MASTER THESIS PRESENTATION

TURBULENT FLOW SEPARATION AROUND A ROV BODY

Presented by:

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Outline

1- Introduction

2- Numerical modeling of the ROV

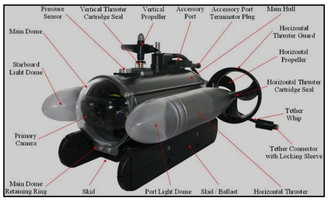
3- Choice of the turbulence model and used grids

4- Solution of simulations

5- Conclusion

1-INTRODUCTION

- A Remotely Operated Vehicle (**ROV**)
  - Important robot
  - Variety of task underwater.



Contribution →
- Exploration, inspection
- Maintenance and repair of underwater structures
- Maritime security

Underwater environment dynamic!

- Purpose of this work: Investigate the propulsive performance of the ROV

Scope of this work

- Design a ROV,
  - **ellipsoidal body**,
  - four ducted propellers → 2 for horizontal motion; 2 for vertical displacement
- Perform steady-state computations with **CFD code FLUENT**;
- Investigate on the **effects of the angle of attack** on
  - Separation pattern
  - Hydrodynamic forces and moments.

Methodology

C F D Method → To assess and to investigate on ROV's hydrodynamics.

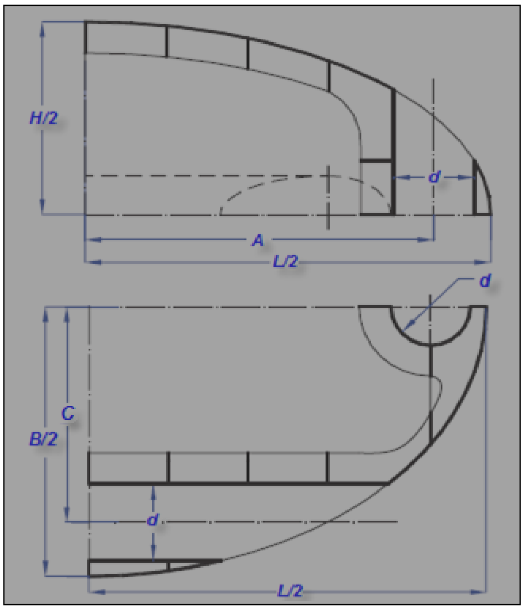
V & V Method From ASME → To determine the best turbulence model suited for simulations

