Recent Advances in Performance Prediction of Planing Hulls Using Mathematical Modelling

Assis/Prof Abbas Dashtimanesh
KTH Royal Institute of Technology

Contact me at abbas.Dashtimanesh@taltech.ee

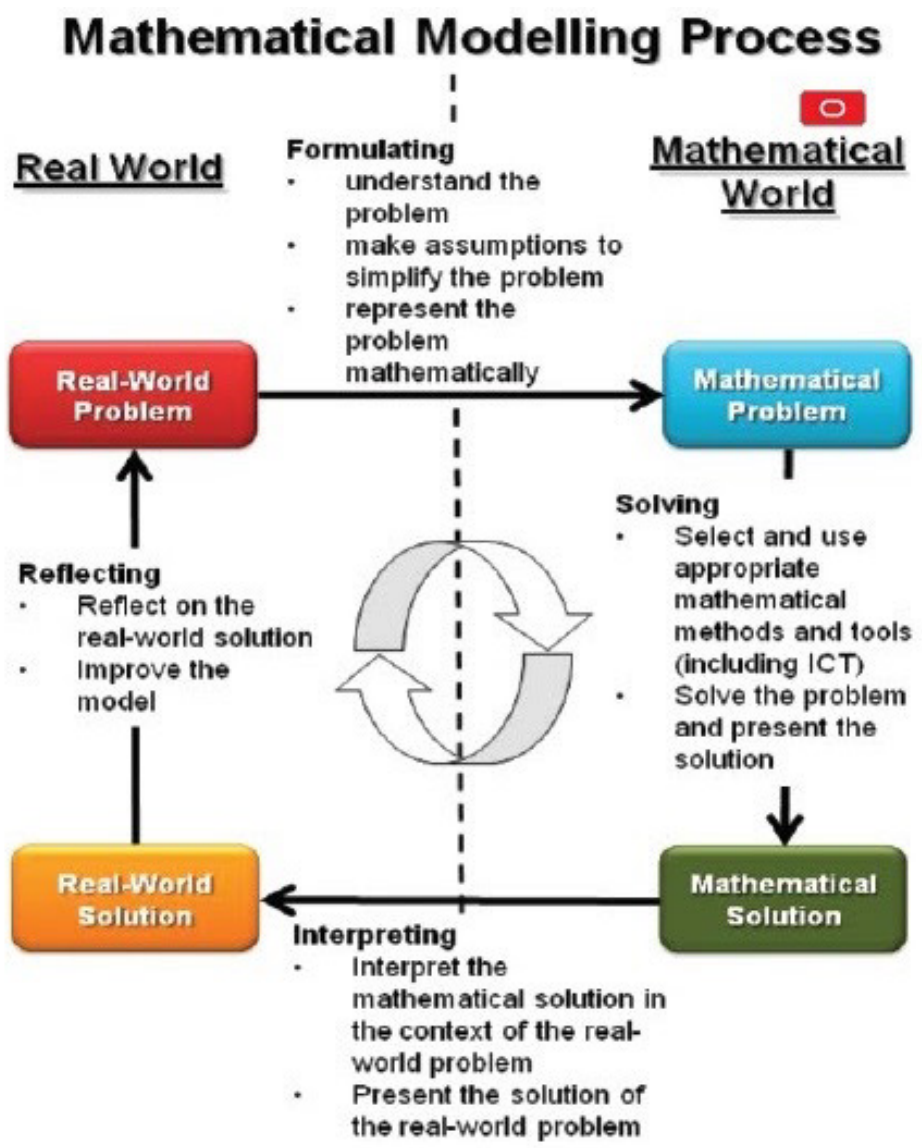
High Speed Boat Operation Forum Conference
Gothenburg, Sweden, Aug 31 – Sep 2, 2021

CONTENT

- What's the idea?
- What problem is our research contributing to solve?
- What is our solution to the problem?
- Some Results
- What will the next steps be?
- Who/What benefits from our research?
- What do we need stakeholders to do?

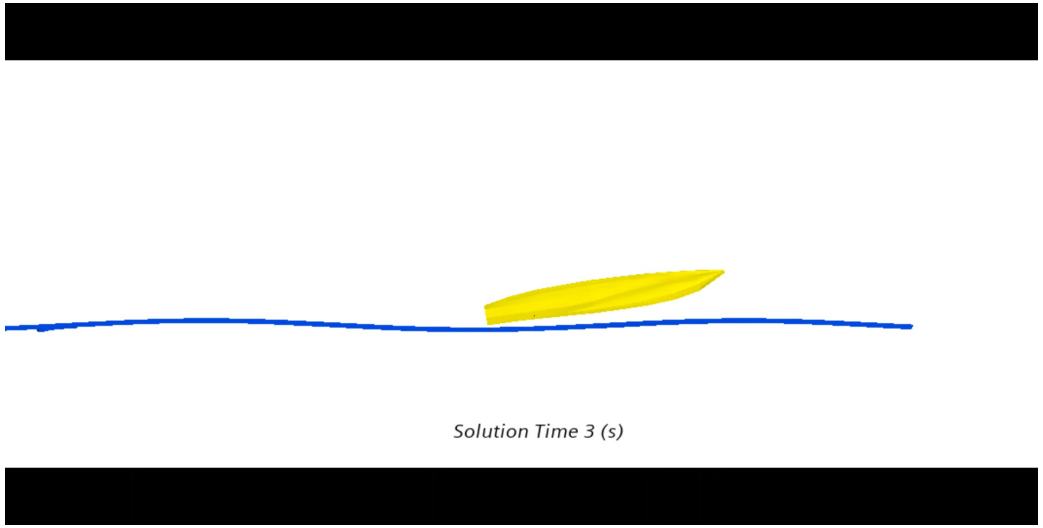
WHAT'S THE IDEA?

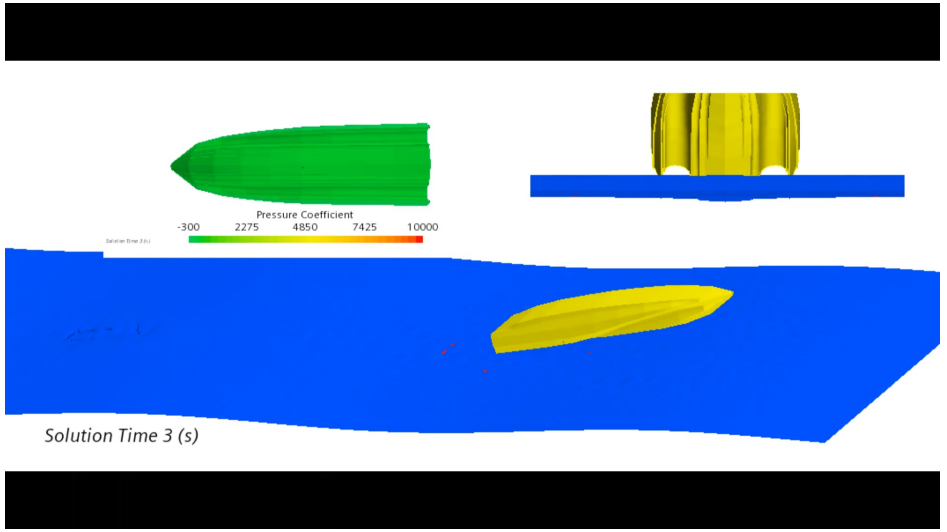
- We have two different worlds: Real world and Mathematical world!
- Converting the complicated real world phenomena to the simplified mathematical expressions!
- Mathematical models are just a part of reality with an approximate solution.
- We need a reasonable solution accuracy at least for engineering purposes in early stage design.



https://sites.google.com/a/bedoknorthsec.edu.sg/bnss-mathematical-modelling-project-teachers/group-5

What Problem Is our Research Contributing to Solve?

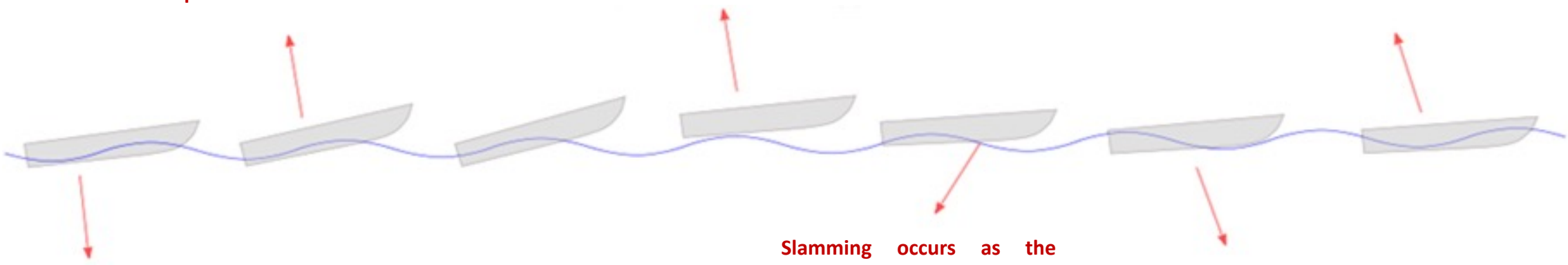




As the vessel moves upward, the pressure area decreases

The vessel may come out of the water. This phenomenon is known of fly-over.

