# IV CONGRESO INTERNACIONAL DE DISEÑO E INGENIERÍA NAVAL

11 - 13 DE MARZO DE 2015

IV Congreso Internacional de Diseño e Ingeniería Naval
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# Recreación de la prueba de Tracción a punto fijo de un remolcador de doble propulsor mediante dinámica de fluidos computacional

## “Modeling and Simulation of the Bollard Pull Test for a twin propeller tugboat using computational fluid dinamic”

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**Technological University of Panama**

# OUTLINE

- Introduction and Motivation
- Computational simulations
- Mathematical model
- Results validation
- Parametric study
- Conclusions

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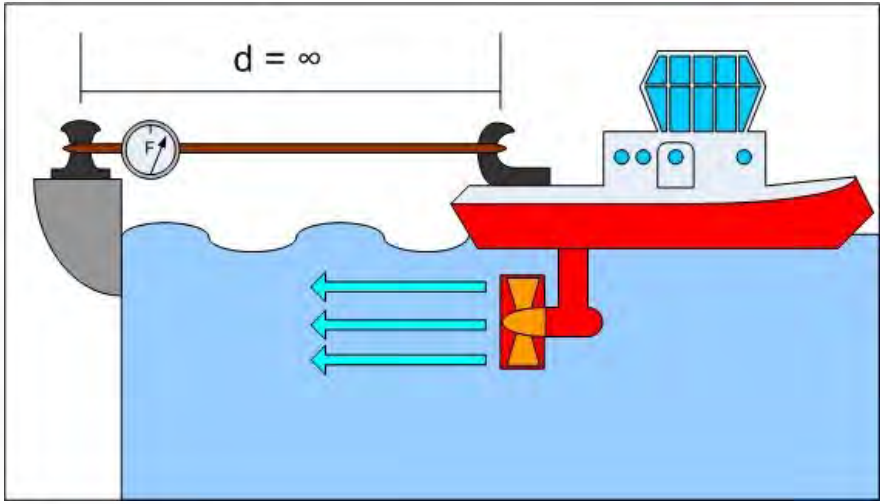
# INTRODUCTION

## Bollard Pull Test general conditions:

- Environmental conditions
  - Wind speed
  - Currents
  - Tides
- Requirements
  - Depth
  - Stern
  - Beam
  - Draught



# Motivation

- The analytic methods to study the hydrodynamic behavior are highly complicated.
- There are only a few works that study the bollard pull condition.
- To carry out the bollard pull test the vessel must has been already built.
- To determine the appropriate configuration of propeller that must be set to achieve the desired design characteristics.

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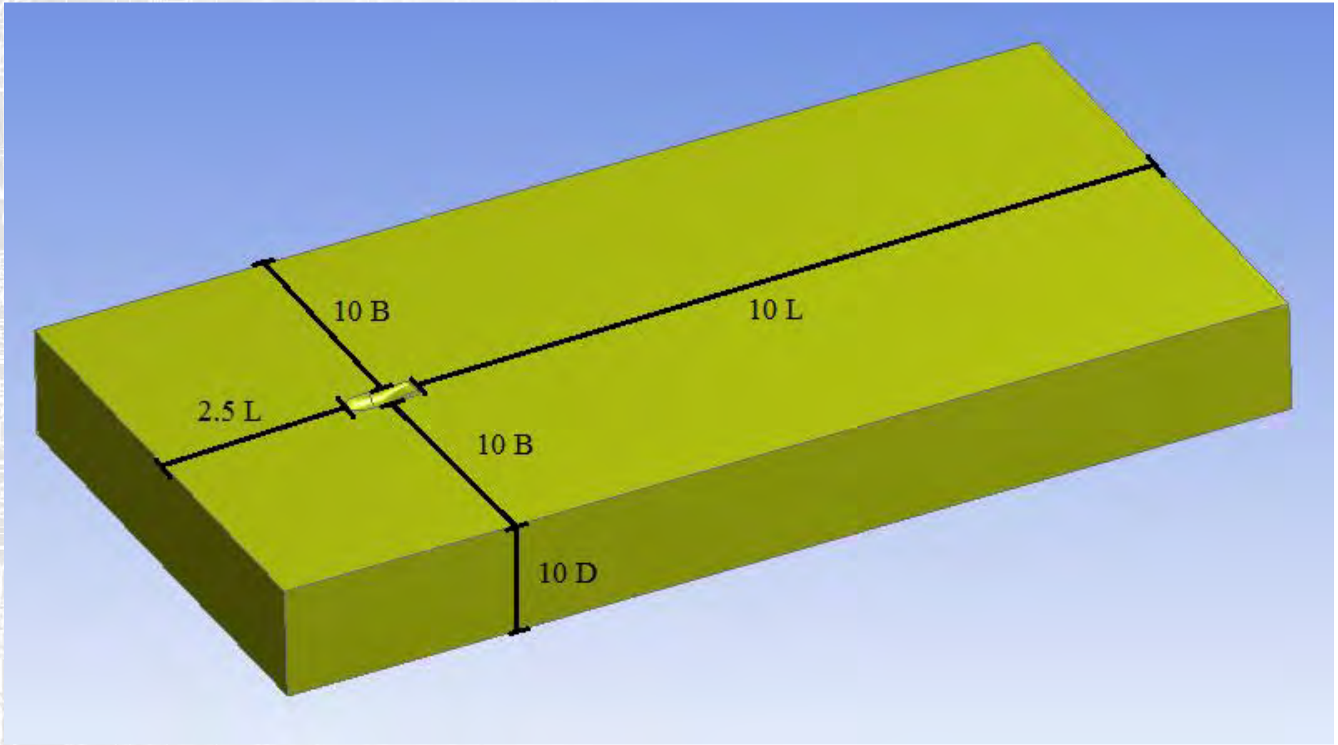
# Problem domain

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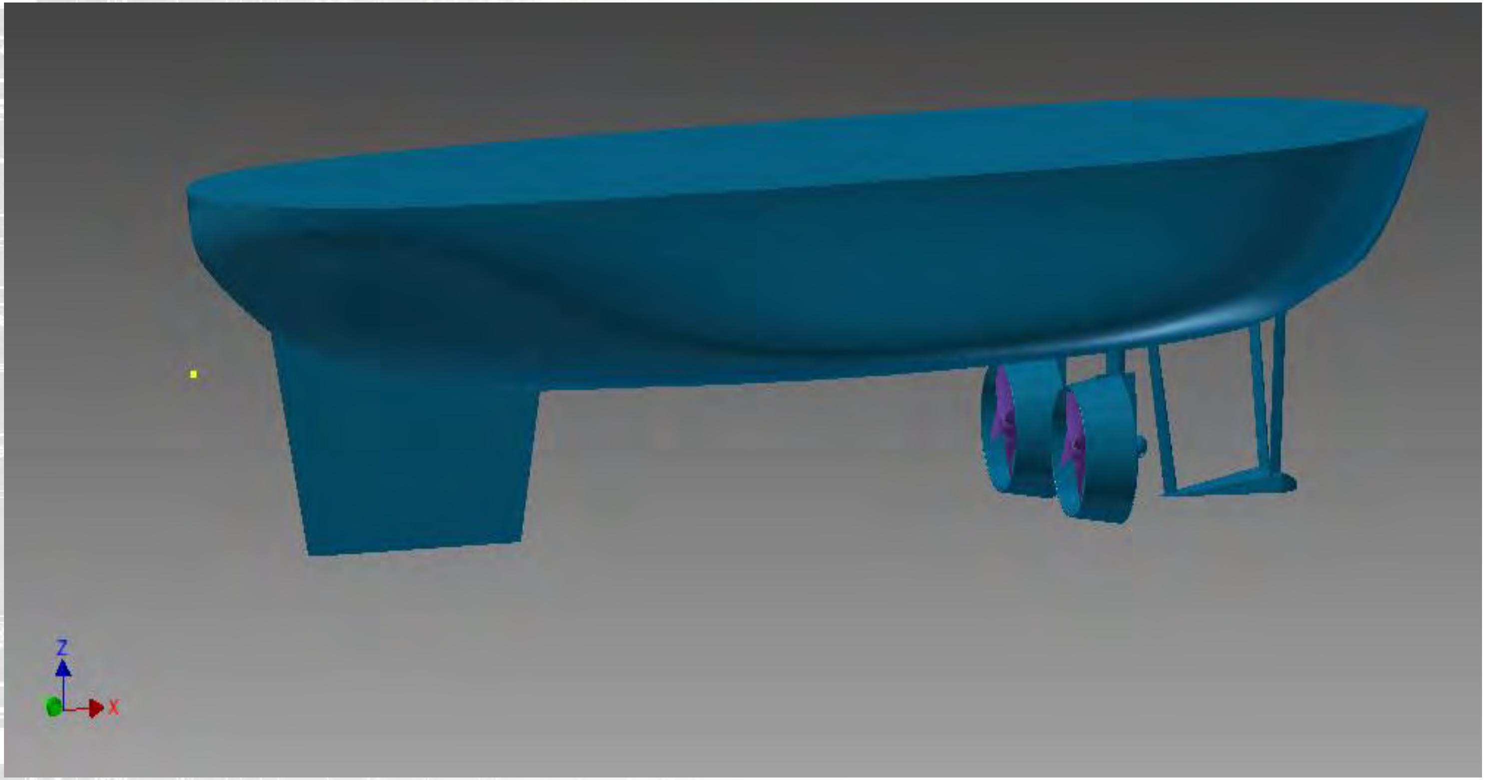
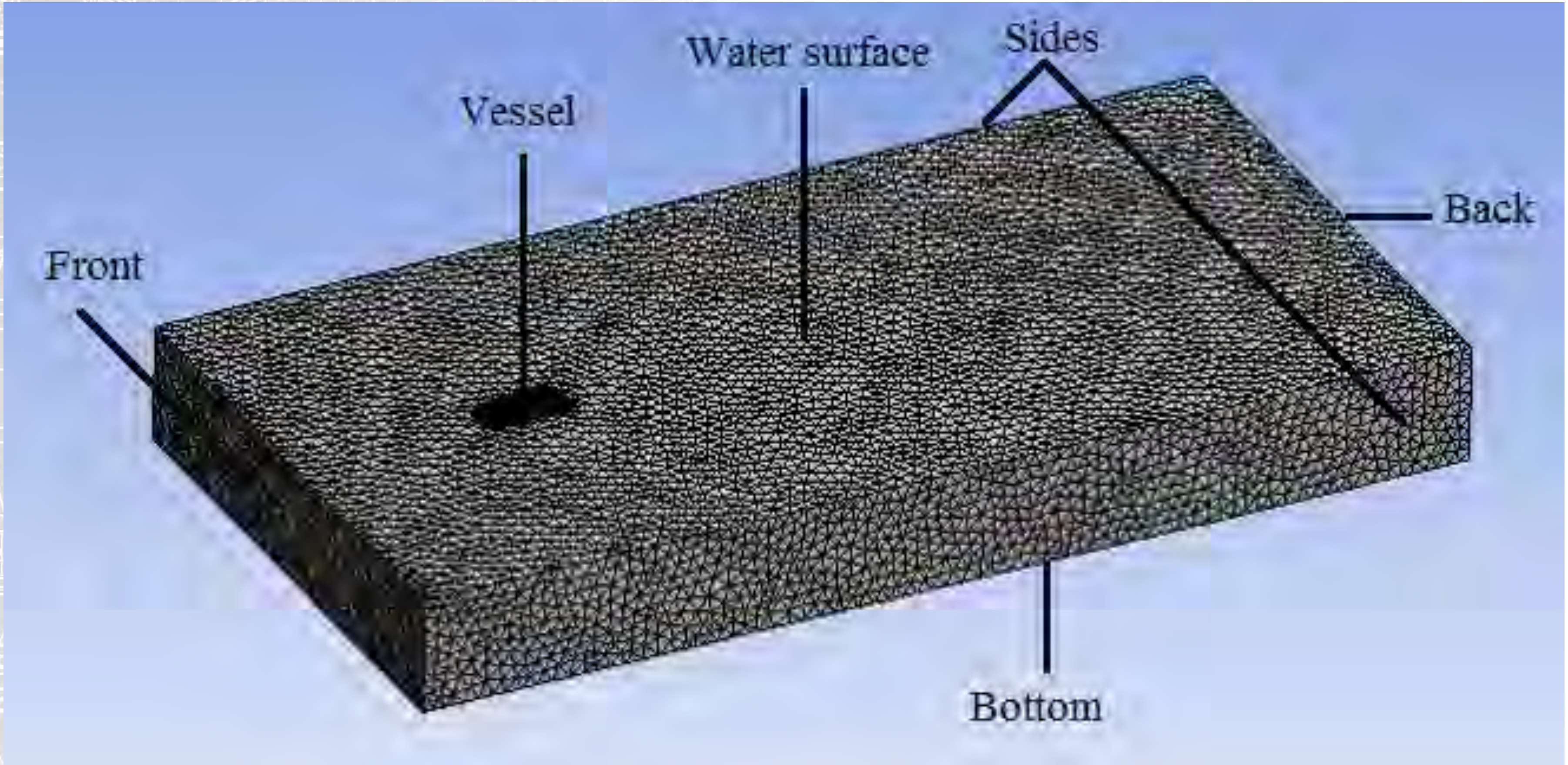
# Problem domain



