Use of CFD techniques to improve the energetic efficiency of a hull form with particular reference to bulbous bows

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"EMSHIP"

Erasmus Mundus Master Course

in "Integrated Advanced Ship Design"

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Introduction:

- Simulation of ship resistance in calm water of a super motor Yacht.
- Optimization of bulbous bow using KRACHT theory.
- Ship resistance simulation of the initial and the modify bulbs in order to define the optimum Hull form.

- Outline:

❶ Ship resistance and its components.

❖ Viscous and pressure resistances.

❷ Bulbous Bow design

❖ KRACHT theory.

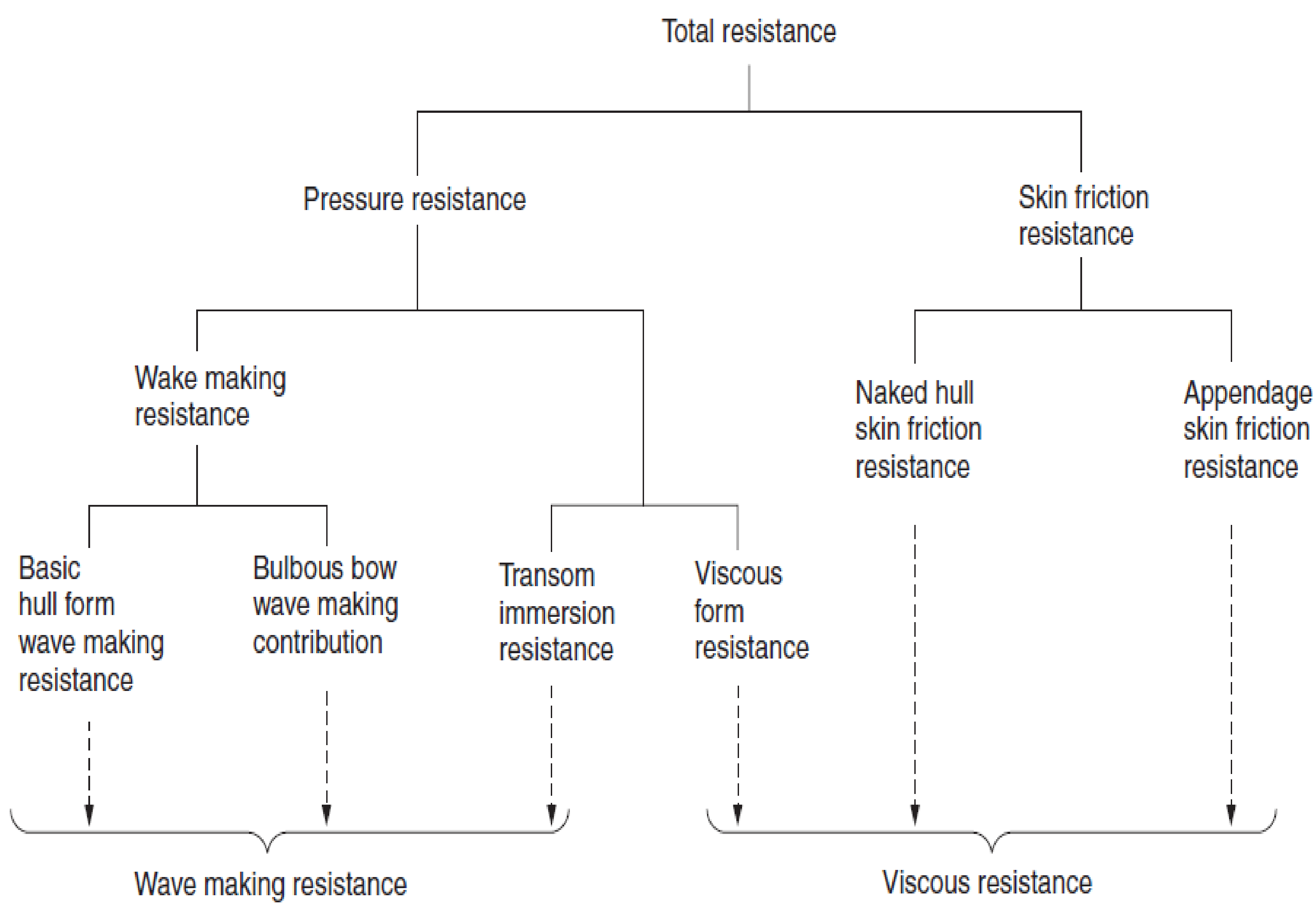
❸ Simulation of ship resistance and optimization of bulbous bow.

❖ Simulation of ship resistance using STARCCM+.

❹ Comparison between the initial and optimal hull form.

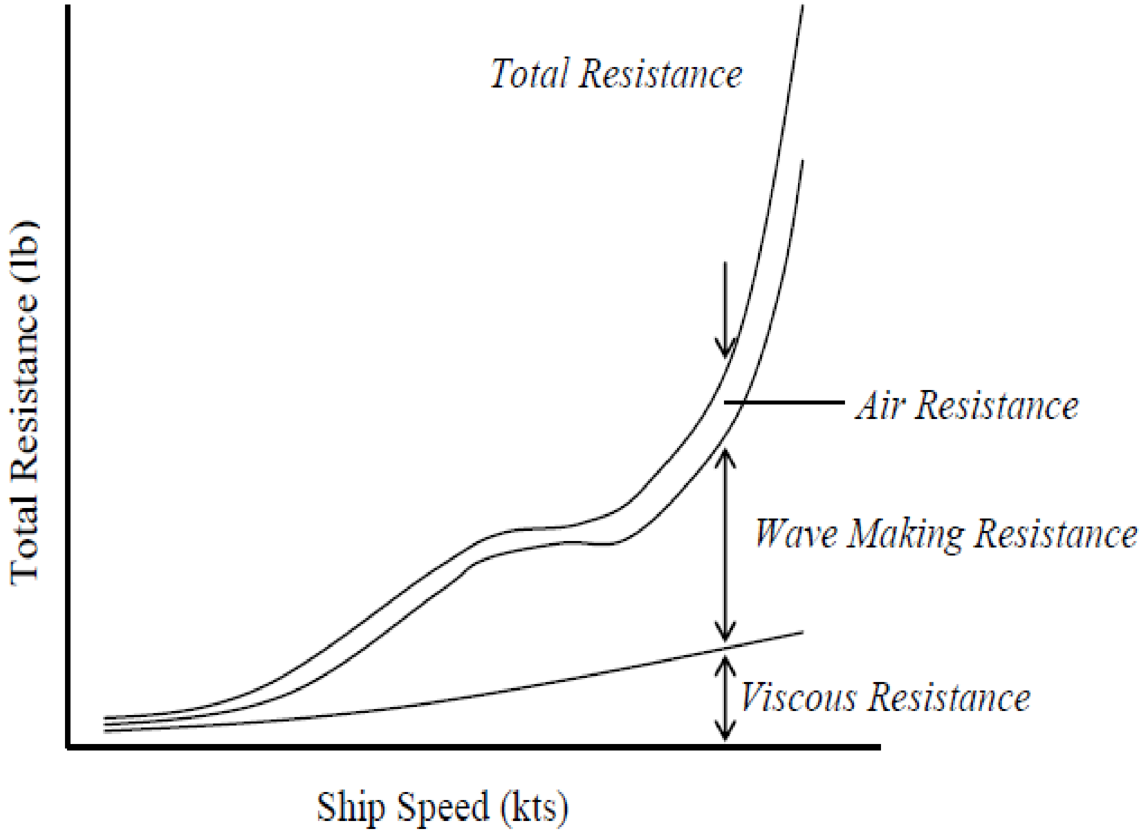
1 Ship resistance and its components:

- The components of ship resistance for a ship moves through calm water are:



- There are also others resistances as the air resistance and added resistance due to rough weather.

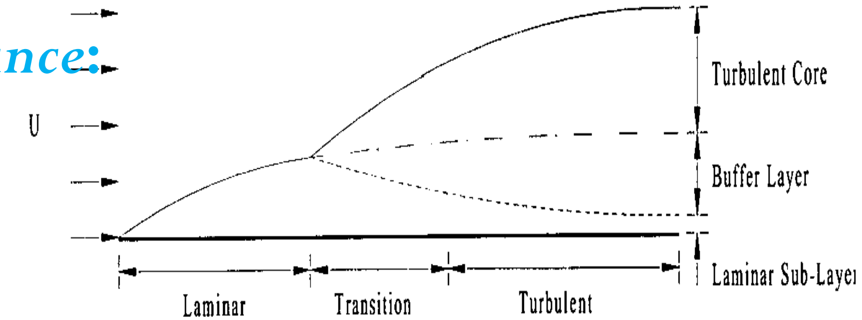
The magnitude of each component of resistance varies with ship speed is shown in figure below:



Components of Hull Resistance.

