NUMERICAL INVESTIGATION OF FLOW AROUND AN APPENDED SHIP HULL

EMSHIP master thesis presentation

developed in the frame of the European master course
in "Integrated advanced ship design" named "EMSHIP"
for "European education in advanced ship design", ref.: 159652-1-2009-1-BE-ERA MUNDUS-EMMC

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Contents

Introduction

- Objective and presentation of the hull DTMB 5415

Used software

- SHIPFLOW presentation

Solution

- Preliminary potential flow solution
- Hybrid viscous solution using potential free surface

Key results

Conclusion

Introduction

- Main objective: to determine the flow around the fully appended ship hull, influences exerted by different configurations of the appendages on the wake structure in the propeller disk on combatant DTMB 5415

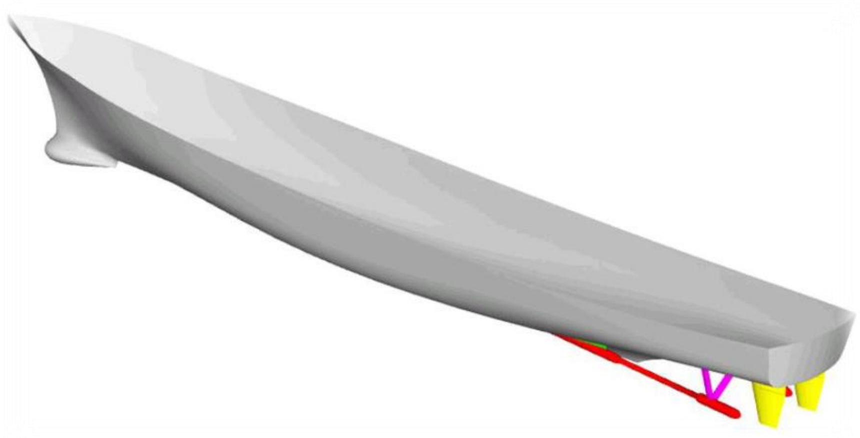

Fig.1: DTMB 5415 Geometry

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Used software

SHIPFLOW by FLOWTECH International AB with:

- Potential flow theory utilizing Laplace equation combined with boundary layer theory for estimating the skin friction coefficient and total resistance.
- Viscous flow theory utilizing RANS (Reynolds Averaged Navier Stokes equations) for detailed investigation of the flow in the stern region and zone around the sonar dome of the ship.

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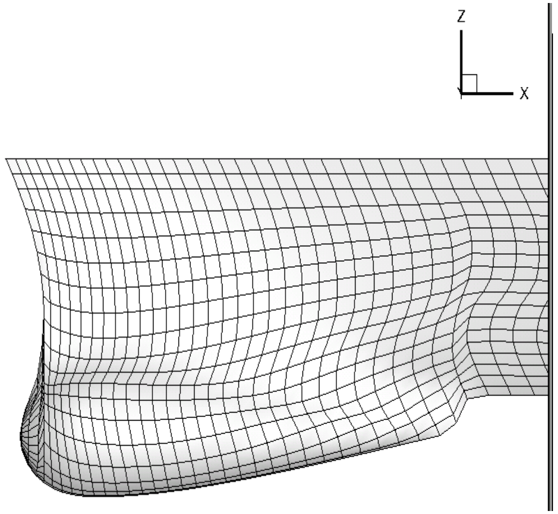
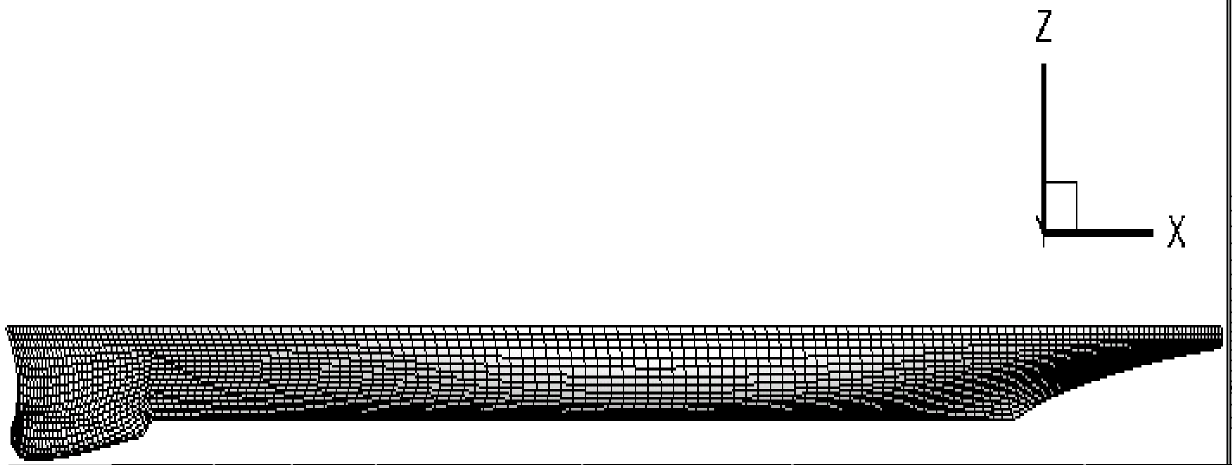
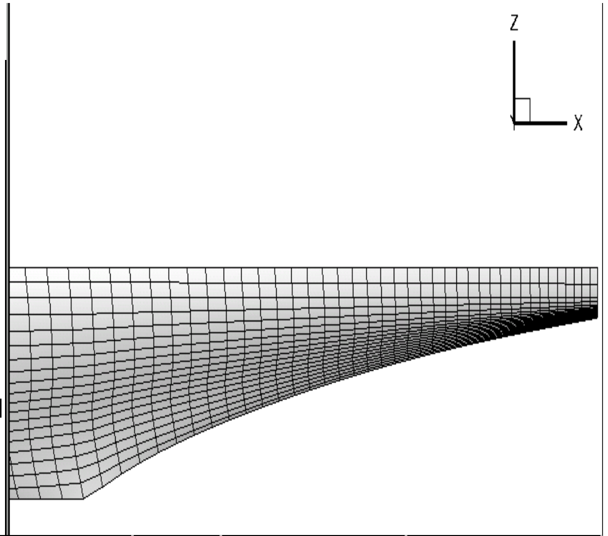
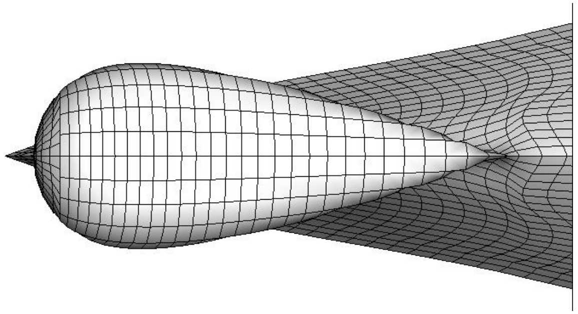
Preliminary potential flow solution

- Panazlization on the body

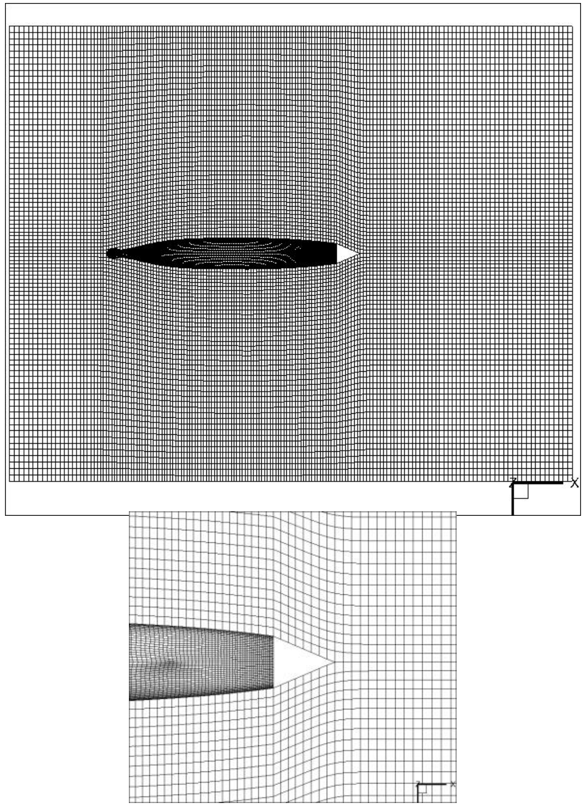
	Free surface				Hull		Bulb		No Transom		Transom			
Froude	points	stau	stam	stad	station	point	station	points	Total number of panels	Total number of nodes	points	stad	Total number of panels	Total number of nodes
0.24	45	25	84	61	150	18	5	18	10247	10650	4	61	10427	10894
0.28	43	21	63	54	150	18	5	18	8569	8938	4	54	8728	9154
0.31	43	20	53	50	150	18	5	18	7939	8293	4	50	8086	8493
0.35	42	18	43	47	150	18	5	18	7204	7542	4	47	7342	7730
0.40	43	17	33	43	150	18	5	18	6381	6703	4	43	6507	6875
0.44	43	16	28	41	150	18	5	18	6045	6359	4	41	6165	6523

Potential flow panalization

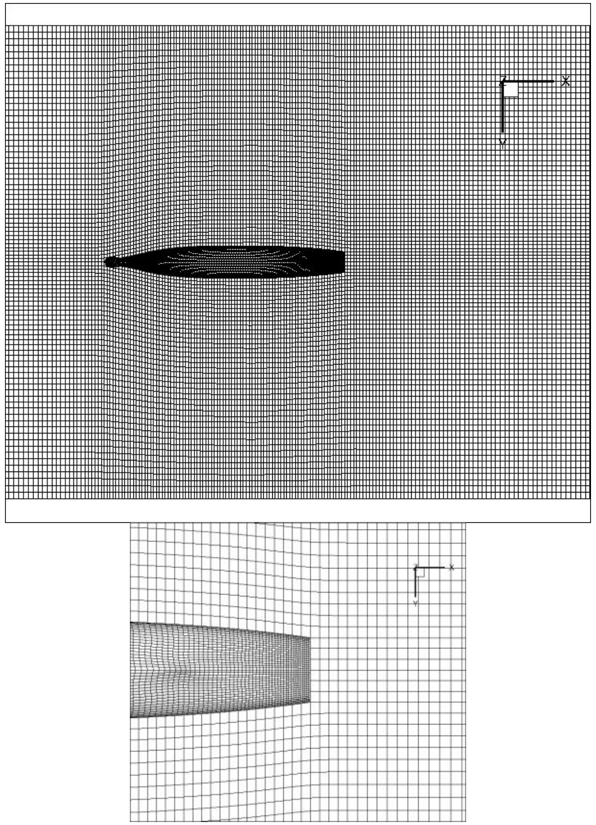
Table with different configurations of grids for different Froude numbers

Preliminary potential flow solution

- Panalization of the free surface generated based on $\lambda = 2\pi L Fn^2$
- Example of grids for Fn = [0.24]



