Technical Committee on Manoeuvring

2017-2021

Chairman : Guillaume DELEFORTRIE
Members : Eduardo TANNURI, Xide CHENG, Sanghyun KIM, Takashi KISHIMOTO, Zhi LEONG (since 2019), Salvatore MAURO (until 2018), Janne FLENSBORG OTZEN, Zhiming YUAN

29th ITTC Manoeuvring Committee – Outline

1. Introduction
2. Tasks
3. State of the Art
4. Procedures
5. Benchmark Data
6. Underwater Vehicles
7. EFD Challenges
8. Conclusions
9. Recommendations

1.1 Membership

1. Dr. Guillaume Delefortrie (Chair). Flanders Hydraulics Research (FHR), Belgium.
2. Prof. Dr. Eduardo A. Tannuri (Secretary). Escola Politécnica da Universidade de São Paulo (USP), Brazil.
3. Prof. Dr. Xide Cheng, Wuhan University of Technology, China.
4. Prof. Dr. Sang-Hyun Kim. Inha University, South-Korea.
5. Dr. Takashi Kishimoto. Akishima Laboratories Inc., Japan
6. Dr. Zhi Leong, Australia Maritime College, Australia (since January 2019).
7. Dr. Salvatore Mauro. INM, Italy (until October 2018).
8. Ms. Janne Flensborg Otzen. FORCE Technology, Denmark.
9. Dr. Zhiming Yuan. Universities of Glasgow and Strathclyde, UK.

1.2 Meetings

1: INM, Rome, January 2018

2: Akishima Lab, Tokyo, November 2018

3: Strathclyde University, Glasgow, June 2019

1.2 Meetings

4: @home, April 2020
5: @home, January 2021

Task 1

Update the state-of-the-art for predicting the manoeuvring behaviour of ships, emphasizing developments since the 2017 ITTC Conference. The committee report should include sections on:

- the potential impact of new technological developments on the ITTC
- new experiment techniques and extrapolation methods
- the practical applications of computational methods to manoeuvring predictions and scaling, including CFD methods
- the need for R&D for improving methods of model experiments, numerical modelling and full-scale measurements
- the effects of free surface, roll, sinkage, heel and trim in numerical simulation of manoeuvring
- Include specifically, the prediction and testing of low speed manoeuvring to understand the impact of these types of manoeuvres in model testing

⇒ Literature review 2017 – 2020: see section 3. State of the Art

Task 2

During the first year, review ITTC Recommended Procedures relevant to manoeuvring, including CFD procedures, and

- identify any requirements for changes in the light of current practice and, if approved by the Advisory Council, update them,
- identify the need for new procedures and outline the purpose and contents of these.

⇒ No new proposals, but slight updates, see 4. Procedures

Task 3

Coordinate and exchange information with the Specialist Committee on Ice with regard to the possible updating of ITTC Recommended Procedure 7.5-02-04-02.3, Manoeuvring in Ice.

⇒ Preliminary input has been delivered, see 4. Procedures

Task 4

Update 7.5-02-06-03 2014 Validation of Manoeuvring Simulation Models, including verification, sensitivity analysis, results from the SIMMAN conferences and step by step validation of manoeuvring models.

⇒ Update will be discussed in 4. Procedures

Task 5

Investigate the missing elements in the Procedure on Uncertainty Analysis for Manoeuvring Prediction Based on Captive Model Tests, such as the accuracy of carriage kinematics and the data filtering (noise). Update 7.5-02-06-04 if necessary according to the requirements of the ISO GUM.

⇒ Update will be discussed in 4. Procedures and 7. EFD Challenges

Task 6

Update 7.5-02-06-02 Captive model test procedure to provide a definitive, agreed, method for each of the testing approaches.

⇒ Update will be discussed in 4. Procedures

Task 7

Assist with the organization of SIMMAN 2019. Use the output from this conference and others to develop a guideline for the setup, execution of benchmark tests and use of benchmark data for manoeuvring.

⇒ SIMMAN 2019 became SIMMAN 2021, to be held at the end of 2021
⇒ The guideline will be discussed in 4. Procedures

Task 8

Investigate the uncertainties associated with manoeuvring tests in shallow water including aspects such as structural strength of moveable bottoms, extent of gaps around the edges and the degree to which a fixed floor is level.

⇒ Update will be discussed in 7. EFD Challenges

Task 9

Investigate the results from the previous ITTC questionnaire on captive model tests especially related to concerns over turbulence stimulation and full scale effects; update 7.5-02-06-02, if necessary, concerning this matter.

⇒ A new questionnaire was distributed in 2018. The results will be discussed in 7. EFD Challenges

Task 10

Liaise with Specialist Committees on Combined CFD/EFD Methods and Manoeuvring in Waves as required.

⇒ Contacts have been established with these committees. Specifically the CFD/EFD specialist committee reviewed our RANS procedures.

Task 11

Develop guidelines for the model testing and sea trials of autonomous underwater vehicles (AUVs) (resistance, manoeuvring, propulsion and control, computational methods for the low Reynold’s Number flow around AUVs).

⇒ Upon our request, this very broad scope has been limited in 2018 by the AC to

the study of AUVs and the creation of guidelines for model testing and sea trials focusing at manoeuvring.

⇒ The guidelines will be discussed in 4. Procedures
⇒ A general discussion and the state of the art is covered in 6. Underwater Vehicles

3.1 Deep Unrestricted Water

3.2 Shallow, Restricted or Confined Water

3.3 Unmanned Surface Vehicles

3.4 Autopilot Applications

EFD, potential flow, RANS, hybrid, empirical

AI, NN, VIRTUAL, EFD, potential flow, RANS, hybrid, empirical

3.1 Deep Unrestricted Water: EFD

Model testing in heeled/trimmed conditions

Bonci, M., Jong, P., Van Walree, F., Renilson, M., Keuning, L. and Huijsmans, R., 2017, "Experimental and Numerical Investigation on the Heel and Drift Induced Hydrodynamic Loads of a High Speed Craft", FAST 2017 , Nantes, France, pp. 209–218.

