Ship Hull Optimization
in Calm Water and Moderate Sea States

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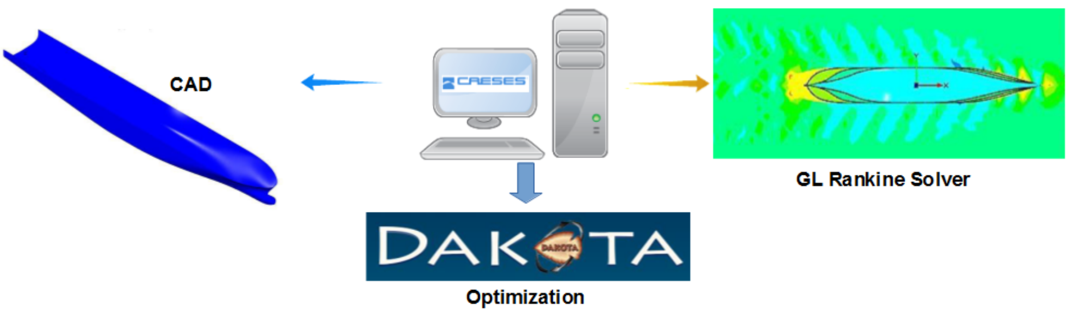
OBJECTIVES

FRIENDSHIP SYSTEMS – Computer Aided Engineering platform **CAESES**

PerSee - "Performance von Schiffen im Seegang" (Performance of ships in sea-states)

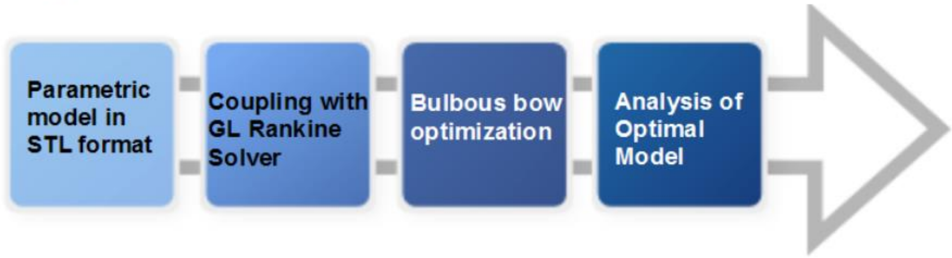
- **Hydrodynamic optimization of bulbous bow** for energy efficiency and performance of ships in seas.



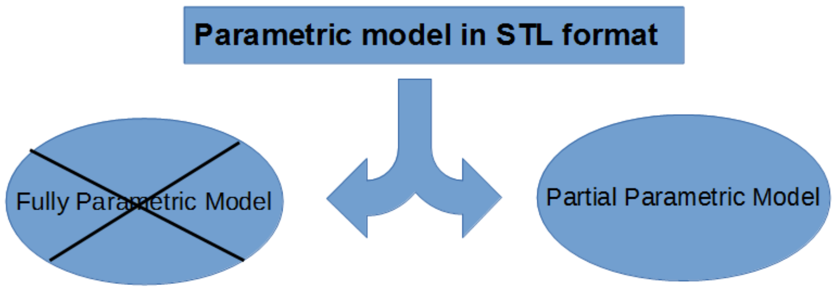
WORK FLOW

Main Dimensions of DTC (Duisburg Test Case)Container Vessel

Length Between Perpendiculars	L_{pp} [m]	355.0
Waterline Breadth	B_{wl} [m]	51.0
Design Draft Amidships	T_{Dm} [m]	14.5
Moulded Depth	D [m]	32.0
Block Coefficient	C_B [-]	0.661
Volume Displacement	V [m3]	173467.0
wetted surface under waterline without appendages	S_W [m2]	22032.0



PARAMETRIC MODELING



- Can be modeled from sketch.
- Entire shape defined by parameters.
- Very powerful for optimization processes.
- Too much of computational time and cost.

