The new hull form with twin rudders utilizing duct effects
(3rd Report)

ダクト効果を有する非対称断面ツイン舵船型の開発
(第3報　操縦性能)

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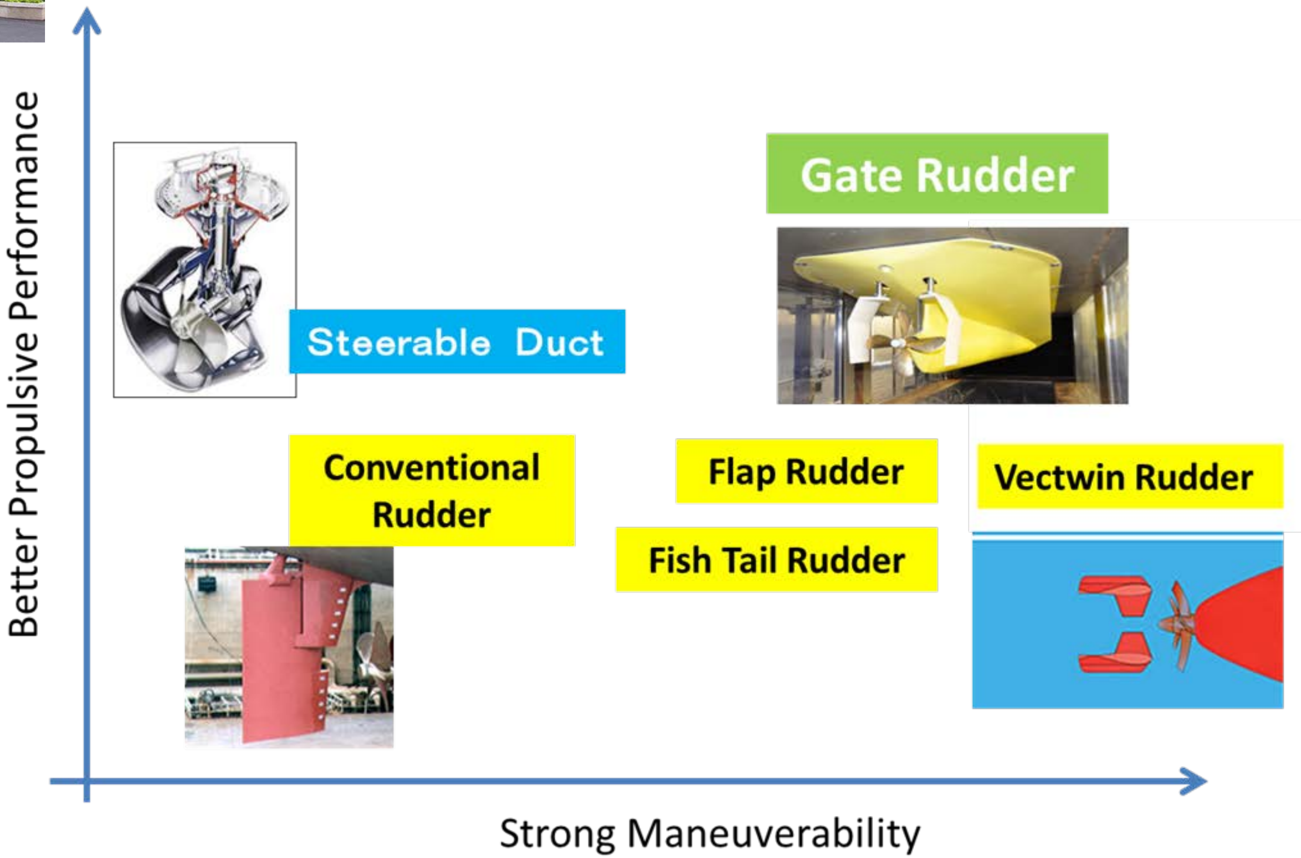
Gate Rudder Concept

Target Position of Gate Rudder

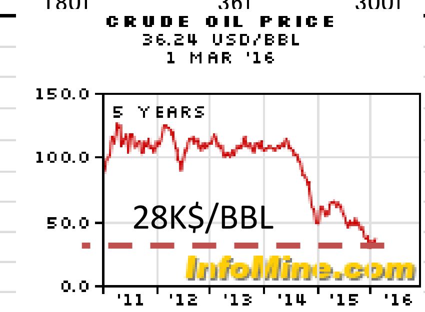


Pros and Cons

	Conventional Rudder	Gate Rudder	Remarks
Energy Saving	No	Yes	Depends on ship fullness
Course keeping Ability	Normal	Better	
Turning	Normal	Slightly Better	
Stopping Ability	Normal	Better	
Maneuvering at low speed	Normal	Even by Crabbing Mode	
Noise and Vibration	Normal	Superior	
See Keeping	Normal	Excellent	By active rudder control
Cargo Space	Normal	Can be increased	E/R can be moved aft
Ship Length	Normal	Can be reduced	AP position can be moved
Cost	Normal	Slightly high	Plus one rudder system

Return On Investment

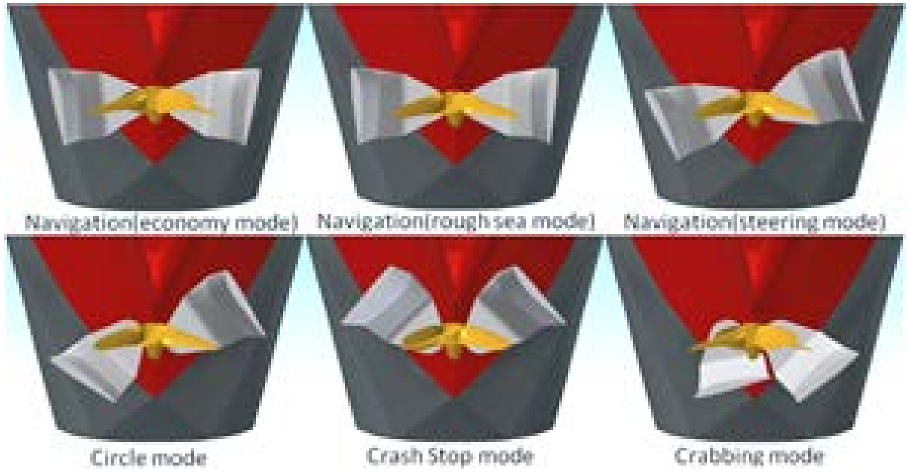
	Lpp	B	d	CB/(L/B)	M/E Output	70%	SFO	ton/day	days	ton/year
CAPE	300	50	18.3	0.145	18000	12600	180	54	300	16,330
COAL	223	50	13.45	0.173	11760	8232	180	36	300	10,669
PANAMAX	225	32.2	14	0.125	11000	7700	180	33	280	9,314
HANDY	180	30	12.2	0.133	8000	5600	180	24	280	6,774
VLCC	320	60	20.8	0.156	28000	19600	180	85	300	25,402
AFRA	230	42	14	0.150	12000	8400	180	36	300	10,886



Additional Contruction

	Rudder Area	Rudder Weight	Cost of Rudder	St. Gear Capa	Cost of St. G
	m**2	ton	k$	ton-m	k$
CAPE	46	35	130	75	50
COAL	25	16	58	30	20
PANAMAX	26	17	62	32	22
HANDY	18	11	40	19	13
VLCC	55	46	171	102	68
AFRA	27	17	64	33	22
			3.75 /ton		0.67 /ton-m

				COST UP					
	Power Save	FO save	**FO Save**	Rudder	ST. GEAR	System	DOCK	**Total Cost Up**	**ROI(year)**
	%	ton/year	**K$/year**	k$	k$	k$	k$	k$	
CAPE	5.3	868	**191**	130	50	45	0	**225**	**1.18**
COAL	7.4	793	**174**	58	20	20	0	**98**	**0.56**
PANAMAX	3.7	349	**77**	62	22	21	0	**104**	**1.36**
HANDY BC	4.4	300	**66**	40	13	13	0	**66**	**1.00**
VLCC OIL	6.1	1,557	**342**	171	68	60	0	**299**	**0.87**
AFRA OIL	5.7	618	**136**	64	22	21	0	**107**	**0.79**

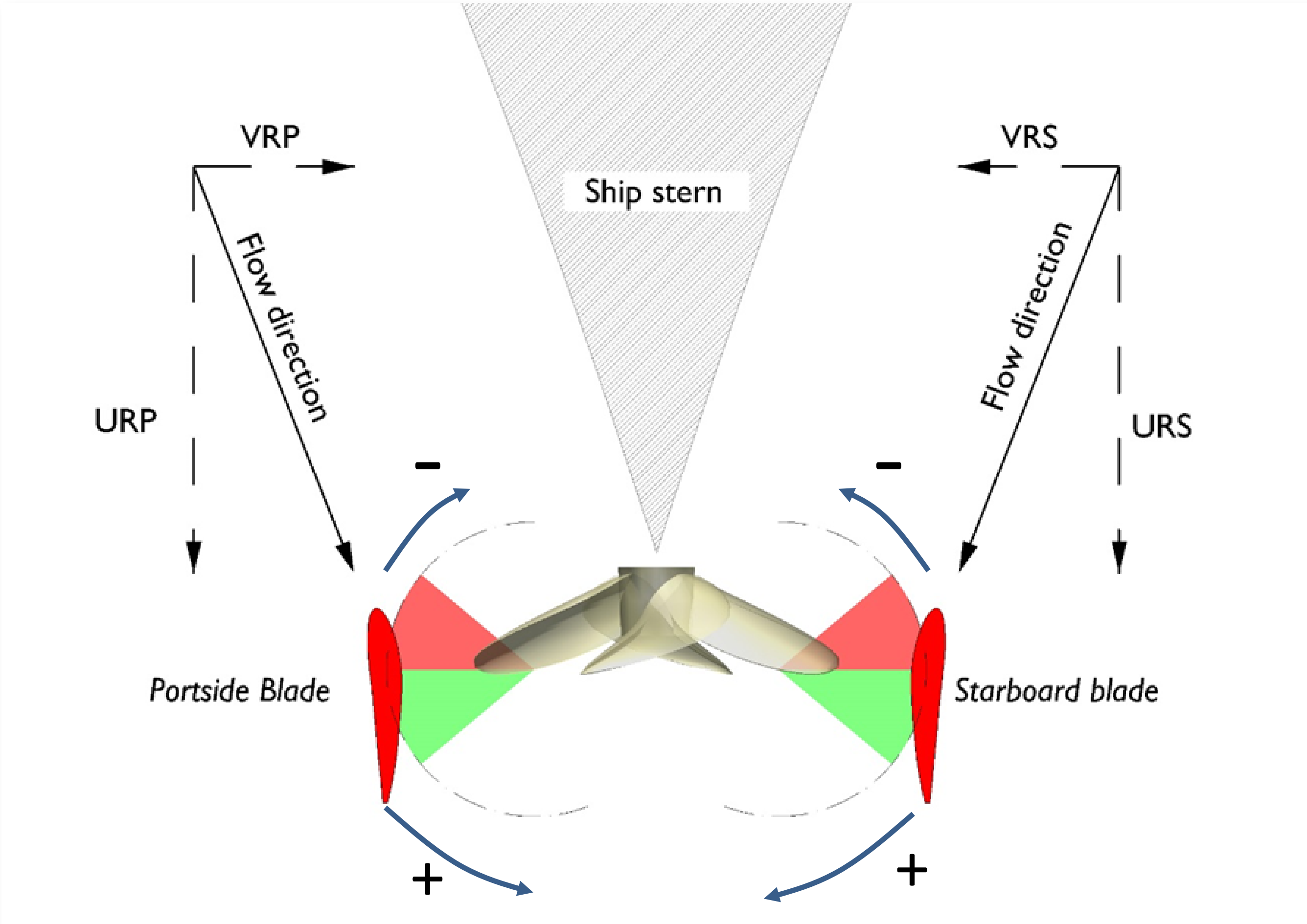


modes	functions	rudder angle
Economy mode	The most efficient operation at calm sea condition	+ 3 ~ + 5 deg.
Rough sea mode	The propeller speed can be increased by accelerated flow	+ 0 ~ + 2 deg.
Steering mode	Normal steering (change the course)	Example -10 &+10dg.
Circle mode	Emergency steering (circle motion)	-30 & +35 deg.
Crash Stop mode	Emergency steering (crash stop)	-30 & -30 deg.
Crabbing mode	Berthing & de-berthing motion	+110 & +60 deg.