# Development of CFD model



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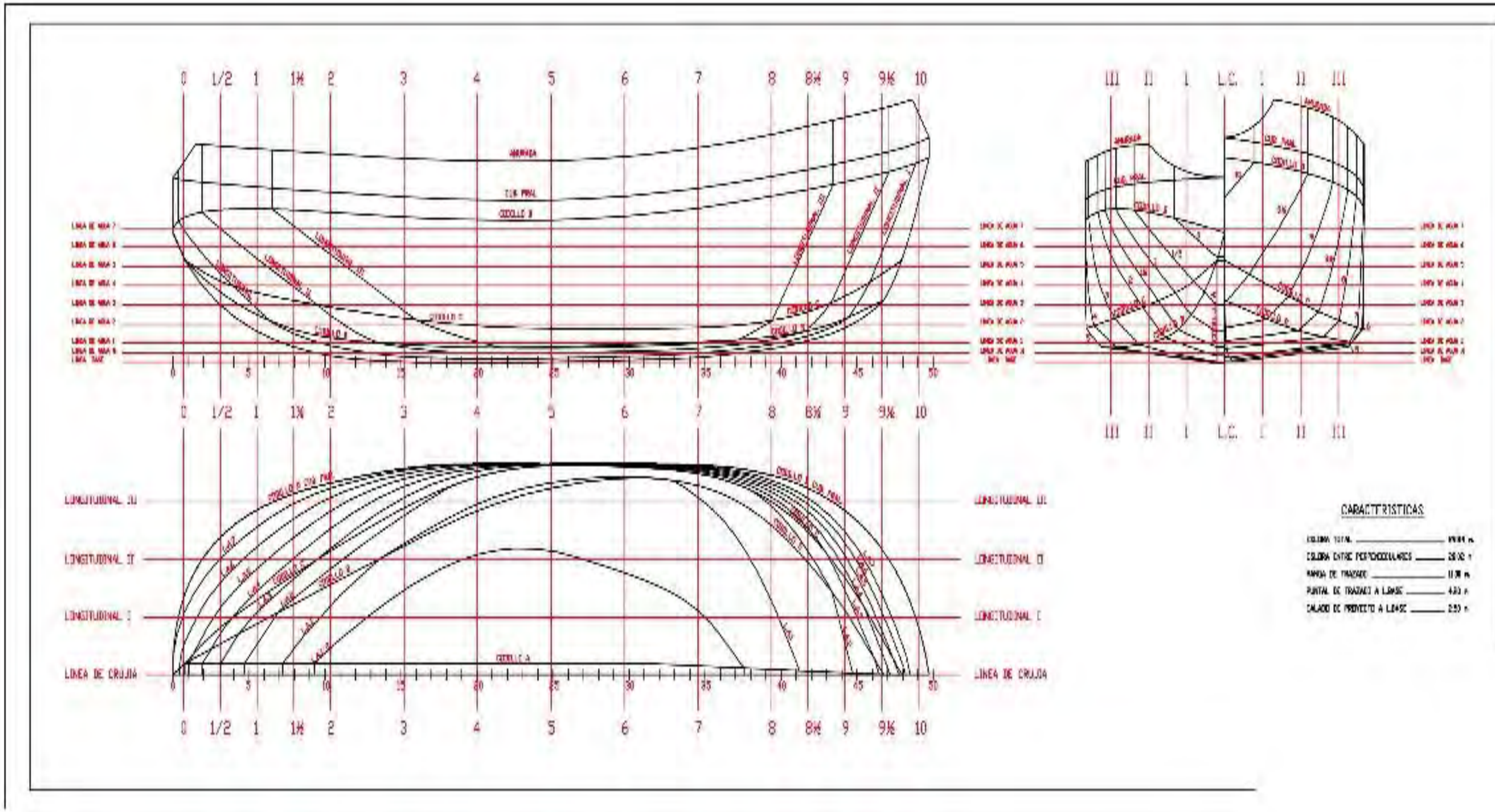

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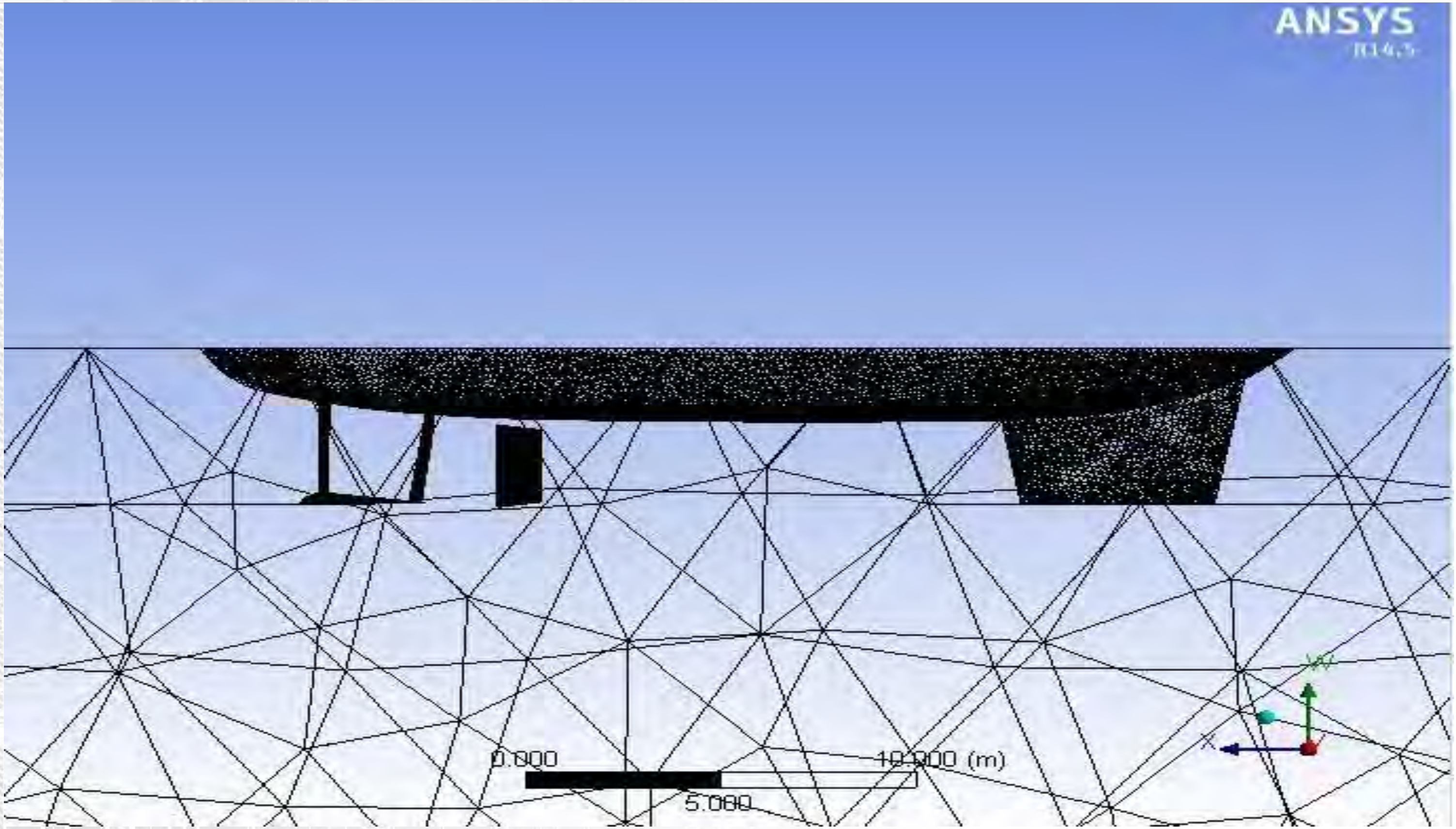
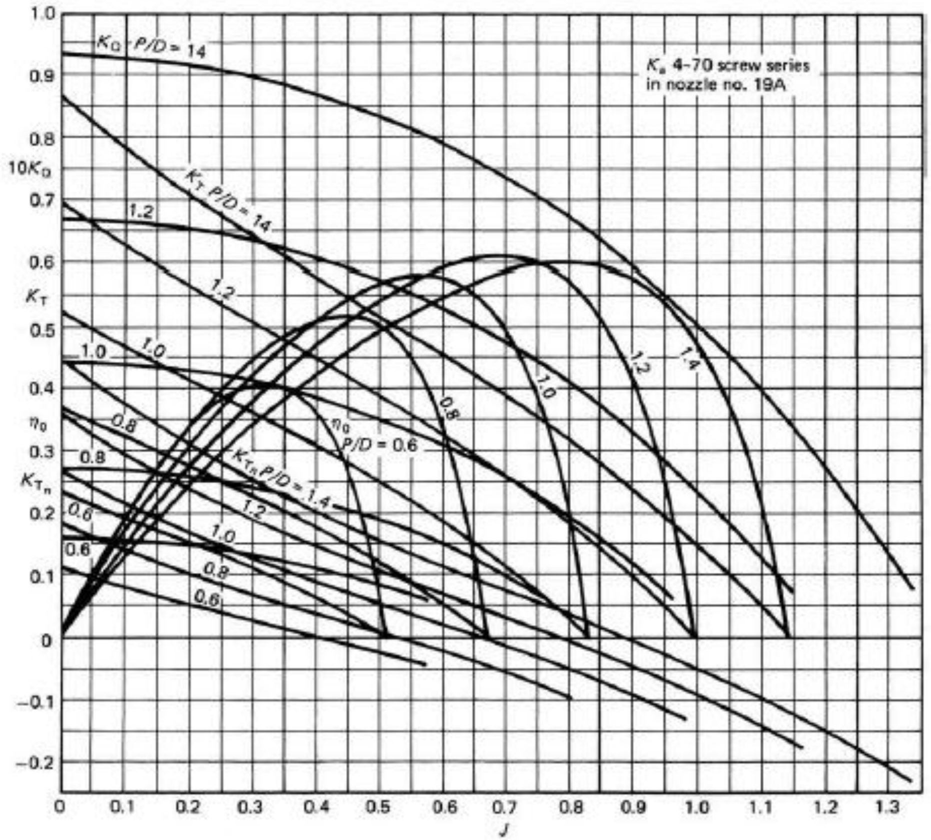