- Local modification can be defined by few parameters.
- Quick and easy to set up.
- Does not look much different from the initial design.
- Free form deformation and shift transformation

PARTIAL PARAMETRIC MODEL

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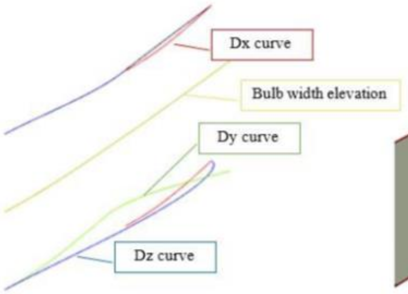
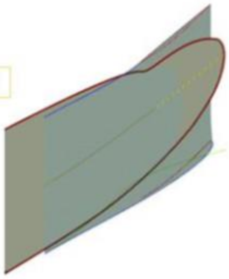
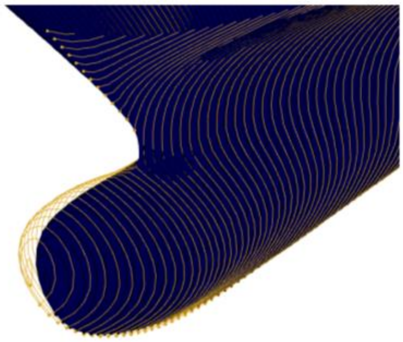
- Initial Geometry in STL format

- Apply Surface delta-shift with 5 design variables







GL RANKINE SOLVER

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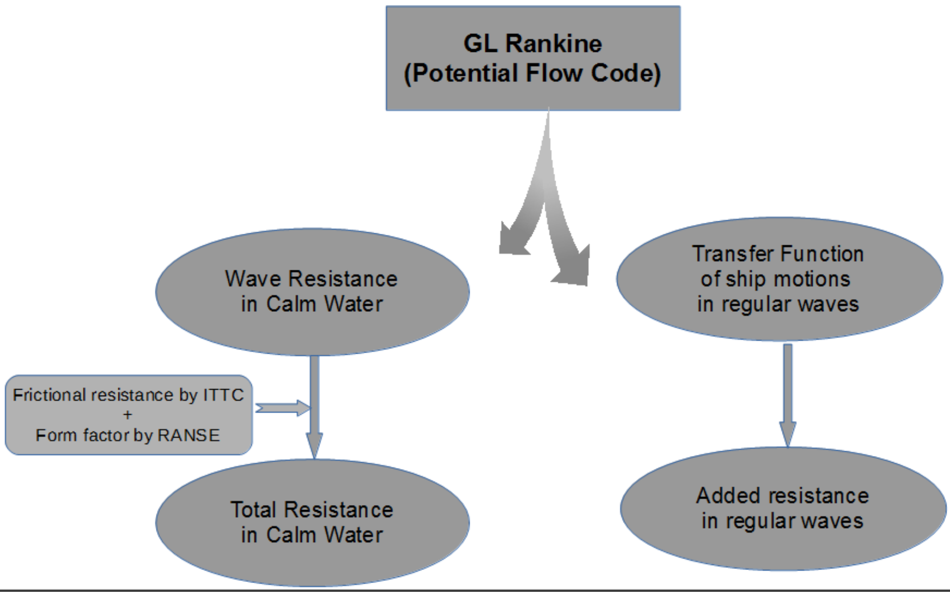
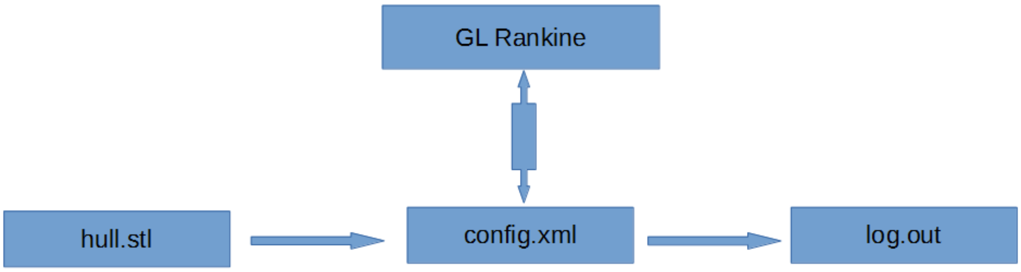


USE OF GL RANKINE



Geometry of hull in STL format

All commands for computations

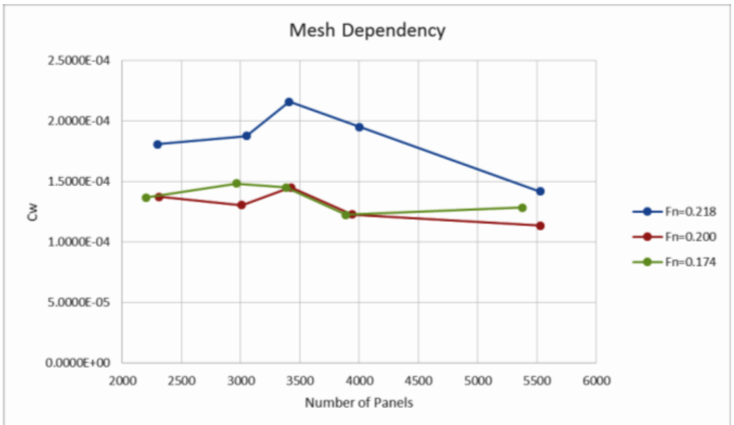
- Panel grid generation (unstructured)
- Free Surface grid generation (structured)