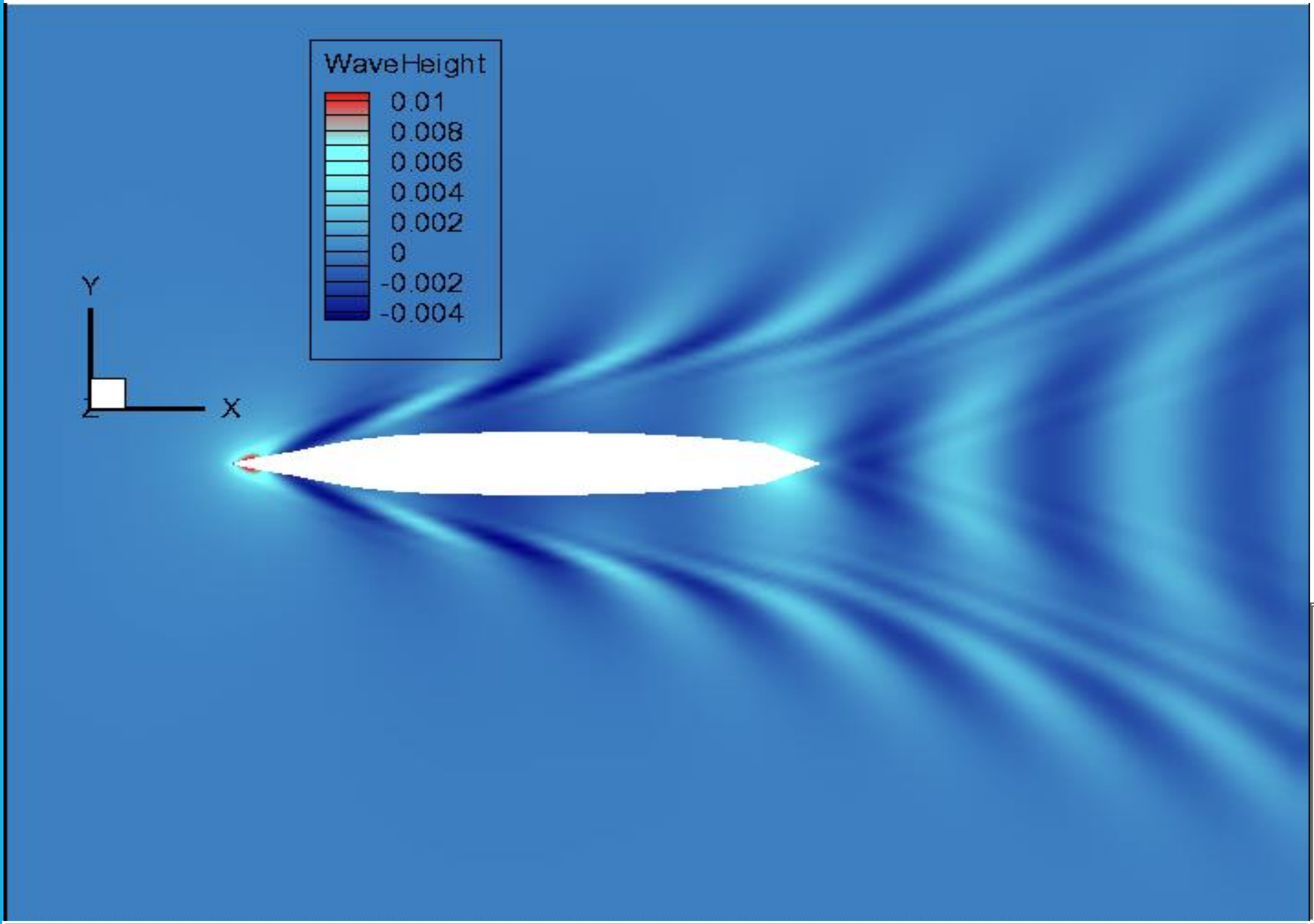
Free surface no transom case



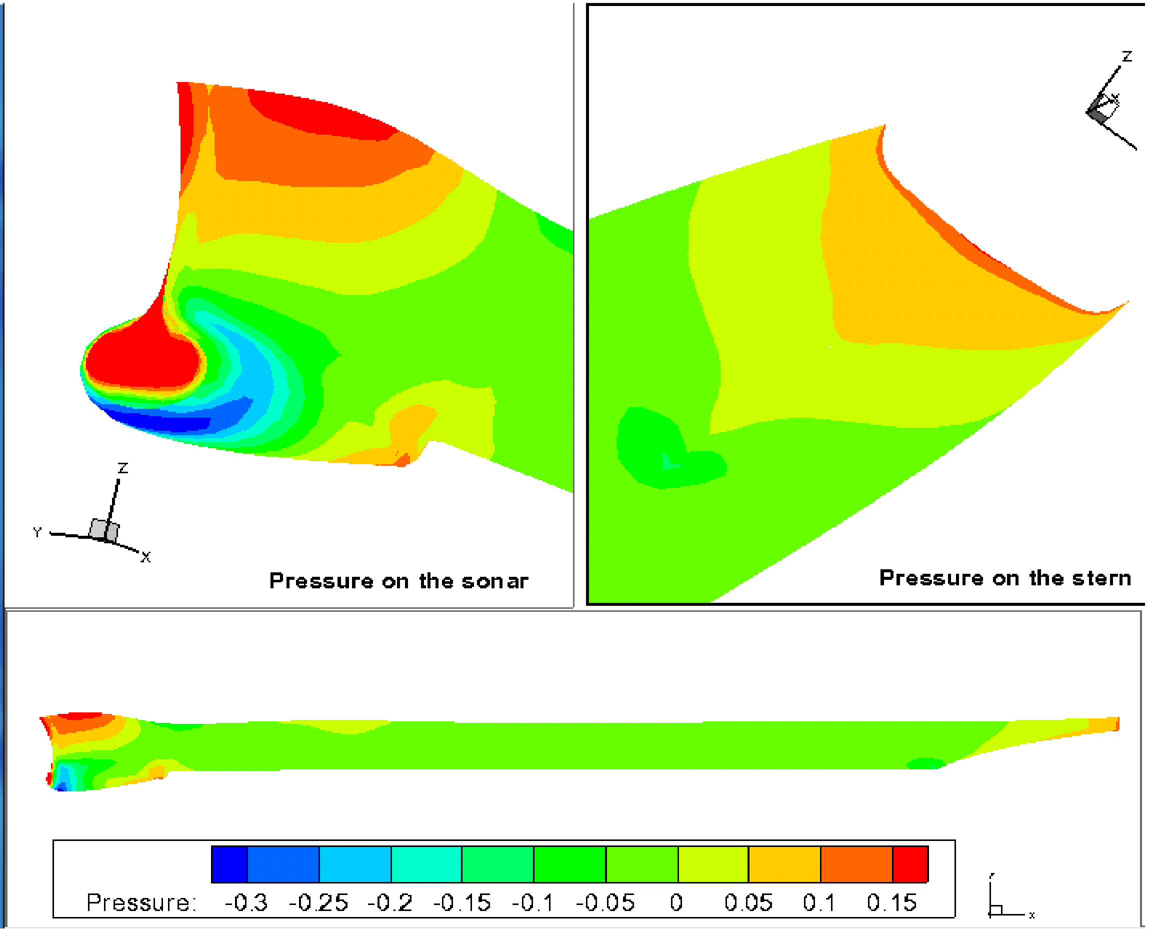
Free surface with transom case

Preliminary potential flow solution

- Example of results for Fn = [0.24]



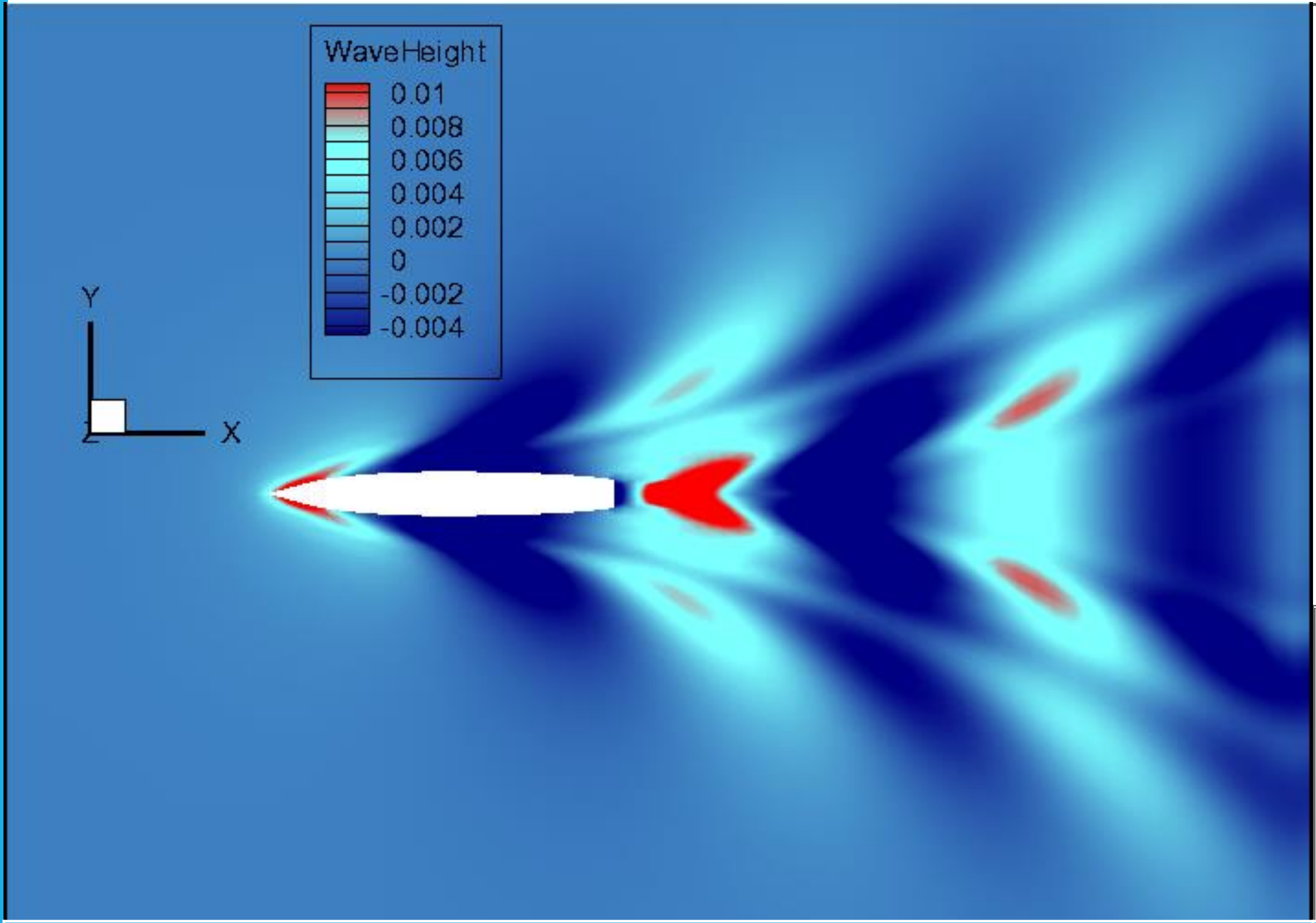
Free surface computation



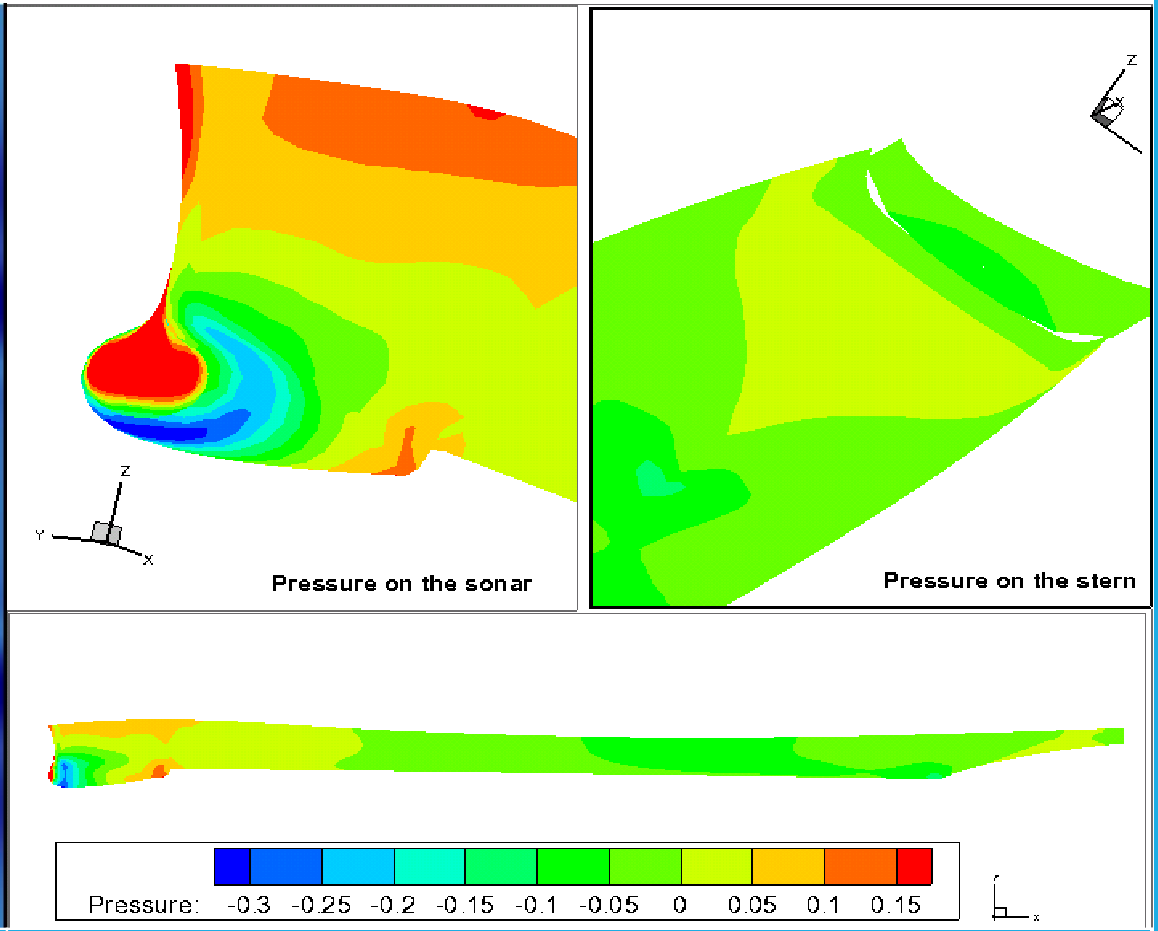
Pressure distribution

Preliminary potential flow solution

- Example of results for Fn = [0.40]