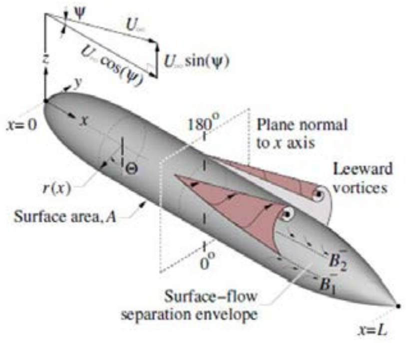
Yeo, D. J., Yun, K. and Kim, Y.-G., 2018, "A Study on the Effect of Heel Angle on Manoeuvring Characteristics of KCS", MARSIM 2018, Halifax, Canada, pp. 1–10.

3.1 Deep Unrestricted Water: EFD

New techniques: propeller loads in single blades

Ortolani, F. and Dubbioso, G., 2019, "In-Plane and Single Blade Loads Measurement Setups for Propeller Performance Assessment during Free Running and Captive Model Tests", AMT 19 , Rome, Italy.

Pressure measurements for drifting slender bodies



Lee, S. K. and Jones, M. B., 2018, "Surface Pressure of Inclined Slender-Body Flows", Proceedings of the 21st Australasian Fluid Mechanics Conference, AFMC 2018 , Adelaide, Australia, pp. 1–4

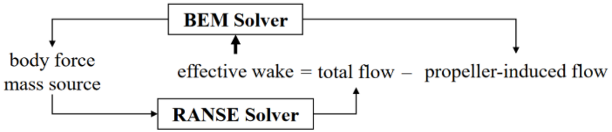
Gate Rudder

Sasaki, N., Kuribayashi, S., Fukazawa, M. and Atlar, M., 2019, "Gate Rudder® Performance", AMT 19 , Rome, Italy, pp. 9–15.

3.1 Deep Unrestricted Water: CFD (RANS)

- Trend towards commercial packages
  - Most frequently cited: commercial packages, with Star CCM+
  - Less with open source, like OpenFOAM
  - Very few with own code

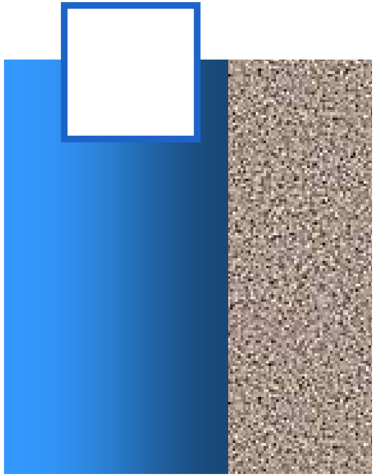
- Papers dealing with application of commercial code to derive manoeuvring derivatives are (too) common versus
  - complexer free running CFD manoeuvres. Example:
    - Stopping – manoeuvre (Wang, J. and Wan, D., 2020, "CFD Study of Ship Stopping Maneuver by Overset Grid Technique", Ocean Engineering, Vol. 197, pp. 1–12.)
  - Hybrid methods (combination BEM/RANS). Example: Study of hull-propeller-rudder interaction



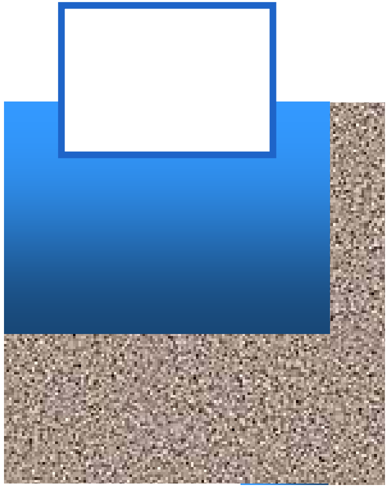
Su, Y. and Kinnas, S. A., 2018, "A Time-Accurate BEM/RANS Interactive Method for Predicting Propeller Performance Considering Unsteady Hull/Propeller/Rudder Interaction", 32nd Symposium on Naval Hydrodynamics , Hamburg, Germany, pp. 5–10.

3.2 Shallow, Restricted, Confined ,… why important?

$h < 4T$



$y < y_{\mathrm{infl}} = 5B(Fr_h + 1)$



$h < 4T$

$y < y_{\mathrm{infl}} = 5B(Fr_h + 1)$

Grounding of Ever Given in Suez Canal (March 2021)

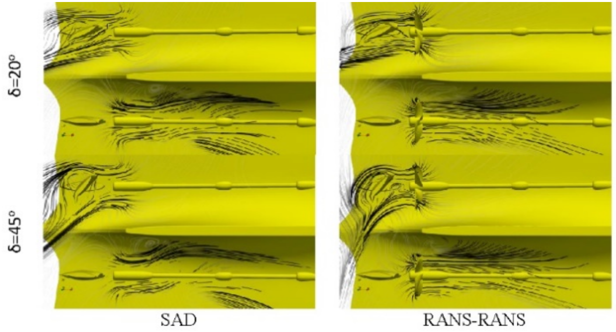
3.2 Shallow, Restricted, Confined

New shallow water towing tank built at Flanders Maritime Laboratory (part of Flanders Hydraulics Research): operational in 2022-2023

Delefortrie, G., Geerts, S., Lataire, E., Troch, P. and Monbaliu, J., 2019, "Coastal and Ocean Basin and Towing Tank for Manoeuvres in Shallow Water at Flanders Maritime Laboratory", AMT 19 , Rome, Italy, Vol 53, pp. 1689–1699.

3.2 Shallow, Restricted, Confined

- More complex research reported:
  - Hull-propeller-rudder interaction studies for ships equipped with multiple control units: examples:
    - Delefortrie, G., Tello Ruiz, M. and Vantorre, M., 2018, "Manoeuvring Model of an Estuary Container Vessel with Two Interacting Z-Drives", Journal of Marine Science and Technology, Vol. 23, No.4, pp. 739–753.
    - Kaidi, S., Smaoui, H. and Sergent, P., 2018, "CFD Investigation of Mutual Interaction between Hull, Propellers, and Rudders for an Inland Container Ship in Deep, Very Deep, Shallow, and Very Shallow Waters", Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 144, No.6.
    - Gornicz, T. M., Ferrari, V. and Toxopeus, S. L., 2019, "Estimating Berthing Performance of Twin Shaft Ship by Means of CFD", PRADS 2019 , Yokohama, Japan, pp. 1–20.



