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Presentation on:

Operational profile optimization and energy saving device study on a container ship

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Operational profile optimization on a container ship

Operational profile

	T(m)	Vs(kn)	Ratio
About 9000TEU	12.5	15	15%
		19	30%
		23	5%
	14.5	14	15%
		18	30%
		22.5	5%

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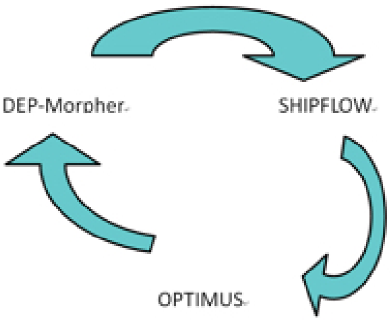
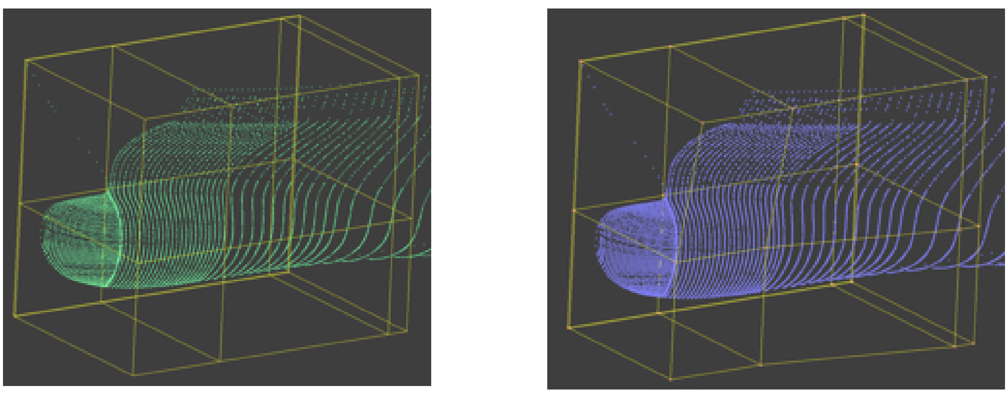
Integrated System of Automatic Optimization



Flowchart of Optimization

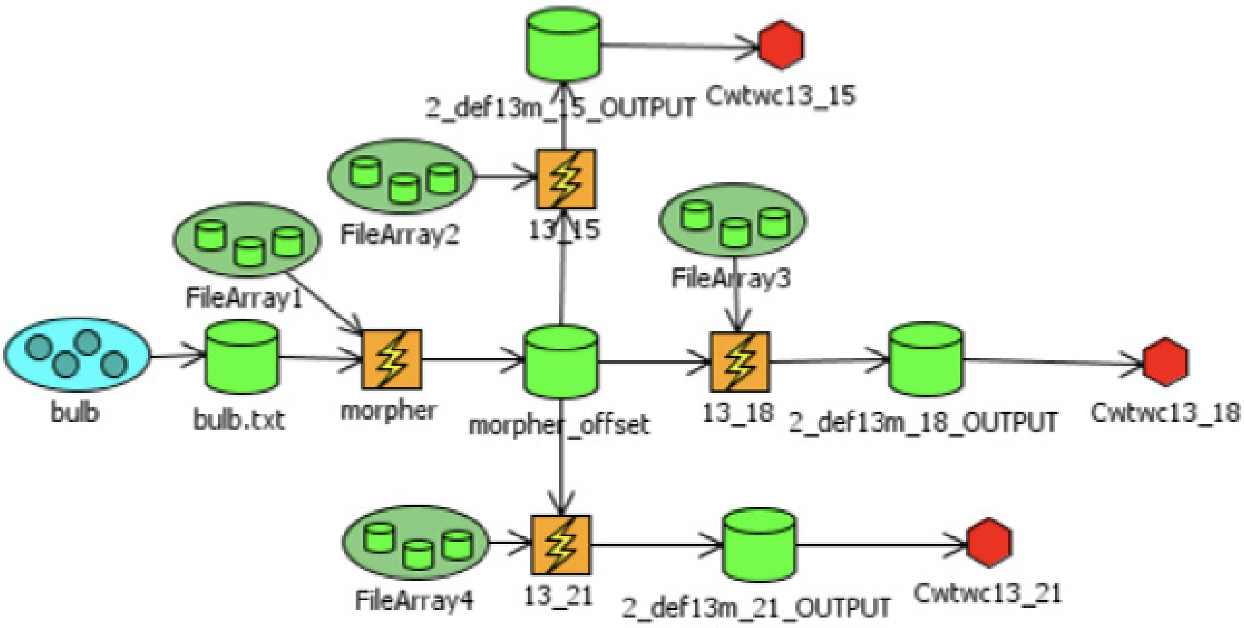
- DEP-Morpher：Surface deformation on parametric expression
- Shipflow：Solution to wave-making resistance
- Optimus：Optimization algorithm

