Colombiamar 2019

Analysis of a Bow Thruster using a RANS Method

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Motivation:

Bow thrusters widely used for manoeuvres at zero or very slow speeds

Broader range of application requested

The Problem:

Loss of efficiency already at moderate forward speed

Normally disregarded in design process

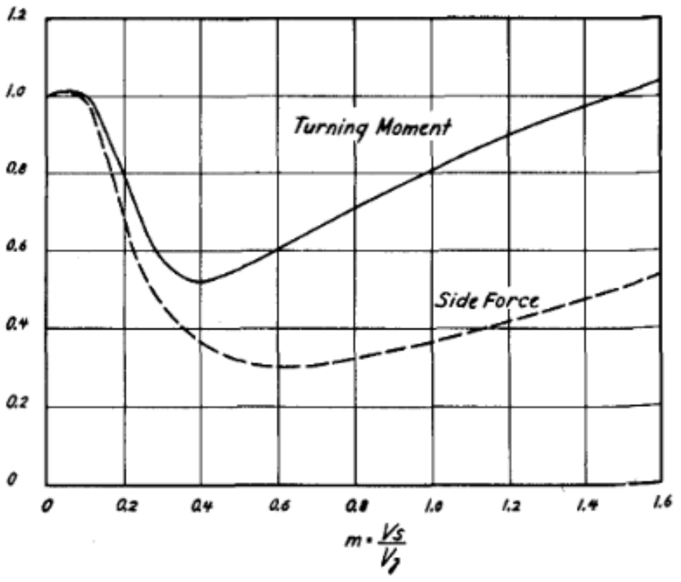
The Goal:

Integrate application scenarios in design process

The Contribution of TUB:

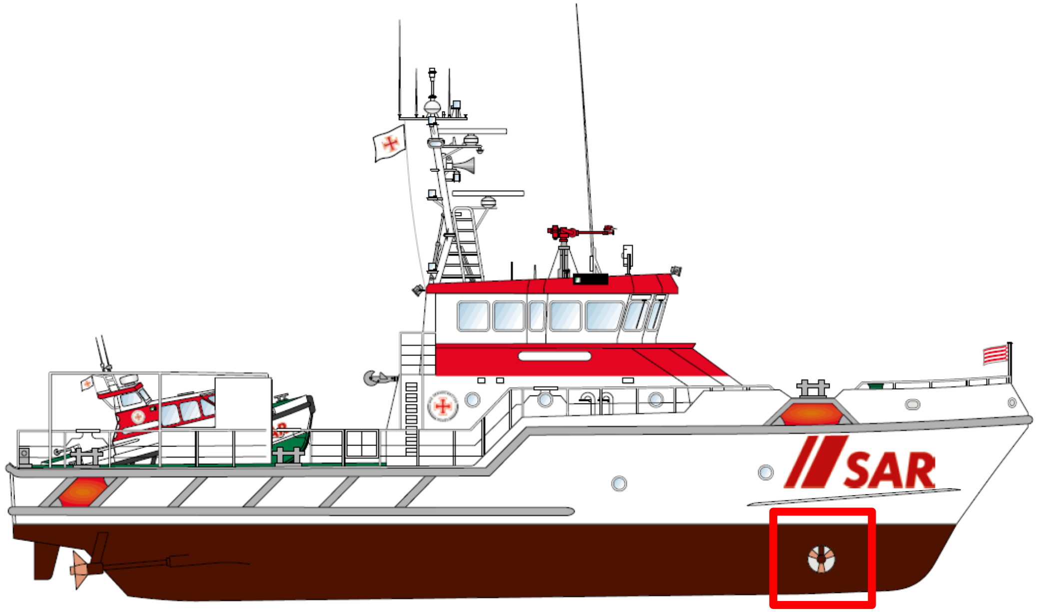
Manoeuvring simulation with bow thruster

Extensive full scale experiments for Validation



Source: www.revolvy.com/page/Marine-thruster

Approach



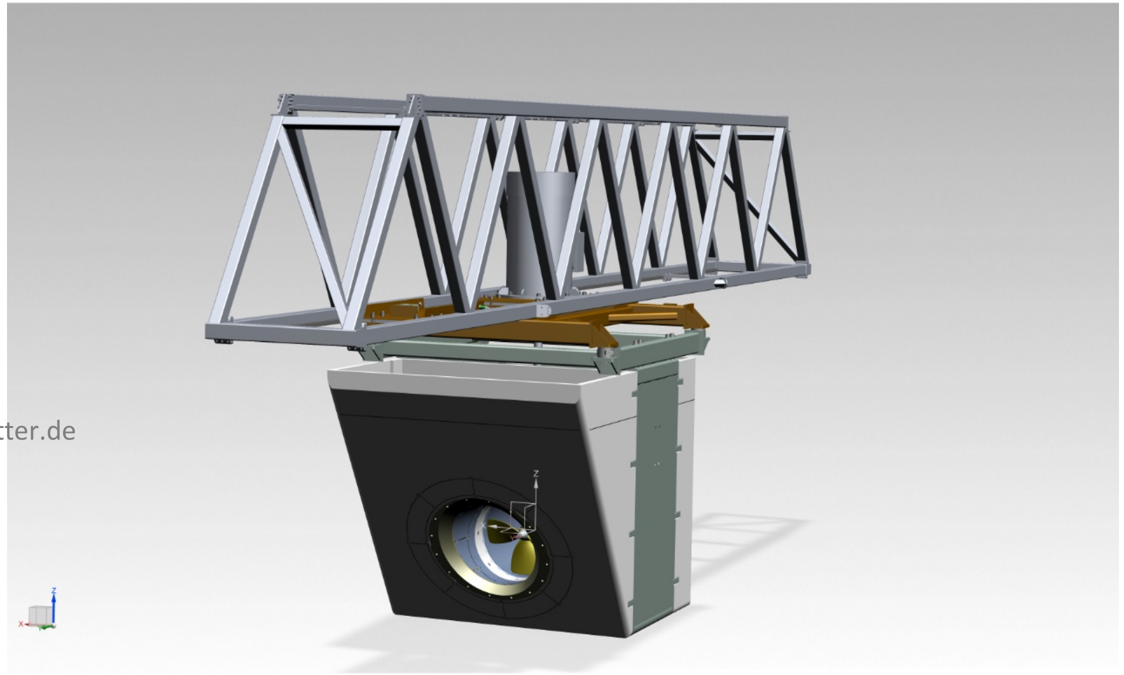
Source: www.seenotretter.de

The Ship:

Built by Fassmer GmbH

Search and Rescue Vessel

L_{pp}: 27.9m



The Dummy for Experiments:

Full scale

Width: 2.3m

Thruster: 1029 rpm

75kW

Approach

Launch of experiments in November 2018

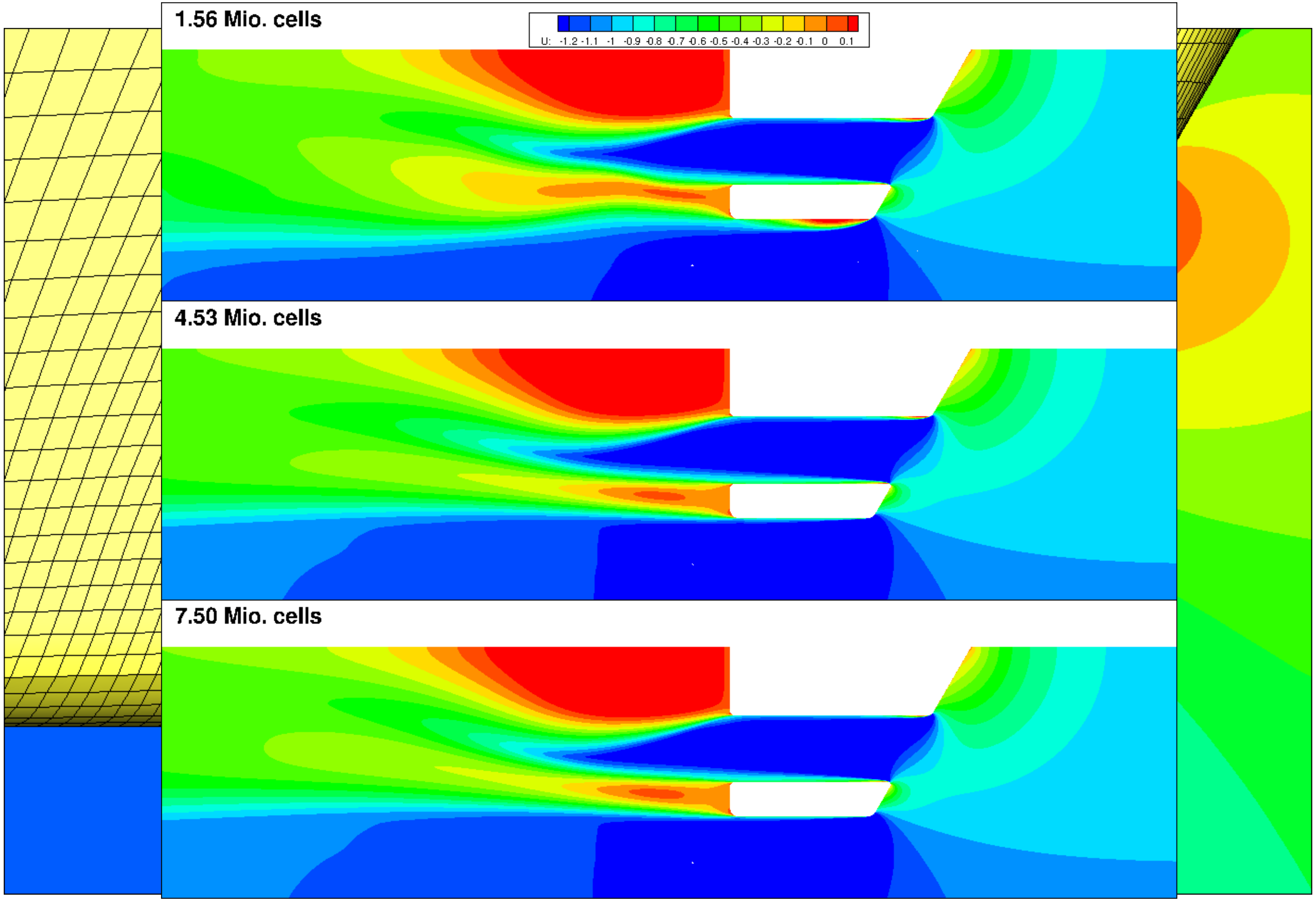
Towing tank of TU Berlin:

250m x 8m x 4.8m

Max. speed of carriage 5m/s

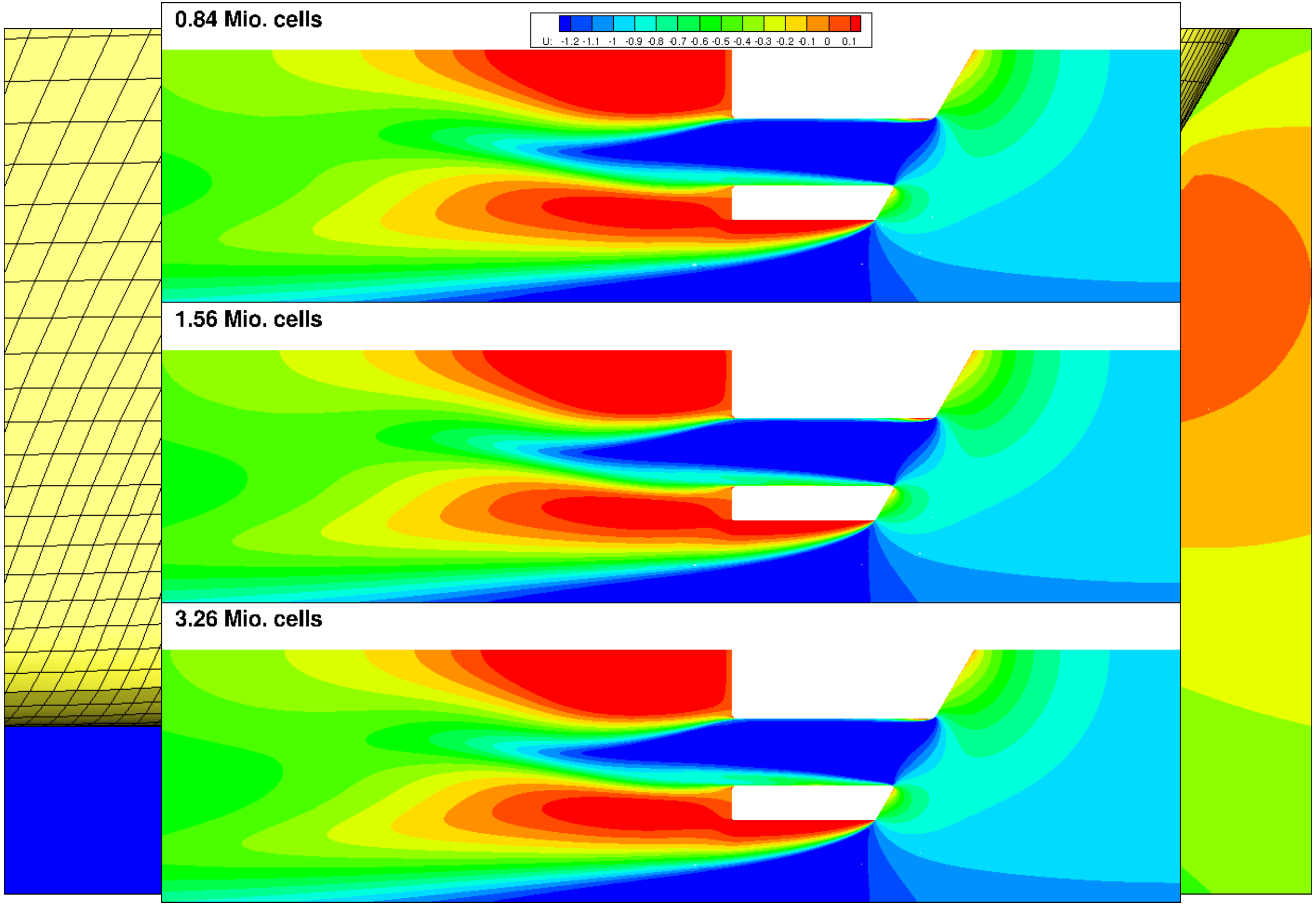
Preliminary Study

- RANS code Neptuno
- Steady state
- No free surface
- W/o propeller
- Edge radius 75mm



