Ocean Engineering Group (OEG)/EWRE

(August 21, 2019)

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Kinnas Home Page
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Research in the area of computational hydrodynamics with applications on the prediction of performance and design of high-speed marine propulsors or turbines, modeling of cavitating or separated flows, and wave/body interaction.

Teaching:

- ***CE358: Introductory Ocean Engineering (Fall '19 - 12:30-2:00, Tu & Th)***
- ***CE319F: Elementary Fluid Mechanics***
- ***CE380P.4: Boundary Element Methods***
- ***CE380T: Computational Envir. Fluid Mech. (Fall '19 - 9:30-11:00, Tu & Th)***
- ***CE397-32: Theory of Propellers and Turbines (Spring '20 – tent.)***

Facilities:

- ***CHL (Computational Hydrodynamics Laboratory) in ECJ 8.502***

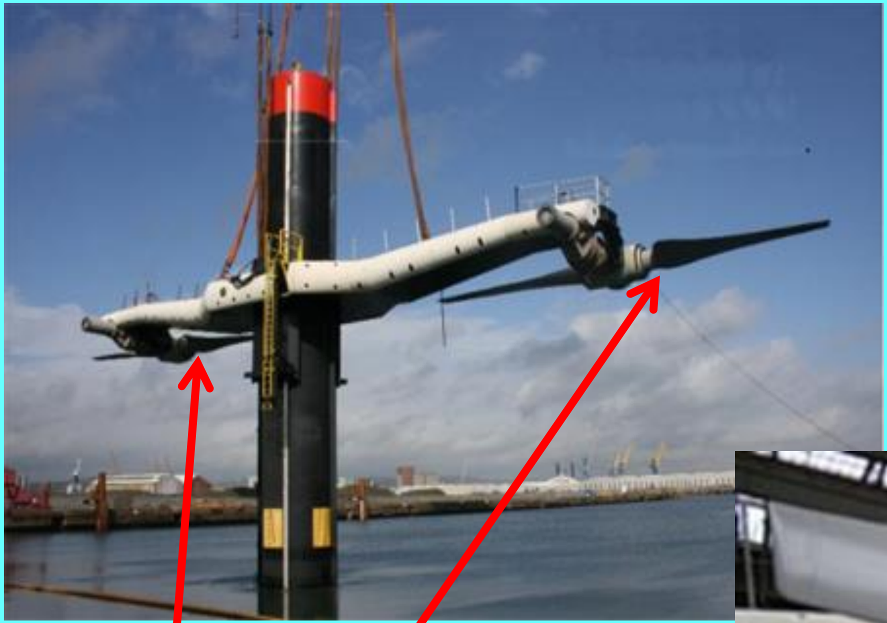
Fuel-Efficient marine propulsors …

Must comply with new EEDI (Energy Efficiency Design Index) regulations on CO_2 emissions from newly built ships

Contra-rotating props

Ducted prop

…and some water-turbines (used to generate energy from ocean currents)

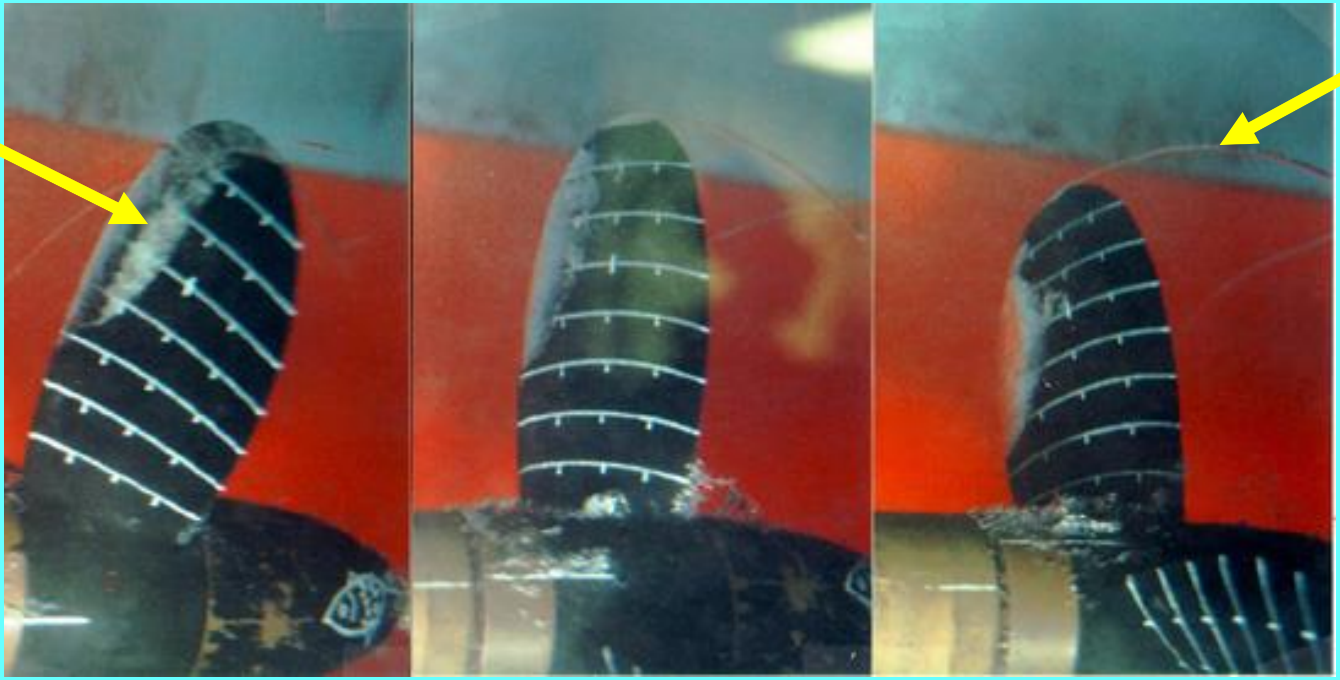


Twin turbines (each 0.6 MW) pulled out of the sea for maintenance

For high-speed propellers cavitation is often inevitable

Sheet Cavity

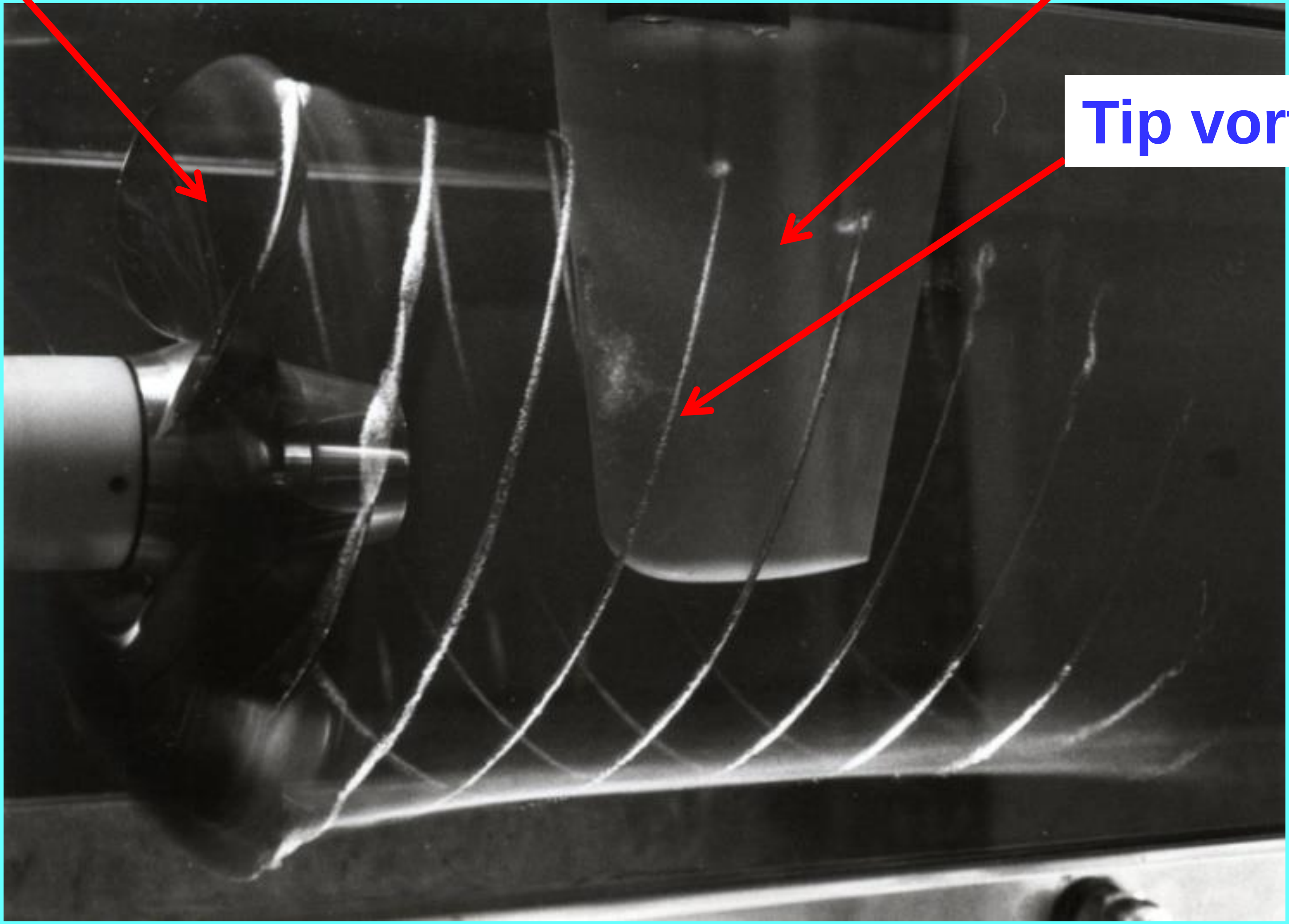
Tip vortex



- **Cavitation can accelerate erosion of blades, produce noise, or result in sudden loss of thrust**
- **However, allowing for some cavitation can increase efficiency**