Investigation for Maneuverability of a Ship with Gate Rudder

	Contents	Facility etc.
Tank Tests	Rudder Force Measurements with 6m Large Ship Model (without yaw angle) Hull Force Measurements with 2 m Ship Model Captive Tests and Free Running Tests with 2.5m Ship Model	NMRI FEL Kyusyu Uni.
Simulation	Development of Simulation Program based on MMG model Rudder Control System	Newcastle Uni. & Kamome Propeller Tokyo Keiki
Full Scale Tests	Maneuvering Tess at Sea Trial Monitoring at After Delivery	Yamanaka Ship Yards Newcastle Uni.

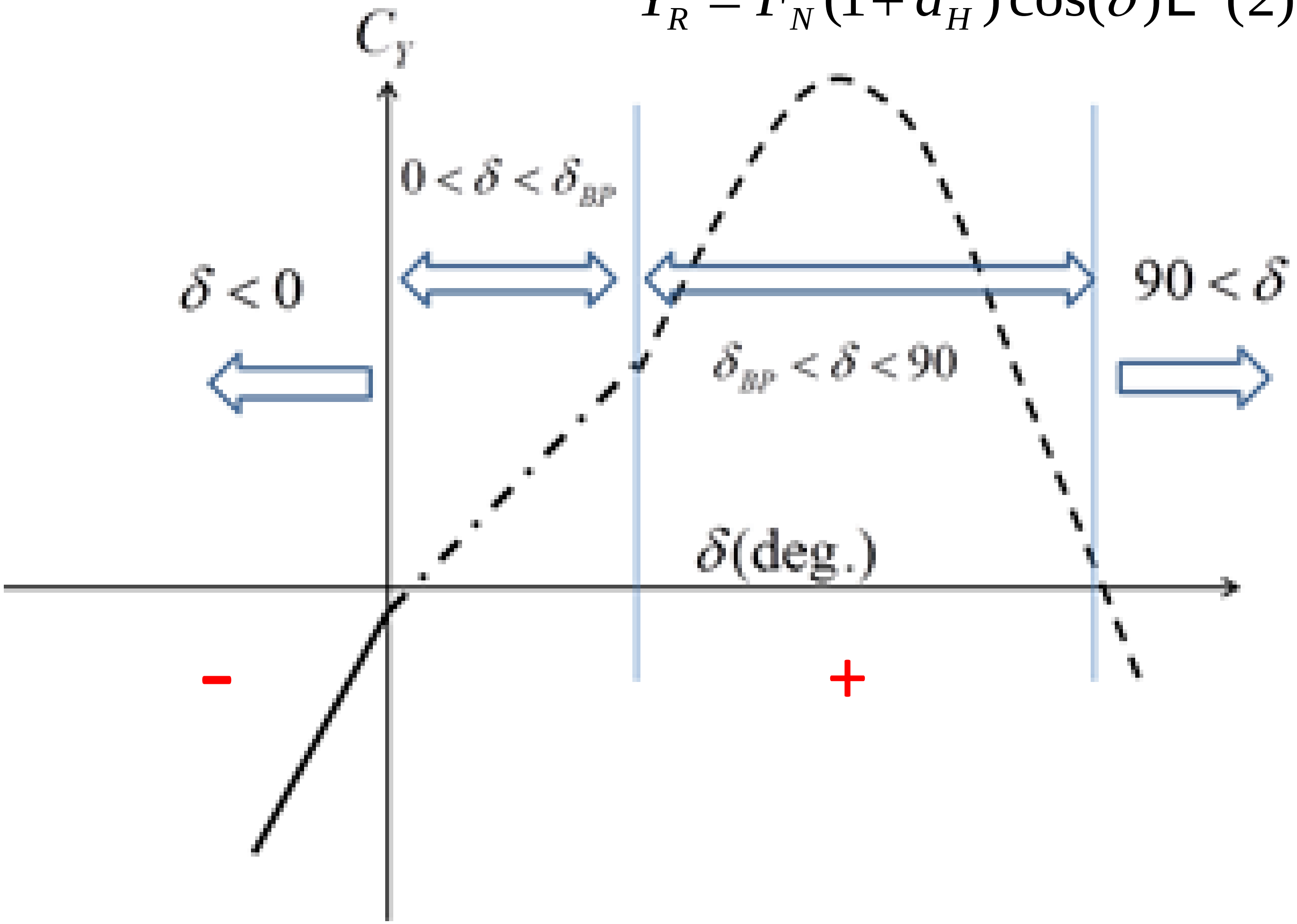
Rudder Angles



Hull Sway Force and Rudder Angles

$$C_Y = \frac{Y_R}{0.5\rho U^2 dL} \quad \ldots (1)$$

$$Y_R = F_N(1 + a_H)\cos(\delta) \quad \ldots (2)$$



$\delta < 0$：前方に操舵した場合で船体との干渉が最も大きい領域

$$F_N = \frac{1}{2}\rho U_R{}^2 f_1 \sin(\delta) A_R \mathrm{L} \quad (3)$$

$0 < \delta < \delta_{BP}$：後方への小舵角の操舵であり、プロペラ後流の外に舵が存在する

$$F_N = \frac{1}{2}\rho U_R{}^2 f_2 \sin(\delta) A_R \mathrm{L} \quad (4)$$

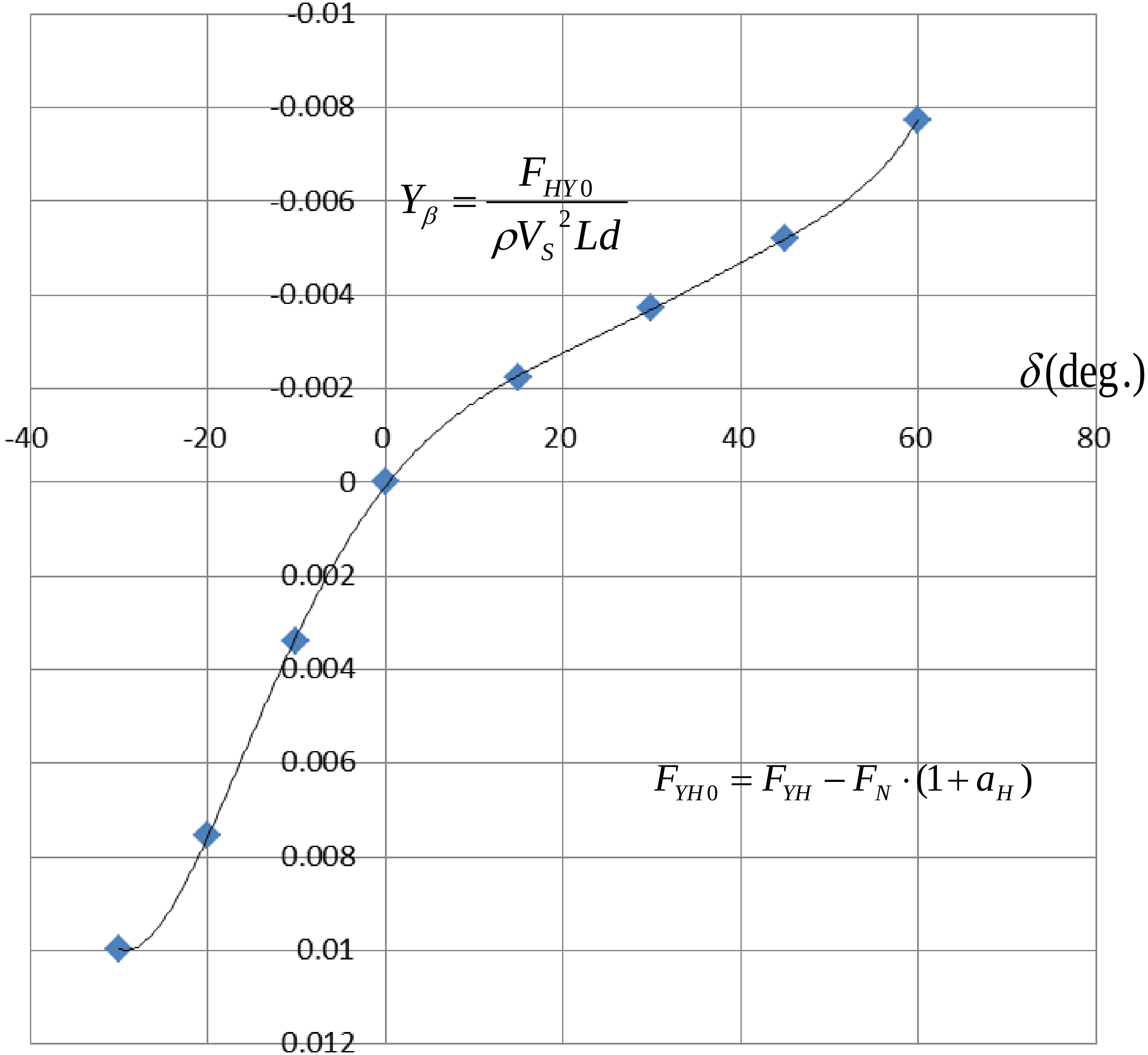
$\delta_{BP} < \delta < 90$：後方への大舵角で、プロペラ後の影響を受ける領域

$$F_N = \frac{1}{2}\rho (U_R{}^2 f_3 A_{R1} + U_P{}^2 f_4 A_{R2}) \sin(\delta) \mathrm{L} \quad (5)$$