3.2 Shallow, Restricted, Confined

- Full scale validations (focussed at squat): examples:
  - Ha, J. H. and Gourlay, T., 2018, "Validation of Container Ship Squat Modeling Using Full-Scale Trials at the Port of Fremantle", Journal of Waterway, Port, Coastal, and Ocean Engineering, Vol. 144, No.1, pp. 1–18.
  - Harkin, A., Harkin, J., Suhr, J., Tree, M., Hibberd, W. and Mortensen, S., 2018, "Validation of a 3D Underkeel Clearance Model with Full Scale Measurements", PIANC World Congress , Panama City, pp. 1–20.
  - Verwilligen, J., Mansuy, M., Vantorre, M. and Eloot, K., 2018, "Squat Formula for Cape-Size Bulk Carriers Based on Towing Tank Results and Full-Scale Measurements", MARSIM 2018, Halifax, Canada, pp. 1–17.
- => useful info to update full scale manoeuvring trials procedure to account for any manoeuvre

- Ship-bank interaction: viscous-flow methods should be adopted to obtain the correct trends of bank suction or repulsion

3.2 Shallow, Restricted, Confined

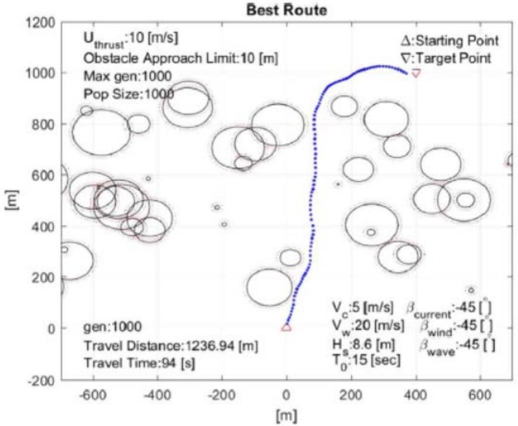
- Ship-ship interaction: BEM ok, but the free-surface effects need to be taken into account for Fr > 0.2. (Yuan, Z.-M., Li, L. and Yeung, R. W., 2019, "Free-Surface Effects on Interaction of Multiple Ships Moving at Different Speeds", Journal of Ship Research, Vol. 63, No.4, pp. 251–267.)

- Ship-tug interaction: extensive research on tug behaviour reported (EFD/CFD) by Figari, M., Martinelli, L., Piaggio, B., Enoizi, L., Viviani, M. and Villa, D., 2020, "An All-Round Design-to-Simulation Approach of a New Z-Drive Escort Tug Class", Journal of Offshore Mechanics and Arctic Engineering, Vol. 142, No.3, pp. 1–12.

3.3 Unmanned Surface Vehicles (USV)

- Excessive amount of literature published:
  - quantity versus quality?
  - (experimental) validation and applicability?

- Path Planning and Path Optimization:
  - Algorithms that consider minimal travel time, environmental loads, (static) obstacles,….
  - AI, e.g. action-reward model
  - Effect of environment on path, but on ship's behaviour?



Kim, H., Kim, S. H., Jeon, M., Kim, J. H., Song, S. and Paik, K. J., 2017, "A Study on Path Optimization Method of an Unmanned Surface Vehicle under Environmental Loads Using Genetic Algorithm", Ocean Engineering, Vol. 142, pp. 616–624.

3.3 Unmanned Surface Vehicles (USV)

- Path Following and Trajectory Tracking:
  - Path following under external disturbances
  - Broken lines path following capability (Zhao, Y., Qi, X., Incecik, A., Ma, Y. and Li, Z., 2020, "Broken Lines Path Following Algorithm for a Water-Jet Propulsion USV with Disturbance Uncertainties", Ocean Engineering, Vol. 201, pp. 1–9.)

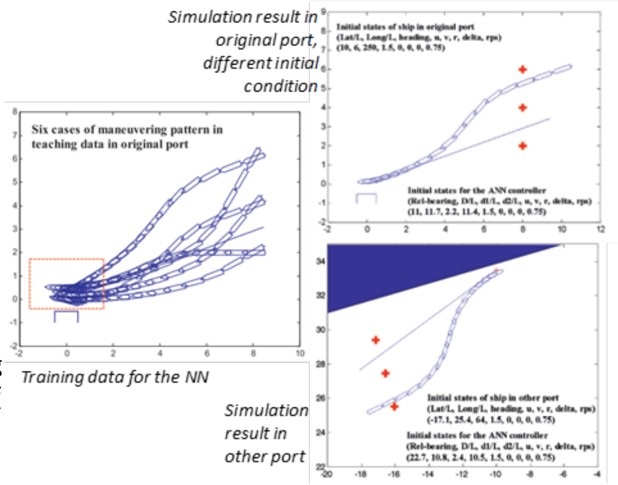
- Collision Avoidance
  - Emergency versus non-emergency (Song, A. L., Su, B. Y., Dong, C. Z., Shen, D. W., Xiang, E. Z. and Mao, F. P., 2018, "A Two-Level Dynamic Obstacle Avoidance Algorithm for Unmanned Surface Vehicles", Ocean Engineering, Vol. 170, pp. 351–360.)
  - Better if ship manoeuvrability is included (also for other processes), examples:
    - Shen, H., Hashimoto, H., Matsuda, A., Taniguchi, Y., Terada, D. and Guo, C., 2019, "Automatic Collision Avoidance of Multiple Ships Based on Deep Q-Learning", Applied Ocean Research, Vol. 86, pp. 268–288.
    - Xie, S., Garofano, V., Chu, X. and Negenborn, R. R., 2019, "Model Predictive Ship Collision Avoidance Based on Q-Learning Beetle Swarm Antenna Search and Neural Networks", Ocean Engineering, Vol. 193, pp. 1–24.
    - Wang, X., Liu, Z. and Cai, Y., 2017, "The Ship Maneuverability Based Collision Avoidance Dynamic Support System in Close-Quarters Situation", Ocean Engineering, Vol. 146, pp. 486–497.