Rotating components interacting with stationary ones

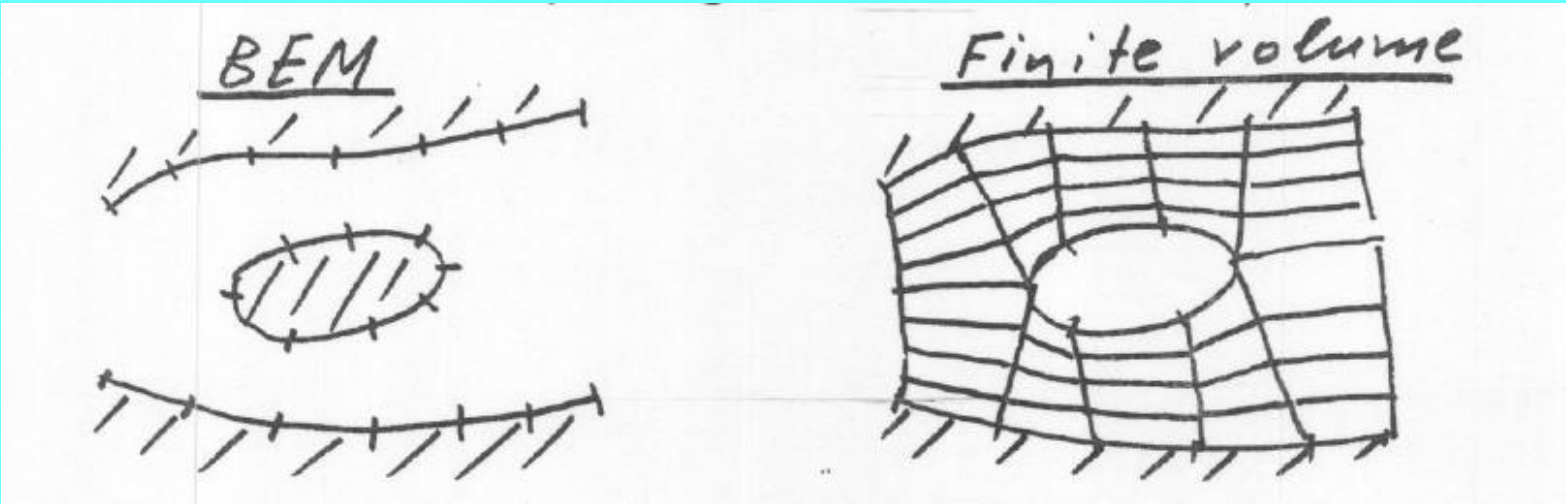
(propeller) (rudder)



Two methods to model flow

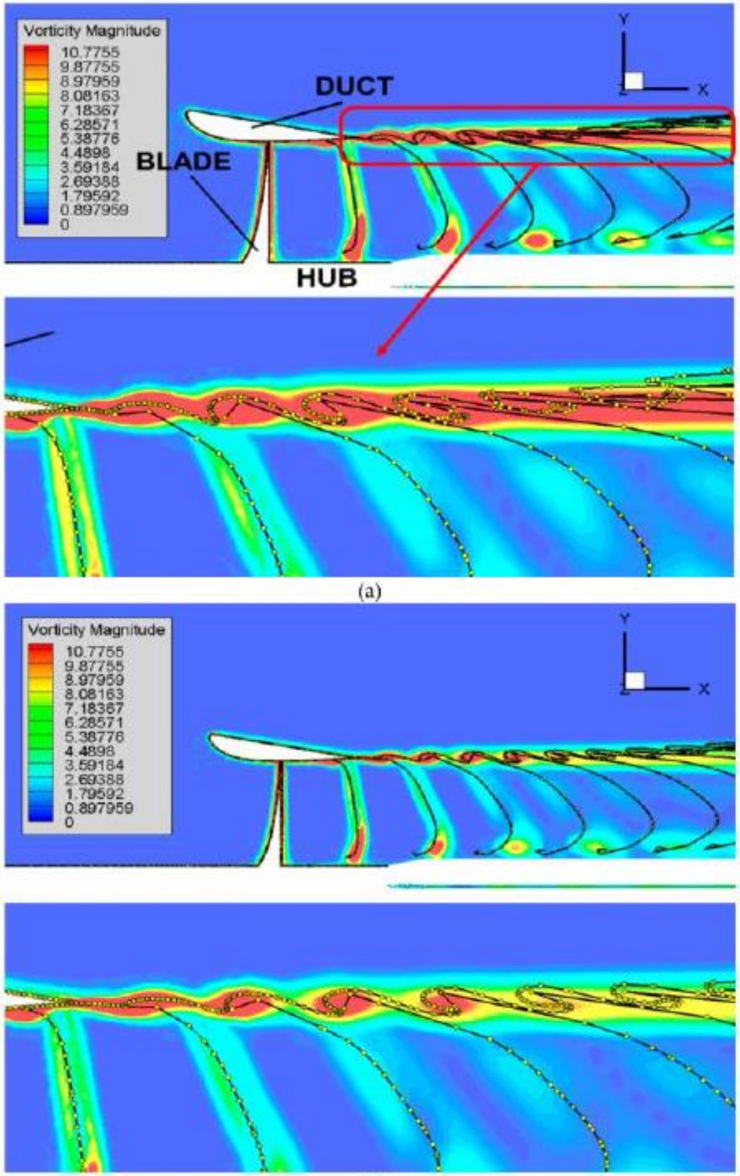
Boundary Element (or Panel) Method (addressed in CE380P.4)

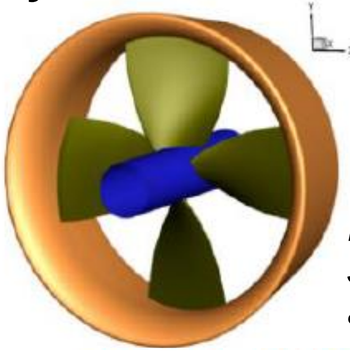
Finite Volume Method (addressed in CE380T)



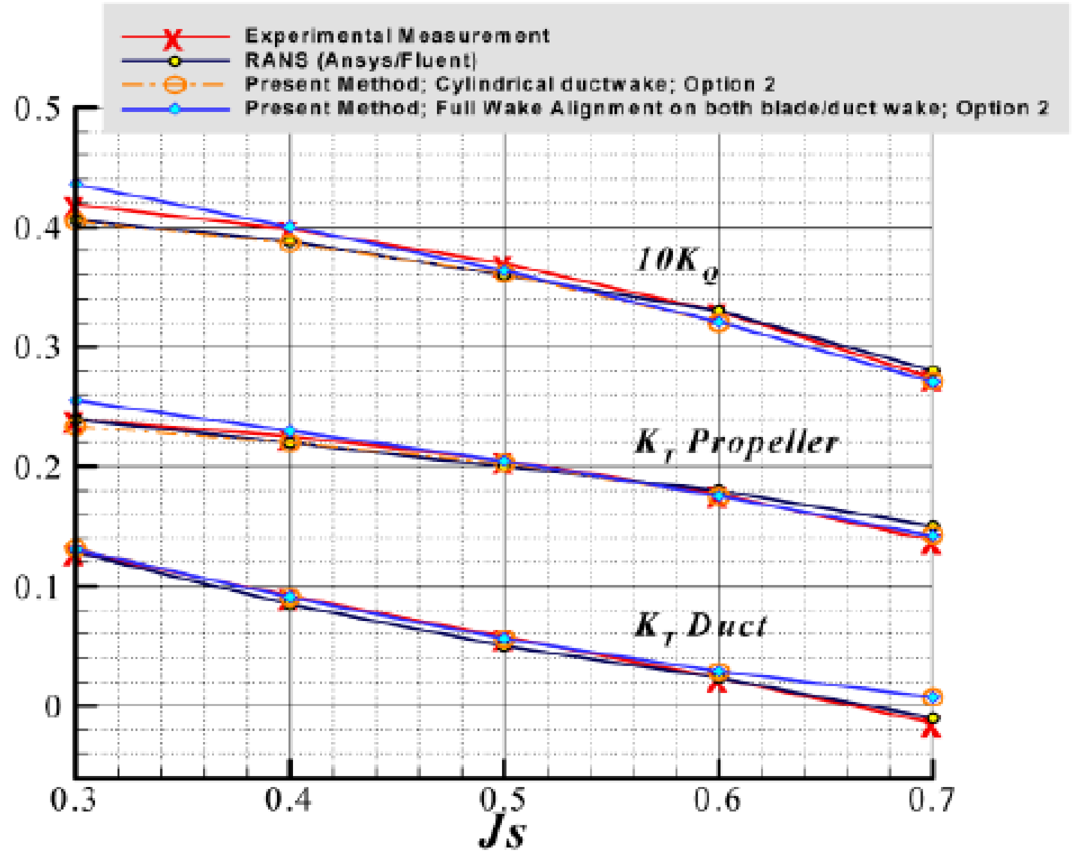
- **BEM can only handle the inviscid part of the flow (i.e. NOT very close to boundaries). The effects of viscosity are included via coupling with integral boundary layer methods**
- **FVM needs a very large number of cells to resolve the whole domain (especially the boundary layer) within acceptable accuracy**

