

# CFD and Stress Simulation report: Wind Wall

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## 1. Abstract

The objective of this report is to analyse the wind flow patterns and the force exerted on the “Wind Wall” and the structural stress and strains the “Wind Wall” can handle. The main objective is to prove that the design can handle day to day stress and loads most importantly the designs can withstand certain limit of unfavourable conditions. The safety factor and stability of the design shall be also looked upon.

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## 3. Introduction

The Wind Wall is a cumulation of Vertical Axis Wind Turbines (VAWTs) Which are designed to extract the kinetic energy of the wind and convert it to electrical energy. The “Wind Wall” as such consists of 10 VAWTs which are of the Savonius Type (drag type wind turbine). The Blade has a profile of the ‘Ugrinsky’ type with a helical twist to enable it to operate with low wind speeds and relative independence on the wind direction. By grouping the VAWTs in a frame, it gives a greater power production and lesser usage of available space. Each unit VAWT in the “Wall” shall be connected in parallel to each other and each unit “Wall” shall be further connected in parallel to each other.

The objective of the CFD simulations is to properly analyse the wind flow pattern around each VAWT and the “Wall” as a whole. The objective of the structural analysis is to observe the stress on the “Wall” due to the incoming winds. The safety factor of the design shall be looked upon.

The wind speeds used in the simulation shall be 3m/s – 20m/s. The force used on the stress test shall be based upon the force generated by the CFD simulation on the structure.

## 4. Materials and Parts

Following are the materials used in the “Wind Wall” for the various simulations:

Slno	Material Used	Part
1	ABS Plastic	Blade
2	Steel	Axial
3	Steel	Axial bearings, Thrust bearings.
4	Steel	Generator Cover
5	Aluminium	Gears and planet holder
6	Copper	Coils
7	ABS Plastic	core