- Formation control of multi-USVs is getting more important due to the expansion of the application area of USV (different approaches presented in report)

3.4 Autopilot Applications

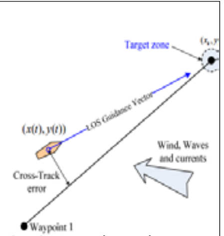
- More difficult cases are being studied:
  - Restricted/shallow water, e.g.
    - Chen, C., Delefortrie, G. and Lataire, E., 2020, "Experimental Investigation of Practical Autopilots for Maritime Autonomous Surface Ships in Shallow Water", Ocean Engineering, Vol. 218, pp. 1–21.
    - Liu, H., Ma, N. and Gu, X. C., 2018a, "Ship Course Following and Course Keeping in Restricted Waters Based on Model Predictive Control", TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 12, No.2, pp. 305–312.
  - Automatic berthing, review by Ahmed, Y. A., Hannan, M. A. and Siang, K. H., 2020, "Artificial Neural Network Controller for Automatic Ship Berthing: Challenges and Opportunities", Marine Systems and Ocean Technology, Vol. 15, No.4, pp. 217–242.

Im, N. K. and Nguyen, V. S., 2018, "Artificial Neural Network Controller for Automatic Ship Berthing Using Head-up Coordinate System", International Journal of Naval Architecture and Ocean Engineering, Vol. 10, No.3, pp. 235–249.

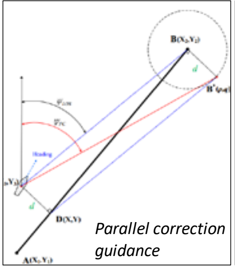


3.4 Autopilot Applications

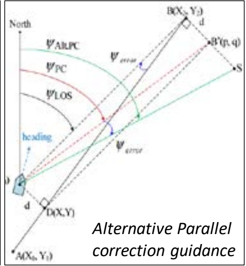
- More difficult cases are being studied:
  - Offshore operations, including ship to ship interaction, e.g. Moreno, F. M., Amendola, J., Tannuri, E. A. and Ferreira, M. D., 2019, "Development of a Control Strategy for Underway Tandem-like Oil Transfer Operation between a Conventional and a DP Tanker", OMAE2019 , Glasgow, Scotland, UK, pp. 1–10.
  - Applications for hovercafts, sailboats, e.g. Wang, Y., Tong, H. and Fu, M., 2019, "Line-of-Sight Guidance Law for Path Following of Amphibious Hovercrafts with Big and Time-Varying Sideslip Compensation", Ocean Engineering, Vol. 172, pp. 531–540.
  - Machine learning autopilots, e.g. Amendola, J., Miura, L. S., Costa, A. H. R., Cozman, F. G. and Tannuri, E. A., 2020, "Navigation in Restricted Channels under Environmental Conditions: Fast-Time Simulation by Asynchronous Deep Reinforcement Learning", IEEE Access, Vol. 8, pp. 149199–149213
- Possible improvement to LOS concept by Lee, S. Der and Chang, B. W., 2018, "Design and Experiment of the New Type Parallel Correction Guidance Autopilot System", MARSIM 2018 , Halifax, Canada, pp. 1–11.



Traditional LOS



Parallel correction guidance



Alternative Parallel correction guidance

4.1 Minor updates

- 7.5-02-06-01 Free Running Model Tests:
  - make sure that the procedure keeps track with the captive model test procedure.
- 7.5-04-02-01 Full Scale Manoeuvring Trials.
  - Missing references included and minor English corrections
- 7.5-03-04-02 Validation and Verification of RANS Solutions in the Prediction of Manoeuvring Capabilities.
  - Missing references included and minor English corrections
- 7.5-03-04-01 Guideline on Use of RANS Tools for Manoeuvring Prediction
  - correction of a few references
- 7.5-02-06-05 Uncertainty Analysis for Free Running Model Tests.
  - Minor English corrections
- 7.5-02-01-06 Determination of Type A Uncertainty Estimate of a Mean Value from a Single Time Series Measurement.
  - Different corrections were proposed to the QSG to solve the differences with the original paper

4.2 Manoeuvring in Ice

- Recommendations were provided to the Ice Committee (see report)
- We received the new version after our last meeting in January => see Ice Committee Report

4.3 Validation of Manoeuvring Simulation Models

- Validation levels:
  - benchmark data, model test data, full-scale data and pilot expertise
- Complexity levels:
  - ship manoeuvrability in deep water, shallow water, restricted water,
  - prediction of ship manoeuvrability using 4-DOF or 6 DOF model
  - application of simulator design for training of crews.

4.4 Captive model tests

- Captive model test procedure
  - AC concerns: aim and goal of procedure was emphasized
  - Focus put towards execution of captive model tests
    - to build a mathematical model
      - to predict IMO standard manoeuvres
  - More attention put on water depth and blockage

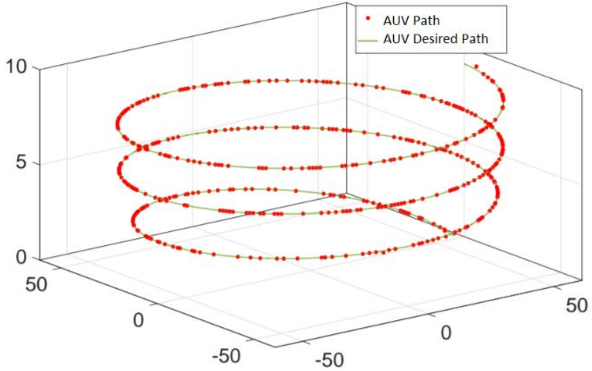
- Uncertainty Analysis for manoeuvring predictions based on captive manoeuvring tests
  - Information added on the following topics:
    - Signal processing (noise, filtering): more details follow in 7
    - Carriage kinematics: Appendix G includes an example with KCS
  - Unification of the examples recommended