C F D code FLUENT → To perform simulations around the ROV body

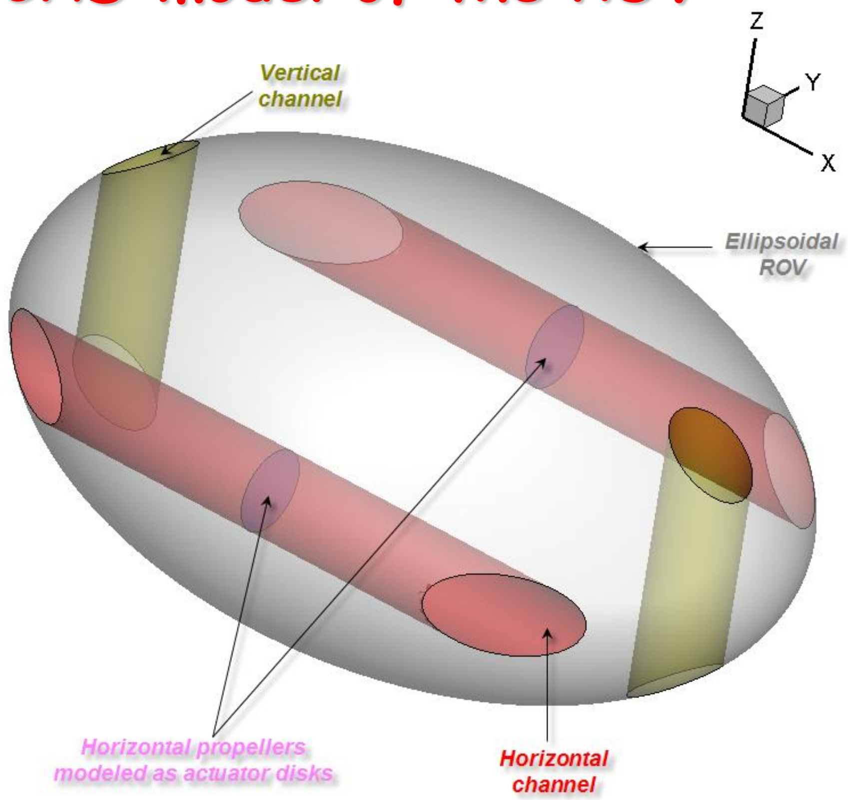
2-Numerical modeling of the ROV

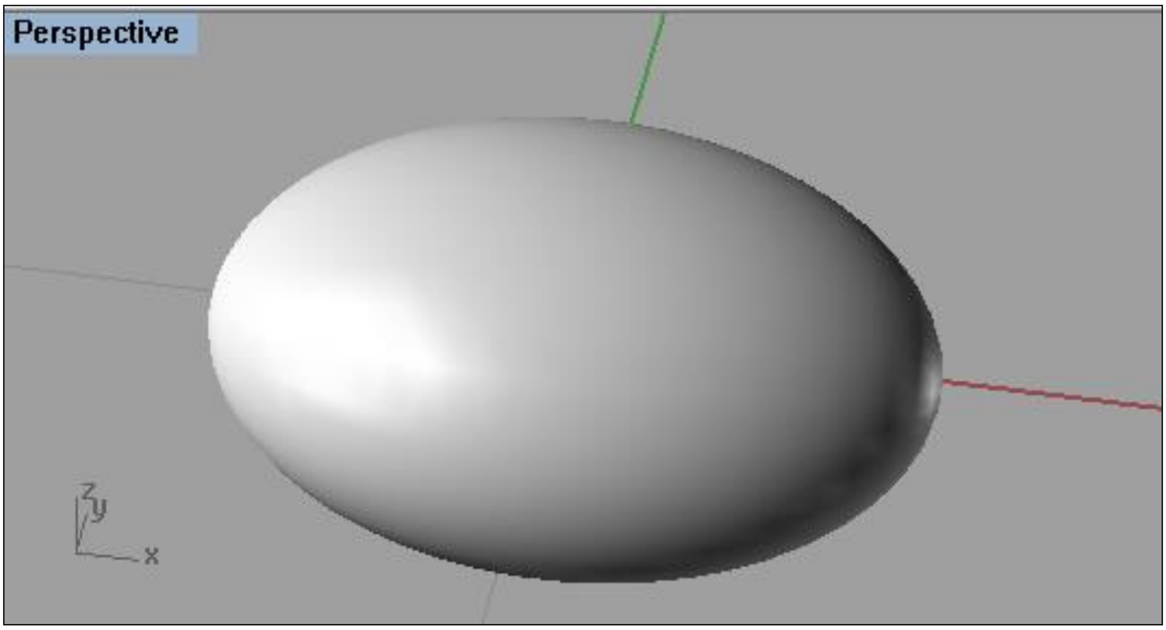
The selected ROV dimensions

Characteristics	Symbol	Value
Length	*L*	500 [mm]
Width	*B*	350 [mm]
Height	*H*	250 [mm]
Horizontal spacing	*A*	215 [mm]
Vertical spacing	*C*	140 [mm]
Propellers diameter	*d*	50 [mm]