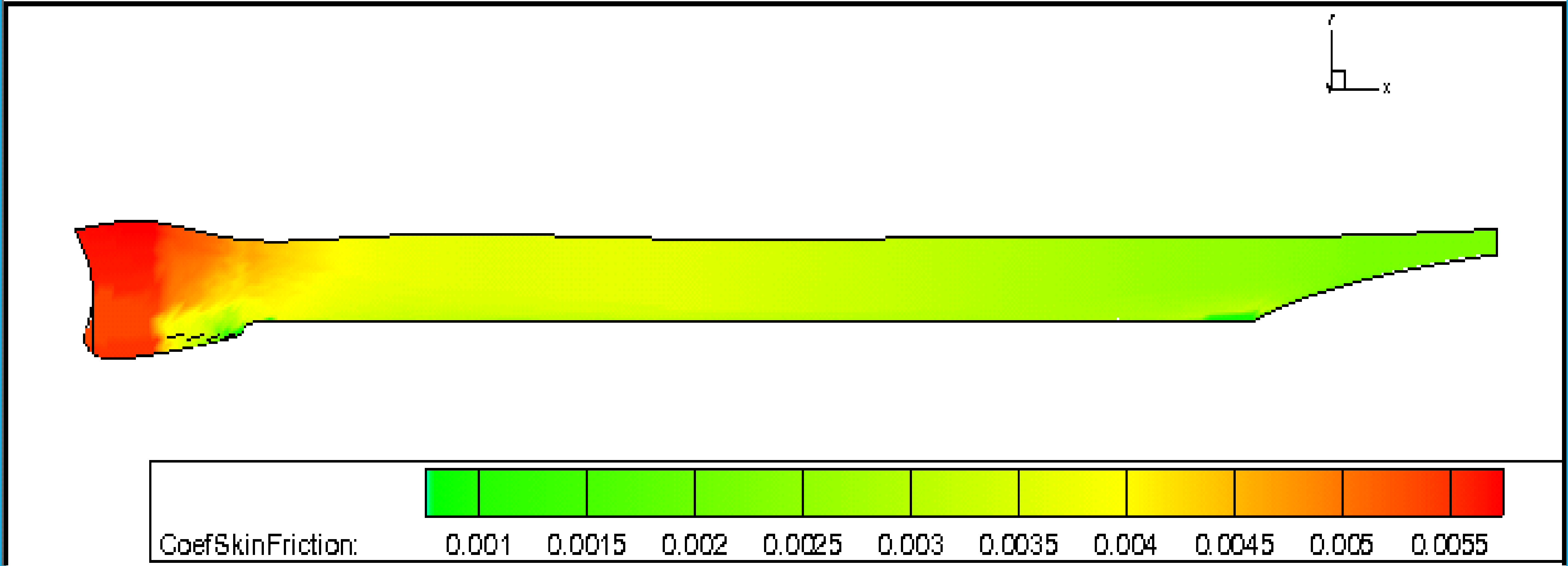
Free surface computation



Pressure distribution

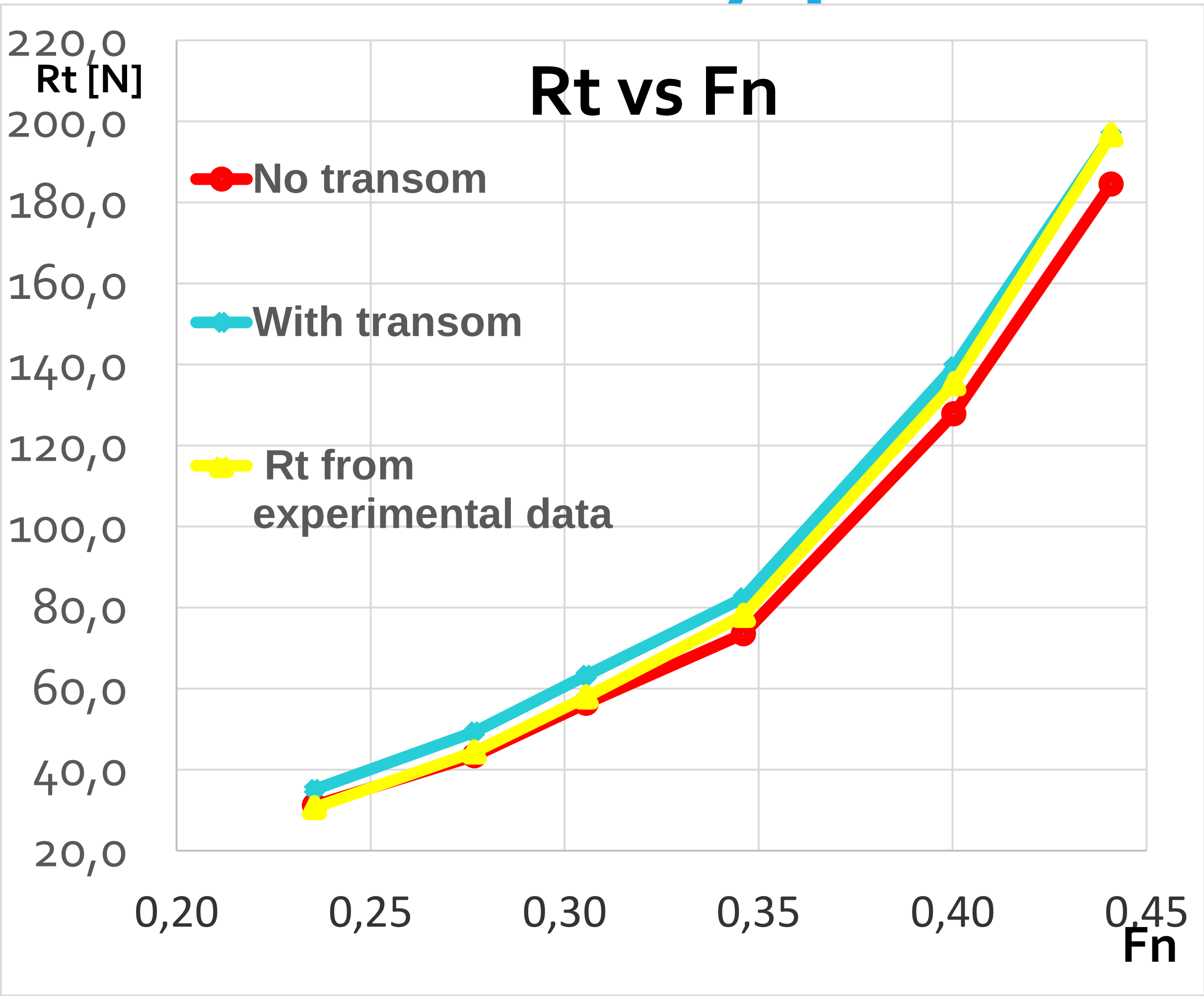
Preliminary potential flow solution

- Example of results for Fn = [0.24]

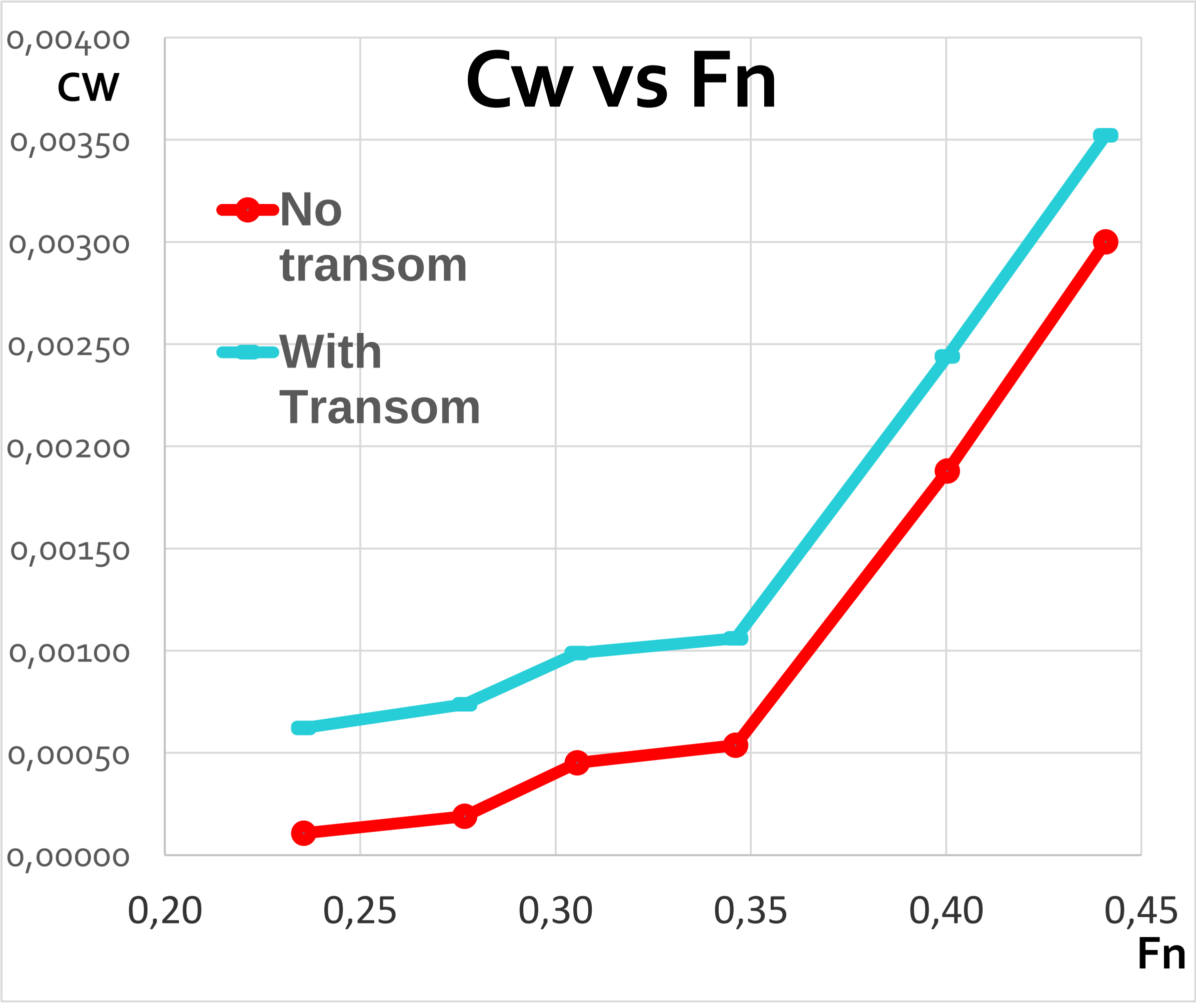


Skin friction coefficient for Fn= [0.24]

Preliminary potential flow solution



Total Resistance [Rt] in function of Froude number [Fn]



Coefficient of wave making resistance [Cw] in function of Froude number [Fn]

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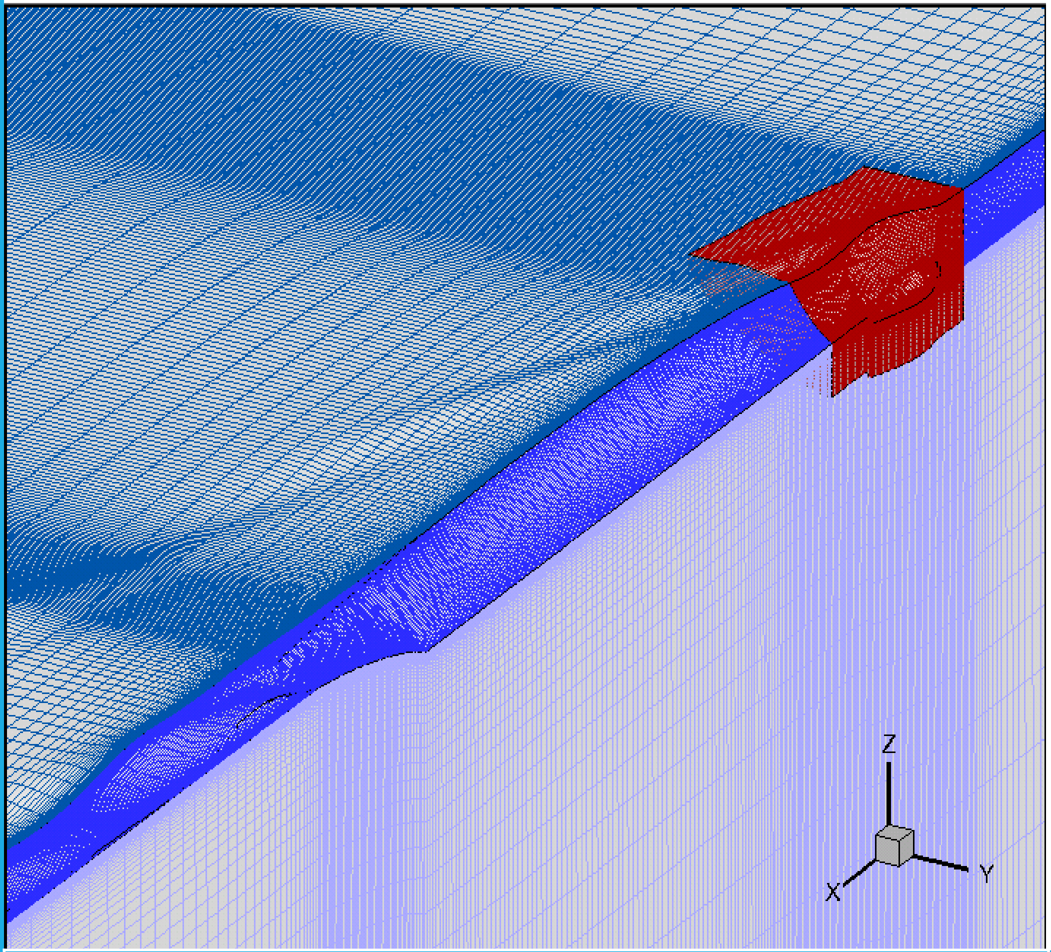
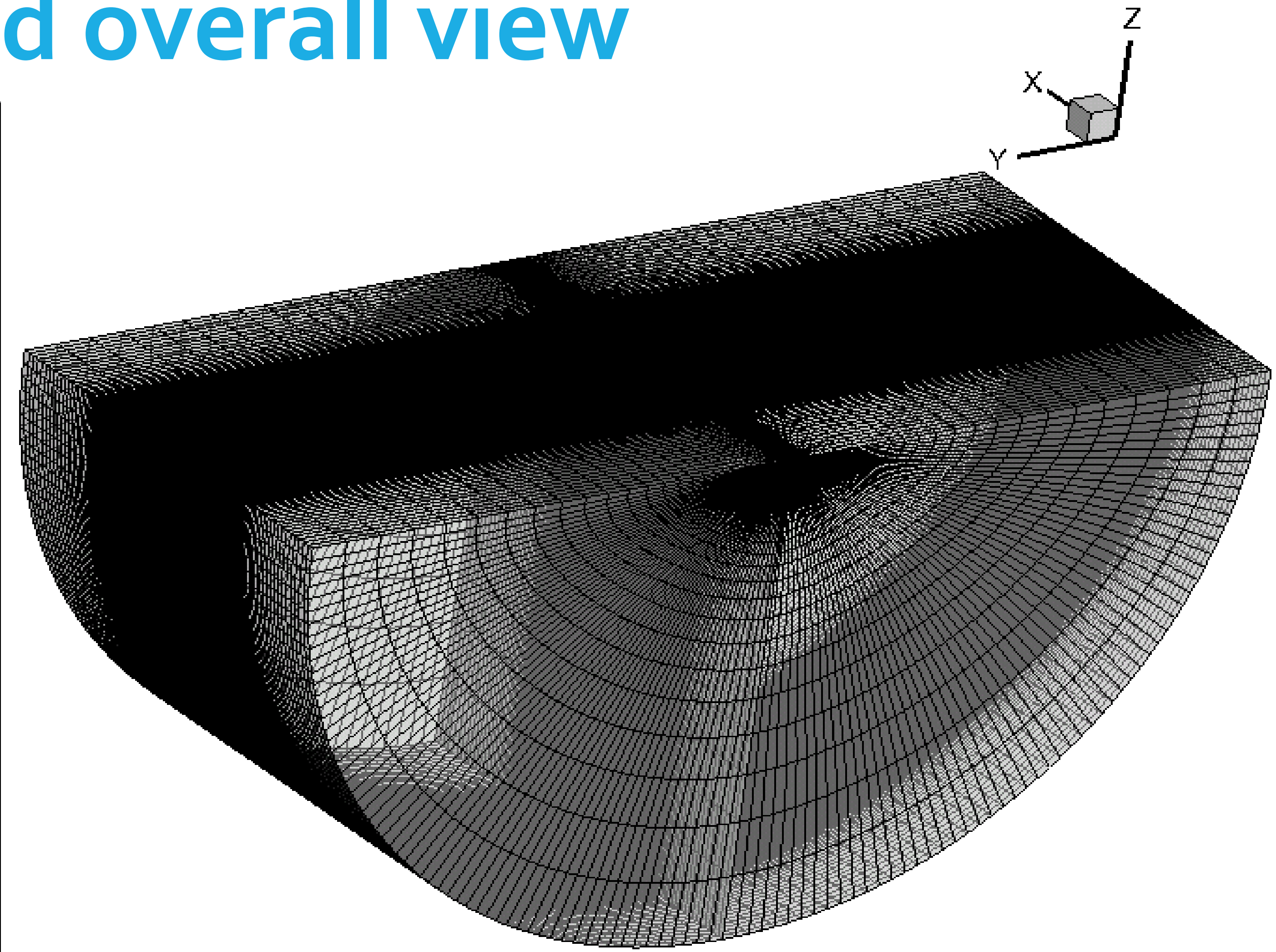
Hybrid viscous solution using potential free surface – grid overall view