4.5 Benchmark Data

- **New guideline**
- Highlight specific requirements for manoeuvring
- Overview of available benchmark sets for manoeuvring

4.6 Underwater Vehicles

- **Two new guidelines**
  - Captive model tests
    - Hydrodynamically valid for any submerged body (submarine, AUV, ROV)
  - Full scale manoeuvring trials
    - Focused presently at AUV
    - Description of 12 manoeuvring tests
- External reviewers acknowledged

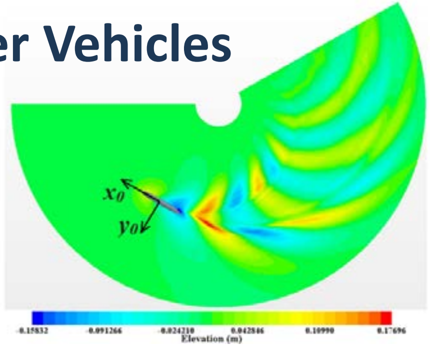


5.1 SIMMAN 2021

- Being postponed due to COVID-19
- Changes with SIMMAN 2014
  - 5415M has been replaced by ONRT
  - Reduced sets to have better statistical analysis opportunities
  - Manoeuvring in waves case added (KCS, ONRT)
- Submissions presently closed and analysis being performed

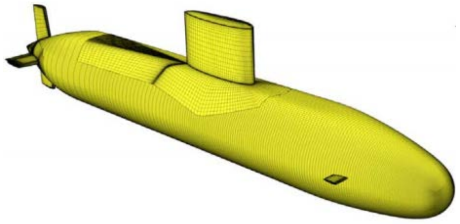
5.2 Datasets

- See new guideline
- Lacking:
  - Full scale equivalent
  - Inland vessel
  - (A)UV

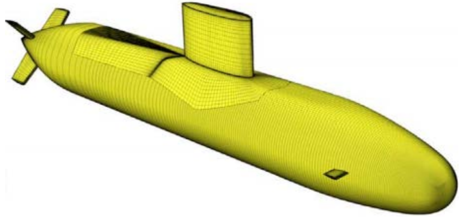


6.1 Manoeuvring Hydrodynamics

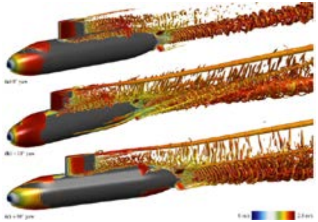
- Can be categorized as:
  - Open water behaviour as a whole
  - Interaction with the environment (bottom, free surface,…), e.g. Amiri, M. M., Esperança, P. T., Vitola, M. A. and Sphaier, S. H., 2020, "An Initial Evaluation of the Free Surface Effect on the Maneuverability of Underwater Vehicles", Ocean Engineering, Vol. 196, pp. 1–22.
  - Assessment of the effect of specific components, e.g. Dubbioso, G., Broglia, R. and Zaghi, S., 2017b, "CFD Analysis of Turning Abilities of a Submarine Model", Ocean Engineering, Vol. 129, pp. 459–479.
- Increasing trend towards the (advanced) CFD approach



(a) Cruciform configuration



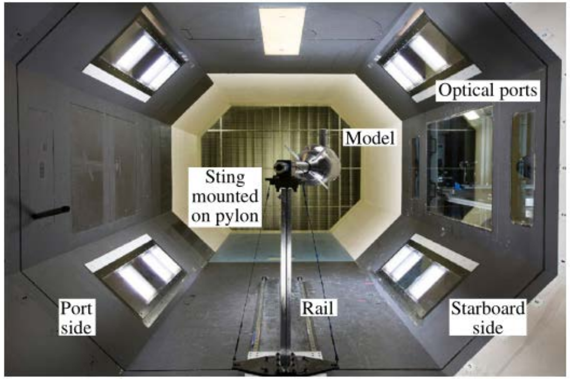
(b) X rudder configuration



Visualisation of the vorticity and wake flow around the full-scale BB2 submarine at different yaw angles (Patterson et al., 2018)

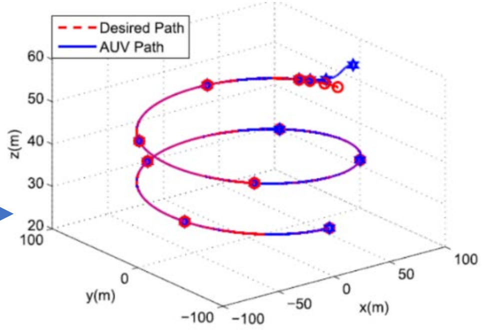
6.1 Manoeuvring Hydrodynamics

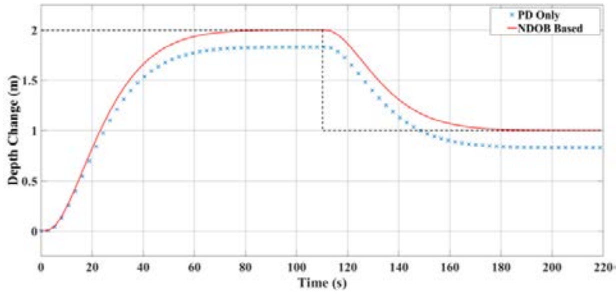
- …but experimental methods still applicable, e.g. Crossland, P., 2017, "Slow Speed Depth Control of a Submarine under Waves", PACIFIC 2017, Sydney, Australia.
- Including in a wind tunnel, e.g. Lee, S.-K., Manovski, P. and Kumar, C., 2020, "Wake of a Cruciform Appendage on a Generic Submarine at 10° Yaw", Journal of Marine Science and Technology, Vol. 25, No.3, pp. 787–799.