# Characteristics of the propeller

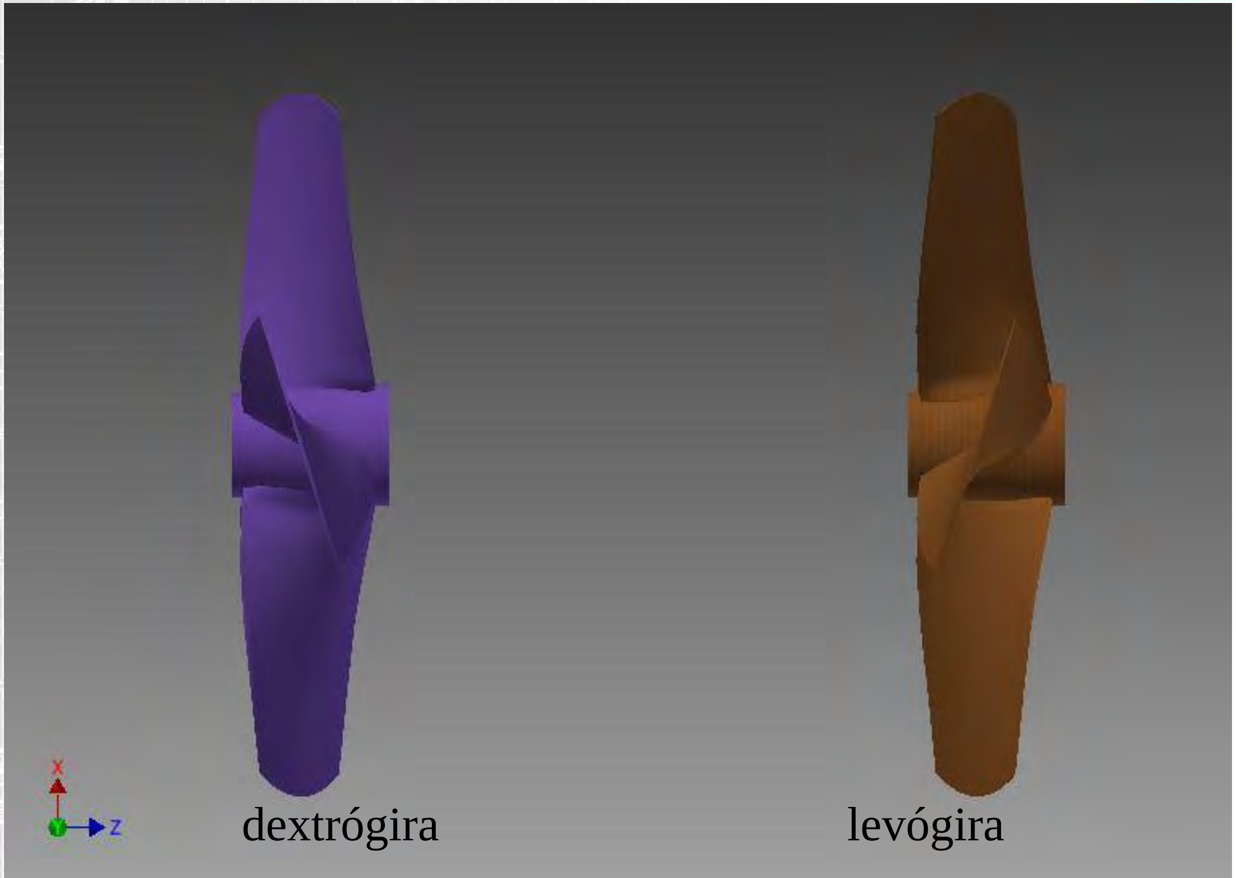
$$J = \frac{V_a}{nD}$$

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

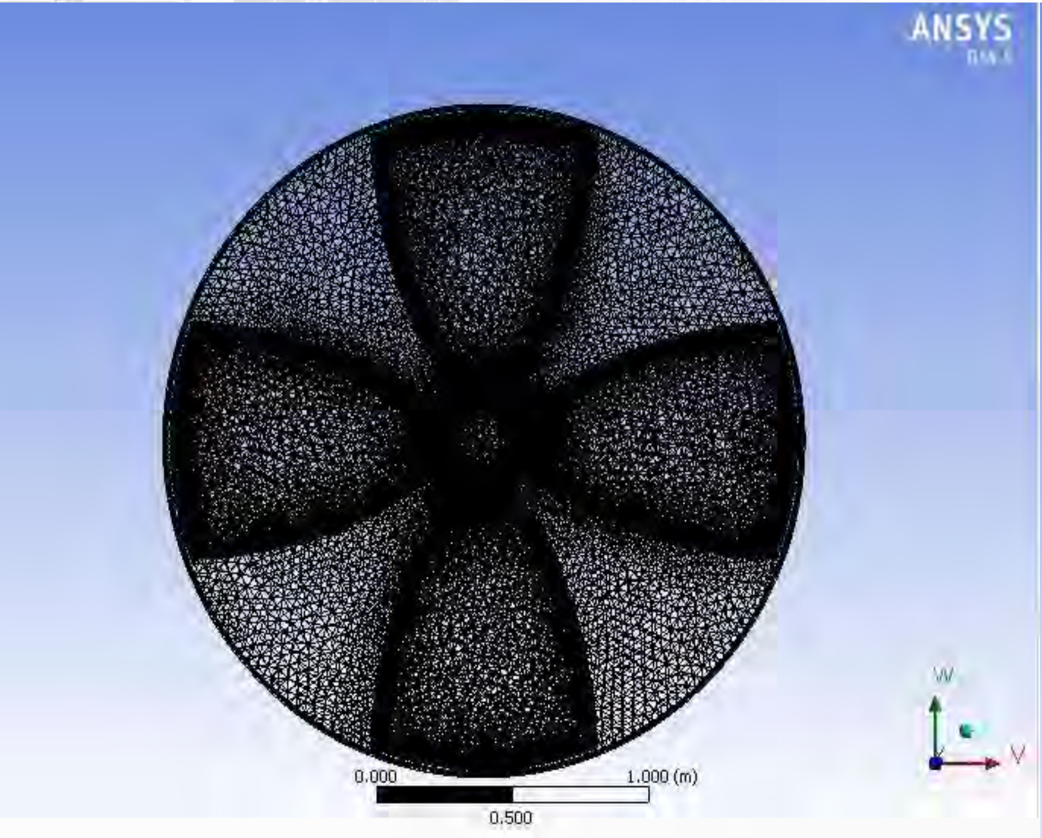
$$K_Q = \frac{Q}{\rho n^2 D^5}$$



# Twin propeller



# Mesh model of propeller and nozzel

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**Continuity equation**

$$\frac{D\rho}{Dt} + \nabla \cdot \left(\rho\vec{V}\right) = 0$$

where

$$\frac{D\rho}{Dt} = \frac{\partial\rho}{\partial t} + u\frac{\partial\rho}{\partial x} + v\frac{\partial\rho}{\partial y} + w\frac{\partial\rho}{\partial z}$$

$$\nabla \cdot \left(\vec{V}\right) = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}$$

$$\nabla \cdot \left(\vec{V}\right) = 0$$

**Momentum equation**

$$\frac{D(\rho\vec{V})}{Dt} = \nabla \cdot \bar{\bar{\sigma}} + \rho\vec{g}$$

where

$$\frac{D\vec{V}}{Dt} = \frac{\partial\vec{V}}{\partial t} + u\frac{\partial\vec{V}}{\partial x} + v\frac{\partial\vec{V}}{\partial y} + w\frac{\partial\vec{V}}{\partial z}$$

and

$$\bar{\bar{\sigma}} = -p\bar{\bar{\delta}} + \bar{\bar{\tau}}$$

# Incompressible flow Navier-Stokes Equation

$$\frac{\rho D(u)}{Dt} = -\frac{\partial p}{dx} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) + \rho g_x$$

$$\frac{\rho D(v)}{Dt} = -\frac{\partial p}{dy} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) + \rho g_y$$

$$\frac{\rho D(w)}{Dt} = -\frac{\partial p}{dz} + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right) + \rho g_z$$

