**FOSSEE Fellowship Report**
**on**

# MODEL VERTICAL AXIS WIND TURBINE WITH DYNAMIC MESH


Submitted by

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**July, 2019**

# Acknowledgment

I would like to express my sincere gratitude to Prof. Shivasubramanian Gopalakrishnan for his guidance. I deeply thank Prof. Kannan M Moudgalya for starting the fellowship program and providing the project work opportunity at FOSSEE, IIT Bombay.

In addition, I am thankful to Sathish Kanniappan, research associate, FOSSEE and Deepa Vedartham, research assistant, FOSSEE for their mentorship and help during my fellowship.

# Contents

# Nomenclature

| | |
|---|---|
| U | Velocity, m/s |
| g | Gravitational acceleration, $m/s^2$ |
| P | Pressure, Pa |

*Greek Symbols*

| | |
|---|---|
| $\upsilon$ | Kinematic viscosity, $m^2/sec$ |
| $\omega$ | Angular speed, rad/sec |

# Chapter1

# Introduction and Problem Statement

## 1.1. Introduction

A vertical axis wind turbines (VAWT) is a type of wind turbine where the main rotor shaft is set transverse to the wind (but not necessarily vertically) while the main components are located at the base of the turbine [1]. VAWT does not require any complex mechanism or motors to yaw the rotor and pitch the blades [2]. One of the major challenges of this technology is dynamic stall of the blades as the angle of attack varies rapidly [3] [4] [5].