6.2 Control

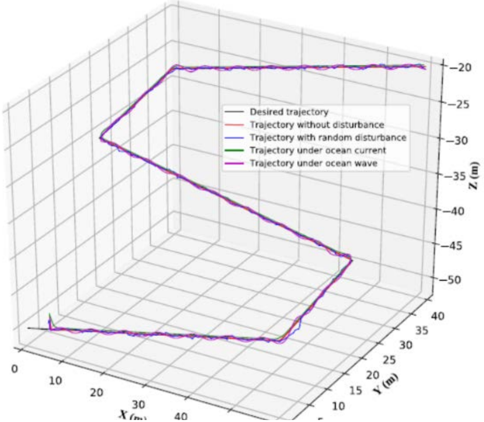
- Path following (without speed settings):
  - 3D LOS needed e.g. Yu, C., Xiang, X., Lapierre, L. and Zhang, Q., 2017, "Nonlinear Guidance and Fuzzy Control for Three-Dimensional Path Following of an Underactuated Autonomous Underwater Vehicle", Ocean Engineering, Vol. 146, pp. 457–467.
  - Take account of steerability in the different DOF, for instance the inertia of the ballast system (Bi, A. and Feng, Z., 2019, "Composite Hovering Control of Underwater Vehicles via Variable Ballast Systems", Journal of Marine Science and Technology, Vol. 25, No.3, pp. 659–666) or the possibility of the sway motion (Sans-Muntadas, A., Kelasidi, E., Pettersen, K. Y. and Brekke, E., 2019, "Path Planning and Guidance for Underactuated Vehicles with Limited Field-of-View", Ocean Engineering, Vol. 174, pp. 84–95).



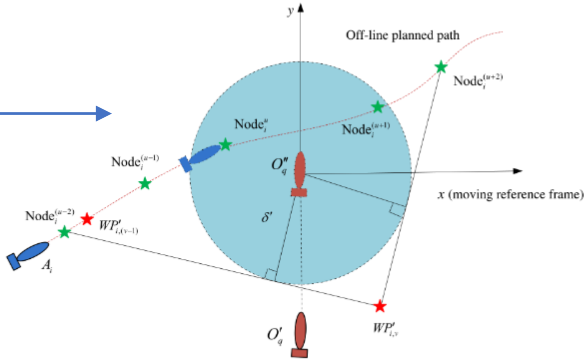


6.2 Control

- Trajectory Tracking (with speed settings):
  - 3D MPC (Model Predictive Control) based (Zhang, Y., Liu, X., Luo, M. and Yang, C., 2019, "MPC-Based 3-D Trajectory Tracking for an Autonomous Underwater Vehicle with Constraints in Complex Ocean Environments", Ocean Engineering, Vol. 189, pp. 1–10.)
  - Use of bio-inspiration (Zhou, J., Ye, D., Zhao, J. and He, D., 2018, "Three-Dimensional Trajectory Tracking for Underactuated AUVs with Bio-Inspired Velocity Regulation", International Journal of Naval Architecture and Ocean Engineering, Vol. 10, No.3, pp. 282–293.)



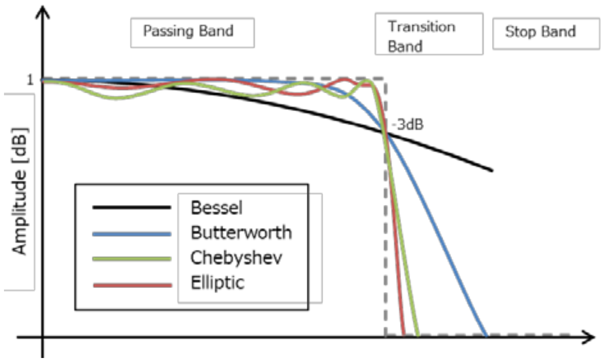
- Collision Avoidance
  - with other AUV, e.g. Zhuang, Y., Huang, H., Sharma, S., Xu, D. and Zhang, Q., 2019, "Cooperative Path Planning of Multiple Autonomous Underwater Vehicles Operating in Dynamic Ocean Environment", ISA Transactions, Vol. 94, pp. 174–186.
  - or environment e.g. Li, Y., Ma, T., Chen, P., Jiang, Y., Wang, R. and Zhang, Q., 2017, "Autonomous Underwater Vehicle Optimal Path Planning Method for Seabed Terrain Matching Navigation", Ocean Engineering, Vol. 133, pp. 107–115.

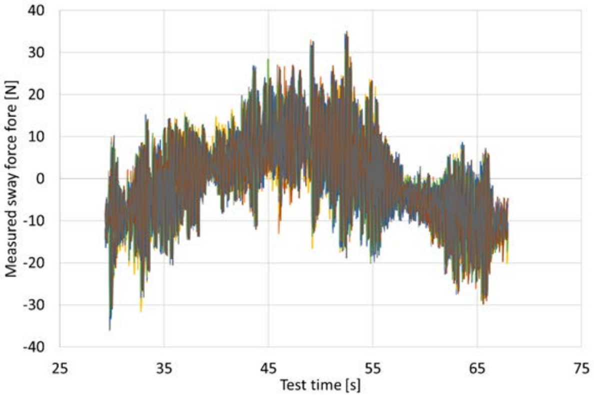


- Formation Control and Docking Control

7.1 Signal Processing

- AD-conversion: $\mathrm{LSB} = \frac{\mathrm{Range}}{2^{\mathrm{bit}}}$ (normally not an issue anymore)
- Filtering:
  - Better representation or condense oversampled signals
  - (blue) Noise removal
  - Caveats!
- Time step (manoeuvring):
  - Commonly 50 – 100 Hz
  - At least twice filter rate





7.1 Signal Processing

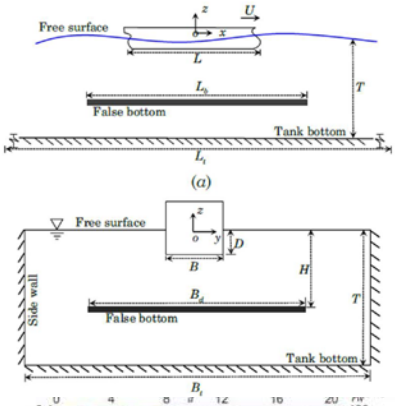
- Propagation of noise uncertainty: extension of 7.5-02-01-06 Determination of Type A Uncertainty Estimate of a Mean Value from a Single Time Series Measurement towards harmonic tests, elaborated in Delefortrie, G. and Kishimoto, T., 2019, "The Uncertainty Induced by Noise and Filtering on the Results of Captive PMM Tests", AMT 19, Rome, Italy: noise uncertainty on higher harmonics is $\sqrt{2}$ times noise uncertainty mean value