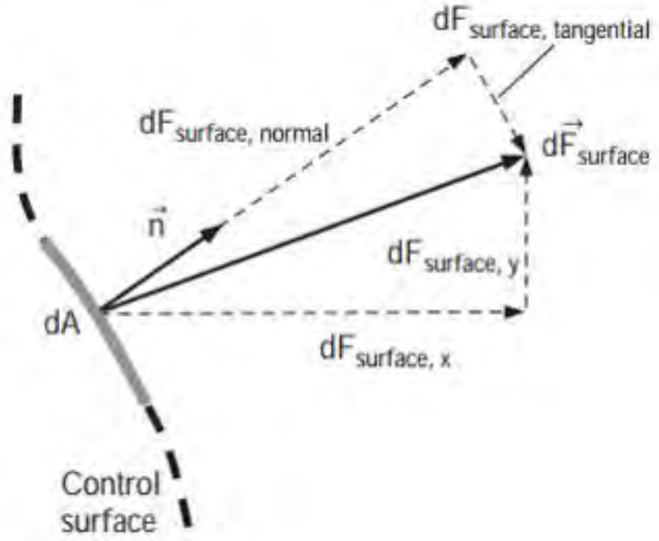
# Hydrodynamic forces

$$\sum \vec{F} = \int \bar{\bar{\sigma}} . \vec{n} \, dA$$

$$F_T = F_P + F_V$$

$$F_P = -\int p . n_z dA$$

$$F_V = \int \bar{\bar{\tau}} . n_z dA$$



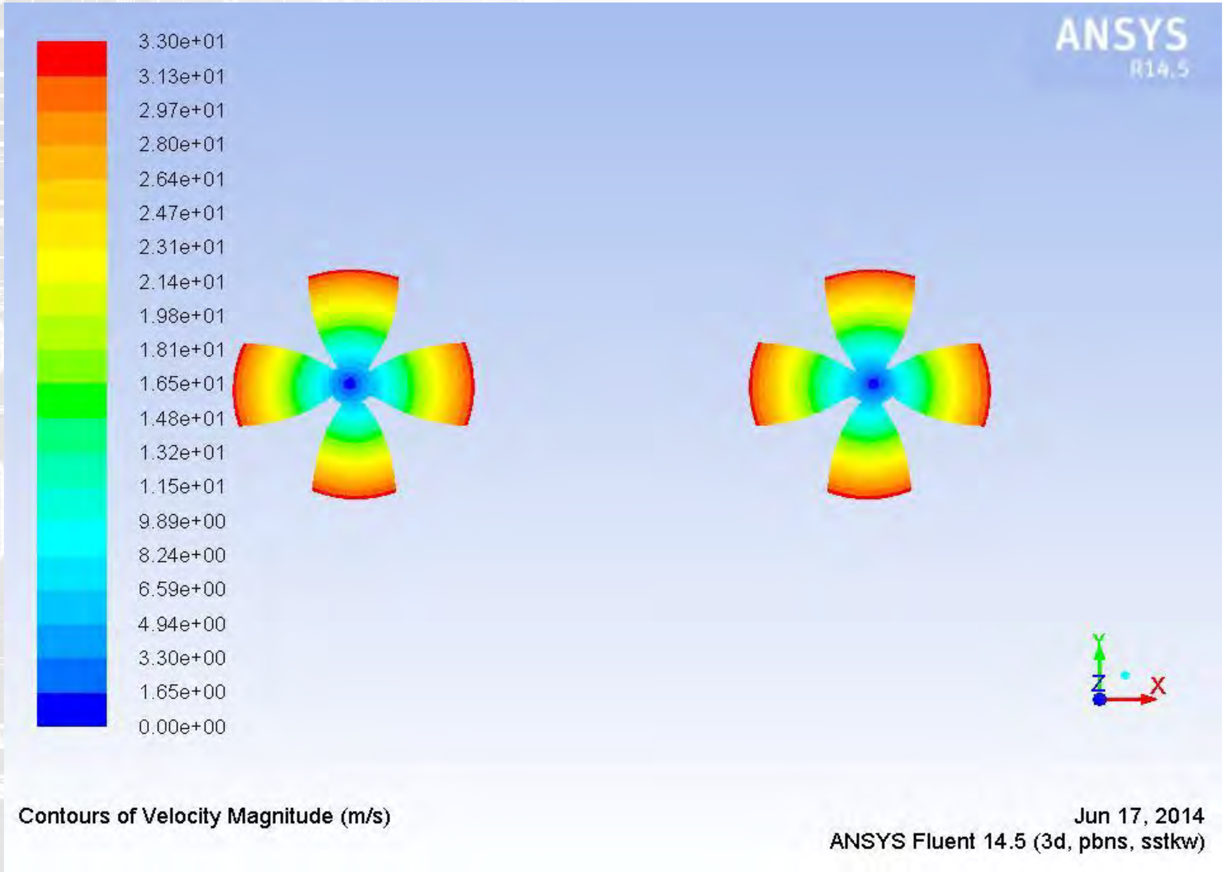

where $n_z$ is the component in z of the unit normal vector in dA

# Steady State Simulation

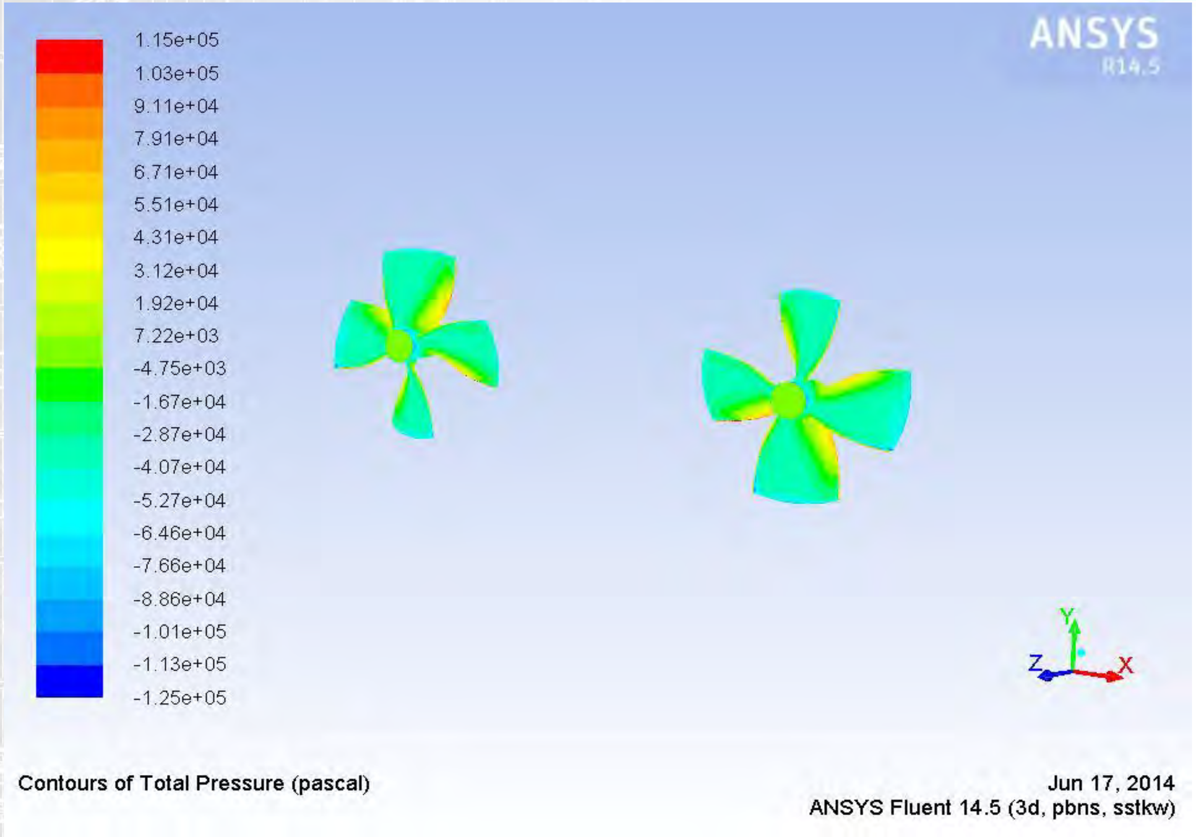
- For the simulations in steady state we used the multiple reference frame approach, this is an approximation of steady state where we can assign translational or rotational speed to zones of the domain.

- We used the shear stress transport k-w turbulence model to study the bollard pull condition.