Result file from GL Rankine

- Total Resistance in Calm Water
- Added Resistance in waves

MESH CONVERGENCE STUDY

Before starting optimization processes, mesh convergence study was carried out by changing different mesh parameters for hull panel generation.



Final Mesh Chosen:

Laft, Lbow **= 0.7%of LPP**

= 2.5 m

Lmid **= 1% of LPP**

= 4 m

VALIDATION WITH EXPERIMENTAL DATA

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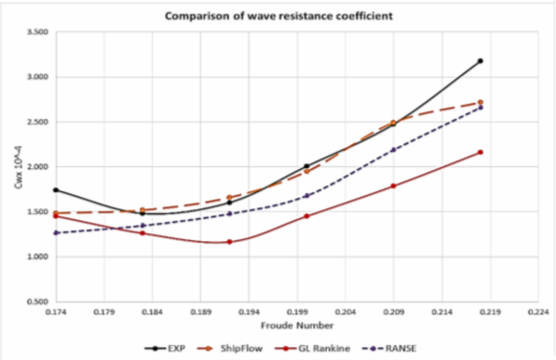
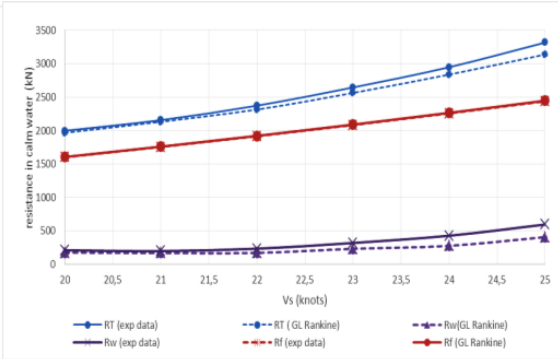
- **Comparison of resistance in calm water**





Form factor =k = 0.117

(obtained from University of Duisburg)

VALIDATION WITH EXPERIMENTAL DATA

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- **Comparison of added resistance coefficient**

Input (config.xml) → **Transfer function (GL Rankine)** → **Output (log.out)**

- Ship hull information
- Result of calm water conditions
- Range of wave frequencies and directions

- Motions and responses in waves
- Average drift forces and moments

VALIDATION WITH EXPERIMENTAL DATA

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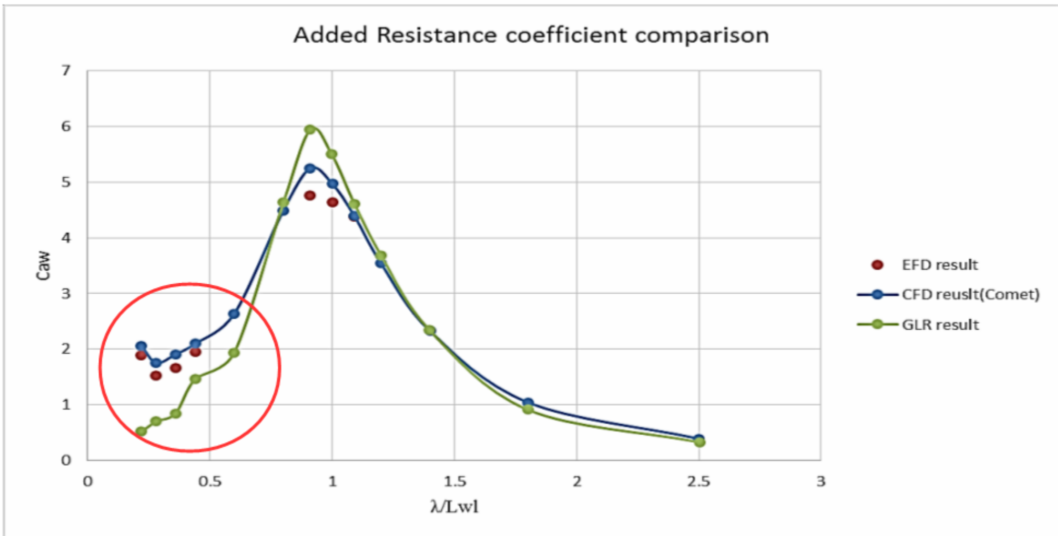
- **Comparison of added resistance coefficient**