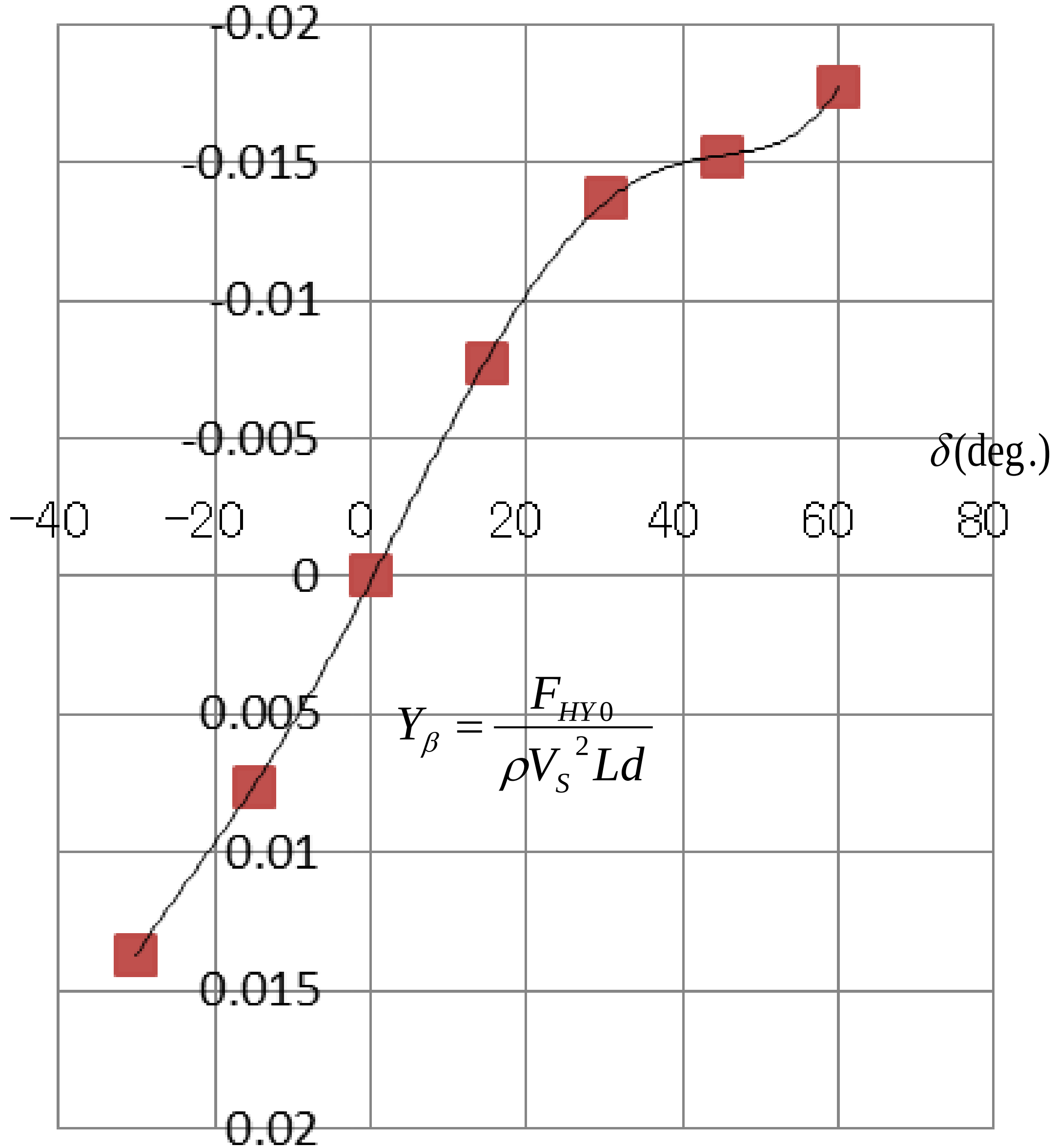
$90 < \delta$：舵の後縁がプロペラに近づき、流れが後縁から前縁へと向かう領域