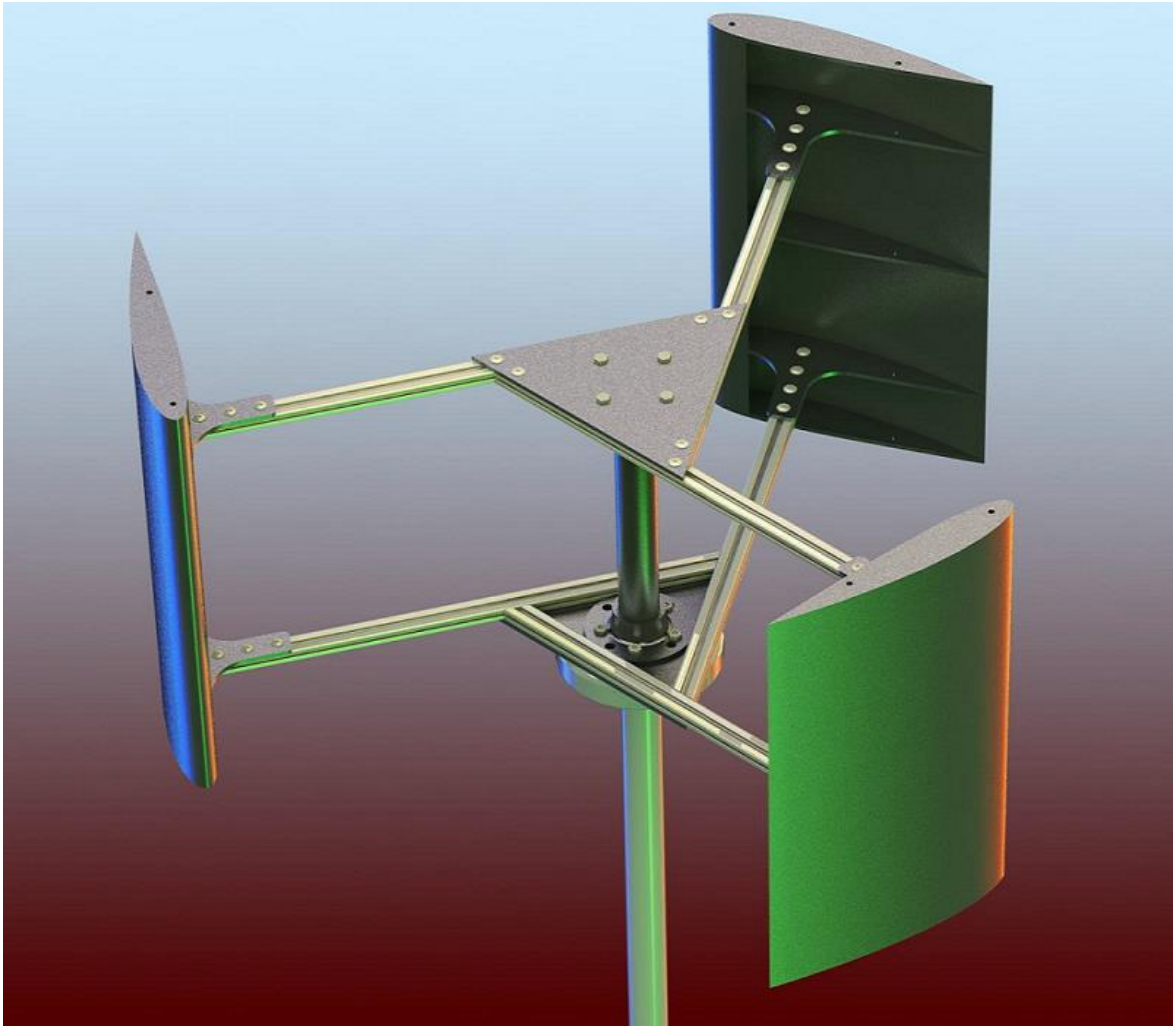


Figure 1.1. CAD model of VAWT [6]

## 1.2. Problem Statement

A model VAWT of 2D geometry was considered for the numerical study of a laminar flow. The details of the geometry can be found in the Figure1.2. Here whole the mesh was created with two different regions so that inner mesh of rotor can be rotated in CCW direction.

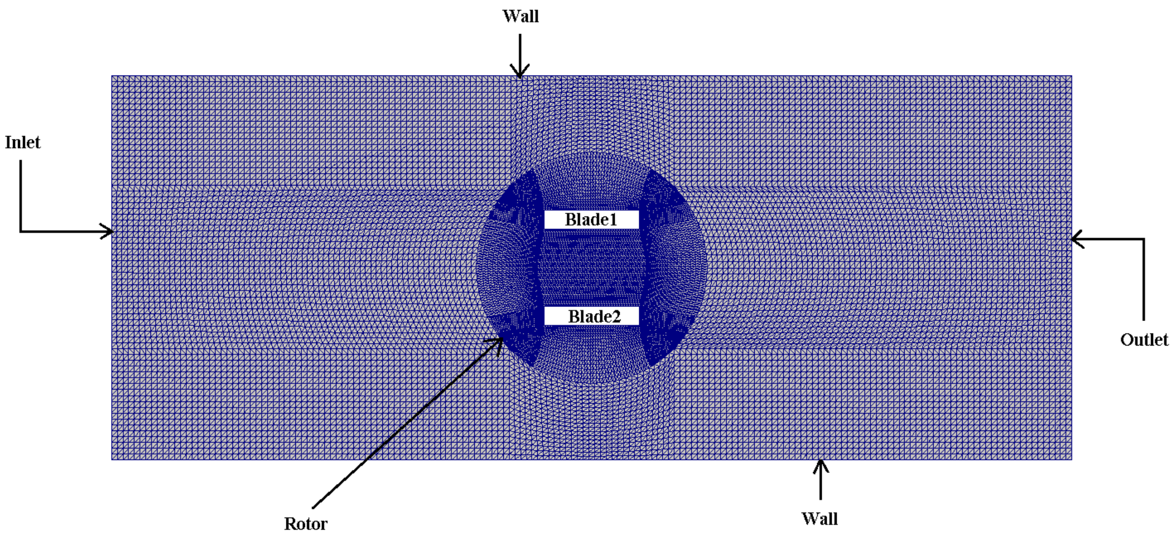



Figure 1.2. 2D Geometry with Mesh

**Table 1. Geometry and Computational Details**

| ***Parameter*** | ***Detail*** |
|---|---|
| Model | 2 Dimensional |
| Geometry-Mesh creating software | ICEM CFD |
| Number of cells | 17,209 |
| Post-processing tool | Paraview, Sigma Plot |
| Solver | pimpleFoam |
| Pressure-velocity coupling | PIMPLE algorithm [7] |
| Convective term solving scheme | Gauss linear upwind [7] |

**Table 2. Fluid properties and initial conditions**

| ***Parameter*** | ***Value/Condition*** |
|---|---|
| $\boldsymbol{\upsilon}_{air}$ | 1e-05 $m^2$/sec |
| $U_{air}$ | 1 m/sec |
| Wall | No slip |
| Inlet | Free stream velocity |
| Blades | Moving wall velocity |
| Rotor rotation | CCW |
| ω | 10 rad/sec |

# Chapter2

# Equations

## 2.1. Continuity Equation [8]

$\nabla . \mathrm{U} = 0$

## 2.2. Momentum Transfer Equation [8]

$\frac{\partial \mathrm{U}}{\partial \mathrm{t}} + \nabla . (\mathrm{UU}) + \nabla . (\upsilon_{\mathrm{eff}} \nabla \mathrm{U}) = -\nabla \mathrm{P} + \mathrm{g}$

# Chapter3
# Results and Discussion
## 3.1. Plots

The velocity and pressure were calculated at the downstream of rotor.