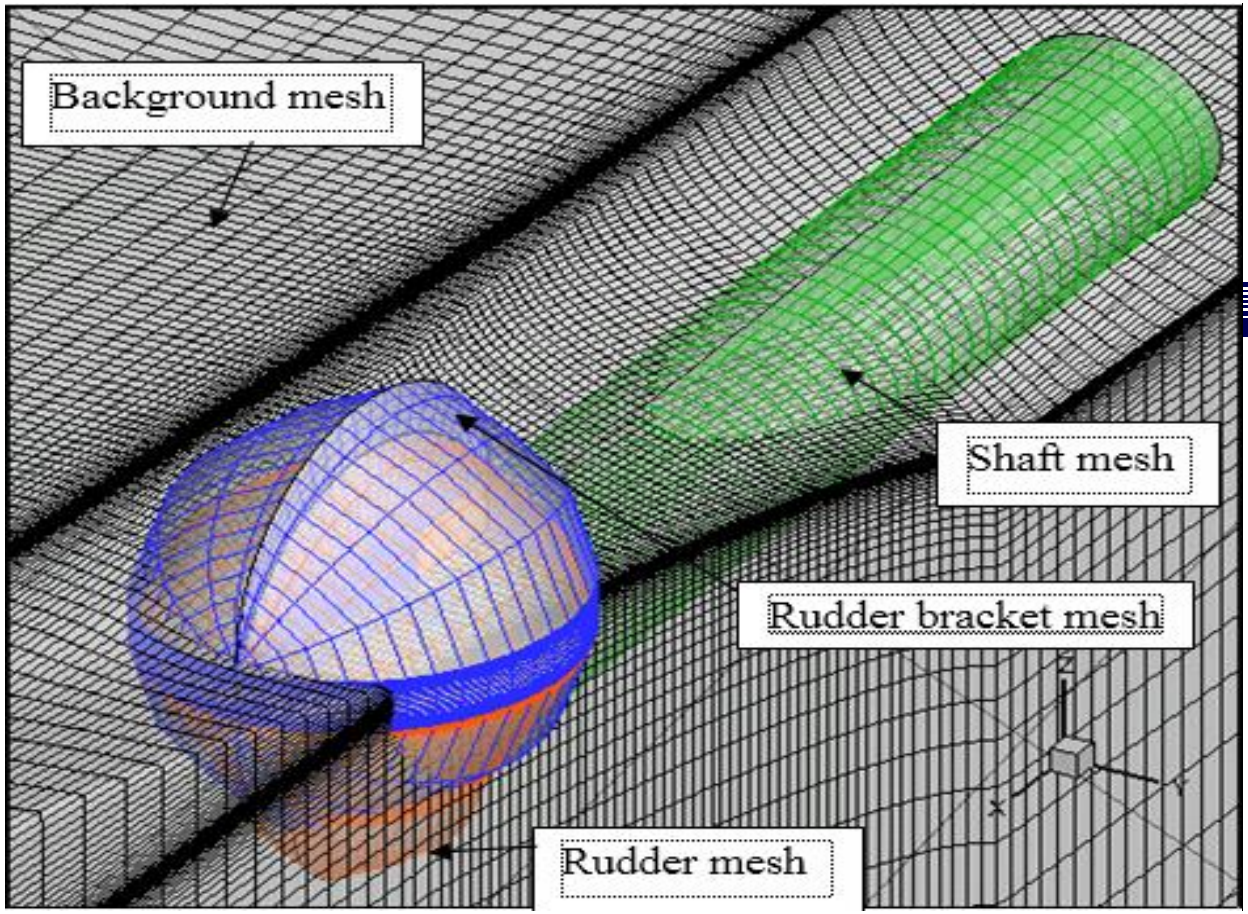


Overall view of the grid

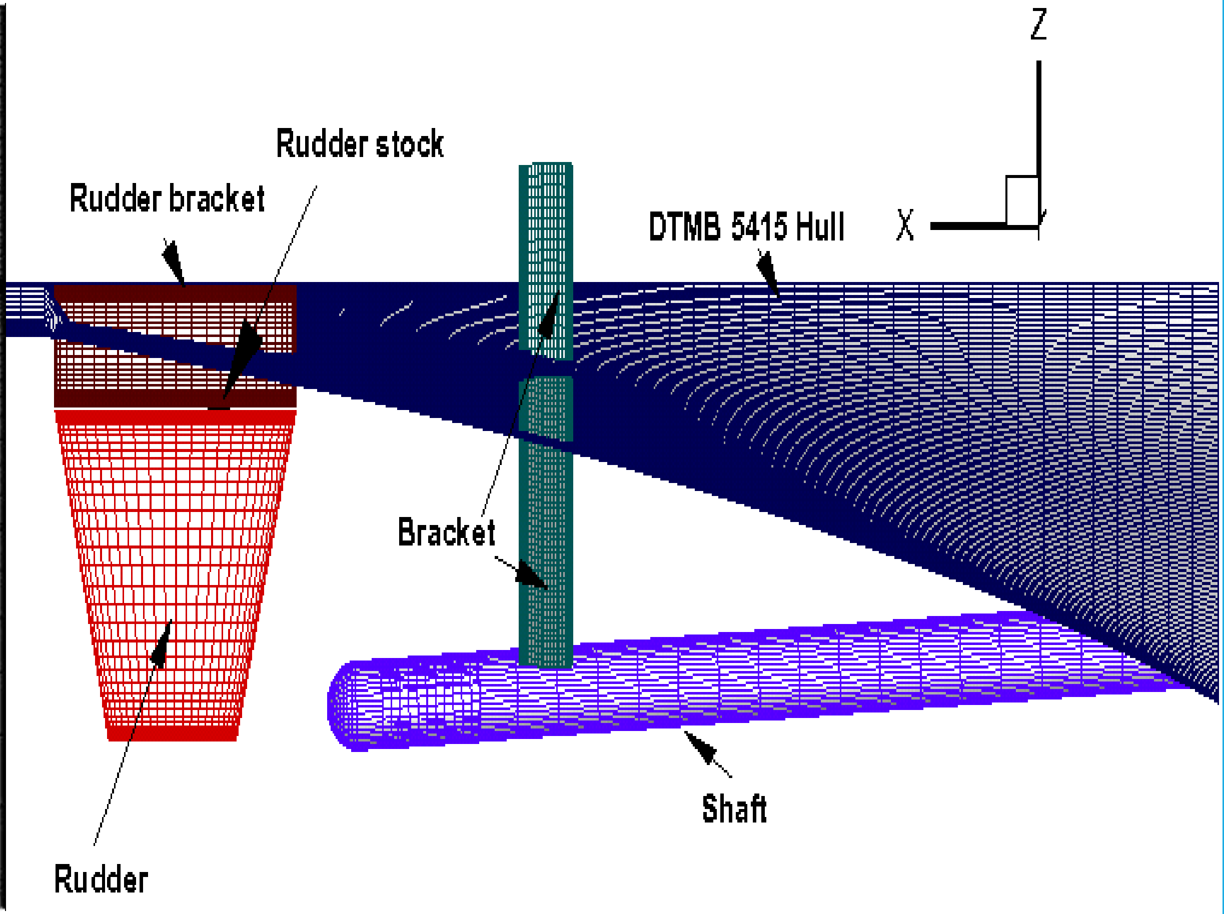


Perspective view of whole viscous domain

Viscous grid in the stern region of the hull with appendages

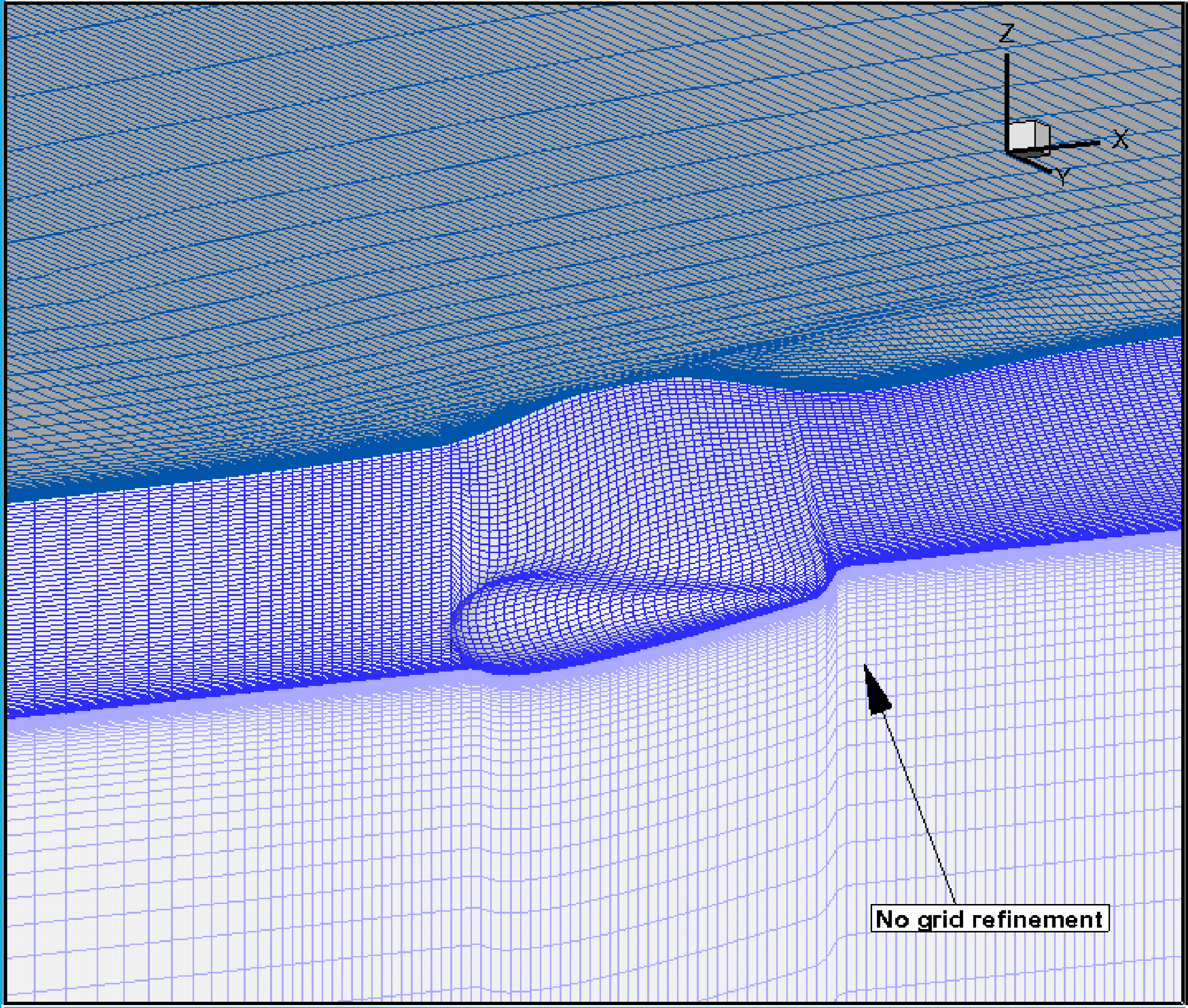


Overlapping grid of shaft - green, rudder – orange, ruder bracket – blue

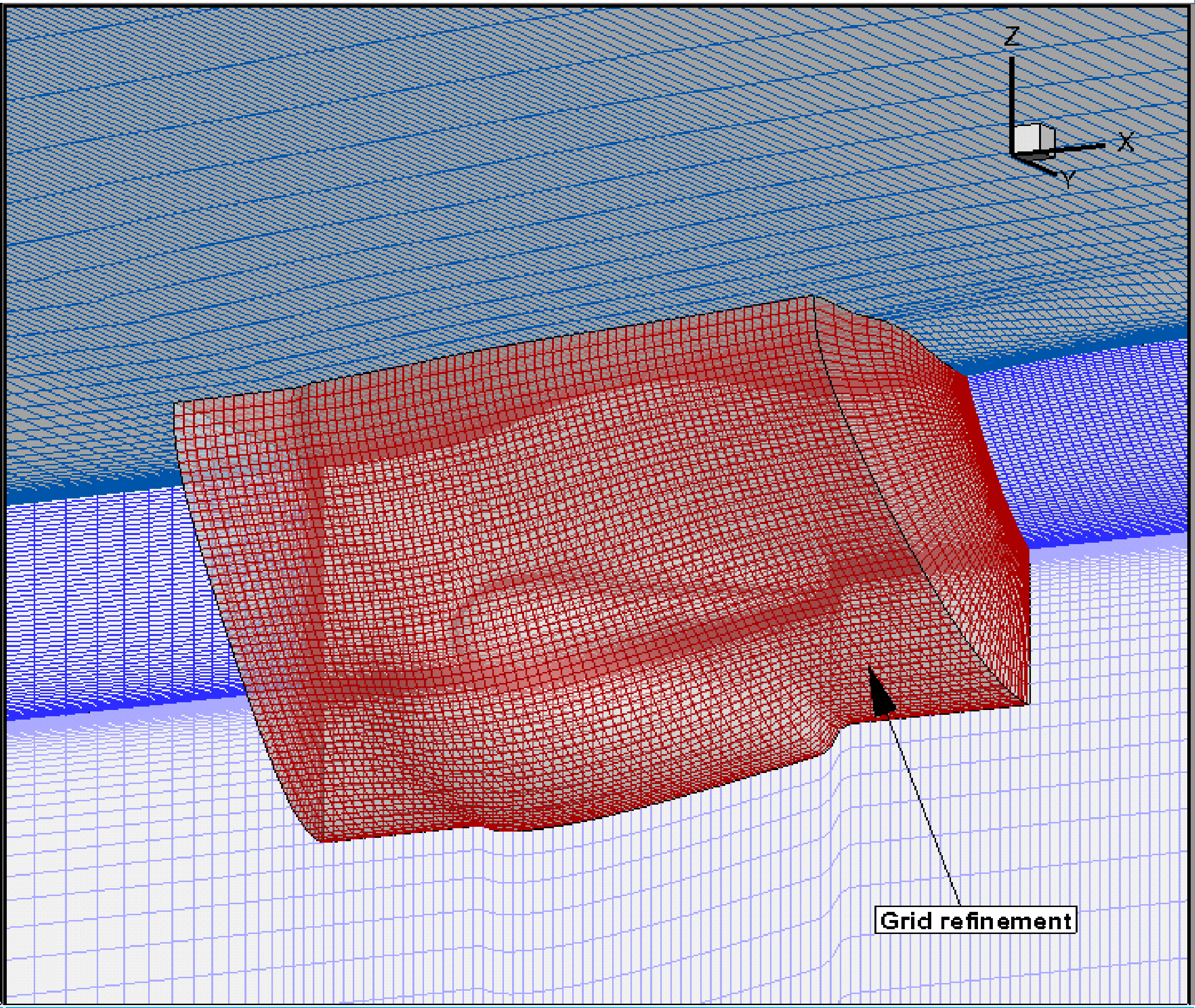


Grid around stern part of the ship with appendages

Viscous grid in the sonar dome region



No refined mesh in sonar region for Fn = 0.28



Refined mesh in sonar region for Fn = 0.28

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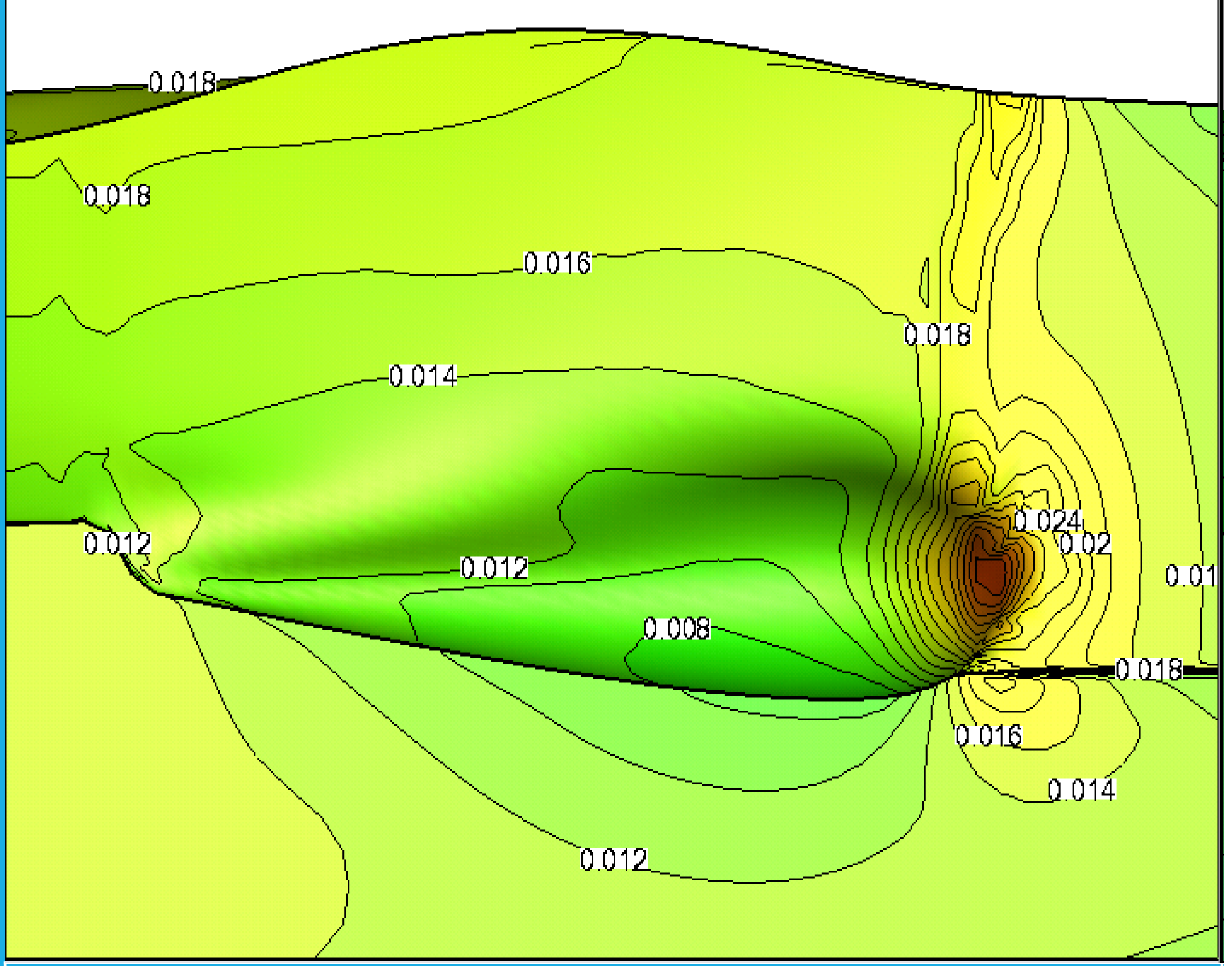
