"EMSHIP"

Erasmus Mundus Master Course in "Integrated Advanced Ship Design"

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Hydrodynamic Performances Analysis and Design of a Containership Propeller

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Master Thesis

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Reviewer: Prof. Lionel Gentaz, "Ecole Centrale de Nantes"

La Spezia, IT. February 2014

OUTLINE

1. INTRODUCTION.
2. METHODOLOGY.
3. PROBLEM DESCRIPTION.
4. PROPULSIVE POWER ESTIMATION.
5. PROPELLER DESIGN PROCESS.
   - 5.1 FIRST STAGE: THE PRELIMINARY DESIGN PHASE..
   - 5.2 SECOND STAGE: THE DETAILED DESIGN PHASE.
   - 5.3 THIRD STAGE: THE ANALYSIS OF THE DESIGN IN OFF-DESIGN CONDITIONS.
6. CONCLUSIONS.

1. INTRODUCTION.

An increase regarding velocity and consequently in powering for all types of ships have demanded more efficient propulsion devices in order to,

a) Provide required thrust;
b) Maximum efficiency possible;
c) Low cavitation should occur (reduced up to admissible limits);
d) Noise avoidance;
e) Minimum hull vibrations…

The following work is focused on the entire **design process of a marine propeller for a container vessel.**

2. METHODOLOGY.

Stages involved during propeller design process:

1. The preliminary design phase;
2. The detailed design phase;
3. The analysis of the design.

A marine propeller for a small feeder containership (800 **TEU's*) is designed and analyzed in off design conditions.

MAIN PARTICULARS			
TEU's	800		No. of Twenty Feet Unit
L_{OA}	140.64	[mt]	Length over all
L_{WL}	136.8	[mt]	Length weater-line
L_{PP}	130.0	[mt]	Length btwn perpendiculars
B	21.8	[mt]	Breadth
D	9.5	[mt]	Depth
T	7.3	[mt]	Mean Draft
	13311.00	[m^3]	Volumetric displacement
Δ	13644	[tons]	Displacement
V_S	18.5	[knots]	Service speed
DWT	9500.00	[tons]	Deadweight
LGHTWT	3811.00	[tons]	Ligthweight

FORM COEFFICIENTS		
C_M	0.966	Midship coeff
C_B	0.611	Block coeff
C_P	0.665	Prismatic coeff
C_W	0.833	Watrplane coeff

**TEU: twenty-foot equivalent unit of cargo capacity.*

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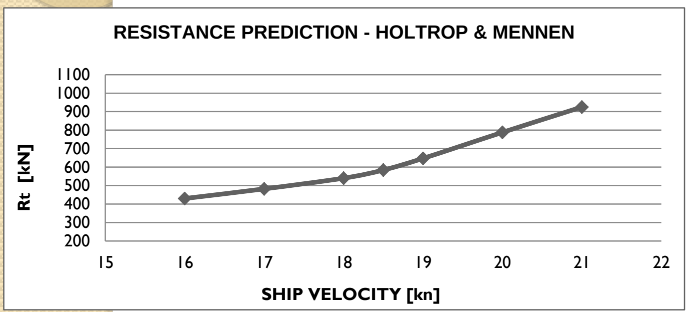
Method used: ***"An Approximate Power Prediction Method – 1982"*** by J. Holtrop & G.G.J. Mennen.

$$R_T = R_F(1+k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A,$$



Resistance at design velocity: **581kN.**

Thrust: **691 kN.**

PROPULSION FACTORS (hull-propeller interaction coefficients)		
w	0.25	Global wake fraction coefficient
t	0.16	Thrust deduction coefficient
η_R	0.993	Relative rotative efficiency