CAD model of the ROV





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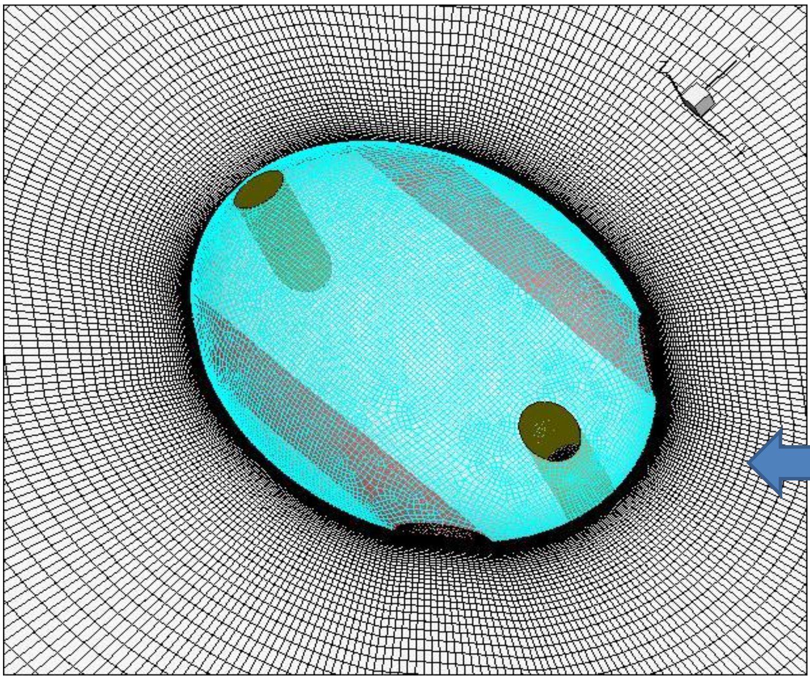
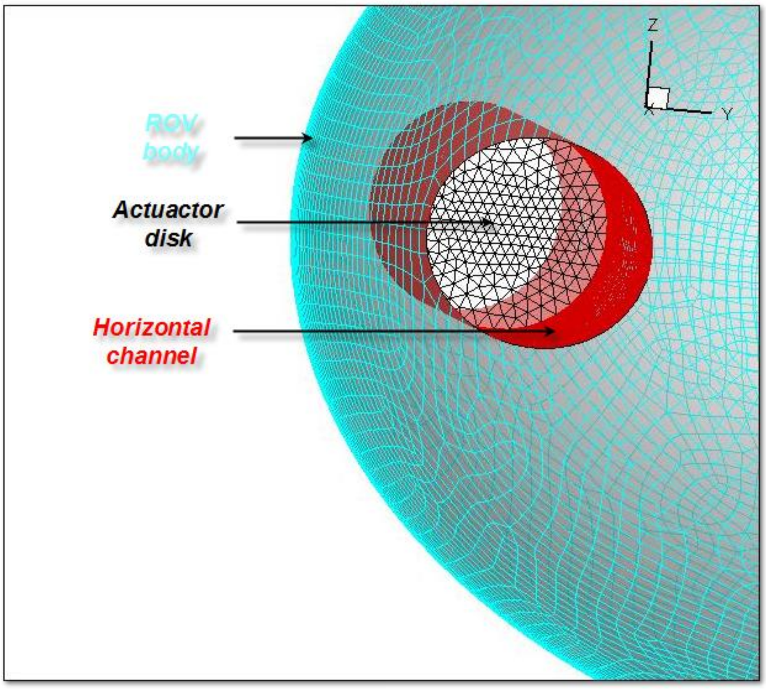
- "Bare hull" ⟷ Ellipsoidal ROV without channels and propellers

3-Grids around the ROV



Structured mesh inside the fluid domain

Grids on the ROV



Choice of turbulent model

- **Verification & Validation method from ASME**

Turbulence model	Fine Grid #1 Force [N]	Medium Grid #2 Force [N]	Coarse Grid #3 Force [N]	Discretization error δG [%]	Discretization Uncertainty IG [%]
SA	7.7207665	7.6112397	9.1473354	0.1089	0.1361
KES	10.274434	10.302896	10.290131	0.2253	0.2816
KERNG	6.1109277	6.2389111	6.488291	2.2080	2.7600
KER	6.5435718	6.6625013	6.8730493	2.3593	2.9491
KWS	32.414518	44.709143	45.449136	2.4291	7.2873
KWSST	11.73214	12.868474	8.0203764	2.9652	3.7065
RSM-LR	9.5472548	9.1122949	16.079741	0.3033	0.3792
RSM-LPS	Divergent	Divergent	Divergent	-	-
RSM-QPS	Divergent	Divergent	Divergent	-	-