Object Function: Minimum wave-making resistance
Variables: Length/breadth/height of Bulbous bow
Range: 18.5#~20#(fore perpendicular)



Parametric expression on Surface and deformation

Deformation and solution



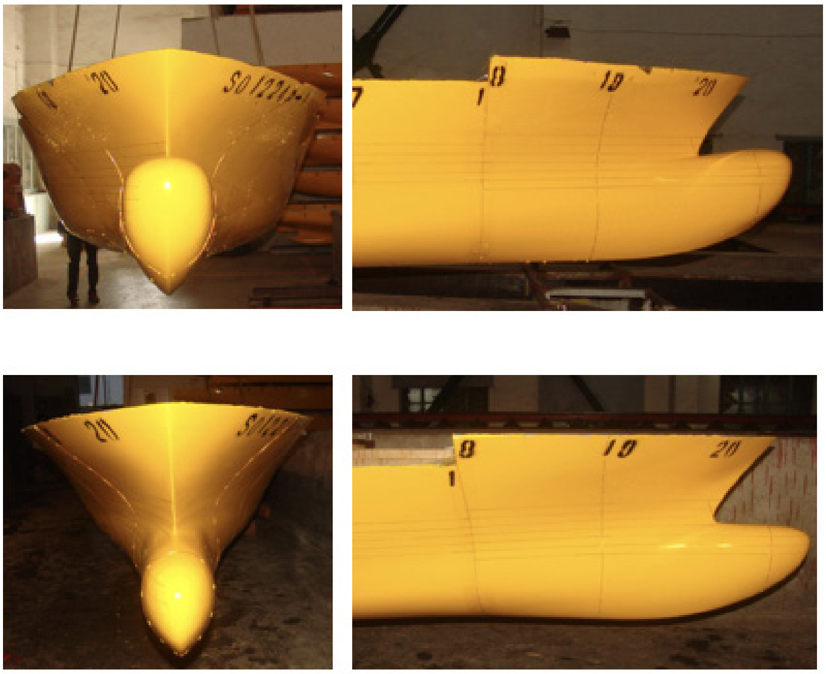
Comparison between original(Up) and optimized(Down) lines

CFD result

T(m)	Vs(kn)	Cw (Opti-Orig)
12.5	15	-0.6
	19	-0.35
	23	-0.08
14.5	14	-0.55
	18	-0.2
	22.5	0.06

➢Potential code shows, optimized line has a lower wave-making resistance except at 14.5m and 22.5kn

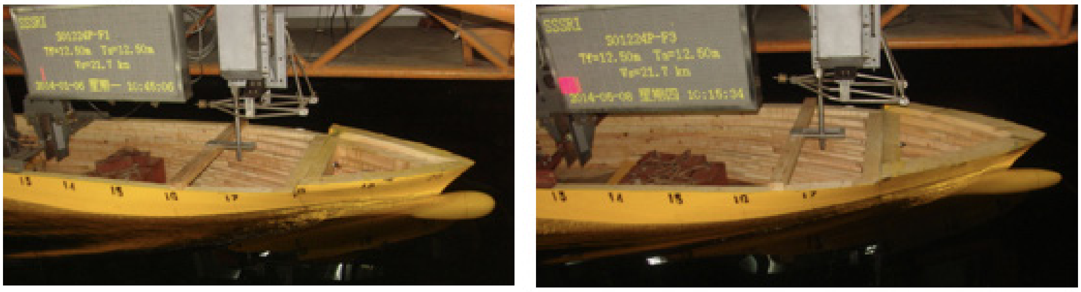
➢Optimized line has a lower and less pronounced bulb