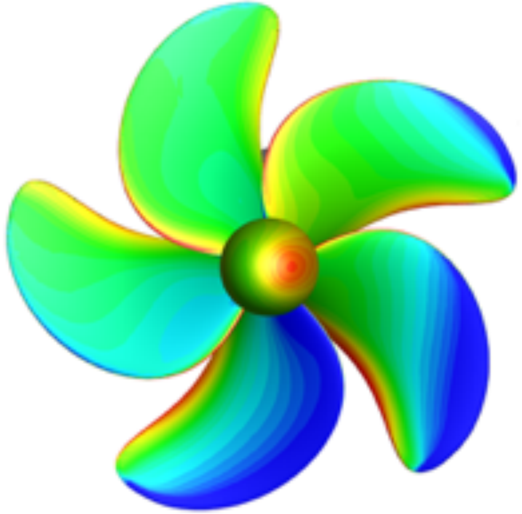
Preliminary Study

- RANS code Neptuno
- Steady state
- No free surface
- W/o propeller
- Edge radius 15mm



Concept of the Body Force Model

1



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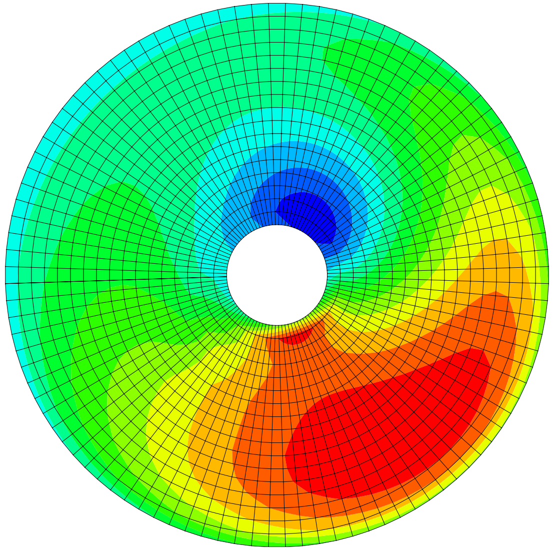

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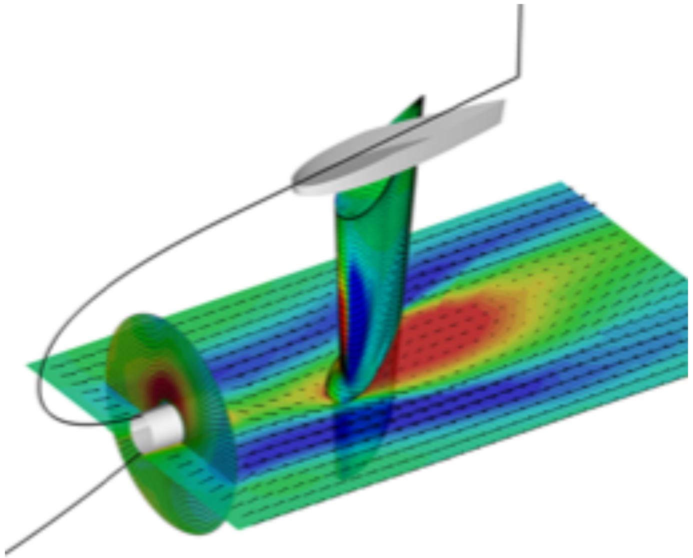

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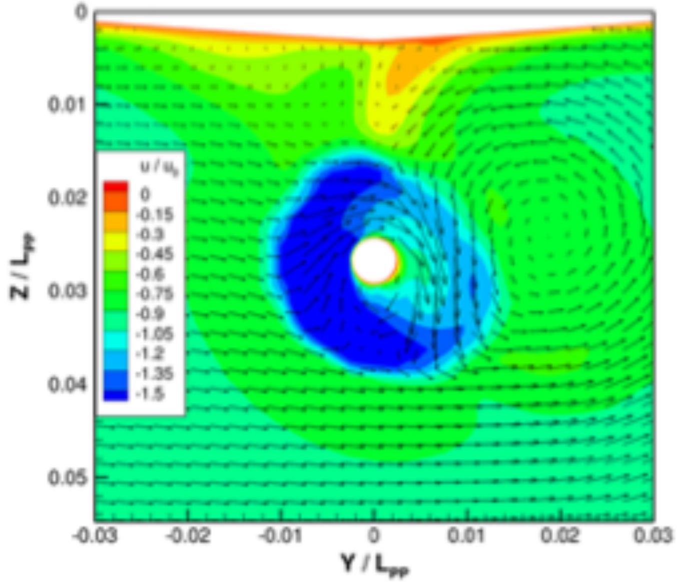