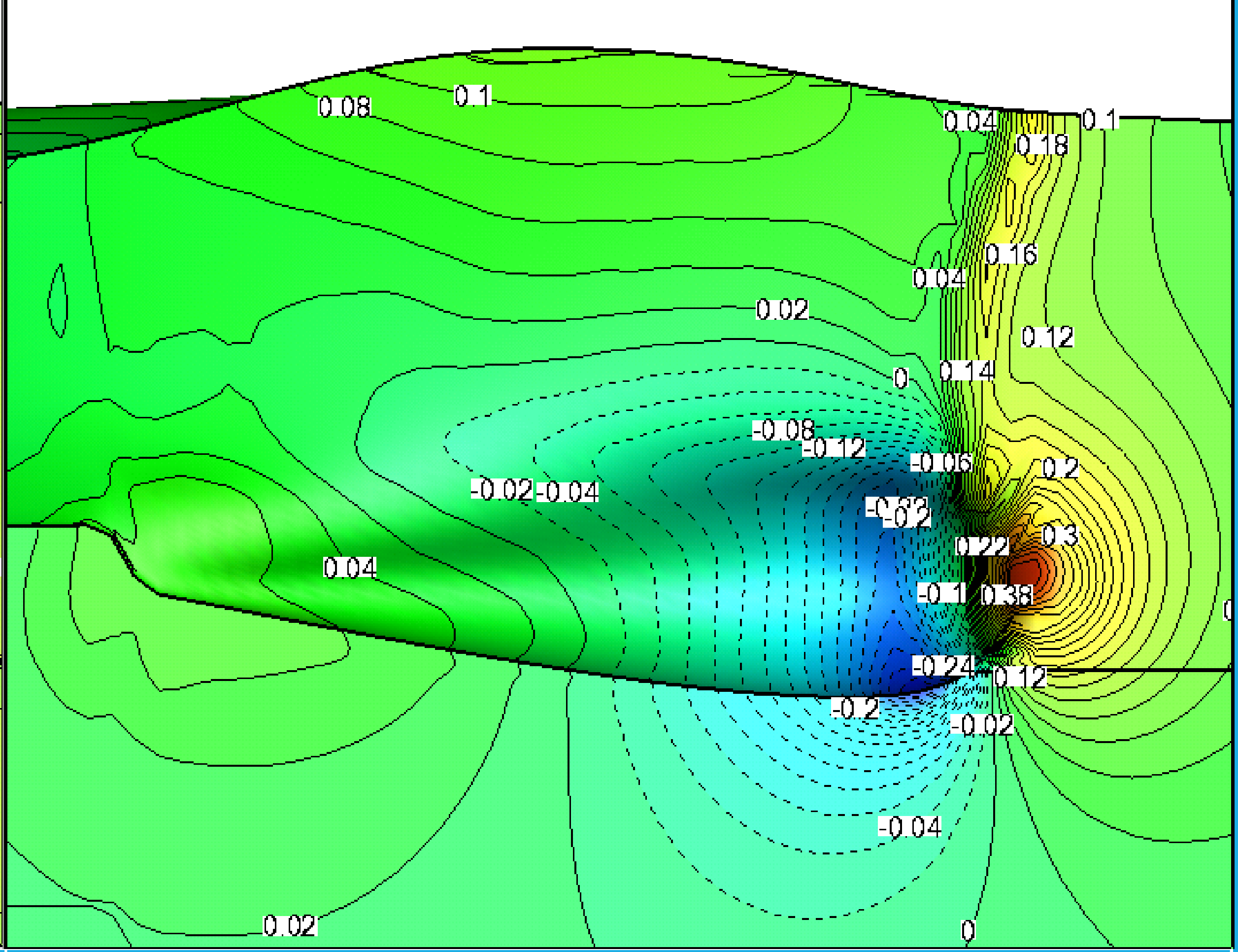
Comparison of the flow results between refined and non refined grid in the sonar dome region



Pressure results in sonar region for Fn = 0.28

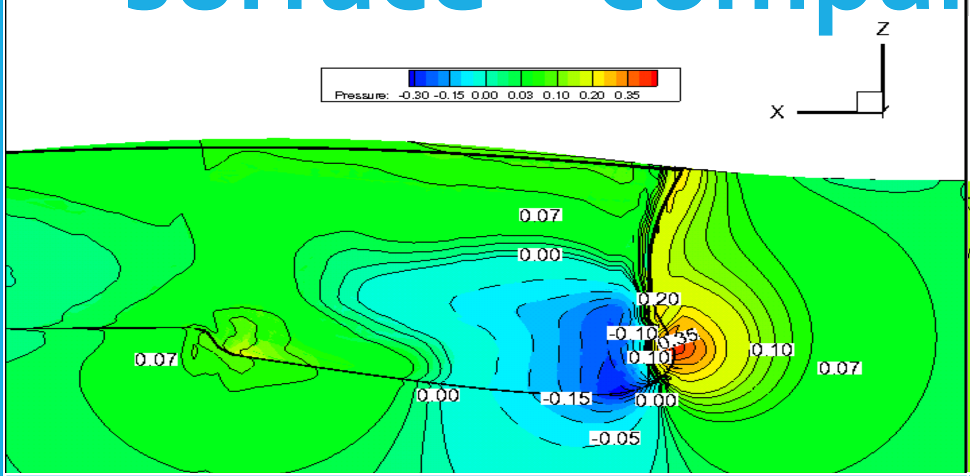
no refined, contour levels = 39



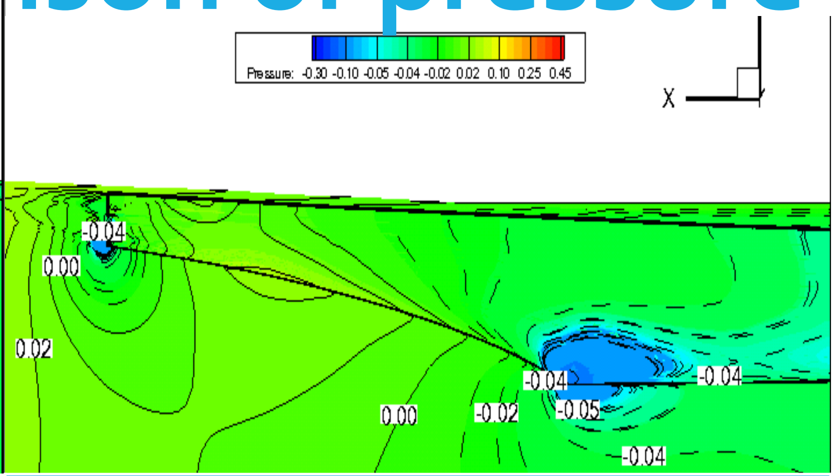
Pressure results in sonar region for Fn = 0.28

refined, contour levels = 39

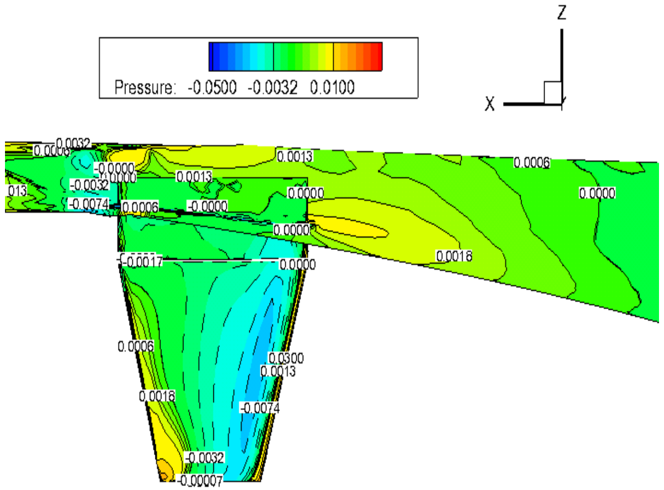
Hybrid viscous solution using potential free surface – comparison of pressure results



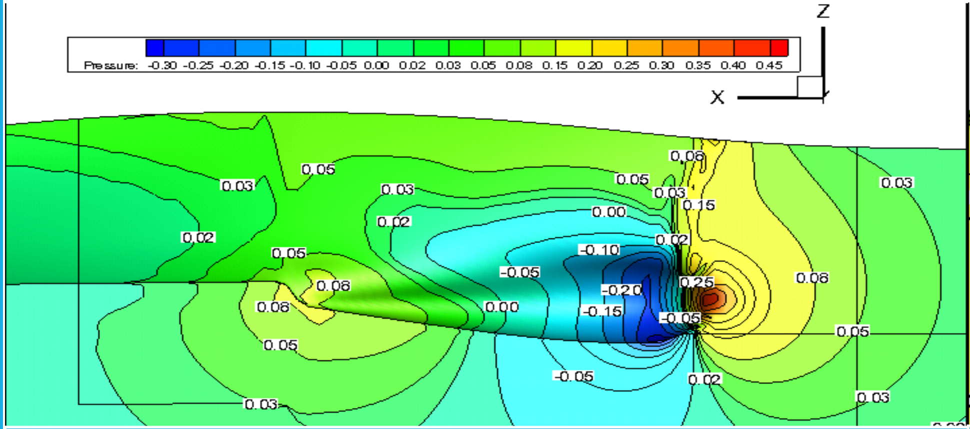
Pressure results at sonar for Fn = 0.28 bare hull