OPTIMIZATION PROCESS

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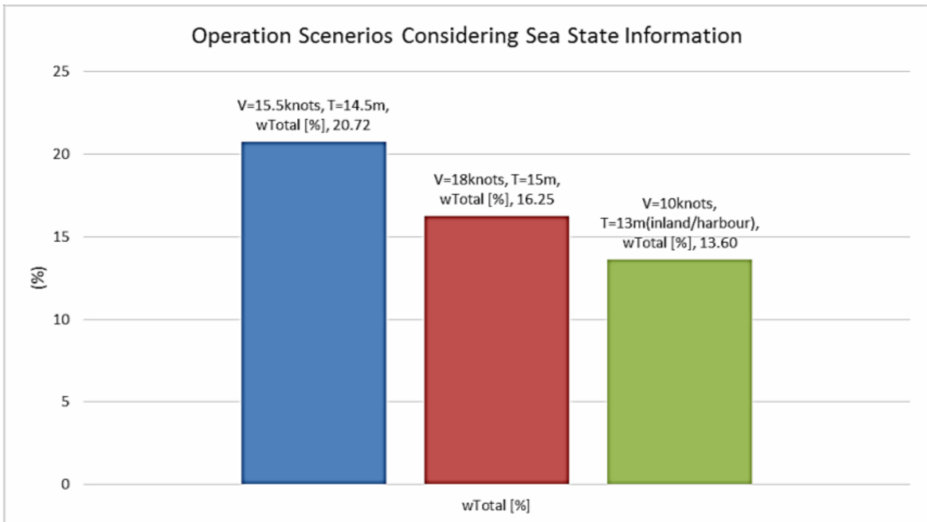
Case Study



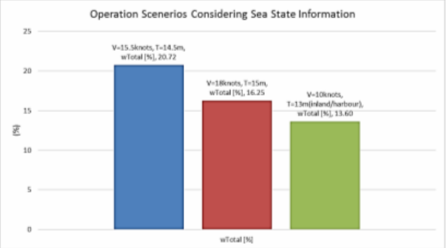
OPTIMIZATION PROCESS

Case Study

For Optimization,

- V_1 = 15.5 knots
- V_2 = 18.0 knots

at the design draft of T=14.5m are to be used.



Optimization processes

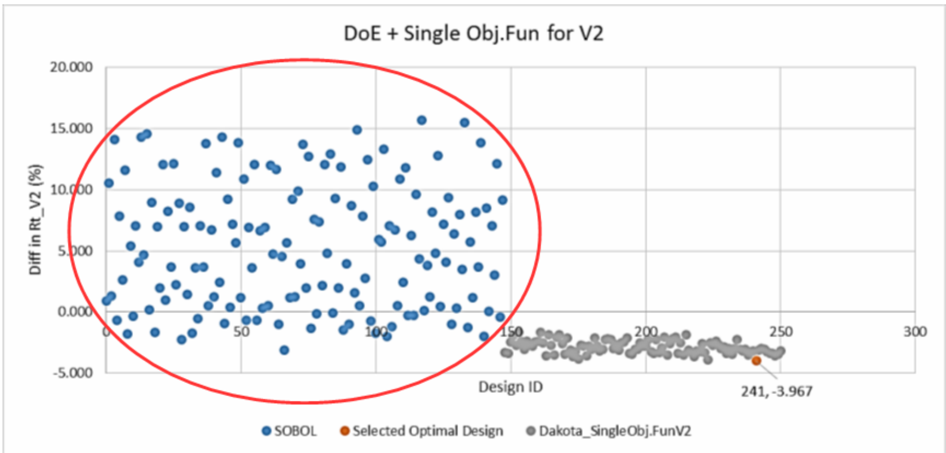
- Single objective optimization for each operation condition
- Single objective optimization with weighted functions
- Multi-objective optimization

More than 1000 CFD runs

OPTIMIZATION PROCESS

How the single objective optimization was performed?