$$F_N = \frac{1}{2}\rho U_P{}^2 f_5 A_R \sin(\delta) \mathrm{L} \quad (6)$$

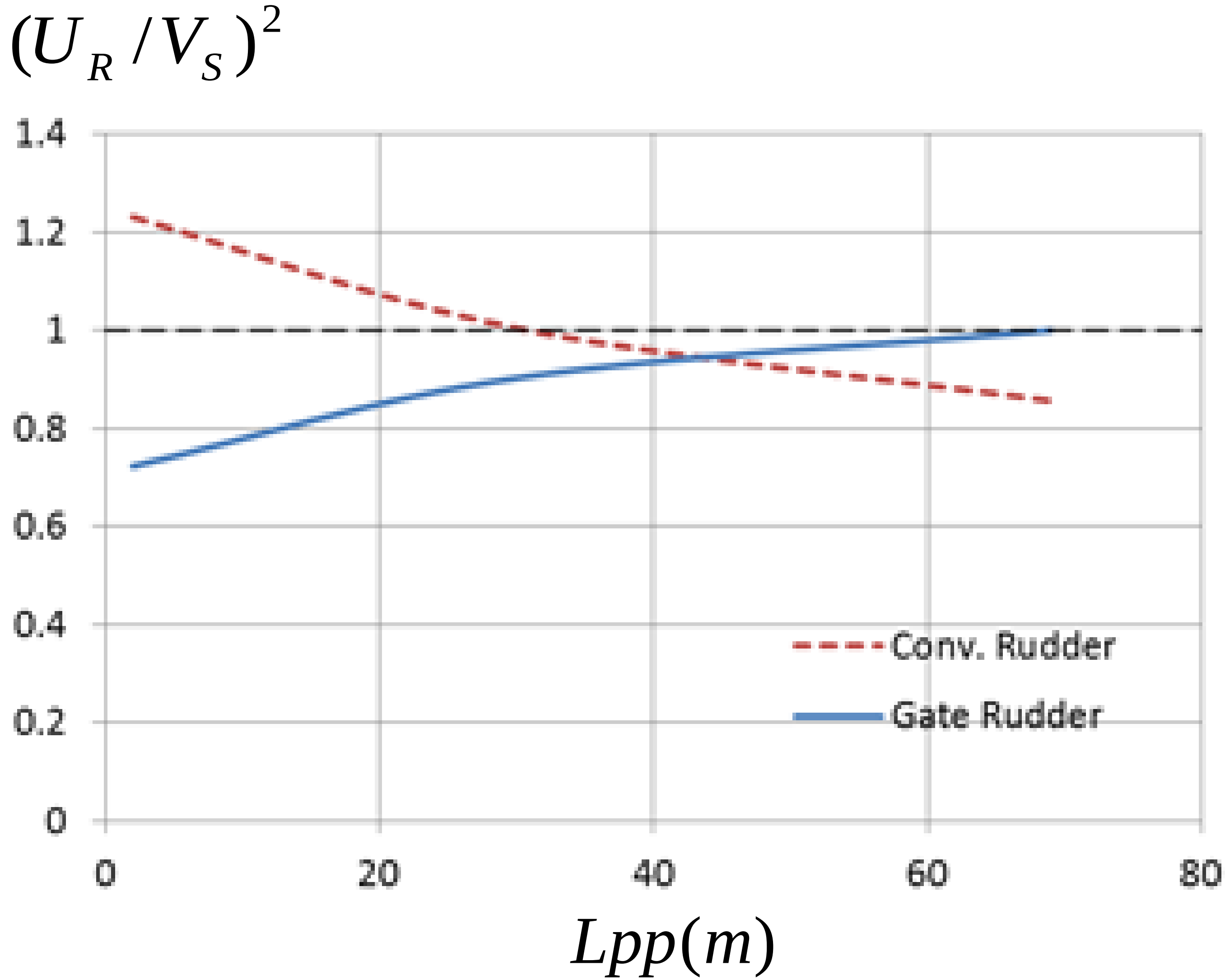
Hull Sway Fore by One Rudder Steering



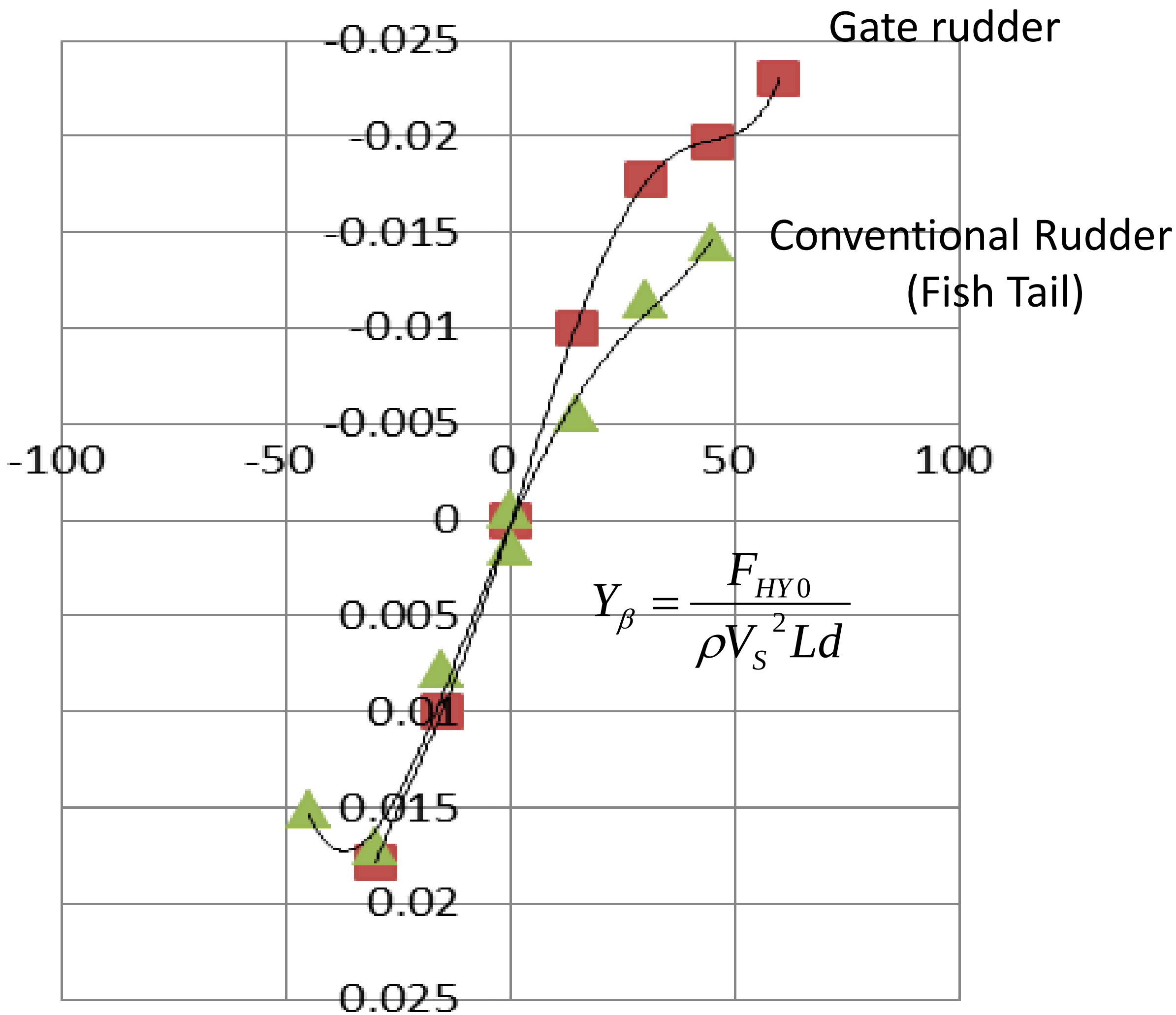
Hull Sway Force by Two Rudders Steering



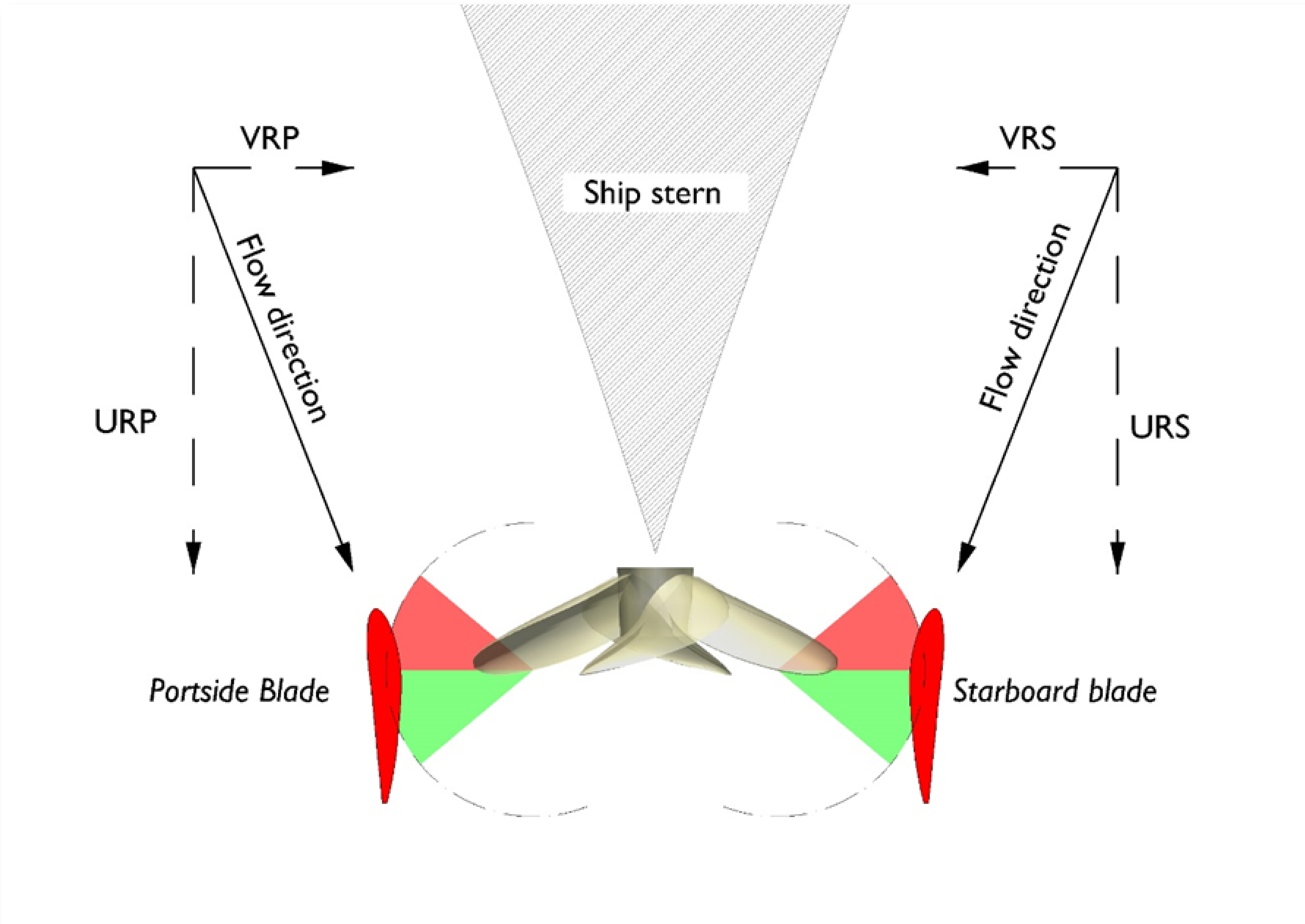
Scale Effect on Velocity at Rudder Position



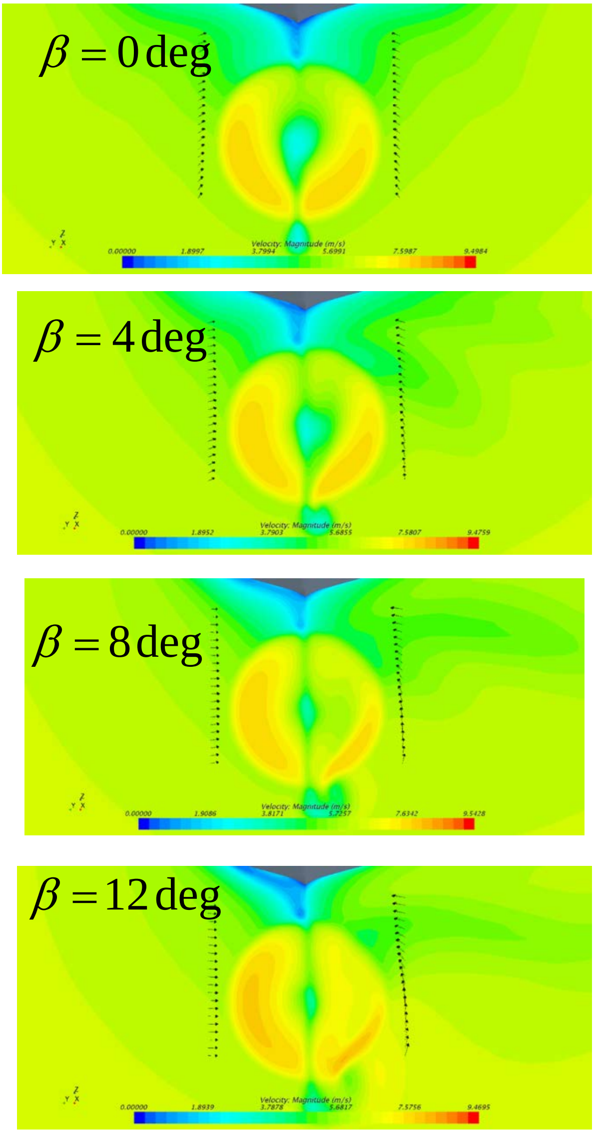
Fy by Two Rudders Steering (corrected for Scale Effect)



Flow Regulation Coefficients

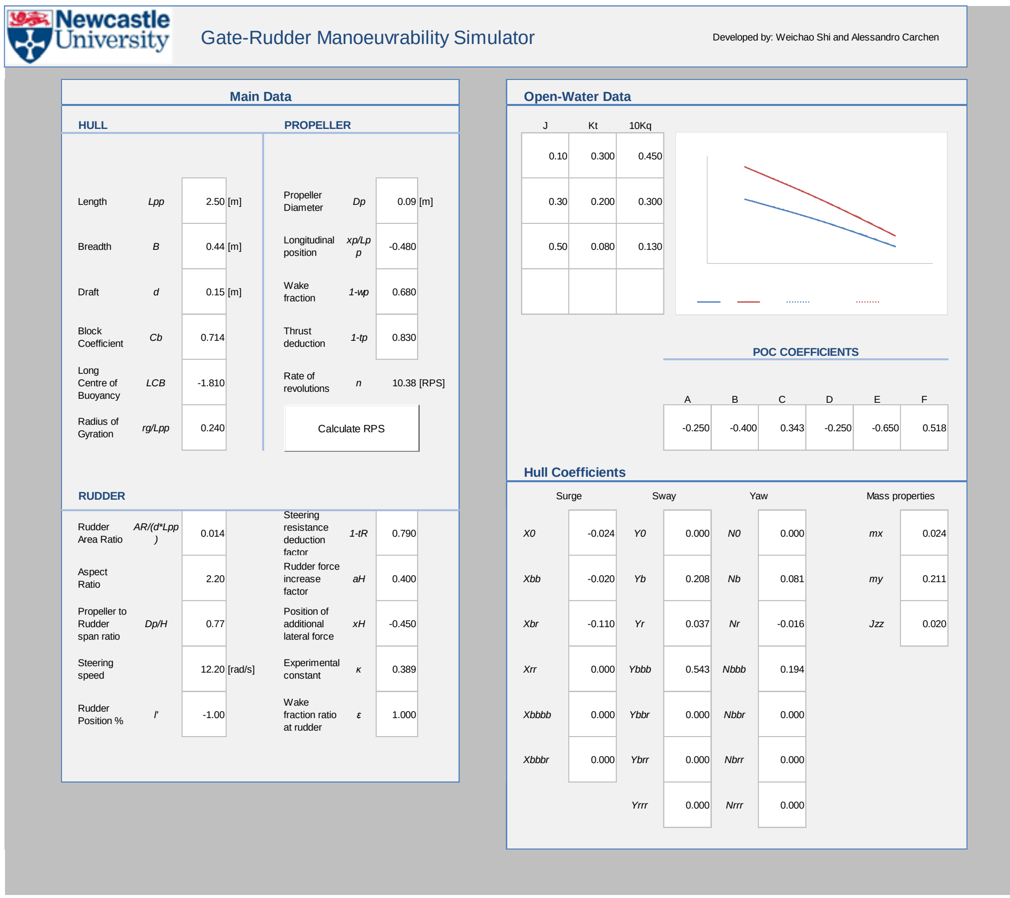


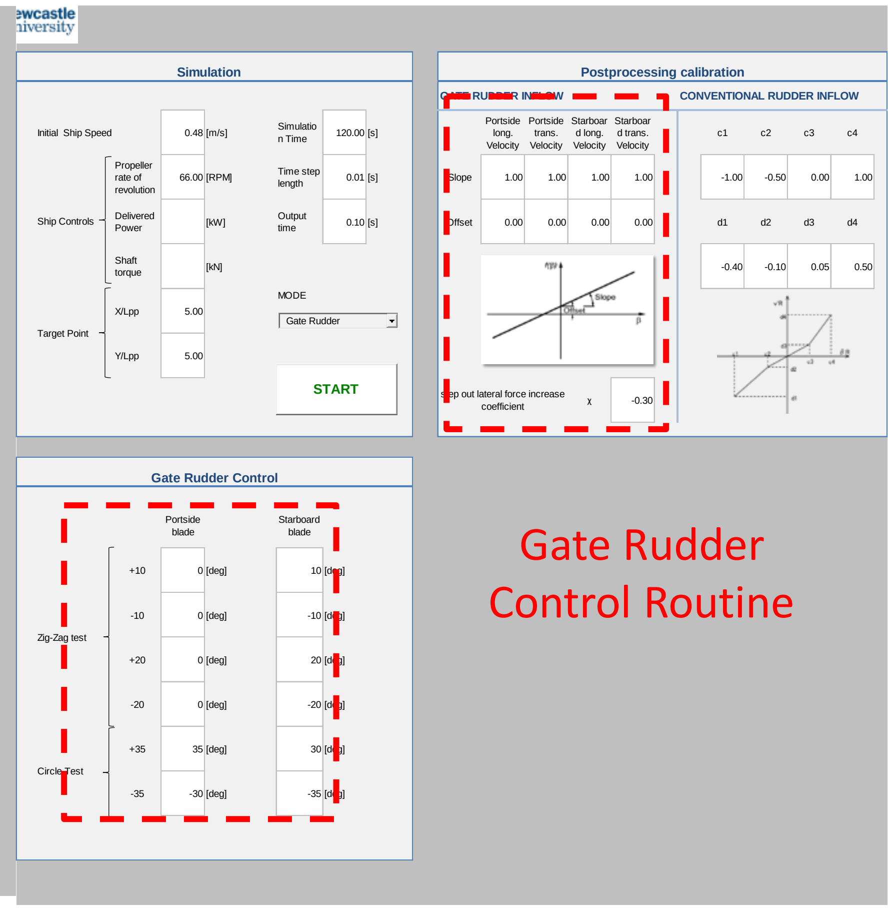
Utilization of CFD Calculation for flow straightening Coefficients