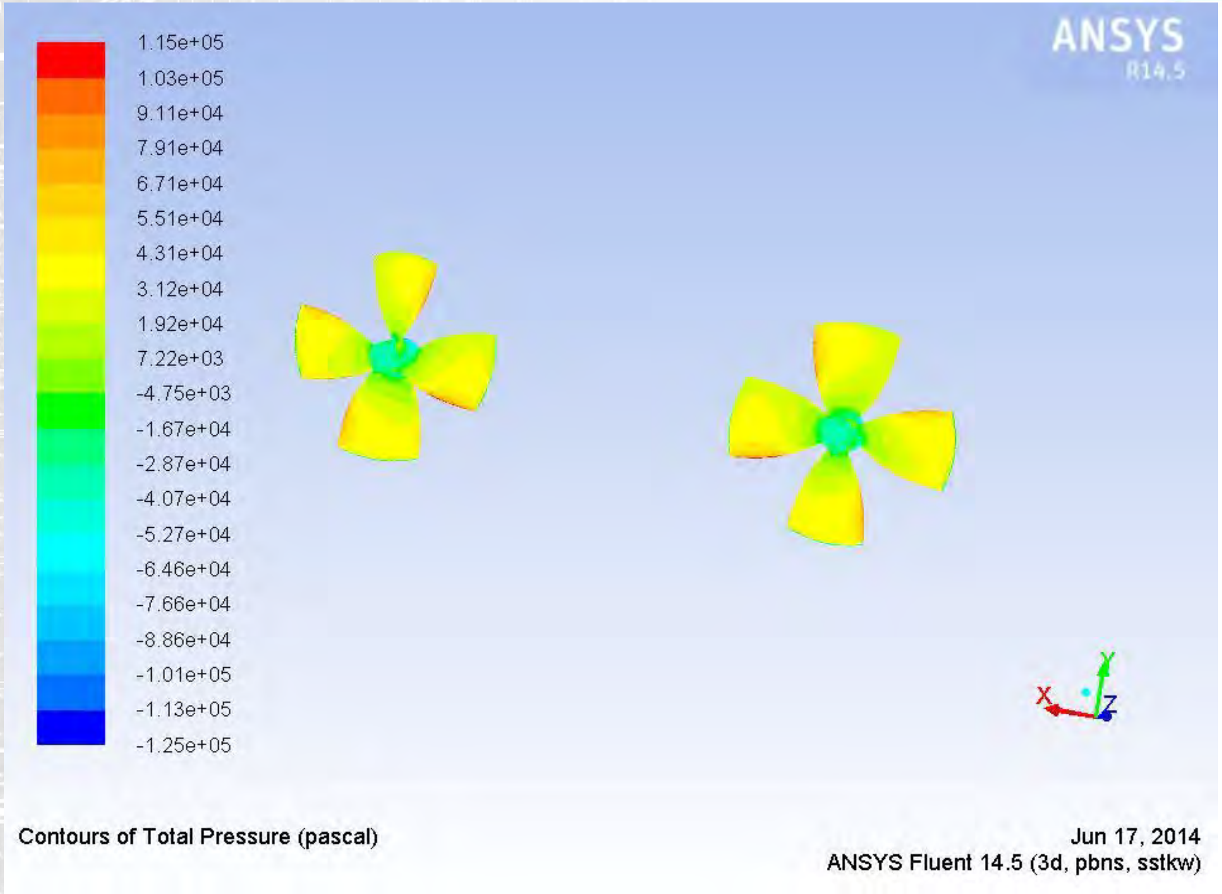
# Lineal Velocity Contours



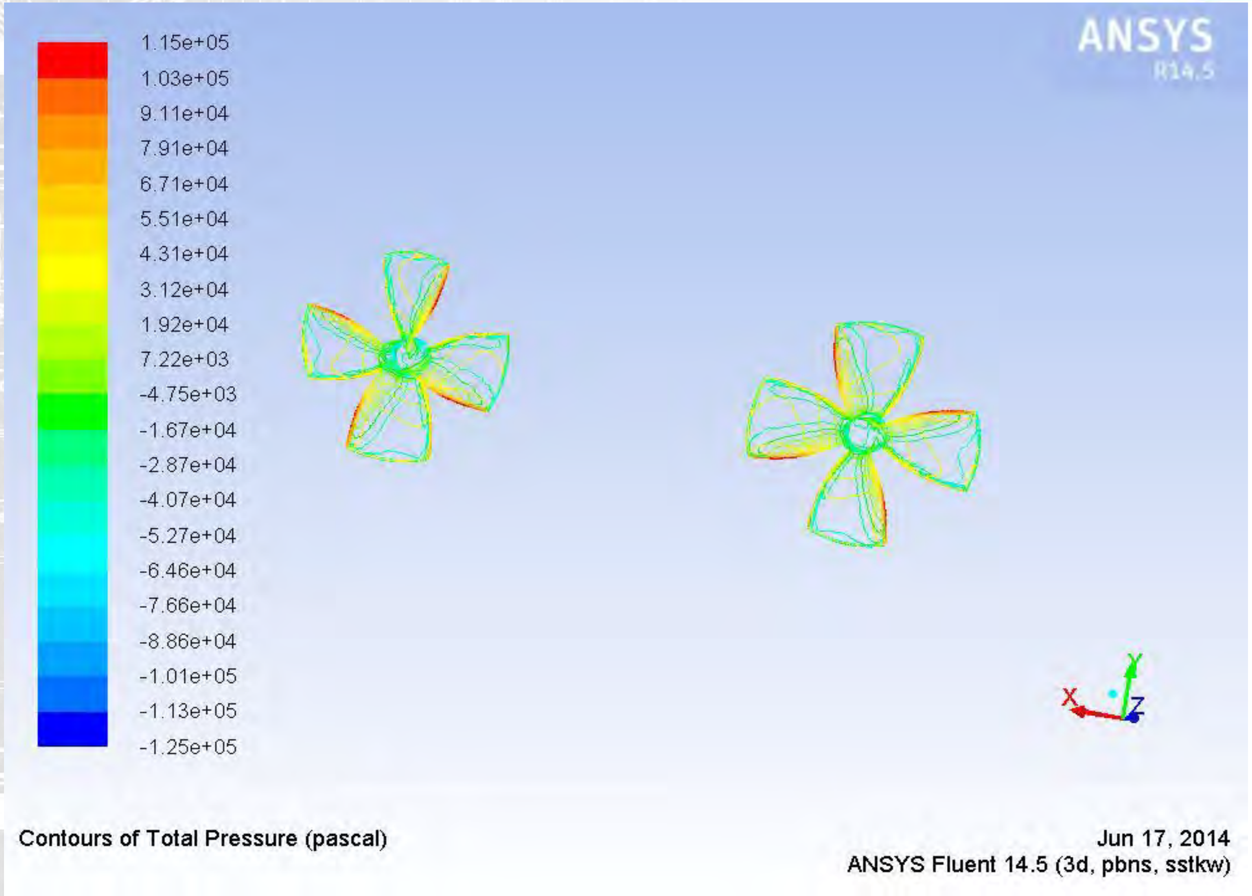
# Pressure Contours (from FWD)



# Pressure Contours (From AFT)



# Pressure at the exit border



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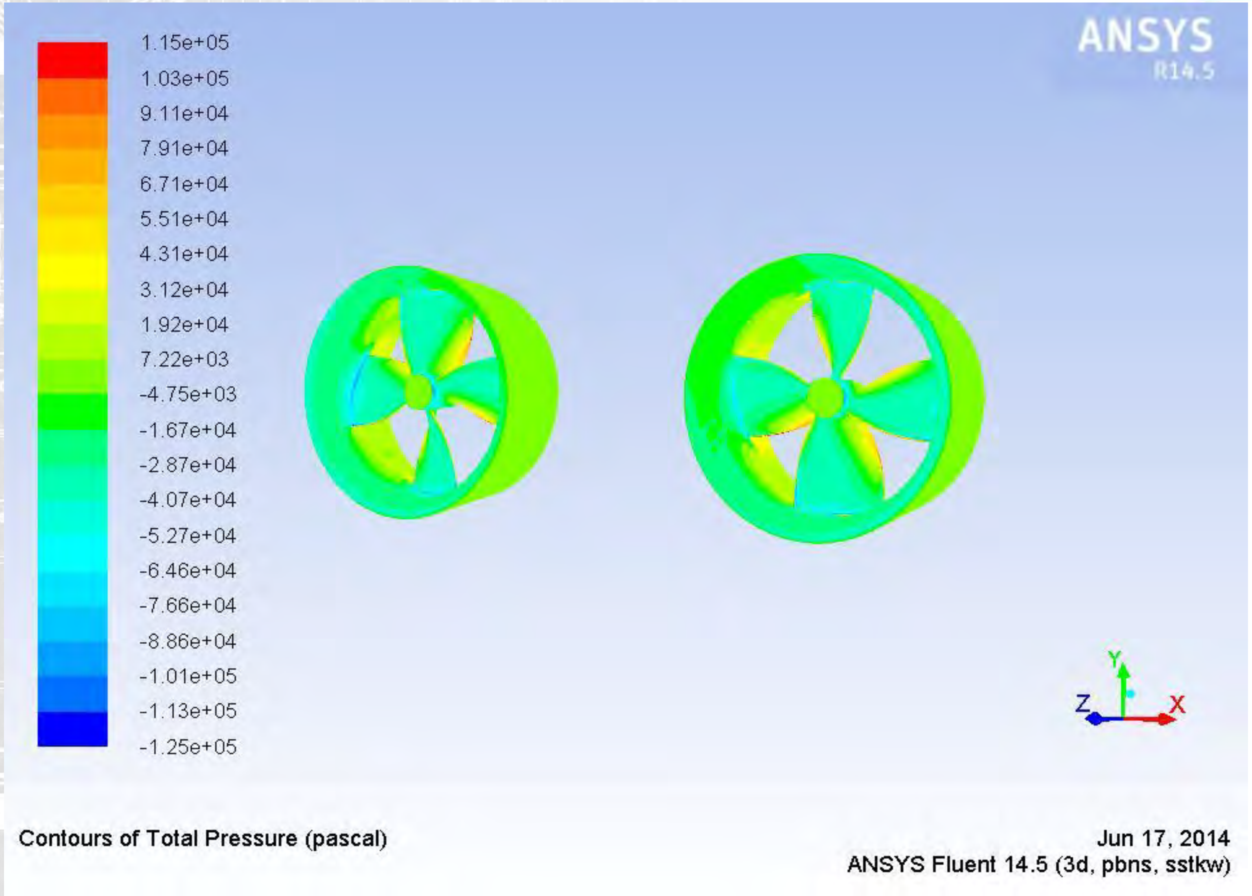

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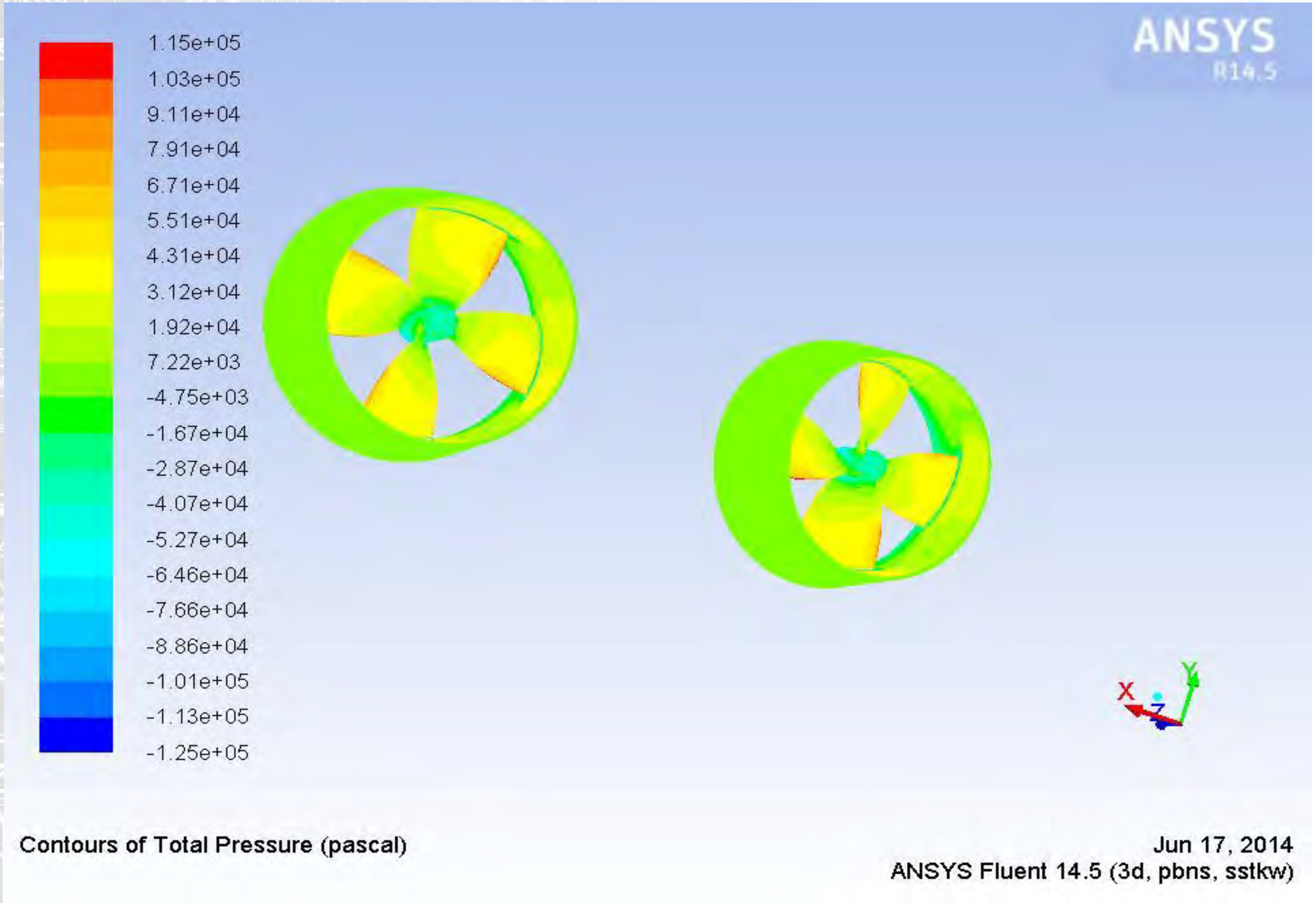

# Transient State Simulation

- For the transient simulation we used the sliding mesh approach.

- The solution from the steady state was used as the time zero of the transient simulation, with the same boundary conditions.

