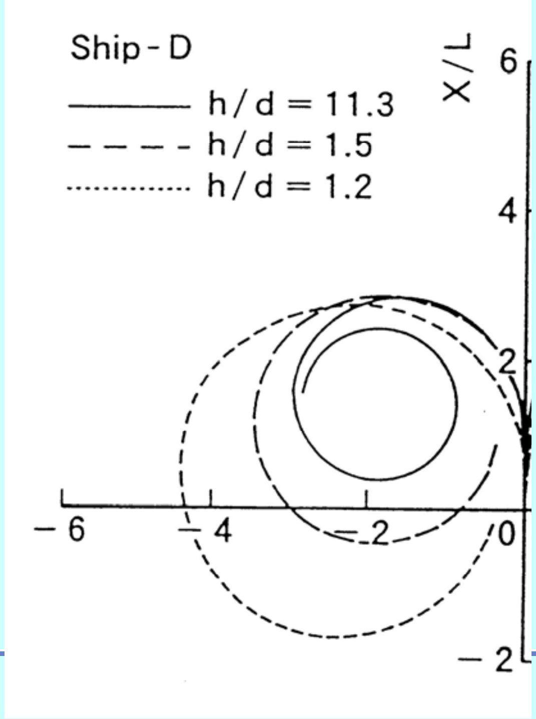
- Many experimental works devoted to CFD validation
- Stereo PIV has become mature enabling the measurement of 3C of velocity field at a manoeuvring ship or submarine
- DGPS in kinematic mode provides a useful tool for accurately measuring the position in both horizontal and vertical plane (squat)
- No significant experimental studies reported on extrapolation methods

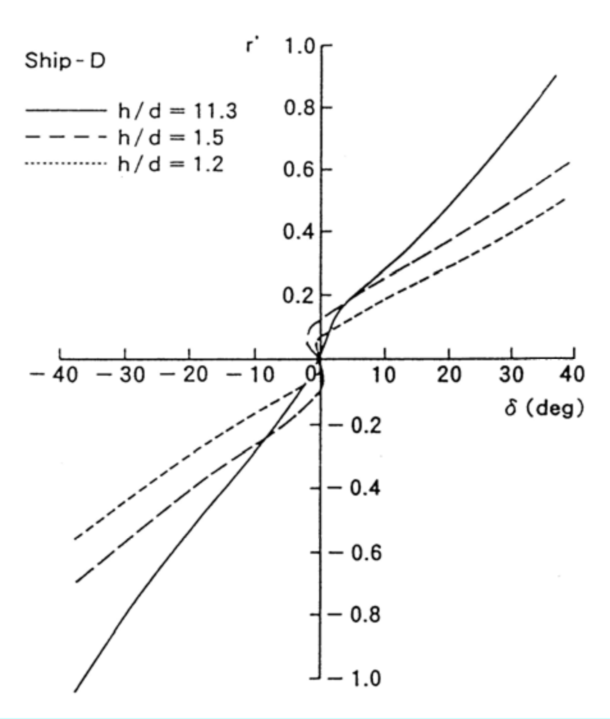
8. Shallow and Confined Waters and Ship-Ship Interactions

- **Shallow water effect on ship manoeuvring**

  Shallow water effects leading to larger tactical diameters than in deep water for some kind of ships and changes in directional stability for medium h/T already shown in Yasukawa et al. (1995)