Comparison between original(Left) and optimized(Right) lines

➢Compared with the original line, optimized line has improved wave-making resistance remarkably at 14kn and 17.8kn(12.5m draft)

Comparison between original(Left) and optimized(Right) lines



➢At 12.5m and 21.7kn, optimized line has a better performance

➢However, at 14.5m and 21.7kn, optimized line has a poor performance

➢The reason should be: lower and slender bulb, which reduced interference intensity between bulb and fore-body.

Comparison and conclusion

		dCr=Optimal-Original		
T(m)	Vs(kn)	Viscous CFD	Modeltest	Pe
12.5	15	-0.69	-0.70	-28%
	19	-0.42	-0.45	-20%
	23	-0.06	-0.09	-4%
14.5	14	-0.50	-0.49	-23%
	18	-0.15	-0.14	-9%
	22.5	0.04	0.08	3.8%

➢CFD shows not only the right direction of optimization, but also very close value to model test

➢Optimized line has a very satisfactory performance , validated by model test with a weighted benefit about 16%

Energy saving device study on a container ship

Rudder Bulb-RB
Propeller Cap Turbine-PCT
Thrust Fin-TF

Rudder Bulb study

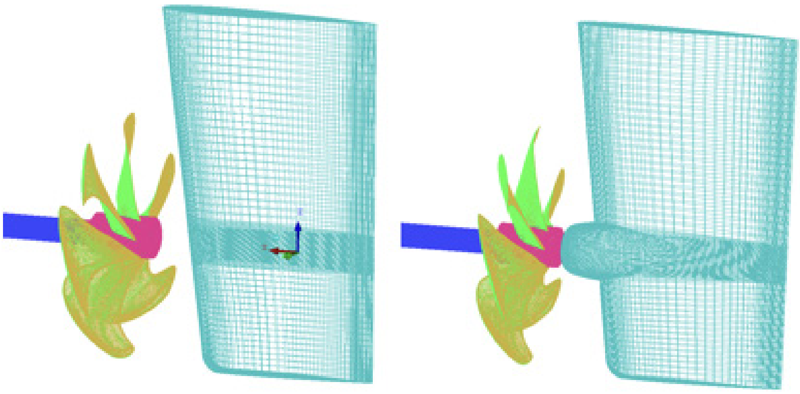
CFD setup:

➢Inflow-uniform

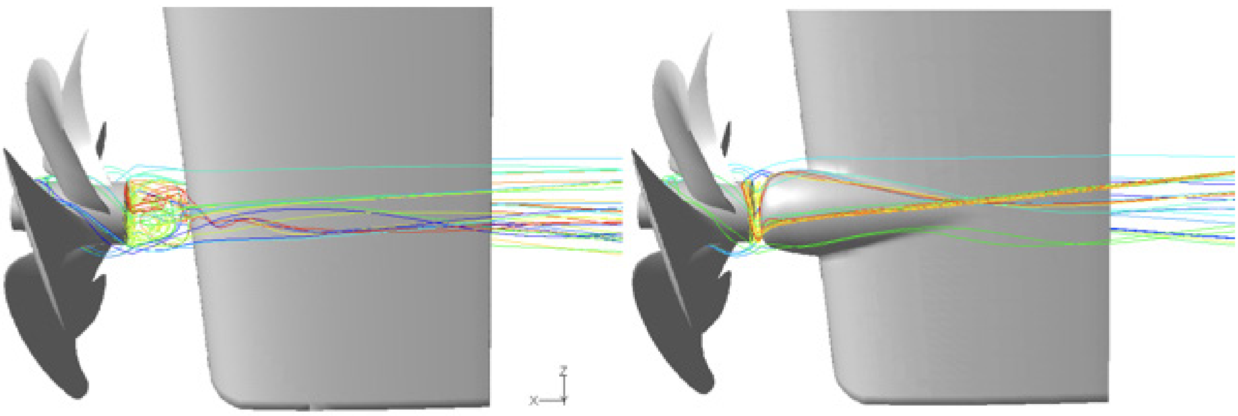
➢Mesh-Sliding mesh

➢Unsteady

Grid configuration



With rudder bulb (Right)
and without(Left)