Large vertical acceleration in upward direction is caused, and the vessel started to exit the water.



Vessel tends to move upward and its bow is pushed up by waves

Slamming occurs as the vessel moves downward.

The vessel is pitched down and larger area is washed by waves.

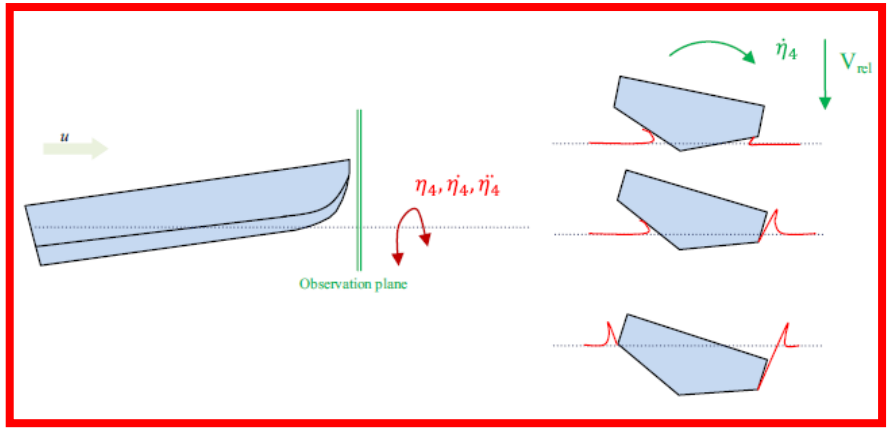
WHAT IS OUR SOLUTION TO THE PROBLEM?

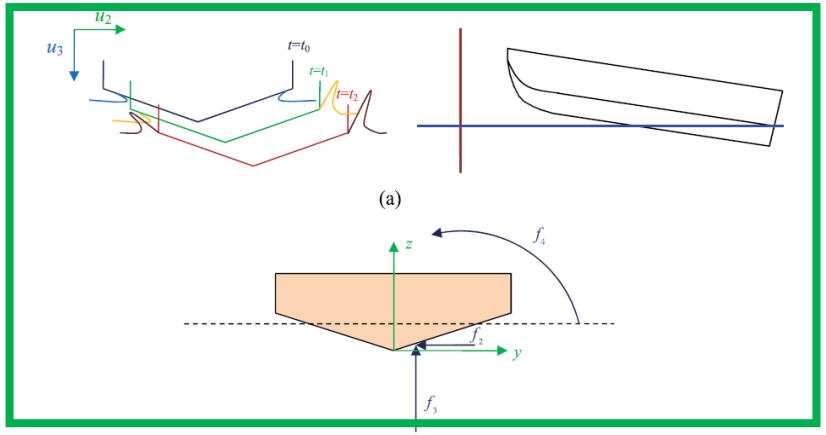
Mathematical modelling

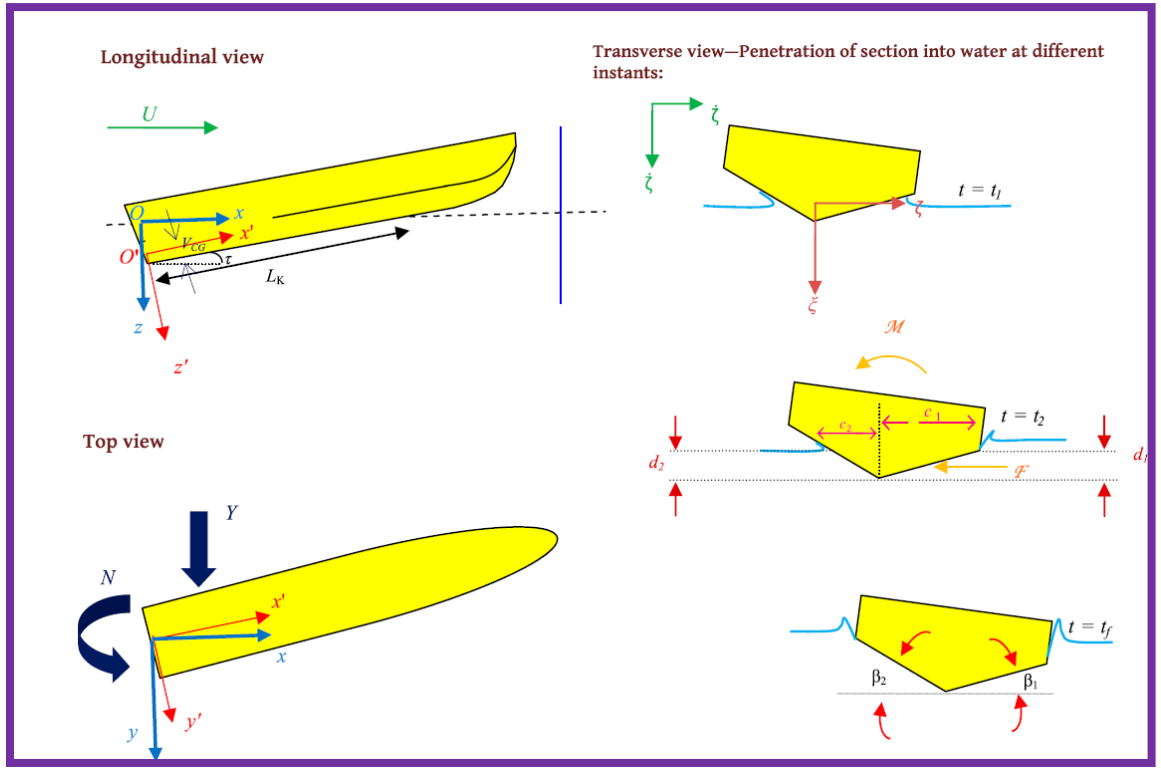
Asymmetric 2D+t Theory

Oblique 2D+t Theory

Oblique- Asymmetric 2D+t Theory







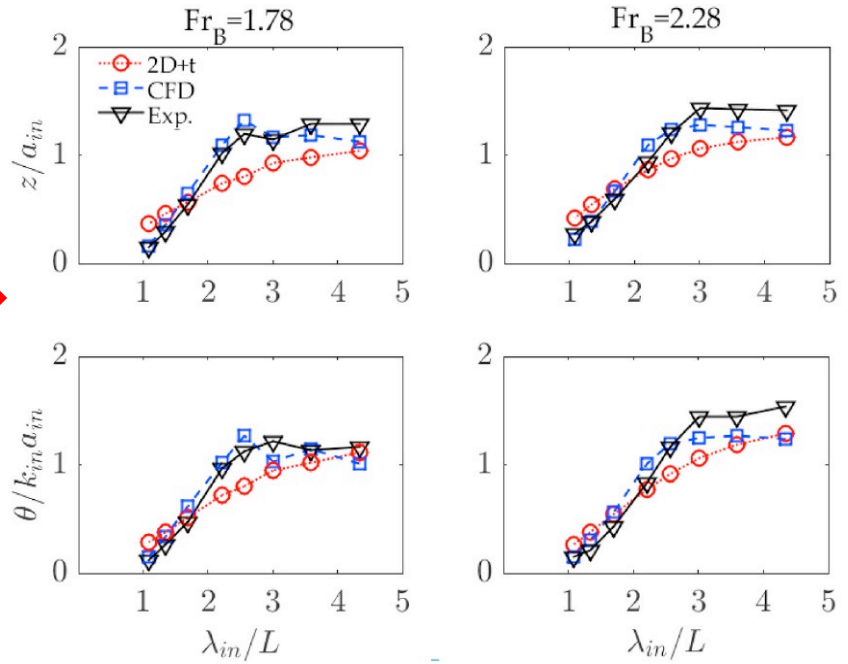
A. Dashtimanesh, H. Enshaei, S. Tavakoli, Oblique-asymmetric 2D+T model to compute hydrodynamic forces and moments in coupled sway, roll, and yaw motions of planing hulls, Journal of Ship Research, Vol. 63, No. 1, pp:1-15, 2019.

P. Ghadimi, S. Tavakoli, A. Dashtimanesh, R. Zamanian, Steady performance prediction of a heeled planing boat in calm water using asymmetric 2D+T model, Journal of Engineering for the Maritime Environment, Vol. 231, No. 1, 2017.