DoE



OPTIMIZATION PROCESS

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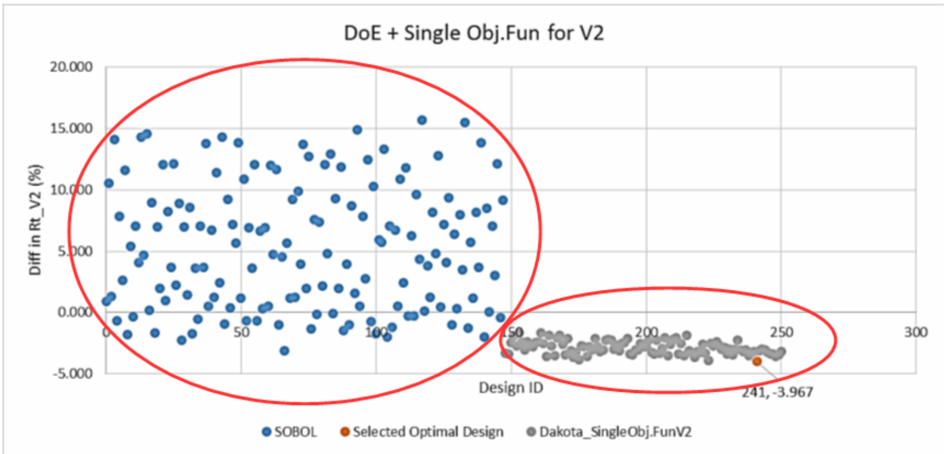
How the single objective optimization was performed?

DoE + Dakota Surrogate Based local optimization



OPTIMIZATION PROCESS

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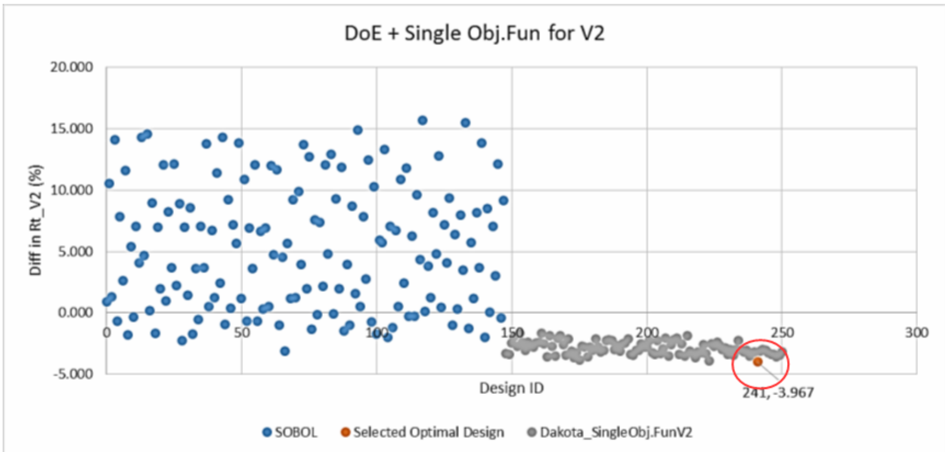
How the single objective optimization was performed?

DoE + Dakota Surrogate Based local optimization → Optimal Design



OPTIMIZATION PROCESS

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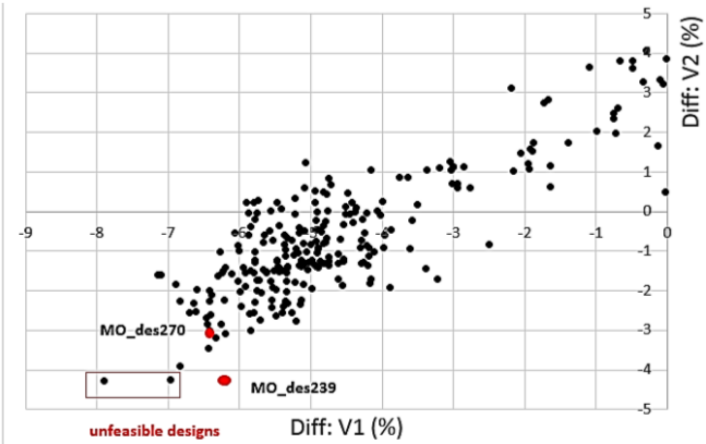
How the multi-objective optimization was performed?

