Eastern Mediterranean University

VAWT FOR URBAN UTILITY

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PRESENTATION CONTENTS

INTRODUCTION

AIM, OBJECTIVES, AND CONFIGURATIONS

AIM

Design to maximize energy output in urban, and inhabited areas.

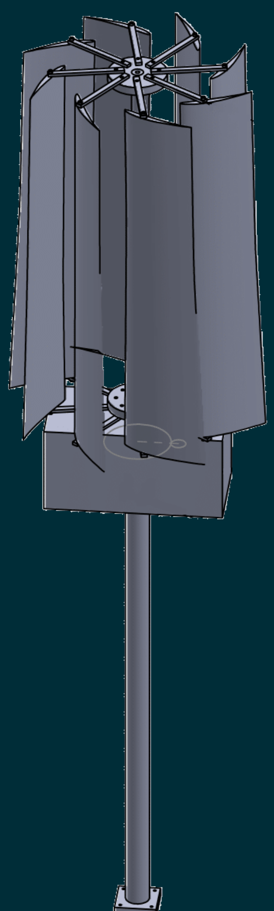
OBJECTIVES

- Self start
- Minimal maintenance
- Noiseless
- Safety
- Bird friendly
- Aesthetic visual integration in urban locations

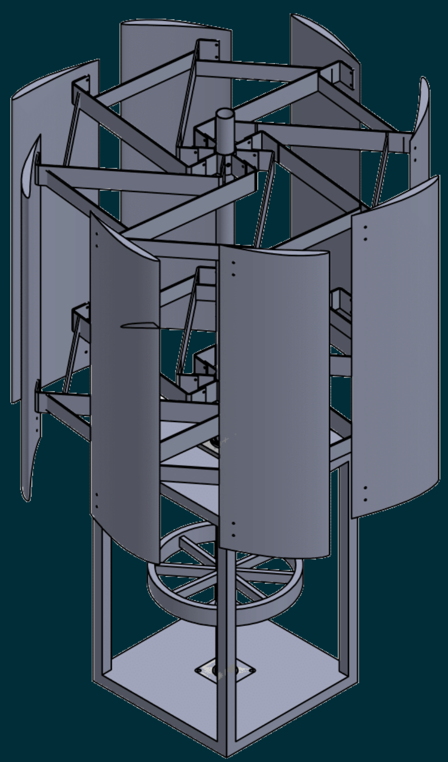
CONFIGURATIONS

There are 2 configurations:

Configuration 1

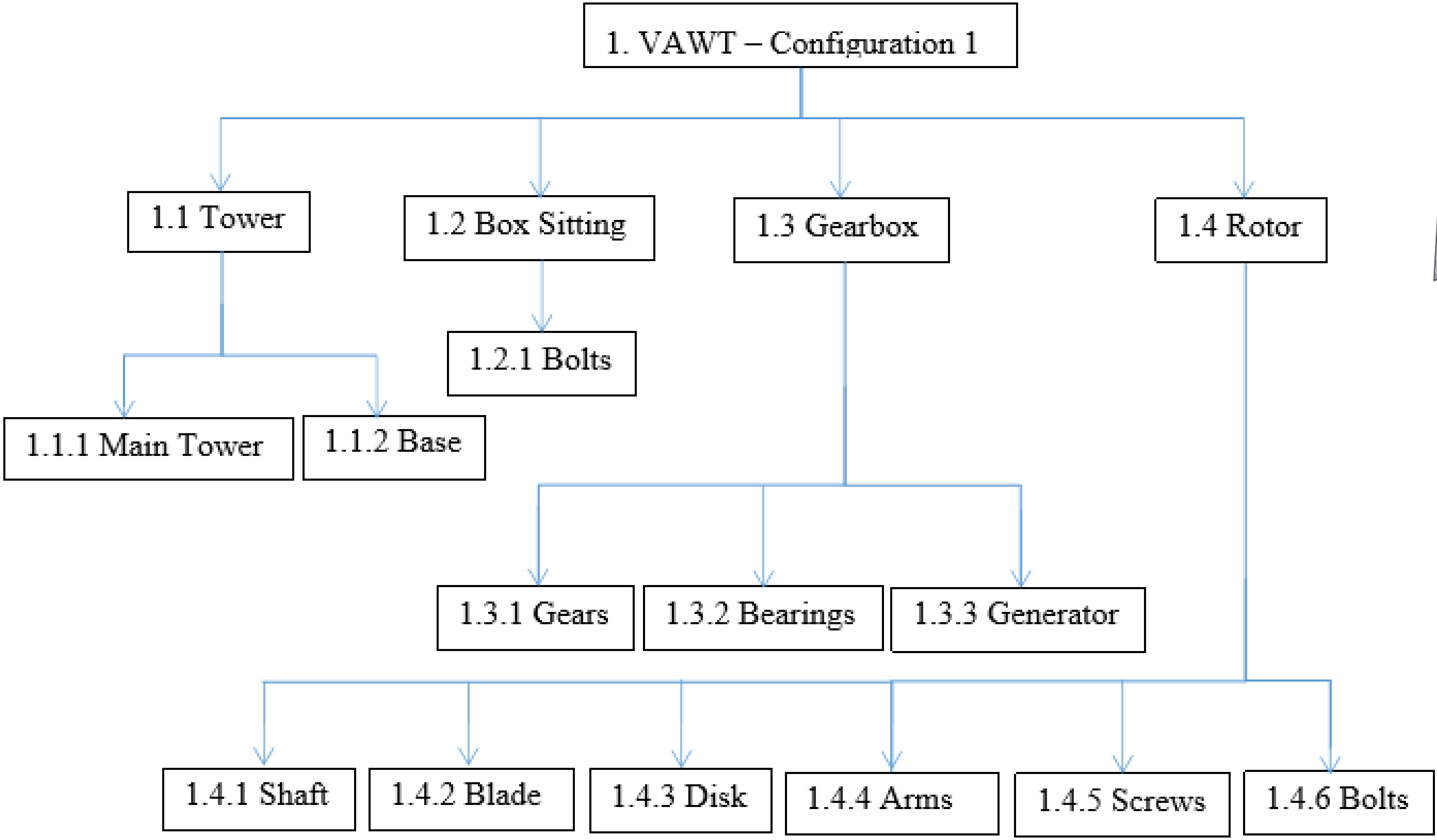


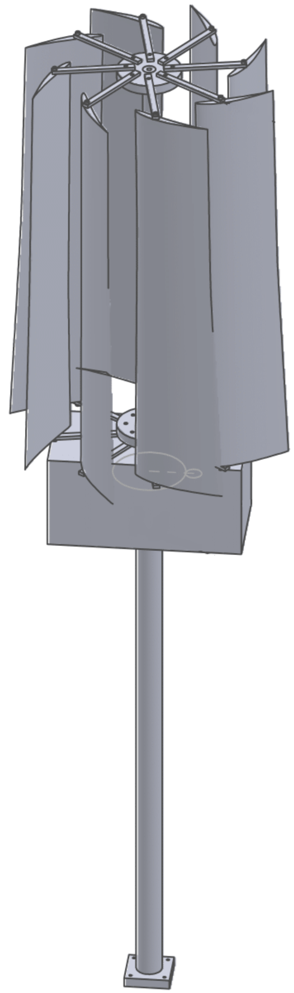
Configuration 2



INSPIRATION

Design: Kliux Zebra
Website: www.kliux.com/en/



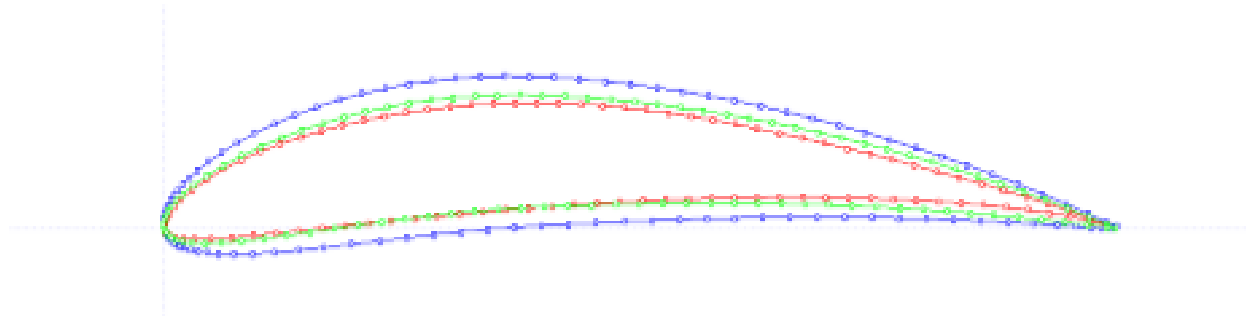


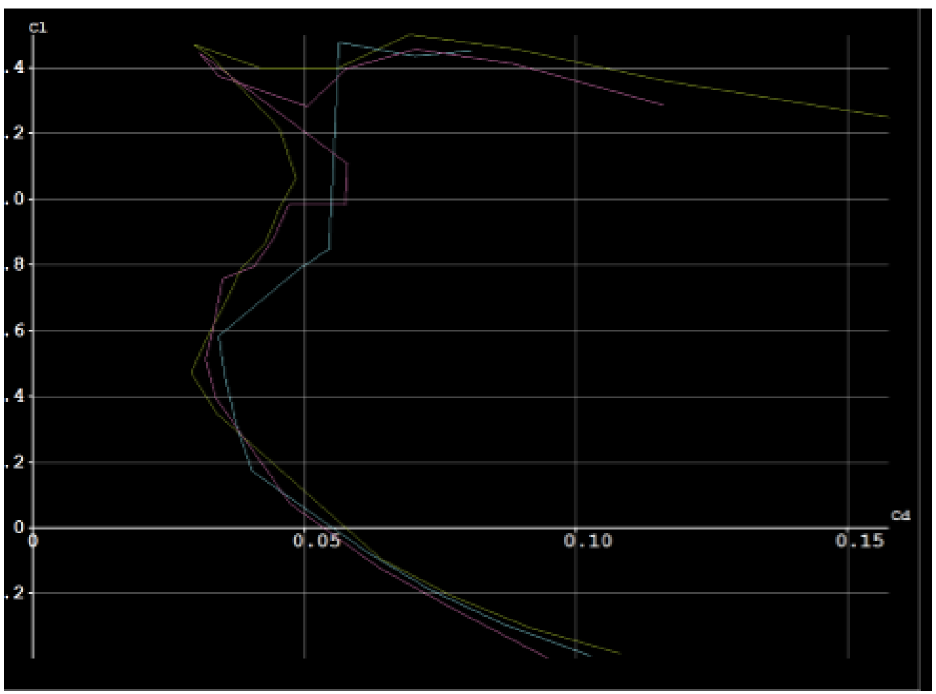
BREAK DOWN STRUCTURE - CONFIGURATION 1

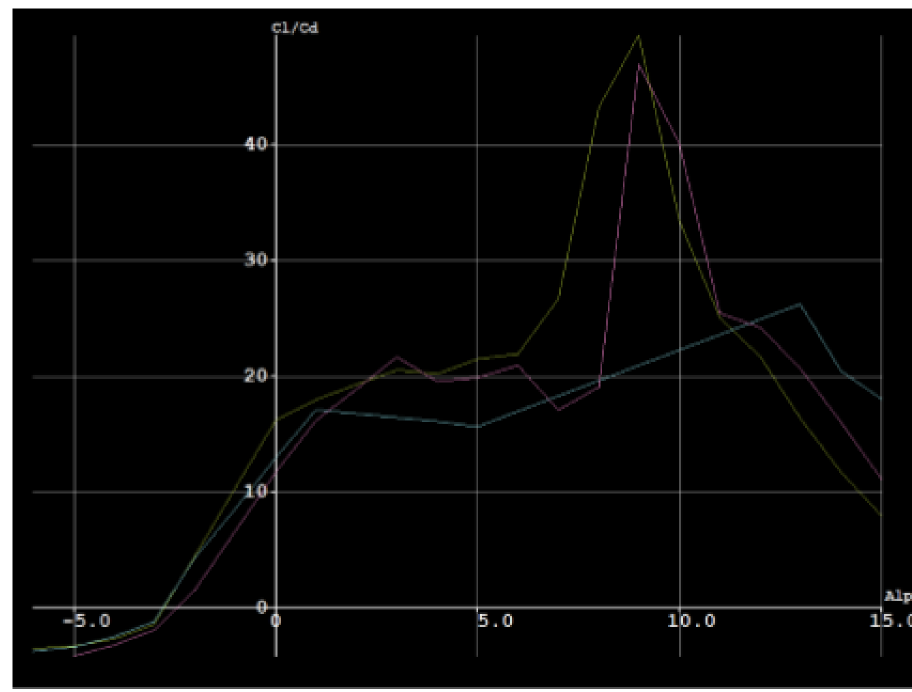
1) BLADE

AIRFOIL CONFIGURATION

NACA 6412 - Blue
NACA 6409 - Green
E385 - Red







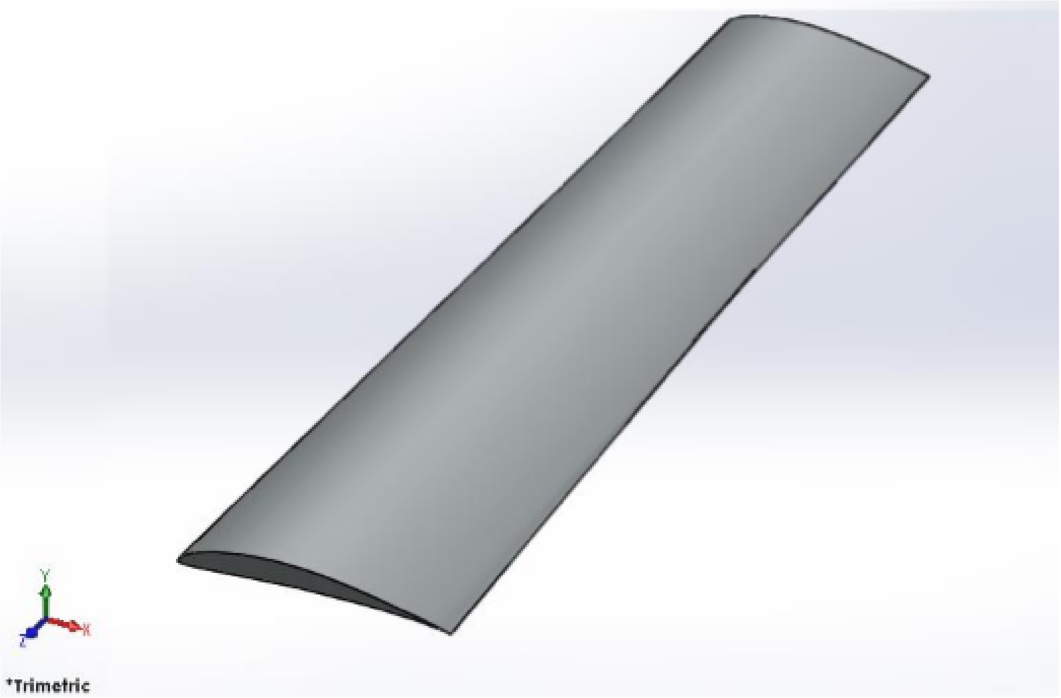
NACA 6412 - Blue
NACA 6409 - Pink
E385 - Green