PROPELLER CHARACTERISTICS.			
D	[mt]	5.4	Initial propeller diameter (d/T =0.74)
Z		4	Blade number
h	[mt]	4.7	Height from the water line to the center line of the shaft
A_E/A_O		0.85	Expanded Area Ratio

$$P_B = \frac{P_D}{\eta_S} = \frac{P_E}{\eta_S \eta_H \eta_R \eta_0}$$

$$P_E = R_T V_S = 5531 kWatt$$

$$\eta_S = 0.97 \text{ (our case)}$$

$$P_D = \frac{P_T}{\eta_0 \eta_R}; \quad P_T = \frac{P_E}{\eta_H}$$

$$\eta_H = \frac{1-t}{1-w} > 1$$

$$\eta_0 = ?$$

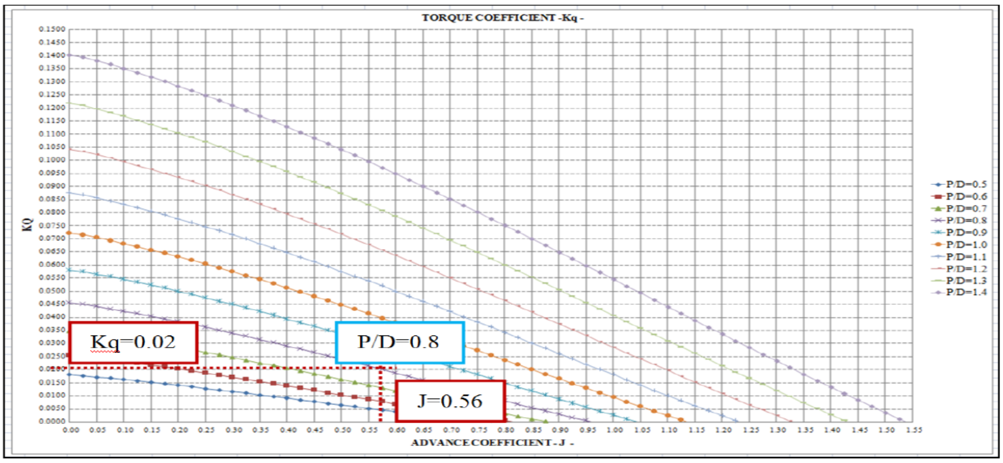
$$\eta_0 = \left(\frac{K_T}{K_Q}\right)\left(\frac{J}{2\pi}\right)$$

$$K_T = \frac{T}{\rho n^2 D^4}$$

$$K_Q = \frac{Q}{\rho n^2 D^5}$$

$$J = \frac{V_A}{nD}$$

B4.85 diagrams



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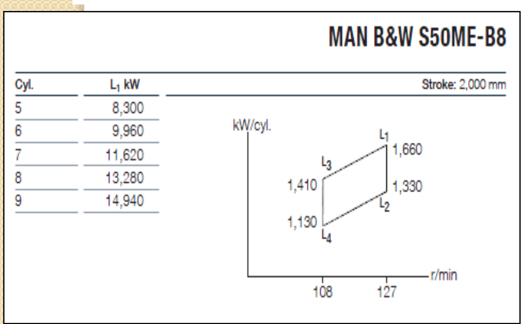
PITCH RATIO	ADVANCE COEFFICIENT	THRUST COEFFICIENT	TORQUE COEFFICIENT	OPEN WATER EFFCICIENCY	RELATIVE ROTATIVE EFFICIENCY	EFFECTIVE POWER [kW]	DELIVERED POWER [kW]	**BRAKE POWER [kW]**
P/D	J	k_T	k_Q	ηB		P_E	P_D	**P_B** + 15%
				η_O	η_R			
0.8	0.56	0.14	0.02	**62.3 %**	0.99	5531	7976	**9456**

ENGINE SELECTION



ENGINE SELECTION						
MAN B&W S50ME-B8			LOW SPEED ENGINE			
			2 STROKES			
			6 CYLINDERS			
N [RPM]	n [rps]	P_B [kW]	L_1	L_2	L_3	L_4
108	1.80	**9960**	1660	1330	1410	1130
127	2.12					

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Looking for the **optimum diameter…**