Simulation of the Bow Thruster

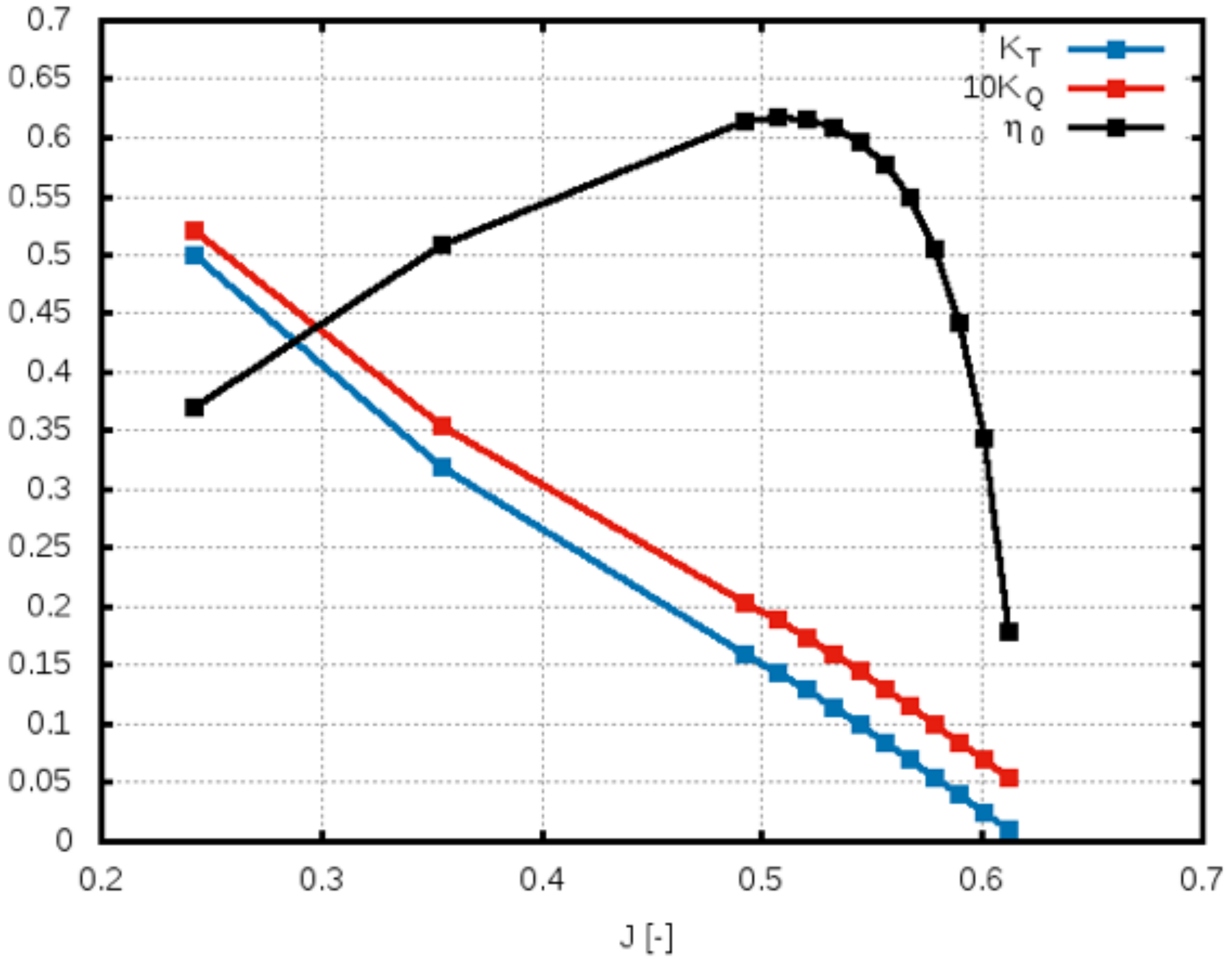
Neptuno

4.1 Mio. cells

Steady state

Tunnel only

Pressure at In- and Outlet



Validation of the Body Force Model

Neptuno

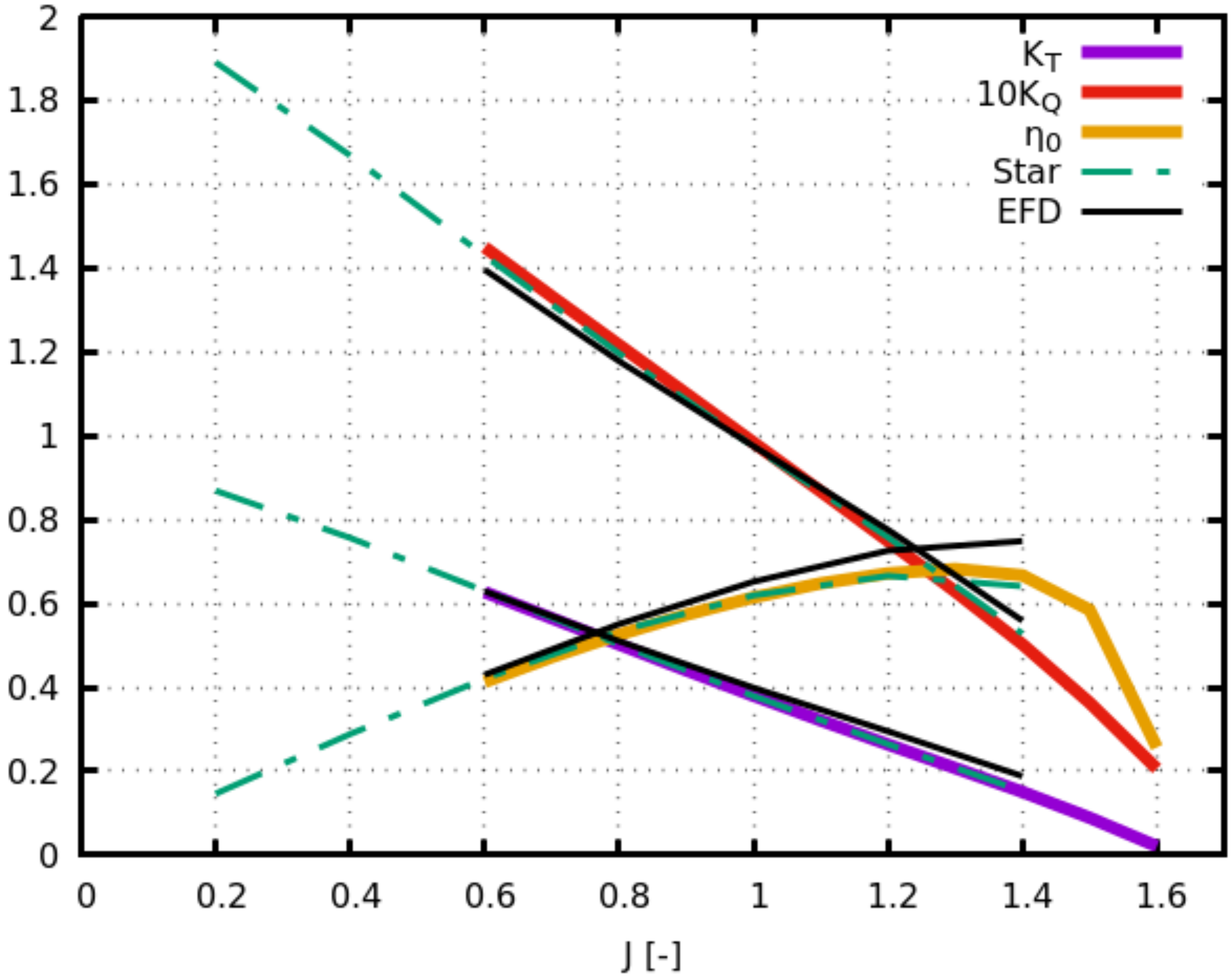
Sliding grids

3.8 mio. cells

Potsdam Propeller Testcase

Open water condition

Straight inflow



Simulations with StarCCM+

by David Fuentes

Manoeuvring Prediciton by means of Virtual Captive Model Tests

Motivation:

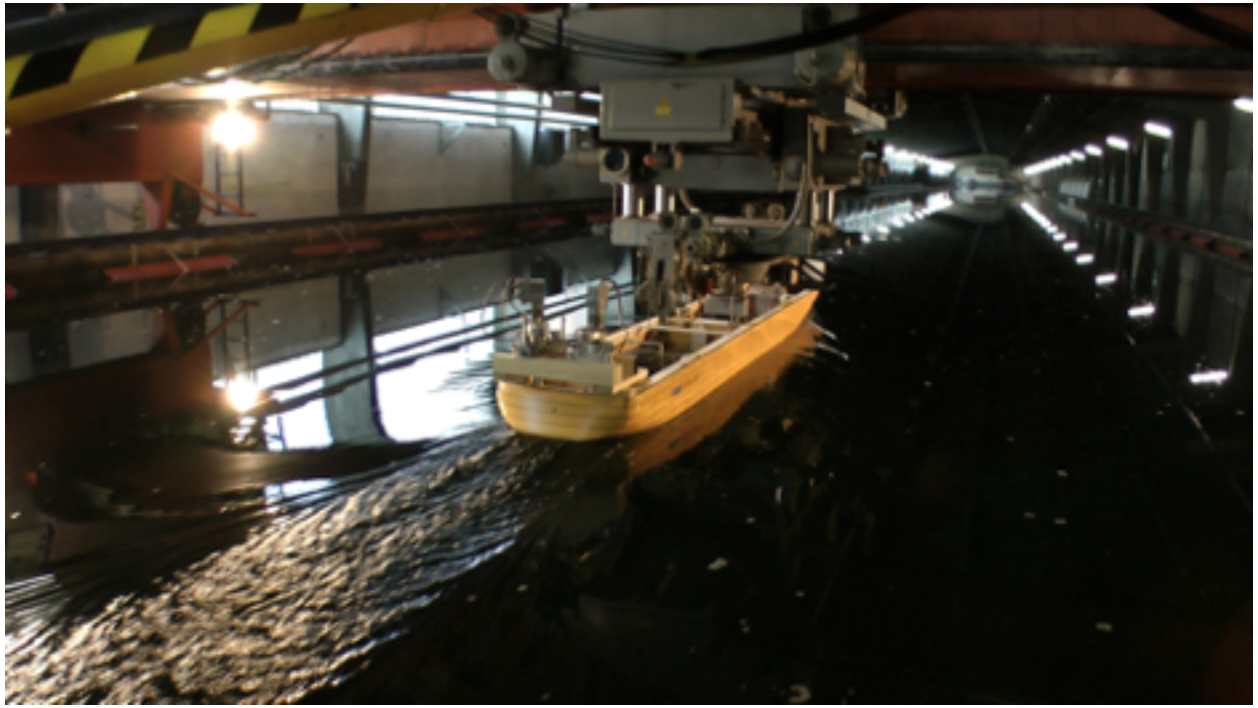
Fast simulation of rudder manoeuvres in waves