Ducted propeller flow/performance predicted by BEM (vorticity location shown in black) FVM (vorticity shown in color)



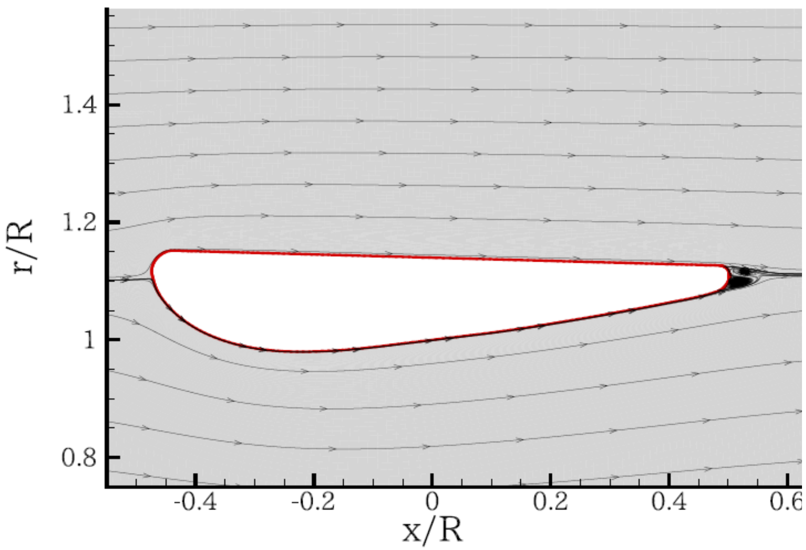


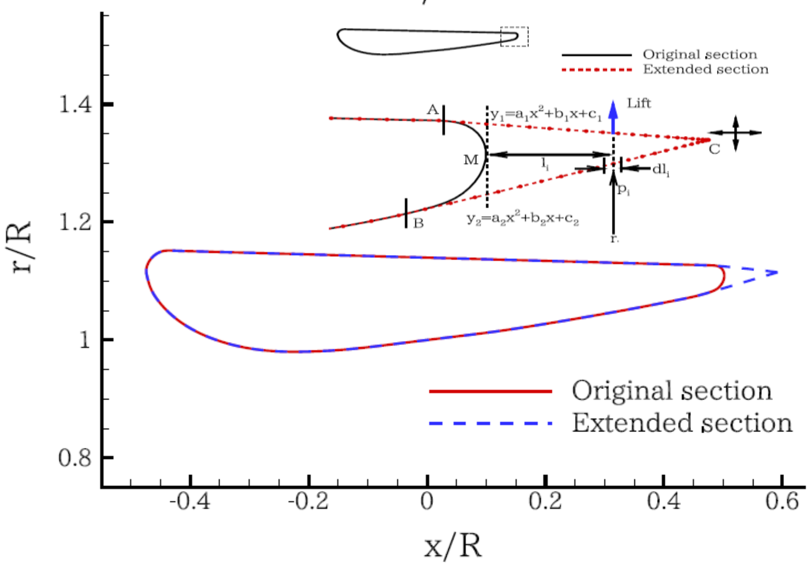
Kim, Kinnas & Du
Journal of Marine Science and Engineering, 2018



How to handle duct/blade sections with blunt TE?

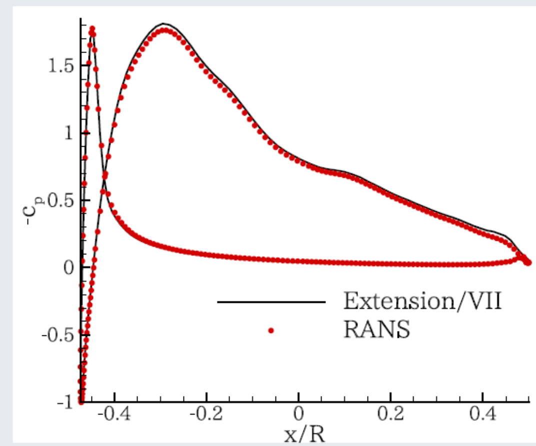
Du & Kinnas, Journal of Fluid Mechanics, 2019



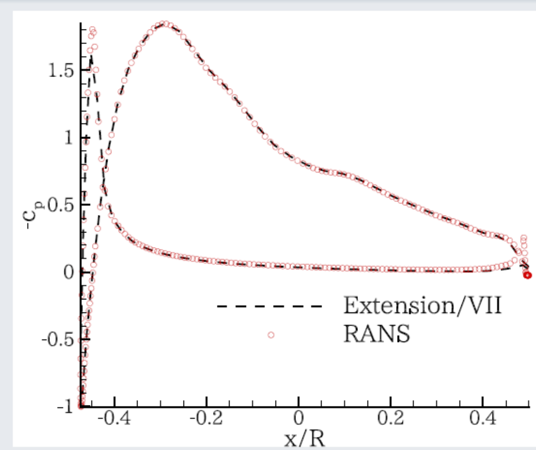


Pressure distributions

$Re = 1.0 \times 10^6$

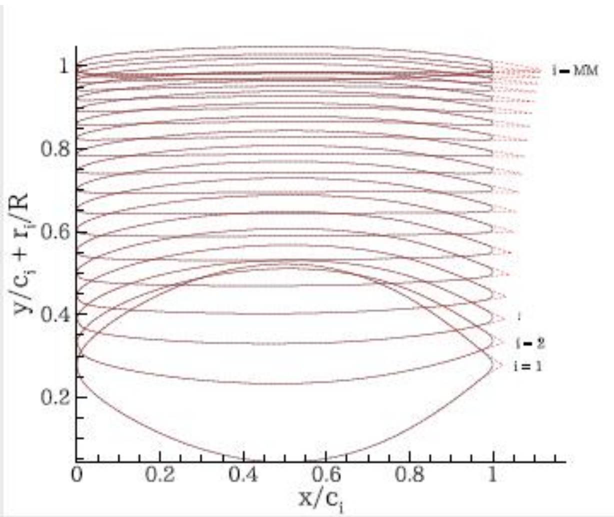


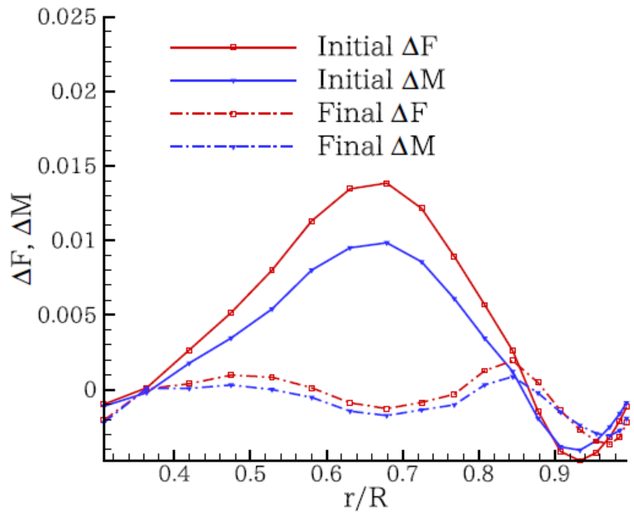
$Re = 1.0 \times 10^7$

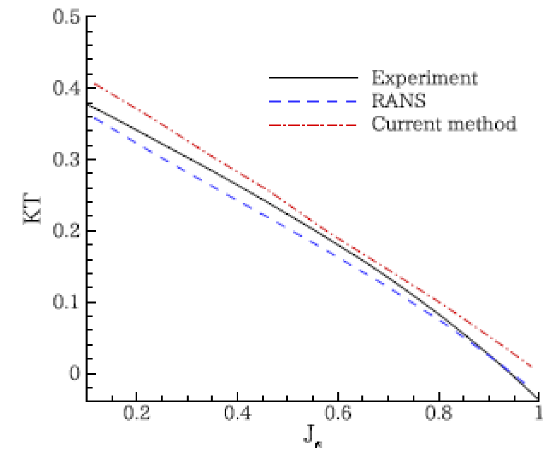


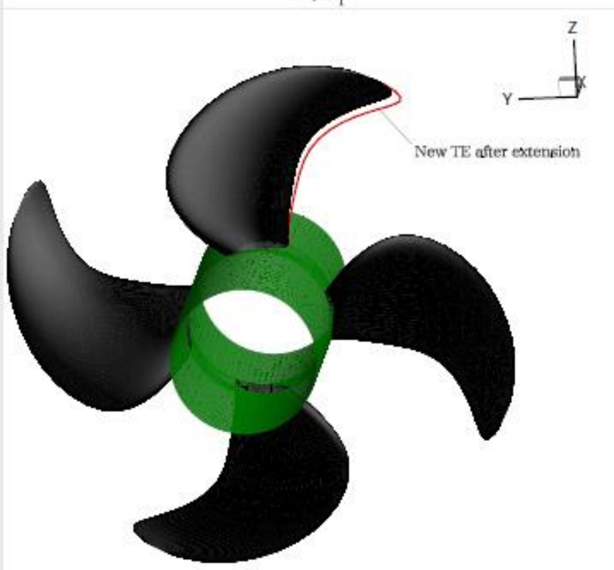
Our extension model applied to propellers