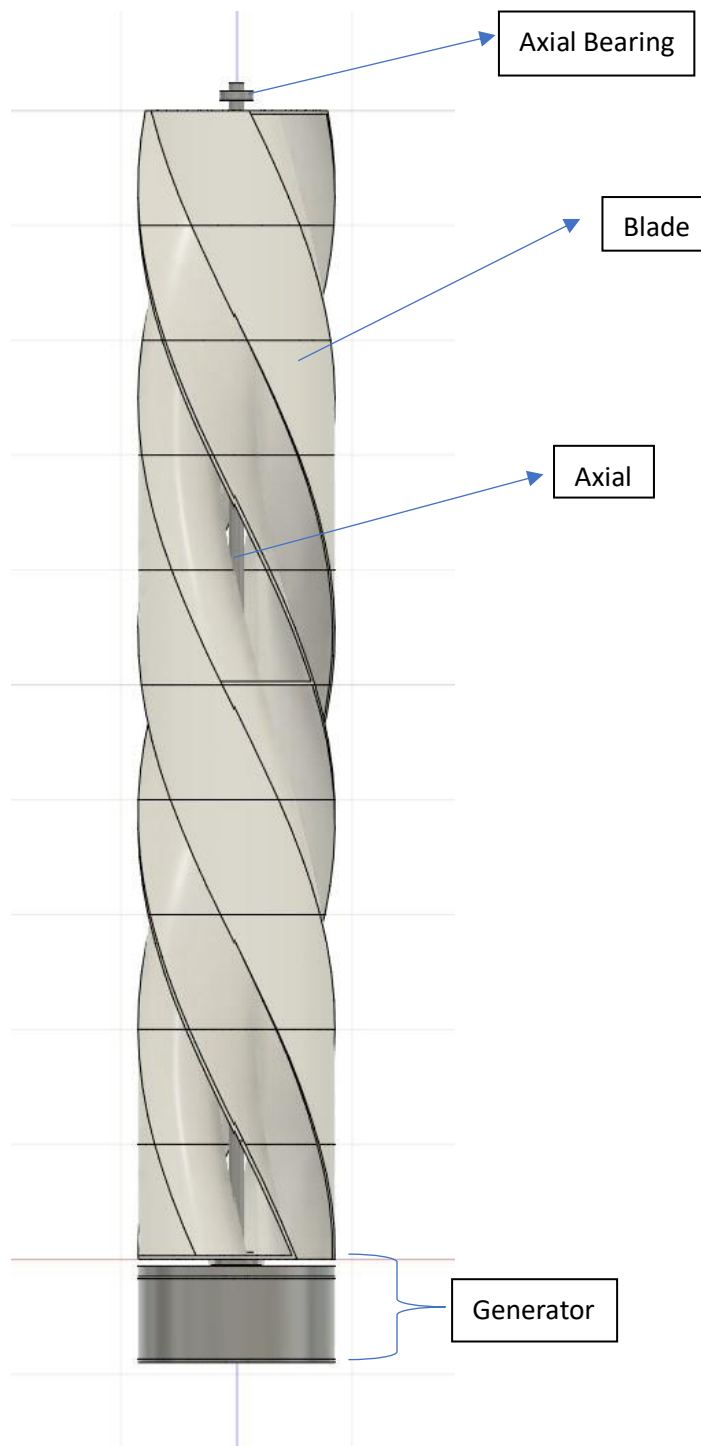


Fig 1: A Single VAWT and its parts

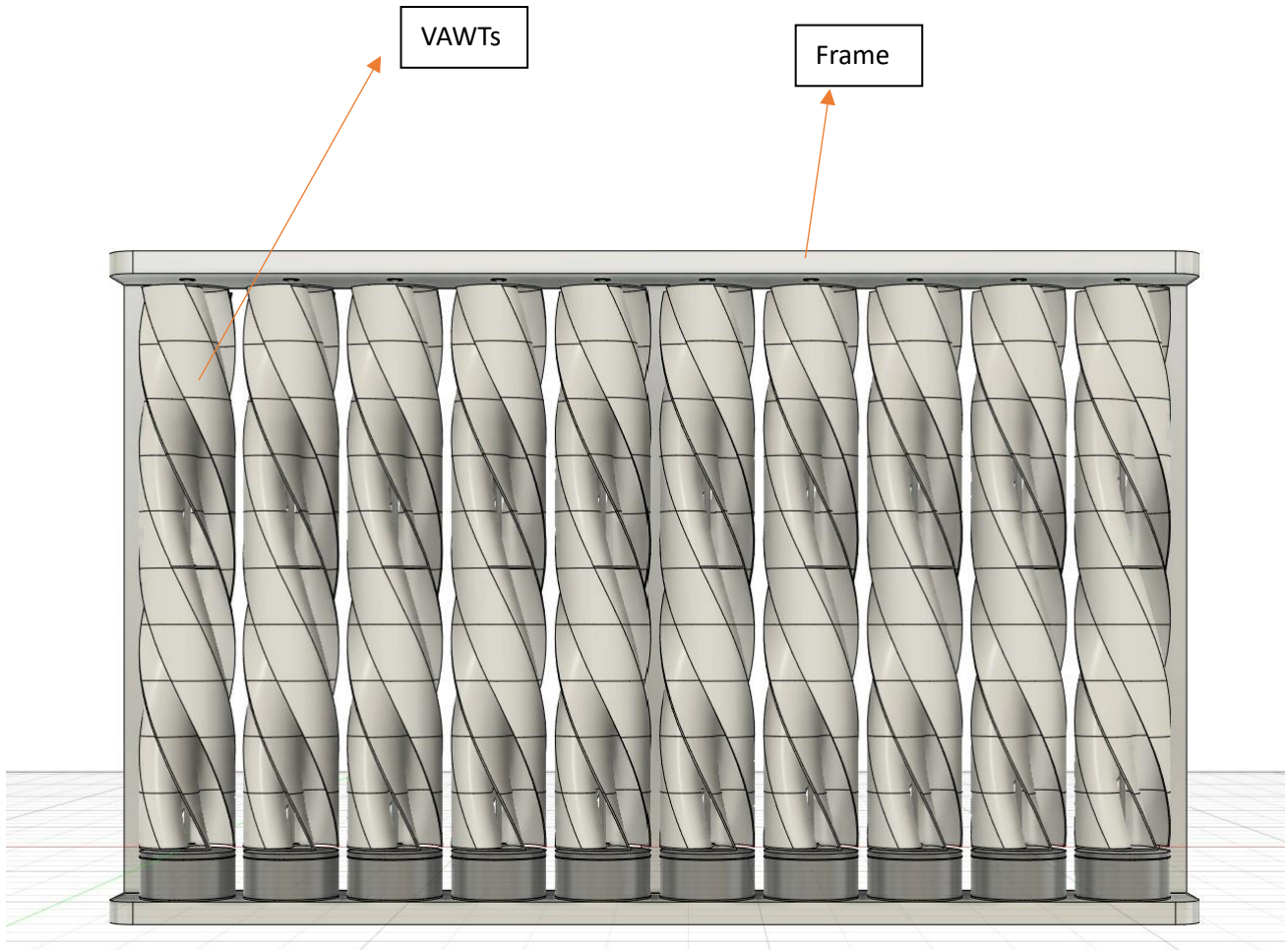


Fig 2: The Wind Wall

## 5. Simulation Setup Details

The Simulation is carried out in 2 main software: 'Fusion360' (**v.2.0.19941**) and 'AutoCAD CFD' (**v.2024**)

For CFD:

- 141958 Total Nodes, 104003 Fluid Nodes, 37955 Solid Nodes} For single VAWT
- 725455 Total Elements, 573228 Fluid Elements, 152227 Solid Elements} For single VAWT
- 1 Inlets (Velocity 3m/s, 8m/s, 17m/s, 20m/s), 1 Outlets (Pressure 0), 0 Unknowns} For single VAWT
- 1225606 Total Nodes, 1201788 Fluid Nodes, 23818 Solid Nodes} For "Wall"
- 4777785 Total Elements, 4090471 Fluid Elements, 687314 Solid Elements} For "Wall"
- 1 Inlets (Velocity 11.5m/s), 1 Outlets (Pressure 0), 0 Unknowns} For "Wall"
- Turbulent Compressible Flow is ON
- Turbulence model: Standard k-epsilon
- Solver Settings: 100 steps, each step 1 iteration. Temp 33degrees Celsius.
- Solver Settings: 200 steps, each step 1 iteration. Temp 33degrees Celsius.

For Stress Test:

- For Single VAWT: -
  - 1508406 Total Nodes.

- 958389 Total Elements.
  - Solver Settings: Gravity ON
  - Forces 3N, 16N, 62N, 87N.
- For The whole “Wall”: -
- 5308006 Total Nodes.
  - 3139313 Total Elements.
  - Solver Settings: Gravity ON
  - Forces 875.722N

## 6. CFD Simulation

For the CFD simulation, it shall be divided into two parts:

**The main goal of the simulation is to get the net force on the VAWT.**

### 1. For single VAWT:

In this simulation the air flow pattern, the pressure differences and most importantly the force acting on the turbine is calculated.

Case1: (3m/s)

For this the wind speed is at 3m/s.