Approach:

Coefficient based approach (*Abkowitz* model)

Extended by influence of waves

Prediciton of propeller torque



Literature: Uharek, S. and Cura Hochbaum, A., Power Prediction for Safe Manoeuvring in Waves, Proceedings of the 32nd ONR Symposium on Naval Hydrodynamics, 2018.

Procedure for Manoeuvring Prediction in 4 DoF

$$m\left[\dot{u}-\dot{\psi}v-x_{\mathrm{G}}\dot{\psi}^2+z_{\mathrm{G}}\left(2\dot{\psi}\dot{\varphi}\cos\varphi+\ddot{\psi}\sin\varphi\right)\right]=X_c+X_w$$

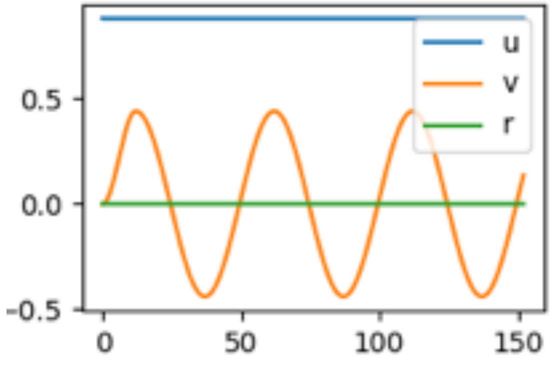
$$m\left[\dot{v}+\dot{\psi}u+x_{\mathrm{G}}\ddot{\psi}+z_{\mathrm{G}}\left(\left(\dot{\psi}^2+\dot{\varphi}^2\right)\sin\varphi-\ddot{\varphi}\cos\varphi\right)\right]=Y_c+Y_w$$

$$\begin{aligned}I_{xx}\ddot{\varphi}-I_{xz}\ddot{\psi}\cos\varphi+(I_{zz}-I_{yy})\,\dot{\psi}^2\sin\varphi\cos\varphi&+\\-mz_{\mathrm{G}}\cos\varphi\left(\dot{v}+u\dot{\psi}\right)&=K_c+K_w\end{aligned}$$

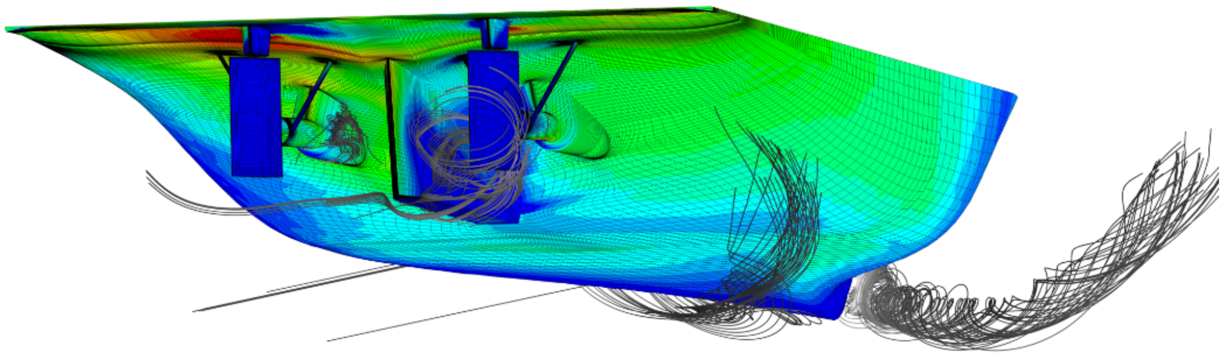
$$\begin{aligned}\left(I_{yy}\sin^2\varphi+I_{zz}\cos^2\varphi\right)\ddot{\psi}&+\\2\left(I_{yy}-I_{zz}\right)\dot{\psi}\dot{\varphi}\sin\varphi\cos\varphi-I_{xz}\left(\ddot{\varphi}\cos\varphi-\dot{\varphi}^2\sin\varphi\right)&+\\mx_{\mathrm{G}}\left(\dot{v}+u\dot{\psi}\right)+mz_{\mathrm{G}}\sin\varphi\left(\dot{u}-v\dot{\psi}\right)&=N_c+N_w\end{aligned}$$