SA with δG = 0.11 % yields less error than others

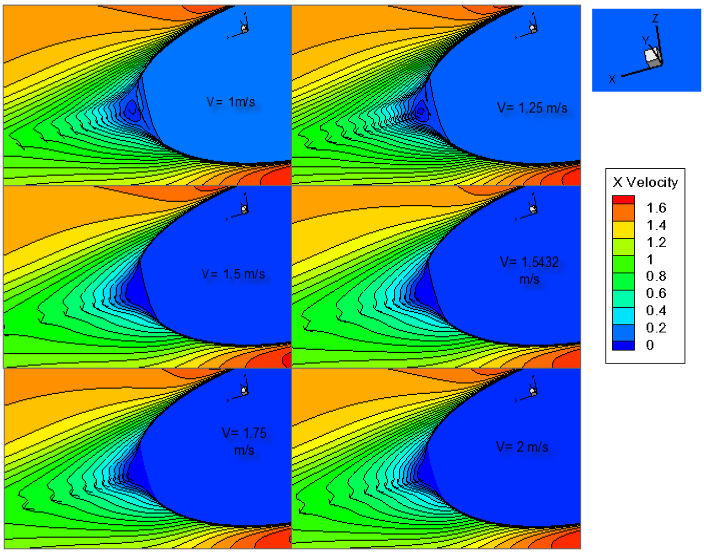
→ **Spalart-Almaras (S A)** is the most suitable turbulence model for simulating flow around the ellipsoidal ROV

4-Solution of simulations

- Main working regime for the ROV → Longitudinal displacement
- Results of simulations will concern all configurations step by step: "**bare hull**", "**ROV's hull**" and "**ROV body**"
- "ROV's hull" results → Study of ROV resistance, R_T
- "ROV body" results → Total thrust developed, T (Propellers effect)

Solution of simulations, bare hull case

Velocity distribution behind the ellipsoid



Velocity behind the bare hull is equal to zero
Disturbances are reduced when the ellipsoid increases in speed

Solution of simulations, ROV's hull case

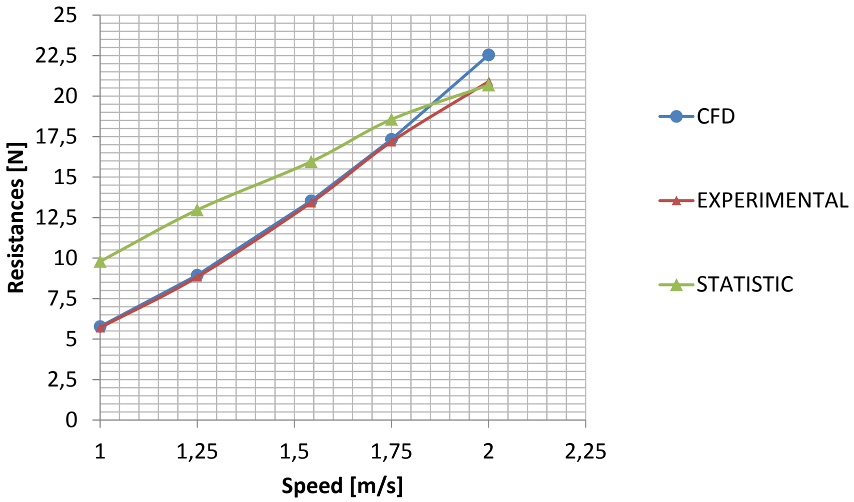
- **ROV resistance**

Speed, v [m/s]	**1**	**1.25**	**1.5432**	**1.75**	**2**
Reynolds number	4.98E+05	6.22E+05	7.68E+05	8.71E+05	9.95E+05
Statistic Method [N]	9.79	12.97	15.95	18.56	20.68
EFD [N]	5.7	8.83	13.42	17.18	20.89
CFD [N]	5.77	8.94	13.53	17.33	22.54
Validation comparison error $E = \frac{(CFD-EFD)}{EFD} * 100[\%]$	1.23	1.25	0.83	0.87	7.89

- ROV's resistance R_T= 13.53 N for design speed of 3 knots (1.5432 m/s)
- The corresponding effective power is 21 W.

