Universal Bladeless Aerogenerator

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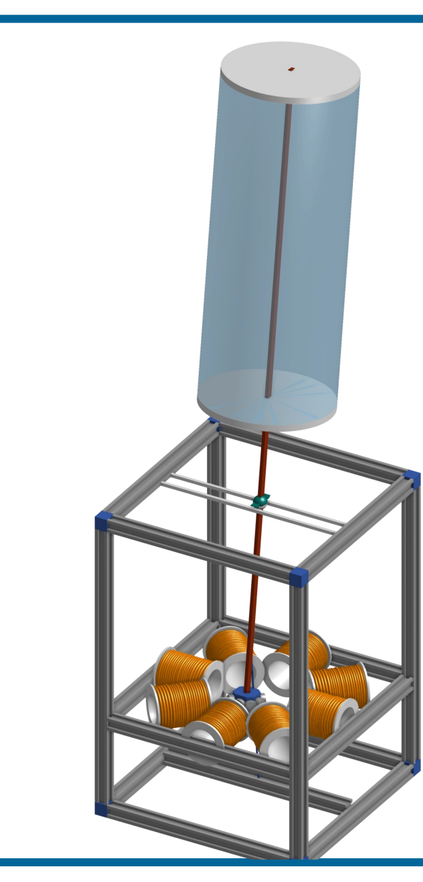
Introduction

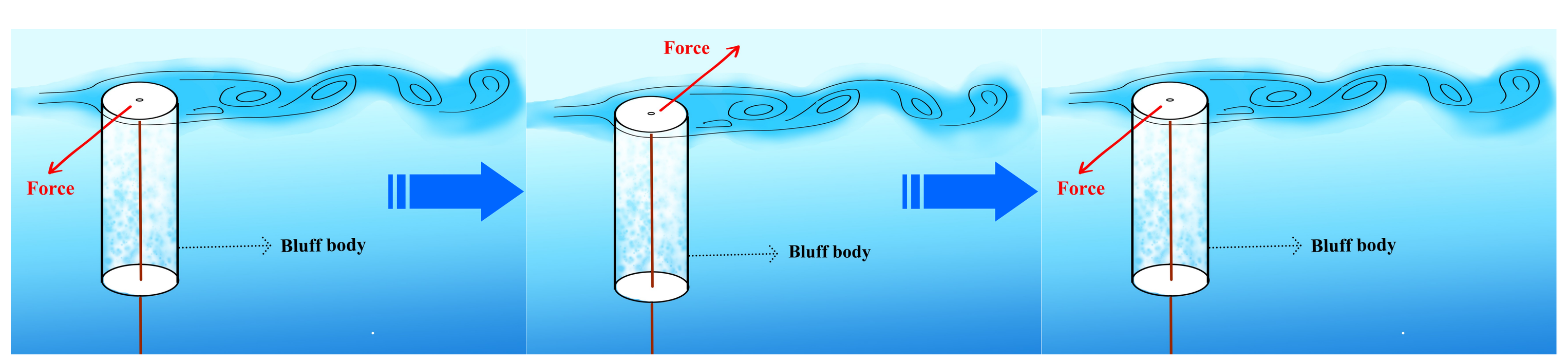
1. UBA is a type of wind turbine that can be widely installed in urban areas. Compared to horizontal axis wind turbines, UBA have the advantage of being smaller in size and have fewer space restrictions for installation.
2. UBA blades are simple in construction and easy to erect, making them cheaper than vertical axis wind turbines.
3. UBA uses the phenomenon called Vortex-Induced Vibration to convert wind energy into kinetic energy.



Research question

1. By the cause of Vortex-Induced Vibration, the bluff body will drive the mast to induce vibration.
2. Identify factors that may affect vortex-induced vibrations.
3. Through the experiment, the relation of each factor to vortex-induced vibration and mast vibration was obtained.
4. Use the Taguchi method to design experiments for optimal parameter settings .
5. ANOVA was used to derive the contribution of each control factor to the system and to carry out a verification experiment.