$$u_R = f(\beta, \delta, C_T, z_R)$$
$$v_R = f(\beta, \delta, C_T, z_R)$$

Maneuvering Simulation Program of a Ship with Gate Rudder



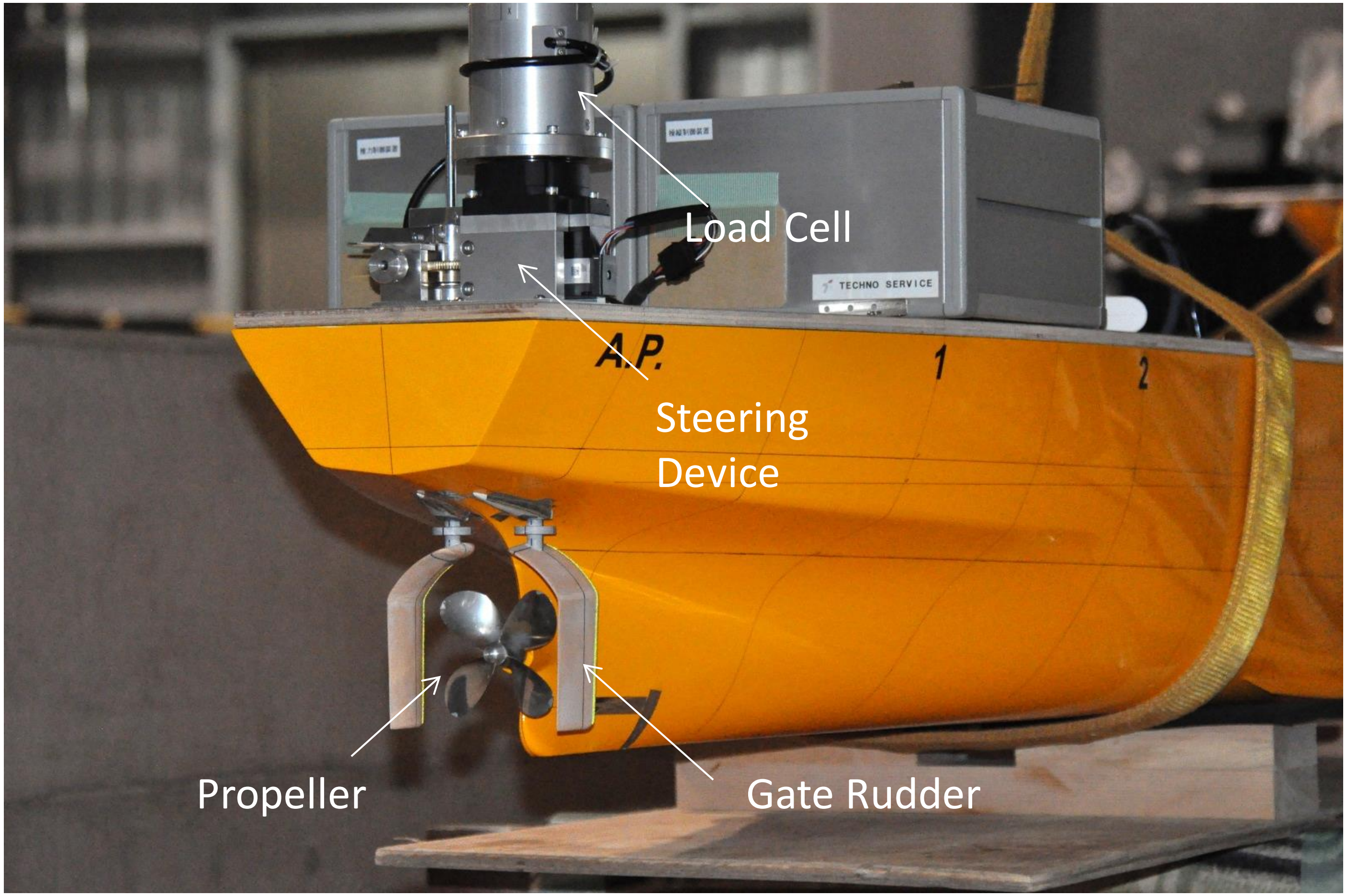


Developed by NCL & Kamome Prop. Co.

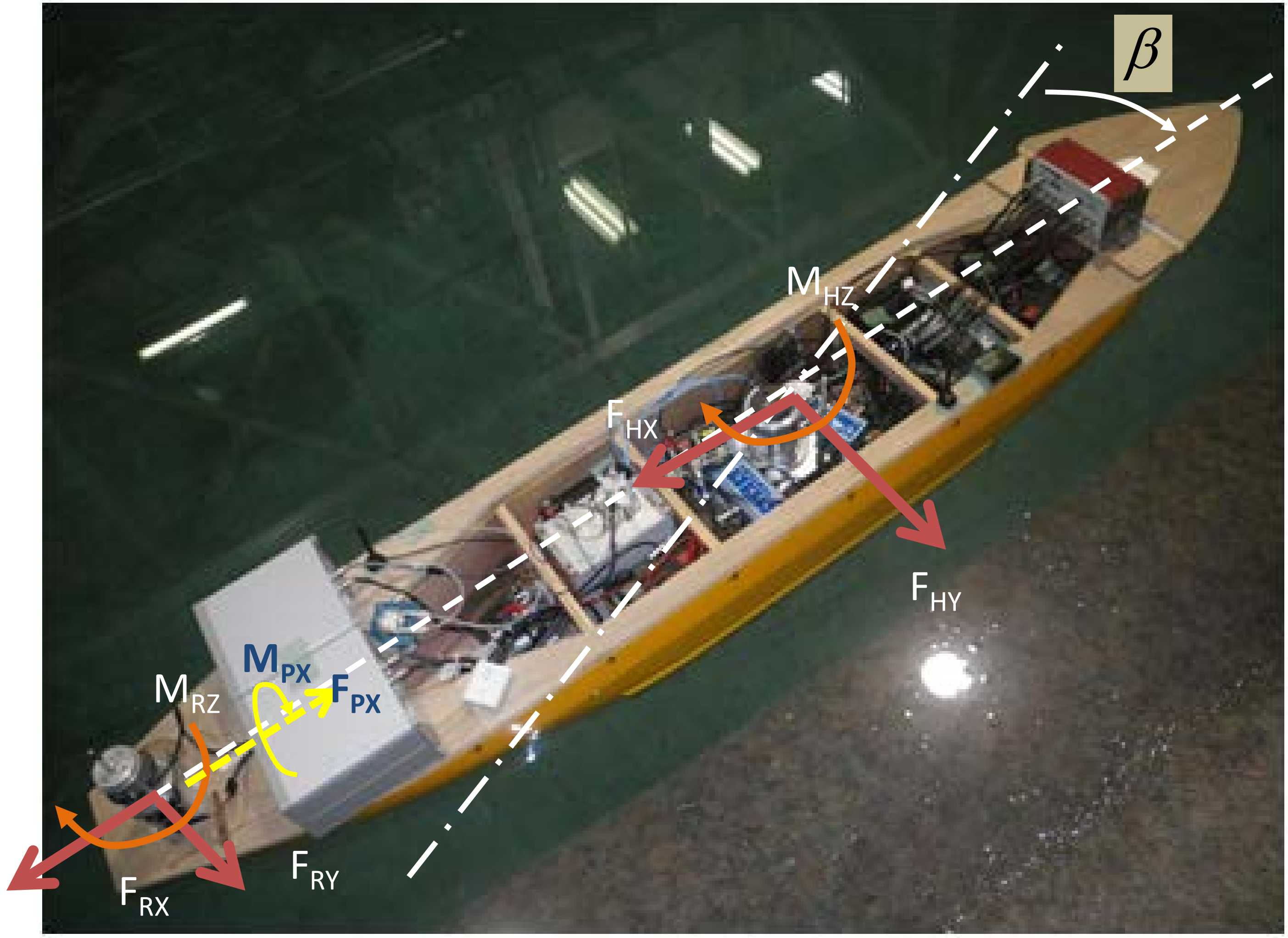
Model Basin of Kyusyu University

船舶運動性能試験水槽は，水槽本体と模型曳引車，プランジャー型造波装置によって構成されています。水槽本体は長さ38.8m，幅24.4m，水深2mです。水槽底部を高精度で平坦に仕上げたことにより，世界的にも数少ない浅水域を対象とした浮体運動の実験が実施可能な水槽となっています。

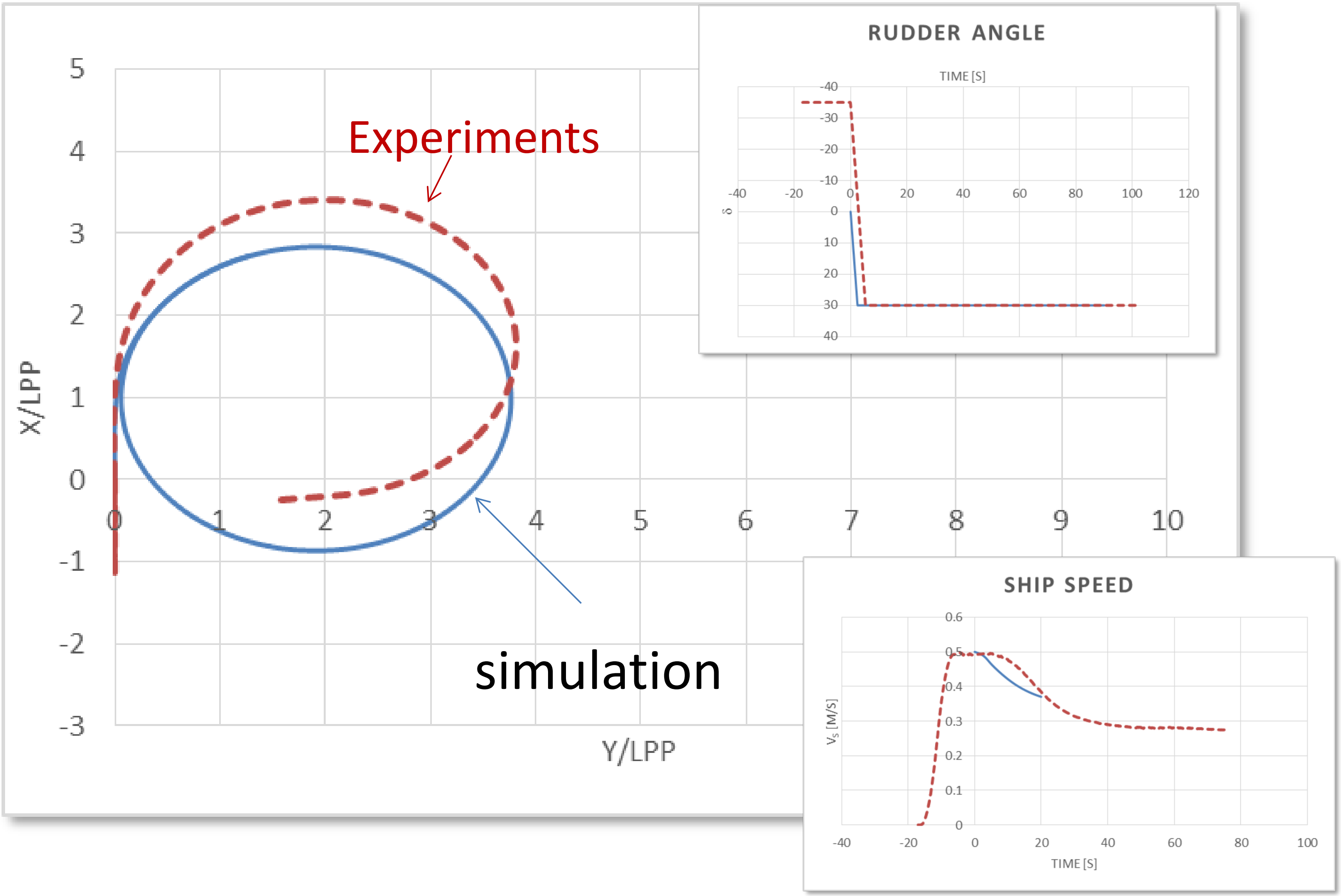
2.5 m model equipped with gate rudder and measurement instrument s