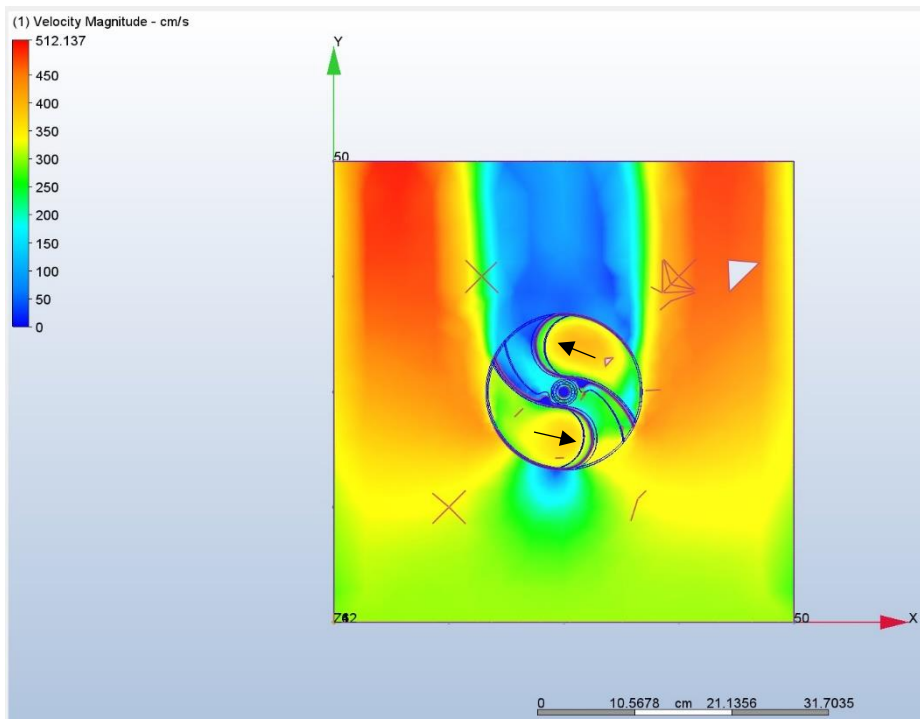


Fig 3: Plane showing wind pattern at 3m/s

The net force on the VAWT is approx. 2N. The vectors(arrows) showing the direction of the forces acting on the blade.

Case2: (8m/s)

For this the wind speed is at 8m/s.

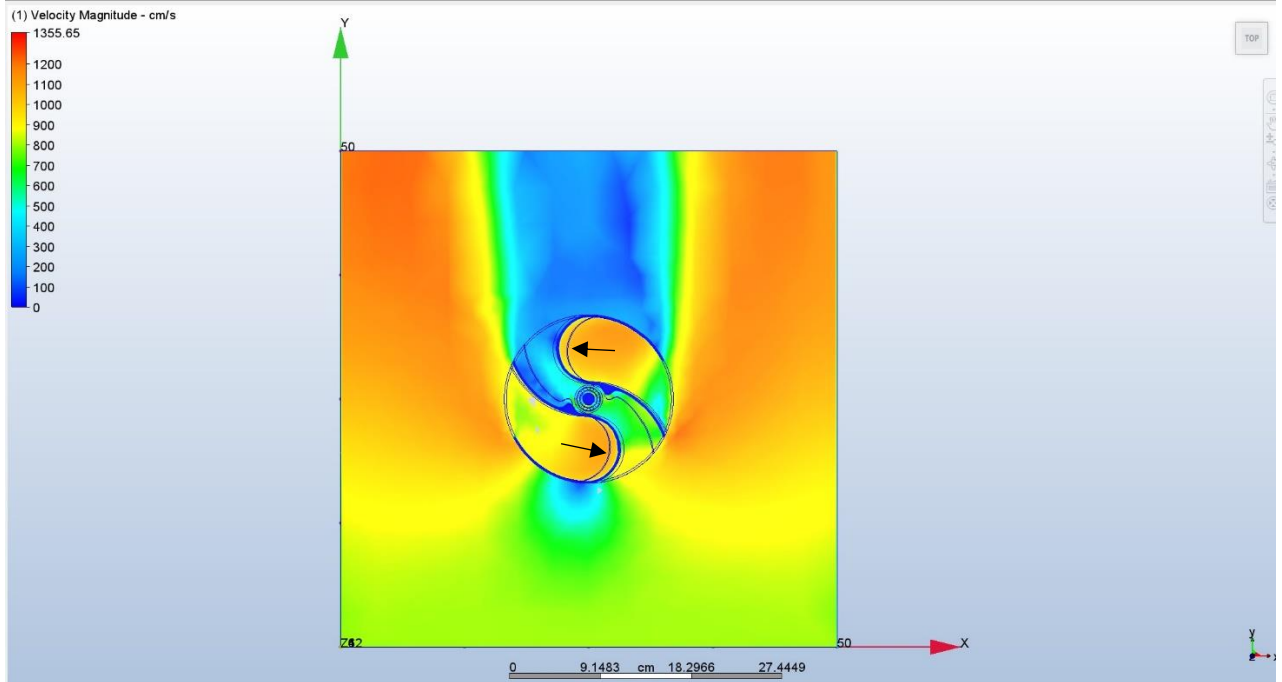


Fig 4: Plane showing wind pattern at 8m/s

The net force on the VAWT is approx. 16N. The vectors (arrows) showing the direction of the forces acting on the blade. The force on the blades increases.

Case2: (17m/s)

For this the wind speed is at 17m/s.