1) BLADE

MATERIAL SELECTION

4 materials: PU, PS, CFRP, &
Steel

Criteria	Polystyrene	Polyurethane	CFRP	Galvanized Steel
Strength	-	0	+	+
Cost	+	0	-	0
Maintenance	+	+	0	+
Longevity	+	+	-	+
Availability	0	0	-	+
Machining	0	0	-	0
Mass Efficiency	0	+	+	0
Safety	0	0	+	-
Net	2	3	-2	3
Rank	2	1	3	1
Continue?	No	Yes	No	Yes



Volume: 6027.05 cm^3
Mass: 6.27 kg
Height: 130 cm

2) SHAFT

GEOMETRY SELECTION

2 main types: Hollow and Solid

Criteria	Solid Shaft	Hollow Shaft
Cost	3	5
Weight	2	5
Manufacturing	5	4
Toughness	3	5
Strength	4	5
Easy to Assemble	4	5
Sum	21	29
Rank	2	1
Continue?	No	Yes

MATERIAL SELECTION

3 main types: Steel, PVC, and Al

Criteria	PVC	Steel	Aluminum
Strength	0	+	0
Cost	+	+	+
Maintenance	+	0	+
Longevity	+	0	+
Availability	+	+	0
Manufacturing	+	0	+
Mass Efficiency	+	-	+
Safety	0	+	0
Net	6	3	5
Rank	1	3	2
Continue?	Yes	No	Yes

CALCULATIONS

The diameter = 5 cm

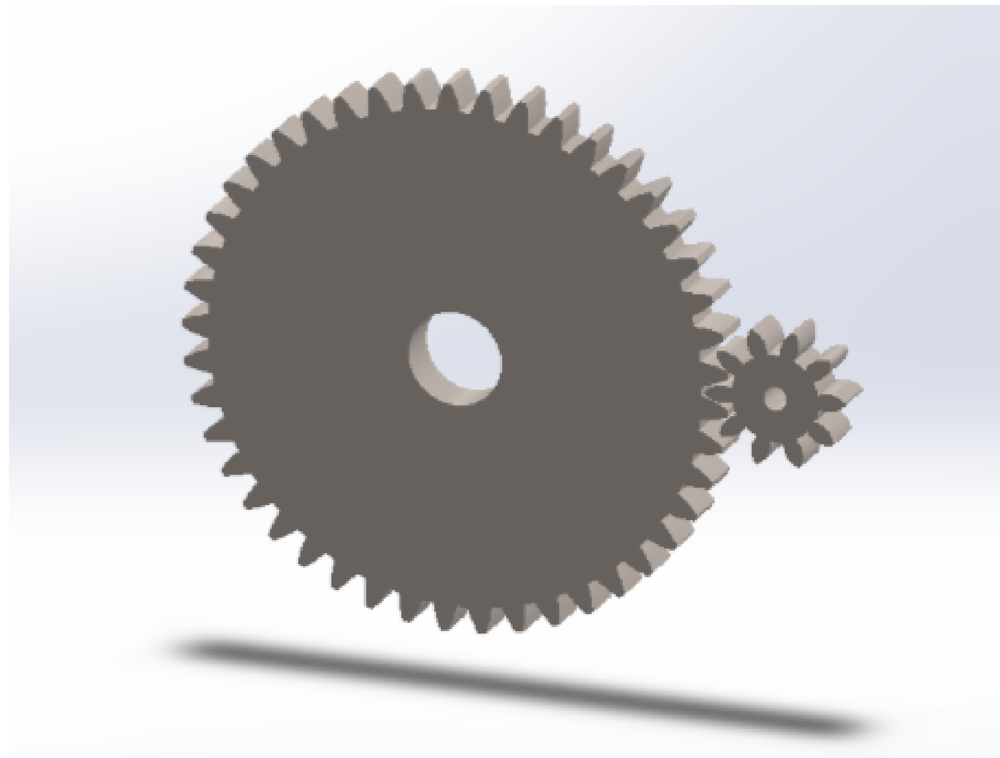
$$d = \left(\frac{16n}{\pi} \left\{ \frac{1}{S_e} \left[4(K_f K_b M_a)^2 + 3(K_{fs} K_t T_a)^2 \right]^{0.5} + \frac{1}{S_{yt}} \left[4(K_f K_b M_m)^2 + 3(K_{fs} K_t T_m)^2 \right]^{0.5} \right\} \right)$$

3) GEARBOX

GEOMETRY SELECTION

2 types: Spur, and Helical Gears

Criteria	Spur Gears	Helical Gears
Efficiency	+	-
Thrust Force	+	-
Manufacturability	+	0
Ease of Assembly	+	0
Noise	-	+
Cost	+	-
Strength	0	+
Net	4	-2
Rank	1	2
Continue?	YES	NO



The gearbox ratio was found using the assumption of 40-70 initial RPM usining:

$$n_1 = \left|\frac{N_2}{N_1} n_2\right| = \left|\frac{d_2}{d_1} n_2\right|$$

DESIGN CALCULATIONS

Theoretical Calculations

Average wind speed is between 3 to 4 m/s;

- Wind Power:

$$P_w = \frac{0.593 \times \rho_{air} \times dh \times V^3}{2}$$

- Tip Speed Ratio:

$$\lambda_{real} = \frac{\omega \times R}{V_\infty}$$

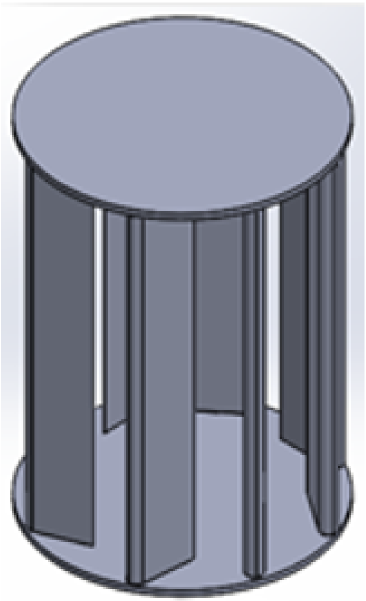
- Mechanical Power:

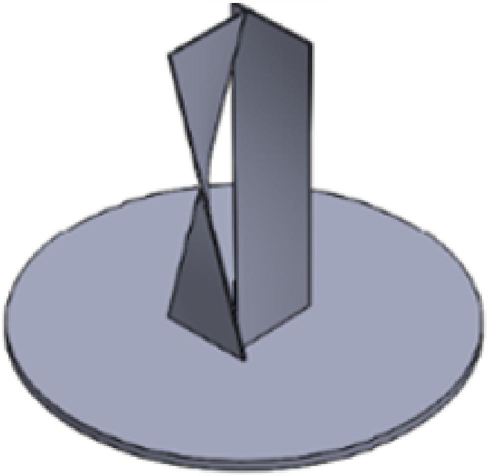
$$P_m = 0.5 \times I_{shaft} \times \omega^3$$

$$I_{shaft} = N \times \rho_B \, (W_B \times L_B \times t_B) R^2 + \frac{N \times \rho_B \, (W_B \times L_B \times t_B)({L_B}^2 \times R^2)}{12}$$