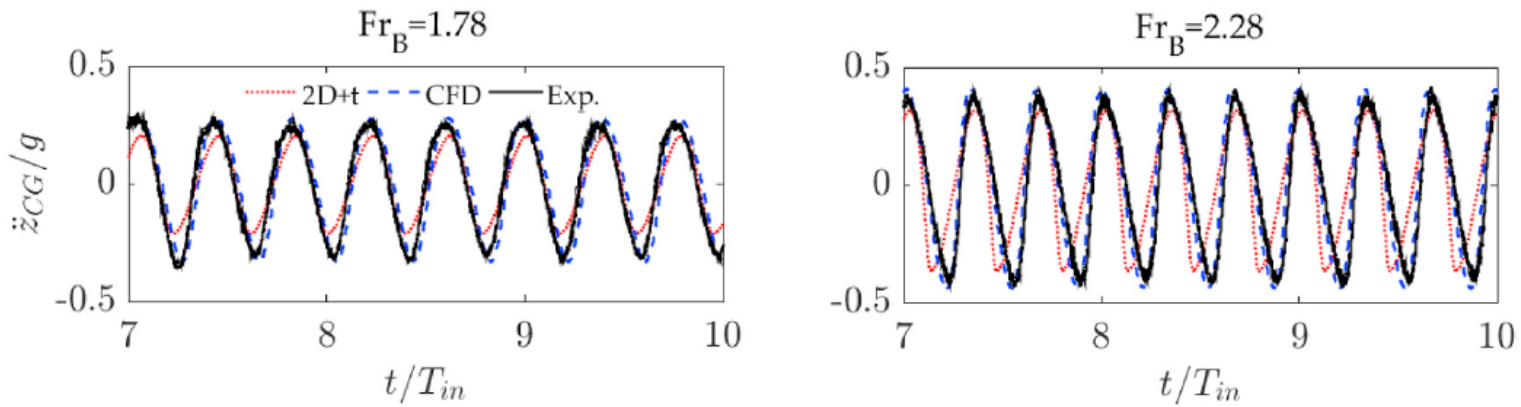
SOME RESULTS

- **Coupled Heave and Pitch motions**
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans

Heave and Pitch **Motions**



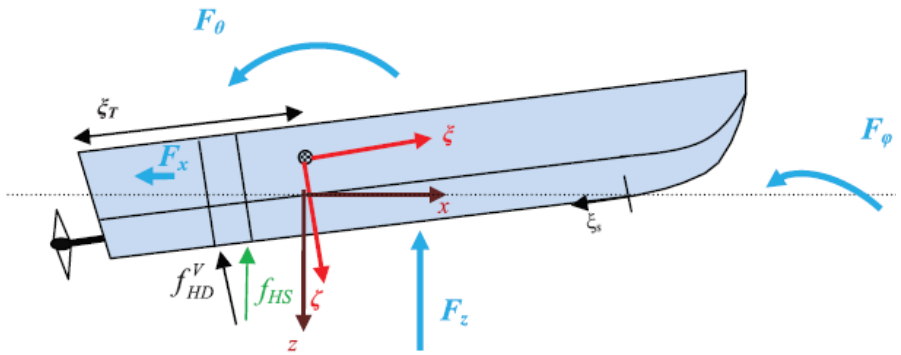
Vertical Acceleration



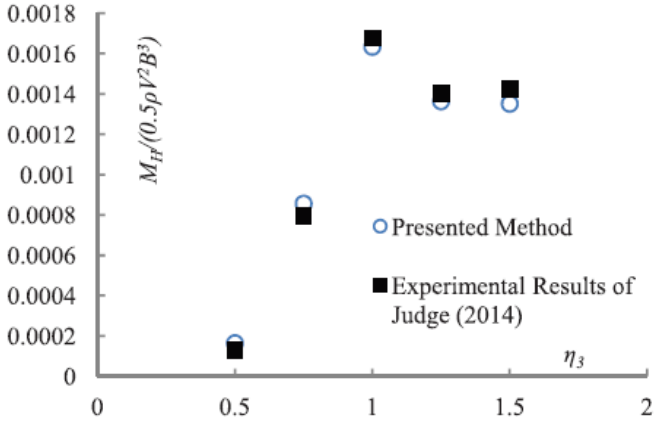
S. Tavakoli, R. N. Bilandi, S. Mancini, F. De Luca, A. Dashtimanesh, Dynamic of a Planing Hull in Regular Waves: Comparison of Experimental, Numerical and Mathematical Methods, Ocean Engineering, Vol. 2017, pp: 107959, 2020.

SOME RESULTS

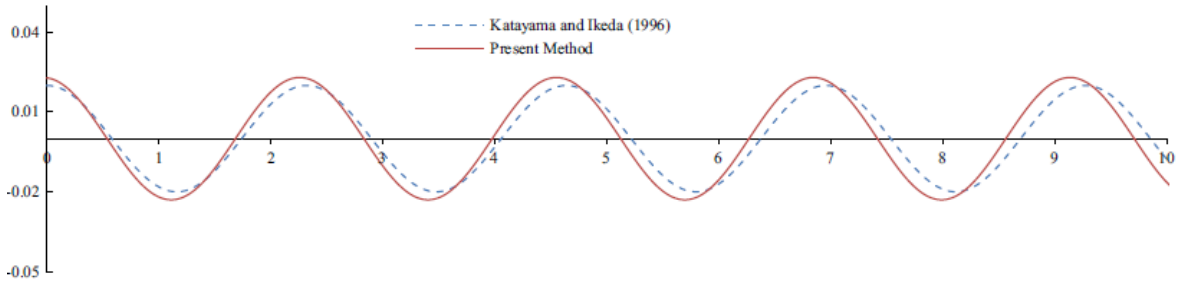
- Coupled Heave and Pitch motions
- **Coupled Heave, Pitch and Roll motions**
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans

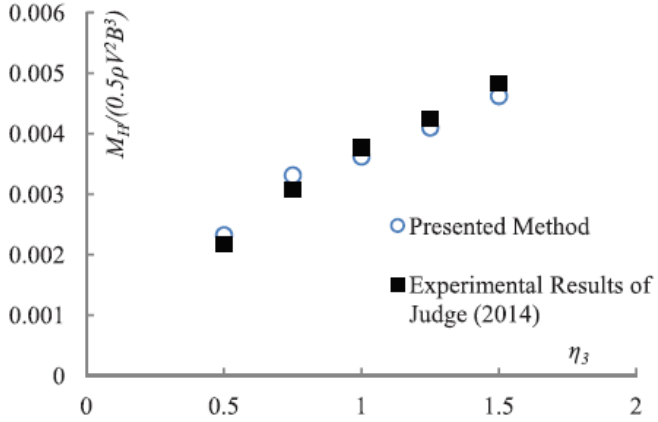


***Rolling* Moment**



Roll Motion

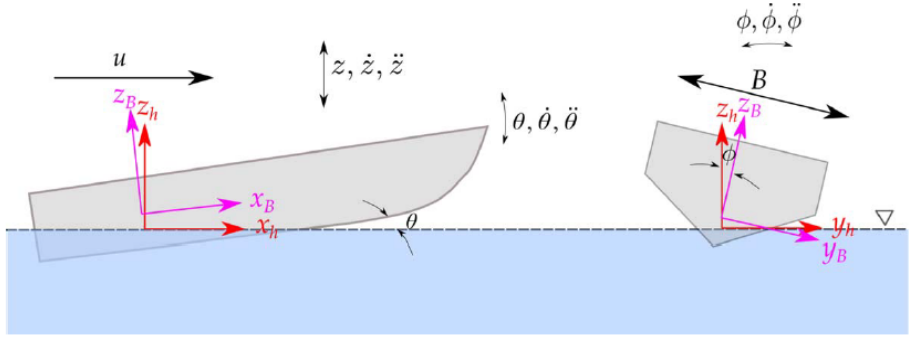




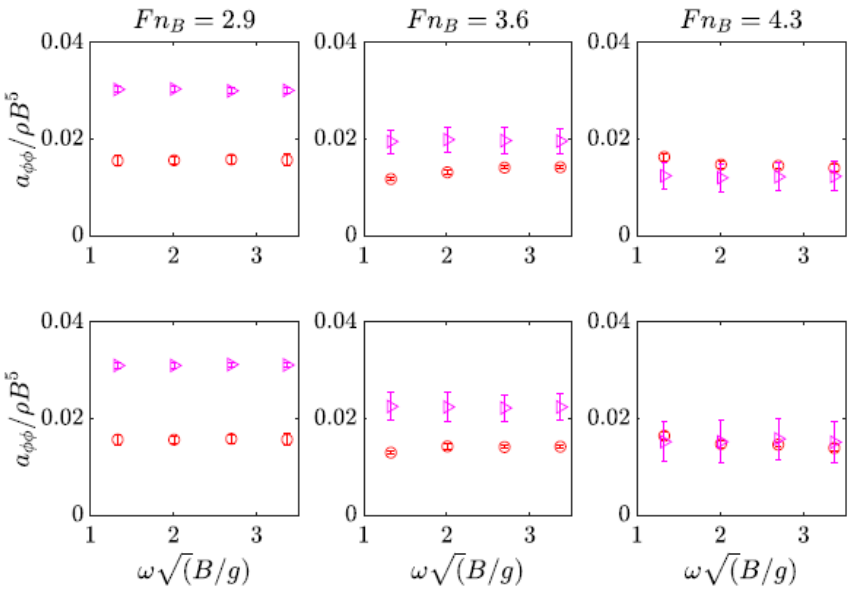
P. Ghadimi, S. Tavakoli, A. Dashtimanesh, A nonlinear mathematical model for coupled heave, pitch, and roll motions of a high-speed planing hull, Journal of Engineering Mathematics, Vol. 104, No. 1, pp: 157-194, 2017.