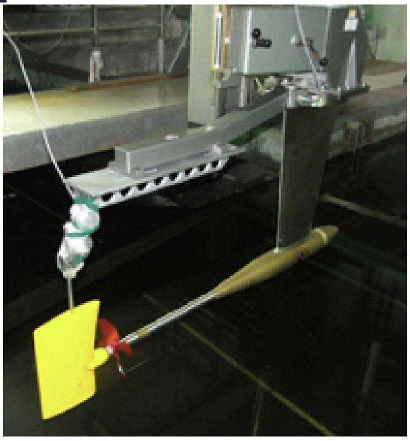


Streamline after Propeller with(right) and w/o(left) rudder bulb

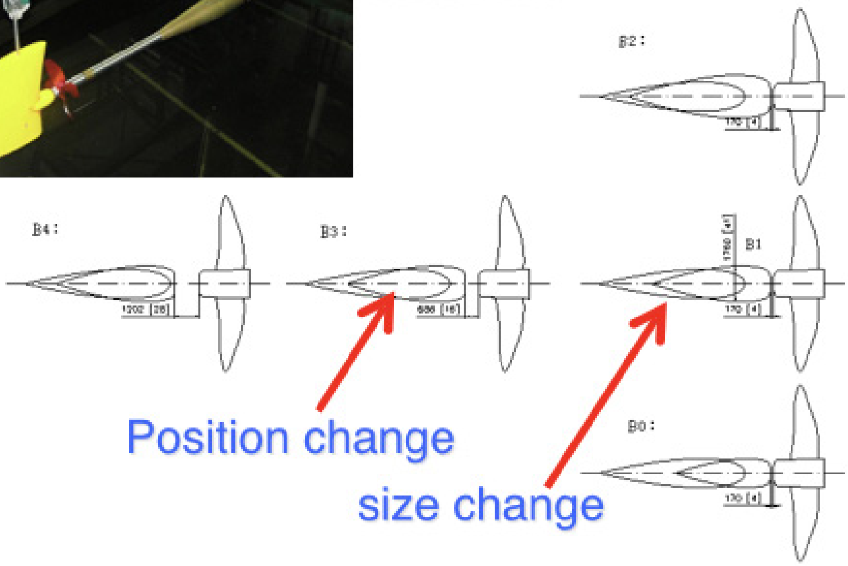
➢Hub outflow improved

➢inflow of rudder also improved

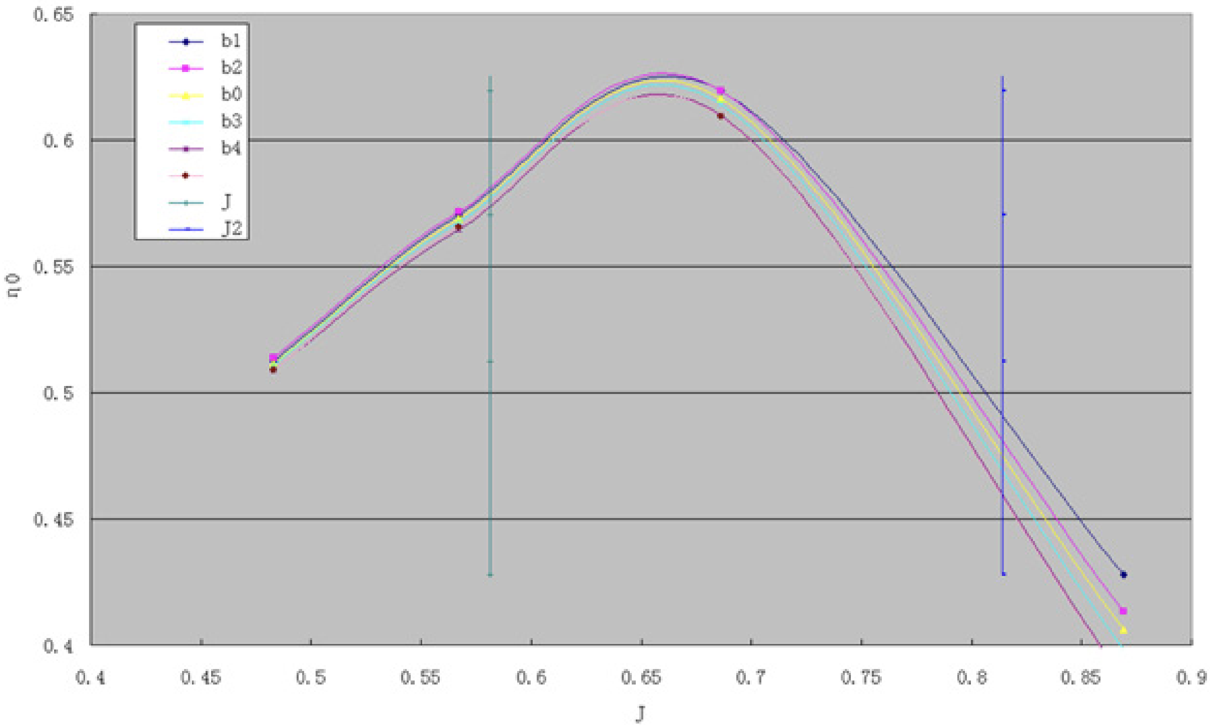
Test setup and Systematic change of size and position



Test setup of rudder bulb



B0:0.8B1
B1:Original bulb
B2: 1.2B1
B3:B1-12mm
B4:B1-24mm



Open-water efficiency comparison from model test
Lowest line-No bulb