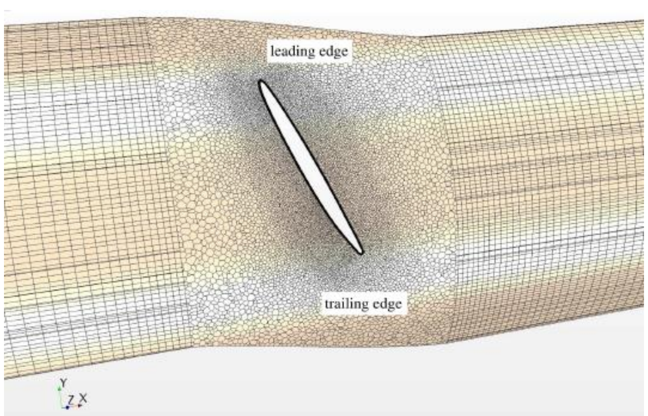
Du & Kinnas, smp'19 ; Du PhD OEG/UT, 2019

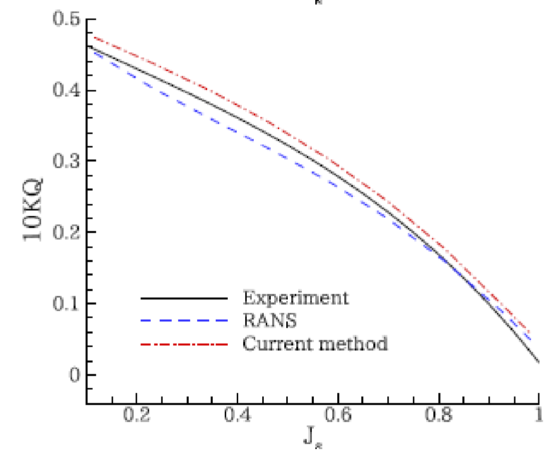




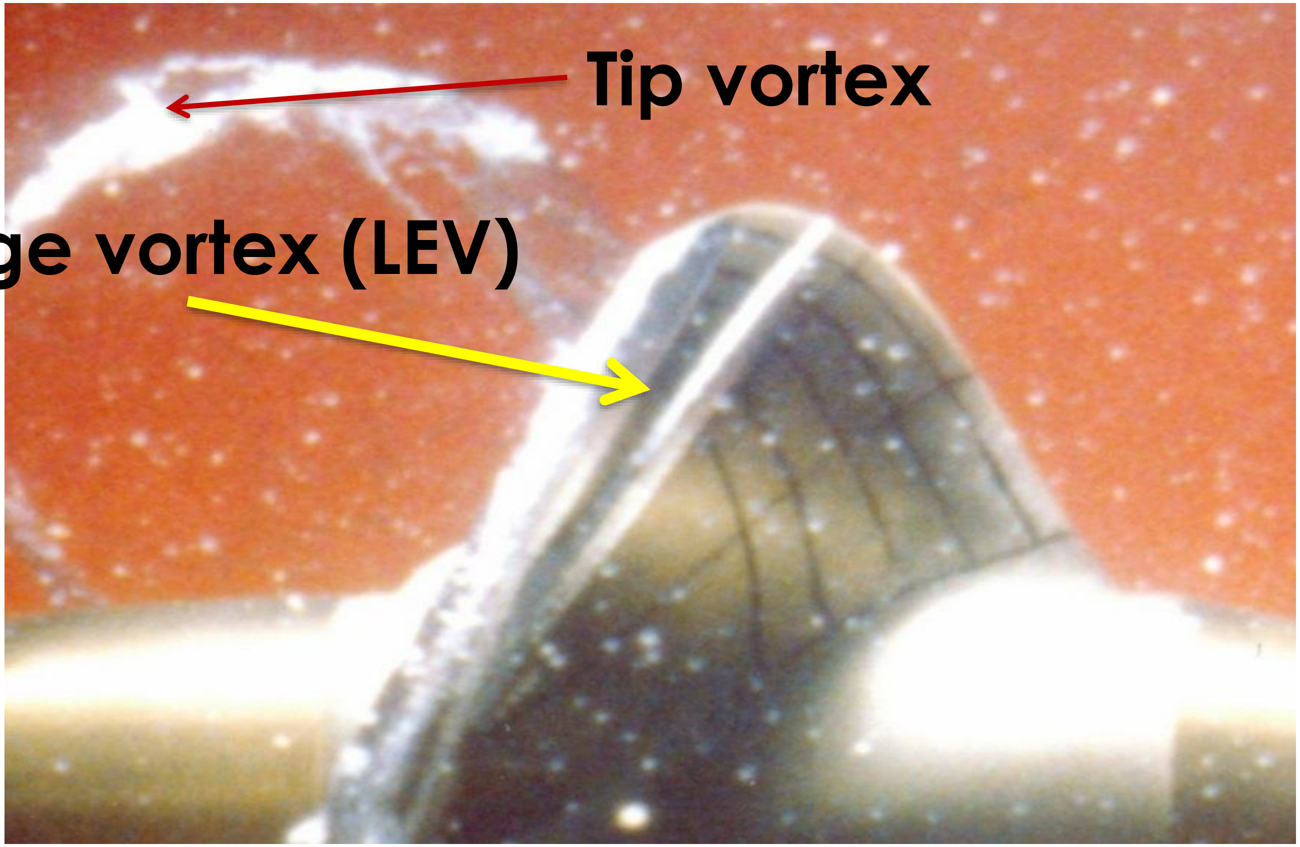








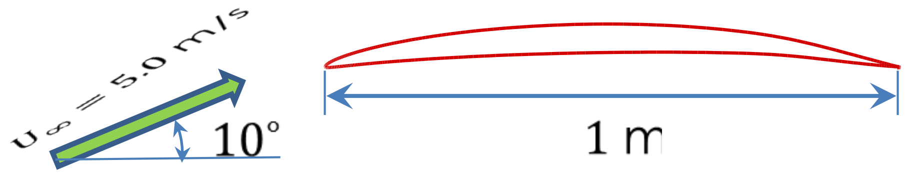
A VIScous Vorticity Equation (VISVE) Model for Propeller at Off-Design with Leading Edge Vortex (LEV)



IMPORTANT FACT: Vorticity ($\omega = \nabla \times q$) vanishes much faster than velocity (q) away from the blade

VISVE APPLIED TO AROUND HYDROFOIL AT AN ANGLE

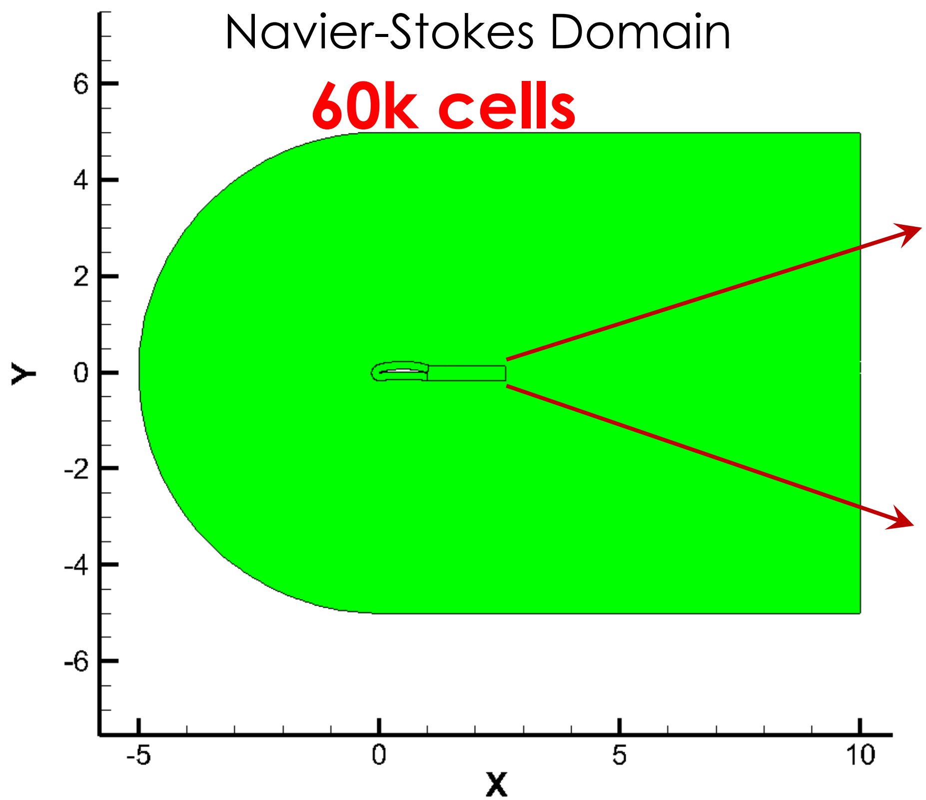
- **2D hydrofoil at high angle of attack**