Determination of calm water coefficients

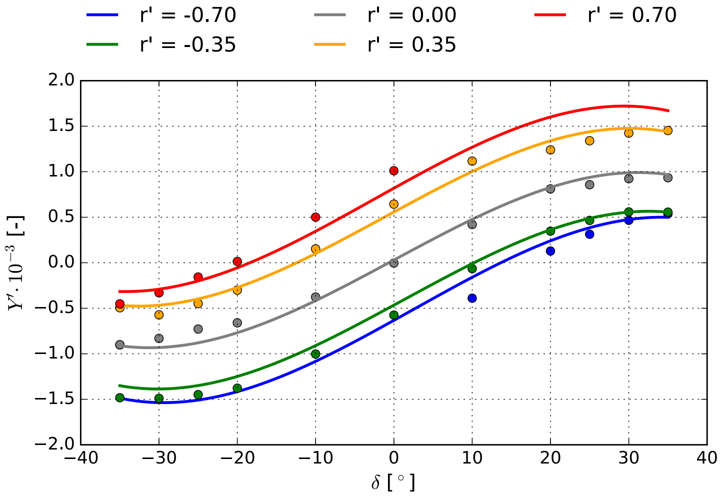
1 Prescribe ship motions



2 Perform RANS Simulations



3 Fit computed forces



4 Obtain coefficient set

1	X'_0	0.000	Y'_0	0.044	K'_0	0.001	N'_0	-0.022
2	X'_δ	0.038	Y'_δ	2.903	K'_δ	-0.040	N'_δ	-1.305
3	$X'_{\delta\delta}$	-1.504	$Y'_{\delta\delta}$	-0.004	$K'_{\delta\delta}$	0.002	$N'_{\delta\delta}$	0.007
4	$X'_{\delta\delta\delta}$	-0.011	$Y'_{\delta\delta\delta}$	-3.067	$K'_{\delta\delta\delta}$	0.046	$N'_{\delta\delta\delta}$	1.283
5	X'_u	-2.585	Y'_u		K'_u		N'_u	
6	X'_{uu}	1.321	Y'_{uu}		K'_{uu}		N'_{uu}	
7	X'_{uuu}	0.000	Y'_{uuu}		K'_{uuu}		N'_{uuu}	
8	X'_u	-0.400	Y'_u		K'_u		N'_u	
9	X'_v	-0.010	Y'_v	-12.776	K'_v	0.373	N'_v	-3.497
10	X'_{vv}	0.070	Y'_{vv}	0.215	K'_{vv}	-0.012	N'_{vv}	-0.087
11	X'_{vvv}	0.046	Y'_{vvv}	-40.493	K'_{vvv}	1.393	N'_{vvv}	-5.964
12	X'_v		Y'_v	-5.759	K'_v	-0.028	N'_v	0.219
13	X'_r	0.014	Y'_r	1.603	K'_r	0.006	N'_r	-1.780
14	X'_{rr}	0.043	Y'_{rr}	0.129	K'_{rr}	-0.003	N'_{rr}	-0.058
15	X'_{rrr}	-0.011	Y'_{rrr}	-1.155	K'_{rrr}	-0.060	N'_{rrr}	-1.616
16	X'_r		Y'_r	-0.399	K'_r	0.019	N'_r	-0.231
17	X'_{vr}	4.289	Y'_{vr}	0.000	K'_{vr}	0.000	N'_{vr}	0.000
18	X'_{vrr}		Y'_{vrr}	-13.498	K'_{vrr}	0.496	N'_{vrr}	-2.957

Application case

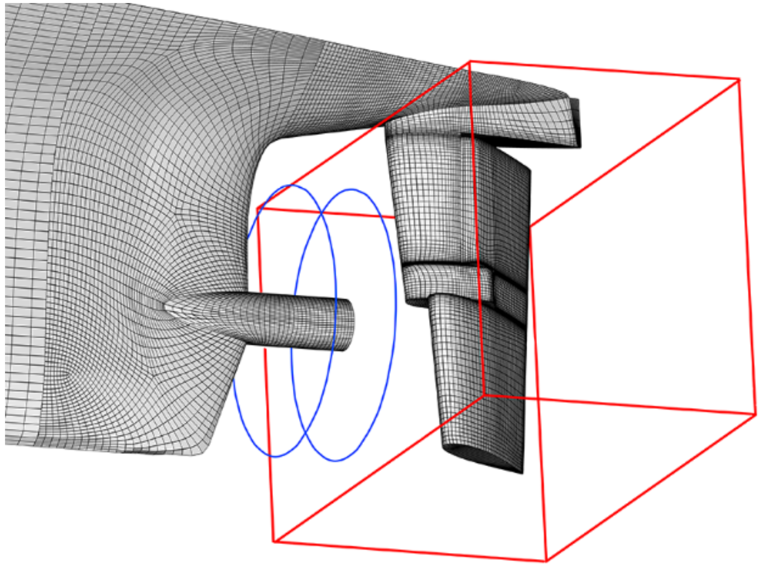
S175 benchmark ship

Extensively tested by Yasukawa and Nakayama (2009)

Computations performed with Neptuno

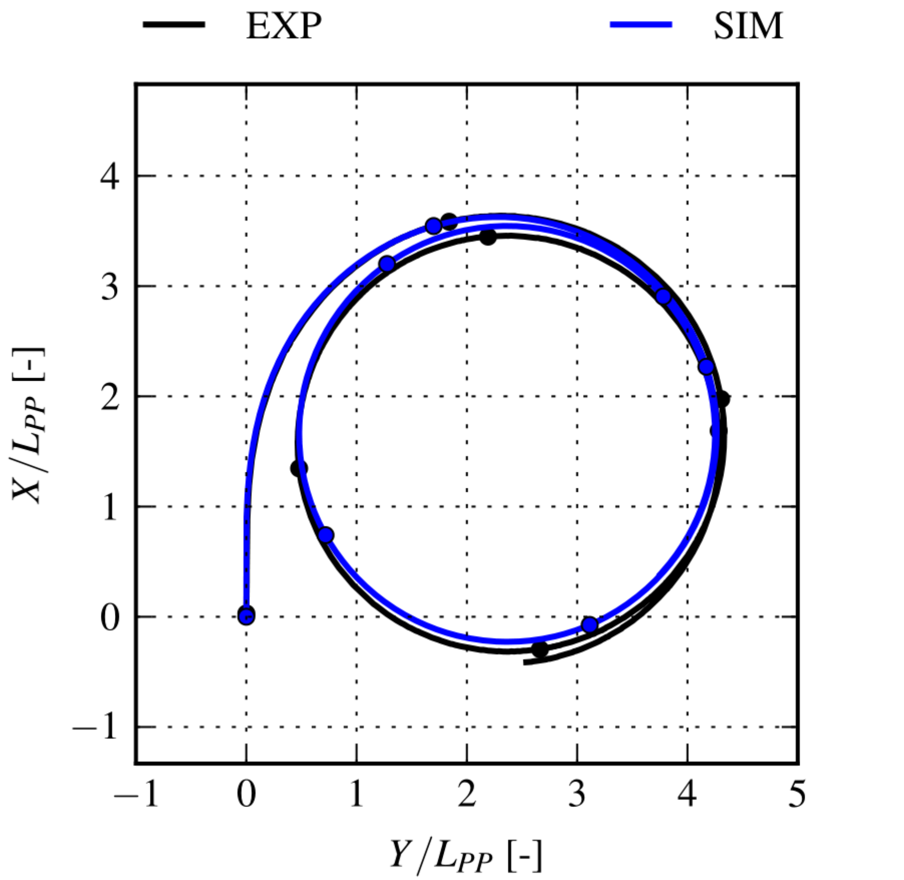
Numerical grids with and without free surface