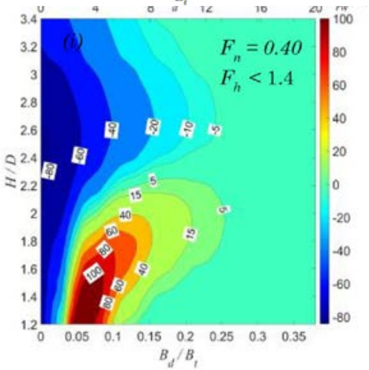
- Application for
  - SI – techniques
  - Sensitivity studies

7.2 Shallow water testing

- False bottom was used by Liu, H., Ma, N. and Gu, X., 2018b, "Uncertainty Analysis of Ship-Bank Interaction Tests Using Planar Motion Mechanism in a Circulating Water Channel", 13th International Conference on Hydrodynamics, Incheon, Korea, pp. 311–320.: uncertainty of water depth is major in the total uncertainty

- Effect of false bottom has been studied by Li, M., Yuan, Z. and Delefortrie, G., 2019, "Investigation of the False Bottom Effects on Ship Model Tests", AMT 19, Rome, Italy, pp. 1–16. based on the effect of wave resistance: effects increase with:
  - Decreasing water depth
  - Increasing gap sizes => y_{infl} seems applicable for false bottom width





7.3 Turbulence stimulation and scale effects

- Questionnaire sent out to 32 ITTC institutes, responses received by 19:
  - Measures taken to deal with scale effects prior or while executing tests;
  - Measures taken to deal with scale effects after executing tests;
  - Means of validating the test results;
  - Applications of turbulence stimulation

- Scale effects (manoeuvring):
  - Concern for 77%
  - Main reasons for smaller scale:
  - Counteract before/during tests by:
    - Turbulence stimulation (86%)
    - Changing rpm (58%)
    - Preliminary numerical research (42%)

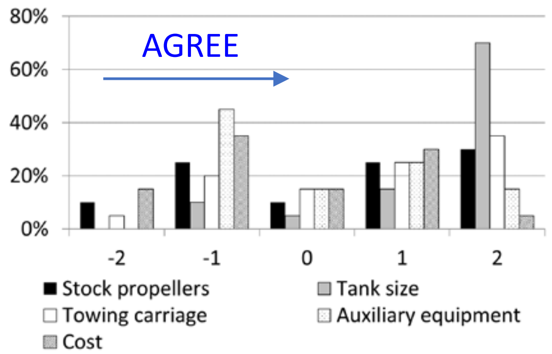


Figure 48. Factors limiting the maximal ship model size

7.3 Turbulence stimulation and scale effects

- Scale effects (manoeuvring):
  - Correct after tests by (minority):
    - Changing rudder (area, forces)
    - Changing lateral force distribution
  - MC opinion:
    - Worse with increasing drift angle (viscous force)
    - Worse with decreasing water depth (increased return flow) (worse with increasing blockage)

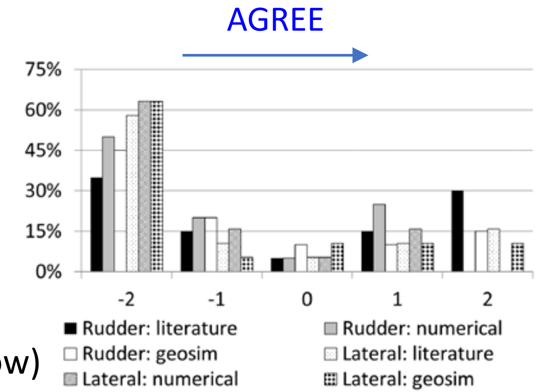


Figure 51. Means to correct for scale effects for manoeuvring forces.

7.3 Turbulence stimulation and scale effects

- CMT validation (manoeuvring)

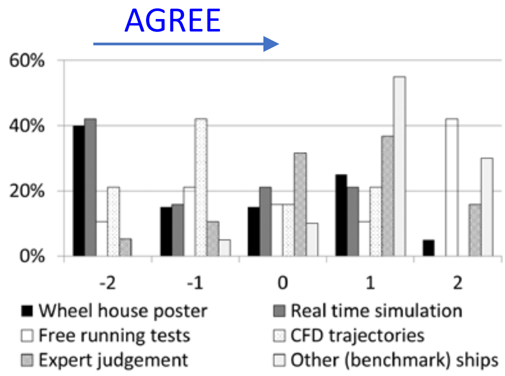


Figure 52. Ways to validate the results of captive manoeuvring tests.

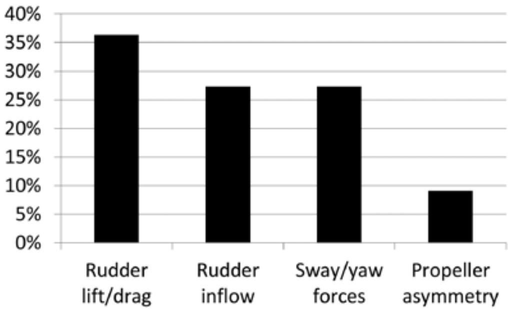


Figure 53. Components of the mathematical model that are tuned if necessary.

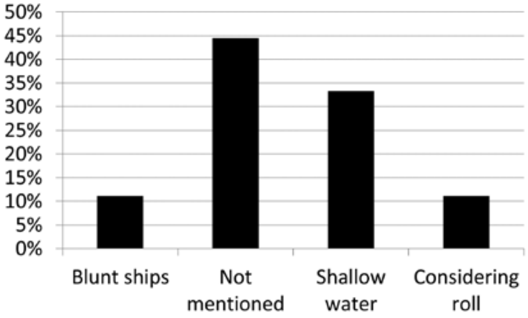


Figure 54. Conditions when tuning is mostly needed.