- Coefficient of Performance:

$$C_p = \frac{P_m}{P_w}$$





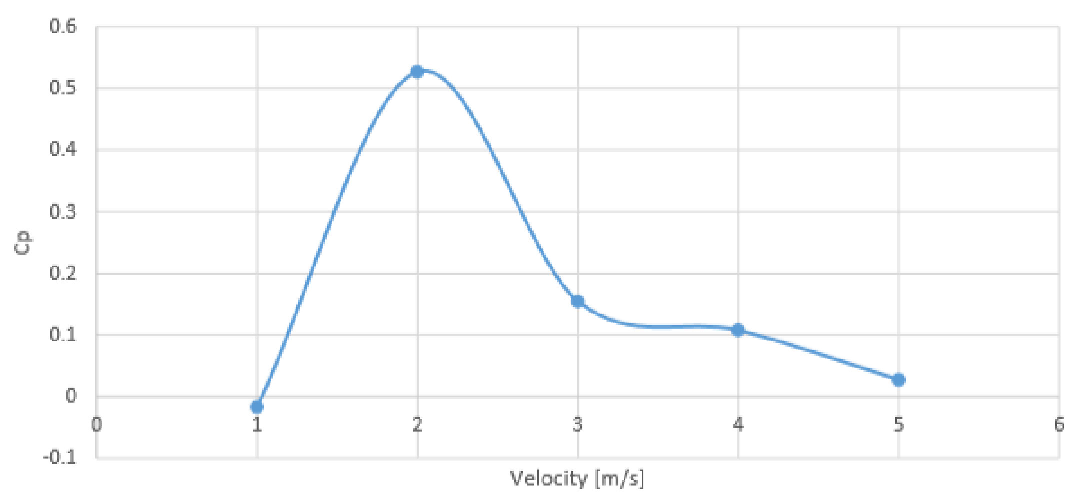
DESIGN CALCULATIONS

Simulation Results

The simulation was done using QBlade software

Parameters	Value(s)
Upper chord length [ClU]	25 [cm]
Lower chord length [ClL]	30 [cm]
Height of the blade [H]	1.3 [m]
Wind speed [v]	1-5 [m/s]
Rotational Speed [ω]	40-70 [RPM]
Diameter of the rotor [d]	1 [m]
Reynolds Number	100,000
Angle of Attack	0-20 [°]

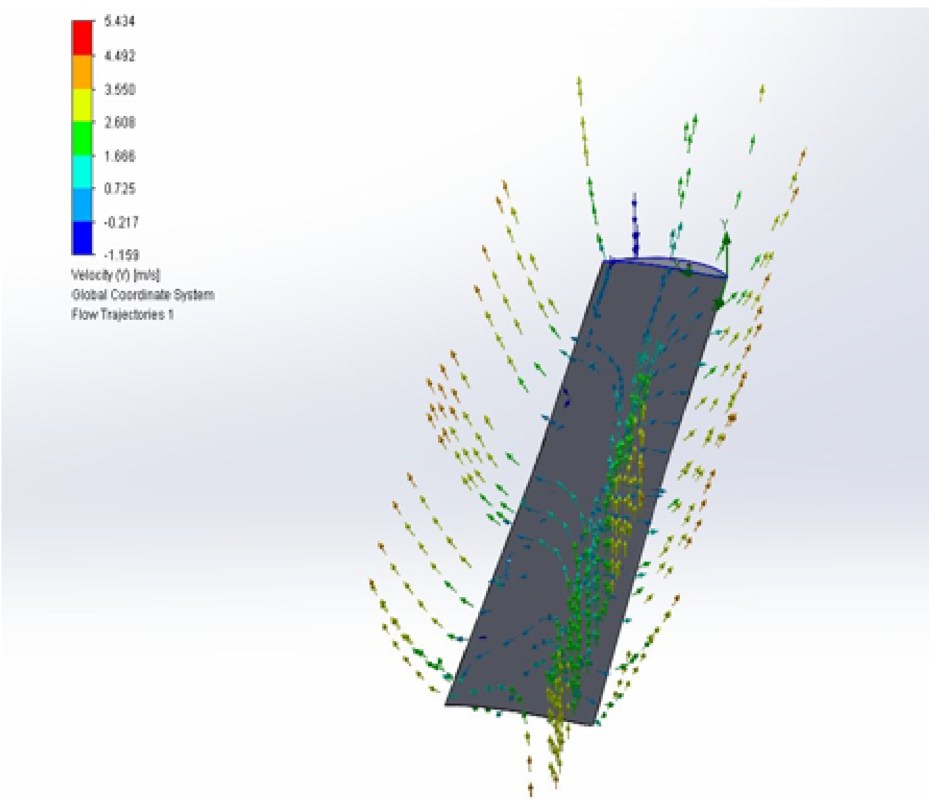
Parameters	Value(s)
C_P	0.11
Power [W]	5.5 [W]
C_L	1.506
C_D	0.29
C_m	0.12
Torque [N/m]	0.75
TSR [Tip speed ratio]	0.91