1.8 and 1.1 million cells

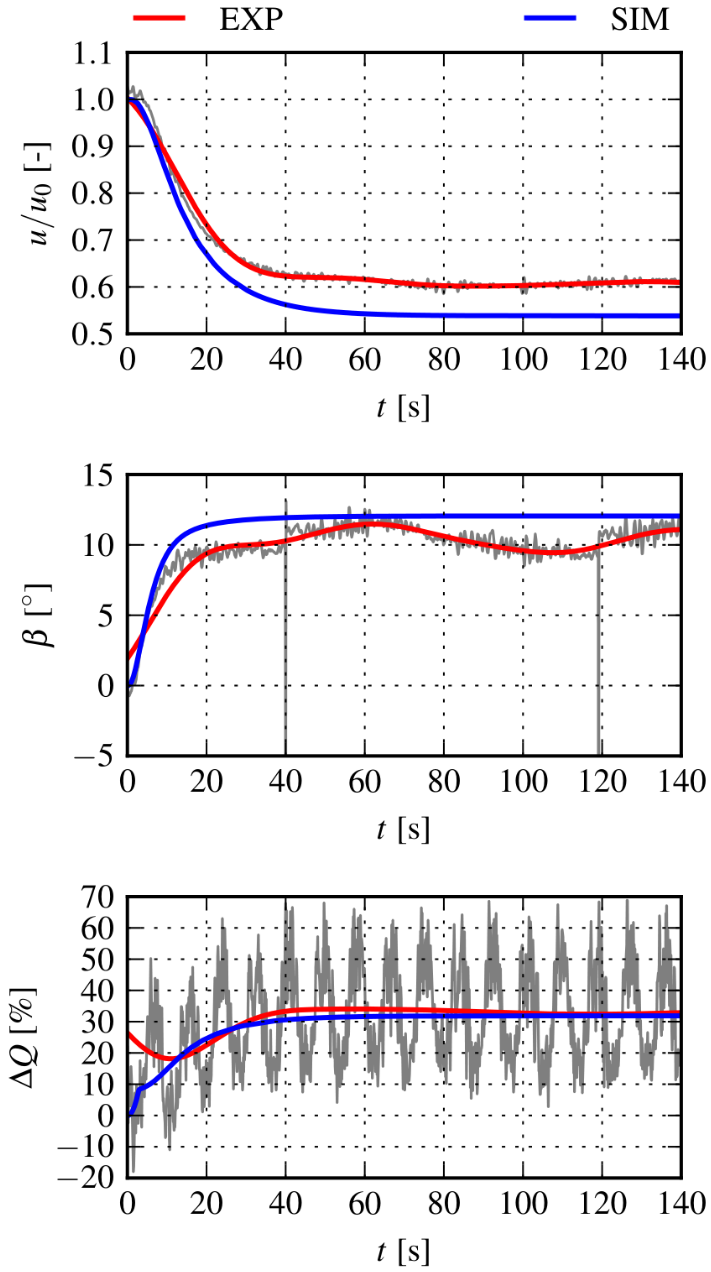


	full scale	model scale
L_{pp}	175 m	3.5 m
B_{wl}	24.5 m	0.508 m
T	9.5 m	0.19 m
$\forall$	24172 m^3	0.1934 m^3
x_G	-2.545 m	-0.051 m
k_{yy}/L_{pp}	0.269	
c_B	0.572	
U	12.1 kn	0.879 m/s
GM	1 m	0.02 m
Fn	0.15	
Re	1.1 10^9	3.1 10^6

Turning circle test in calm water



λ'	α_0	SIM	EXP	DIFF
calm	t_{90}	21 s	21 s	+1 %
	X_{90}	3.6 L_{PP}	3.6 L_{PP}	−1 %
	Y_{90}	1.9 L_{PP}	2.0 L_{PP}	−5 %
	t_{180}	41 s	40 s	+4 %
	Y_{180}	4.2 L_{PP}	4.3 L_{PP}	−2 %