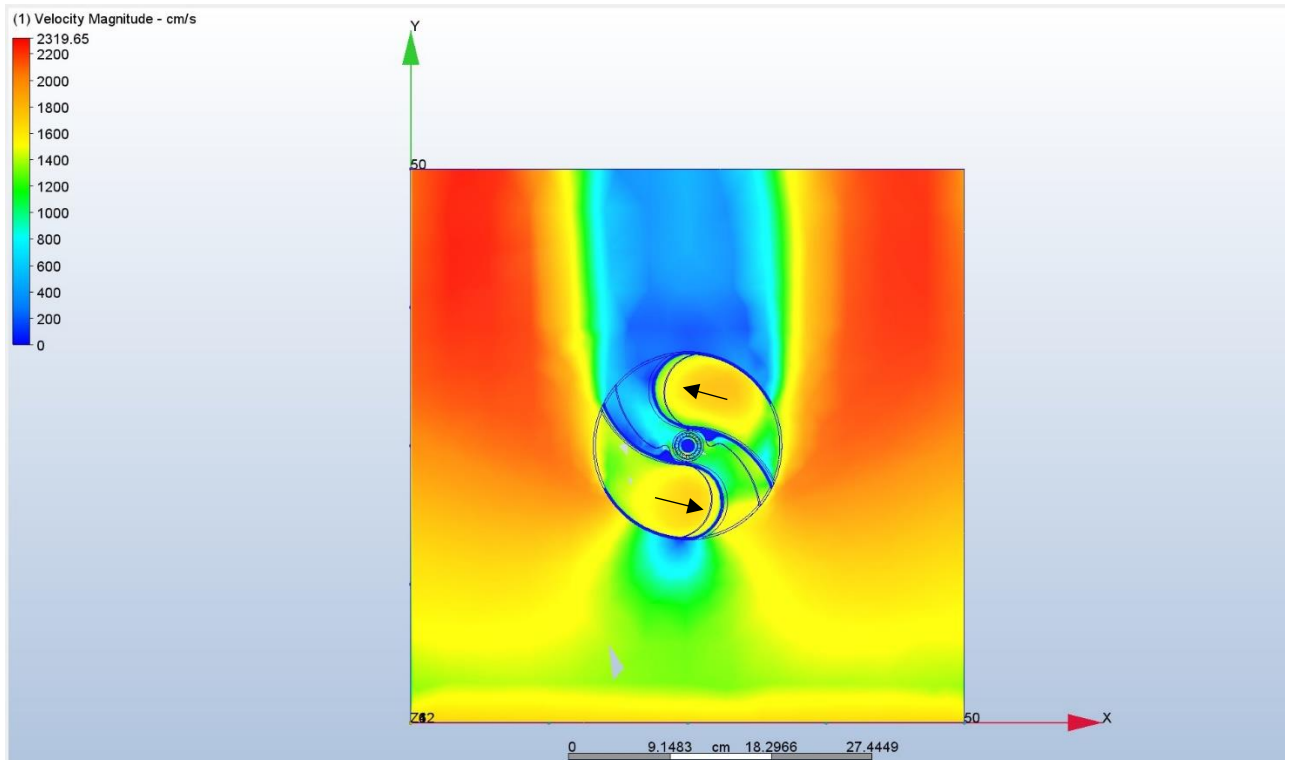


Fig 5: Plane showing wind pattern at 17m/s

The net force on the VAWT is approx. 62N. The vectors(arrow) showing the direction of the forces acting on the blade.

Case2: (20m/s)

For this the wind speed is at 20m/s.

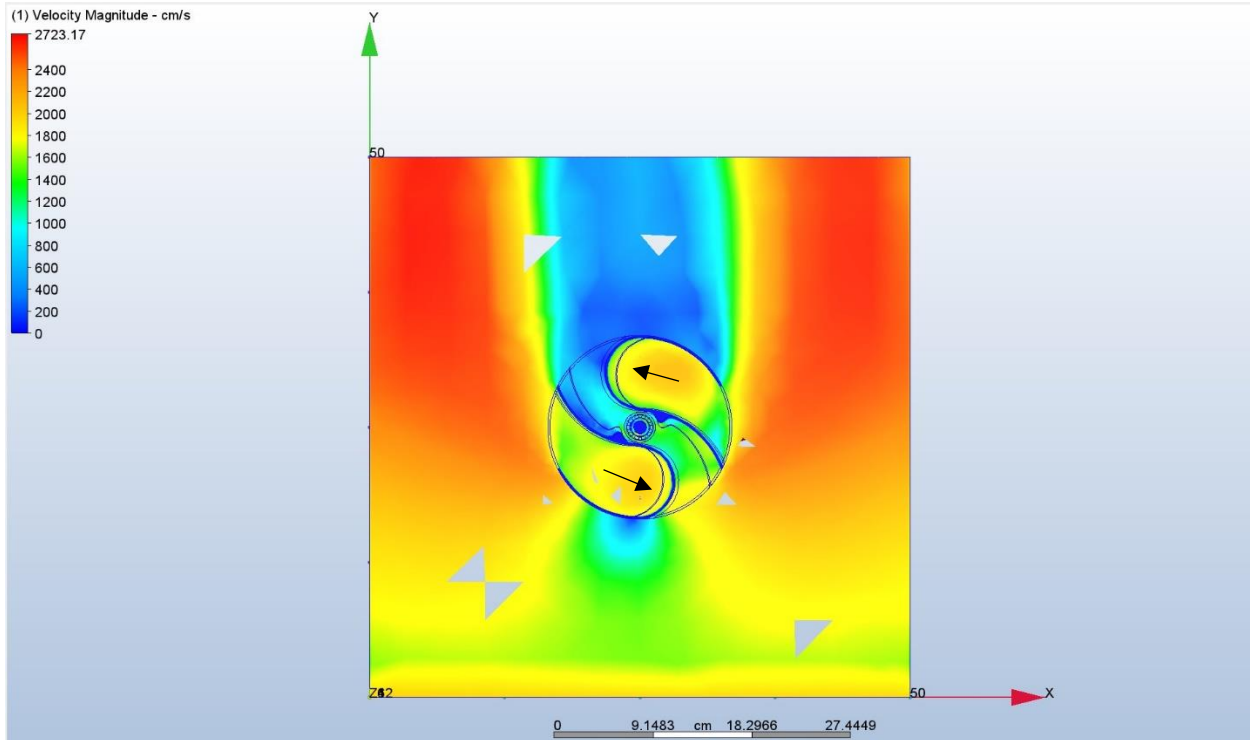


Fig 6: Plane showing wind pattern at 20m/s

The net force on the VAWT is approx. 87N. The vectors(arrow) showing the direction of the forces acting on the blade.

2. For the whole "Wall":

For the simulation of the whole wall, the speed of the incoming wind is 11.5 m/s.