• Comparison between CFD and EFD results

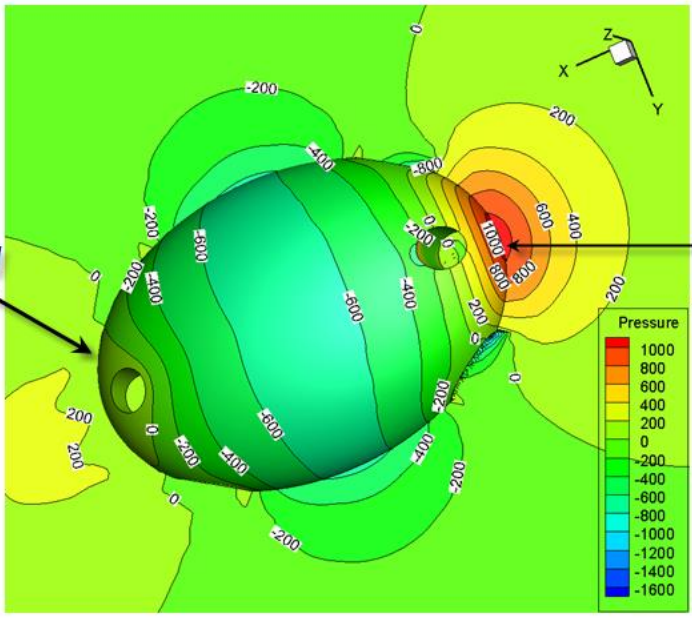
Statistical results and the experimental data from literature **Obreja and Domnisoru [4]**



Simulation results have good agreement with the experiment data

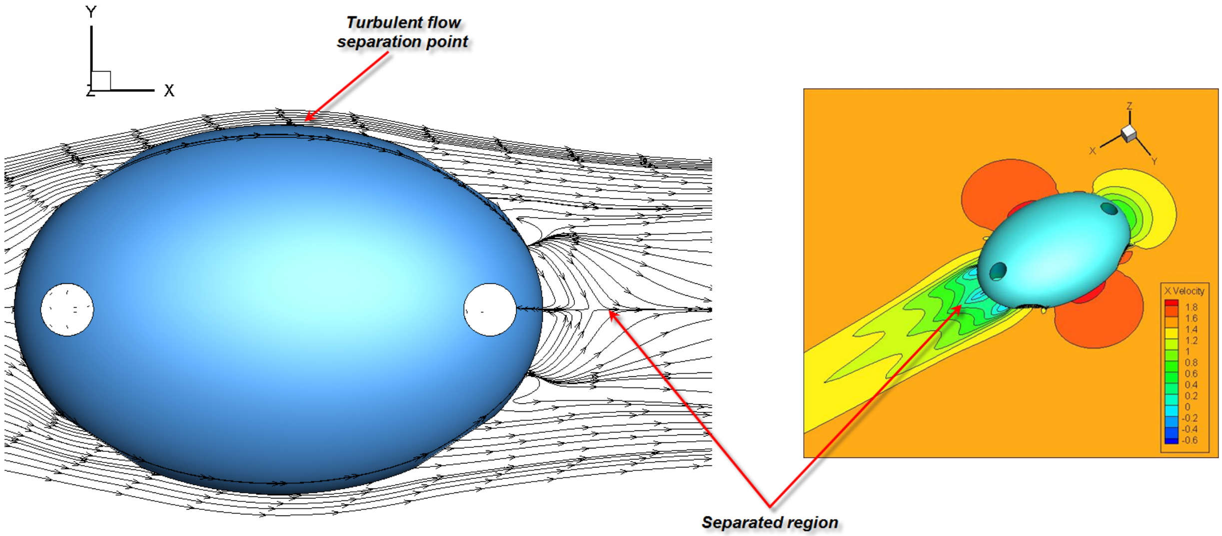
• Pressure distribution for design speed

Low pressure behind ROV's hull



High pressure in front

• Streamlines and Velocity distributions for design speed



- ○ Negative velocity behind the ROV hull
- ○ Separated region behind ROV → Reattachment of two flow streams