$Re = 5 \times 10^4$

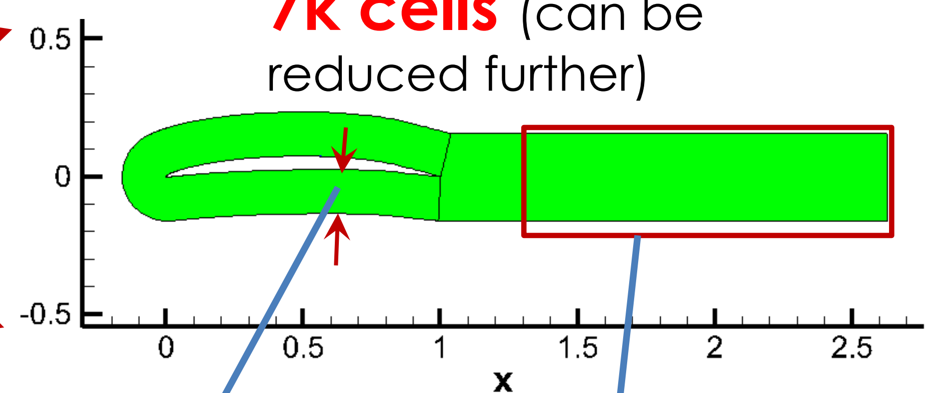
Navier-Stokes Domain

60k cells



VISVE Domain

7k cells (can be reduced further)



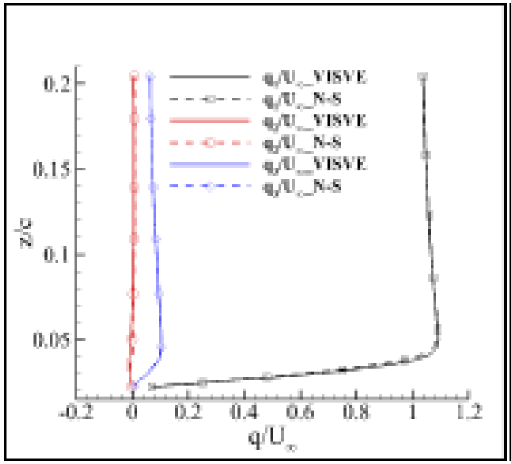
# of layers of cells can also be reduced.

This region is NOT necessary and will be replaced.

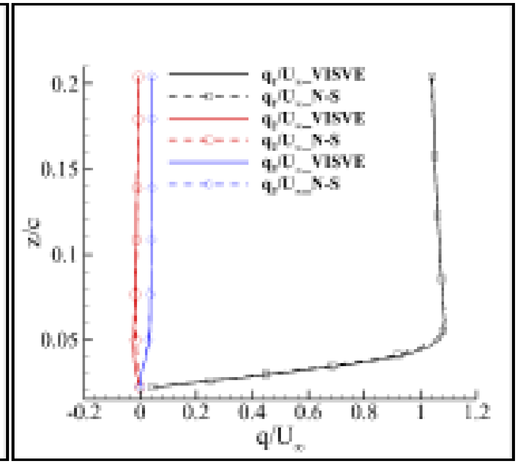
VISVE applied to 3-D Hydrofoil of elliptic planform

Wu & Kinnas, smp'19

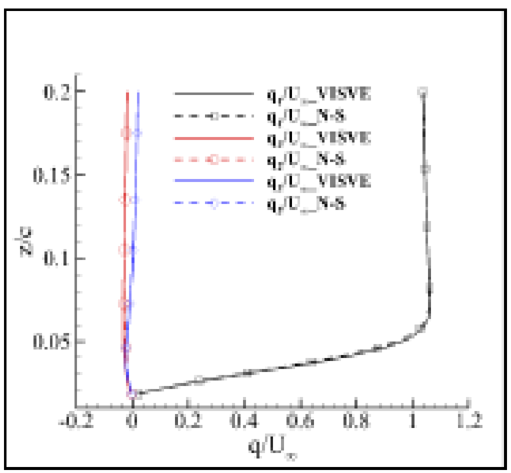
Velocities



21% of chord length



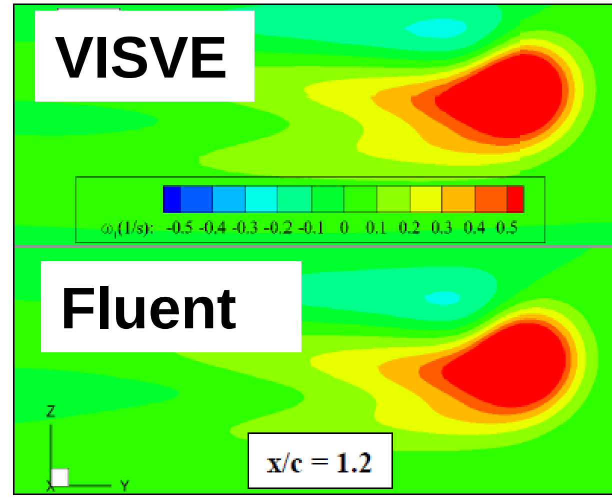
42% of chord length

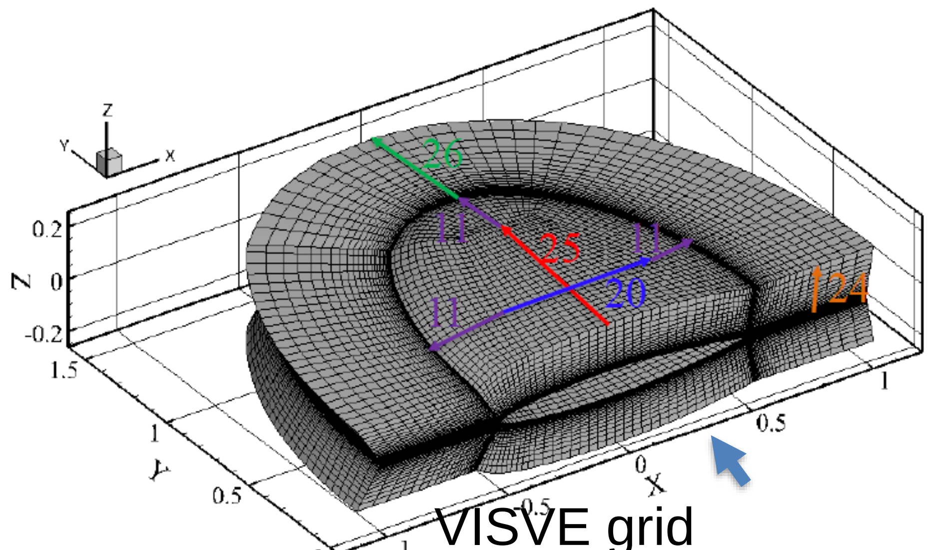


82% of chord length

Comparison on the suction side at span section 88%

Vorticity

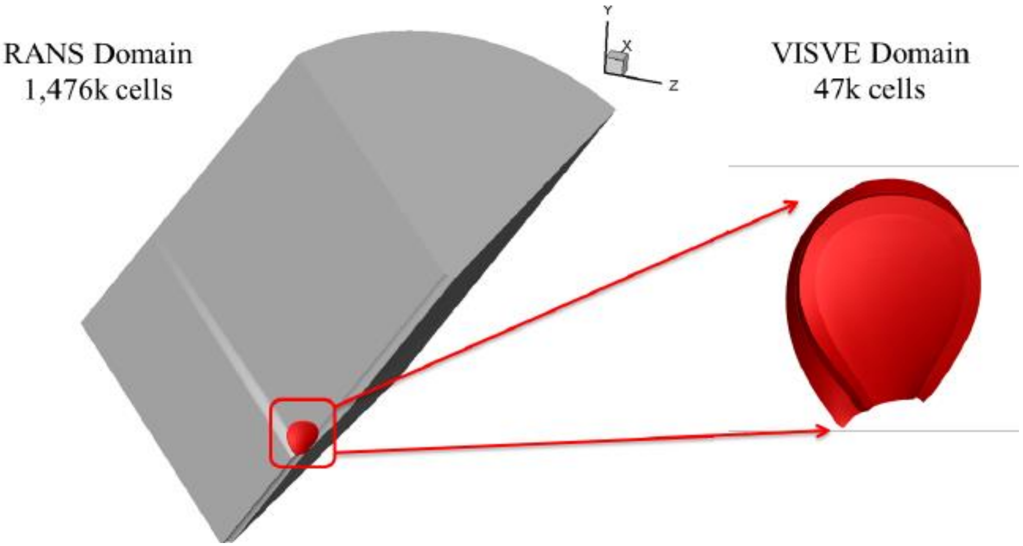


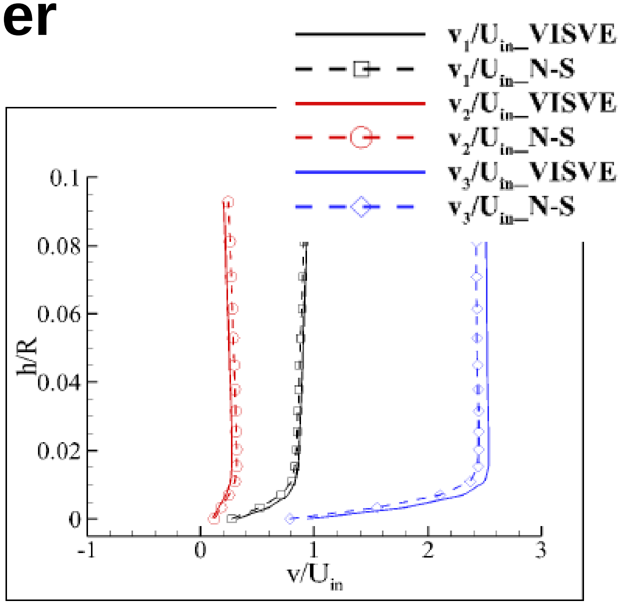


VISVE grid
(only half of the foil is shown)