- ✓ The marine engine particulars: the brake power [P_B]; the revolution rate at M.C.R. [N];
- ✓ The advance velocity [V_A];
- ✓ The delivered power [P_D], where, $P_D = (P_B)(\eta_S)(15\%)$

P_D 'new' [kWatt]	Q [kN*mt]
8212	617

$$D_{opt} = \sqrt[5]{\frac{Q}{\rho n^2 K_Q}}$$

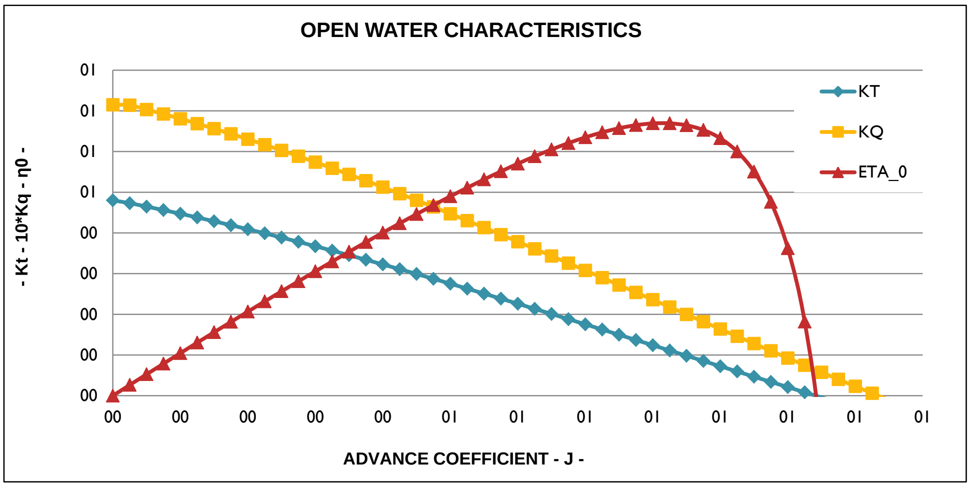
$$\frac{K_Q}{J^5} = \left[\frac{Q}{\rho n^2 D^5}\right]\left[\frac{nD}{V_A}\right]^5 = \frac{Qn^3}{\rho V_A^5}$$

$$\frac{K_Q}{J^5} = \left[\frac{P_D n^2}{2\pi\rho V_A^5}\right]$$

P/D	J	K_Q	K_T	η_O	D [mt]
0.5	0.46	0.0074	0.03	0.274	
0.6	0.49	0.0105	0.06	0.471	
0.7	0.53	0.0149	0.10	0.558	
0.8	0.56	0.0205	0.14	0.592	
0.9	**0.60**	**0.0274**	**0.172**	**0.602**	**5.50**
1	**0.63**	**0.0357**	**0.211**	**0.593**	**5.20**
1.1	0.66	0.0452	0.25	0.580	
1.2	0.69	0.0559	0.29	0.566	
1.3	0.72	0.0678	0.33	0.552	
1.4	0.74	0.0808	0.37	0.540	

THEORETICAL OPEN WATER CHARACTERISTICS (B-WAGENINGEN)

Optimum Diameter	**5.20 mts**
P/D	1.0
Z	4
A.E.R.	0.85



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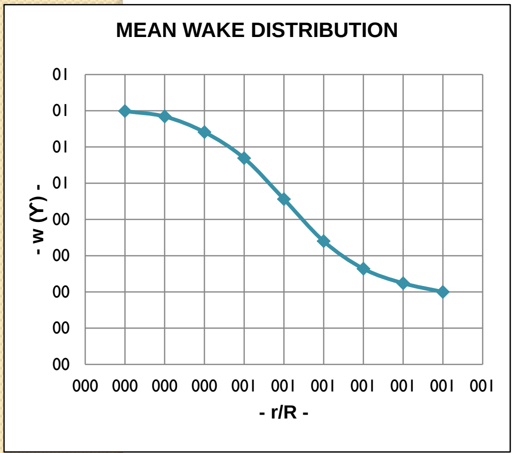
- The geometry of the propeller (unknown);
- The required thrust / delivered power (specified);
- **Fluid flow is assumed to vary radially…therefore;**