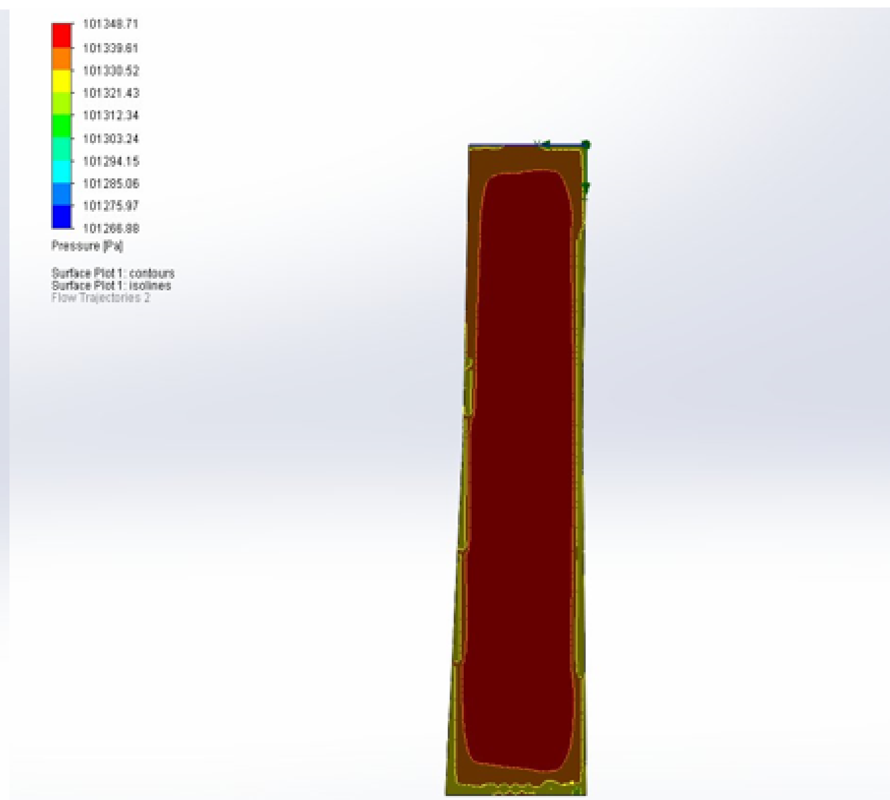


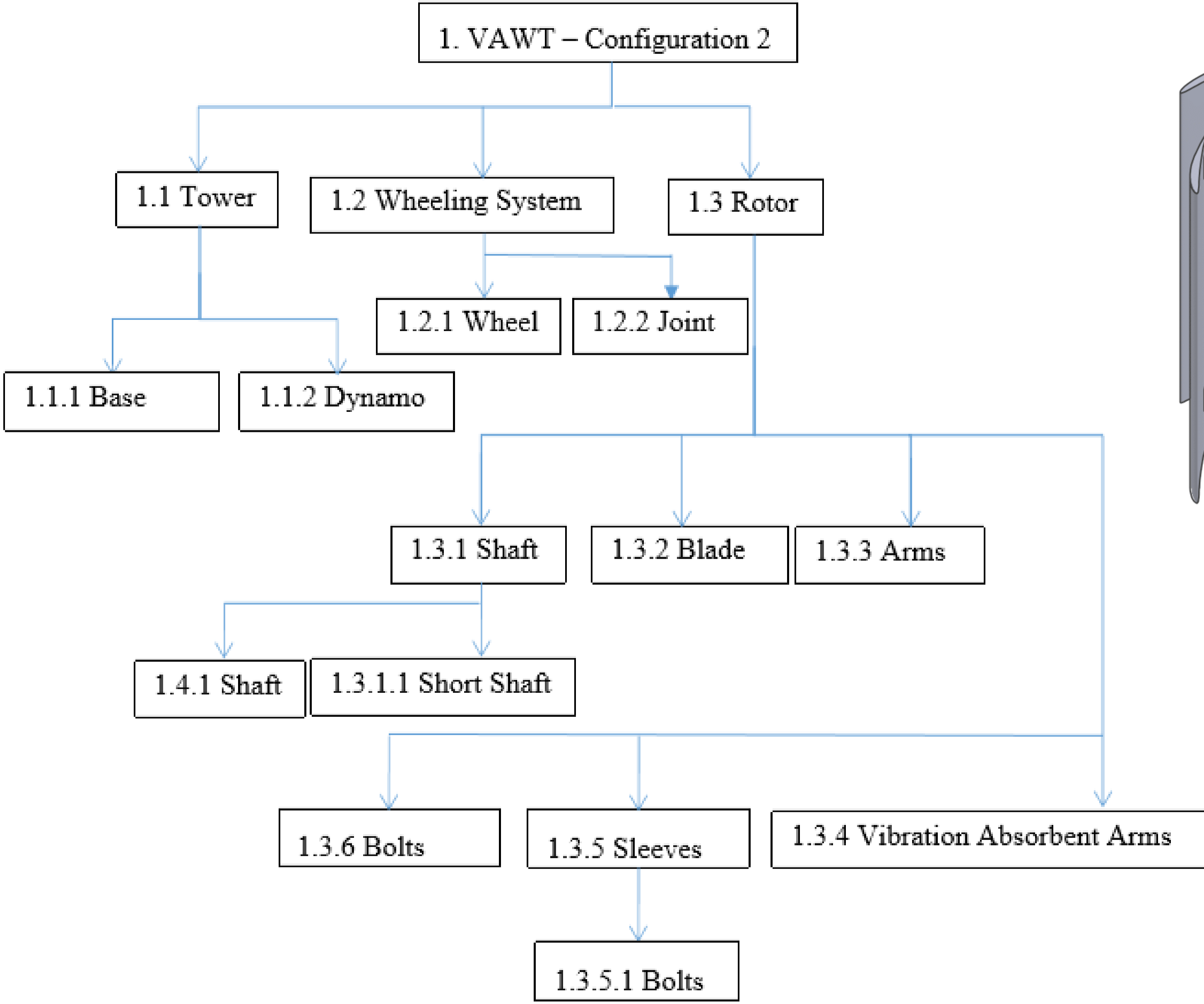
COMPUTATIONAL FLUID DYNAMICS

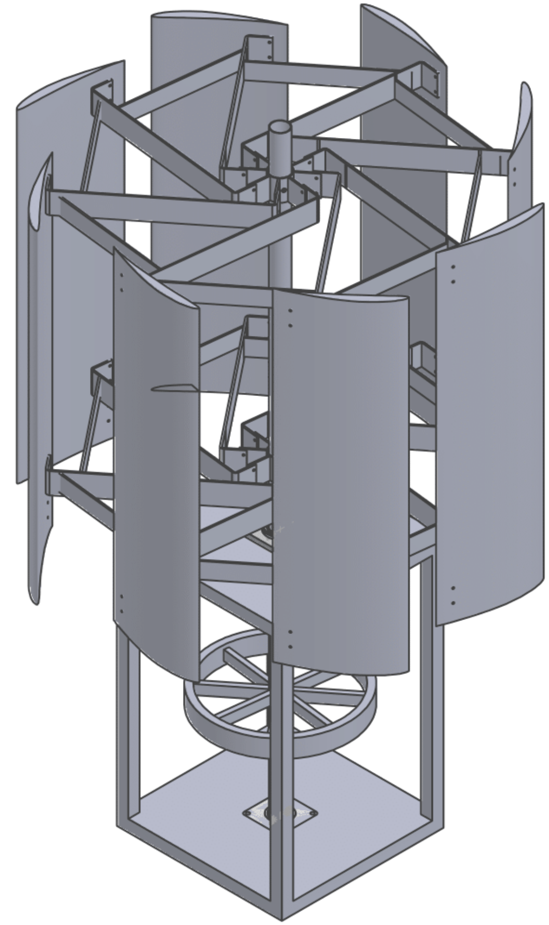
For the blade design

Simulation for the effect of velocity, and pressure distribution using SolidWorks









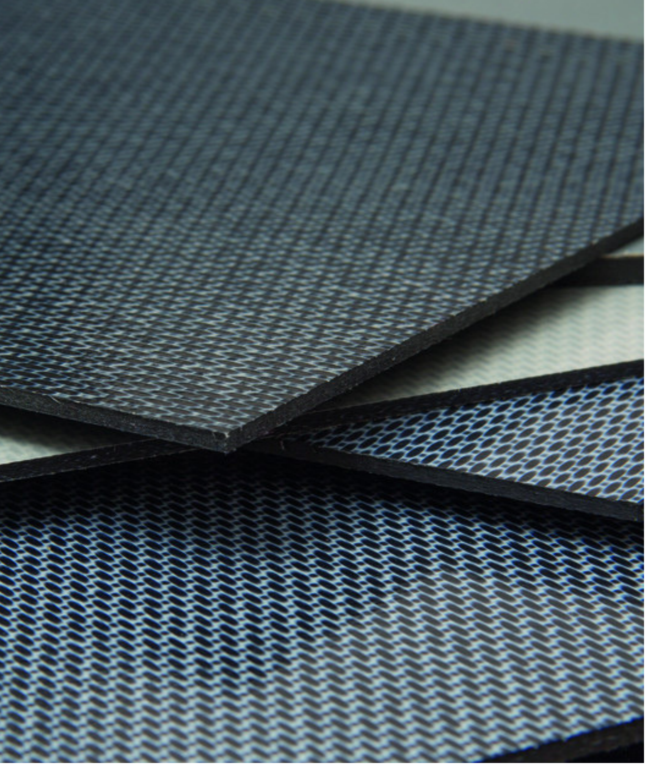
BREAK DOWN STRUCTURE - CONFIGURATION 2

1) BLADE

Manufacturing Constraint of Expanded Polyurethane:
1) Availability: not available in TRNC
2) Cost: expensive to order form abroad
3) Machining: needs a 6-axis CNC machine

Therefore, Galvanized Steel Sheets were used.