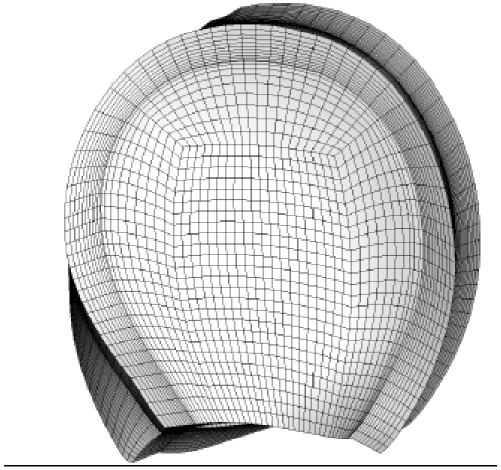
VISVE applied to propeller

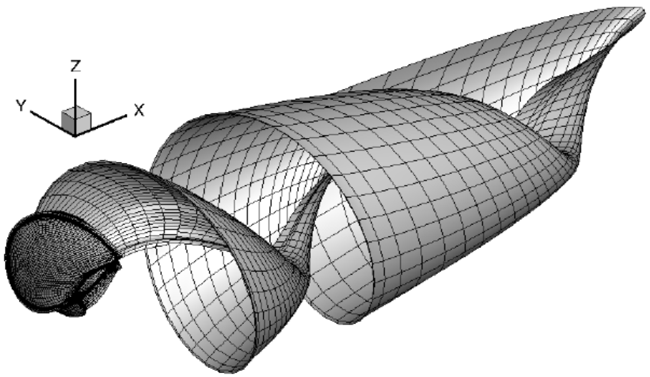
Wu & Kinnas, smp'19

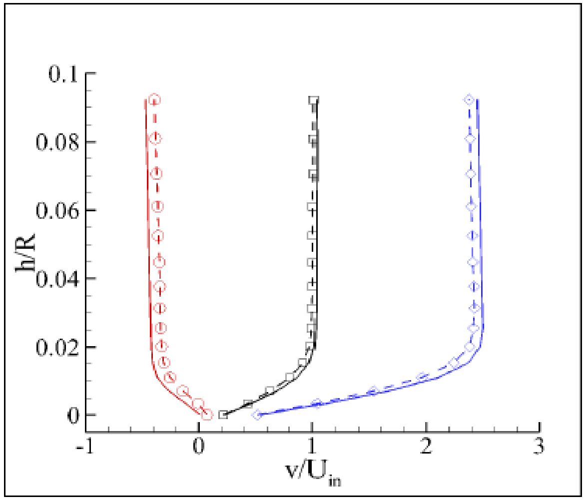




25% of chord length



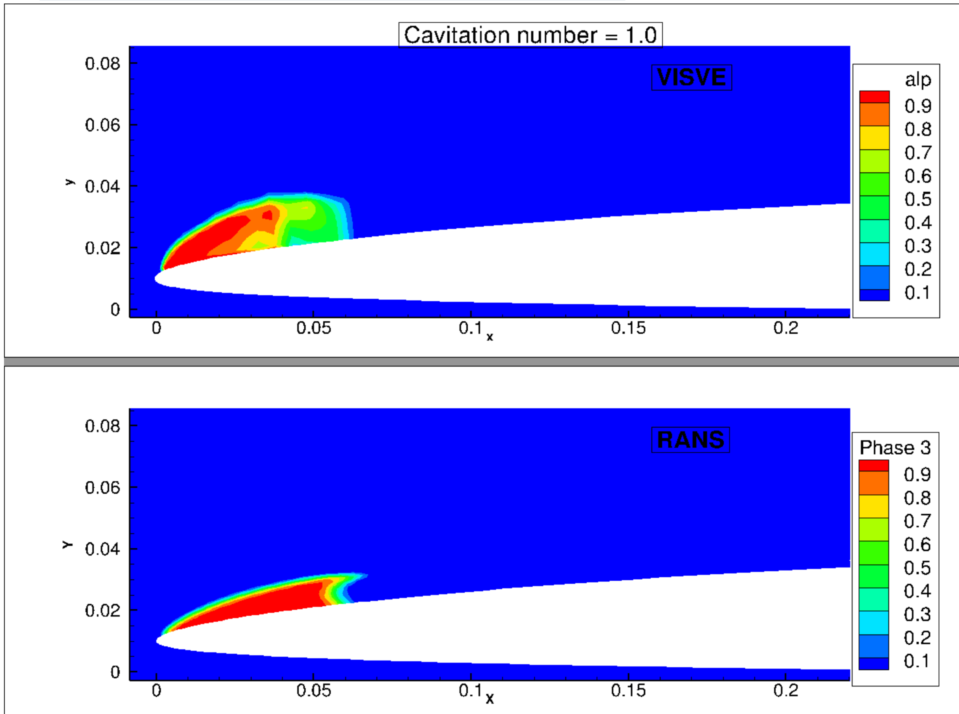




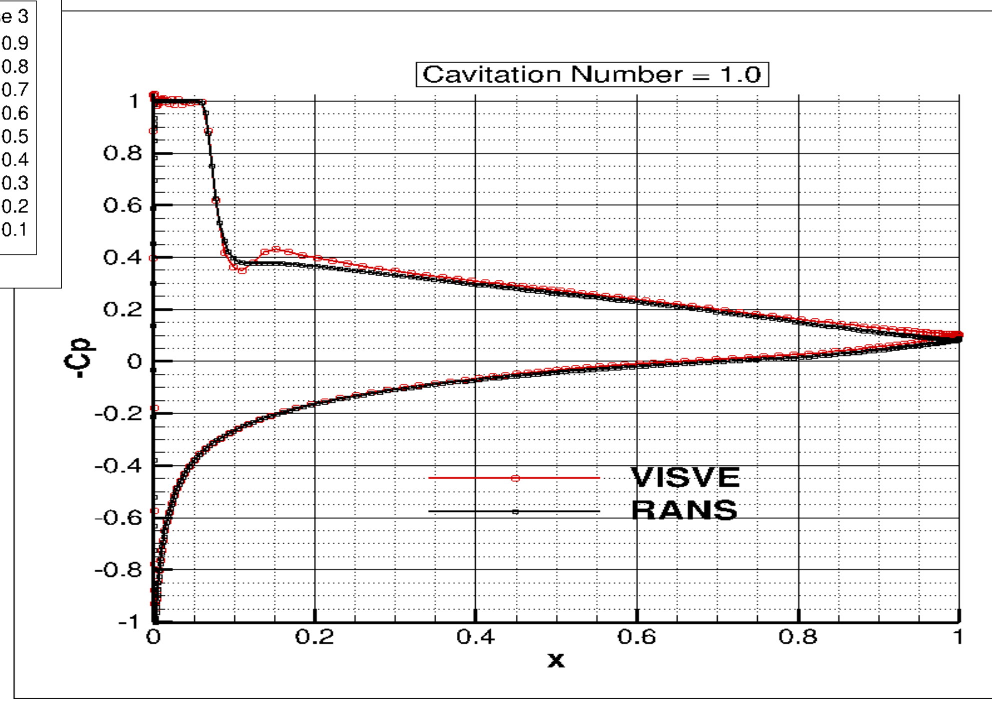
75% of chord length

Prediction of cavitation via VISVE

Cavitation Number = 1.0

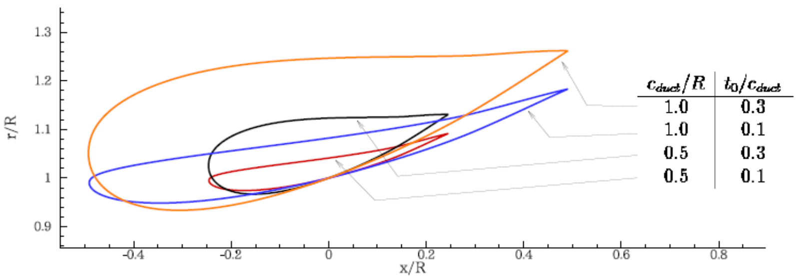


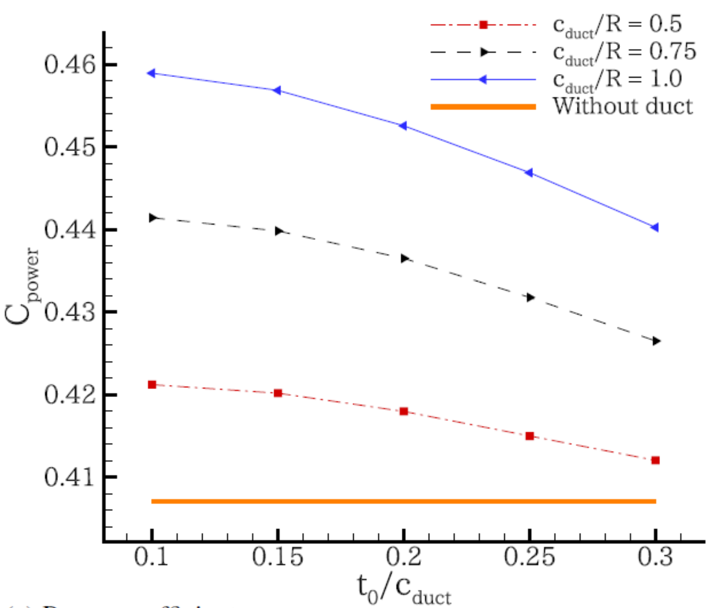
Xing, MS/OEG 2018
Xing, Wu, & Kinnas, CAV2018