- **The aim**: …*"WAKE-ADAPTED PROPELLER"*



THE LIFTING LINE THEORY WITH LIFTING SURFACE CORRECTIONS RESULTS (1)			
SHIP VELOCITY	V_S	[knot]	18.649
		[mt/sec]	9.593
TOTAL SHIP RESISTANCE	R_T	[kN]	599.912
THRUST	T	[kN]	706.462
TORQUE	Q	[kN*mt]	611.791
THRUST COEFFICIENT	k_T		0.212
TORQUE COEFFICIENT	k_Q		0.0354
OPEN-WATER EFFICIENCY	η_0	[%]	0.620
ADVANCE COEFFICIENT	J		0.655
DELIVERED POWER	P_D	[kW]	8218.650
MINIMUM E.A.R.	E.A.R.		0.879
PITCH	P	[mt]	5.009

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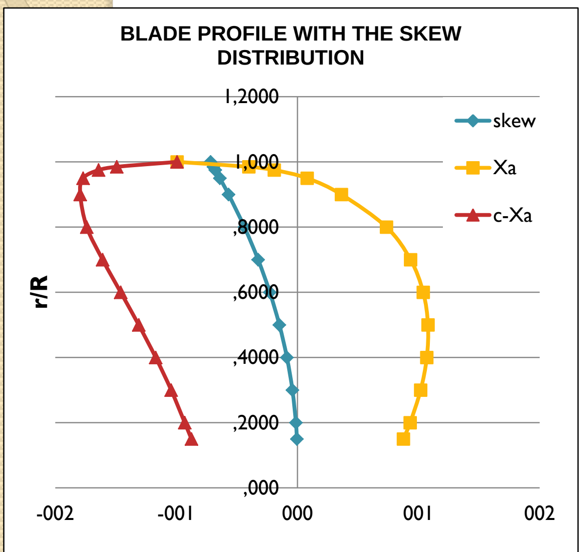
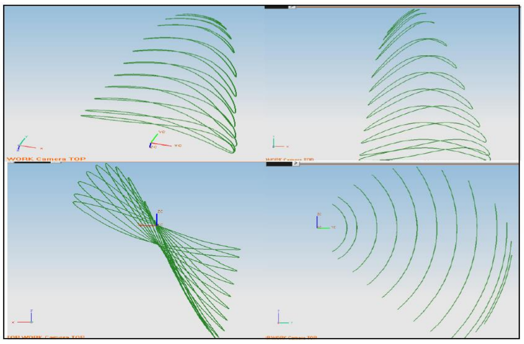
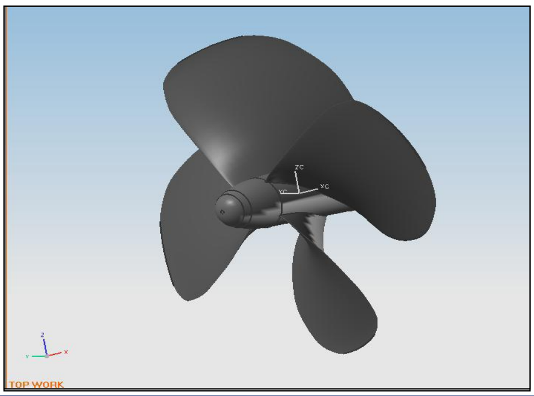
PROPELLER GEOMETRY







Geometry is defined…

The hydrodynamic propeller performances (**steady**/unsteady **flow conditions**) are investigated via:

- **Computational analysis (numerical methods),**
- Experimental tests.

Output data for uniform flow conditions:

- ✓ The **open water characteristics**;
- ✓ Computation of **pressure distribution** on propeller blades **operating in uniform flow** and/or by varying circumferentially the fluid flow.