Comparison between CFD&EFD

Size effect	J=0.81	CFD	1.2times＞Ori＞0.8times＞W/O
		EFD	Same as CFD
	J=0.58	CFD	1.2times＞Ori＞0.8times＞W/O
		EFD	Ori＞1.2times＞0.8times＞W/O
Position effect		CFD	Ori＞BW12＞BW24＞W/O
		EFD	Same as CFD

'>'means better than ; Ori~ Original bulb; BW~ backward

Conclusions:

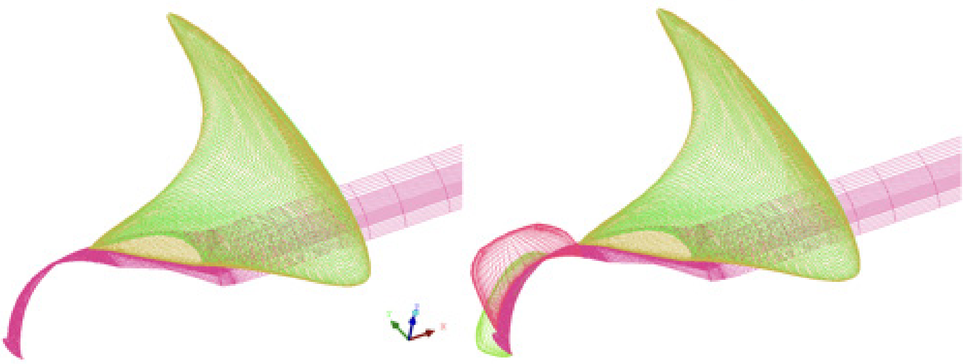
- Generally, CFD agrees with EFD
- Large bulb size tends to performs better
- Rudder bulb should be as close to Prop hub as possible