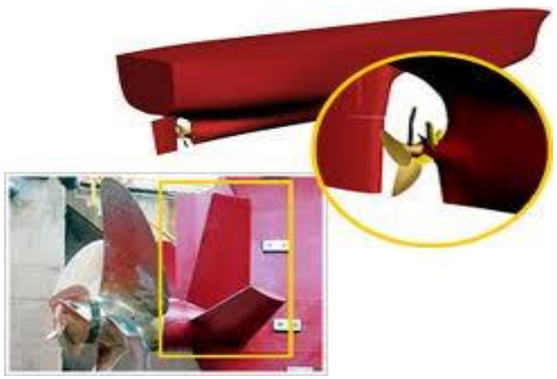
❖ Naked hull skin friction resistance:

$$C_F = \frac{0.075}{(\log_{10} Rn - 2.0)^2}$$

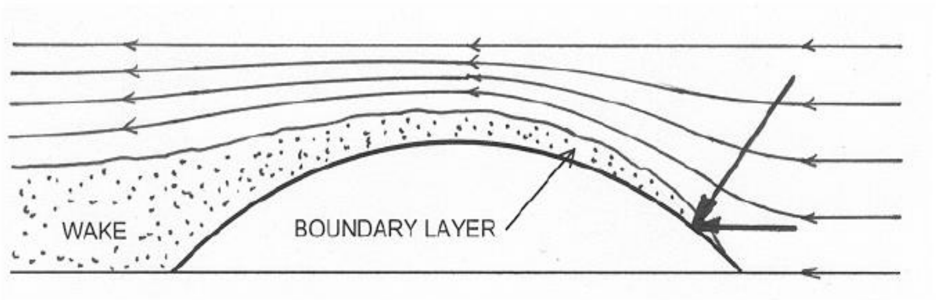


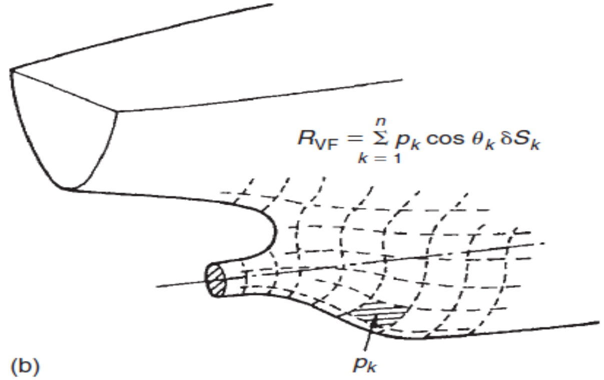
❖ Appendage skin friction:

$$\boldsymbol{R_{APP} = R_{APP(F)} + R_{APP(w)}}$$



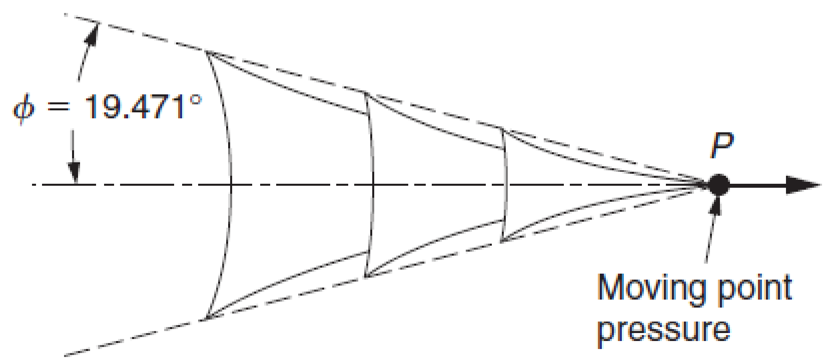
❖ Viscous form resistance:



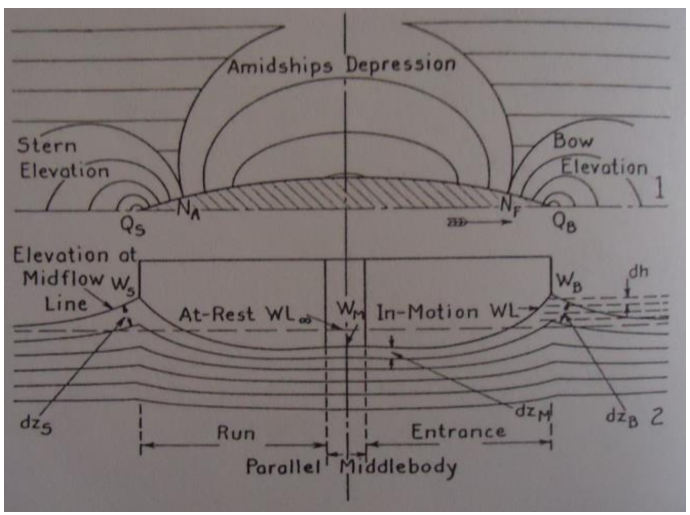


❖ Wave making resistance R_W

- It's consider that a moving ship in 2-dimensional form, the liquid surface around the ship is accompanied by pressures changed along the length of the ship.



Wave pattern induced by a moving-point pressure in calm water.

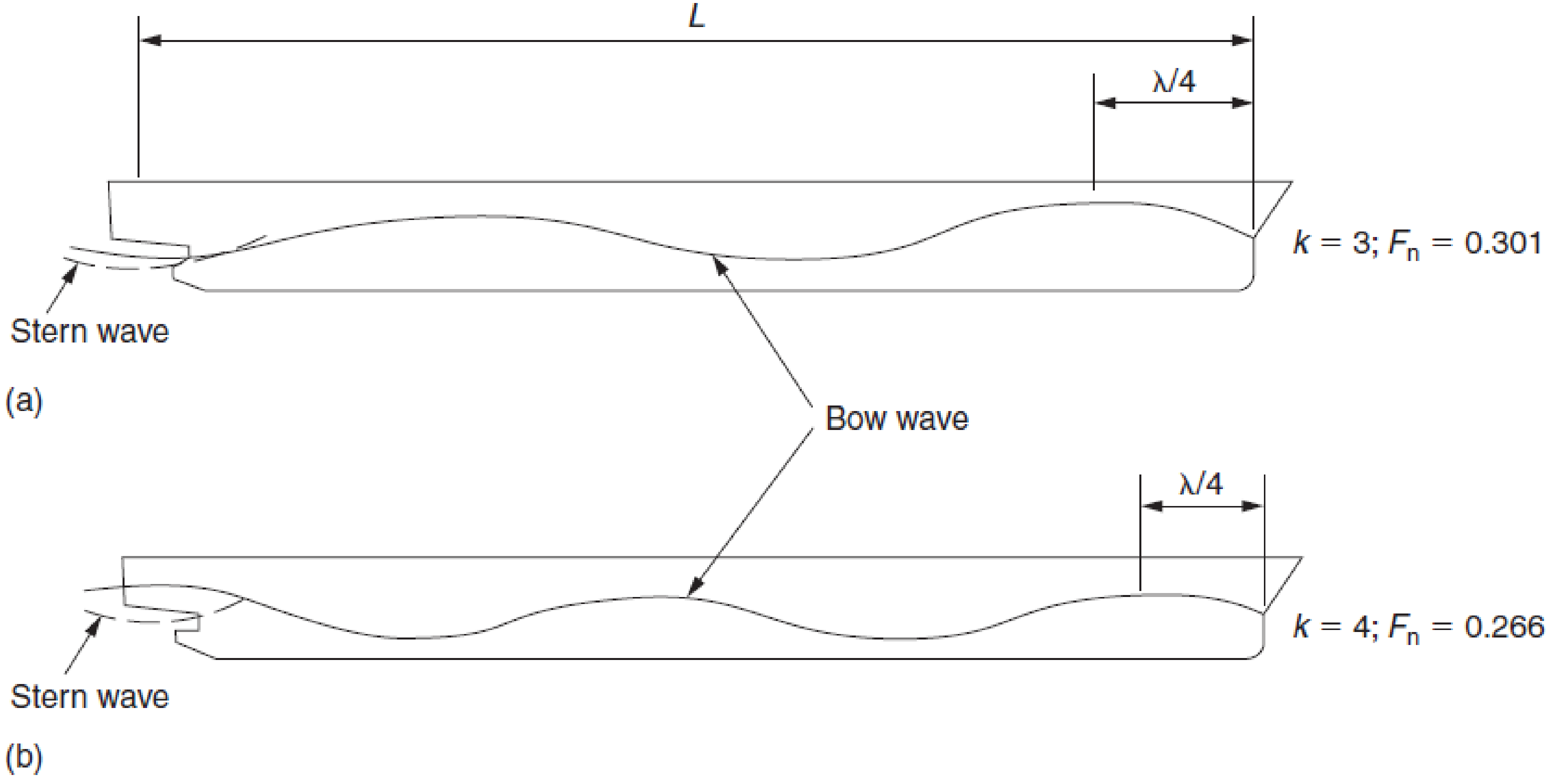


Bernoulli contour system around a simple ship form

- Since that the interference between the divergent and transverse systems gives waves their characteristic shape. And due to the same velocity of the systems and ship, the wave length λ between successive crests is:

$$\lambda = \frac{2\pi}{g}V^2$$

❑ Interference characteristics:



(a) Wave reinforcement at stern

$$L - \frac{\lambda}{4} = k\frac{\lambda}{2} \quad \begin{cases} where\ k = 1,3,5\ldots,(2j+1) \\ with\ j = 0,1,2,3 \end{cases}$$

Form which $\frac{4}{2k+1} = \frac{\lambda}{L} = \frac{2\pi V^2}{gL} = 2\pi(Fn)^2$