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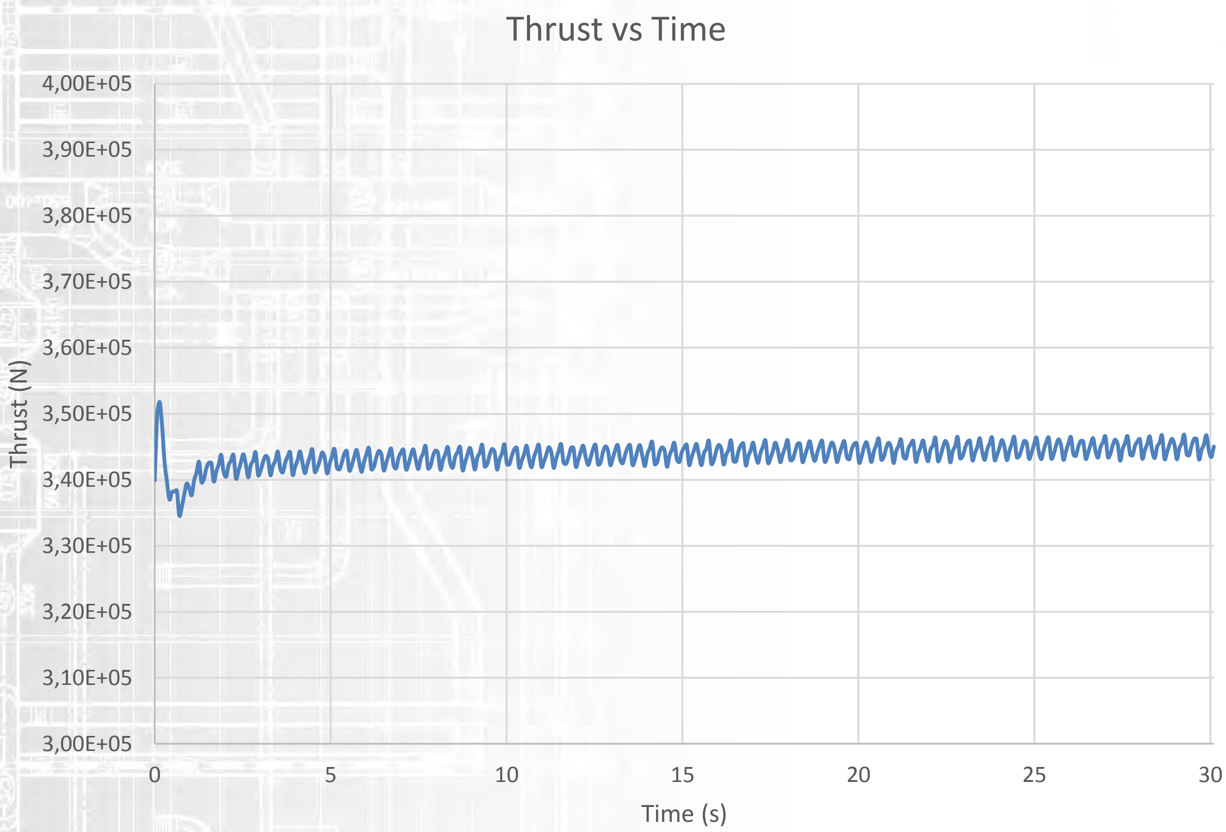
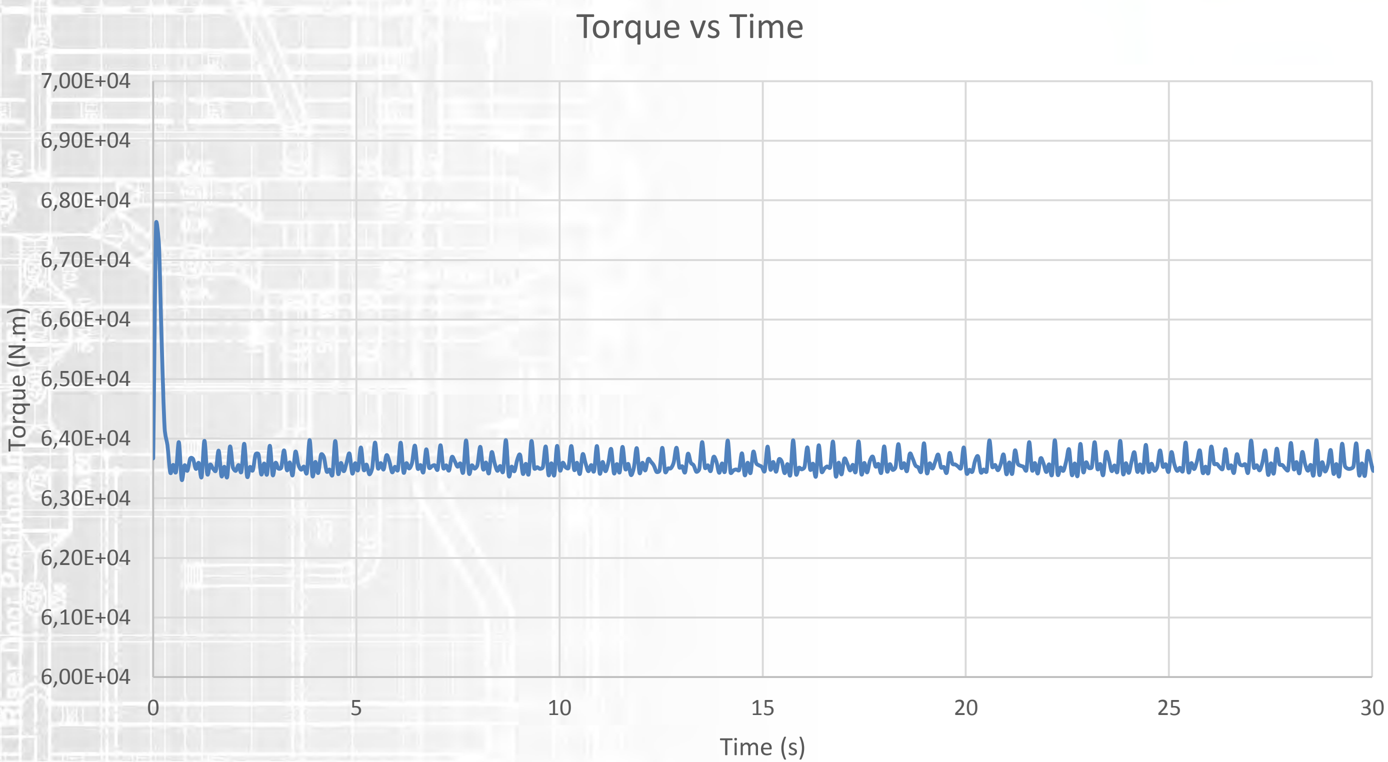
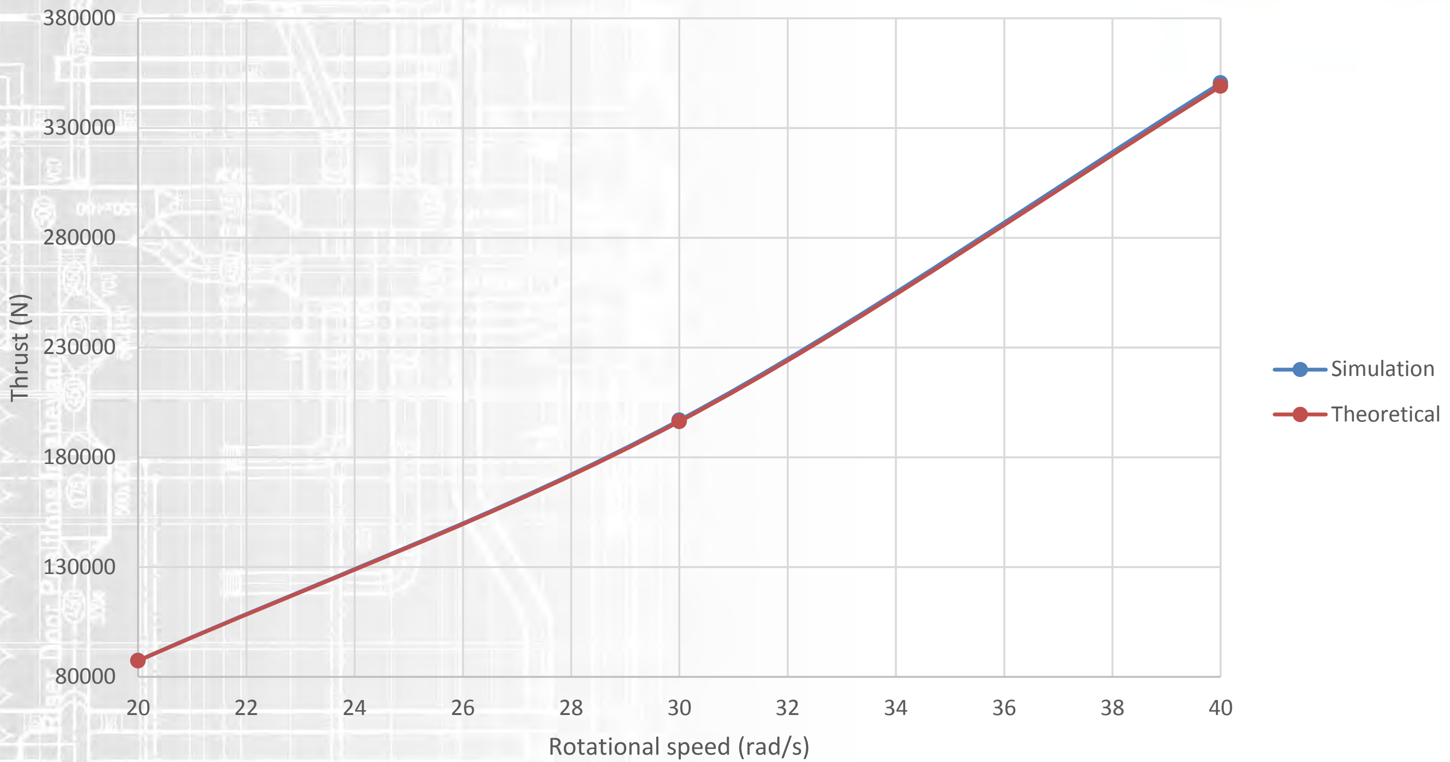
# Transient State Simulation



# Transient State Simulation

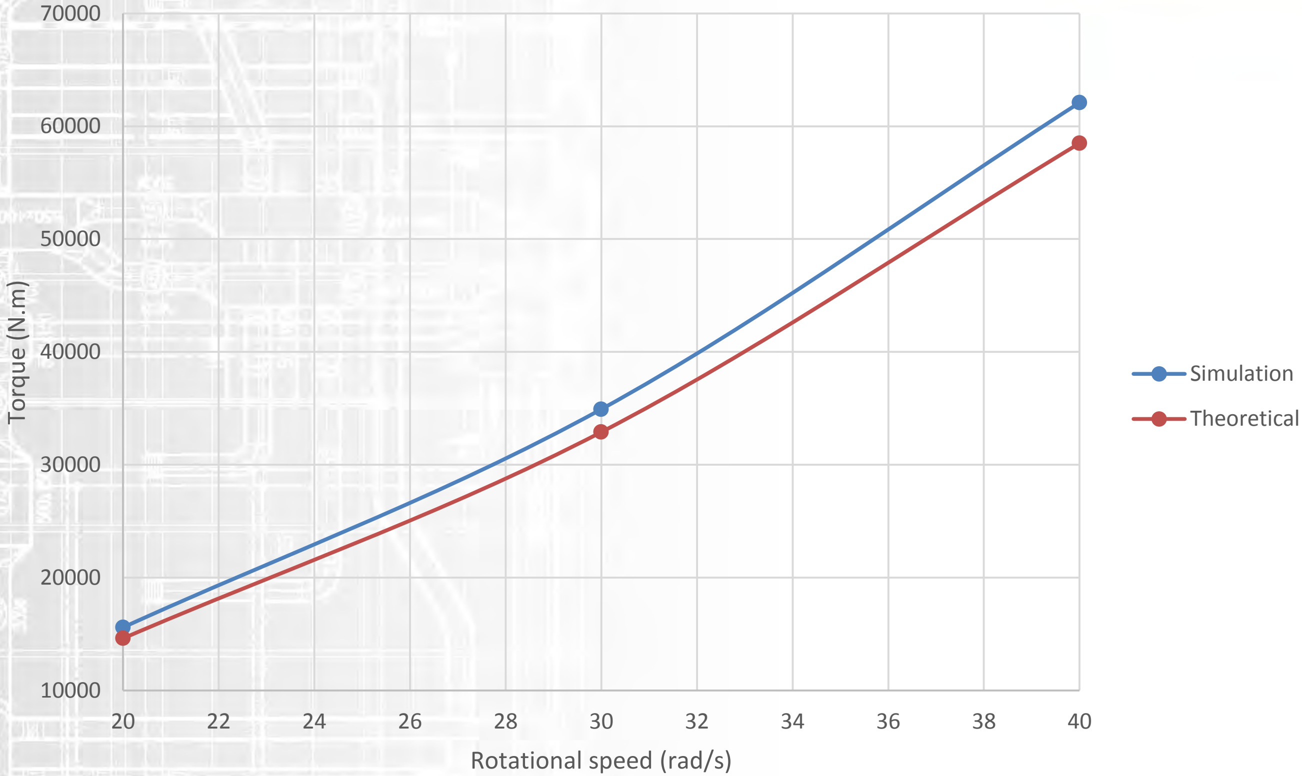


# Thrust



380000
330000
280000
230000
180000
130000
80000
Thrust (N)
20
22
24
26
28
30
32
34
36
38
40
Rotational speed (rad/s)
Simulation
Theoretical