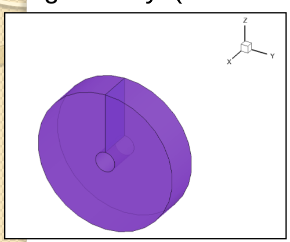
Software employed:

- SHIPFLOW
- FLUENT

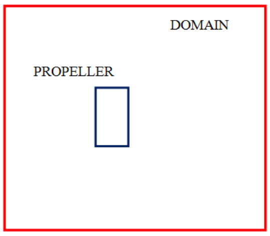
SHIPFLOW

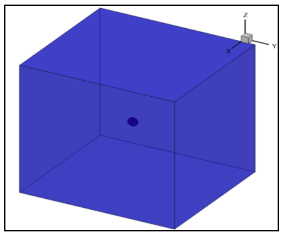
UNIFORM FLOW CONDITIONS

The geometry. (sink-disk)

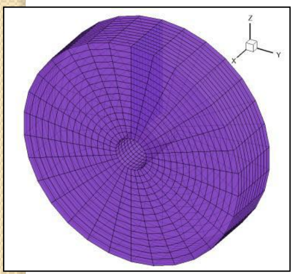


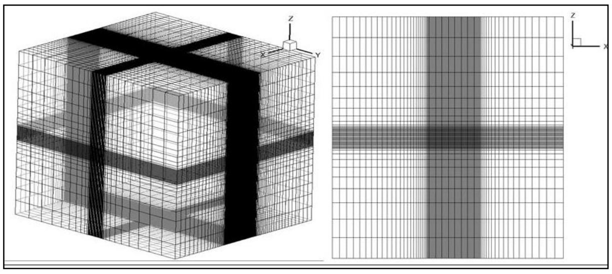
The fluid domain.





Discretization.





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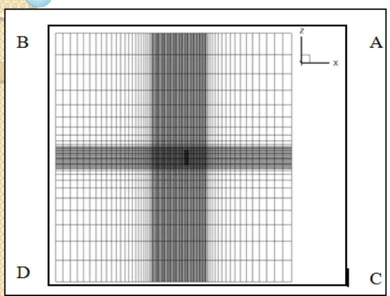
SHIPFLOW

Boundary conditions



- ✓ **Velocity inlet (INFLOW):** 'AC' section
- ✓ **Pressure outlet (OUTFLOW):** 'BD' section
- ✓ **Walls.**
- ✓ **Body:** sink-disk, known with [POW] function.

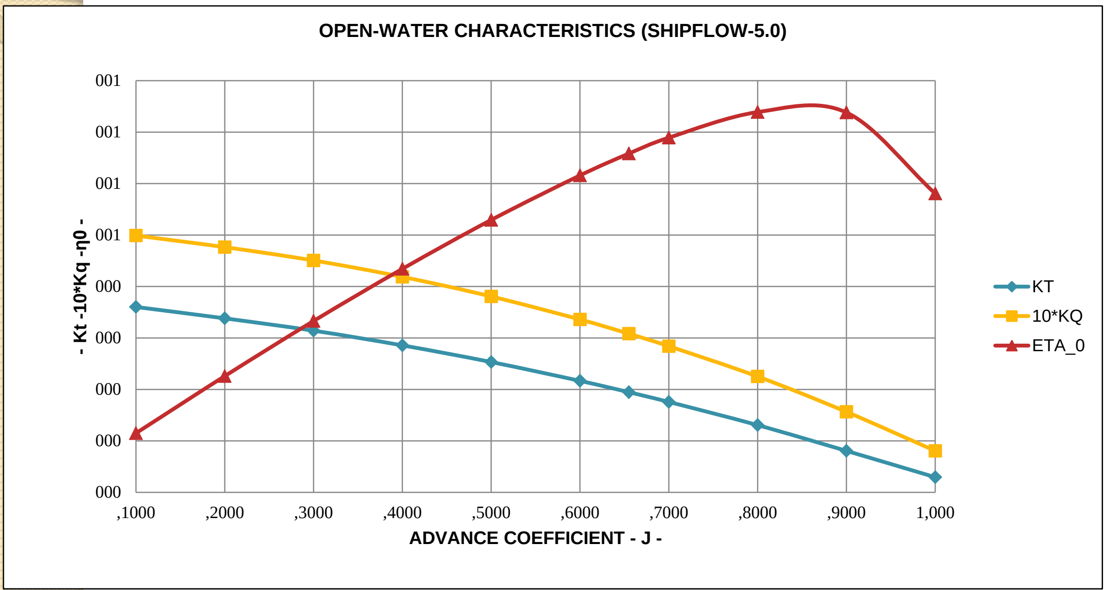
Turbulence Model selection.