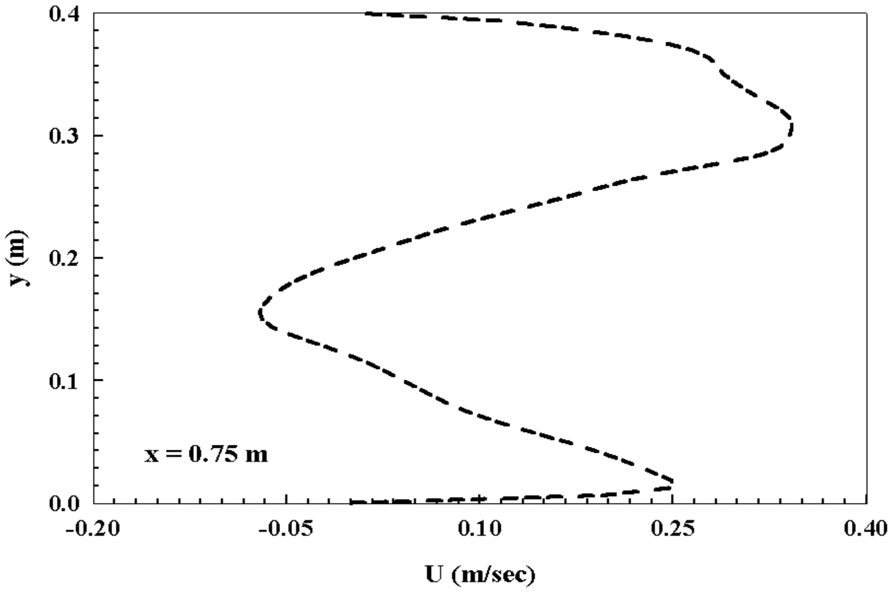



Figure 1.3. Velocity along height at x = 0.75m

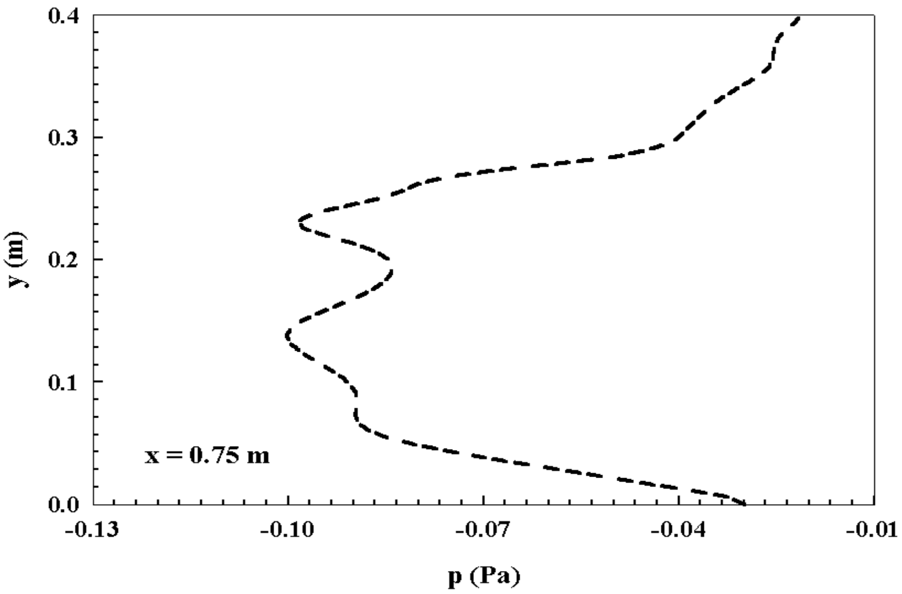



Figure 1.4. Pressure along height at x = 0.75m