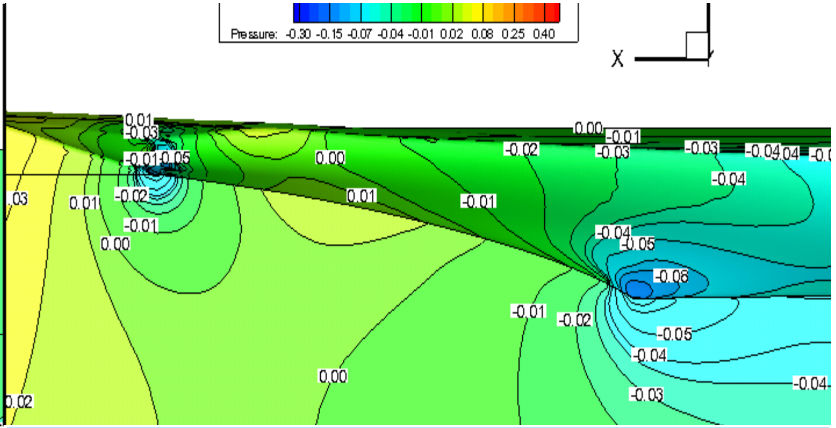
Pressure results in aft region for Fn = 0.28 bare hull



Pressure results in aft region for Fn = 0.28 hull with rudder, bracket and shaft

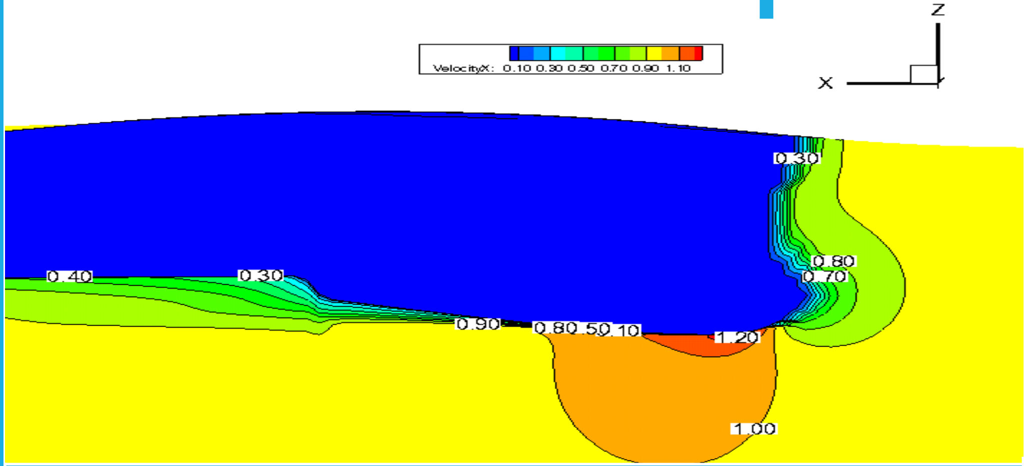


Pressure results at sonar for Fn = 0.41 bare hull

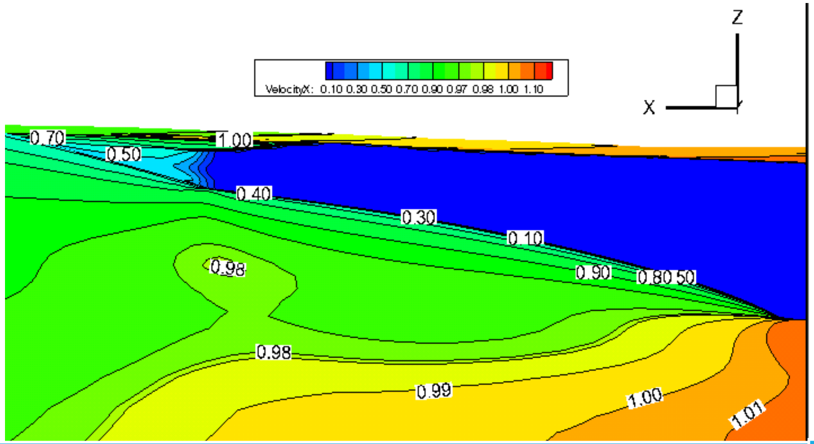


Pressure results at ship aft region for Fn = 0.41 bare hull

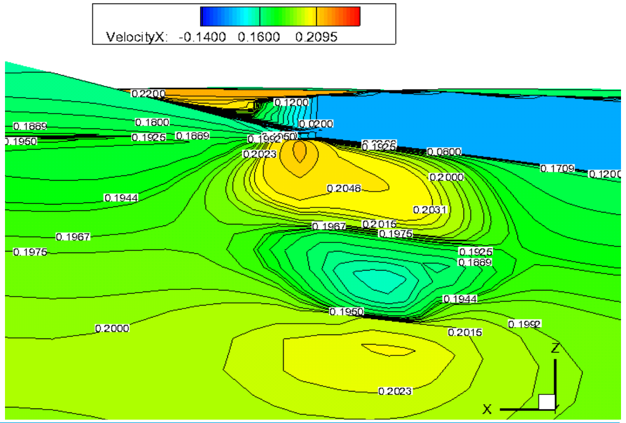
Hybrid viscous solution using potential free surface – comparison of axial velocity results



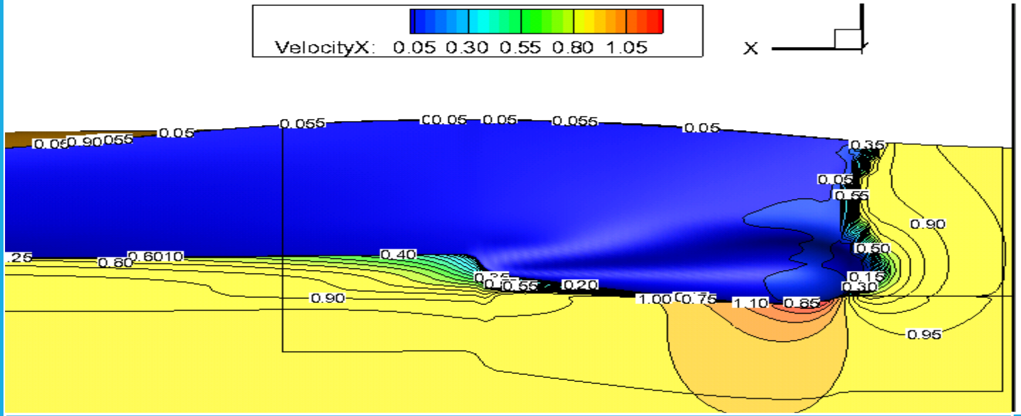
Axial velocity results in sonar region for Fn = 0.28 bare hull



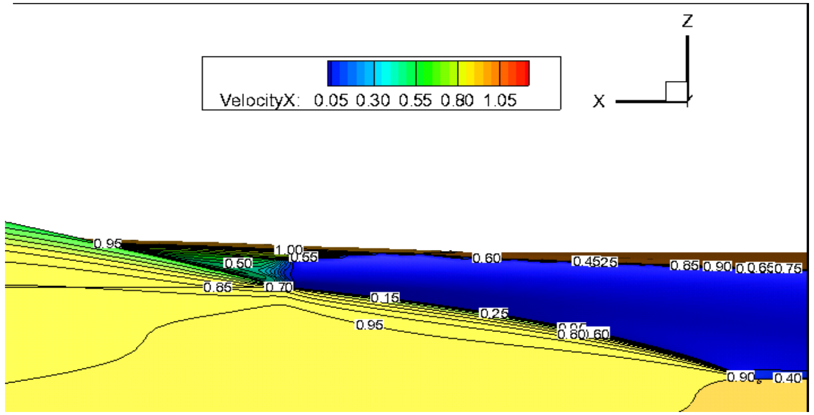
Axial velocity results at ship stern region for Fn = 0.28 bare hull



Axial velocity results at ship stern region for Fn = 0.28 bare hull with rudder, bracket and shaft

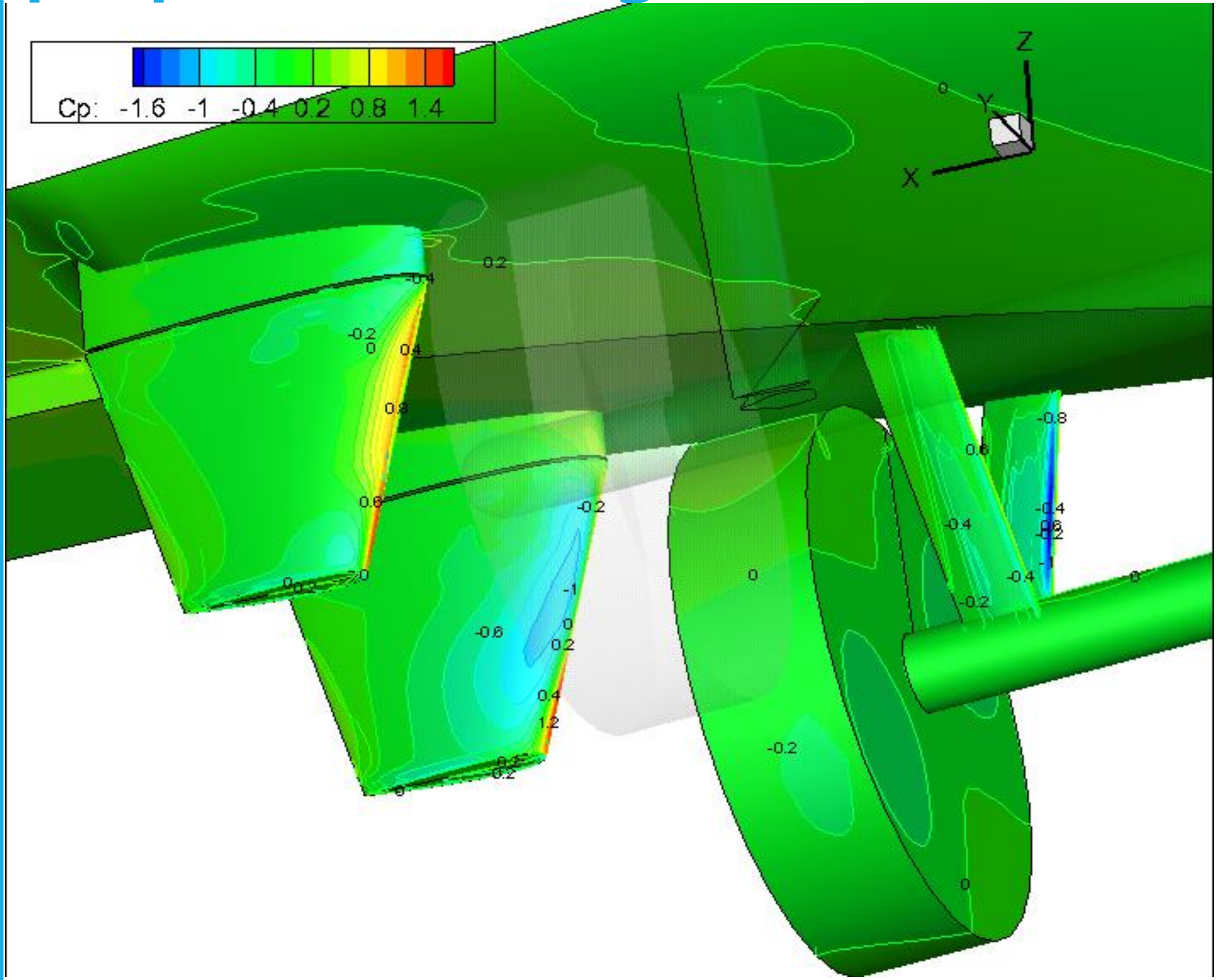


Axial velocity results in sonar region for Fn = 0.41 bare hull

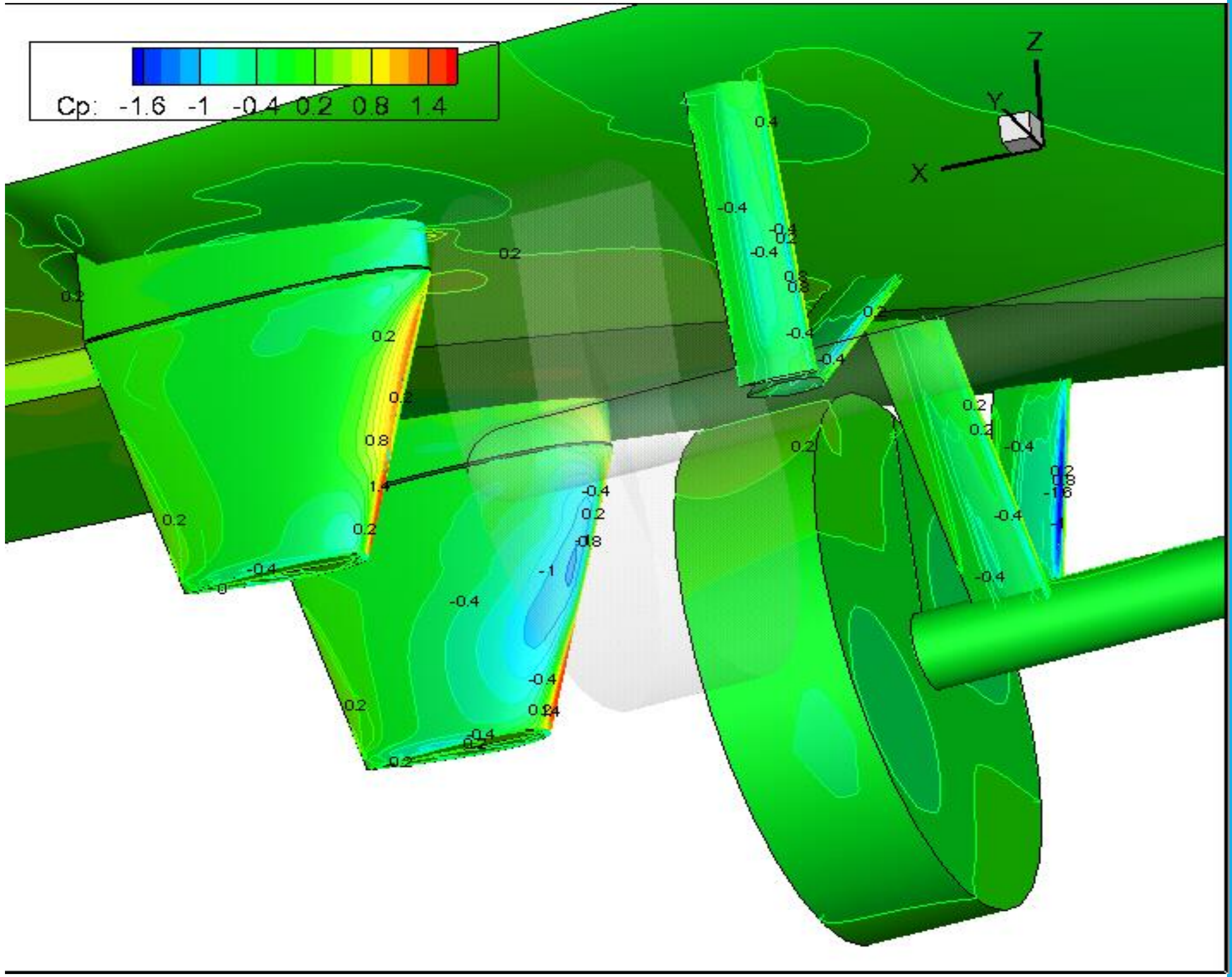


Axial velocity results at ship stern region for Fn = 0.41 bare hull

Comparison between pressure of appended solutions and appended with propeller with two different Fn around the propeller disk region