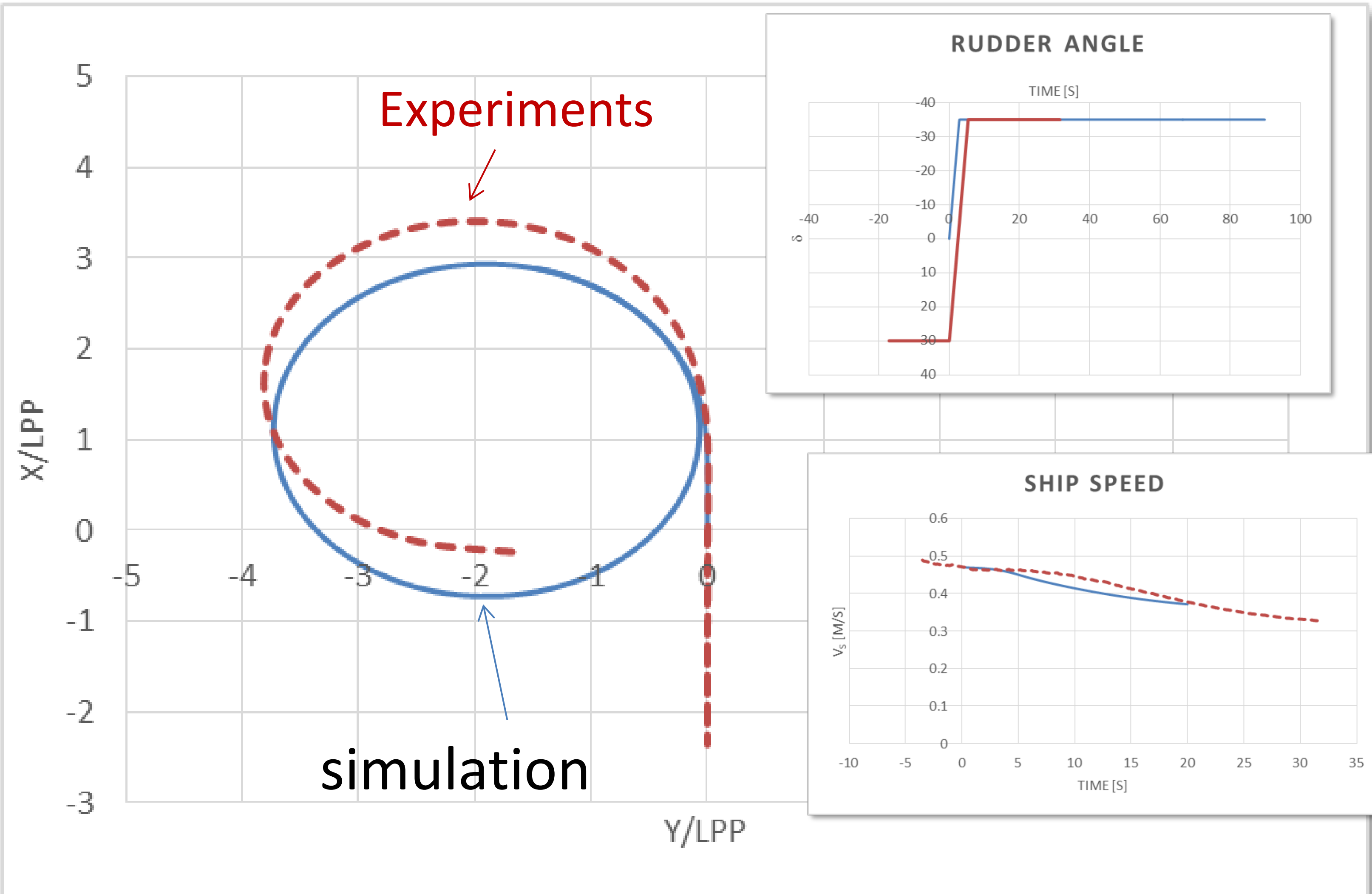
Captive Model Tests



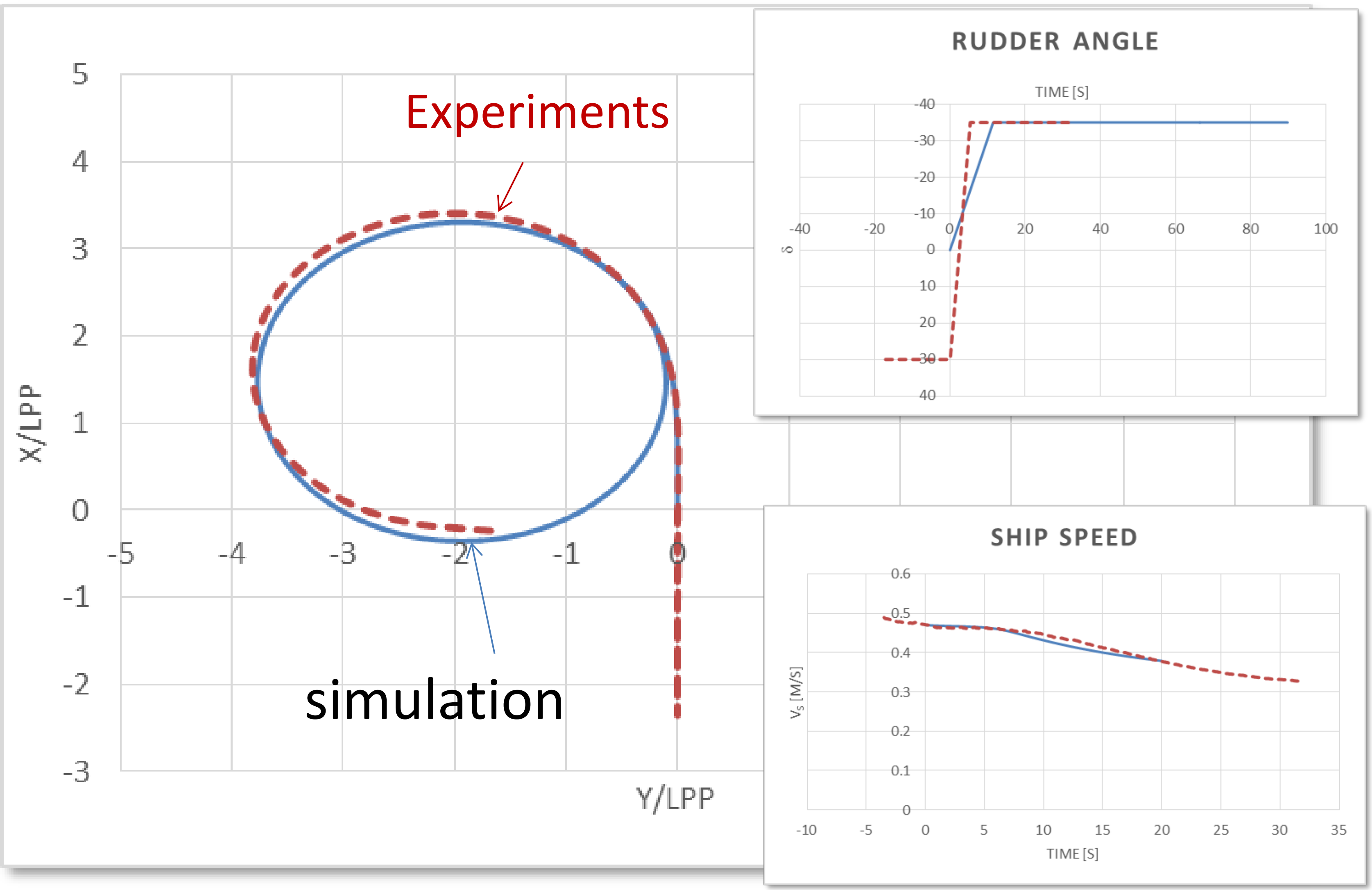
Circle Test (starboard 35 deg.)



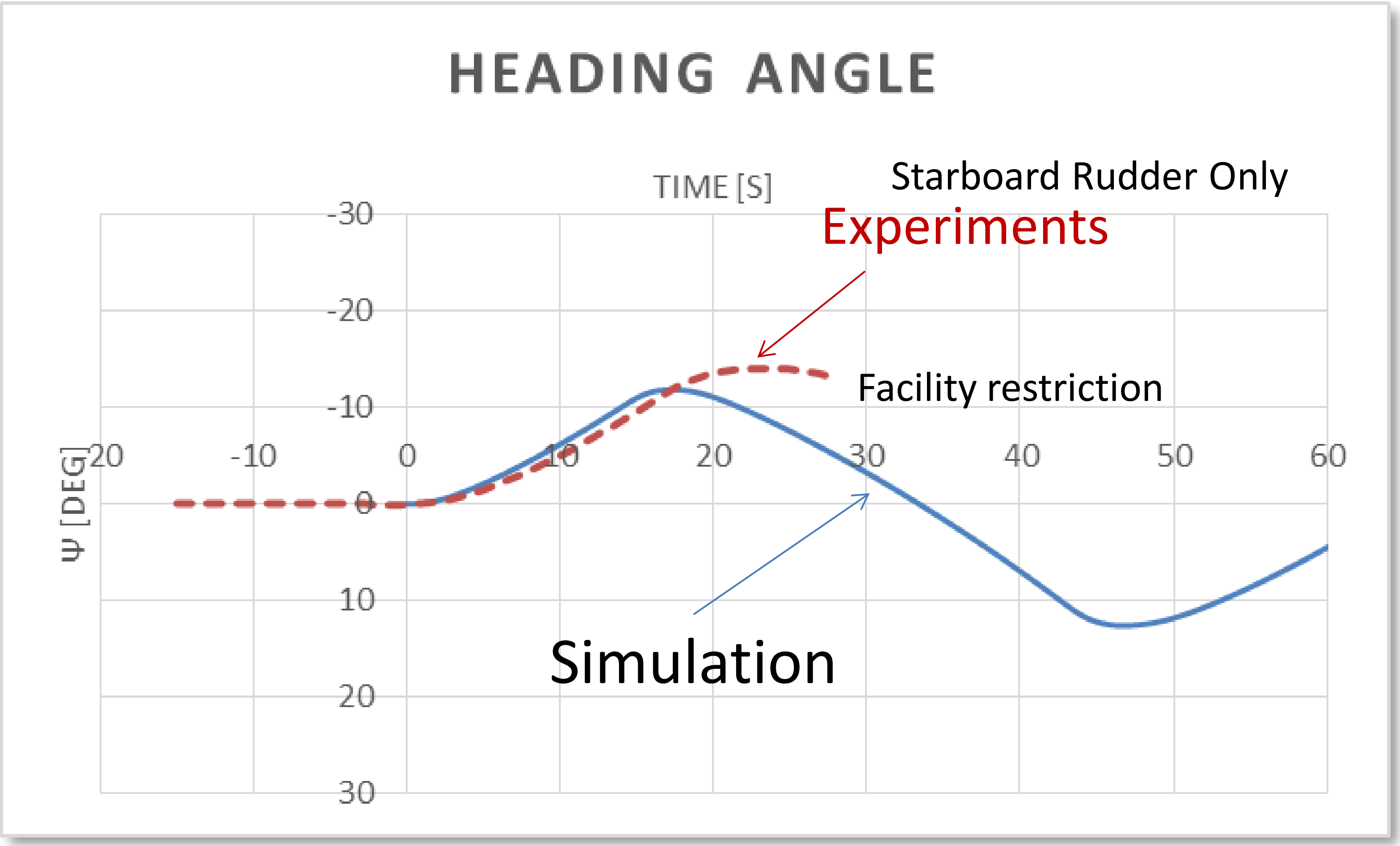
Circle Test (portside -35 deg.)