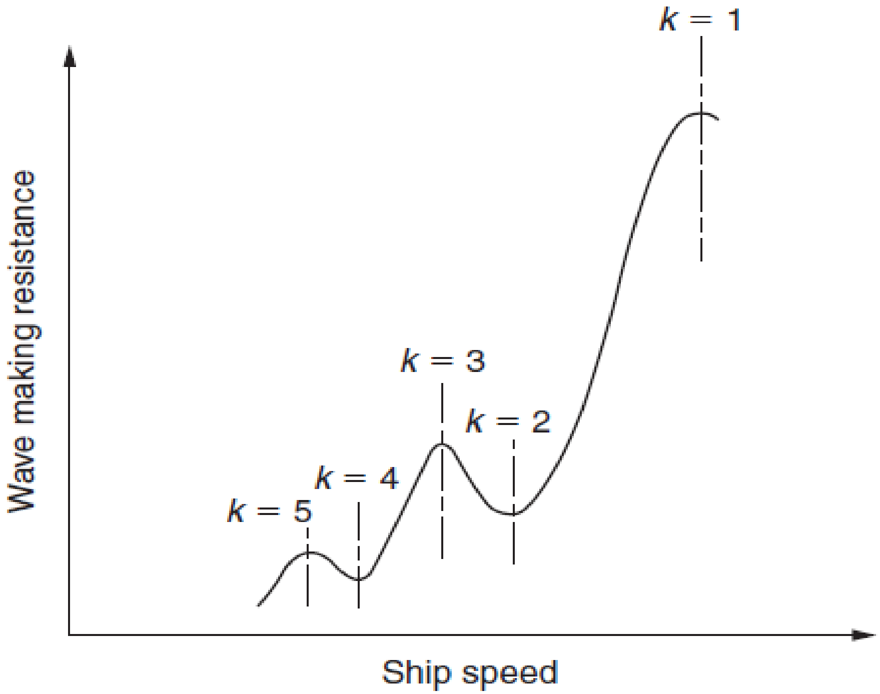
$$F_n = \sqrt{\frac{2}{\pi(2k+1)}}$$

(b) Wave cancellation at stern.

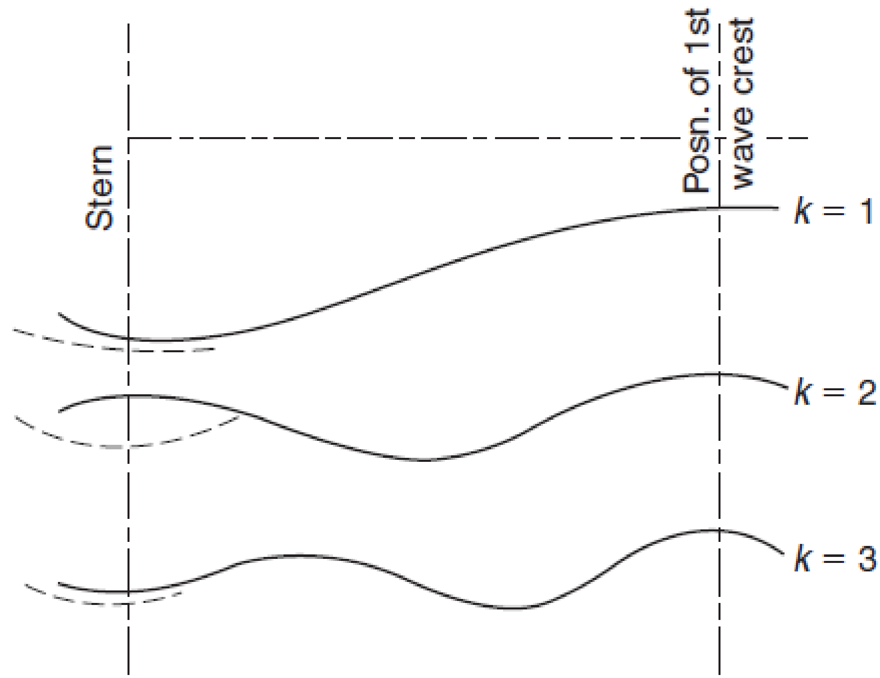
$$L - \frac{\lambda}{4} = k\frac{\lambda}{2} \quad \begin{cases} where\ k = 2,4,6\ldots,2j \\ with\ j = 0,1,2,3 \end{cases}$$

Hence:

$$F_n = \sqrt{\frac{2}{\pi(2k+1)}}$$

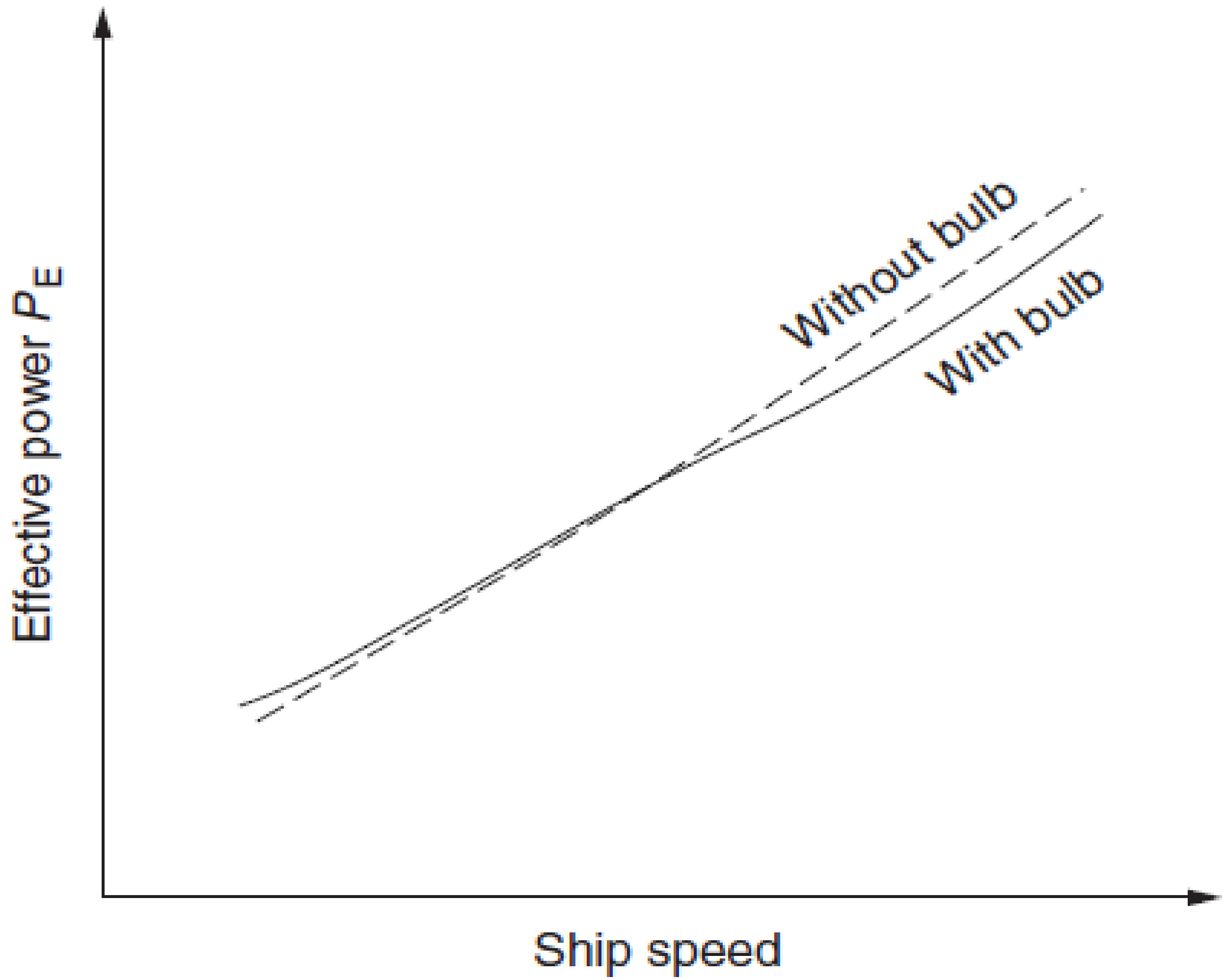


Wave making resistance as function of speed.



Form of wave making resistance curve* associated with the various values of *k.