8. Shallow and Confined Waters and Ship-Ship Interactions (cont.)

- **Hydrodynamic forces and moments in shallow water**

  Some new empirical formula for better capturing shallow water effects

  CFD methods being applied more and more → more insight

- **Manoeuvrability in muddy bottom area**

  Studies still seldom; exceptions are papers from Vantorre's group

  Some forces change significantly for negative ukc

- **Ship-ship interactions**

  Increasing interest due to accidents in rivers and channels

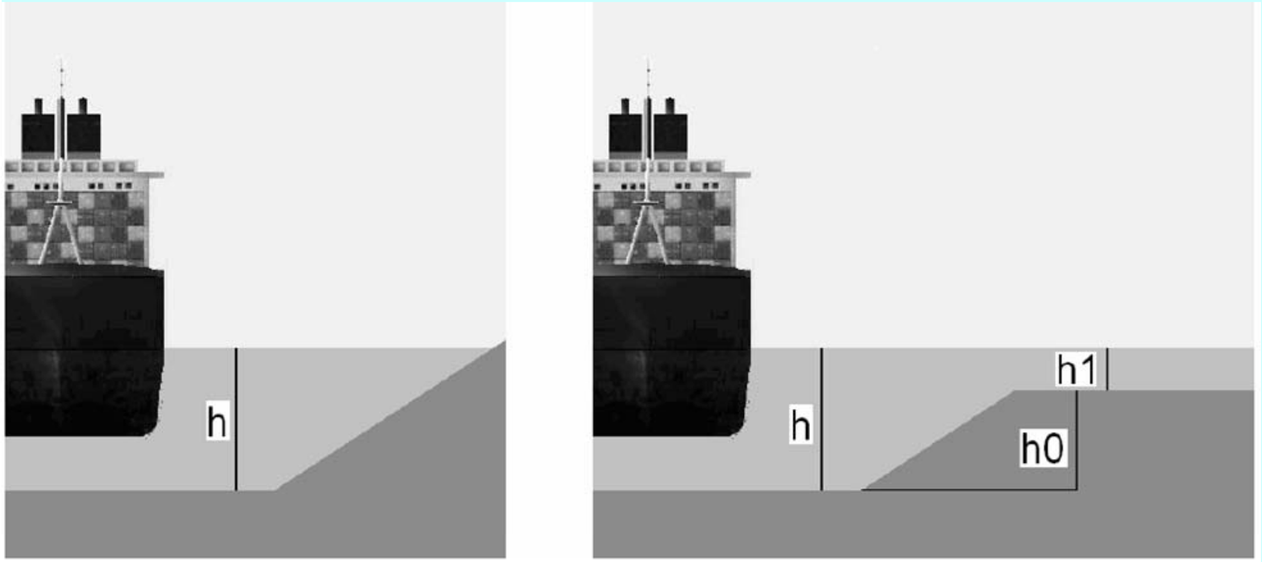
  Mathematical models based on empirical formula & experiments

  Simulation with panel codes

8. Shallow and Confined Waters and Ship-Ship Interactions (cont.)

- **Bank effect and squat**

  Among other papers, very extensive work from Lataire et al. (2007) where submerged and surface piercing banks are considered



Formula for max. distance where influence still present proposed

Conclusions (Section 8)

Shallow and Confined Waters and Ship-Ship Interactions

- Many papers on shallow and confined waters and ship-ship interactions
- Extensions made for muddy bottoms and ship-ship interactions in waves
- Only few significant studies about bank effects reproted
- More effort needed for better understanding of ship manoeuvrability in confined waters

9. Standards and Safety

IMO standards (2002) generally accepted as minimum criteria for conventional ships. Still concerns that standards could be not enough for some real situations (low speed, shallow waters, etc.) and special ships

- **Application of IMO manoeuvring standards**

  New empirical formula for modern ships. Numerical simulations for special ships. Model tests for podded driven ships (sometimes difficult to meet IMO 10°/10°)

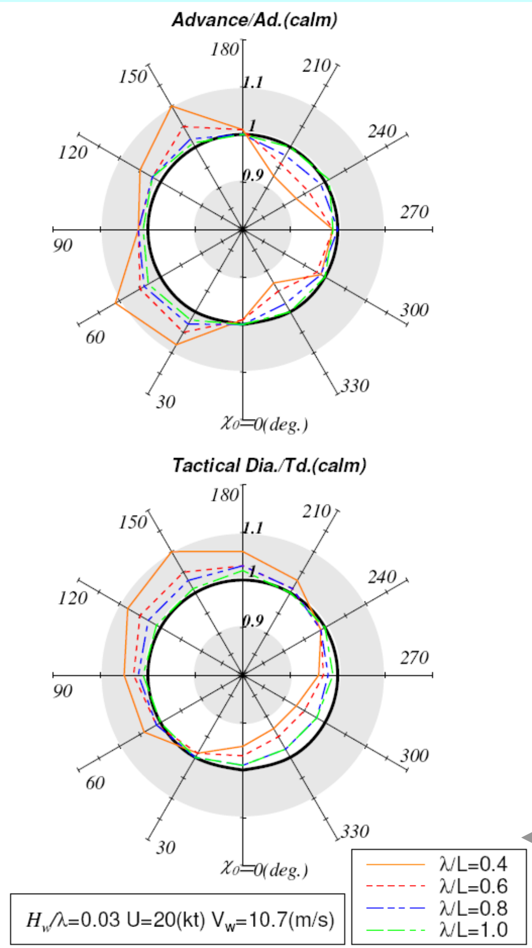
- **Sea trial corrections**

  IMO standards are for full load, deep water and calm environmental conditions (less than Bft 5, sea state 4, uniform current if any)