Dakota Surrogate Based global optimization → **Optimal Design**



OPTIMIZATION PROCESS

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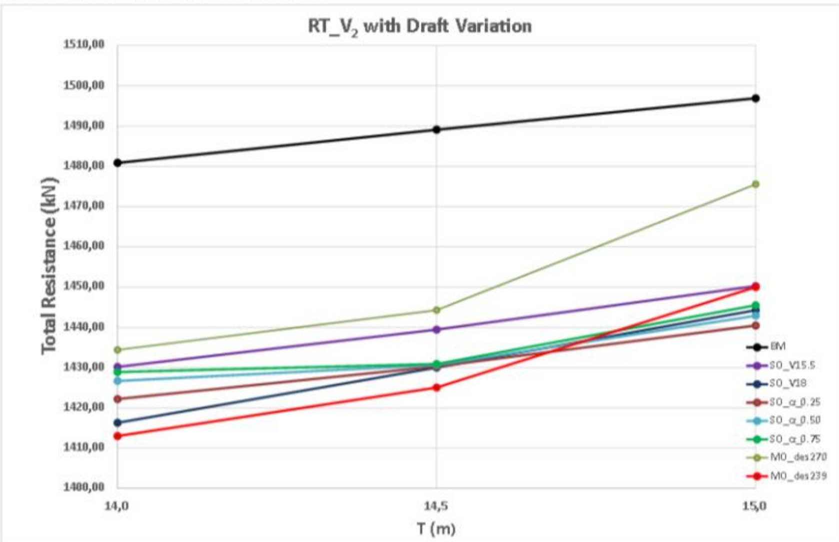
- Sensitivity analysis with draft variation



OPTIMIZATION PROCESS

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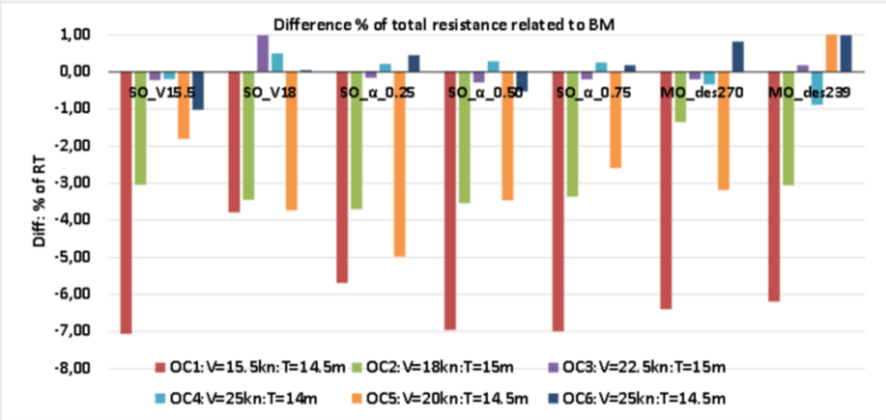
- Sensitivity analysis with draft variation
- Analysis at different operation conditions



OPTIMIZATION PROCESS

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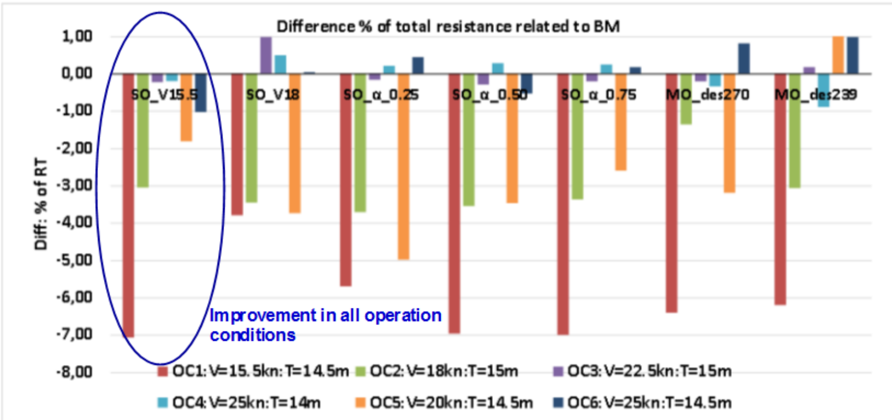