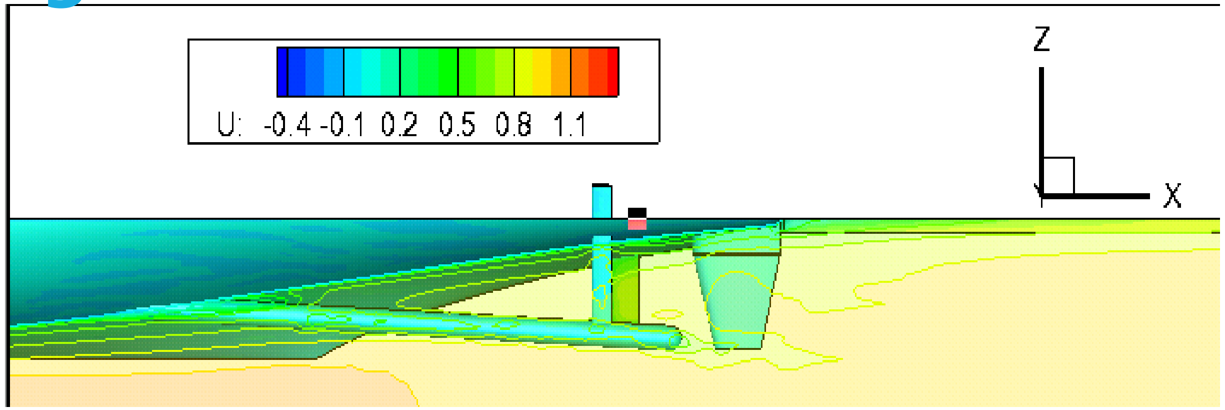


Pressure distribution around the hull at Fn = 0.28
with appendages and propeller

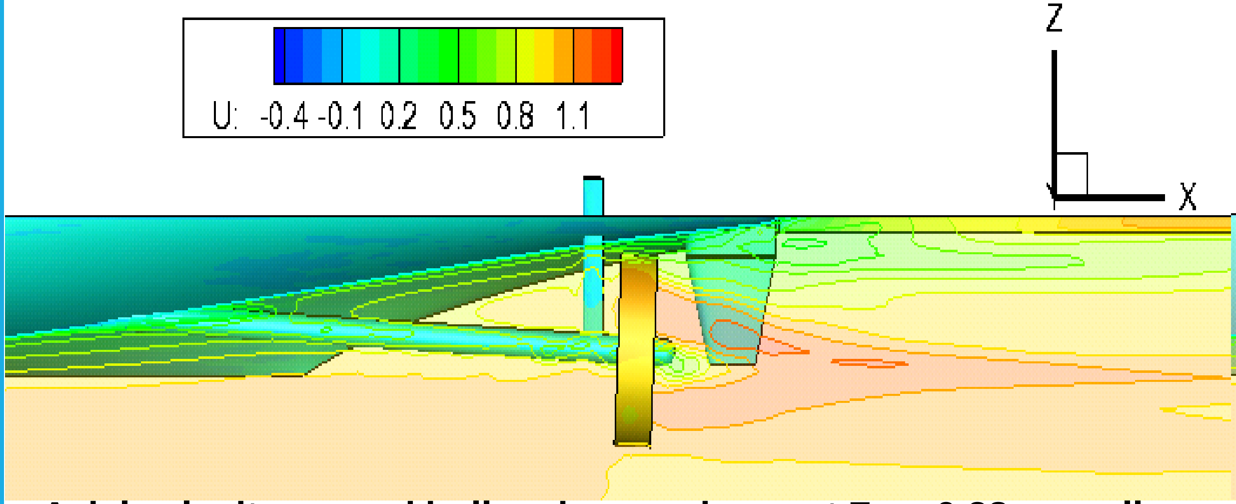


Pressure distribution around the hull at Fn = 0.41
with appendages and propeller

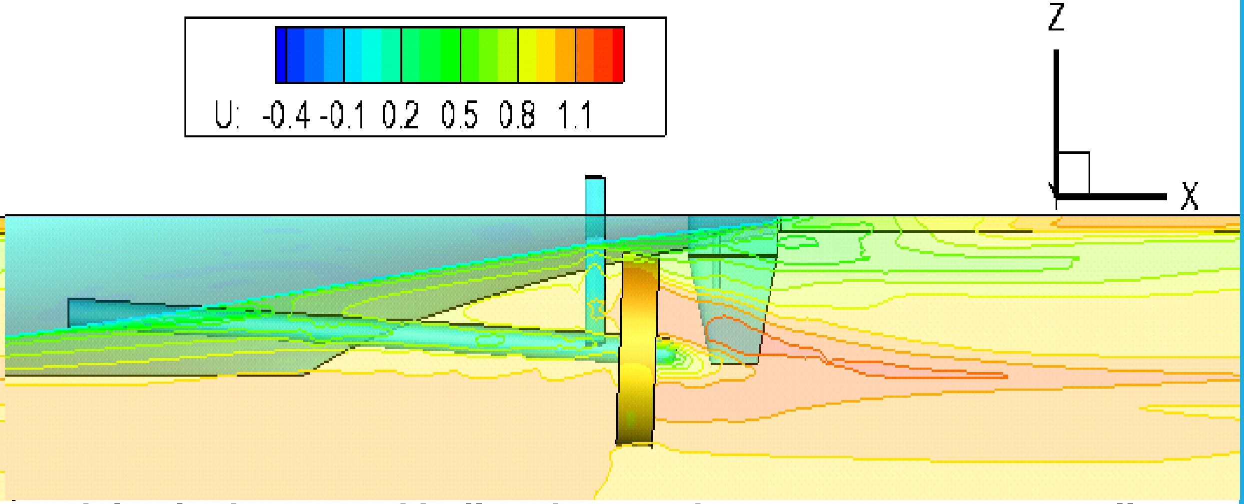
Comparison between axial velocity of appended solutions and appended with propeller with two different Fn around the propeller disk region



Axial velocity around hull and appendages at Fn = 0.28 no propeller - slice on rudder shaft

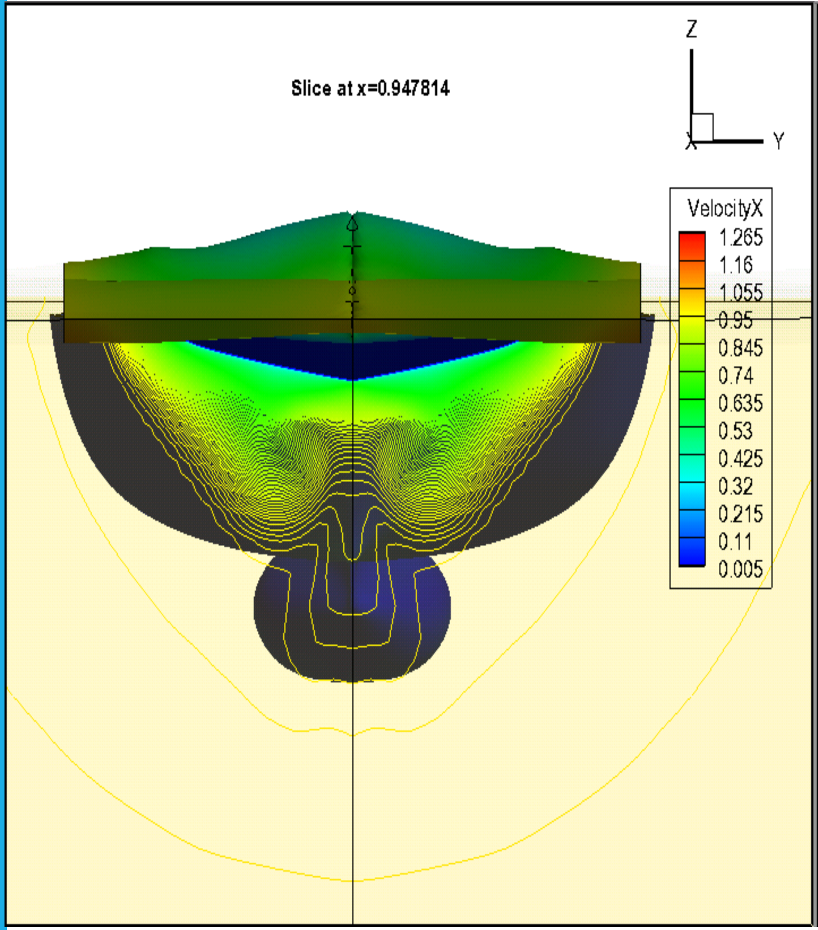


Axial velocity around hull and appendages at Fn = 0.28 propeller slice on rudder shaft

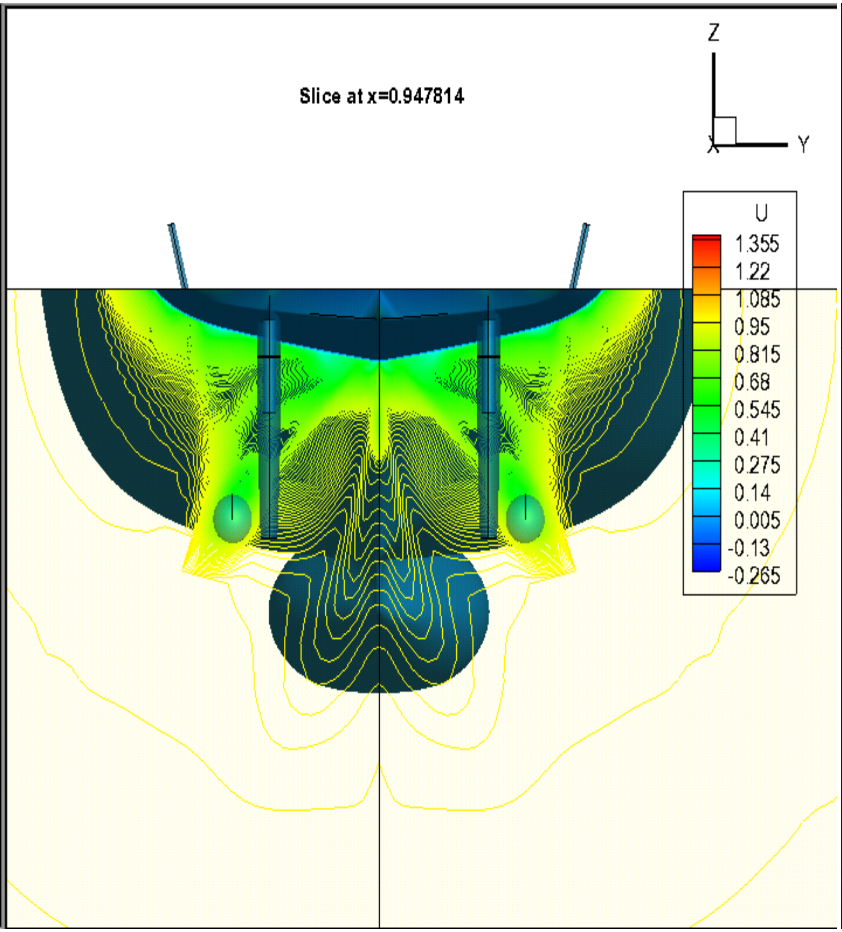


Axial velocity around hull and appendages at Fn = 0.41 propeller - slice on rudder shaft

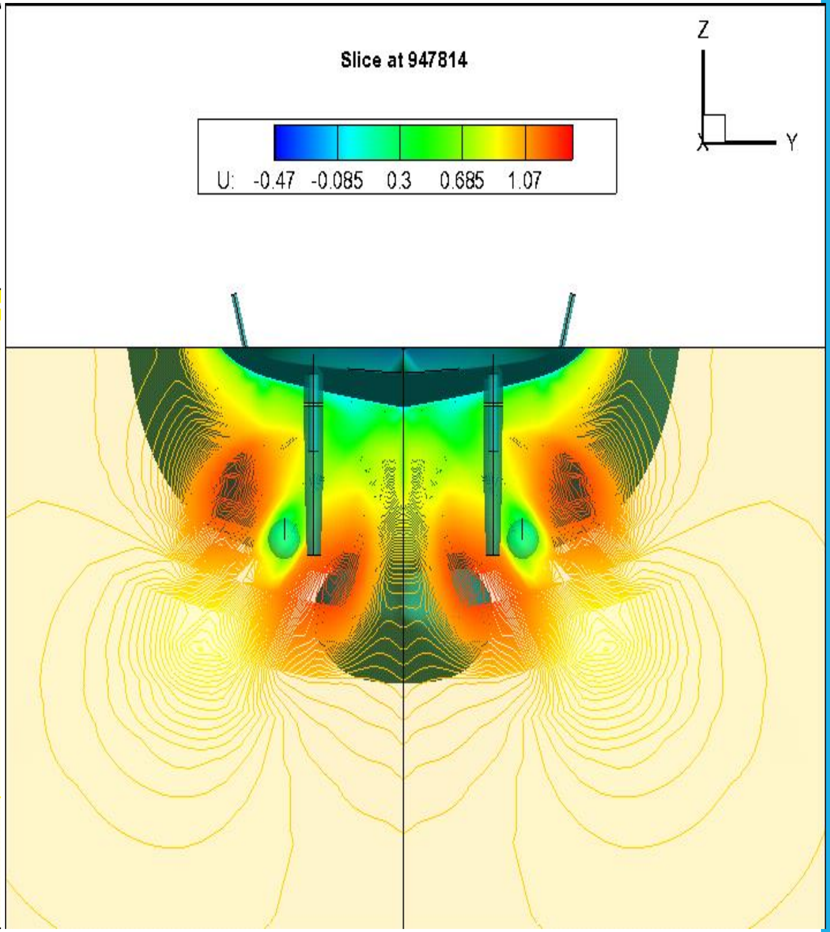
Comparison of axial velocities on the propeller plane at Fn=0.28