Material and Method



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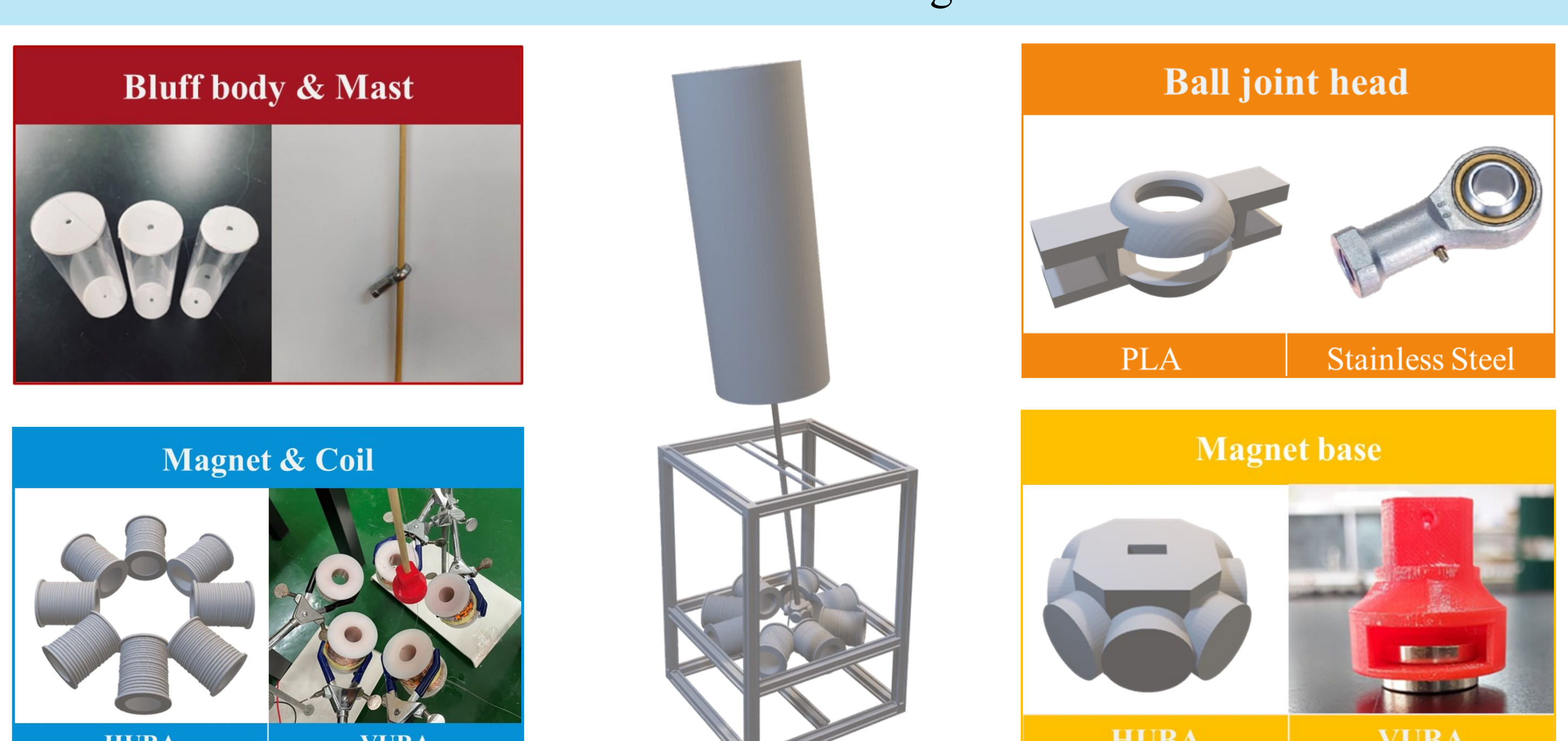


Independent Variable Experiment

1. The effect of each parameter on vortex-induced vibration was determined by independent variable experiments.
2. Used as a basis when designing control factors