Criteria	Polystyrene	Polyurethane	CFRP	Galvanized Steel
Strength	-	0	+	+
Cost	+	0	-	0
Maintenance	+	+	0	+
Longevity	+	+	-	+
Availability	0	0	-	+
Machining	0	0	-	0
Mass Efficiency	0	+	+	0
Safety	0	0	+	-
Net	2	3	-2	3
Rank	2	1	3	1
Continue?	No	Yes	No	Yes




COST CONSTRAINTS

CFRP:
- Material Cost (3.2 m^2): 5600 tl
- Manufacturing Cost: Machining to the airfoil shape was hard, so it was eliminated before checking for the price

GALVANIZED STEEL SHEET:
- Material Cost (3.2 m^2): 200 tl
- Manufacturing Cost: 50 tl [renting the machines]
- **Overall:** 250 tl

POLYSTYRENE:
- Material Cost: 400 tl
- Manufacturing Cost: 1100 tl [using laser CNC machine]
- **Overall:** 1500 tl

Consequently, the best choice was Galvanized Steel Sheet.

2) CONNECTION ARMS

CHANGE IN LENGTH

- Twist was not completely obtained [manufacturing constraints]

- The length of each arm was increased to 0.5 m

- The missing Savonius effect was overcame

USING SLEEVES

Sleeves with fins were used to connect the arms to the shaft in order to increase the damping ratio

3) WHEEL & DYNAMO

COST CONSTRAINTS

Assembling the Gearbox:

- Gearbox = 245 tl
- Generator = 400 tl
- Sitting = 30 tl
- Bearing = 65 tl

Overall: 740 tl

Assembling the Wheel:

- Wheel = 85 tl
- Dynamo = no cost
- Couplings = 40 tl

Overall: 125 tl

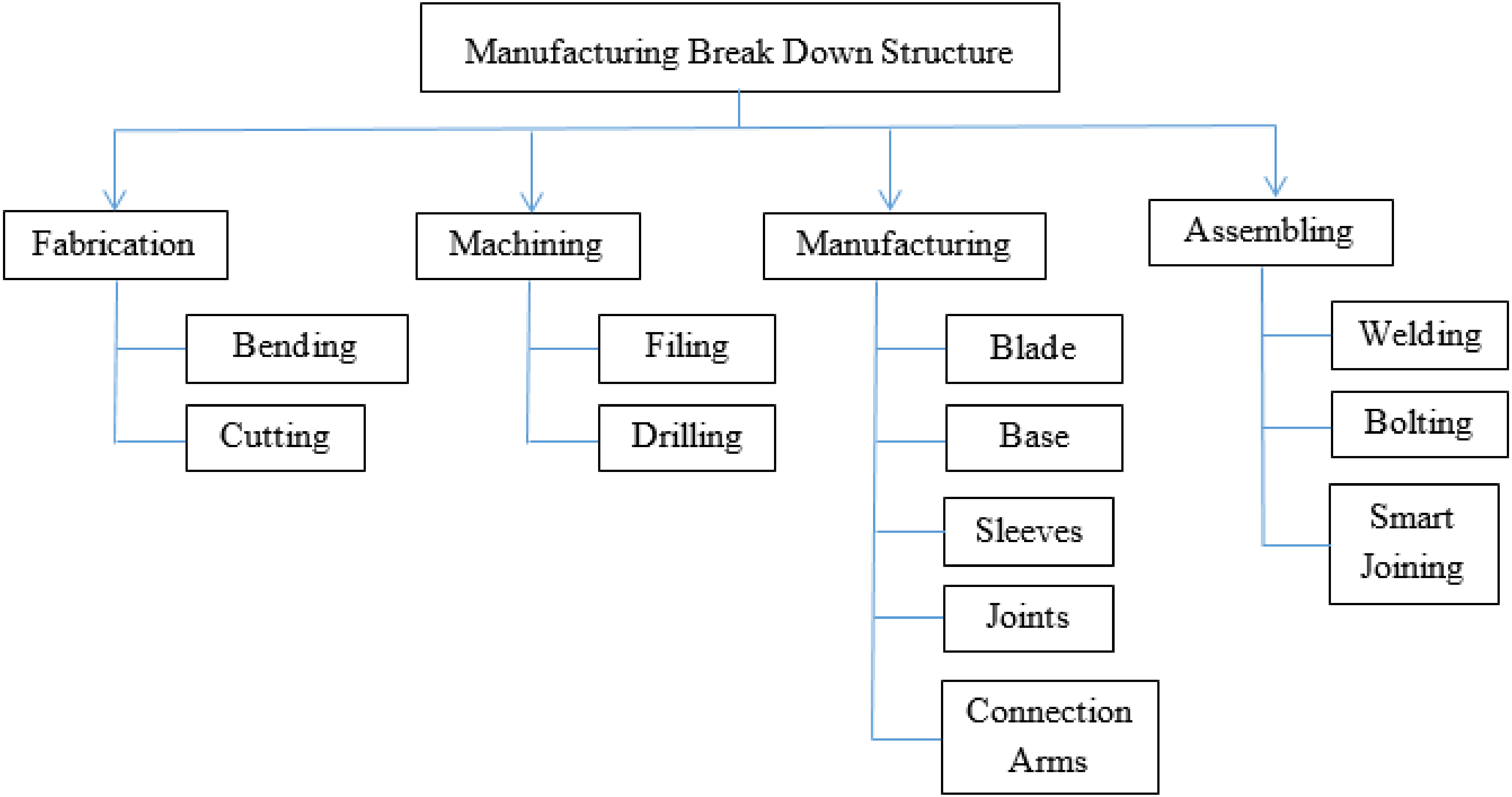
4) TRIANGULATION ARMS

Added to reduce the vibration of the connection arms

Reason for Joining by Welding:

- The vibration problem was noticed until after testing
- Time constraint was a problem to join by bolts
- Welding was used

MANUFACTURING



MANUFACTURING

BLADES FABRICATION

Manual Arm Guillotine Shear:
Safety for Shearing: ANSI B11.4—2003

Plate Bending Roll & Brake Machine:
Safety: ANSI B11.18—2006

MANUFACTURING

JOINING BLADES, SLEEVES, BEARINGS, & COUPLINGS

Standards:

Square Bolts: ASME B18.2.1
Plier: ASME B107.20
Cross Tip Screwdriver: ASME B107.30 - 2008
Twist Drills: ASME B94.11M
Safety for Drilling: ANSI B11.8—2001

Criteria	Joining (Bolts)	Welding
Strength	0	+
Cost Saving	-	+
Maintenance Friendly	+	-
Longevity	+	+
Availability	+	+
Safety	+	0
Disassembling	+	-
Vibration Absorber	+	0
Time Saving	-	+
Net	4	3
Rank	1	2
Continue?	Yes	No

MANUFACTURING

BASE ASSEMBLING

Standards:

Welding: AWS/ASME SFA – 5.1 E 6013

Disassembling (cost constraint):
- Previous dimensions were too small
- Disassembling using circular saw
- Arc welding with 90 degree angle to the ground

Criteria	Joining (Bolts)	Welding	Brazing
Strength	0	+	+
Cost Saving	-	+	-
Maintenance Friendly	+	-	-
Longevity	+	+	0
Availability	+	+	-
Safety	+	0	-
Disassembling	+	-	-
Vibration Absorber	+	0	0
Time Saving	-	+	0
Net	4	3	-4
Rank	1	2	3
Continue?	Yes	No	No

TESTING

RPM

The turbine's RPM was measured using a video by marking one of the blade as a reference and slowing down the video to find the revolution per minute

VOLTAGE & CURRENT

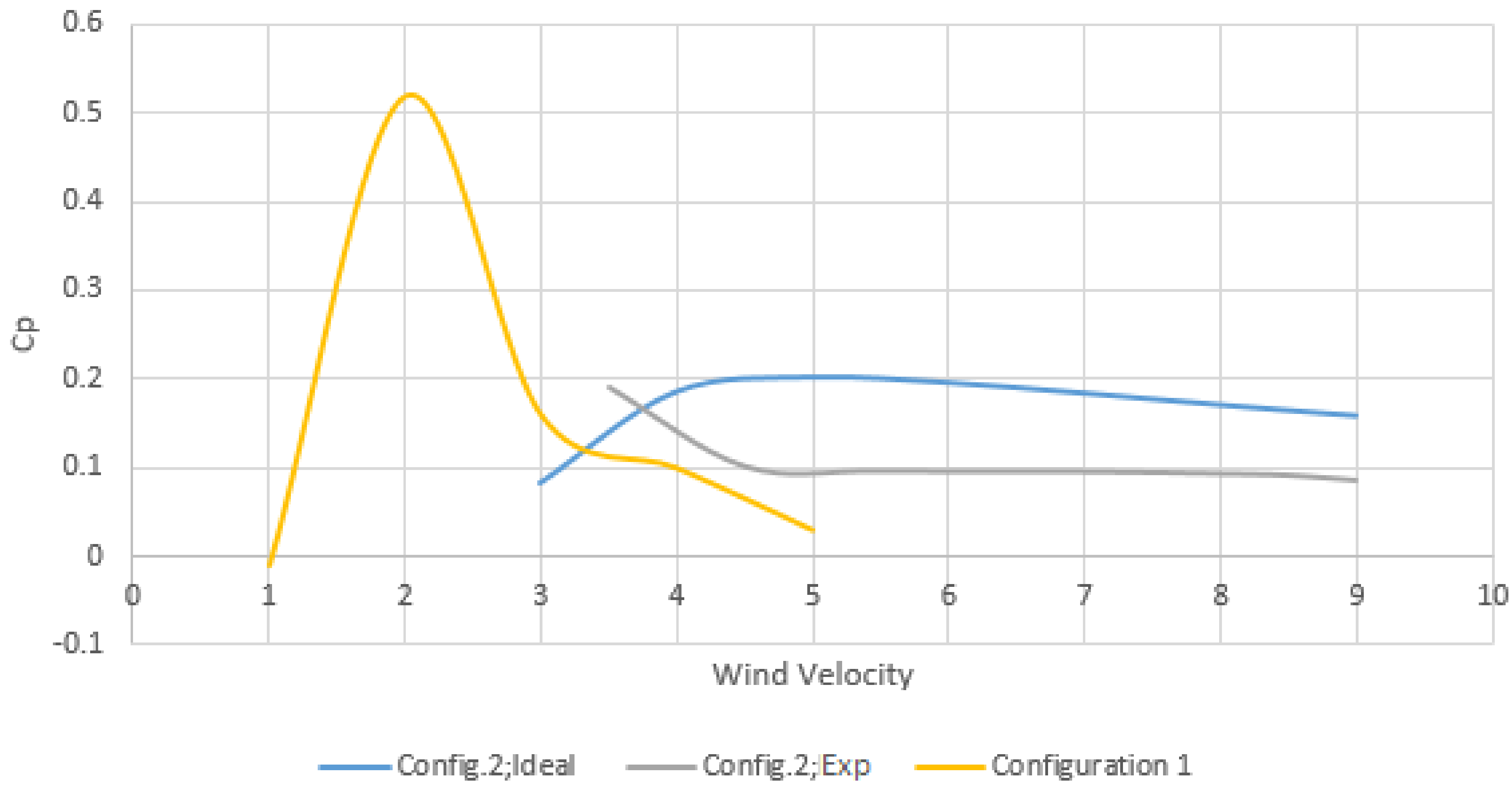
Multimeter was the device used to measure the voltage produced; by recording a video of the voltmeter and finding the average

POWER

With the correlation of data collected with the multimeter (both voltage and current), we found the approximate power generated using the formula
P= VI