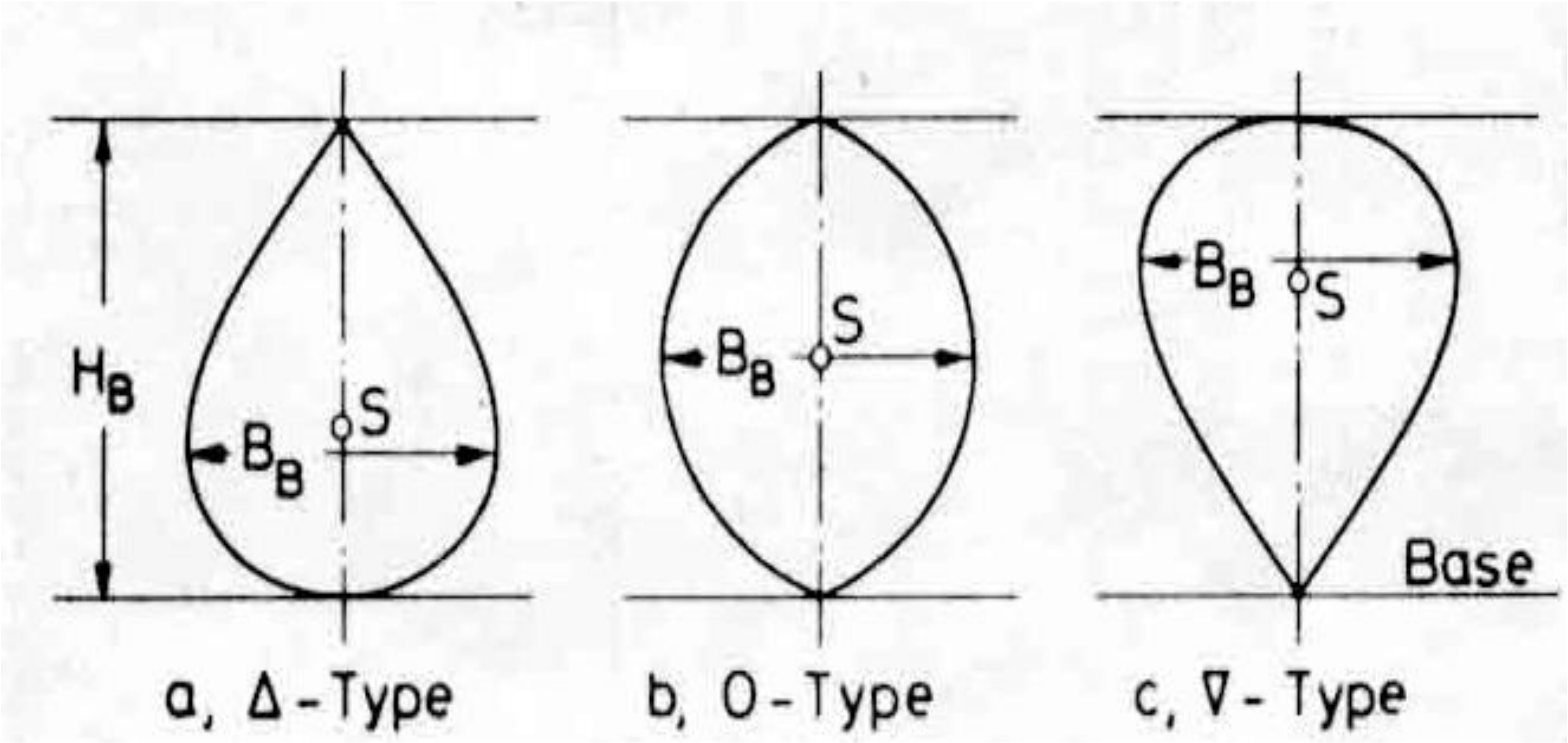
❖ *The contribution of the bulbous bow:*



Influence of a bulbous bow of the effective power requirement

❷ Design of Bulbous bow:

❖ Bulb forms



Bulb types.

❖ Bulb parameters:

- Linear bulb parameters:

The breadth parameter

$$C_{BB} = B_B / B_{MS}$$

The length parameter

$$C_{LPR} = L_{PR} / L_{PP}$$

The depth parameter

$$C_{ZB} = Z_B / T_{FP}$$

- Nonlinear bulb parameters

The cross section parameter:

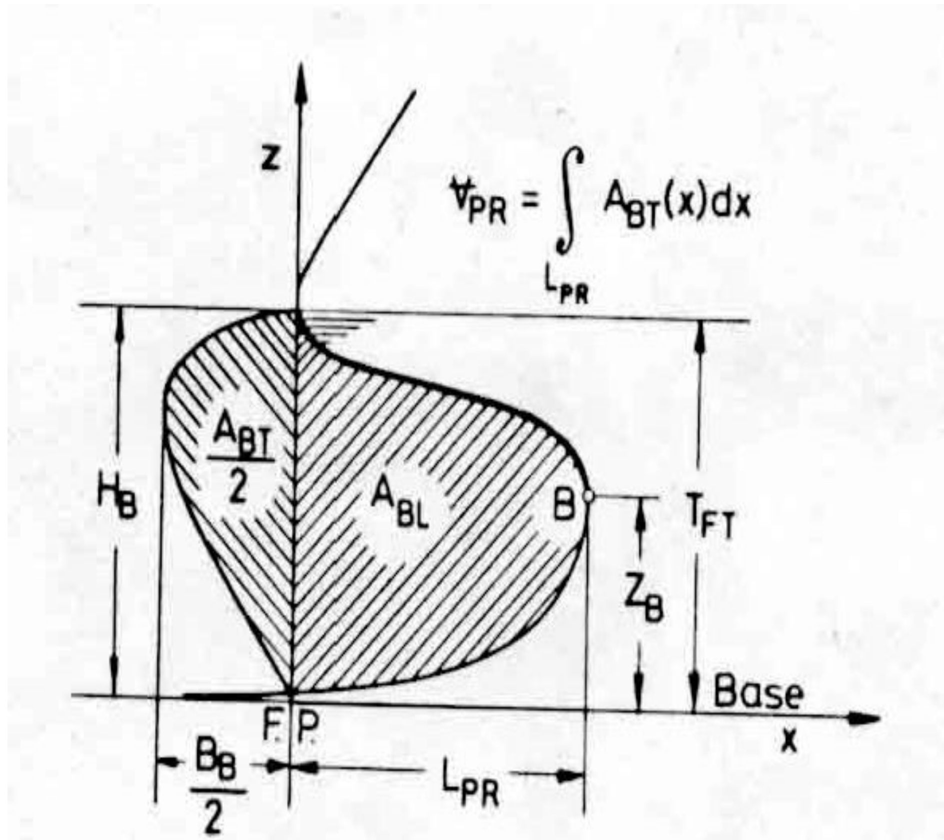
$$C_{ABT} = A_{BT} / A_{MS}$$

The lateral parameter:

$$C_{ABL} = A_{BL} / A_{MS}$$

The volumetric parameter:

$$C_{VPR} = V_{PR} / V_{WL}$$



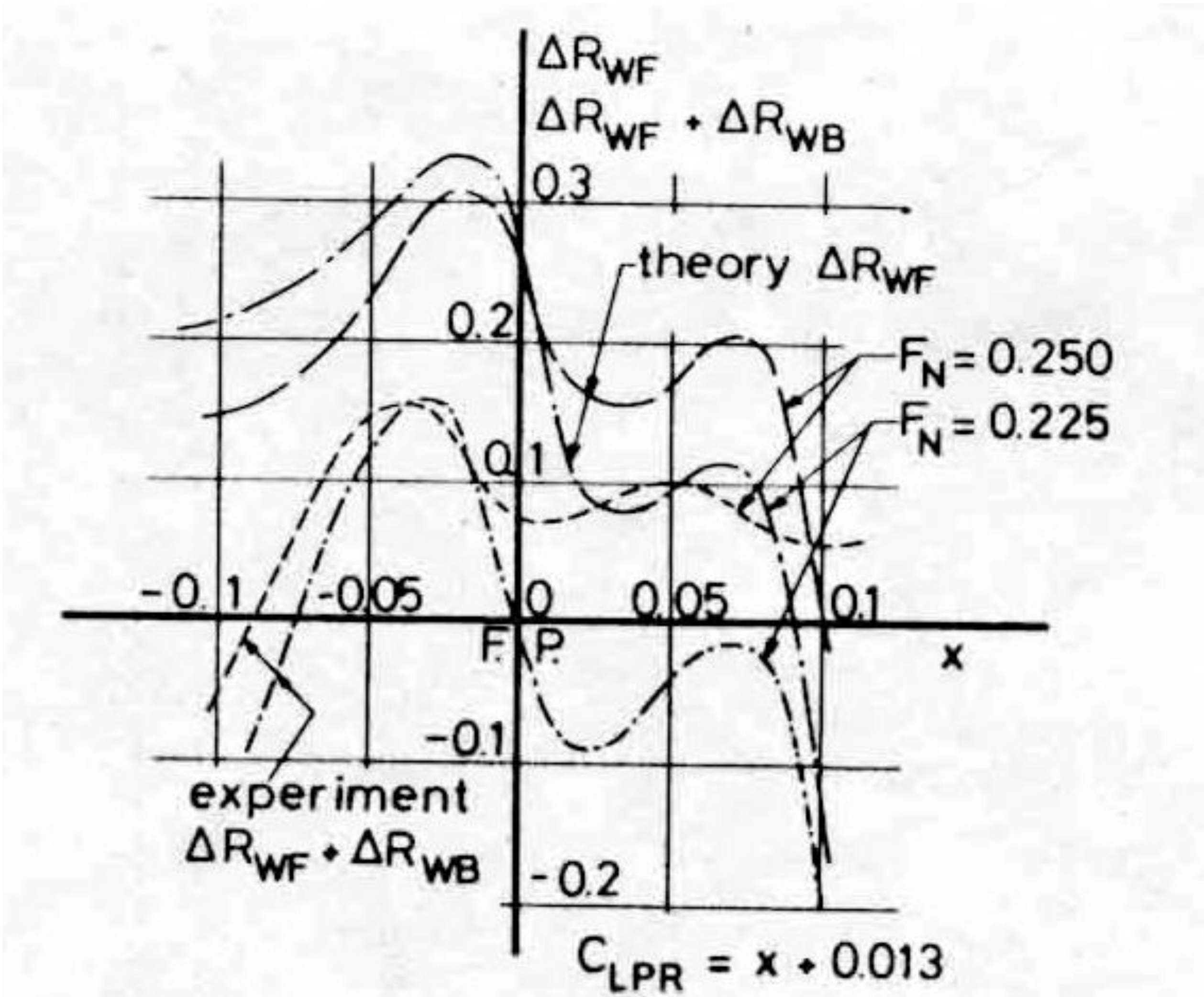
Linear and nonlinear bulb quantities

❖ Influence of bulb parameters on bulb effect:

- At constant Froude number F_N, the bulb effect is a function of all six bulb parameters:

$$\Delta R = f(C_{VPR}, C_{ABT}, C_{ABL}, C_{LPR}, C_{BB}, C_{ZB})$$

- $C_{VPR} = V_{PR} / V_{WL}$: has influence on the interference effect and the breaking effect, with increasing bulb volume, both affect increase up to a maximum with a subsequent decrease.
- $C_{ZB} = Z_B / T_{FP}$ has the interference effect, the interferential effect increases at first monotonically from zero to a maximum, decreases subsequently.
- $C_{LPR} = L_{PR} / L_{PP}$ has a great influence on the interference effect. With increasing C_{LPR}, this effect increases at first and after a maximum decreases monotonically to zero.