Turning circle test

Approach speed 12 kn

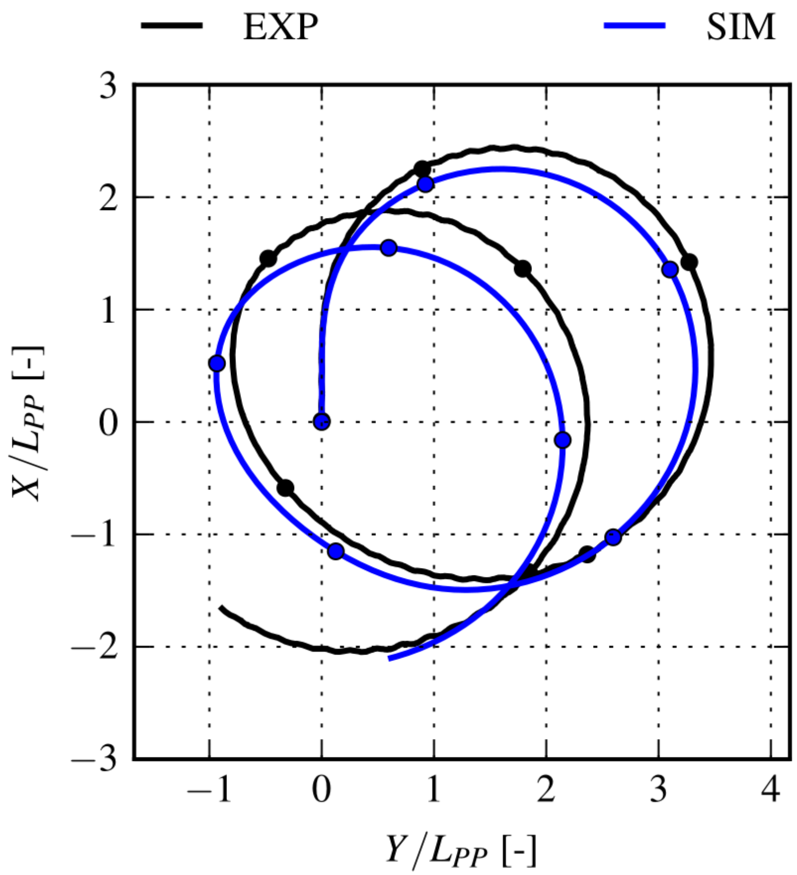
35° rudder deflection

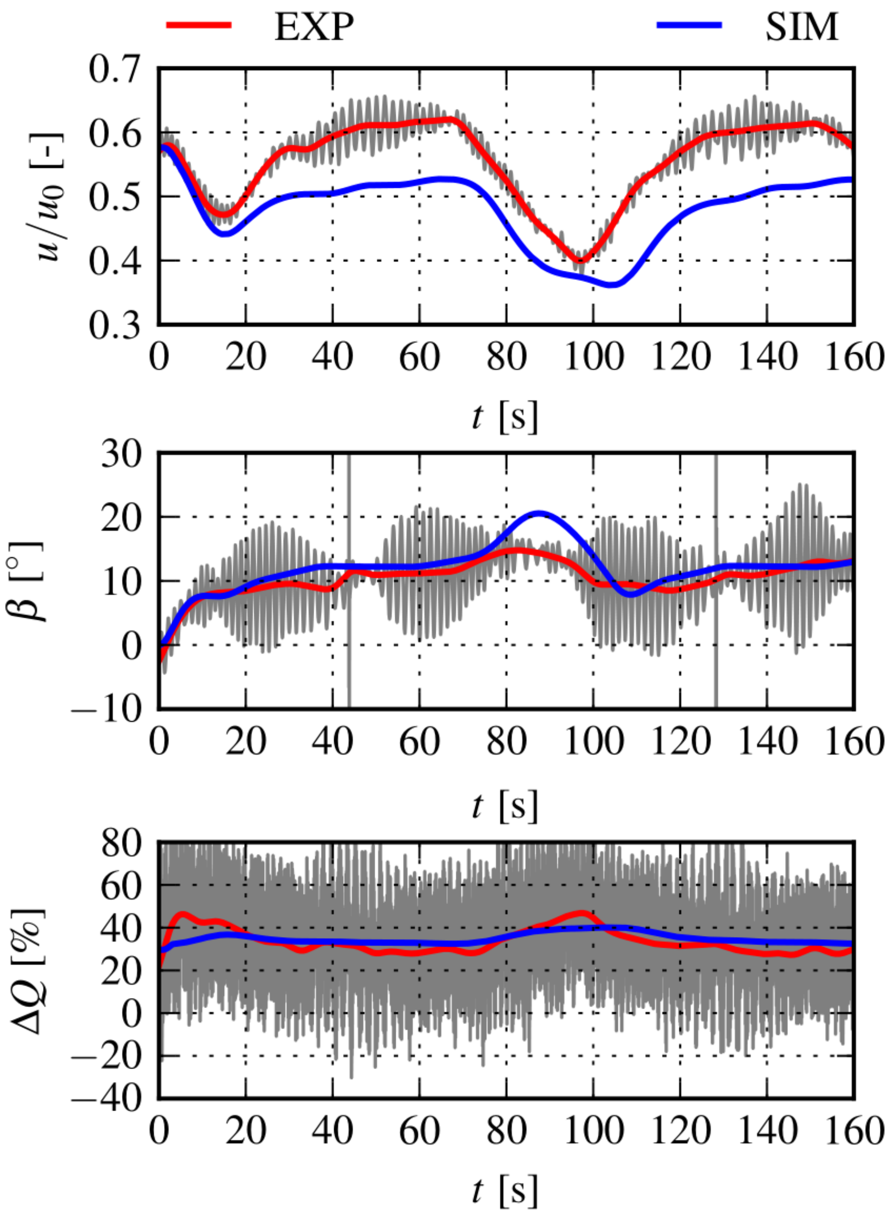
Good agreement with EXP

25% power increase for 90°

30% power increase for 180 °

Turning circle test in head waves with λ‘ = 1.0





λ'	α_0		SIM	EXP	DIFF
1.0	0°	t_{90}	23 s	24 s	−3 %
		X_{90}	2.2 L_{PP}	2.4 L_{PP}	−8 %
		Y_{90}	1.3 L_{PP}	1.4 L_{PP}	−6 %
		t_{180}	44 s	44 s	+1 %
		Y_{180}	3.3 L_{PP}	3.4 L_{PP}	−5 %

Passive course keeping stability

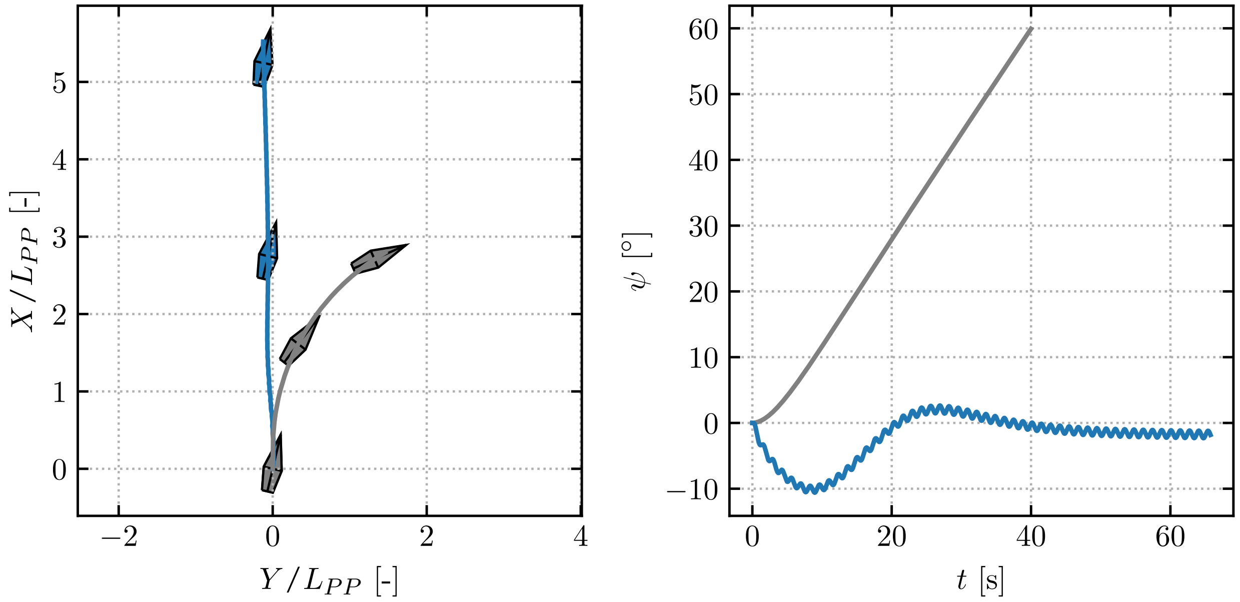
Sum of wave, rudder and drift force can be zero

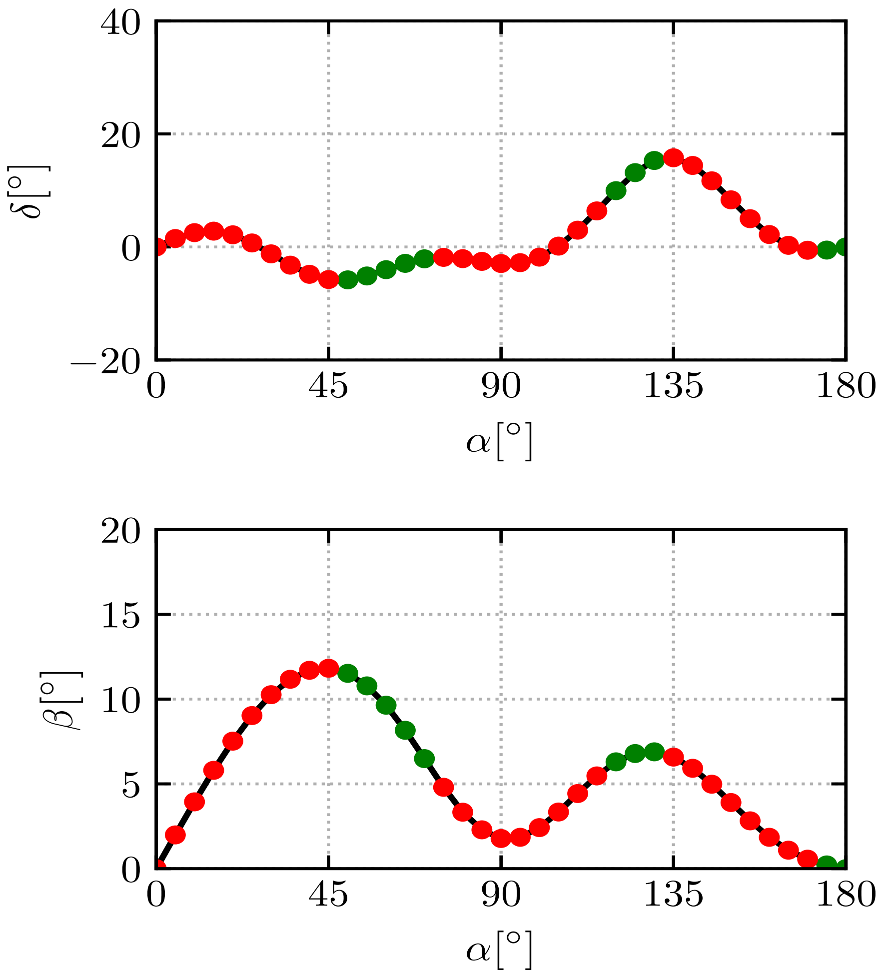
→ Equilibrium situations exist

Some situations are found to be stable

Allow for passive (mean) course keeping

Validation by direct RANS course keeping test





Literature: Cura Hochbaum A. and Uharek S., On the Heading Stability of a Ship in Waves, Ship Technology Research, to appear 2019

Passive course keeping stability

Thank you for your attention!