WIND SPEED

Anemometer was used to obtain different ranges of wind speed

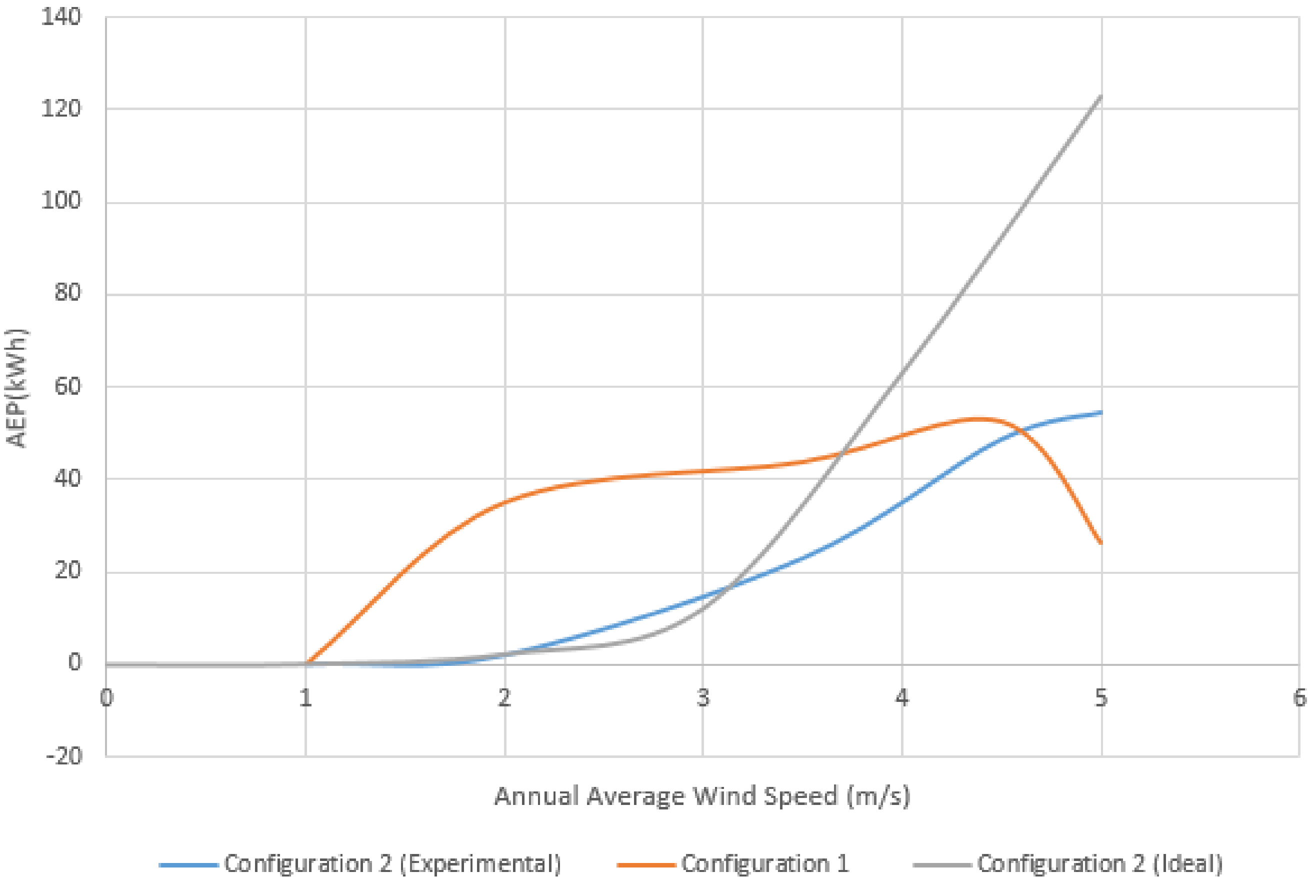


SUPERIMPOSED PERFORMANCE RESULTS OF THE CONFIGURATIONS

ANNUAL ENERGY PRODUCTION

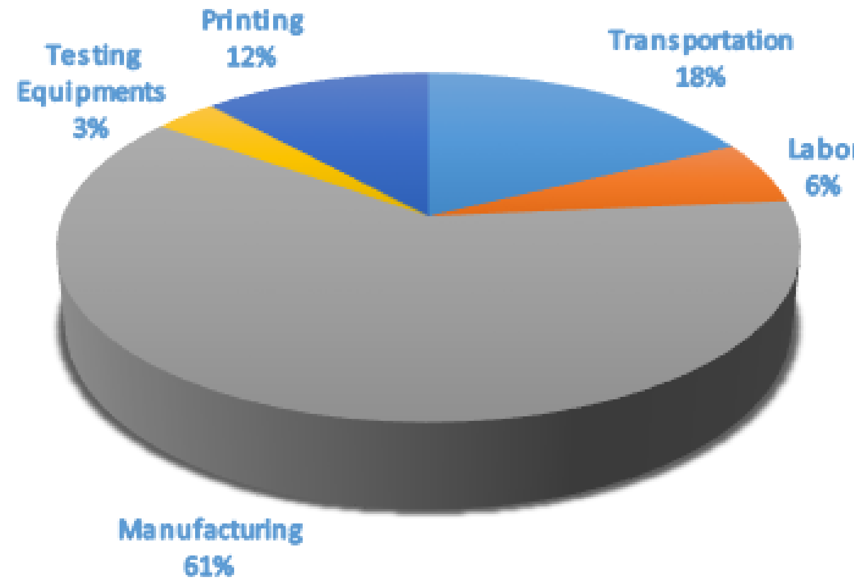
The AEP was calculated using:

$$E_{(kWh)} = P_{(W)} \times t_{(hr)} / 1000$$



BILL OF MATERIALS

Part	Material	Quantity	Cost (tl)	Supplier	Contact
Bolts (M4x30)	Steel	64	50	Sennaroglu Limited	3668457
Bolts (M10x25)	Steel	8	6.41	Ilkay Genc	3665567
Bolts (M5x20)	Steel	4	4.5	Sennaroglu Limited	3668457
Bearing	Steel	2	60	Konpa Ticaret	3668287
Bearing Base	Cast Iron	2	75	Kopa Ticaret	3668287
Wheel	Stainless Steel	1	30	Kutret Guloglu	3660738
Shaft	Aluminum	1	60	Kuzey Yildizi	3654610
Blade (0.6mx0.2m)	PVC	2	44	Ilkay Genc	3665567
L square Connection	Steel	2	1.45	Ilkay Genc	3665567
Connection arm (0.52m)	Plastic	1	14.2	Ilkay Genc	3665567
File hanging connection arm	Plastic	2	23.8	Ilkay Genc	3665567
Silicon gel+Holder	Silicon+Plastic	1	16.75	Ilkay Genc	3665567
Metre (2m)	Plastic	1	5.48	Ilkay Genc	3665567
Nut (M4)	Iron	8	1.49	Ilkay Genc	3665567
Flatwasher (M10)	Steel	2	0.14	Ilkay Genc	3665567
Nut (M10)	Steel	2	0.54	Ilkay Genc	3665567
Sleeve Connection	Steel	2	150	Monargali	5338654117
Blades (1mx0.40m)	Galvanized Steel	8	250	Monargali	5338654117
Base (0.50mx0.51m)	Steel	1	100	Monargali	5338654117
Dynamo	Aluminum	1	0	EMU	6301248
Anemometer	Plastic	1	0	EMU	6301248
Multimeter	Plastic	1	55	Turkoglu Elektronic	3652844
Labor Cost	-	-	100	Monargali	5338654117
Transportation	-	-	300		
Welded Joint b/w 2 arms	Aluminum	16	150	Sobaci Tenek	5338677351
Report Printing	-	3	200	Deniz Plaza	392444 1941
Total			1698.76		



WHY INCONSISTENT RESULTS?

CONFIGURATION 1

- Limitation on the accuracy of the QBlade software: - Assumption of steady flow
  - No tip losses considered
- Fluctuation in the Cp vs. Wind Speed curve, could have been due to the wake expansions or vortices formed within the turbine
- At high wind speed, the rotation of the turbine increases significantly; probably resulting in the blade rotation acting as a barrier wall
- Inability to find the right angle of twist to generate optimum power

CONFIGURATION 2

- Different angle of attack of each blade, (manufacturing constraints)
- Misalignment of the shaft from coupling joints, and unavailability of thrust bearing
- Drag force not coming into play as required, due to inaccurate manufacturing of twist angle
- Triangulation arms added extra weight
- Unavailability of gearbox, so no high rpm to justify the cost of the wind turbine

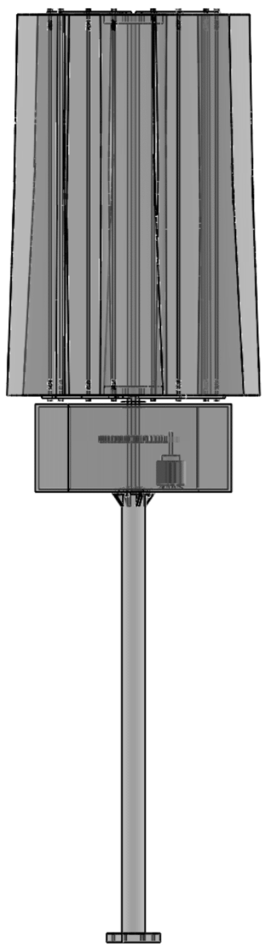
FUTURE IMPROVEMENTS

CONFIGURATION 1

- Use of better simulation software like ANSYS
- Obtaining the proper angle of twist

CONFIGURATION 2

- Precise manufacturing of the blades (Linear and identical angle of attacks and twists)
- Use one shaft for the whole design
- Adding a gearbox
- Thrust bearing being incorporated into the design, to account for movement in the axial direction
- Incorporate three disks instead of two sleeves for more efficient way off tackling vibration



THANKS FOR LISTENING

For more information:
www.me.emu.edu.tr/vawt