Dependence of interference and primary bulb effect on the length parameter $C_{LPR} = L_{PR}/L_{PP}$

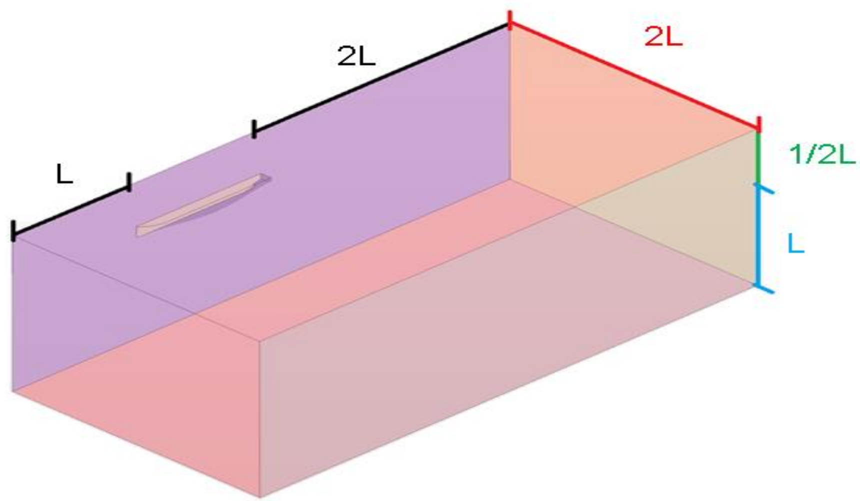
❸ Simulation of ship resistance and optimization of bulbous bow:

❖ *Discretization of computational domain:*

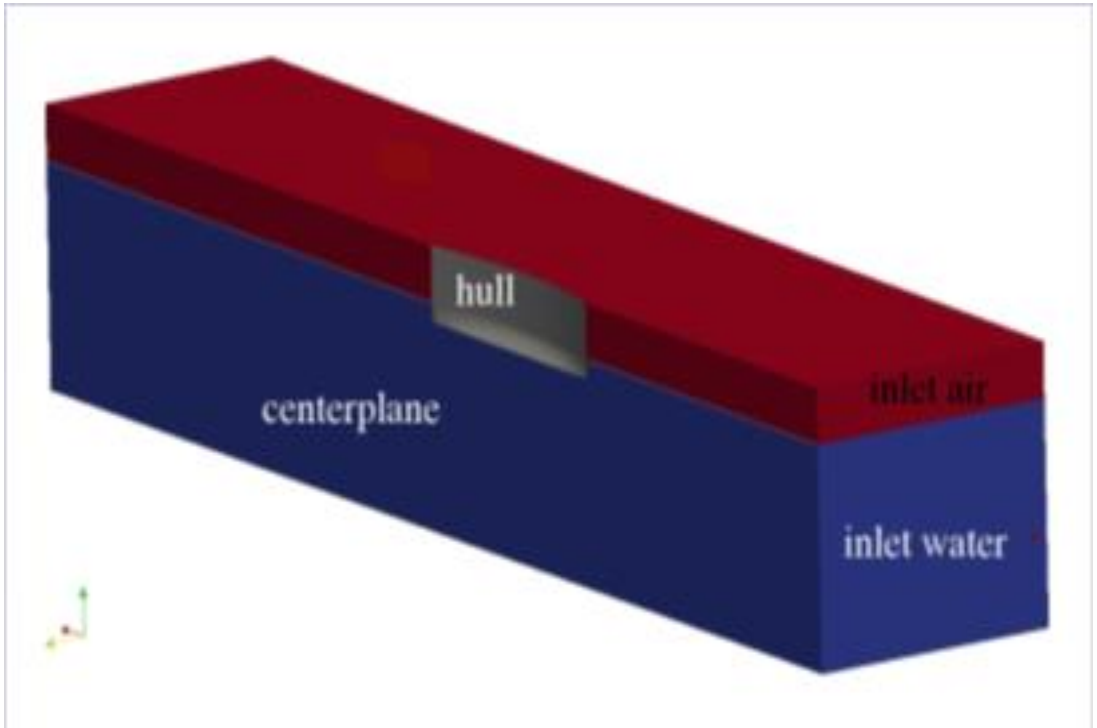
The length of the ship is considered the main factor to determine the size of far field domain, and due to the symmetry of the ship, it's possible to simulate only half of the field

	Ship
WL	41.53 m
LPP	41.40 m
Beam	8.52 m
Design Draught	2.707 m
Design Speed	14 knots
Displacement	450 t

Principle dimensions of the ship.



❖ Boundary conditions of computational domain:



- There are three boundaries:

✓ The first one is the velocity inlet.

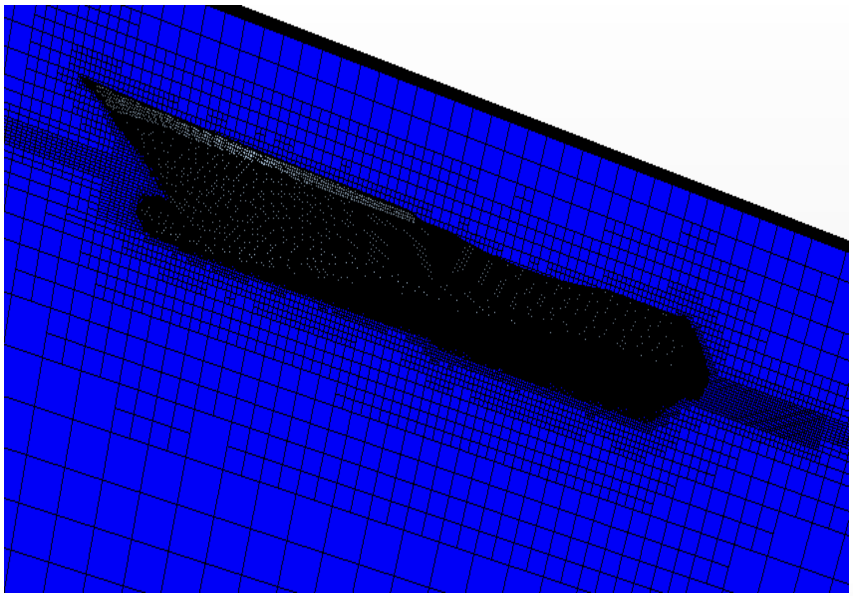
✓ The second boundary is pressure outlet.

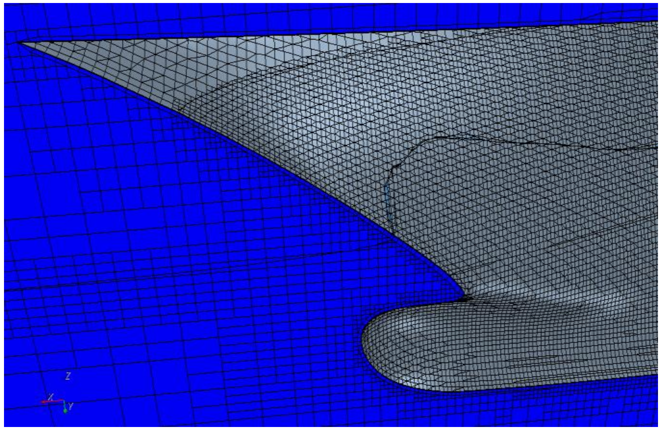
✓ The third boundary is the Symmetry plan.

❖ Grid generation:

- The grid of the domain is divided to three parts:

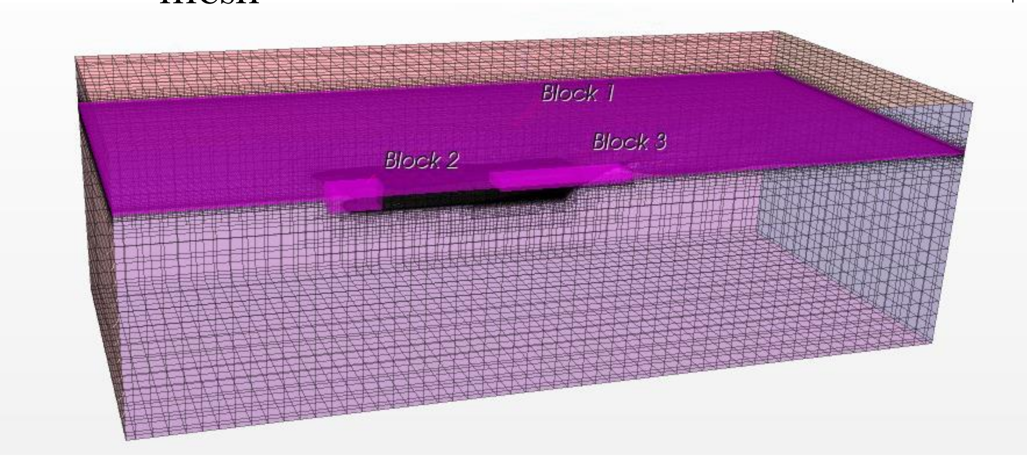
The first one is the prism layer which is generated on the wall.