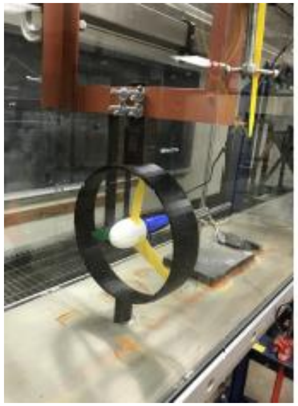
Design, 3D printing, and testing of ducted marine turbine in CAEE's flume

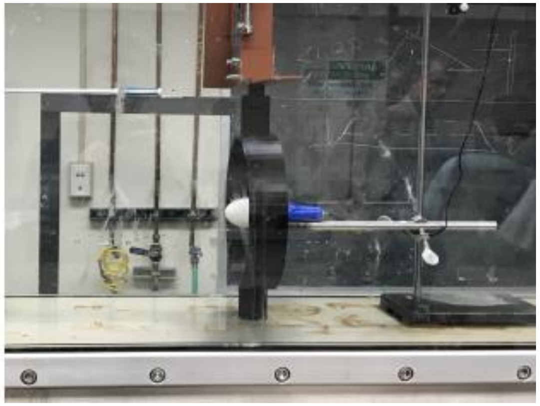
Du, Pham, & Kinnas, ISOPE 2019





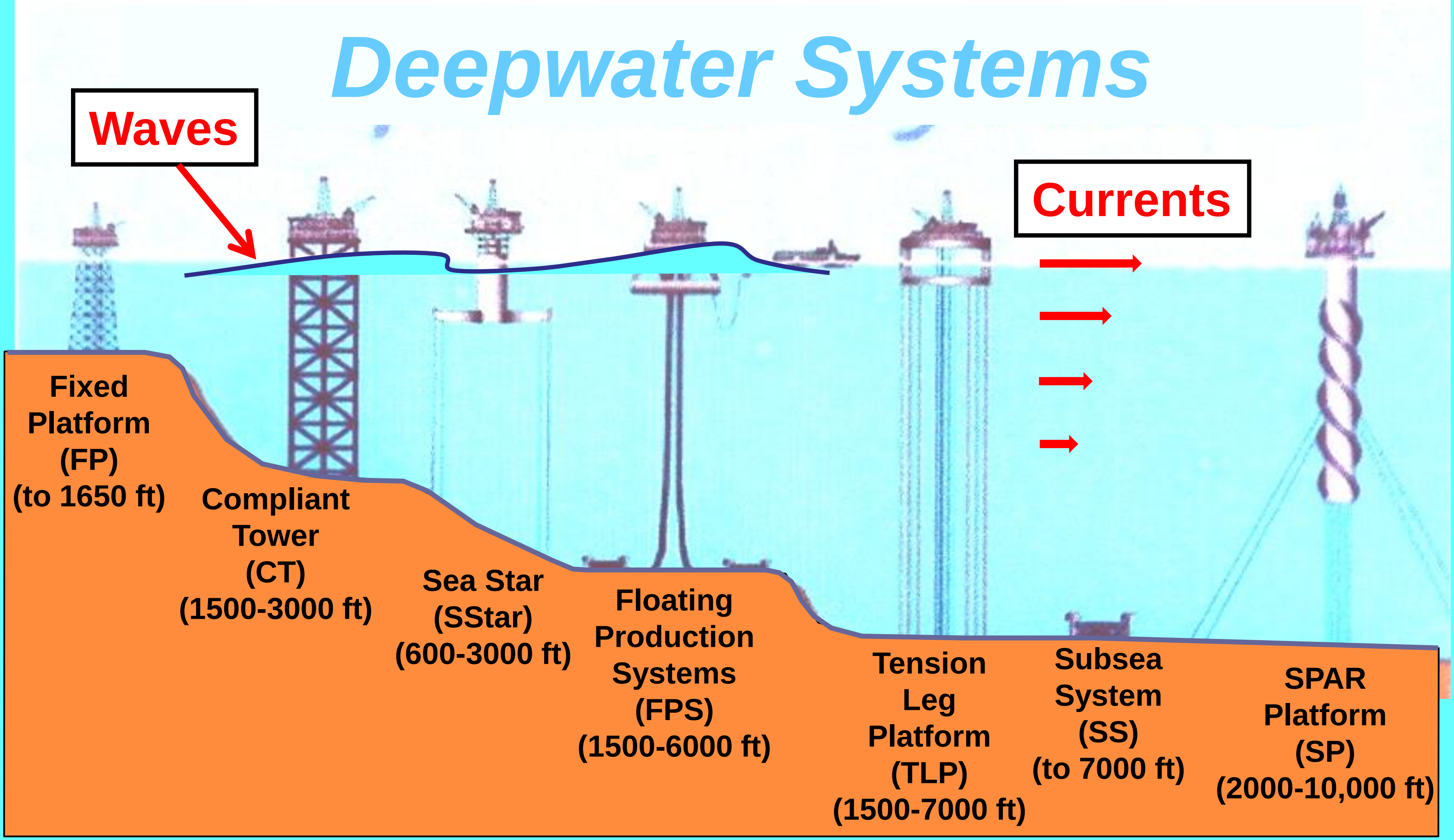
(a) Power coefficient





Check @SpyrosKinnas for updates

OFFSHORE PLATFORMS

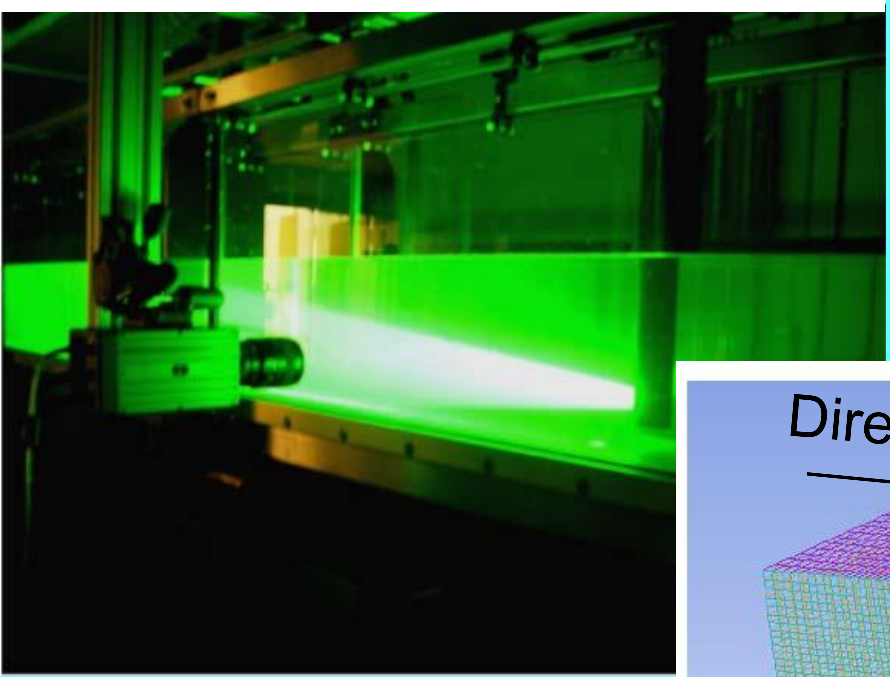


Source: Bureau of Ocean Energy Management

Experiment and simulation of flow around cylinder subject to wave

(G. Wang; OE/MS ’15; Wang & Kinnas, Journal of Offshore and Arctic Engineering, 2018)

UT’s flume and Particle Image Velocimetry (PIV) system



Simulation of viscous flow inside flume (using ANSYS/Fluent)

- Reynolds-Averaged Navier-Stokes (RANS)
- Large Eddy Simulation (LES)