SOME RESULTS

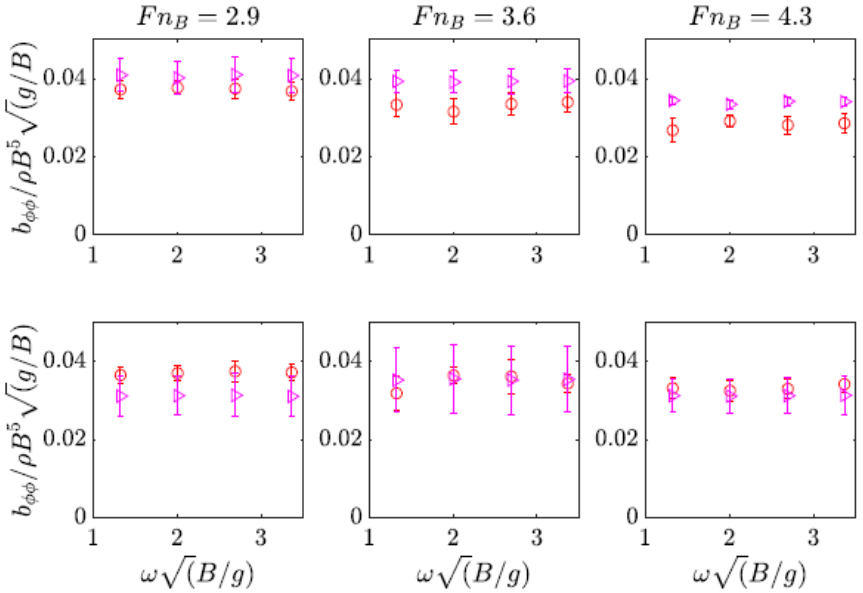
- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- **Roll Motion**
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans



Roll Added Mass Coefficient



Roll Damping Coefficient

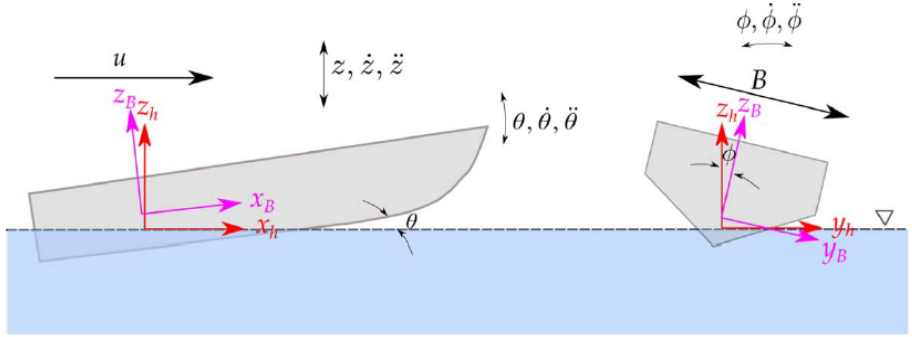


S. Tavakoli, A. Dashtimanesh, S. Mancini, A theoretical method to explore the influence of free roll motion on the behavior of a high-speed planing vessel through a steady yawed motion, Transactions RINA, International Journal of Small Craft Technology, Vol. 160, Issue. B2, 2018.

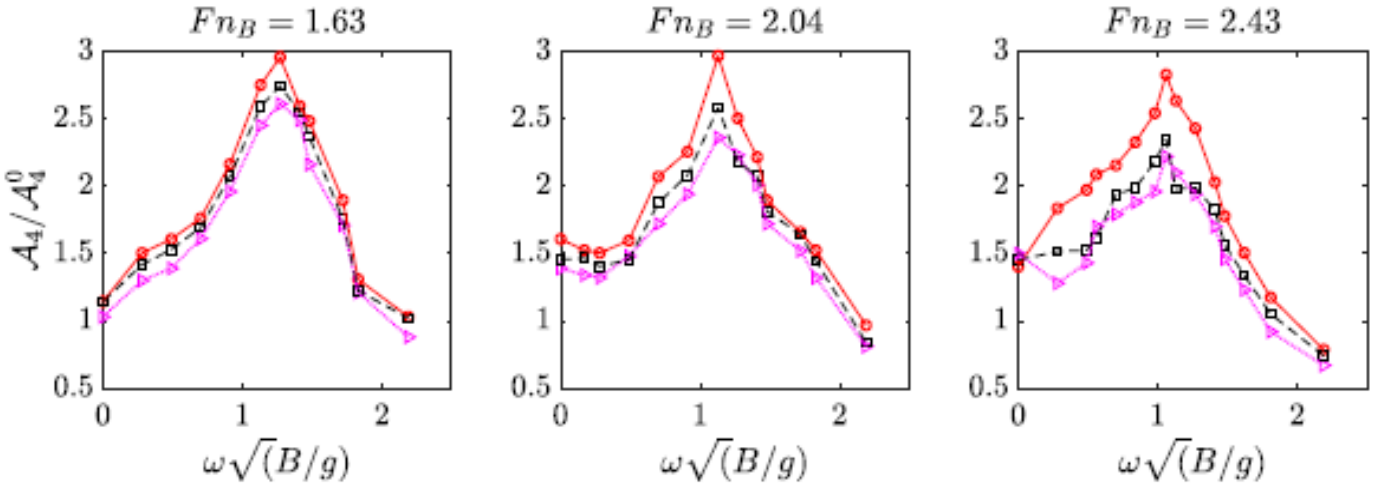
S. Tavakoli, A. Dashtimanesh, S. Mancini, J. A Mehr, S. Milanesi, Effects of Vertical Motions on Roll of Planing Hulls, Journal of Offshore Mechanics and Arctic Engineering, Vol. , pp: 1-22, 2021.

SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- **Roll Motion**
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans



Roll response of the planing hull



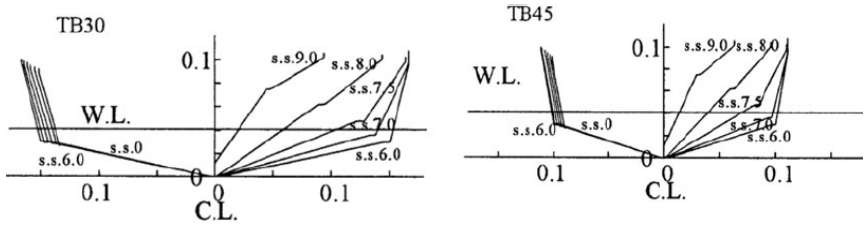
Triangle markers show the experimental data. Square and circle markers, respectively, show the 4DOF and 1DOF mathematical results.

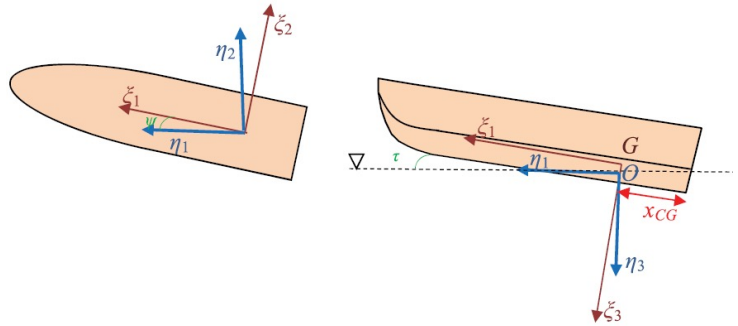
S. Tavakoli, A. Dashtimanesh, S. Mancini, A theoretical method to explore the influence of free roll motion on the behavior of a high-speed planing vessel through a steady yawed motion, Transactions RINA, International Journal of Small Craft Technology, Vol. 160, Issue. B2, 2018.