9000TEU- PCT STUDY

Propeller: six blades with large skew

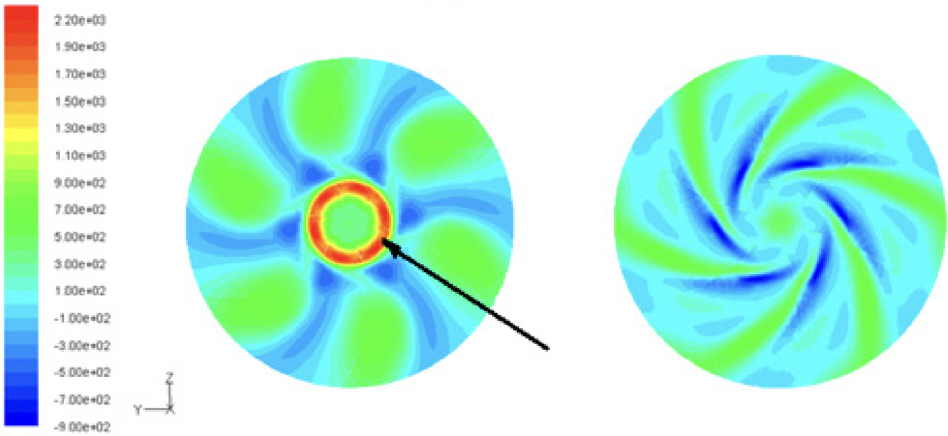
CFD:

- Only one channel, periodical condition is used
- Hex, multi-block structural, boundary layer grid



Grid configuration

Votex intensity comparison w&w/o PCT



votex intensity distribution after hub
w/o(left) and w(right) PCT

- Remarkable decrease of votex intensity with PCT

Comparison of open-water efficiency between CFD&EFD w&w/o PCT

J	Etao(CFD-PBCF)			Etao(EFD-PBCF)		
	A (W/O)	B (W)	(B/A-1)%	A (W/O)	B (W)	(B/A-1)%
0.40	0.4366	0.4418	1.19	0.4362	0.4423	1.40
0.50	0.5223	0.5260	0.71	0.5244	0.531	1.26
0.60	0.5846	0.5876	0.51	0.5977	0.6045	1.15
0.70	0.6092	0.6123	0.51	0.6451	0.6524	1.13

Conclusions:

- PCT can increase open-water efficiency
- Effect of PCT tends to decrease with advance ratio increase
- CFD slightly underestimates the effect of PCT

More study on PCT

	P1	P2	P3	P4
Prop Diameter(m)	2.25	2.25	2.25	2.25
Hub length (m)	1.316	1.316	0.98	0.98
Pitch angle （°）	45	40	change	45
skew （°）	0	0	0	0
Number of blades	6	6	6	6

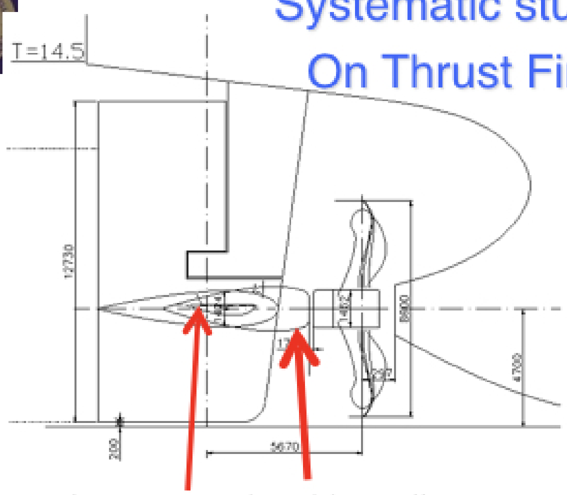
J	P1 （%）	P2 （%）	P3(%)	P4(%)
0.40	1.4	1.23	1.2	1.42
0.50	1.26	1.21	1.11	1.47
0.60	1.15	1.21	1.02	1.54
0.70	1.1[illegible]	1.2[illegible]	0.92	1.66

Benefit from EFD

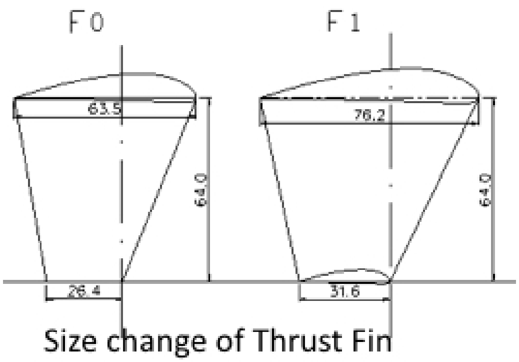
Conclusions:

- All PCT has helped to increase open-water efficiency
- Benefit from all PCT seems not to change much with advance ratio increase
- Hub length and pitch angle are not very sensitive to PCT effects. Relatively, Shorter hub length and 45°pitch angle performs best

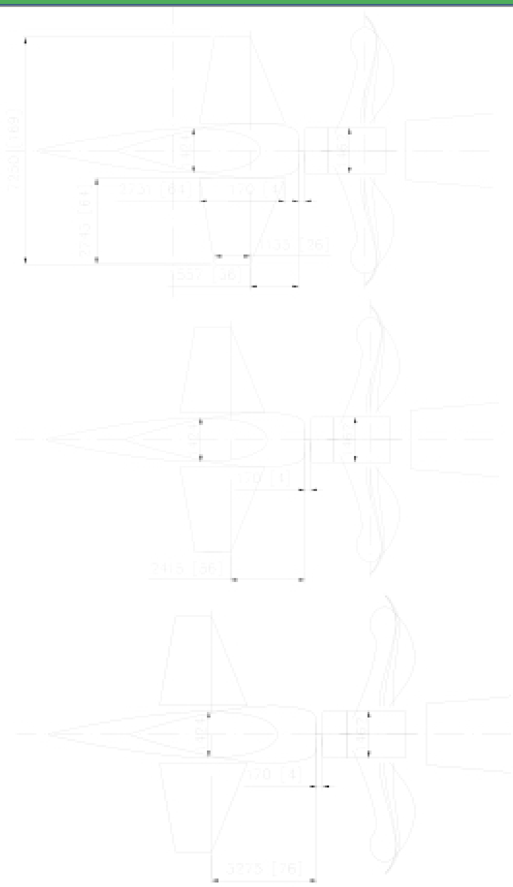
Systematic study On Thrust Fin



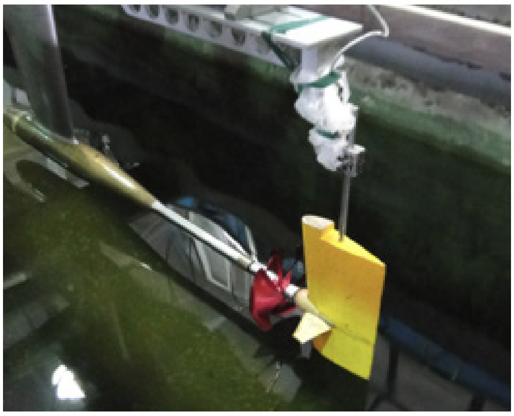
Thrust Fin and Rudder Bulb

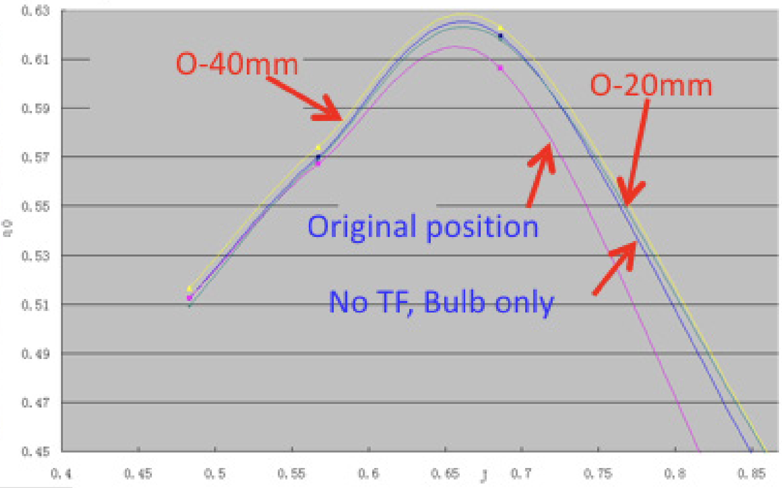


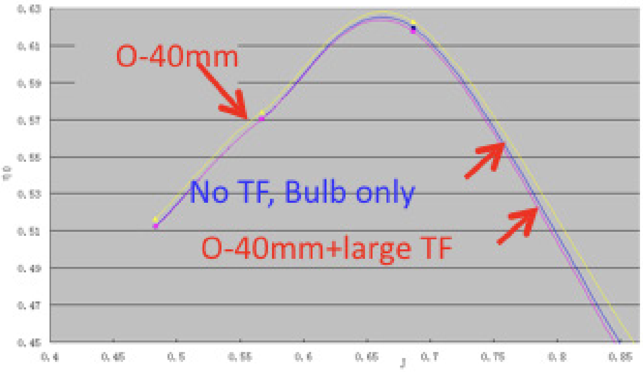
Size change of Thrust Fin


X-position change of Thrust Fin

Model test setup and comparison



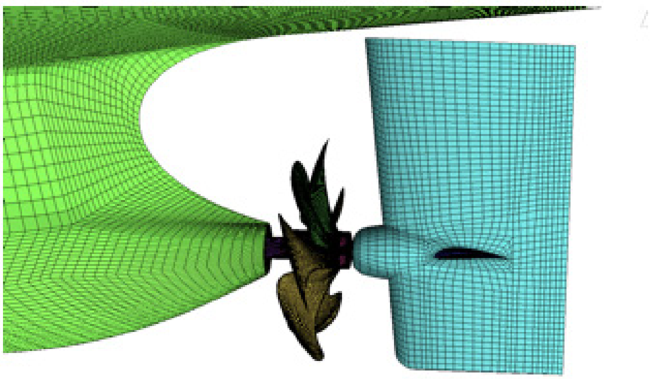


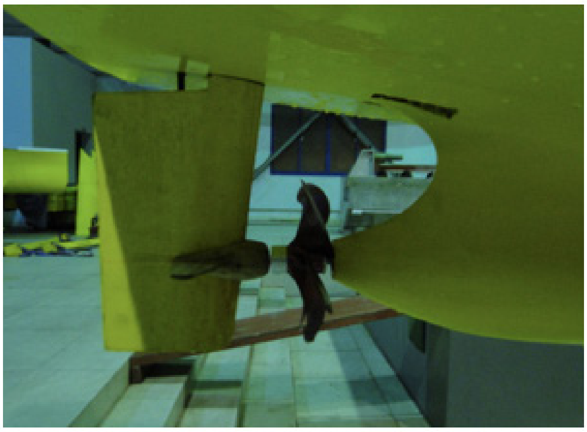


Conclusions:

- TF has better performance when further from propeller
- Large TF seems to be unnecessary
- Unsuitable position or size could deteriorate the performance

Further simulation and validation





CFD	EFD
2.2%	3.9%

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Summarize of ESDs

➢RB should be large enough to match propeller hub and the thickness of rudder, and the distance between hub and RB should be as close as possible.

➢PCT can increase open-water efficiency by 0.9%-1.7% at different advance ratio J=0.4-0.75. Kt increases and Kq decreases. PCT is not very sensitive to pitch angle, hub length and installation angle.

➢For RTF, installation angle, longitudinal position, are important parameters. From open-water efficiency, it's found that -1°is the best one. Afterwards 40mm position is the best. Chord length change is not so sensitive to efficiency.

➢Model test further shows, propulsive efficiency increases by 3-4% with RB and RTF for the studied case.

General Conclusions

Operational profile has aroused more and more attention in the past years. EEDI pressure on new ships and profit-driven motivation have pushed ship owners to take every possible measures to improve ship's performance. For the container ship,

➢From CFD study and model test, it's possible to reduce weighted resistance over 10% taking operational profile into account

➢PCT, RB and RTF are suitable energy saving devices. Model test shows, RB and RTF are suitable combination which contributes 3-4% power reduction.

➢Work in this paper will help to reduce overall resistance and increase propulsive efficiency with suitable energy saving devices.

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Thank you

for your attention!

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