## 3.2. Contours

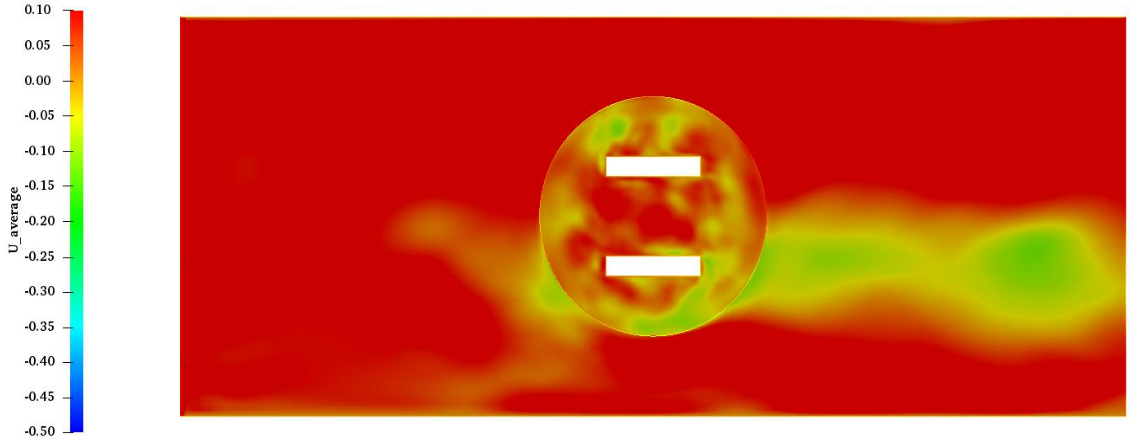



Figure 1.5. Velocity contour

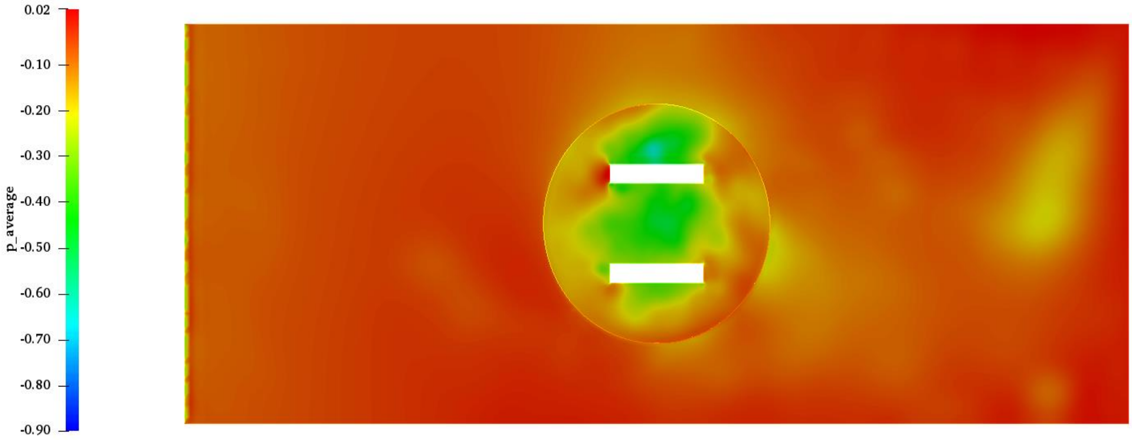
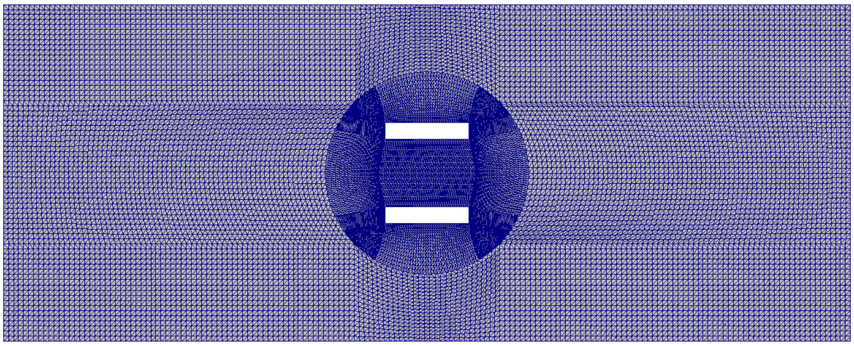