Solution of simulations, ROV body case

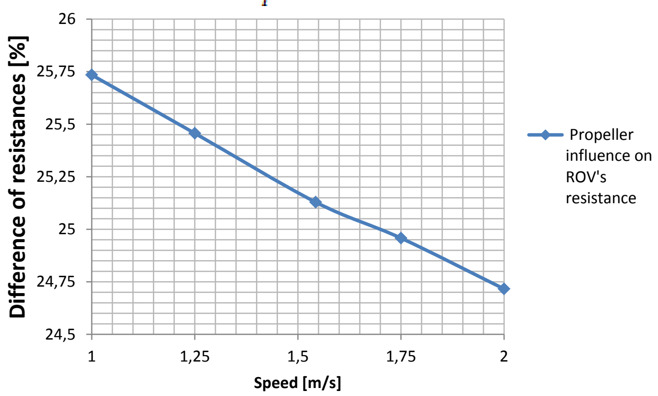
• Propeller influence

Defined by the **resistance augmentation factor** ΔR

R_T: Resistance from "ROV's hull" case

T: Resistance from "ROV body" case

$$\Delta R = \frac{T - R_T}{R_T} \Rightarrow T = R_T(1 + \Delta R)$$



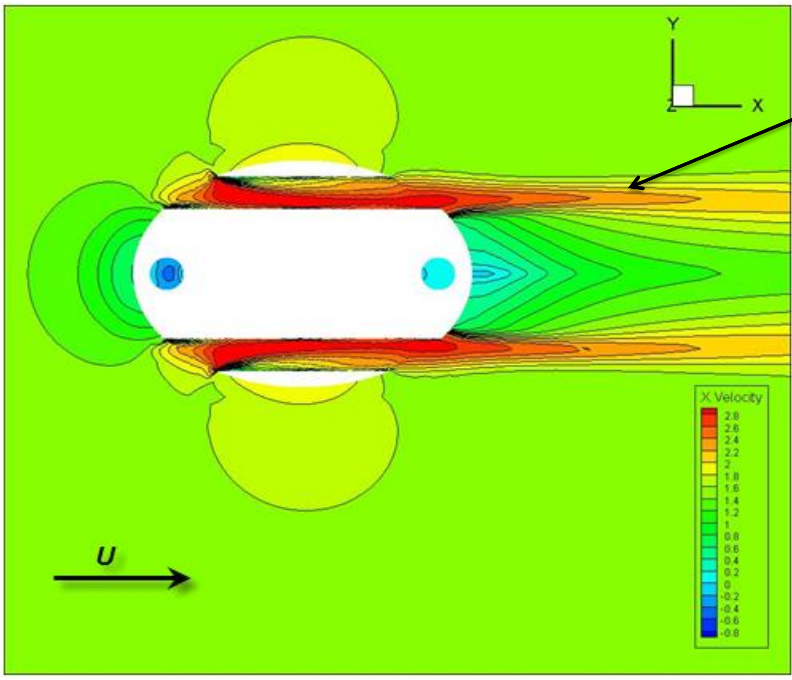
Velocity [m/s]	Thrust per propeller [N]	Thrust deduction fraction, t
1	3.63	0.205
1.25	5.61	0.203
1.5432	8.47	0.201
1.75	10.82	0.199
2	14.05	0.198