***k*-ω Shear Stress Transport (SST) model** (given as a default).

[XCHAP]: finite volume code that solves the RANS equations. It uses several turbulence models *(EASM, k-w BSL, k-w SST)*.

SHIPFLOW

The open-water characteristics diagram.



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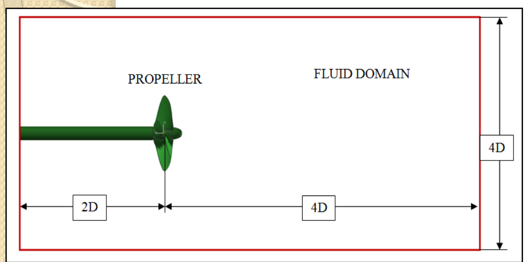
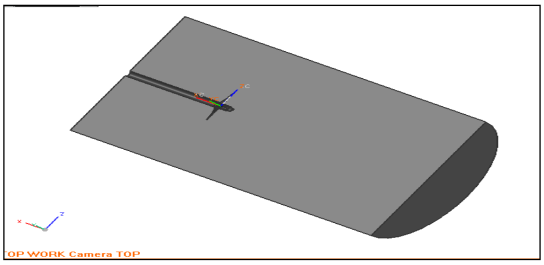
FLUENT

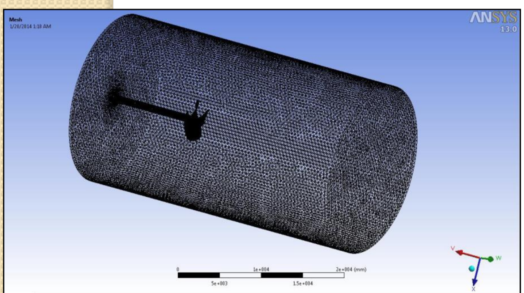
UNIFORM FLOW CONDITIONS

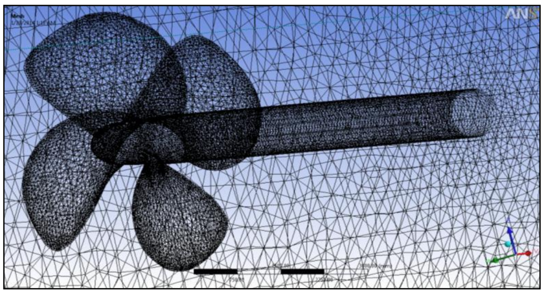
The fluid domain.





Discretization.





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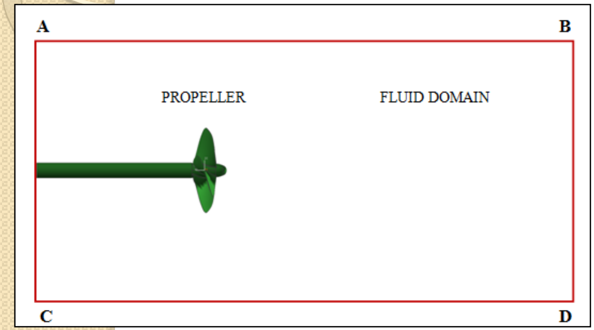
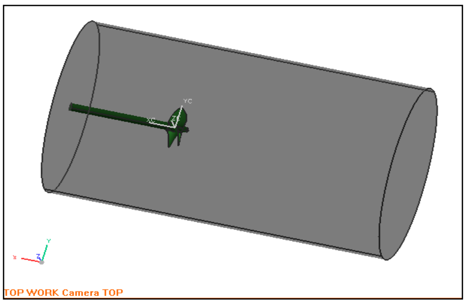
Boundary Conditions.