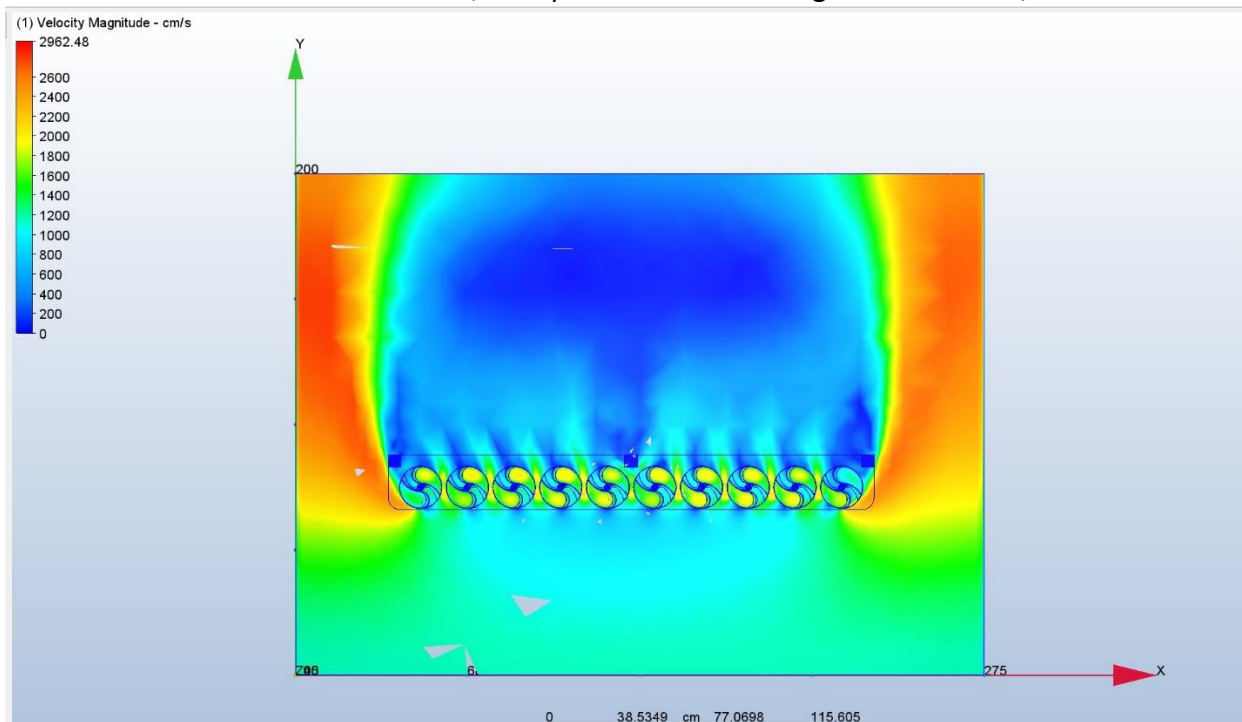


Fig 6: Plane showing wind pattern at 11.5 m/s

The interference by the frame is minimal.

The net force acting on the "Wall" is 875.722N.

Overall, the simulation is satisfactory and there is no excessive drag on the entire structure, the blades are able to give sufficient lift and the fluid flow pattern around and in between the blade is smooth with minimal formation of vortex(drag).

## 7. Structural test

### 1. For Single VAWT:

Case1:

Simulated wind speed – 3m/s

Load – 2N

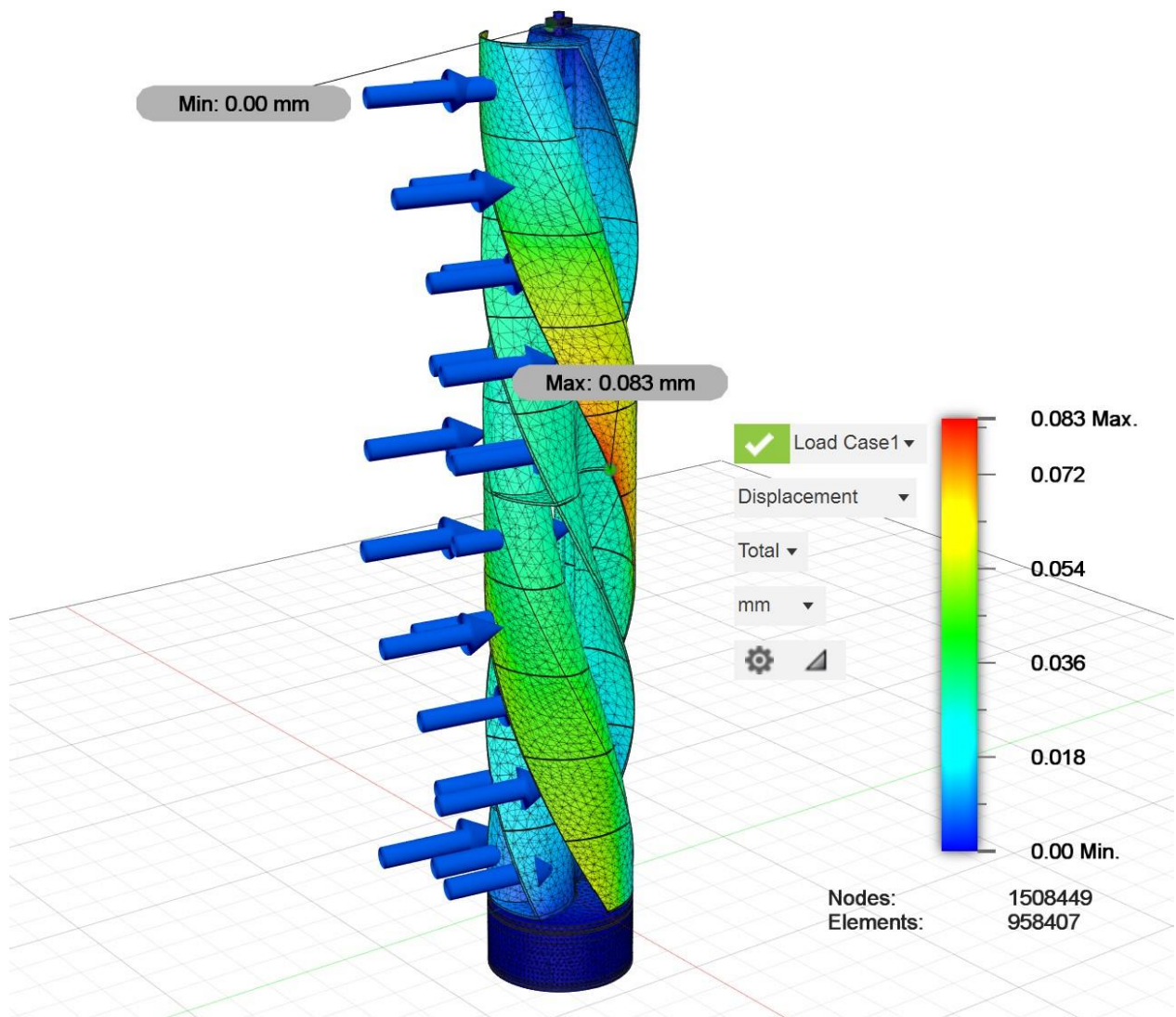


Fig 7: Max and Min displacement at 3N

Maximum displacement is 0.083N, minimum displacement is 0mm

Case2:

Simulated wind speed – 8m/s

Load – 16N

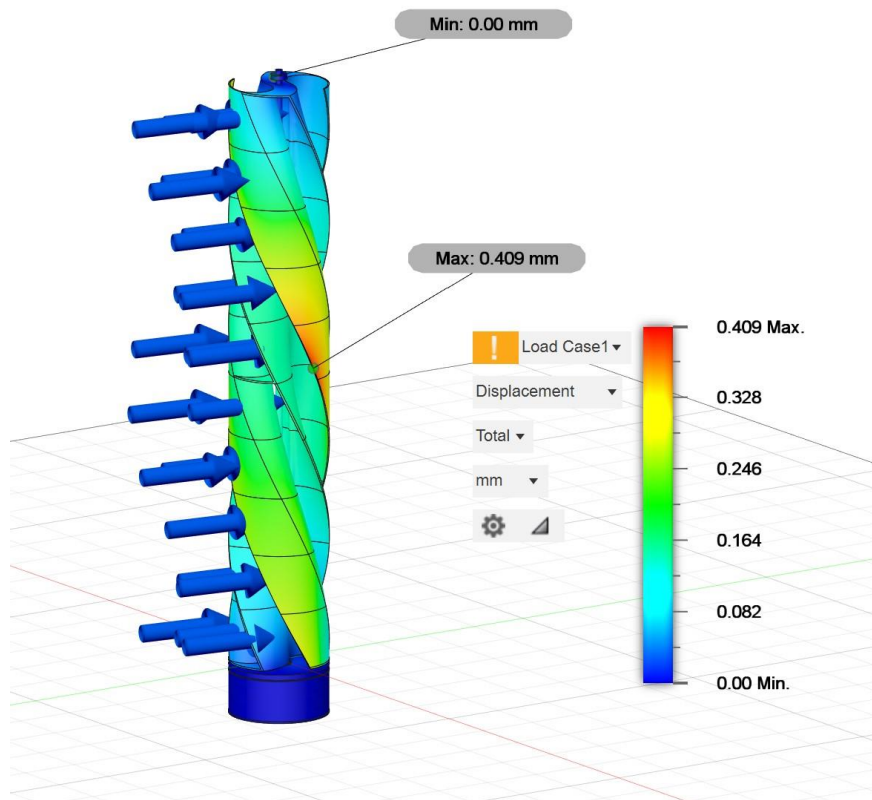


Fig 8: Max and Min displacement at 16N

Maximum displacement is 0.409mm, minimum displacement is 0mm

Case3:

Simulated wind speed – 17m/s

Load – 62N

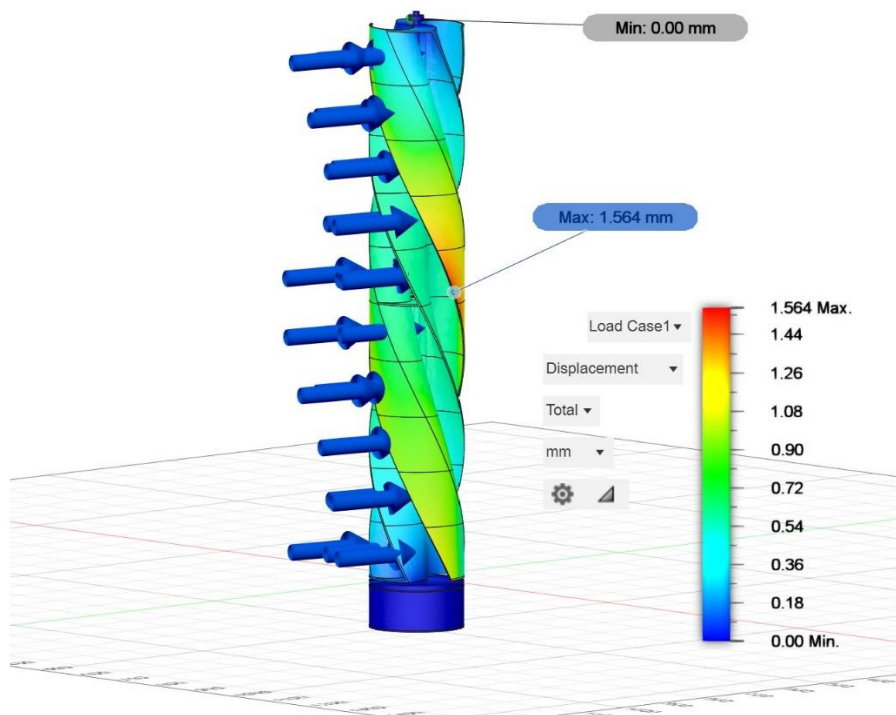


Fig 9: Max and Min displacement at 62N

Maximum displacement is 1.564mm, minimum displacement is 0mm

Case 4:

Simulated wind speed – 20m/s

Load – 87N

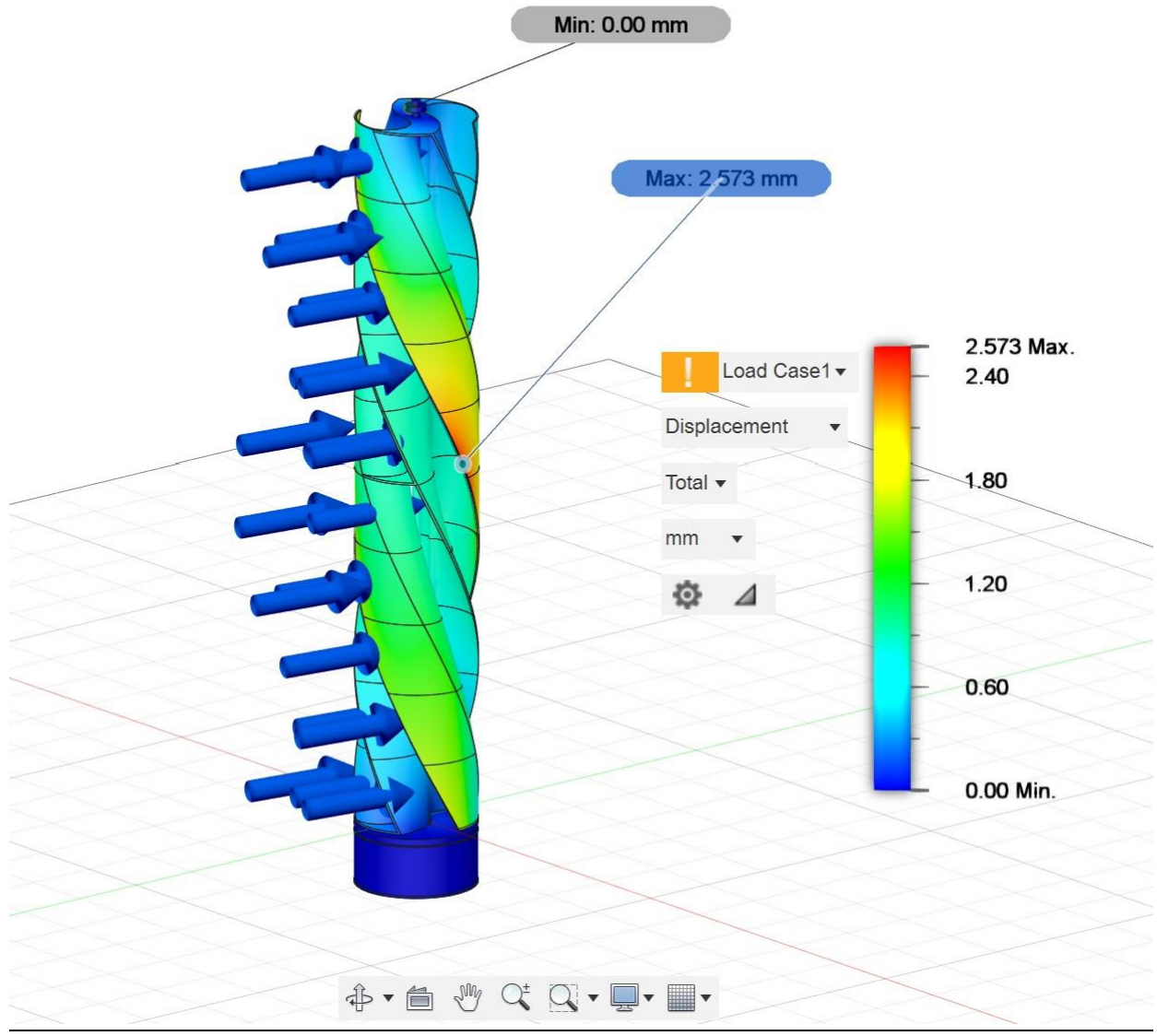


Fig 10: Max and Min displacement at 87N

Maximum displacement is 2.573mm, minimum displacement is 0mm

Here it is seen that the part undergoing maximum displacement is the edges of the blades. This is also due to the fact that the simulation is done with the blades fixed in position. If the blades were given motion, the force on the edges will reduce drastically.