# Torque

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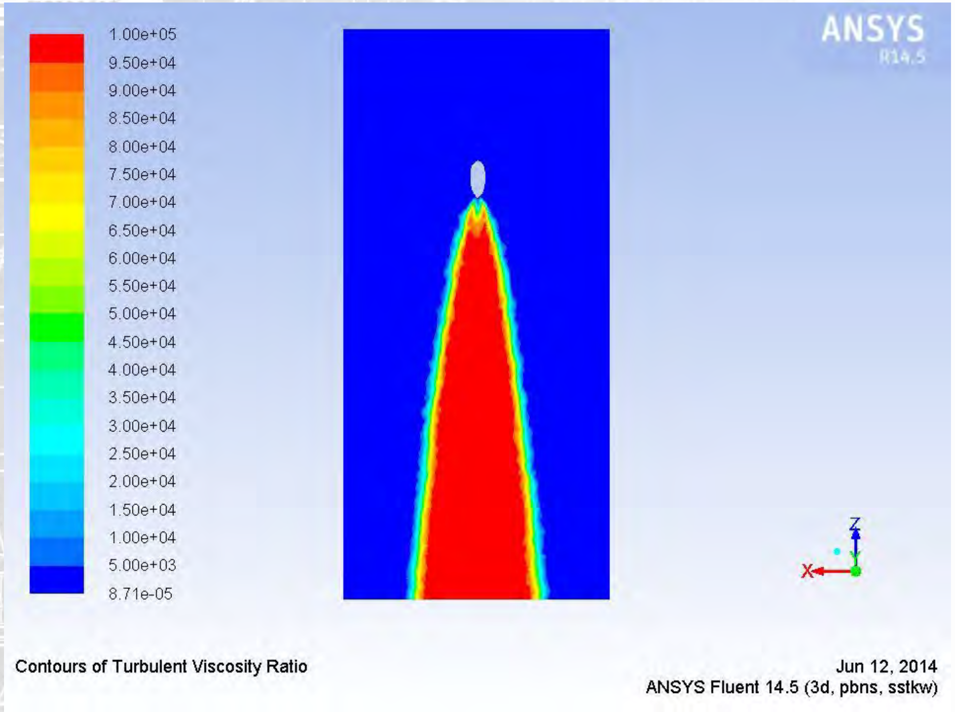
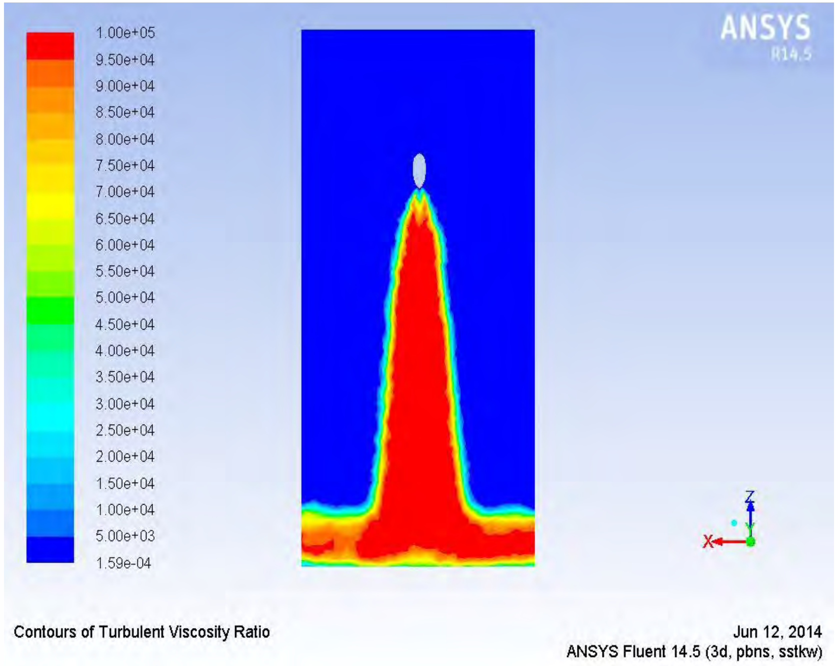
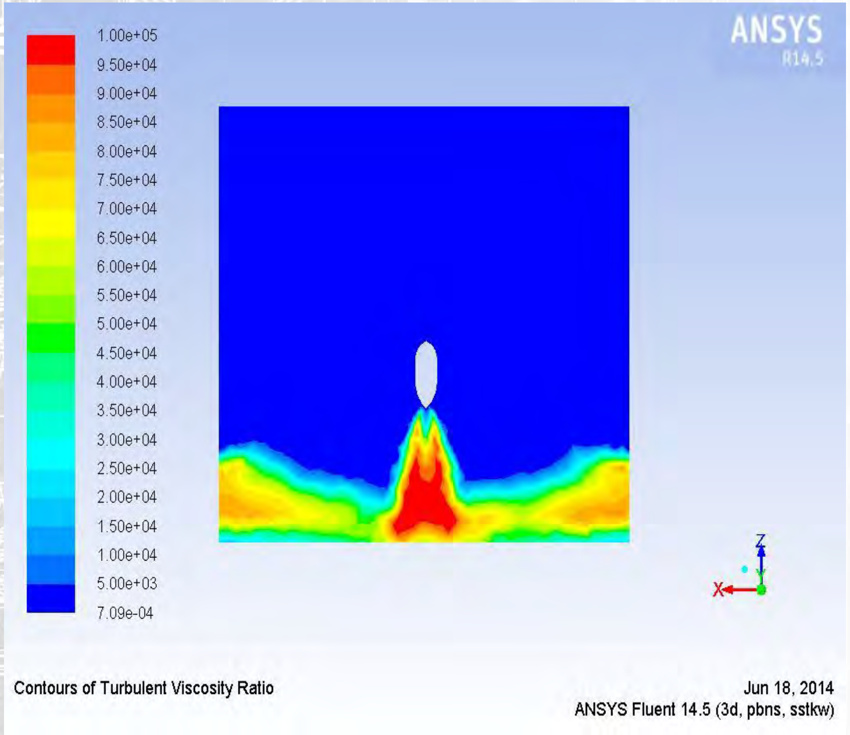
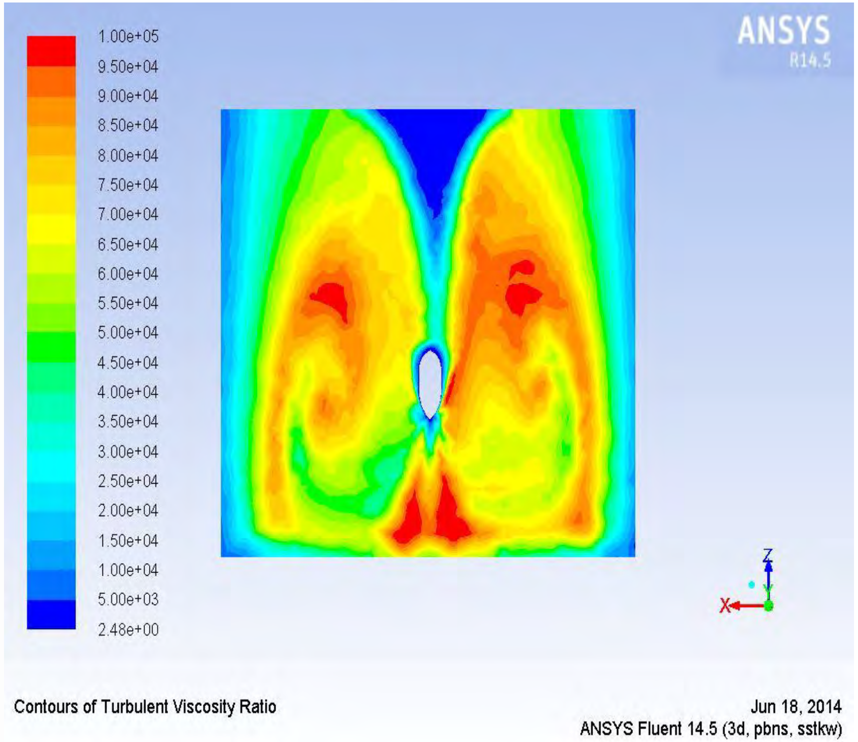
# Parametric Study