Taguchi Methodology

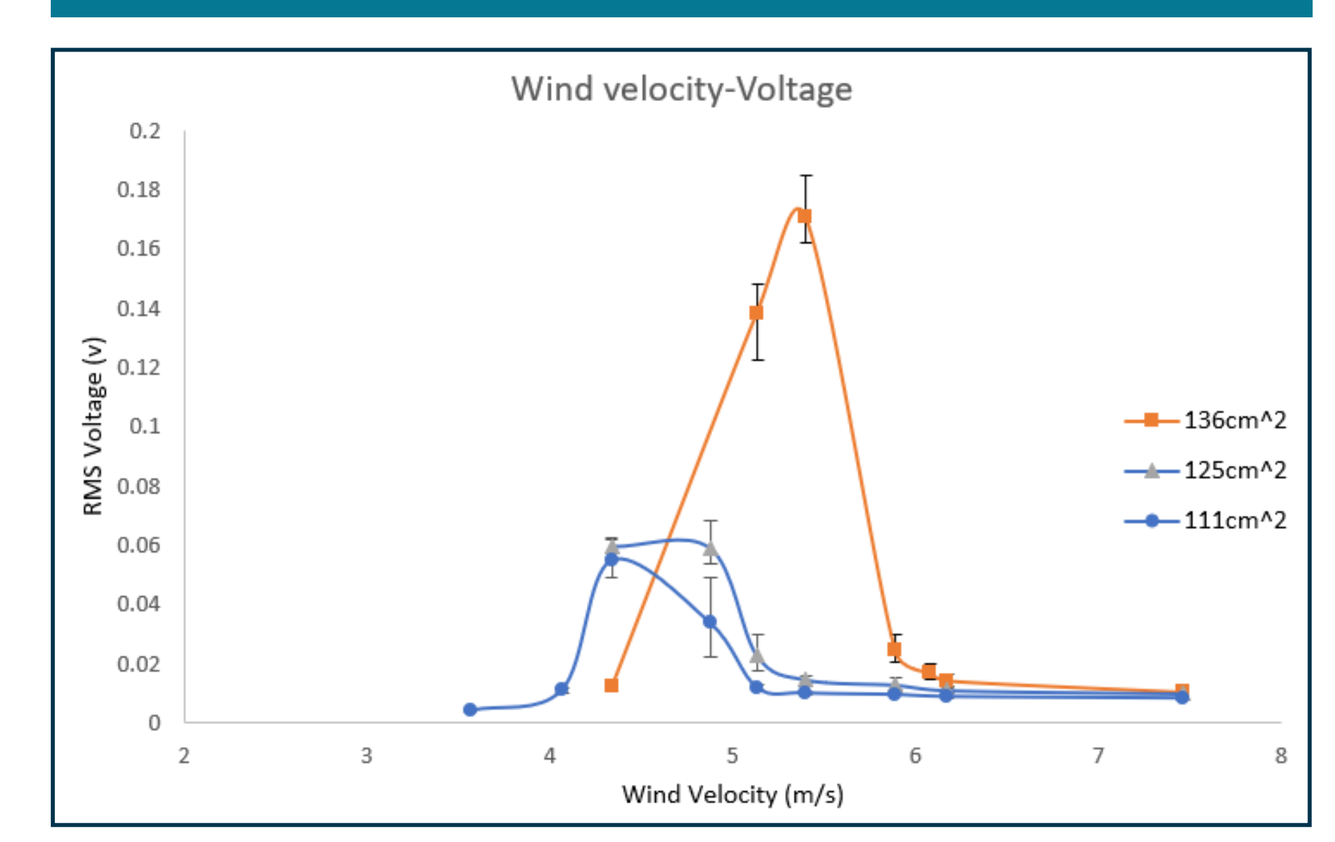
1. Determine the best levels of control factors based on "Orthogonal Arrays"
2. Find out the significant factor based on "ANOVA (Analysis Of Variance)"

Factor	description	Level 1	Level 2	Level 3
A	Bluff body diameter	5cm	6cm	7cm
B	Hanging Weight	69gw	75gw	81gw
C	Magnetic intensity	2000Gs	4000Gs	6000Gs
D	Coil diameter	0.6mm	0.9mm	1.2mm