Figure 1.6. Pressure contour

## 3.3. Dynamic Mesh



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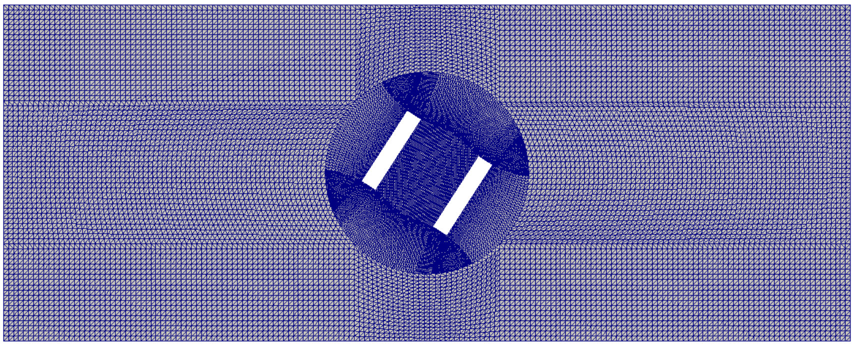

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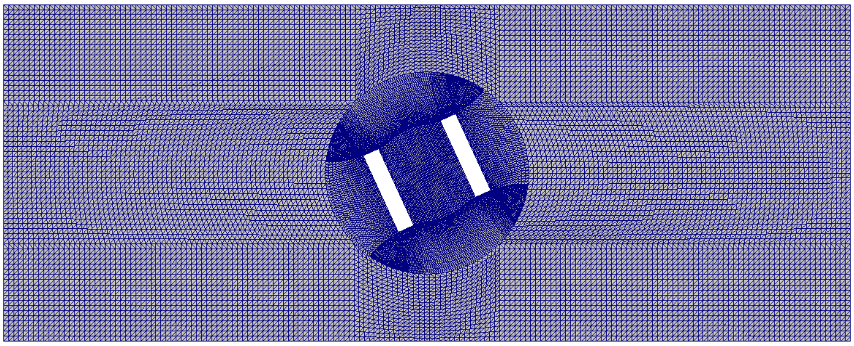

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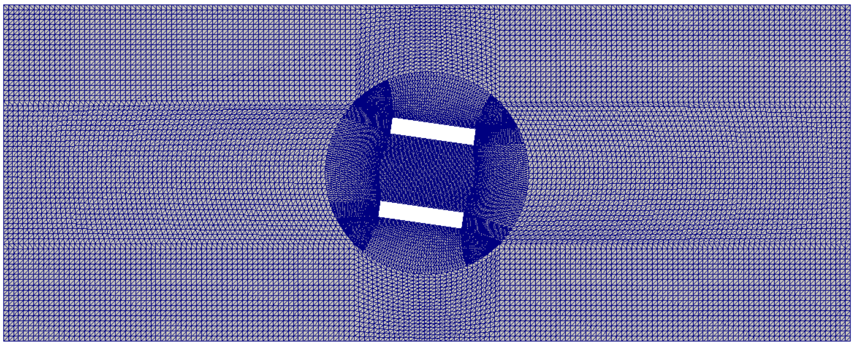

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Figure 1.7. Moving mesh at different time

## 3.4. Conclusion

A physical problem of vertical axis wind turbine can be simulated for dynamic mesh with pimpleFoam solver.

# Reference

[1] https://en.wikipedia.org/wiki/Vertical_axis_wind_turbine

[2] AIP Conference Proceedings 1931, 030040 (2018)

[3] Buchner A.J., Soria J., Honnery D., Smits, A.J., Dynamic stall in vertical axis wind turbines: Scaling and topological consideration, Journal of Fluid Mechanics, 841: 746–66 (2018)

[4] Buchner A.J., Lohry M.W., Martinelli L., Soria J., Smits A.J., Dynamic stall in vertical axis wind turbines: Comparing experiments and computations, Journal of Wind Engineering and Industrial Aerodynamics, 146: 163–71 (2015)

[5] Carlos S.F., Gijs V.K., Gerard V.B., Fulvio S. Visualization by PIV of dynamic stall on a vertical axis wind turbine, Experiments in Fluids, 46: 97–108 (2008)

[6] Heppner J.,Vertical Axis Wind Turbine Strut and Blade Design for Rural Alaska (2015)

[7] OpenFOAM User Guide version 6.0 (2018)

[8] Romanò Francesco, 2-D Flow Past an Airfoil, [302.044] Numerical Methods in Fluid Dynamics (2015)