7.3 Turbulence stimulation and scale effects

- Turbulence stimulation:
  - mainly used for resistance (92% follows appropriate ITTC procedure)
  - Manoeuvring: bilge keels, classified

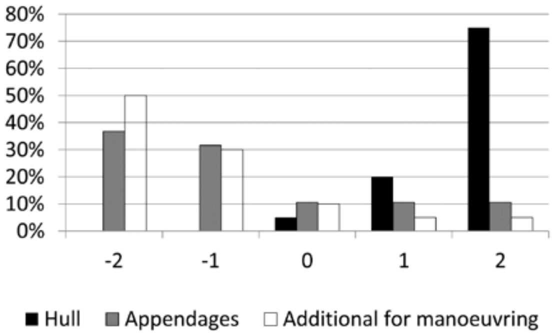


Figure 55. Use of turbulence stimulation.

- Scale effects in literature (manoeuvring):
  - Means:
    - Geosim, e.g. Araki, M., 2018, "Scale Effects on Ship Maneuverability Using RANS", OMAE2018 , Madrid, Spain, pp. 1–7.
    - Auxiliary thrusters, e.g. Suzuki, R., Tsukada, Y. and Ueno, M., 2019, "Estimation of Full-Scale Ship Manoeuvring Motions from Free-Running Model Test with Consideration of the Operational Limit of an Engine", Ocean Engineering, Vol. 172, pp. 697–711.
    - RANS studies for squat in shallow water (Kok et al. (2020), Shevchuk et al. (2019), Zhang H. et al. (2018)): divergent conclusions…

8.1 State of the Art

- Manoeuvring performance in deep unrestricted water: commercial RANS most used method (*in publications*) with advanced applications
- USV: highly digitized research and overwhelming presence (*in publications*): lack of experimental/full scale validation
- Autopilots: more advanced applications are being studied (strong link with USV)
- Shallow, restricted, confined water: also confirmed trend towards RANS (*in publications*) .

8.1 State of the Art

- *Personal thoughts spanning MC terms of chairman/secretary:*
  - *Number of publications read/considered:*
    - *27th: 237 (79/year)*
    - *28th*: 333 (111/year)
    - *29th*: 782 (196/year)
  - *Commercial basin work is hardly published in literature ↔ academic work?*
  - *Reviewers are selected among authors ↔ academization of review work?*
  - *Example of reviewer comments, rejecting an EFD-based paper the chairman co-authored:*

1. This paper does not contain technical difficulties and new and significant information, and lacks innovations, looking more like a technical report than a paper.
[…]
7. How does the mathematical motion model describe the influence of the shallow and confined water on the hydrodynamics of ships ?
8. What is the 'restricted water' and what is' confined water'? Please clearly give their meanings.
[…]
11. The 'propeller revolution' and 'propeller rate' are both used in this paper, what is the difference between them?

8.2 Procedures and Guidelines

- All manoeuvring procedures/guidelines have been revised
- Major changes to:
  - Validation of Manoeuvring simulation models (7.5-02-06-03)
  - Uncertainty Analysis for manoeuvring predictions based on captive manoeuvring tests (7.5-02-06-04)
  - Captive Model Test Procedure (7.5-02-06-02).
- New guidelines created:
  - UV Full Scale Manoeuvring Trials (7.5-04-02-02)
  - Benchmark Data for Validation of Manoeuvring Predictions (7.5-02-06-06)
  - Captive Model Test for underwater vehicle (7.5-02-06-07)

8.3 Benchmark data

- Presently available datasets covered in Benchmark Data for Validation of Manoeuvring Predictions (7.5-02-06-06)
- SIMMAN (covid) postponed to end 2021

8.4 Underwater Vehicles

- Manoeuvring hydrodynamics:
  - Also noted increase towards numerical methods
  - Increase of joint EFD-CFD applications, enjoying the benefits of both worlds
- Manoeuvring control:
  - Increasing research in control systems, lagging experimental applicability

8.5 EFD Challenges

- Noise uncertainty of higher harmonics is $\sqrt{2}$ times the uncertainty of the mean as computed in 7.5-02-01-06
- Water depth is dominant in UA propagation, hence well designed (false) bottoms are crucial
- Scale effects are important for manoeuvring (8/10 concerned), relationship with tuning of mathematical models

Recommendations (1/2)

- Study the potential impact of Unmanned Surface Vehicles (or Autonomous Navigation) to the Manoeuvring Committee:
  - the state of the art of autopilots, with proven applicability in a tank environment or at full-scale;
  - the state of the art of artificial intelligence.

- Support SIMMAN with the post processing and analysis of the results of SIMMAN 2021.

- Continue the work with (autonomous) underwater vehicles towards completion of the guidelines:
  - draft a guideline on the validation of UV models for manoeuvring purposes;
  - extend the AUV full-scale trials guideline to consider submarines and ROV as well.

- Support the creation of benchmark data, specifically for:
  - (autonomous) under water vehicles;
  - inland navigation, including pushed or towed convoys;
  - model scale vessels with a documented full-scale variant.

Recommendations (2/2)

- Expand the full-scale manoeuvring trials procedure to account for the measurement of any kind of full-scale manoeuvre as a supplement to (virtual) tank tests.
- Maintain the attention on scale effects and the effect of tank blockage on the interpretation of results, by stimulating geosim research.
- Continue the update of the captive model test procedure, with specific attention to the treatment of amplitudes, frequencies and inertial coefficients as recommended by SIMMAN.
- Update the captive model uncertainty procedure, to have a single integrated example, based on the SIMMAN results (2021), instead of different appendices.
- Investigate the effect of novel manoeuvring devices and clean fuel technologies on the manoeuvrability.
- The Manoeuvring Committee recommends to the Full Conference to adopt the updates to the procedures and the newly created guidelines.