Circle Test (portside -35 deg.)

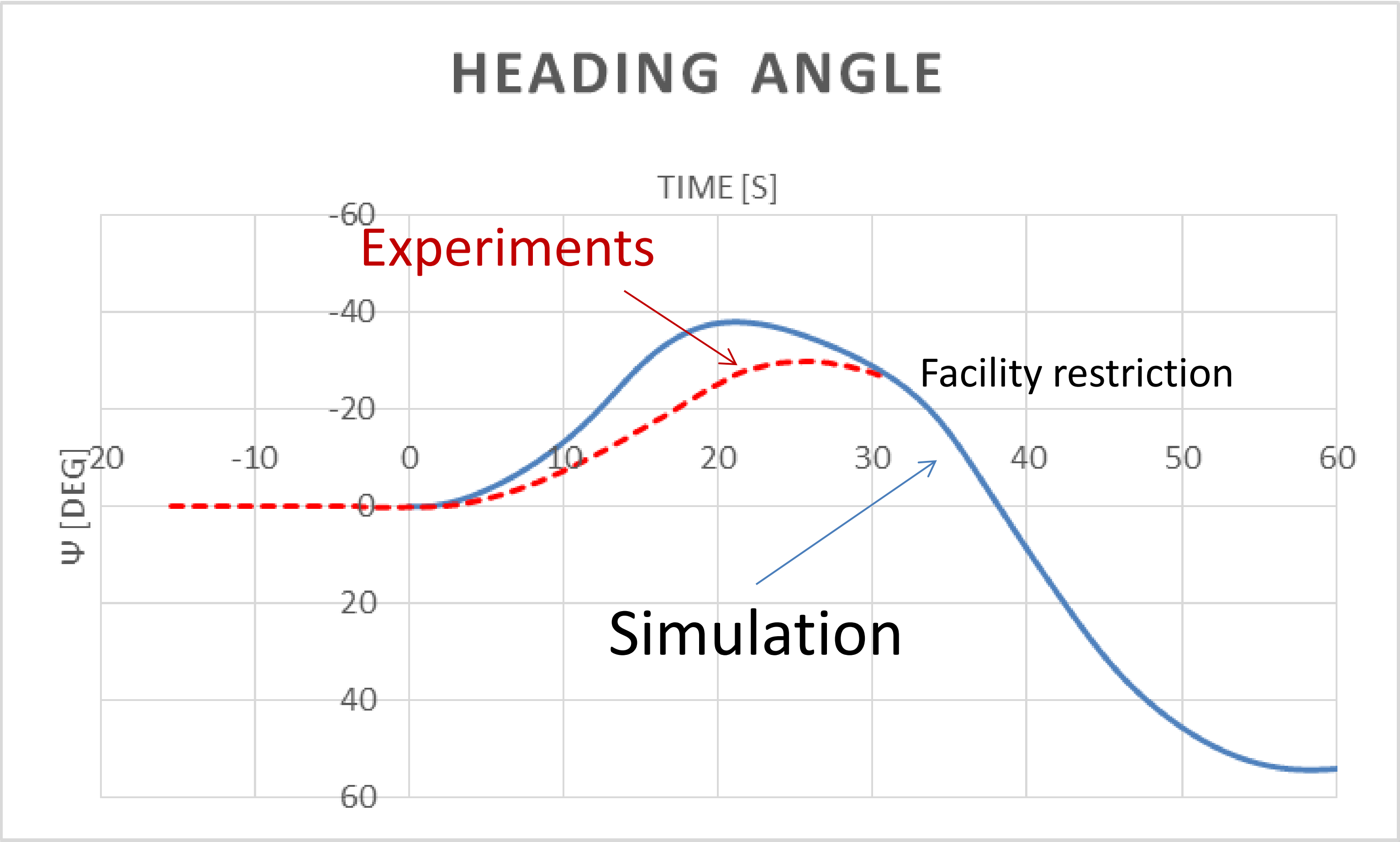


Zig Zag Test (10 deg.)

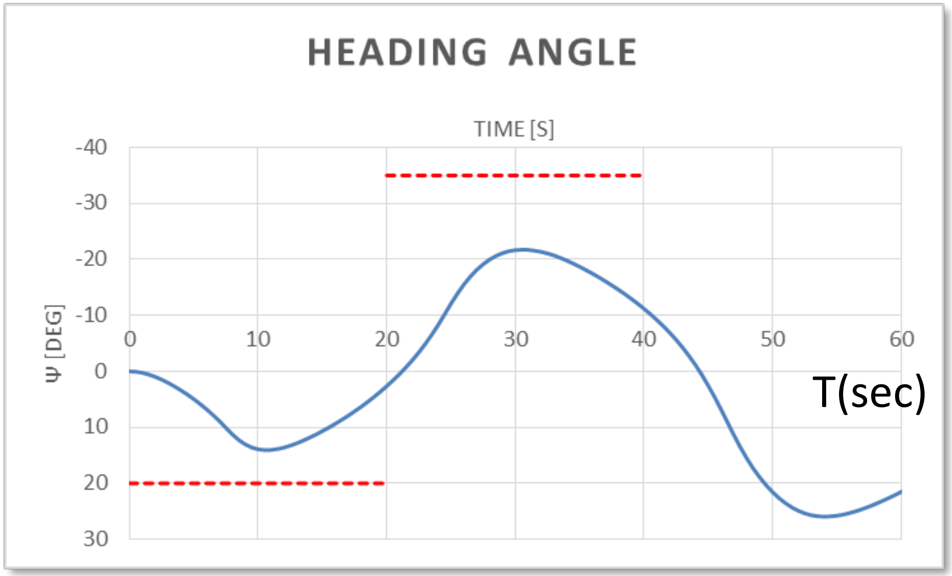


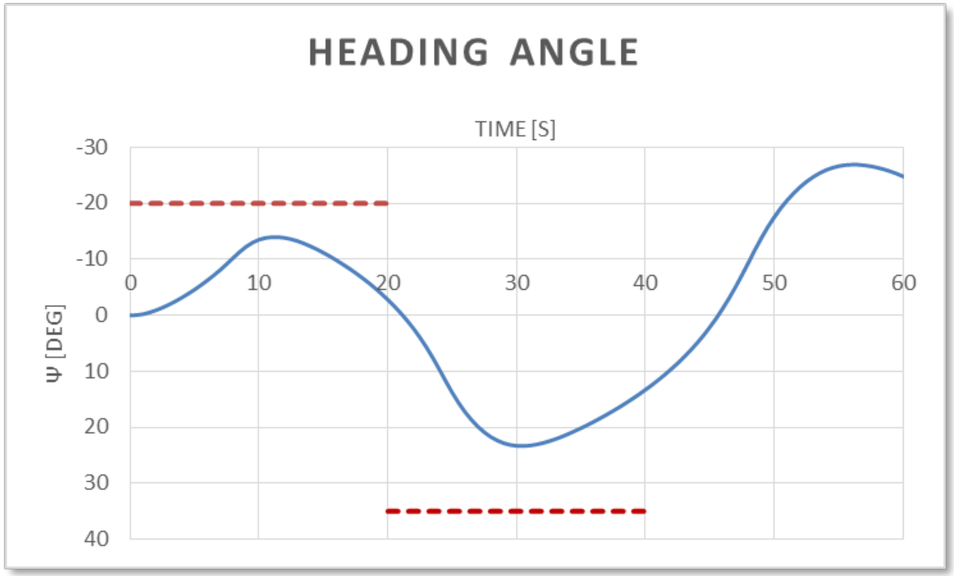
Zig Zag Test (20 deg.)