# Parametric Study



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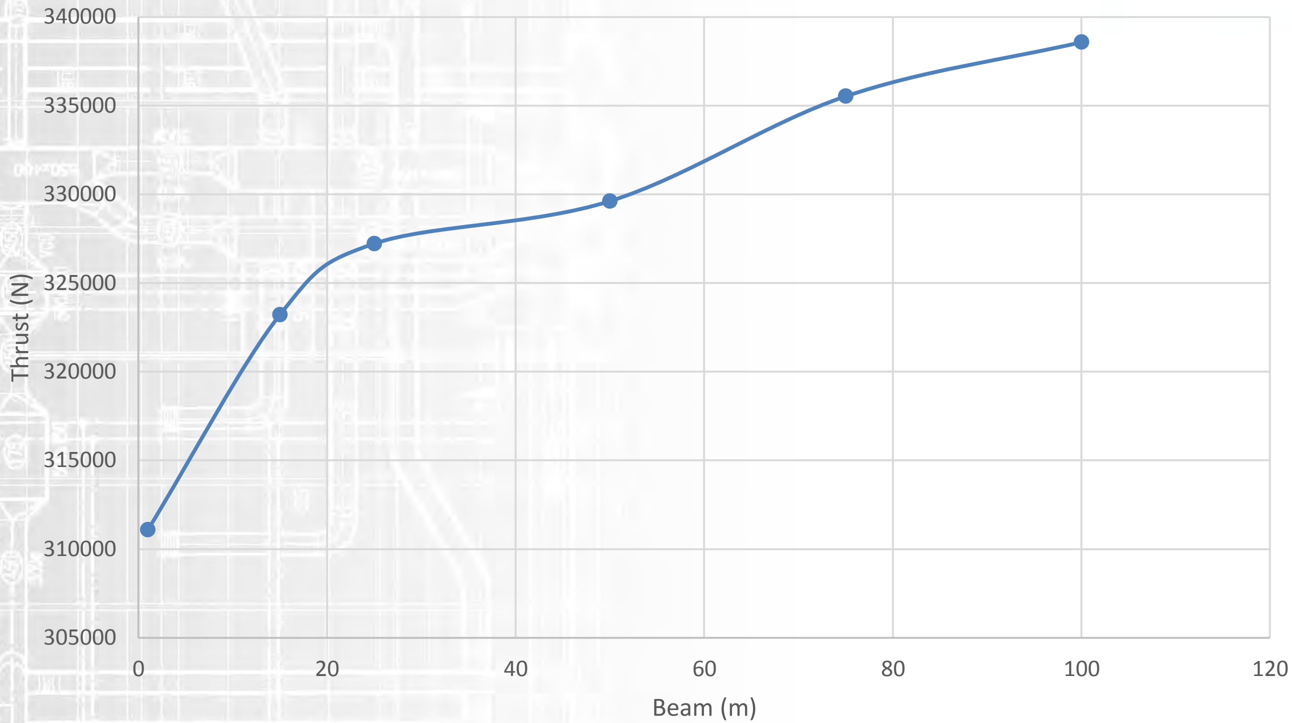
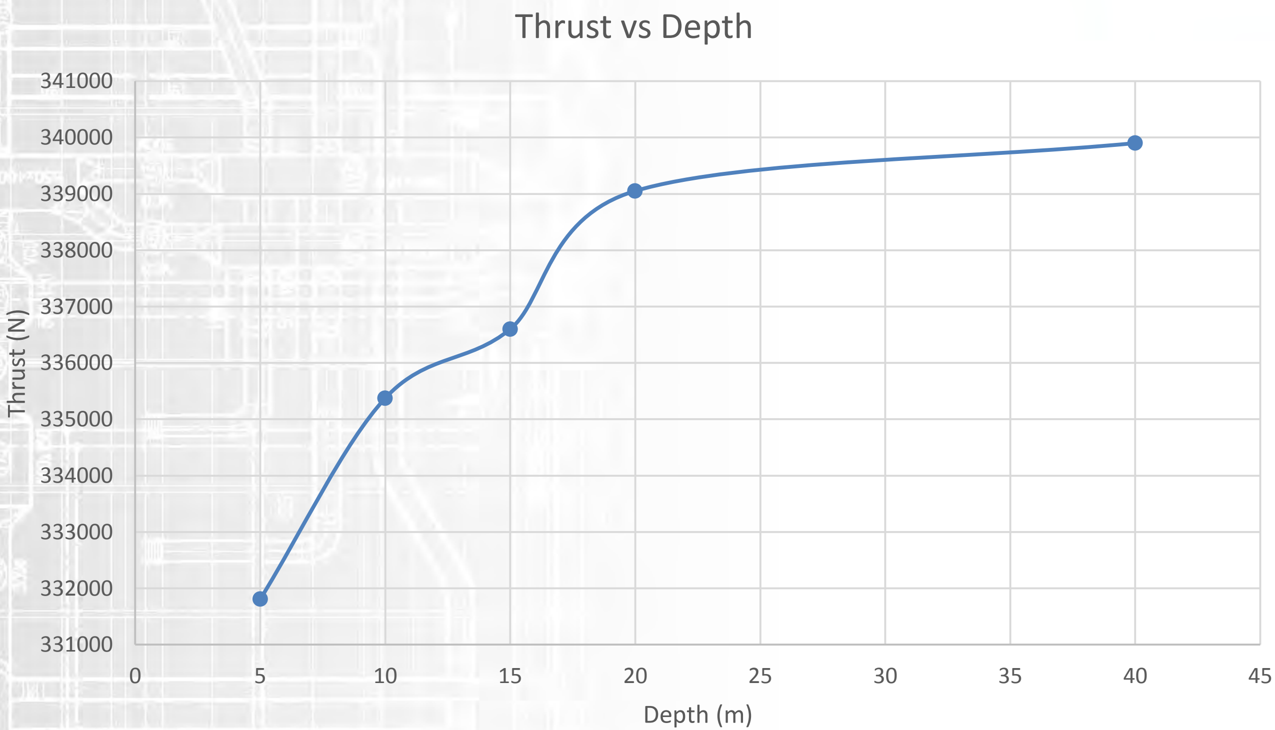


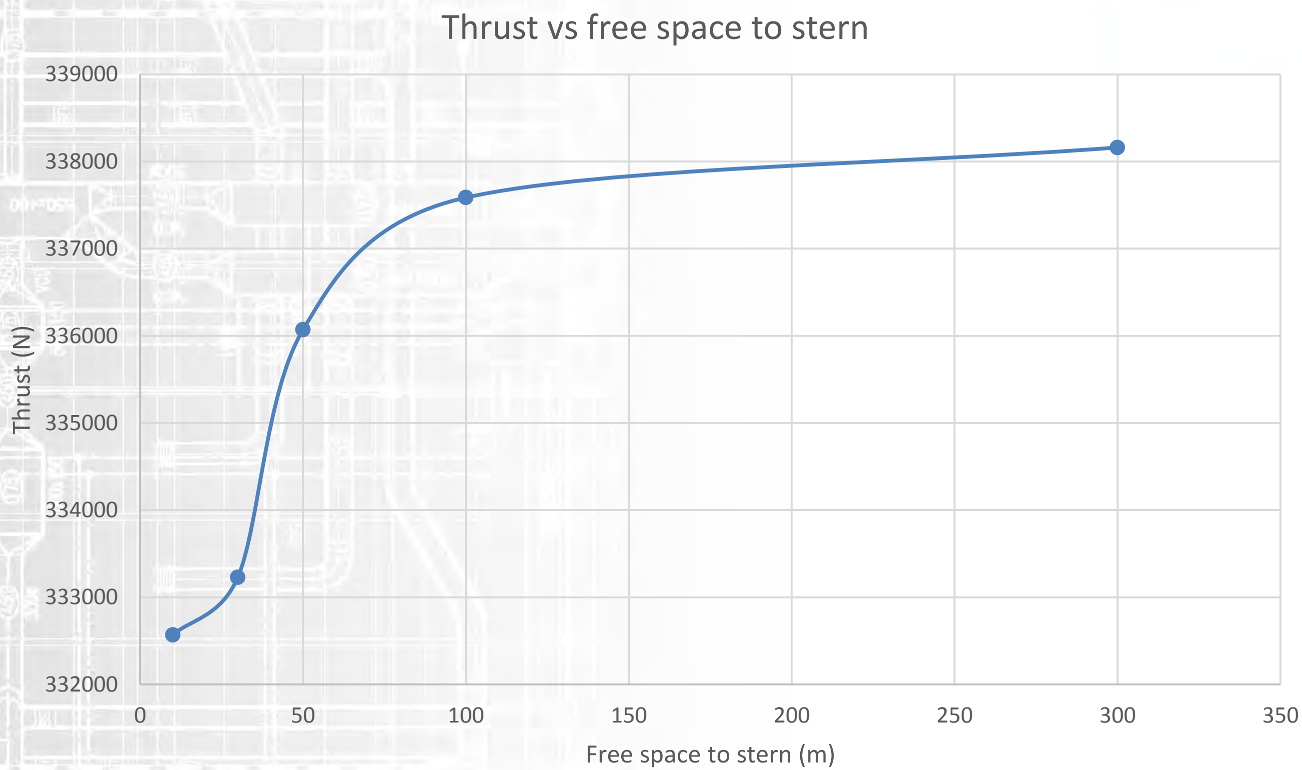

Free space to the sides

# Parametric Study



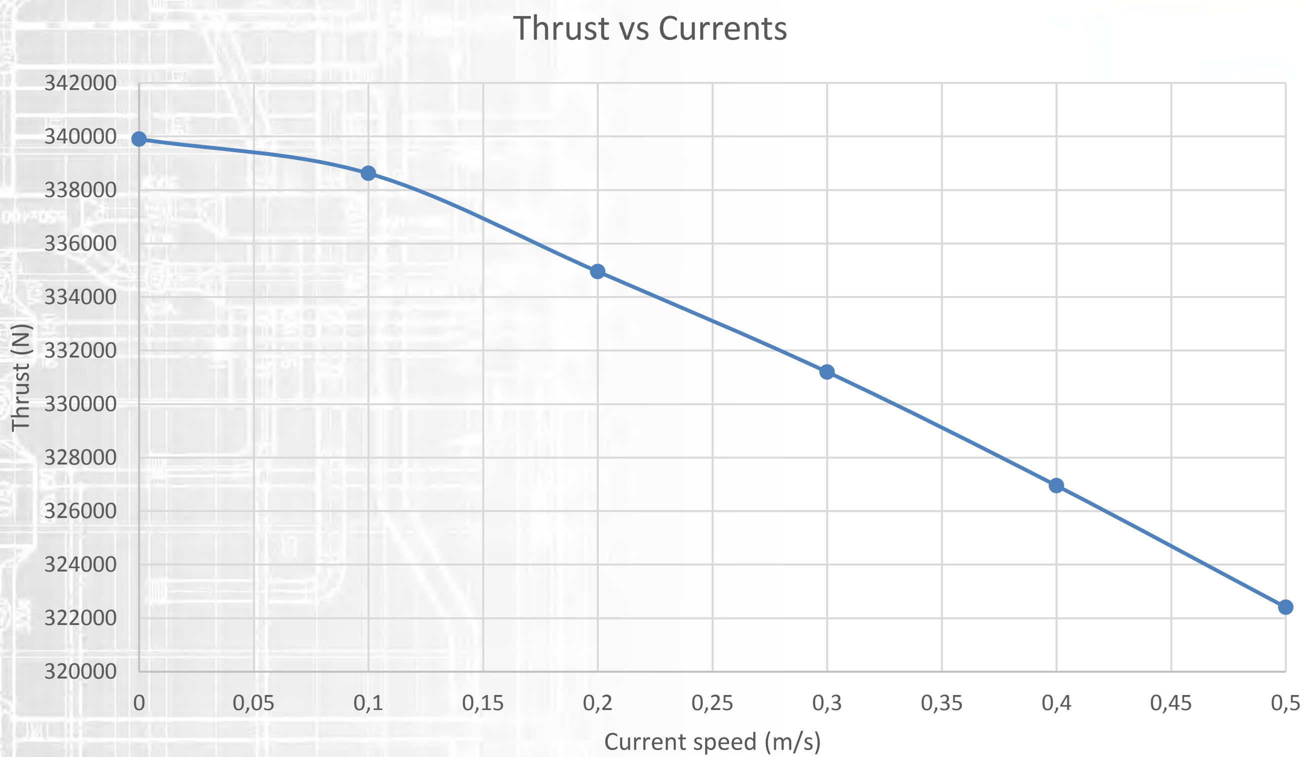

Depth under the vessel

# Parametric Study




Free space between the stern and the shore

# Parametric Study




Effect of the currents

# Conclusions

- The methodology developed with the shear stress transport k-w turbulence model is an effective method to study the bollard pull condition.
- Comparing the steady and transient simulations, the steady simulation shows advantages to study the bollard pull condition.
- We proved the negative effects in bollard pull test of inadequate geometric space dimensions and currents.
- The versatility of the method was verified by running simulations with different diameters and rotational speeds.

# THANK YOU VERY MUCH FOR YOUR KIND ATTENTION

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