- ✓ **Velocity inlet :** 'AC' section
- ✓ **Pressure outlet:** 'BC' section
- ✓ **Wall (boundary surface of the domain):** limits of declared domain with non-slip wall.
- ✓ **Body:** propeller geometry.

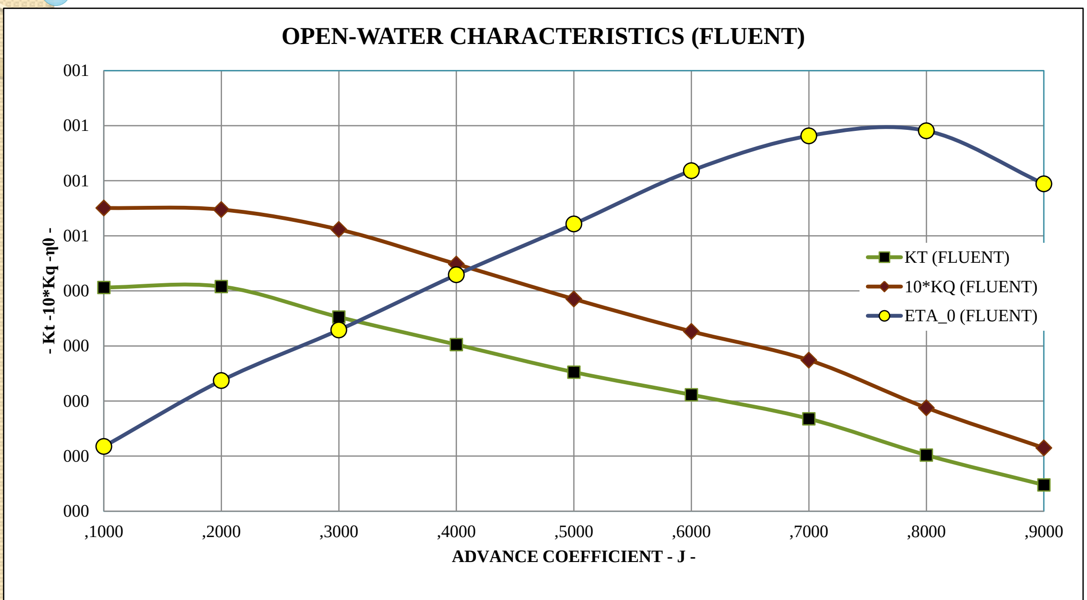


Turbulence Model selection.

The 'Realizable k-ε turbulence model'.

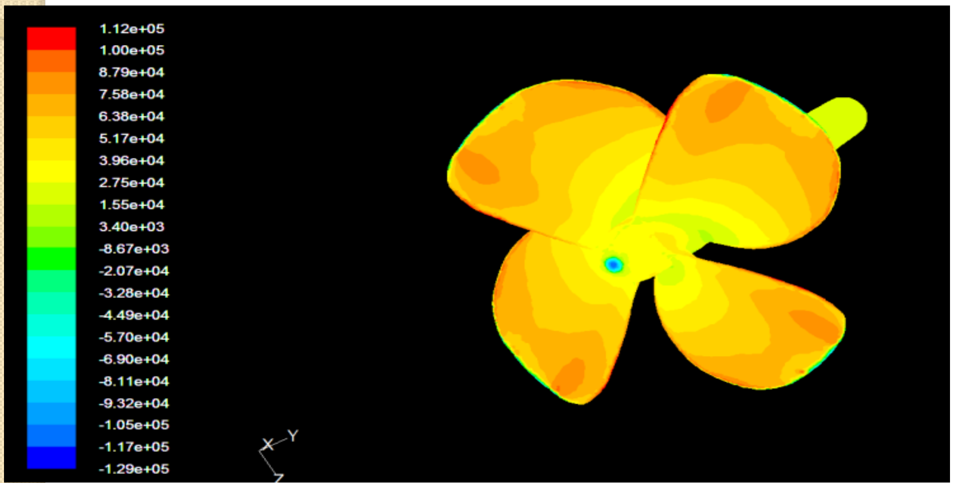
FLUENT

The open-water characteristics diagram.