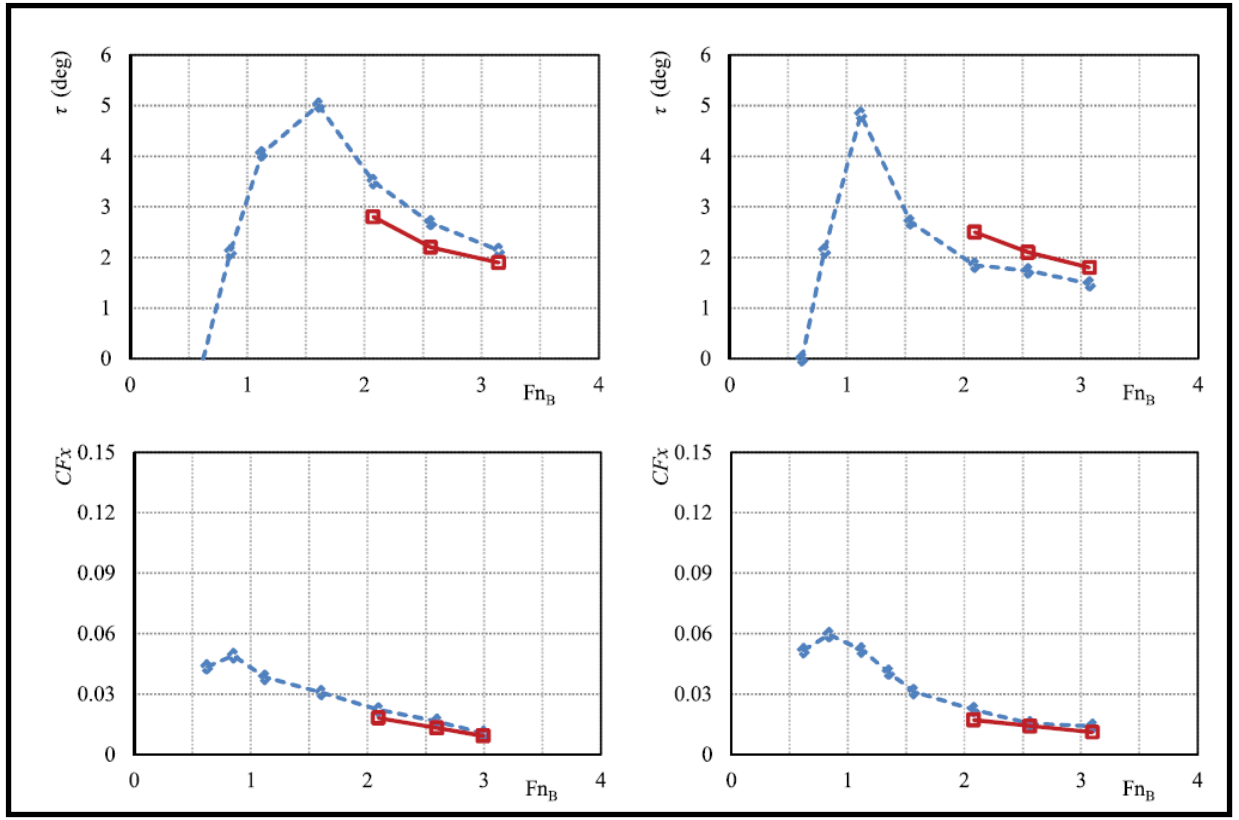
S. Tavakoli, A. Dashtimanesh, S. Mancini, J. A Mehr, S. Milanesi, Effects of Vertical Motions on Roll of Planing Hulls, Journal of Offshore Mechanics and Arctic Engineering, Vol. , pp: 1-22, 2021.

SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- **Yawed Planing Boat**
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans







Steady Yawed Planing Motion

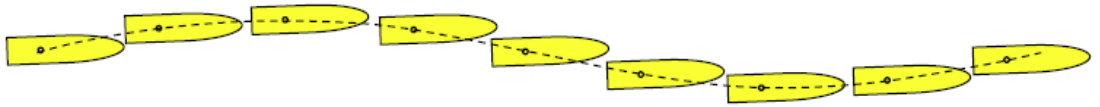
S. Tavakoli, A. Dashtimanesh, Running attitudes of yawed planing hulls in calm water: development of an oblique 2D+ T approach, Journal of Ships and Offshore Structure, Vol. 12, No. 8, pp: 1086-1099, 2017.

S. Tavakoli, A. Dashtimanesh, P. Sahoo, An oblique 2D+T approach for hydrodynamic modeling of yawed planing boats in calm water, Journal of Ship Production and Design, Vol. 34, No. 4, pp: 335-346, 2018.

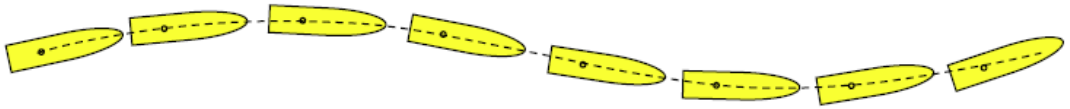
SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- **Planar Motion Mechanism Test**
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans

Pure sway motion

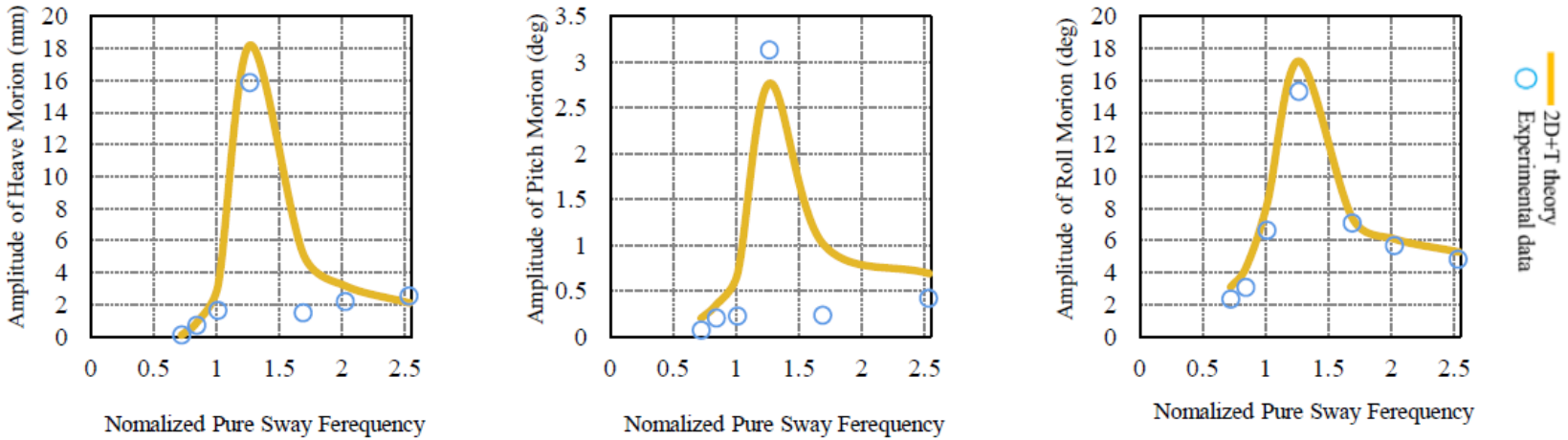


Pure yaw motion



Possible motions in vertical motions during forced sway/yaw motions

Possible roll motion during forced sway/yaw motions

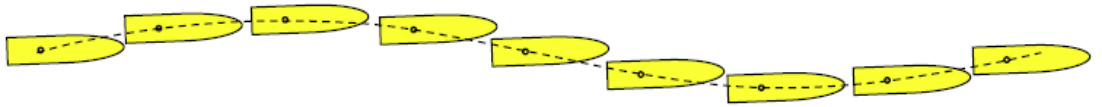


S. Tavakoli, A. Dashtimanesh, Mathematical simulation of planar motion mechanism test for planing hulls by using 2D+ T theory, Ocean Engineering, Vol. 169, pp: 651-672, 2018.

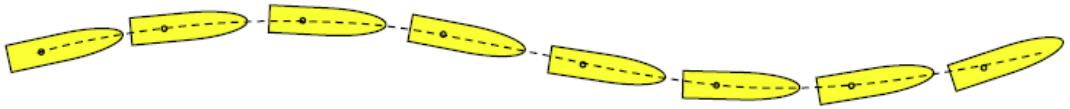
SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- **Planar Motion Mechanism Test**
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans

Pure sway motion

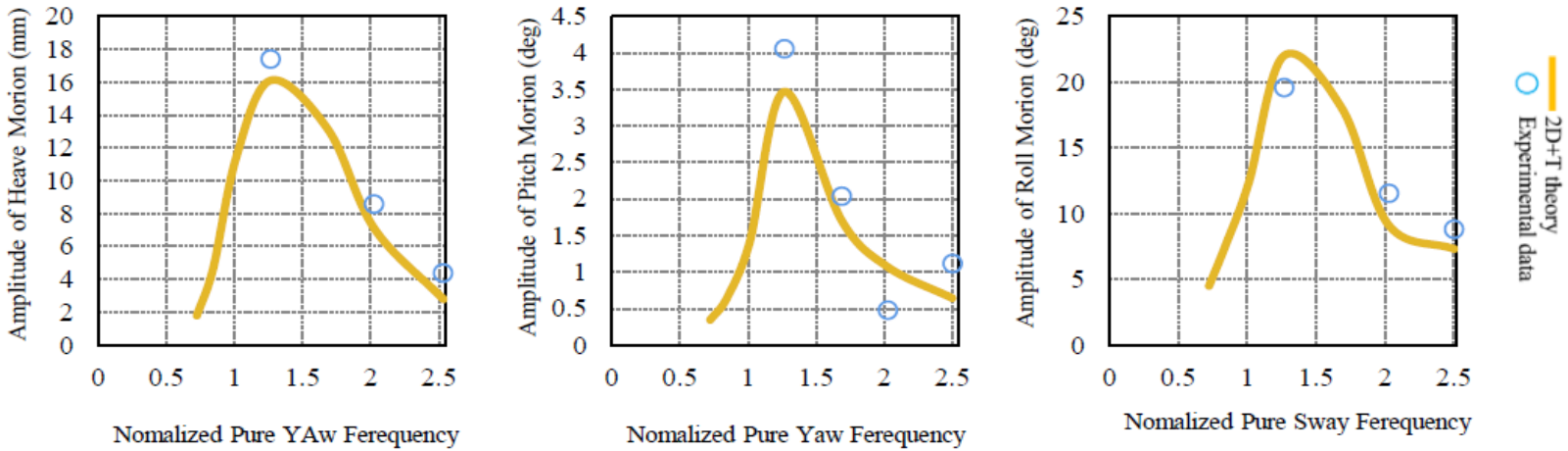


Pure yaw motion



Possible motions in vertical motions during forced sway/yaw motions

Possible roll motion during forced sway/yaw motions

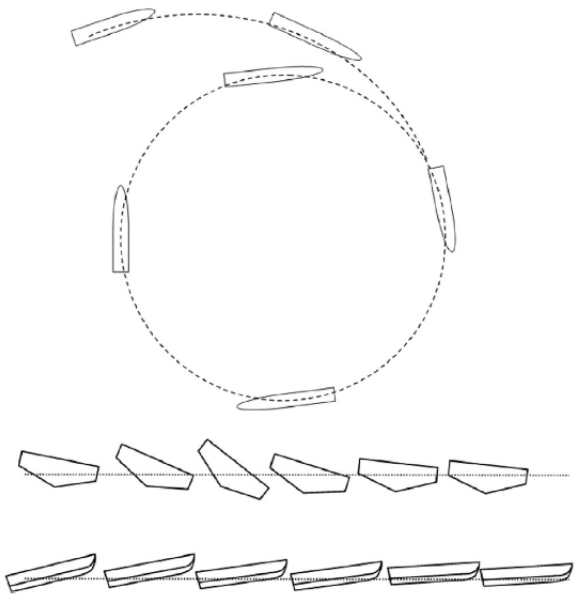


S. Tavakoli, A. Dashtimanesh, Mathematical simulation of planar motion mechanism test for planing hulls by using 2D+ T theory, Ocean Engineering, Vol. 169, pp: 651-672, 2018.

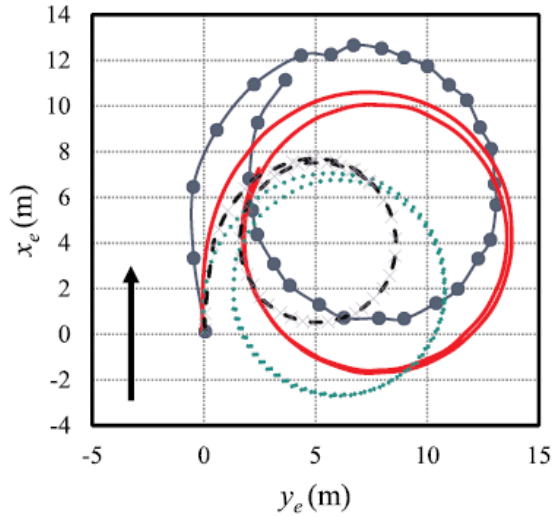
SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- **Steady Turning Manoeuvr**
- Performance of Stepped Hulls
- Performance of planing Catamarans

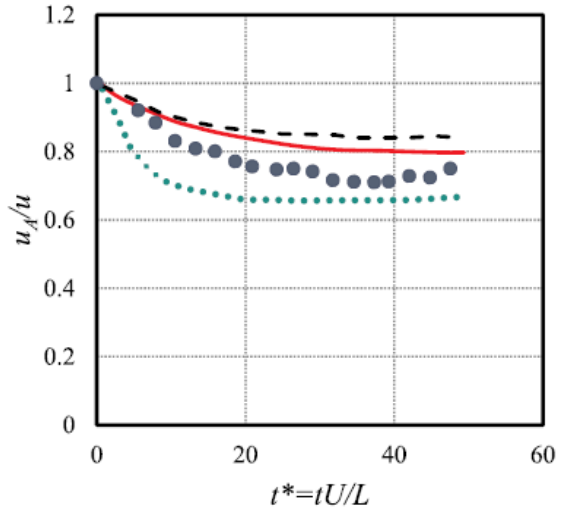
❑ *Comparison of 2D+t results against experimental data, conventional method, and interpolation method in steady turning*



trajectory of the vessel



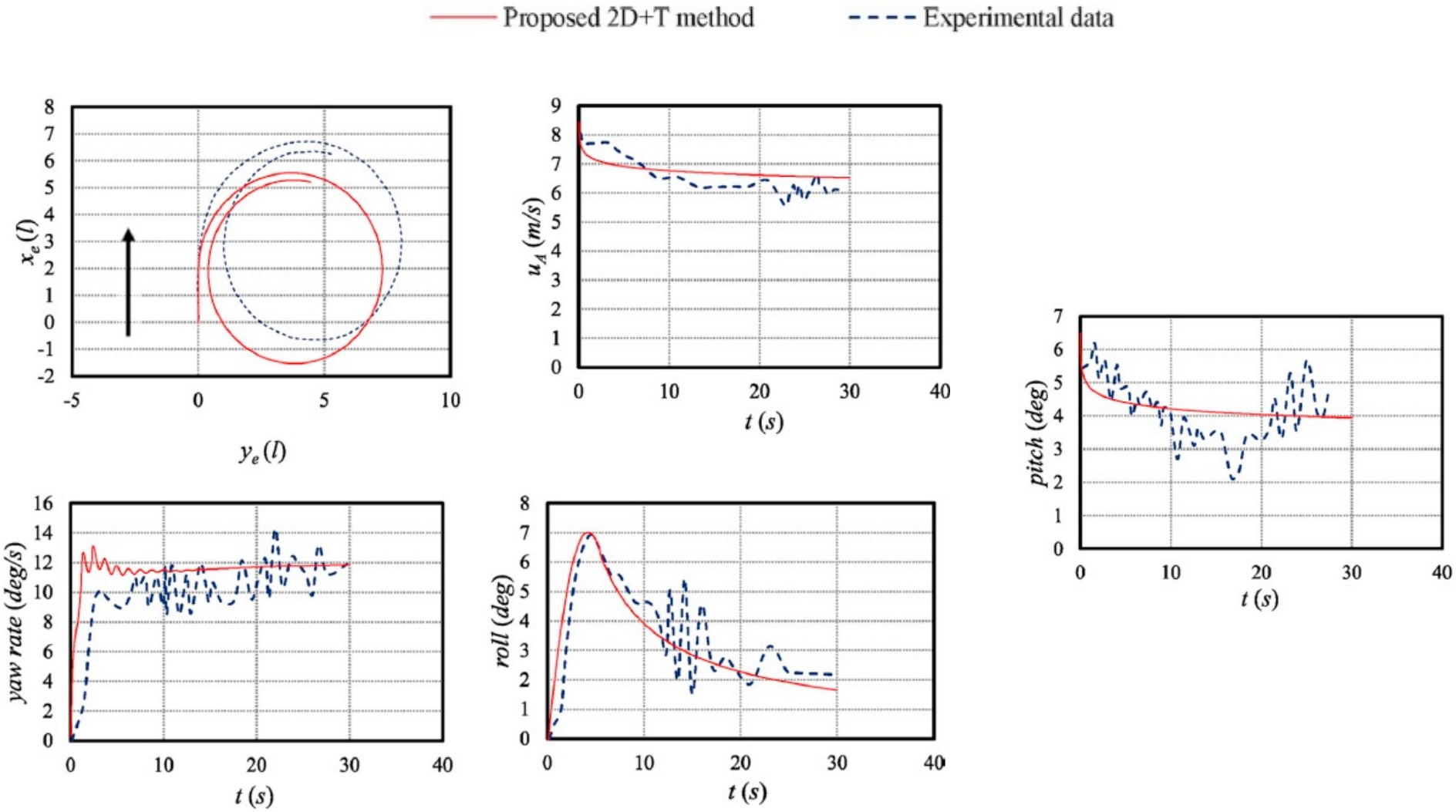
speed reduction



S. Tavakoli, A. Dashtimanesh, A six-DOF theoretical model for steady turning maneuver of a planing hull, Ocean Engineering, Vol. 189, pp: 106328, 2019.