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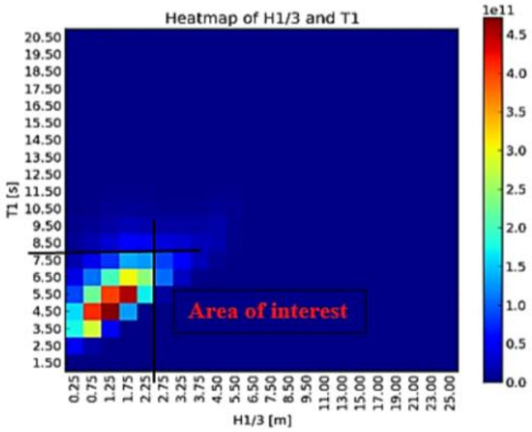
Analysis for Added Wave Resistance

$$R_{AW} = 2 \times \int_0^{\infty} \frac{R_{wave}(\omega, Vs)}{\zeta_A^2} \quad S_f(\omega)\, d\omega$$

$R_{wave}(\omega, Vs) / \zeta_A^2$ = quadratic transfer function of the mean longitudinal drift force obtained from GL Rankine

$S_F(\omega)$ = frequency spectrum, for ocean waves modified Pierson-Moskowitz type



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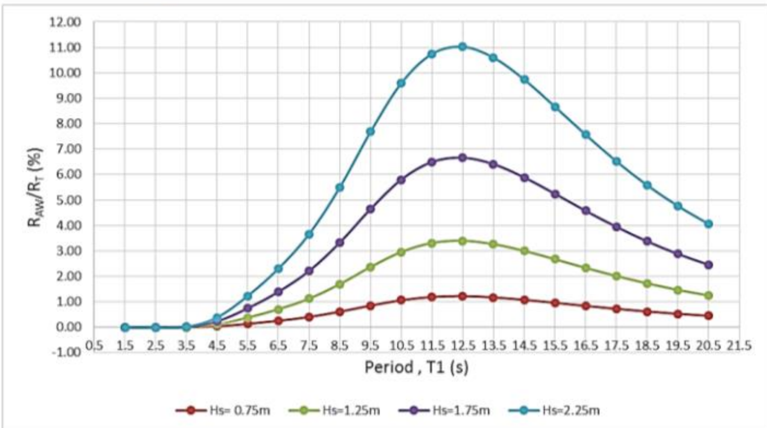
Analysis for Added Wave Resistance

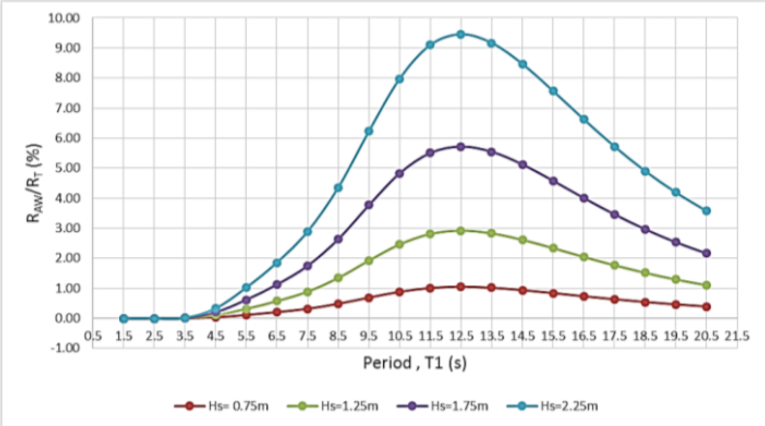
The result of added wave resistance due to head waves for the initial model can be seen for different wave periods and significant wave heights.



Added wave resistance due to head waves (V = 15.5 knots ,T=14.5m)

Analysis for Added Wave Resistance

The result of added wave resistance due to head waves for the initial model can be seen for different wave periods and significant wave heights.



Added wave resistance due to head waves (V = 18 knots ,T=14.5m)

Analysis for Added Wave Resistance

Comparison of Optimal Model with base model

- each calm water combination is added its most frequent sea state, which has the advantage of not increasing the number of combinations of optimization process.

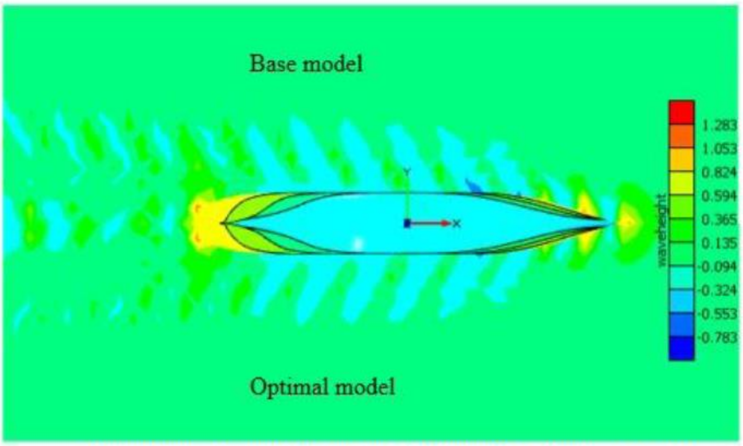
- Wave scenario data for two operation conditions