  Corrections proposed in Explanatory Notes not really robust → improvement needed

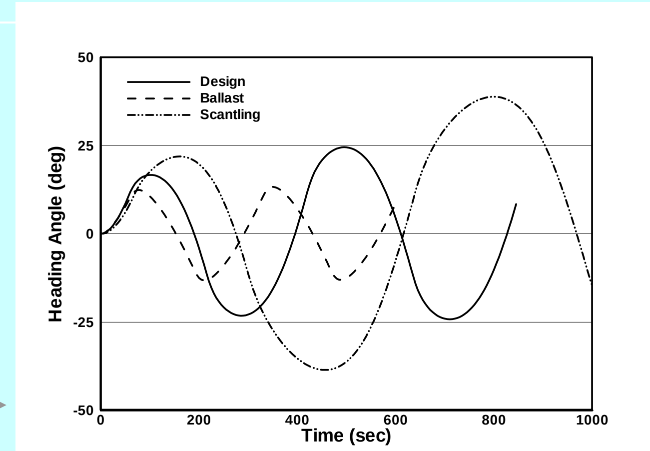
  Some works on corrections for current effects (also for zigzag test) as well as for waves and wind effects

9. Standards and Safety (cont.)



Gong et al. (1998)

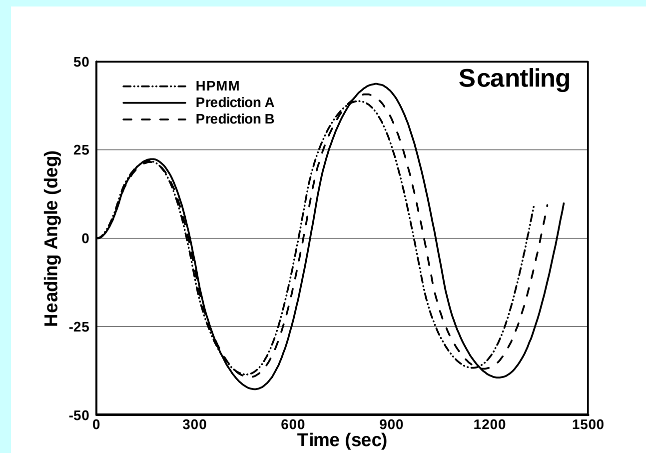
10° /10° zigzag test at different loading conditions (top) and corrected based on HPMM data at design draft (bottom)



Kijima et al. (2006)

Large influence even in “calm environmental condition”

Guideline for corrections proposed



9. Standards and Safety (cont.)

- **Issues and shortcomings of IMO standards**

  Discussed already by Dand (2003, 2005) and other authors

- **Low speed manoeuvring standards**

  Need for low speed / shallow waters manoeuvring criteria frequently claimed but only no research found since 2005

  Difficult to check compliance with such criteria during sea trials (no const. depth)

- **Other standards**

  Criteria for certification of mathematical models for simulators being developed by IMSF

  Some additional criteria to those covered by IMO standards have also been proposed based on experience and have still to be done ship-size-independent

Conclusions (Section 9)

Standards and Safety

- IMO standards accepted as minimum criteria for conventional ships. However, standards for restricted waters and for achieving better than minimum performance needed
- Validity of IMO standards for special ships questionable. Standards for not covered ship types required
- Some research carried out on corrections for environmental conditions. Further research required to develop a standard method for correction of sea trial data
- Necessity of low speed manoeuvring criteria constantly raised. Some manoeuvres and indices proposed. However, no criteria including limits

10. Procedures

2nd and 3rd Task: Review / rewrite procedures

Review procedure 7.5-02-06-01 on Free Model Tests	Limits and usual values of parameters of relevant parameters included
Review procedure 7.5-02-06-02 Captive Model Tests	Tests needed for 4-DOF models included. Distinction between PMM and CPMC. UA section extracted.
Review Procedure 7.5-02-06-03 on Validation of Manoeuvring Simulation Models	Distinction between validation and documentation. Examples of documentation. New benchmark data.
Review Procedure 7.5-02-05-05 on Manoeuvrability of HSMV	No changes

10. Procedures

2nd and 3rd Task: Review / rewrite / **develop** procedures

Rewrite procedure 7.5-04-02-01 on Full Scale Manoeuvring Trials

New structure. More consistent with IMO. Guidelines for GPS measurements. No procedure for MHSV and podded driven vessels at present. Limiting environmental conditions not included yet.

~~Support the SC on UA in reviewing procedures handling UA~~

Develop procedures on UA for manoeuvring tests

New procedure on UA for PMM tests developed.
Procedure for free model tests could not be initiated

12. Recommendations

- Adopt the improved procedure 7.5-02-06-01, “Testing and Extrapolation Methods, Manoeuvrability, Free Model Test Procedure”
- Adopt the improved procedure 7.5-02-06-02, “Testing and Extrapolation Methods, Manoeuvrability, Captive Model Test Procedure”
- Adopt the improved procedure 7.5-02-06-03, “Testing and Extrapolation Methods, Manoeuvrability, Validation of Manoeuvring Simulation Models”
- Adopt the improved procedure 7.5-04-02-01, “Full Scale Manoeuvring Trials”
- Adopt the procedure on UA in captive model tests, “Forces and Moments UA example for PMM tests”