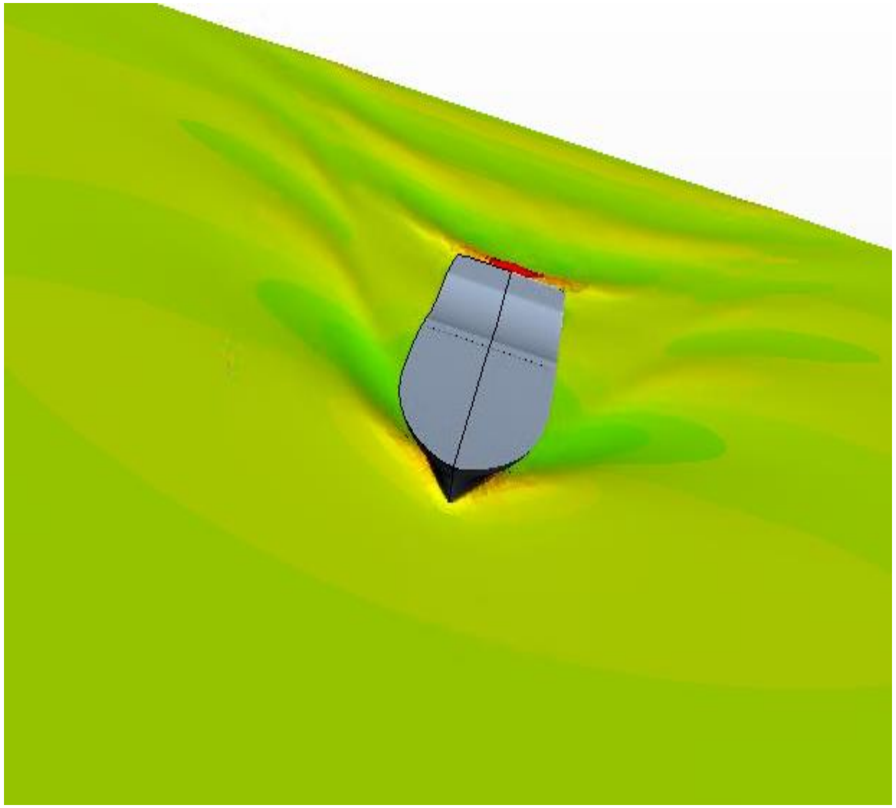


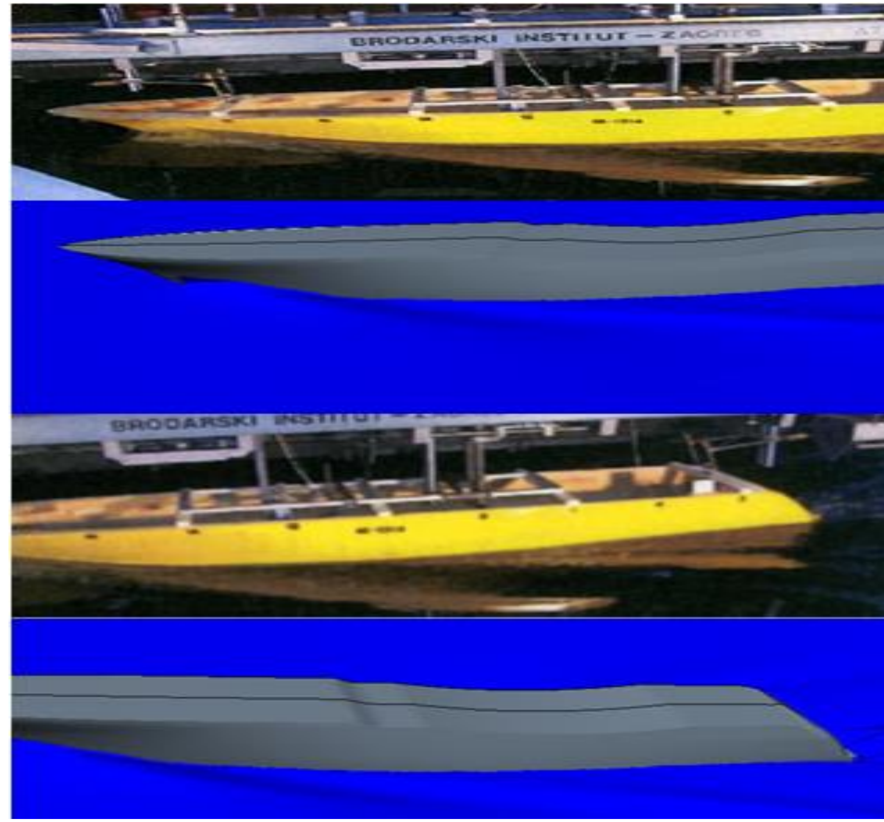
- Third part is the independents mesh which are the blocks (volume control) added on the hard (critical) part of the domain in order to get more refined mesh

- The second part of the mesh domain is Cartesian grid, where the mesh is very fine near to the wall and starts to increase as the distance from the free surface increase



❖ Comparison between experimental and numerical results:

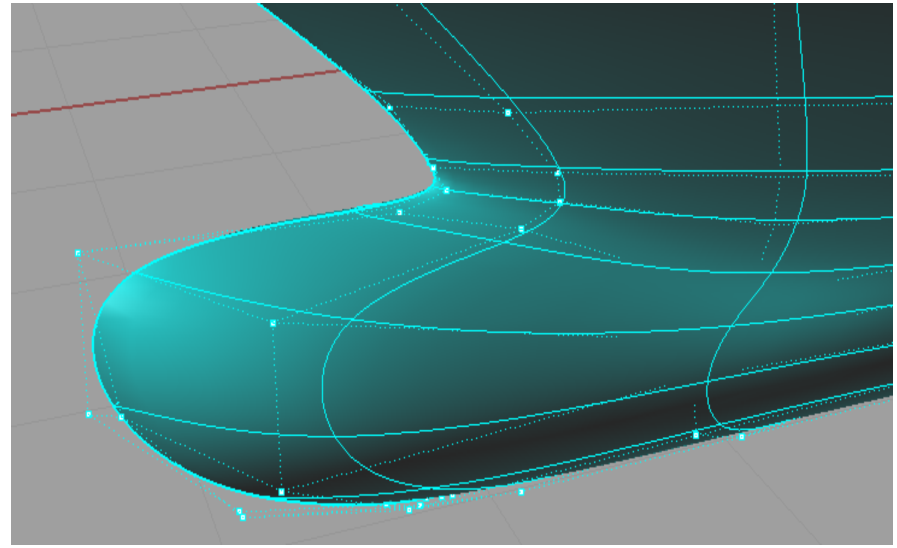




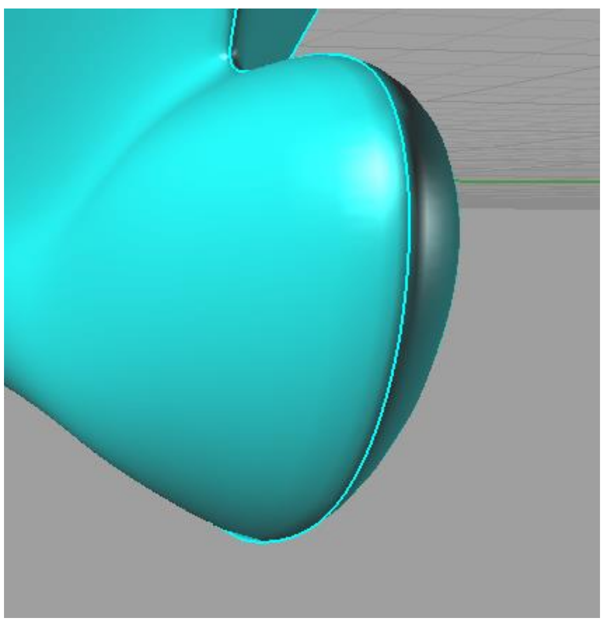
V (kn)	Numerical simulation(KN)	Experimental test(KN)	Deference
14	65.50	63.9	2.5%

- The comparison between the experimental and numerical results is only for one velocity of the ship which is the cruising speed. The maximum deference required by the company is about of 5 %.