Operation Condition	Speed , Vs	Draft , T	Peak Period, T_p	Significant Wave Height, H1/3
(-)	(knots)	(m)	(sec)	(m)
OC1	15.5	14.5	12.5	1.25
OC2	18	15.0	12.5	1.75

Analysis of Optimal Model

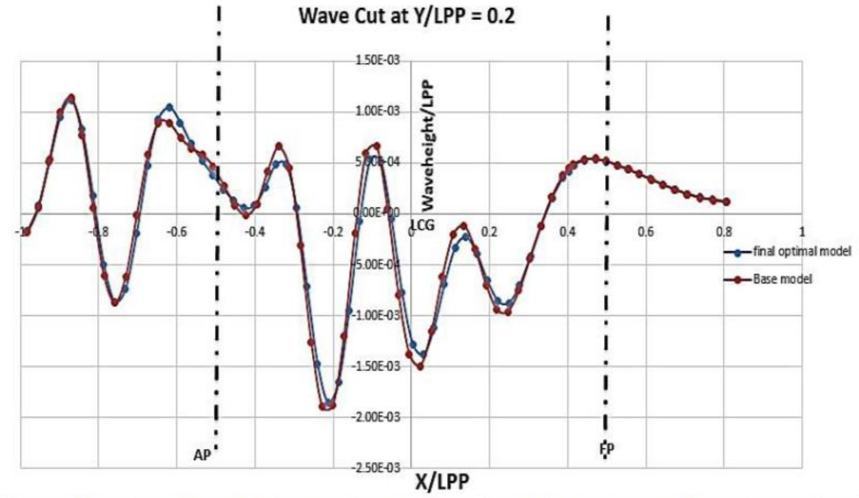
		Calm Water Resistance	Added Wave Resistance	Total Resistance
Designs		[kN]	[kN]	[kN]
BM	15.5 knots	1190	40.5	1230.5
	18 knots	1489	87	1576
SO_V15.5	15.5 knots	1106	39.4	1145.4
	Diff. from BM	-7.06%	-2.72%	-6.92%
	18 knots	1439	87.5	1526.5
	Diff. from BM	-3.36%	0.575%	-3.14%

Analysis of Optimal Model



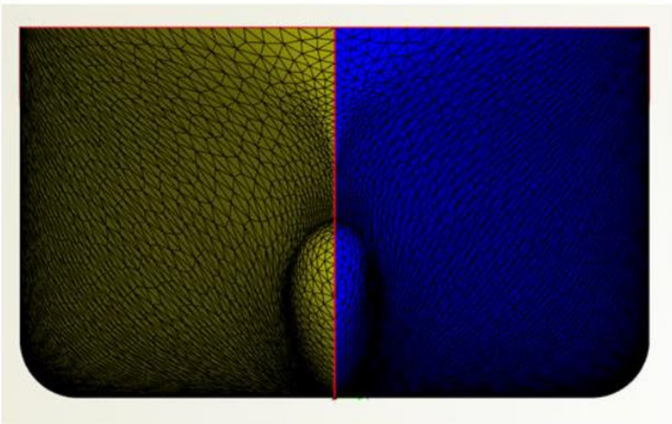
Wave pattern of the optimal and base hull form (V=15.5knots, T=14.5m)

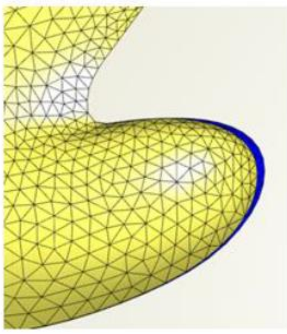
Analysis of Optimal Model



Wave Cut at Y/LPP=0.2 for Base and Optimum model (V=15.5knots, T=14.5m)

Analysis of Optimal Model





Base model and final optimal model comparison

CONCLUSION

- Parametric modeling and choice of design variables
- Coupling of GL Rankine in-house solver with CAESES software
- Different optimization approaches with CAESES/Dakota toolkit and check of sensitivity