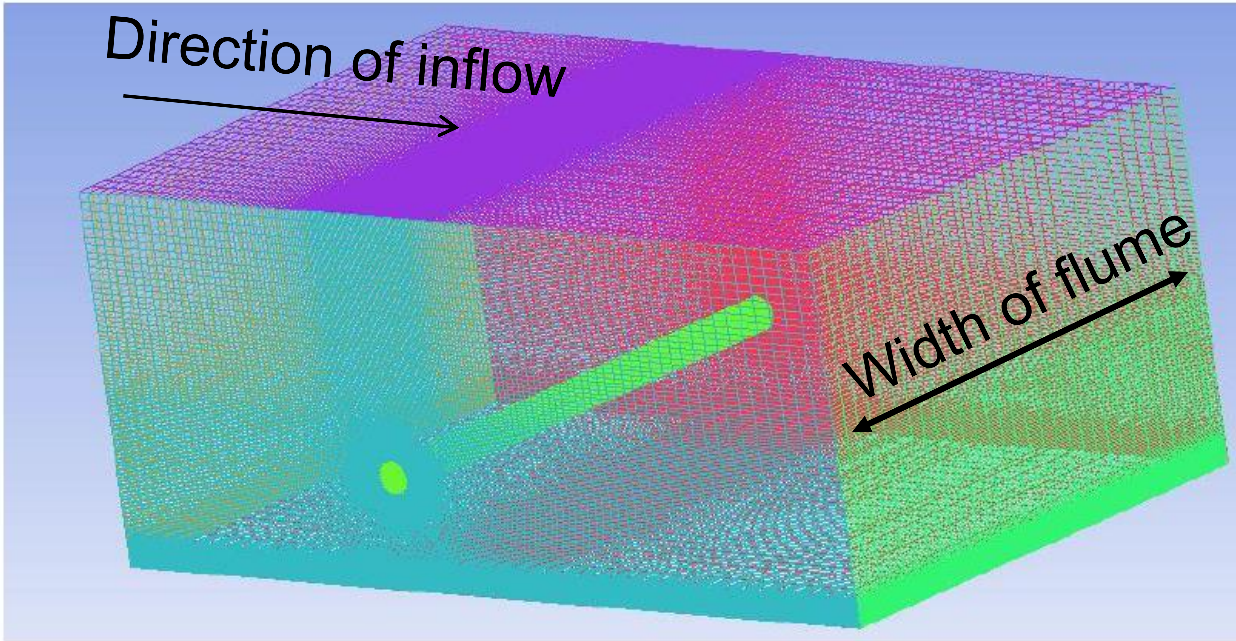
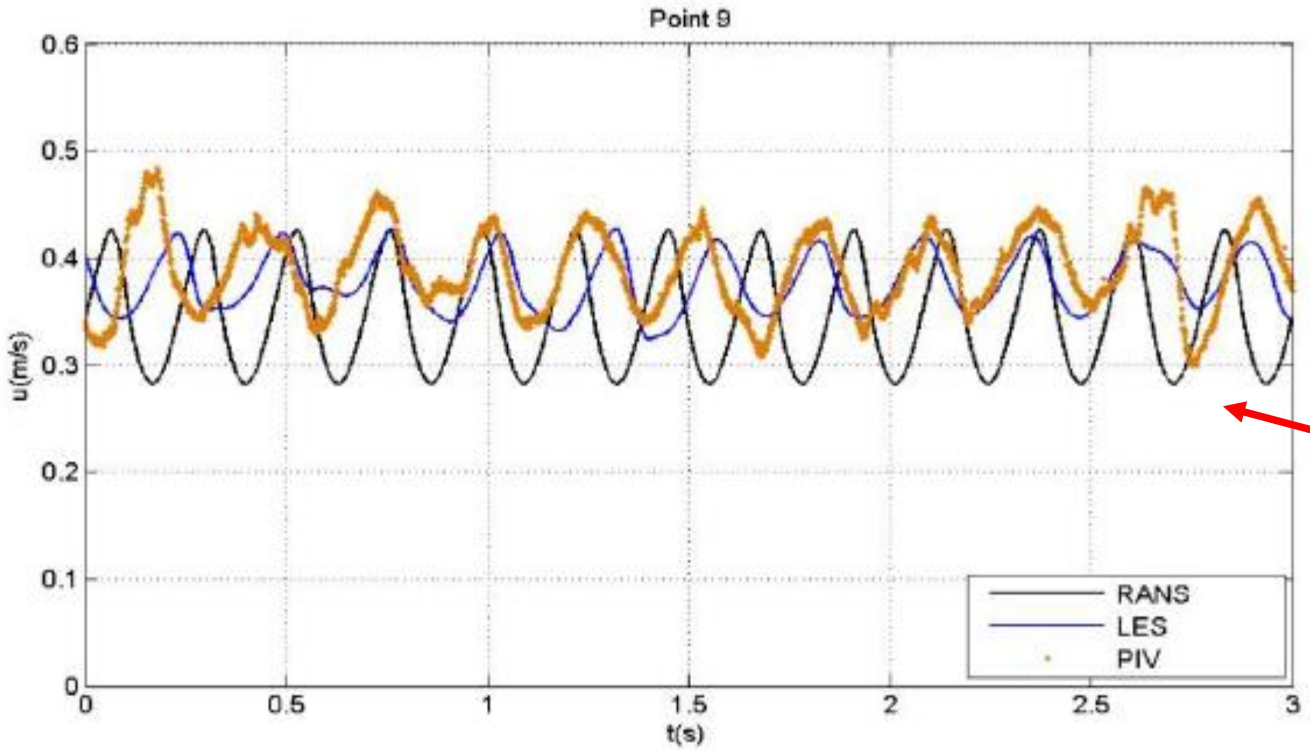


Figure 4.37 3D mesh including free surface

Measured vs. predicted velocity over time



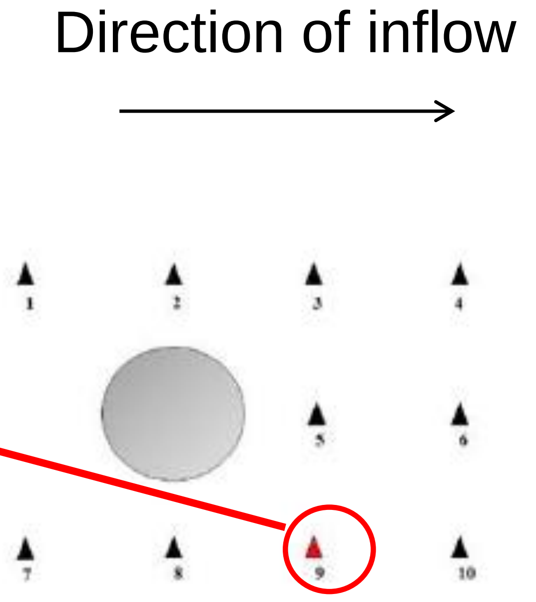


Figure 4.13 Time history of horizontal velocity of point 9

Measured vs. computed time averaged velocities (Reynolds stresses)

LES appears to do a much better job than RANS in simulating the viscous flow

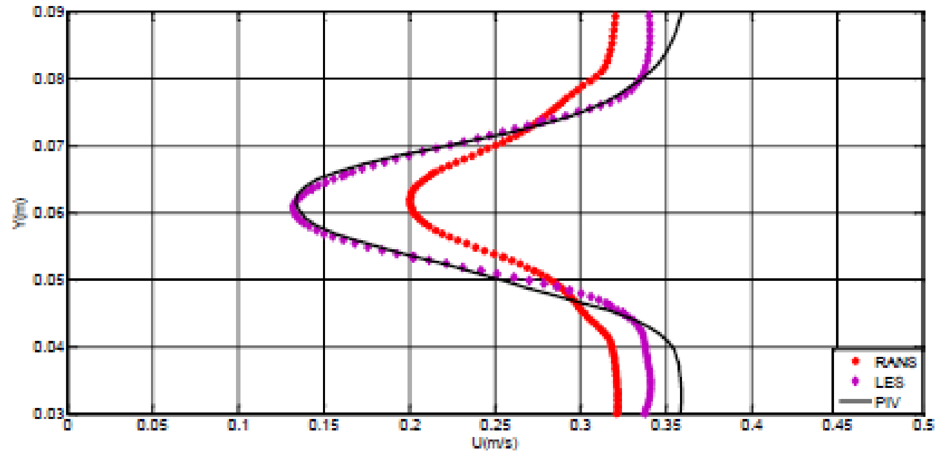


Figure 4.16 Time-averaged horizontal velocity at section 1

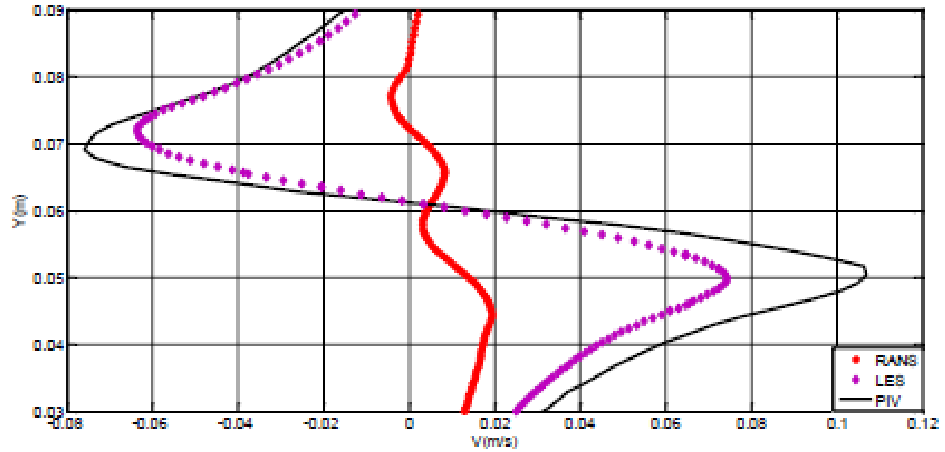


Figure 4.17 Time-averaged vertical velocity at section 1

2019-20 Opportunities in OEG:

- **MS Thesis in OE on the topics listed (unfunded) – Requires strong background in Fluid Mechanics, Advanced Calculus, and Computational Methods**