❖ Bulbous bow optimization:

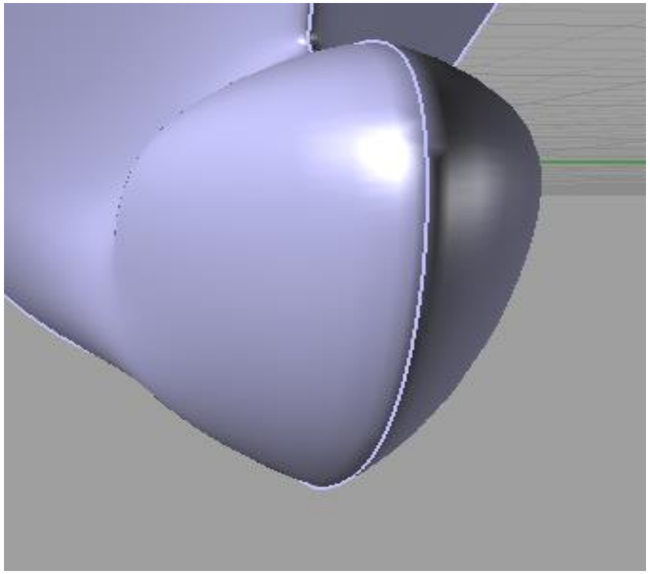


- The systematic method is used to optimize the bulb.
- The bulb geometry has been changed according to the KRACHT theory.
- Using the software Rhinoceros to modify the bulbous shape,.



Initial bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.034
C_{ZB}	0.53
C_{VPR}	0.0027

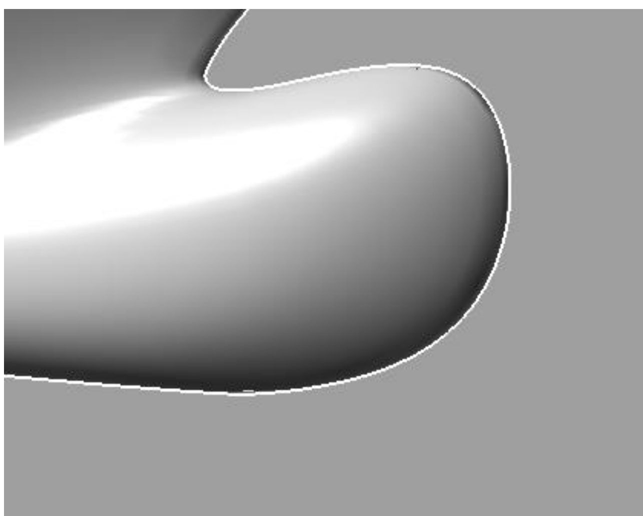
Initial bulb.



❑ *Bulb Transversal Section modification*

First bulb geometry coefficients	
C_{BB}	0.079
C_{LPR}	0.034
C_{ZB}	0.53
C_{VPR}	0.003

V (kn)	Initial bulb resistance(KN)	Section bulb modification (KN)	Deference
14	65.50	65.73	0.4%

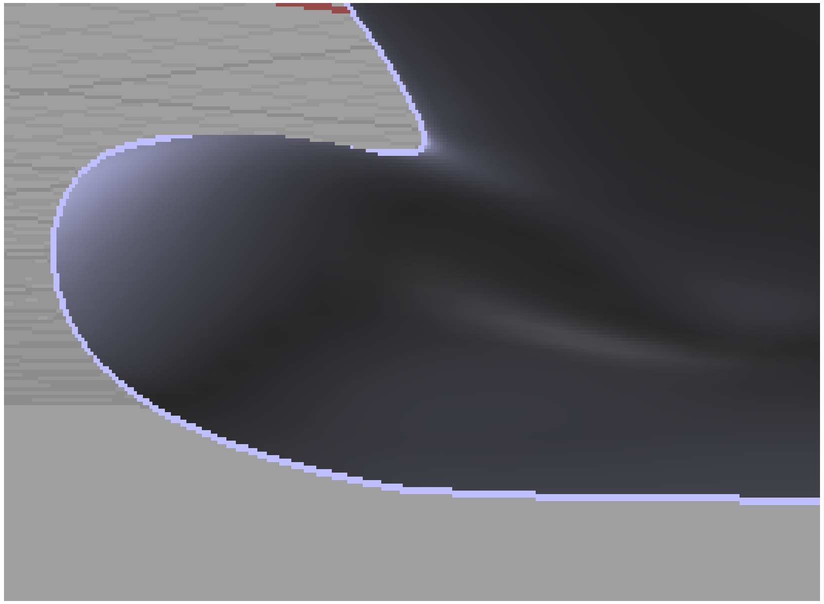


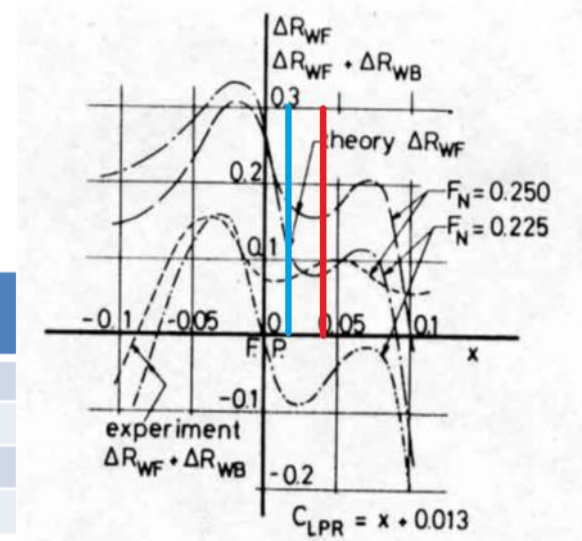
❑ *Bulb Depth parameter modification*

Second bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.034
C_{ZB}	0.64
C_{VPR}	0.0029

V (kn)	Initial bulb resistance(KN)	Second bulb modification (KN)	Deference
14	65.50	67.74	2%

❑ *Bulb Length parameter modification :*

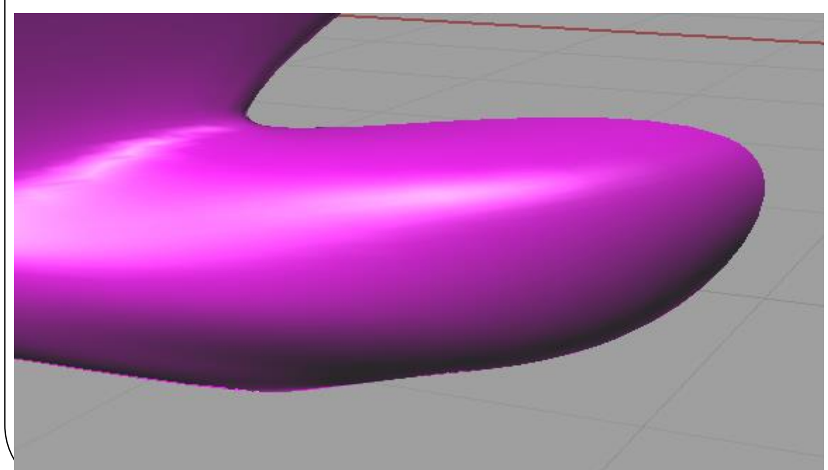




bulb geometry coefficients	
C_{BB}	0.65
C_{LPR}	0.055
C_{ZB}	0.64
C_{VPR}	0.0061

V (kn)	Initial bulb resistance(KN)	Third bulb modification (KN)	Deference
14	65.50	66.90	2.2%

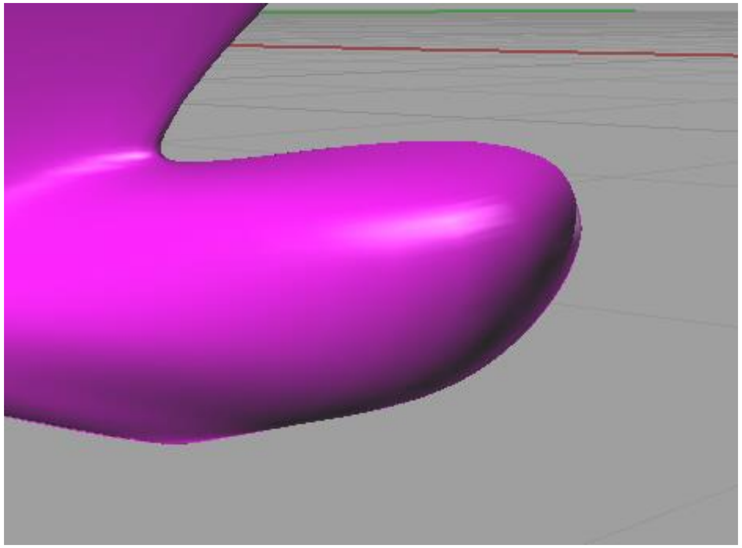
❑ *Bulb modification (Length coefficient Clrp =0.063 and Depth)*



bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.063
C_{ZB}	0.65
C_{VPR}	0.0068

V (kn)	Initial bulb resistance(KN)	Fifth bulb modification (KN)	Deference
14	65.5	66.61	1.7%

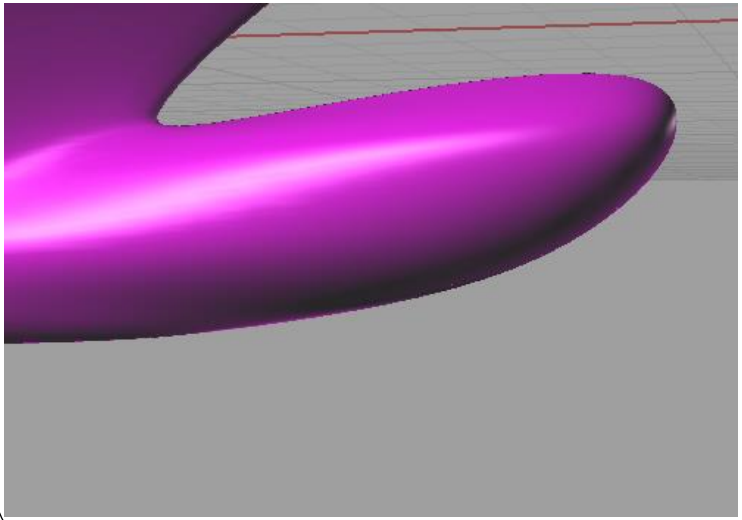
- ❑ ***Bulb Modification (Length Clrp =0.063 + Depth+ Volume):***



bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.063
C_{ZB}	0.65
C_{VPR}	0.0076