When speed ↗ ΔR ↘

thrust ↗ , thrust deduction fraction ↘

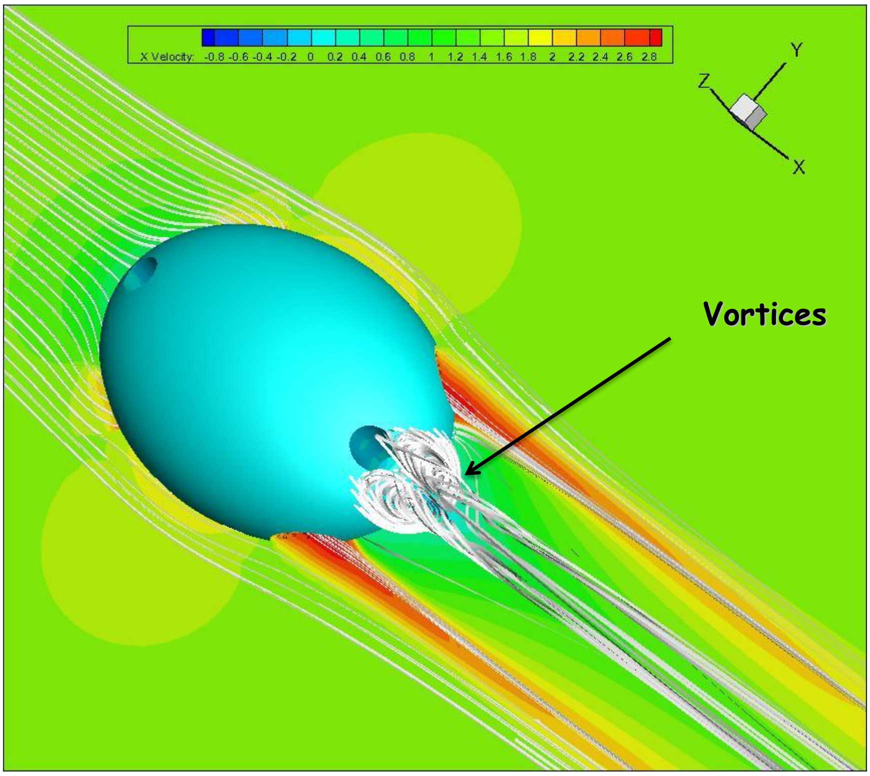
Solution of simulations, ROV body case

- Velocity distribution



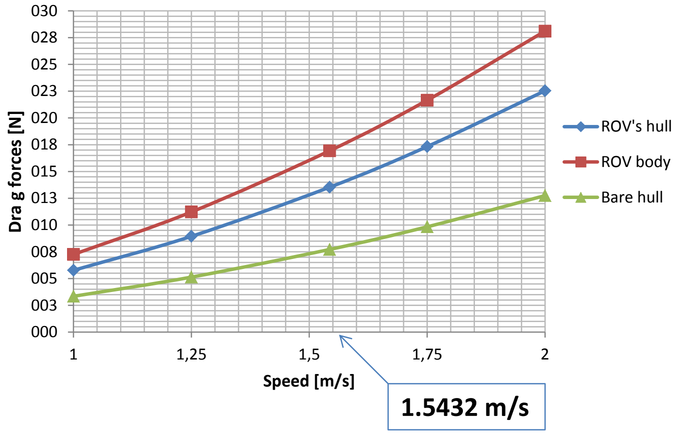
Flow accelerated by propellers

- Streamlines

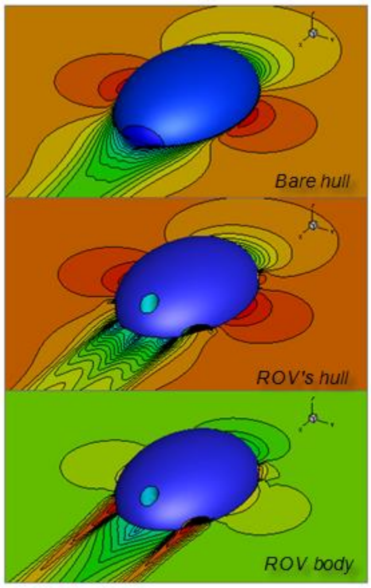


Comparison between all cases

- Resistance



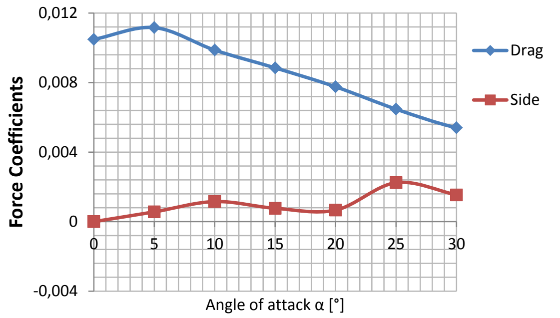
- Velocity distribution for design speed (1.5432 m/s)

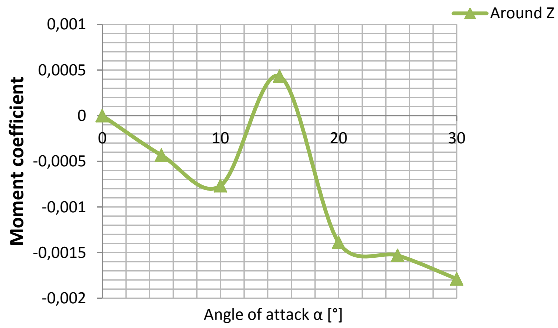


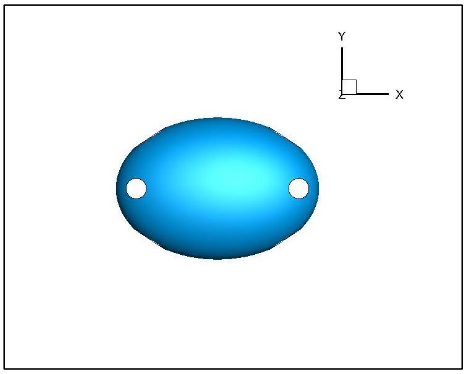
- Bare hull , less resistance with creation of separated region
- separated region disturbed by cylindrical channels
- Separated region reduced by propellers action's