2. For the whole "Wall":

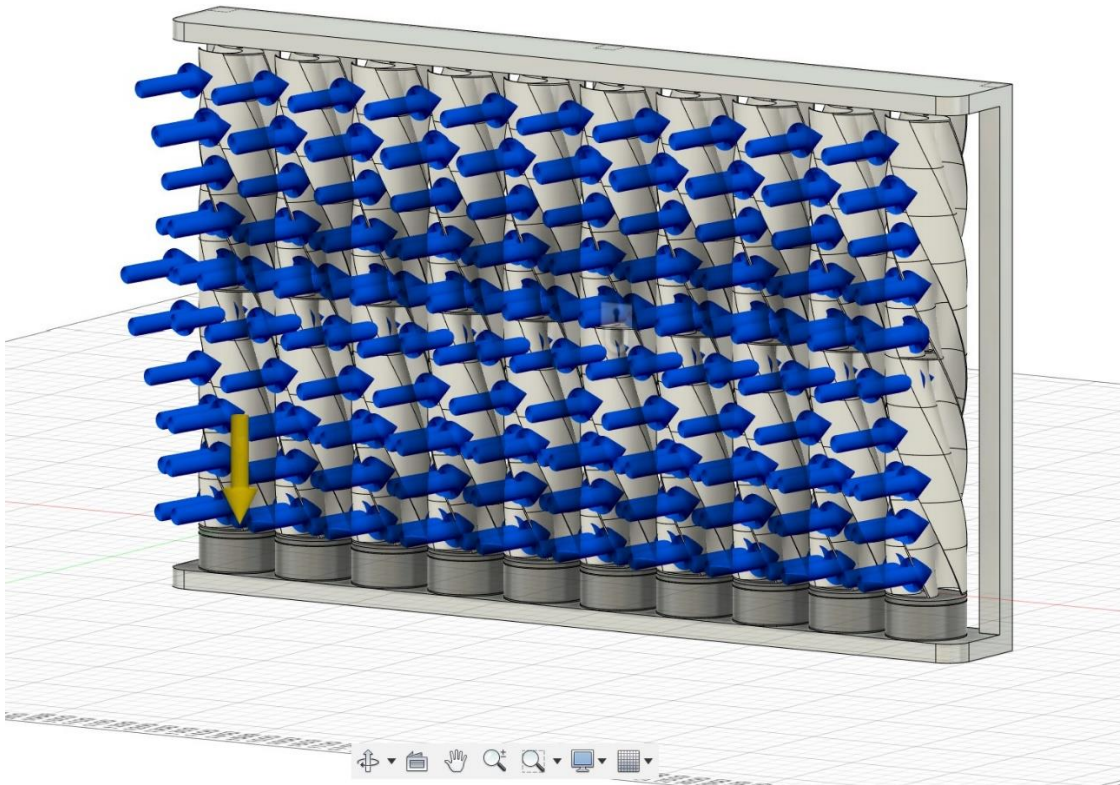


Fig 11: The forces on the wall

Simulated wind speed - 11.5m/s  
Load - 875.722N

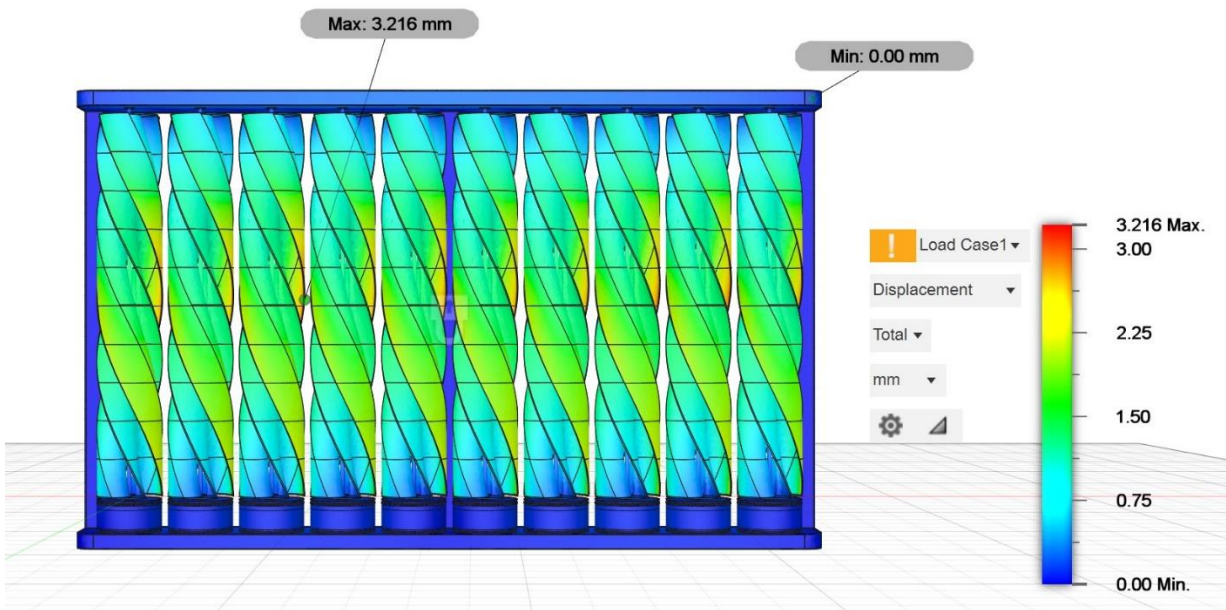


Fig 12: Max and Min displacement at 875.722N  
Maximum displacement is 3.216mm. Minimum displacement is 0mm.

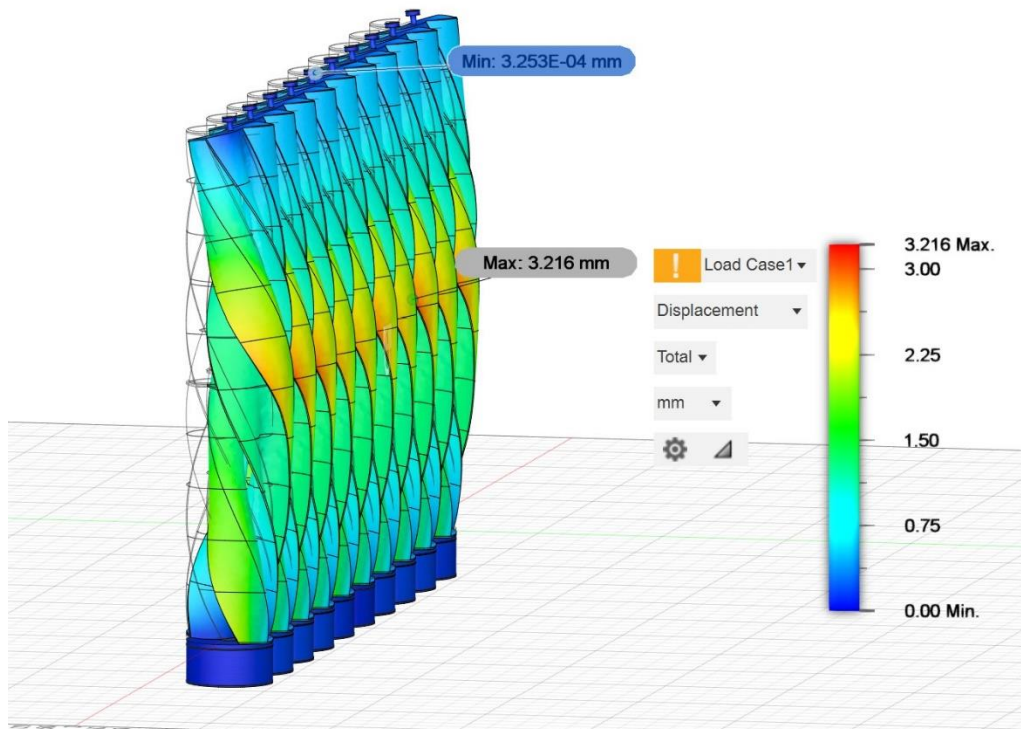


Fig 13: Adjusted view of the VAWTs displacement of the “Wind Wall”

We can see that the ‘axial’ in the middle of the blades gives extra strength to the blades of the wind turbine.

## 8. Analysis of Result

Overall, the simulation results are satisfactory, showing no excessive drag on the entire structure. The blades provide sufficient lift, and the fluid flow pattern around and between them remains smooth, with minimal vortex formation, which helps reduce drag. The analysis also highlights that the maximum displacement occurs at the edges of the blades. This is primarily because the blades were simulated in a fixed position; if motion were introduced, the forces acting on the blade edges would significantly decrease. Additionally, the axial component in the middle of the blades enhances their structural strength, further contributing to the overall performance of the wind turbine.

The average Safety factor of the turbine is at about 8.591. The weakest part being the connections between the axial and bearings, the connection between the gears and the connection between the thrust bearings. The connections between the weak parts are not excessively weak and performs satisfactorily under stressful environment simulations.

## 9. Conclusion

In conclusion, The Wind Wall performs satisfactorily well under the fluid flow dynamics with limited drag. The stress test is also satisfactory as it has minimum displacement under load and high wind speeds. The overall structural integrity is satisfactory and does not give or break under load. The safety factor of the turbine is also satisfactory as it is above 5 and is average of 8.591 and at 15+ at most parts.

The prototype of the Wind Wall can be built for further testing of electrical performance and efficiency of the turbine.