Axial velocity at the propeller slice x=0.95 at Fn=0.28 – bare hull



Axial velocity at the propeller slice x=0.95 at Fn=0.28 - hull with appendages



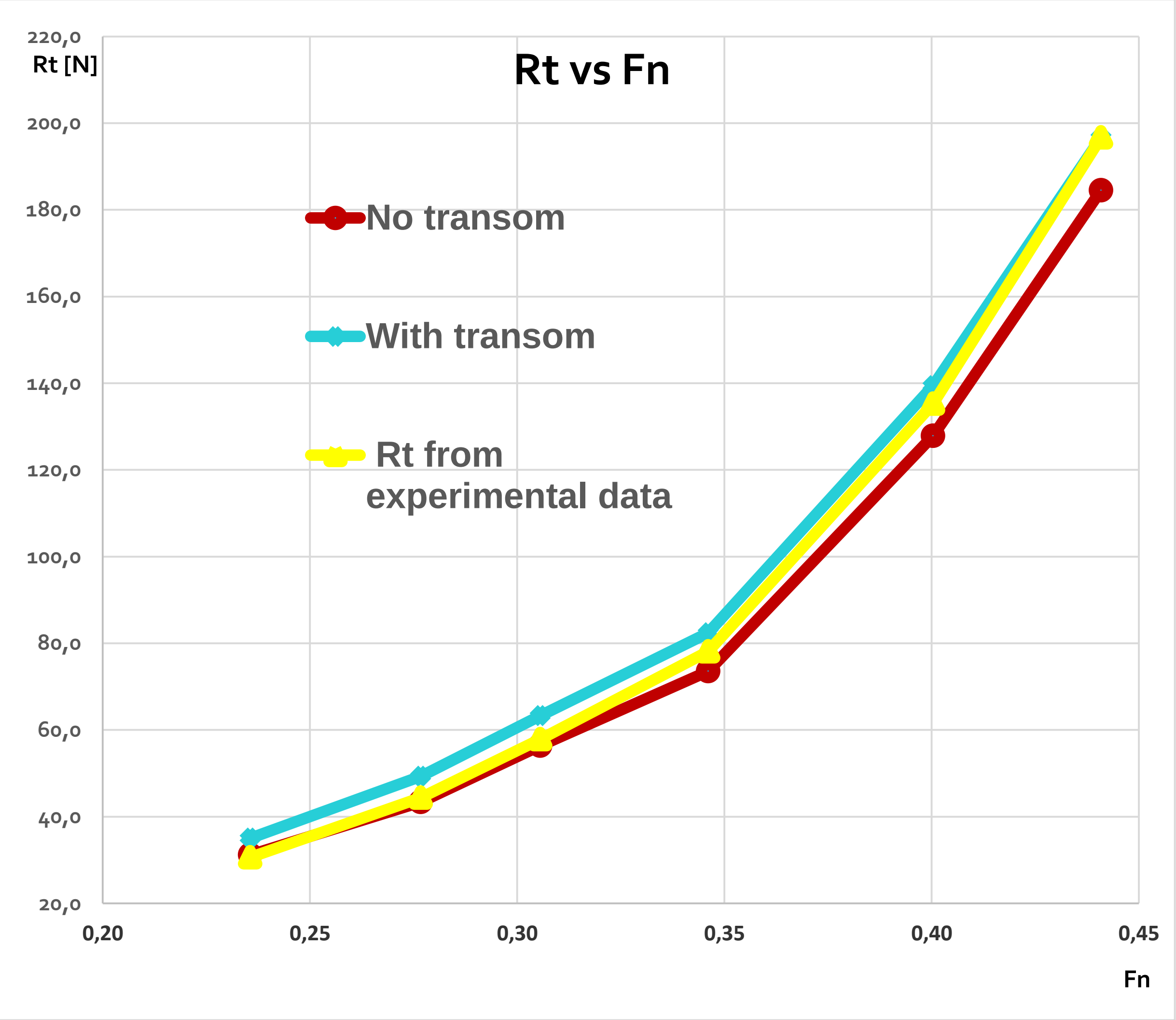
Axial velocity at the propeller slice x=0.95 at Fn=0.28 - hull with appendages and propeller

The strong contra rotating vortexes created from the sonar dome traveling through the ship's hull interfere with appendages and the addition of the propeller actuator disks further complicates the axial velocity distribution.

Accuracy of the solution is around 3% for most of the cases of potential flow solution except Fn=0.35

General Table of the resistance under potential flow

			Case 1		Case 2	
		Experimental	No transom		Transom	
Speed =Fn.sqrt(gL)	Froude	results [N]	Value	% difference from Experimental data	Value	% difference from Experimental data
1.76	0.24	30.6	31.2	1.93%	35.0	14.51%
2.07	0.28	44.3	43.4	-2.12%	49.3	11.10%
2.29	0.31	57.9	56.3	-2.69%	63.3	9.32%
2.59	0.35	78.1	73.6	-5.81%	82.4	5.52%
2.99	0.40	135.3	127.8	-5.53%	139.4	3.03%
3.30	0.44	196.7	184.5	-6.20%	196.6	-0.02%



Found workarounds and reported bugs in SHIPFLOW Software

- Found bugs which break the solution at certain Froude numbers in the software and reported to the support team of SHIPFLOW version 4.6.00-x86_64.

- A workaround of the problematic Froude numbers was found with inserting dummy values after wanted Froude numbers get from experimental results. This gives correct solution for potential flow with XBound and later it can be used for viscous computation. Example:

```
vshi(fn=[0.350032],rn=[1.04e+007])
/instead of vshi(fn=[0.35],rn=[1.04e+007])
Gives good solution for Xbound and CF – skin friction coefficient.
```

Found workarounds and reported bugs in SHIPFLOW Software

- Other problem with “BRACKET” command was found with the using of section option, which blocks the software and it was also reported, and confirmed from the support team of SHIPFLOW FLOWTECH software. This error will be fixed for next version of the software product and workaround for now is to use “RUDDER” command with replacement of “from” and “to” to “span” and “origin” and for the angle is used ANGLE, CANT and TILT.
- Example:

```
rudder ( id="ax_carma", s=[0,1], c=[0.01488,0.01488], span=0.085837,
dimension=[51,51,48], orig=[5.5640,0.1248,0.134163], rmax=1.6,  section=["ax"])
/ Instead of  brack ( id="ax_carma", s=[0,1], c=[0.01488,0.01488], dimension=[51,51,48],
/           from=[5.5640,0.1248,0.134163], to=[5.5640,0.1248,0.22], rmax=1.6,
/         section="ax") gives good results for simulating hull with appendage bracket
```

- All good results and also bad are reported to support team of the software product with great appreciation of their help.

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- SHIPFLOW software captures well the main structures and characteristics of the flow in complex hulls with appendages and predicts total resistance allowing towing tank alternative.
- Results for combatant benchmark case were capturing reasonably well the free surface wave elevation with main Kelvin wake pattern developed by the hull.
- Potential flow theory determined the free surface elevation successfully, and it is used as a starting point for further investigation with viscous flow theory. Observation during the simulation is to use for free surface elevation computation the cases without transom for smaller Froude numbers, and cases with transom for bigger Froude numbers. This gives less than 3% deviation from the experimental data except for the Froude number 0.35, there the deviation is around 6%.

Conclusion

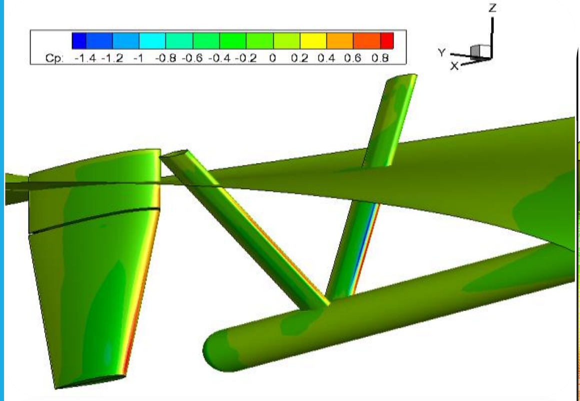
- Hybrid methodology allows incorporating free surface flow solution from potential flow into viscous flow computation.
- Viscous computation of the software helps understanding of interferences between developing vortexes from the sonar dome and the complicated interactions at the stern region of the ship.

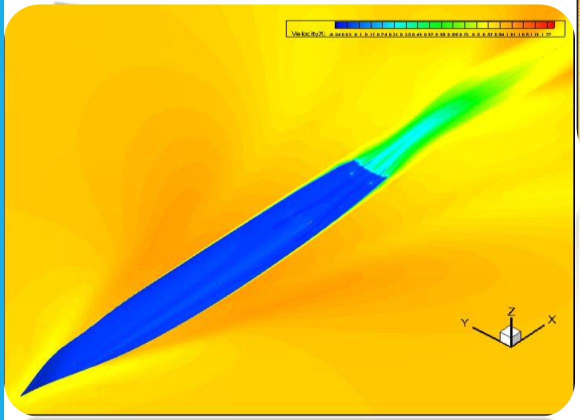
CFD has future in the ship research problems.

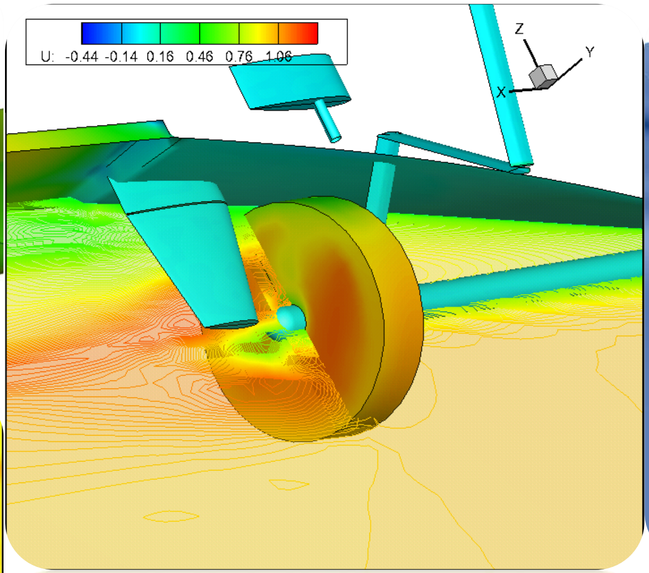
Quotes:

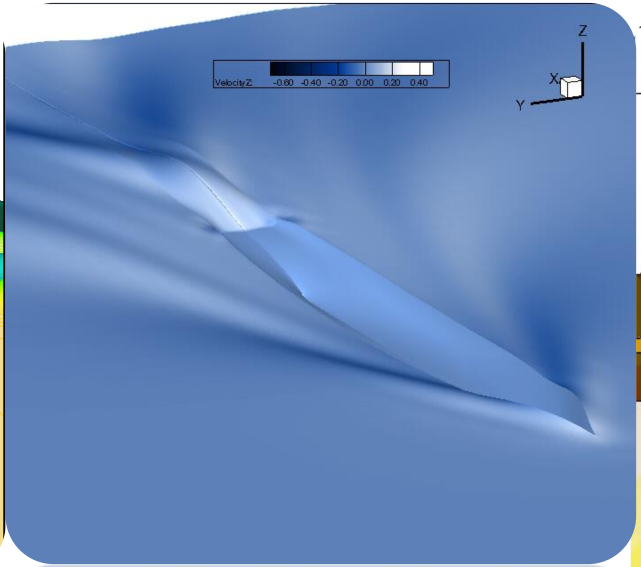
“There should be no such thing as boring mathematics. ” - Edsger Dijkstra

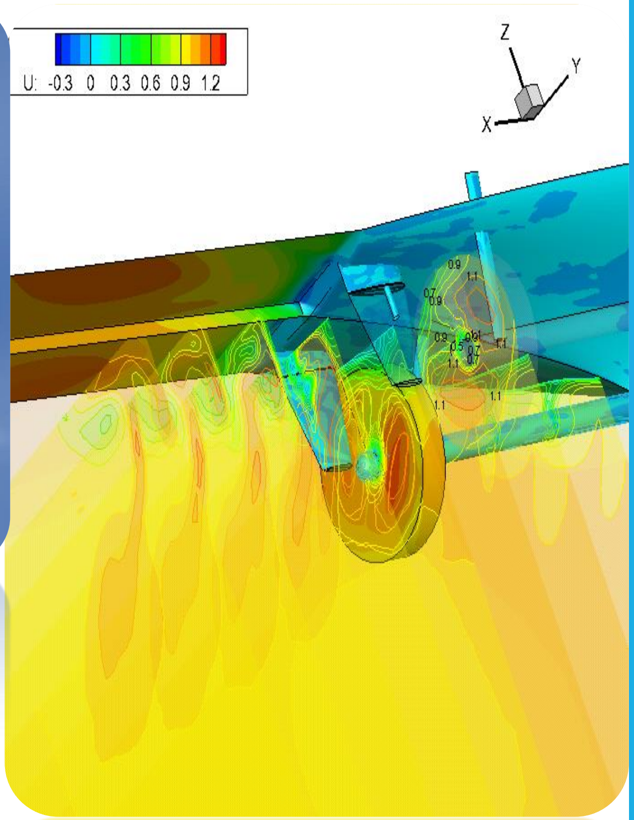
“Do not worry about your difficulties in mathematics. I can assure you mine are still greater.” - Albert Einstein











Thank you for the attention!

Svetlozar Neykov (sinmania@abv.bg)