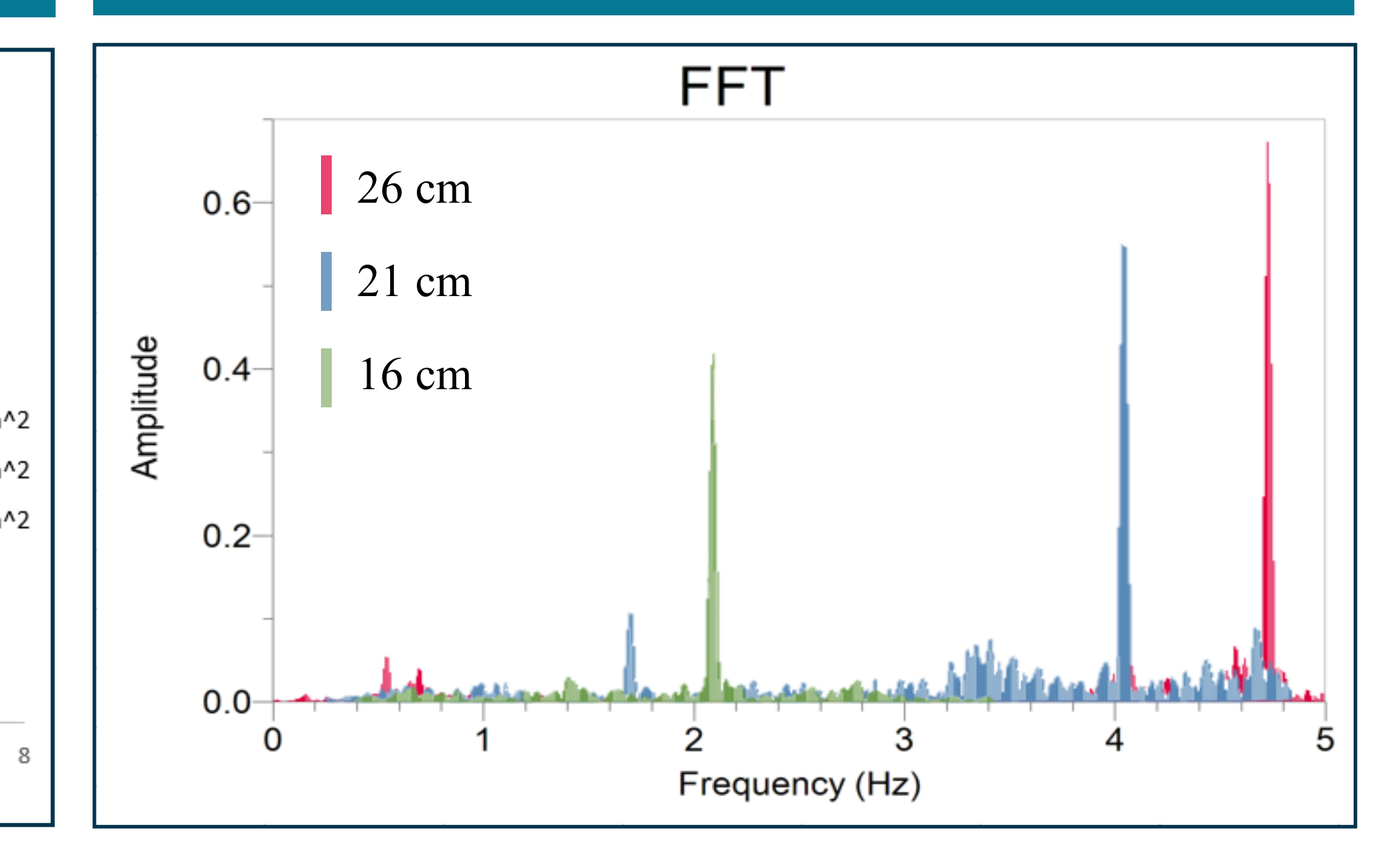
Result

Independent Variable Experiment

Wind Velocity—RMS Voltage



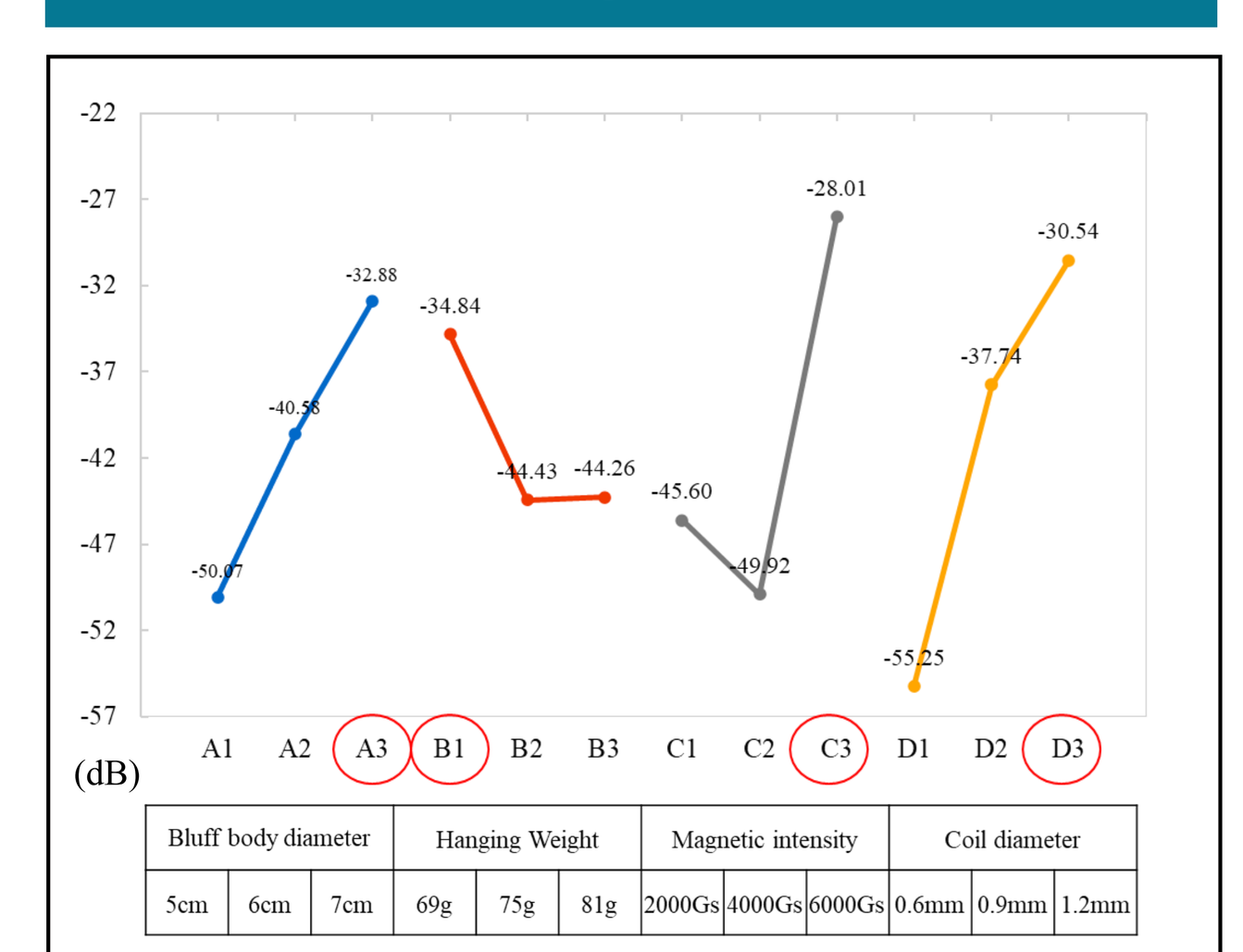
Bluff Body Volume - Frequency of Mast Vibration



1. When the sectional area of the bluff body gets bigger and so is the RMS voltage peak corresponds wind velocity.
2. The RMS voltages reach the peak in specific wind velocity.
3. Bigger the sectional area, the higher the frequency of mast vibrations.