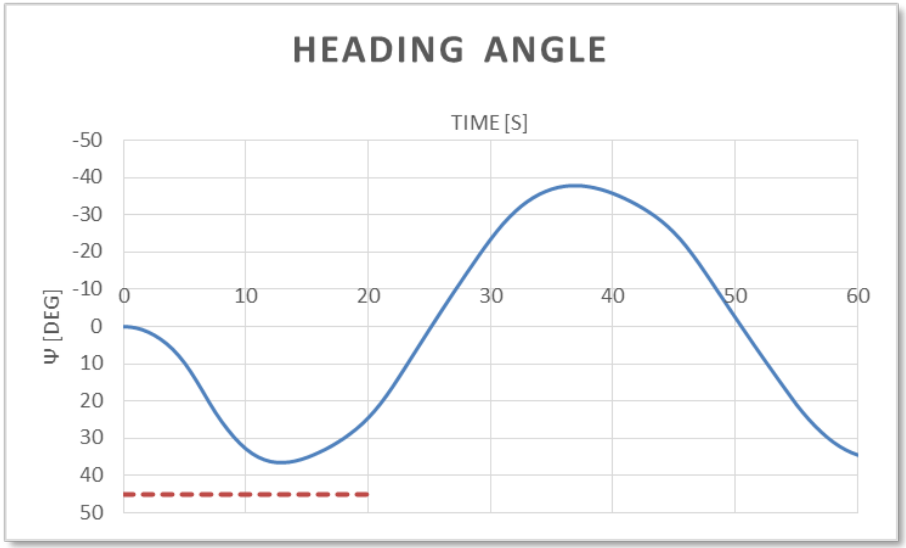
With Starboard Rudder only

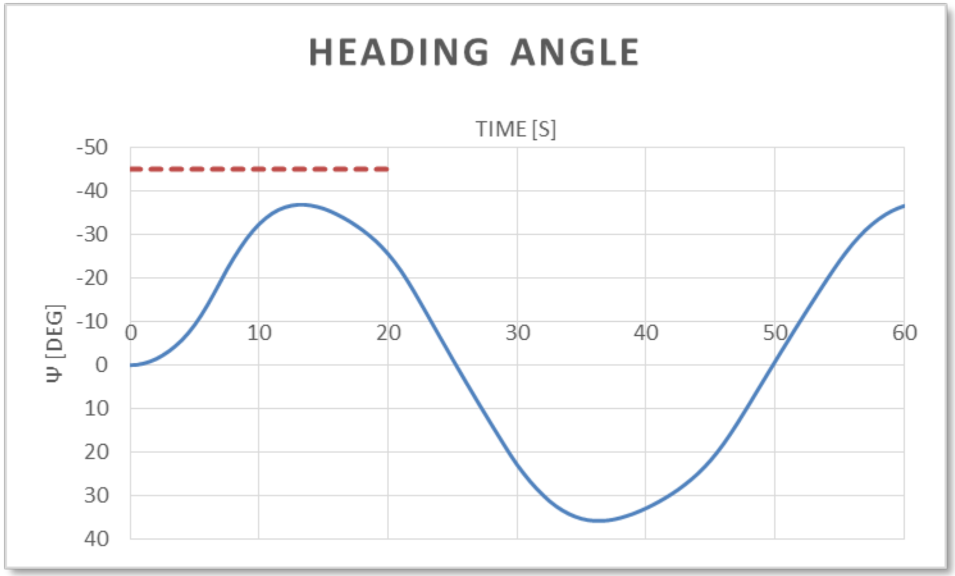


Simulated Zig Zag Tests





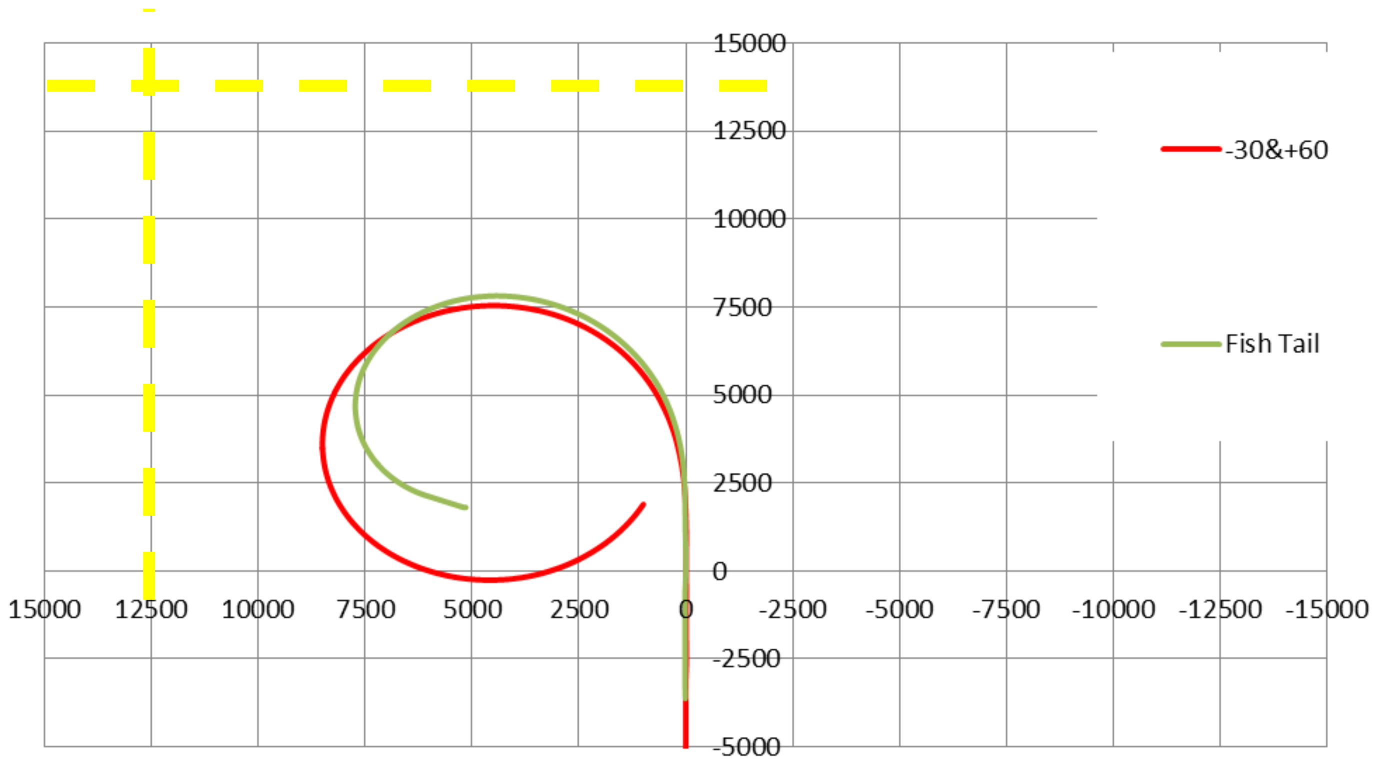




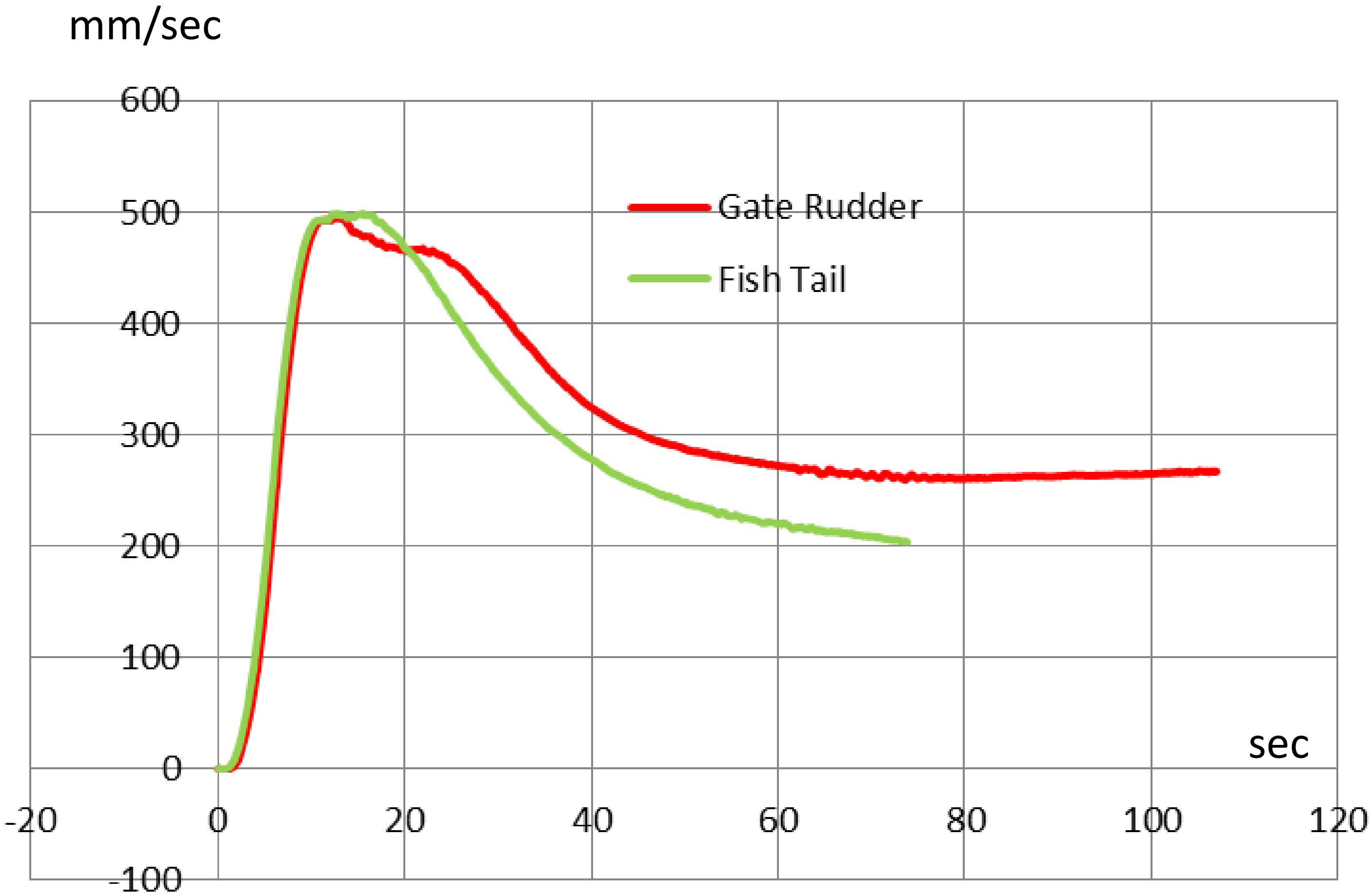
Comparison of turning ability between Gate Rudder and High Lift Rudder

model test

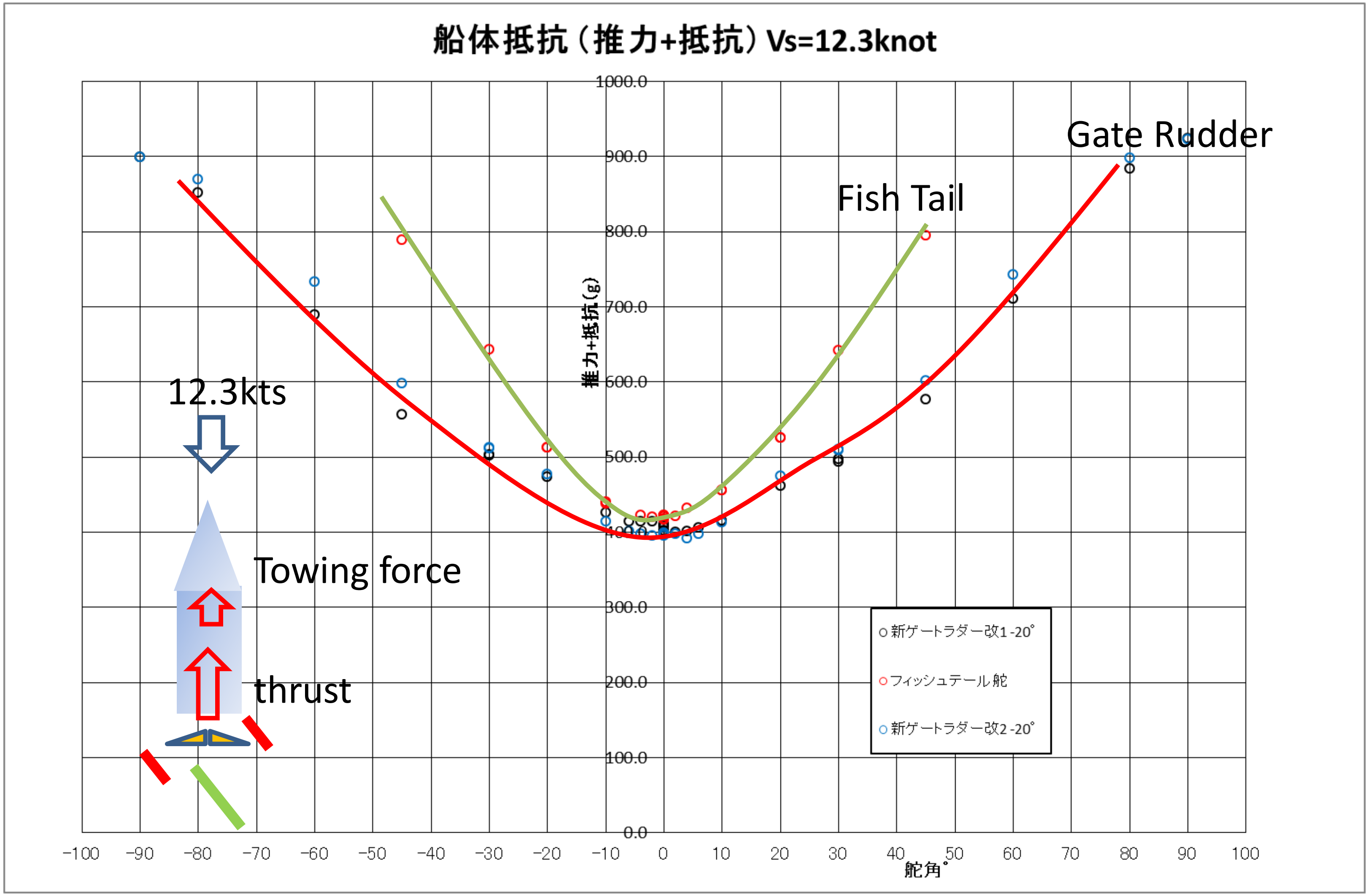
IMO maneuvering standard



Comparison ship speeds between Gate Rudder and High Lift Rudder



Rudder Induced Resistance in a Steering Mode w (yaw angle=0)



結論

（１）ゲートラダーを搭載予定の499内航船の操縦性能を模型試験と操縦性のシミュレーションプログラムにより調査した

（２）施設や計測装置の制約があり、一部、確認できない操縦性能があったが、シミュレーションにより確認ができた。

（３）ゲートラダーは、操舵角が大きいこともあり、従来舵断面を用いても高揚力舵と同等または同等以上の操舵力を発揮できる。

（４）ゲート舵は、操舵時の舵抵抗が小さく、航海中の微小操舵による馬力増加の減少が期待できること、また、海象悪化時の操船能力が高い可能性があることが分かった。

VIDEO　紹介