V (kn)	Initial bulb resistance(KN)	sixth bulb modification (KN)	Reduction
14	65.5	61.82	5.5 %

- ❑ ***Bulb Modification (Length Clpr=0.083 + Depth + Volume):***



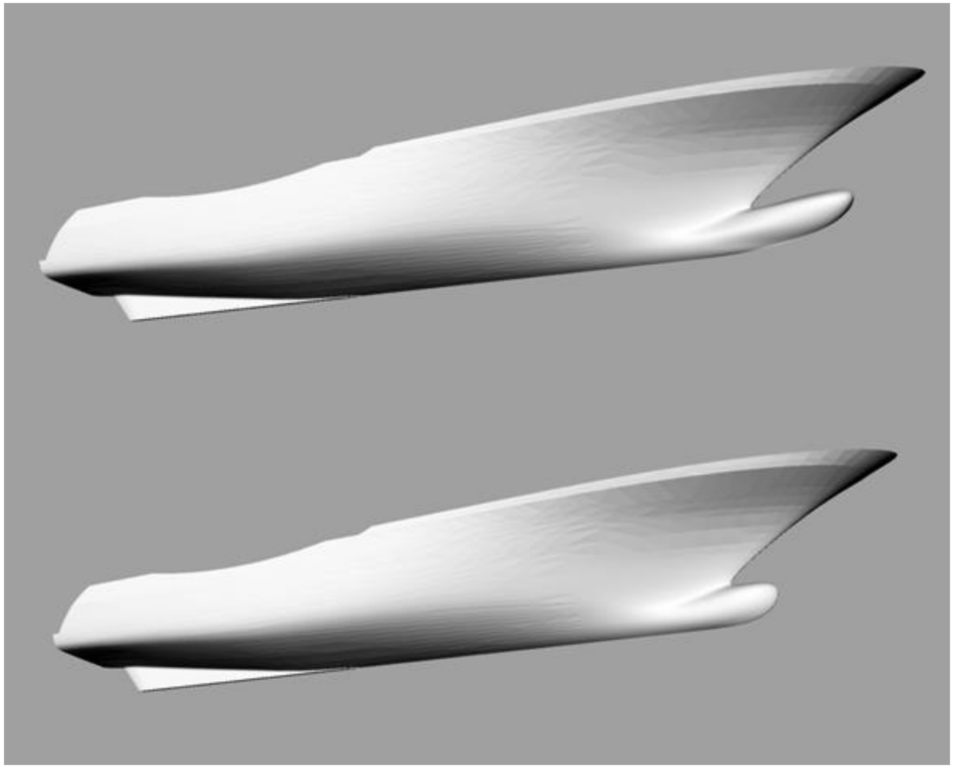
bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.063
C_{ZB}	0.70
C_{VPR}	0.012

V (kn)	Initial bulb resistance(KN)	seventh bulb modification (KN)	Reduction
14	65.5	61.74	5.7 %

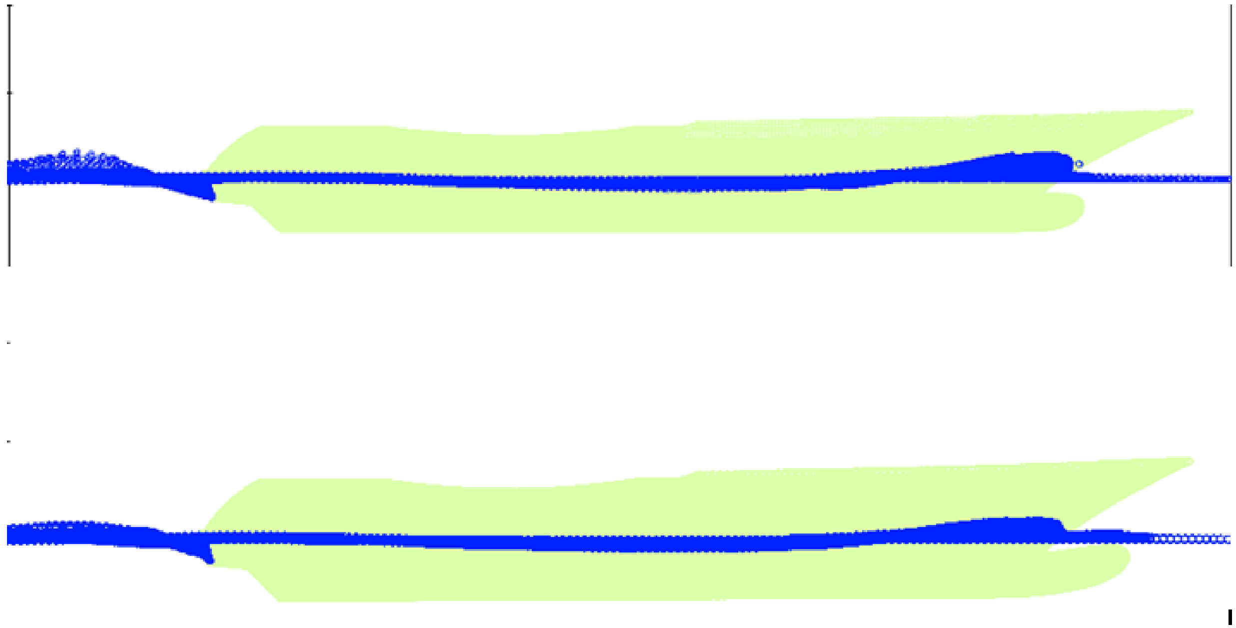
4 Comparison between the initial and optimal hull form.

Optimum bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.063
C_{ZB}	0.70
C_{VPR}	0.012

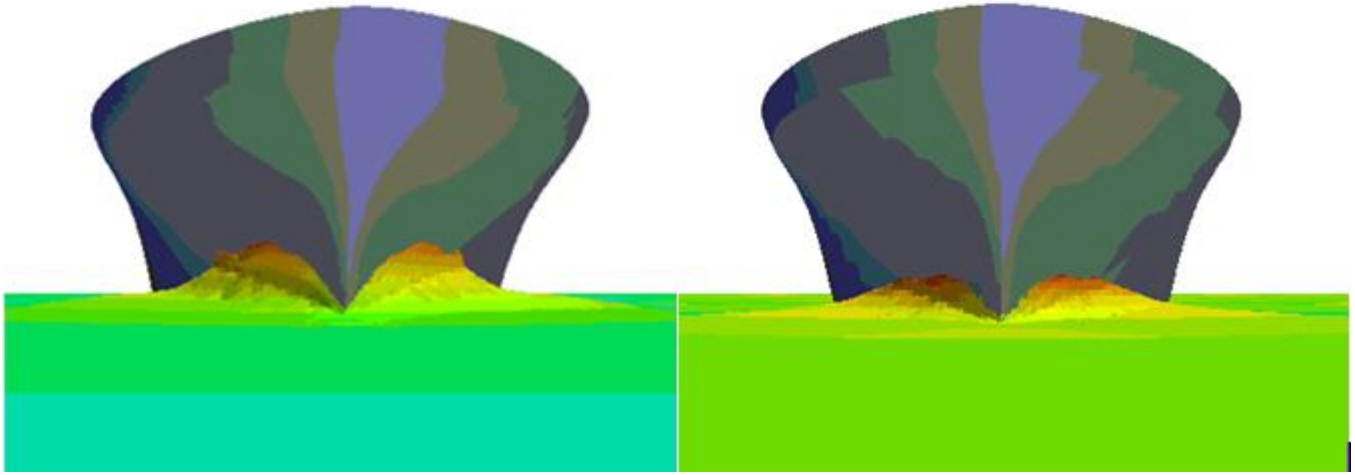
Initial bulb geometry coefficients	
C_{BB}	0.065
C_{LPR}	0.034
C_{ZB}	0.53
C_{VPR}	0.0027



Rendered view of the bulbous bow before (bottom) and after (top) optimization.



Wave profiles along the optimized bulbous bow (bottom) and the bulbous bow before optimization (top).



CFD results for the bulbous bow optimization wave height, optimized bulbous bow (right), bulbous bow before optimization (lift).

Conclusion:

- The results of the shape optimization procedure demonstrated some improvements to the bow section that produced a reduction in total resistance of up to about 5.5%.
- Each parameter of the bulb geometry has an influence on the bulb efficiency, and each parameter has a degree effect on the bulb efficiency.
- There is a relationship between the geometries parameters of the bulb; sometimes we cannot modify only one parameter to get efficiency bulb.
- The results obtained from this optimization exposed indicate how the systematic method can be useful in design cycle as it's faster and less expensive comparing to the automatic optimization in case some guidance on the physical phenomenon is available.

Grazie per l’attenzione

شكراً على انتباهكم