SOME RESULTS

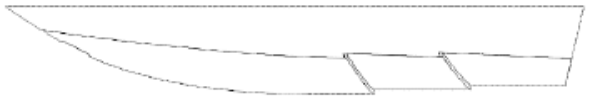
- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- Performance of planing Catamarans

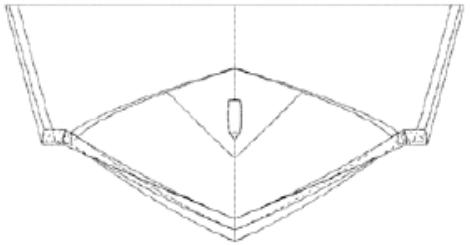


S. Tavakoli, A. Dashtimanesh, A six-DOF theoretical model for steady turning maneuver of a planing hull, Ocean Engineering, Vol. 189, pp: 106328, 2019.

SOME RESULTS

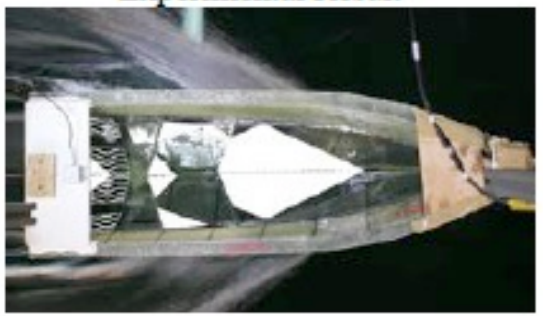
- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- **Performance of Stepped Hulls**
- Performance of planing Catamarans



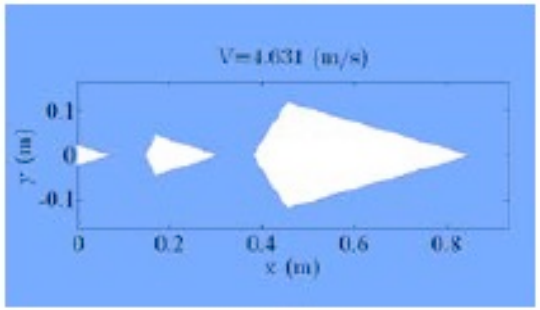


Wetted surface

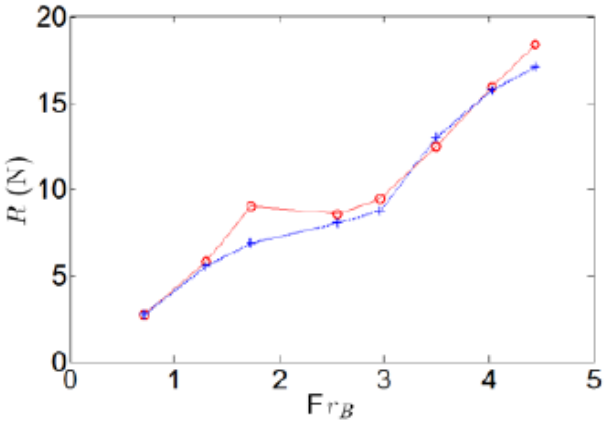
Experimental Result

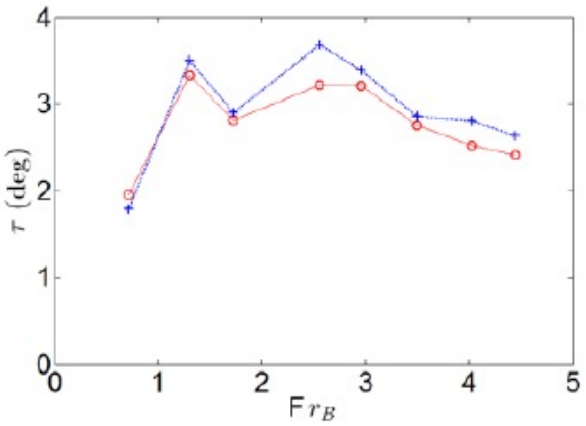


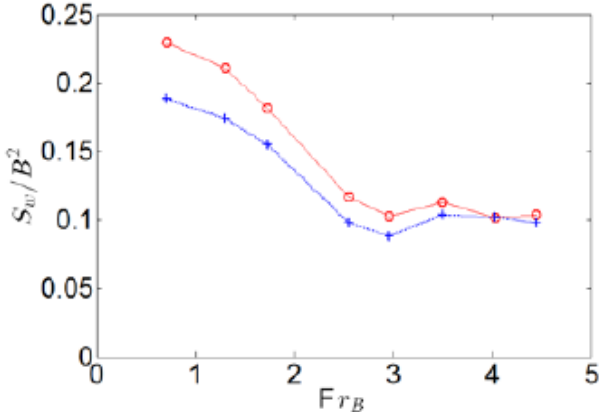
Mathematical Method



Running Attitude



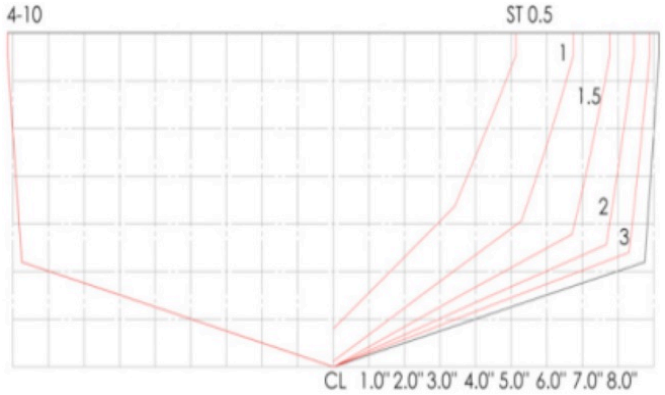


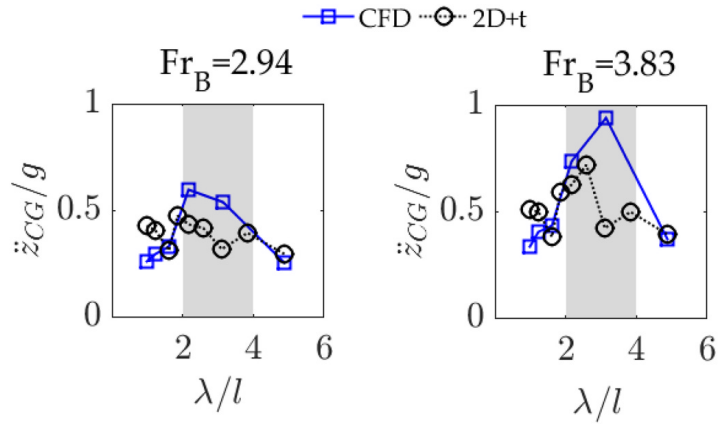


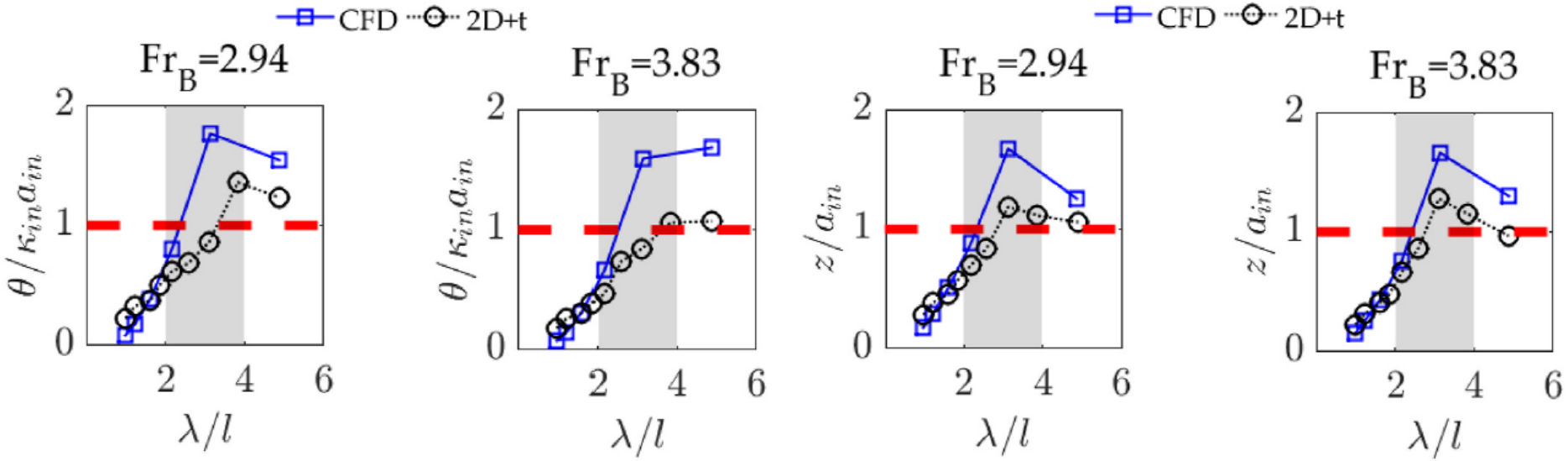
R. N. Bilandi, L. Vitiello, S. Mancini, V. Nappo, F. Roshan, S. Tavakoli, A. Dashtimanesh, Calm-water performance of a boat with two swept steps at high-speeds: Laboratory measurements and mathematical modeling, Procedia Manufacturing, Vol. 42, pp: 467–474, 2020.

SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- **Performance of Stepped Hulls**
- Performance of planing Catamarans



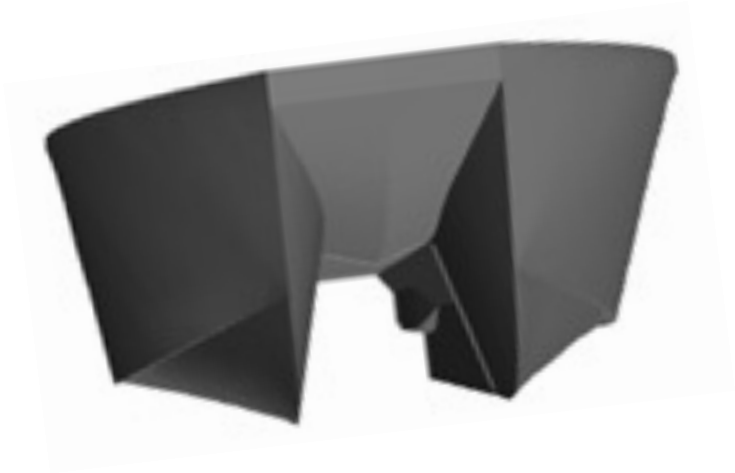


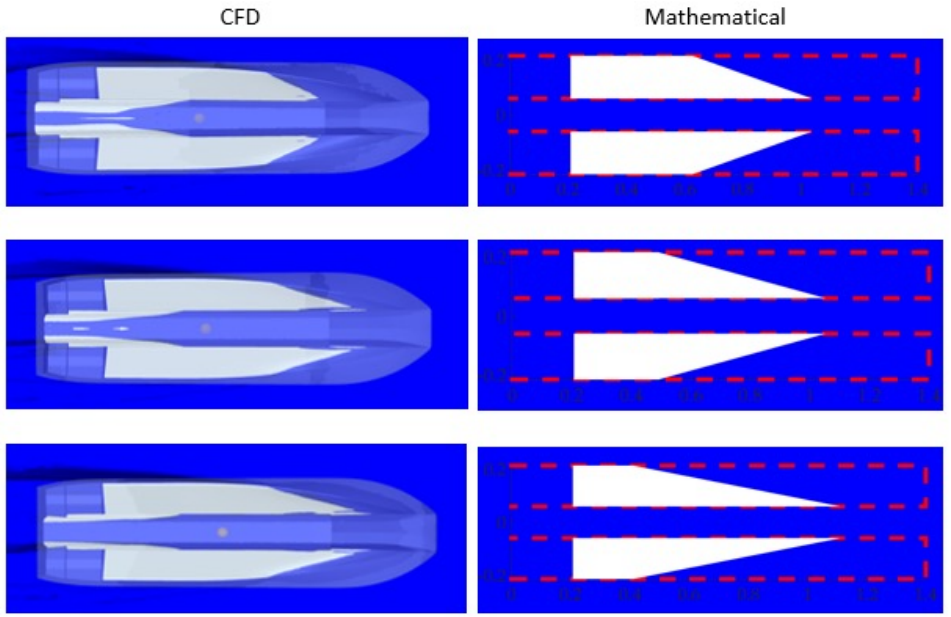


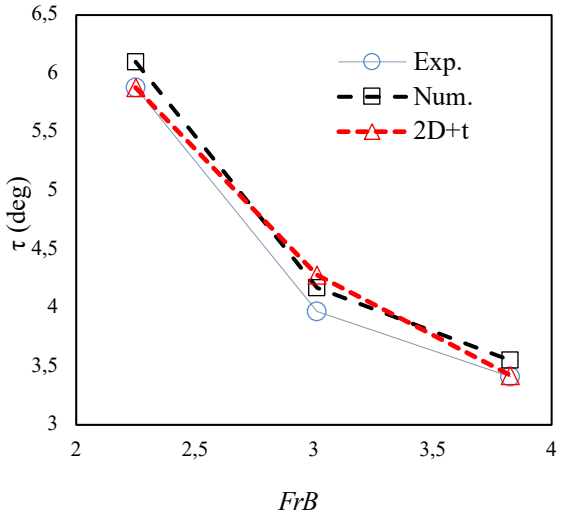
R. N. Bilandi, S. Tavakoli , A. Dashtimanesh,, Seakeeping of double-stepped planing hull, Journal of Ocean Engineering, Vol. 236, pp: 109475, 2021.

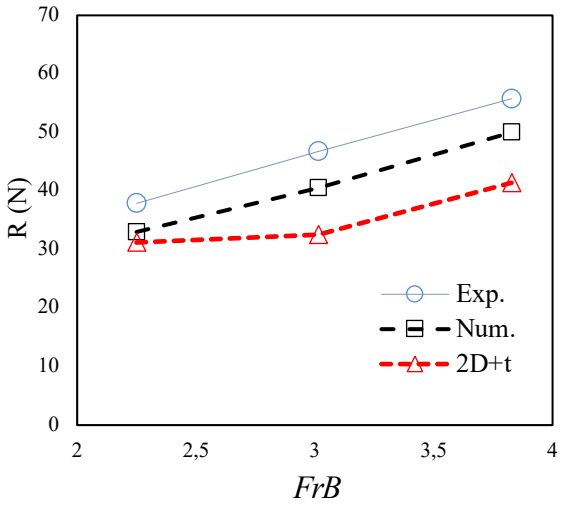
SOME RESULTS

- Coupled Heave and Pitch motions
- Coupled Heave, Pitch and Roll motions
- Roll Motion
- Yawed Planing Boat
- Planar Motion Mechanism Test
- Steady Turning Manoeuvr
- Performance of Stepped Hulls
- **Performance of planing Catamarans**







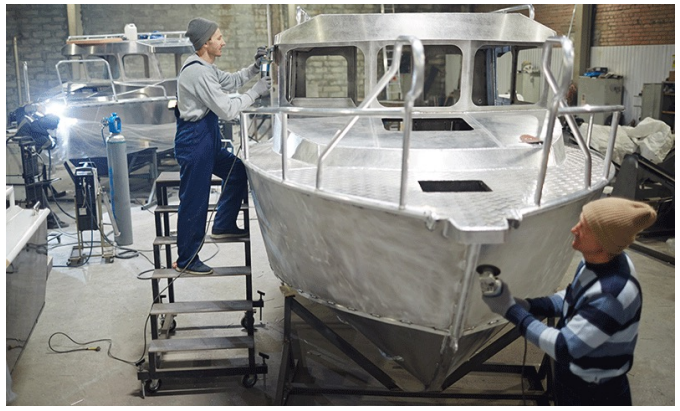


A. Ghasemzadeh, A. Dashtimanesh, M. Hababiasl, P. Sahoo, Development of a mathematical model for performance prediction of planing catamaran in calm water, Transactions RINA International Journal of Maritime Engineering, Vol. 161, Part A2, pp: 183-194, 2019.

WHAT WILL THE NEXT STEPS BE?

- ❑ We are switching to Python.
- ❑ More comprehensive validation and verification studies are still needed.
- ❑ Merging the mathematical models with artificial intelligence/machine learning tools.
- ❑ Developing new models for performance prediction of hydrofoil boats.
- ❑ Studying the simultaneous effects of active control trim tab and shock mitigation seats on crew comfort.

WHO/WHAT BENEFITS FROM OUR RESEARCH?



https://www.bostik-industrial.com/marine-manufacturing-build-sustainable-boats/

Orca3D
Marine Design for Rhinoceros®

STAKEHOLDERS

https://www.thewoodenboatschool.com/boatbuilding/boat-design-elements.php

STAR-CCM+

WHAT DO WE WANT STAKEHOLDERS TO DO?

- ❑ Share their experiences with us!
- ❑ Let’s know what their demands are.
- ❑ We need more data for validation of our manoeuvring models among others.

Keep in touch!

Recent Advances in Performance Prediction of Planing Hulls Using Mathematical Modelling

Assis/Prof Abbas Dashtimanesh
KTH Royal Institute of Technology

Contact me at abbas.Dashtimanesh@taltech.ee

High Speed Boat Operation Forum Conference
Gothenburg, Sweden, Aug 31 – Sep 2, 2021