Solution of simulations, angle of attack effects

- In xy-plane



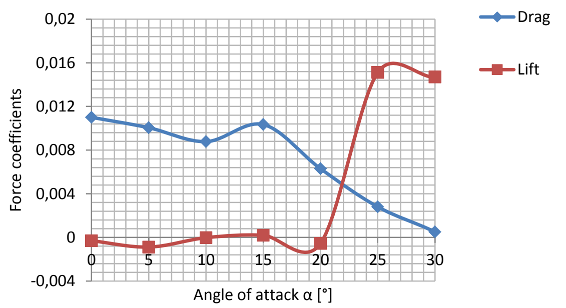


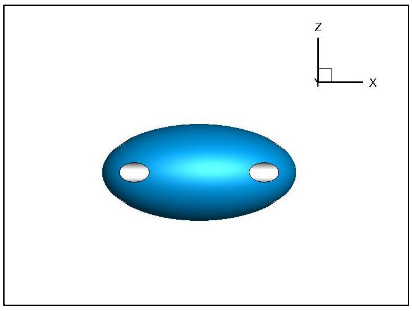


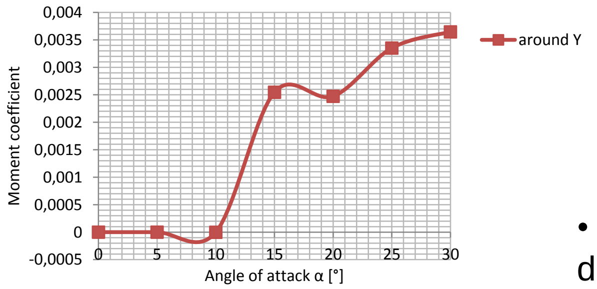
- Maximum moment is reached around z-axis at $\alpha = 15°$
- Drag force is more significant than others forces

Angle of attack effects

- In xz-plane





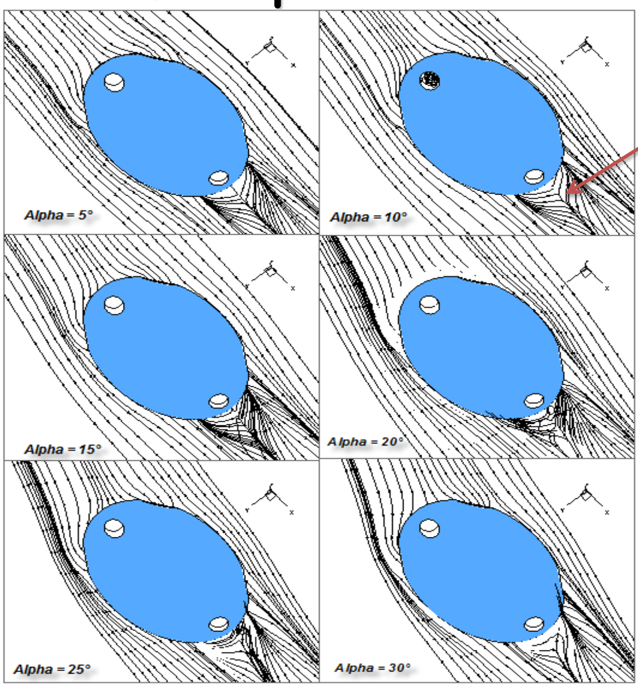


- Moment coefficient around y-axis and the lift force are more important when increasing the angle of attack.

- In both planes, the total drag coefficients decrease when the angle of attack increases

Angle of attack effects

Streamline patterns at the ROV section



Separated region

•Separated region decreases when the angle of attack increases

5-Conclusion

• CFD results have good agreement with experimental data

•The turbulent flow around the ROV body
- characterized by flow separation
- inducing the creation of separated region behind the ROV;

•The effects of flow separation around the ROV body are felt in form of reduced velocity;

•The action of the propellers reduces the separated region and low pressure gradient.

• ROV's resistance and separated region decrease at high angle of attack;
- Linear dependence between the separated region and the drag pressure.
- The smaller separated region is, the smaller the ROV resistance is obtained, leading to energy savings.

Thank you for your attention