FLUENT

Analysis on pressure field. (J= 0.655)



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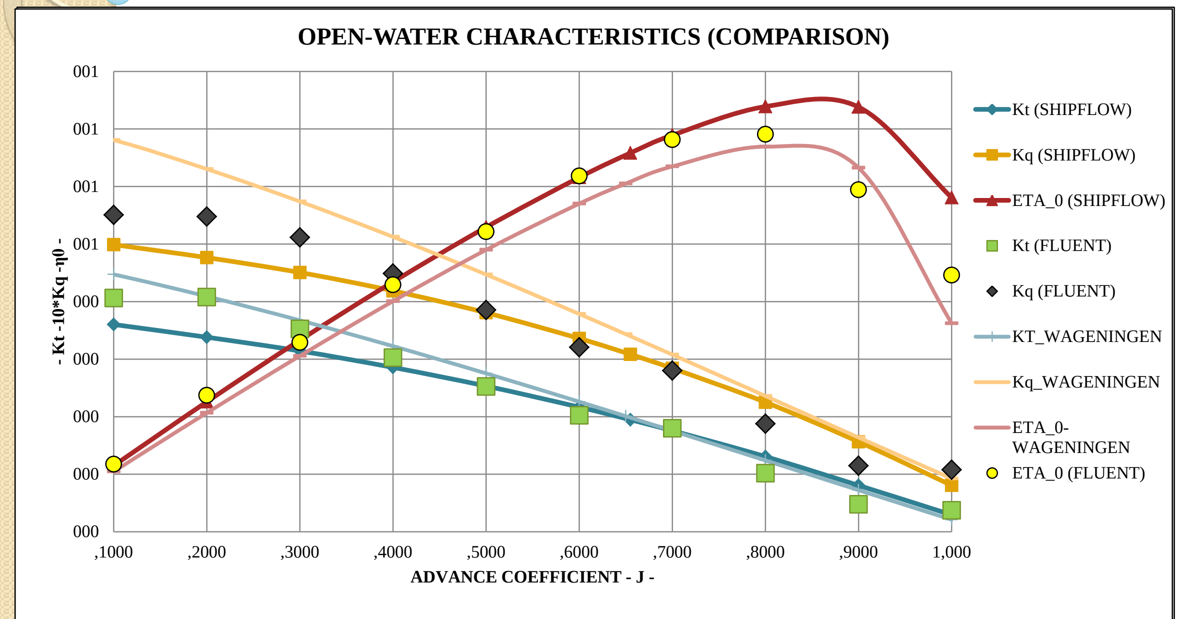
THE OPEN WATER CHARACTERISTICS DIAGRAM COMPARISON

B_WAGENINGEN / SHIPFLOW / FLUENT



8. CONCLUSION.

❖ Designing the propeller through systematic series is a topic which we cannot avoid it. It permits us to get an idea about the device but, due to its disadvantages explained before, there is no justification for waiving the propeller design by direct calculation using lifting line methods with surface corrections which provides feasible results.

❖ The implementation of computational fluid dynamics codes provides reliable information in order to validate the design. There were discrepancies regarding results due to, the lack of experience about numerical simulations (the physics of it) and the ability to manipulate these tools as well as the selection of different parameters for example from personal point of view. Even this, it is a good starting point for further analysis employing computational fluid dynamics on this field.

❖ Propeller design process concludes after the design is analyzed with numerical simulations to later on, built on scale and tried out. Once this examination is approved, we can determine that the design is finished. But, we cannot assure the expected hydrodynamic performances until the real propeller is checked on real conditions.

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