Taguchi Methodology

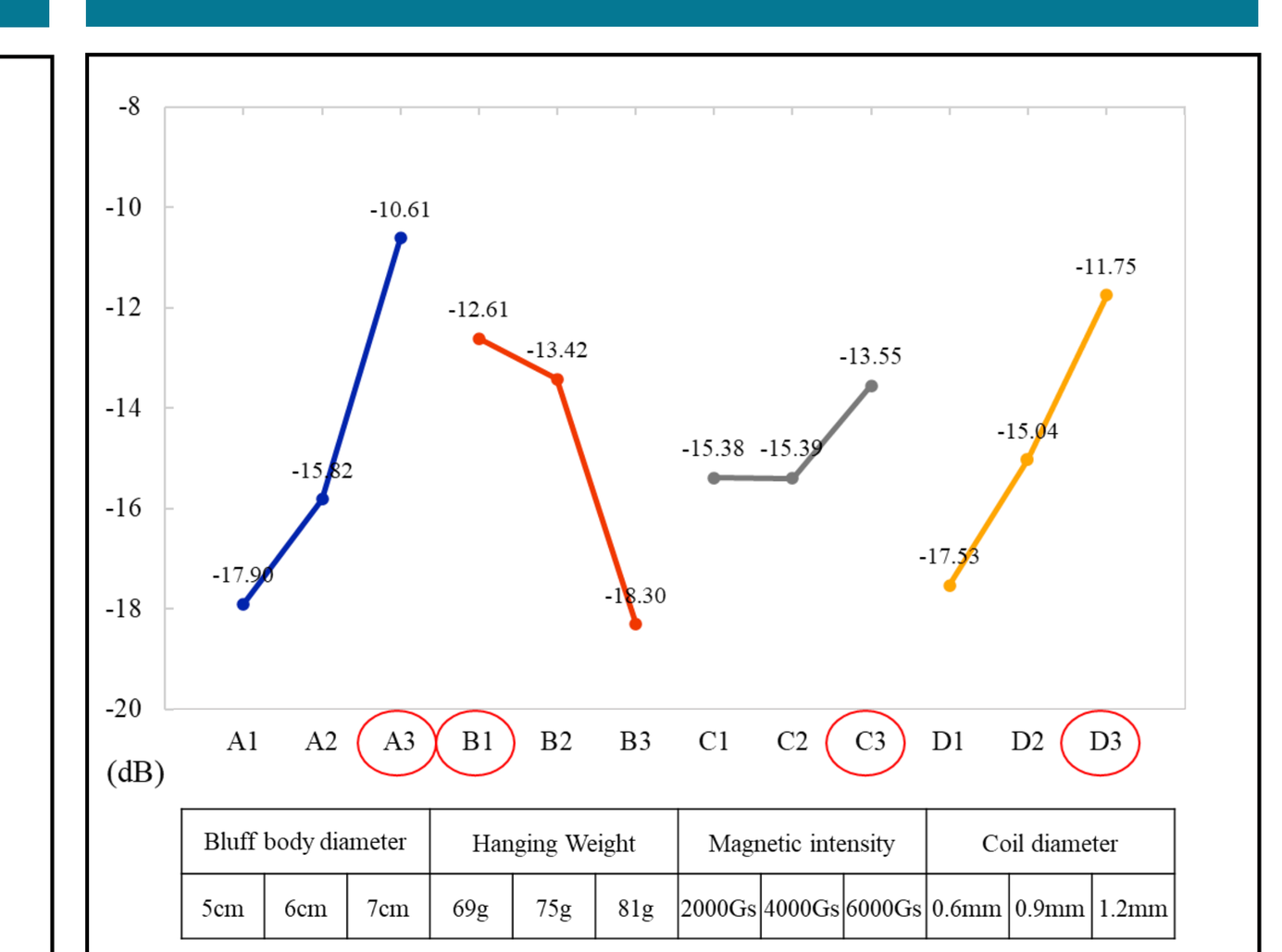
HUBA



Level	A	B	C	D
1	-50.07	-34.83	-45.59	-55.24
2	-40.58	-44.43	-49.92	-37.73
3	-32.87	-44.25	-28.01	-30.54

▲ S/N ratio of each control factor (Unit : dB)

VUBA



Level	A	B	C	D
1	-17.90	-12.60	-15.38	-17.53
2	-15.81	-13.41	-15.39	-15.04
3	-10.60	-18.30	-13.54	-11.75

▲ S/N ratio of each control factor (Unit : dB)

Figure out S/N ratio via experiment data Both HUBA and VUBA have the same trend for all four parameters, The contribution rate is, in descending order, the sectional area of the bluff body, the moment of inertia, the coil diameter, and the magnetic intensity. And the optional parameter setting of VUBA and HUBA also share a common result which is A3 B1 C3 D3.

Analysis of Variance

HUBA

Factor	Sum of squares	Mean square	F_0	Percent contribution
A	2225.36	1112.68	2.46	18.52%
(B)	904.49	452.24	0.99	7.52%
C	4041.58	2020.79	4.46	33.63%
D	4843.18	2421.59	5.35	40.31%
Error	904.50	452.25	1	
Total	12014.63			100%

VUBA

Factor	Sum of squares	Mean square	F_0	Percent contribution
A	141.17	70.58	12.44	42.57%
B	94.96	47.48	8.37	28.64%
(C)	11.33	5.66	0.99	3.41%
D	84.09	42.04	7.41	25.36%
Error	11.33	5.66	1	
Total	331.57			100%

The percentage contribution of each factor was calculated by ANOVA in order to identify the significant factors and estimated the predicted S/N ratio.

Verification Experiment

HUBA

Result of Verification Experiment							
1	2	3	4	5	average	stdev	S/N (dB)
0.34	0.31	0.26	0.31	0.22	0.29	0.04	-8.77
S/N ratio 95% Confidence interval							
-55.56 ~ 50.09 (dB)							
Predicted S/N ratio				S/N ratio of the verification experiment			
-2.73				-8.77			

VUBA

Result of Verification Experiment							
1	2	3	4	5	average	stdev	S/N (dB)
0.47	0.45	0.43	0.41	0.43	0.44	0.02	-4.75
S/N ratio 95% Confidence interval							
-10.09 ~ 1.73 (dB)							
Predicted S/N ratio				S/N ratio of the verification experiment			
-4.18				-4.75			

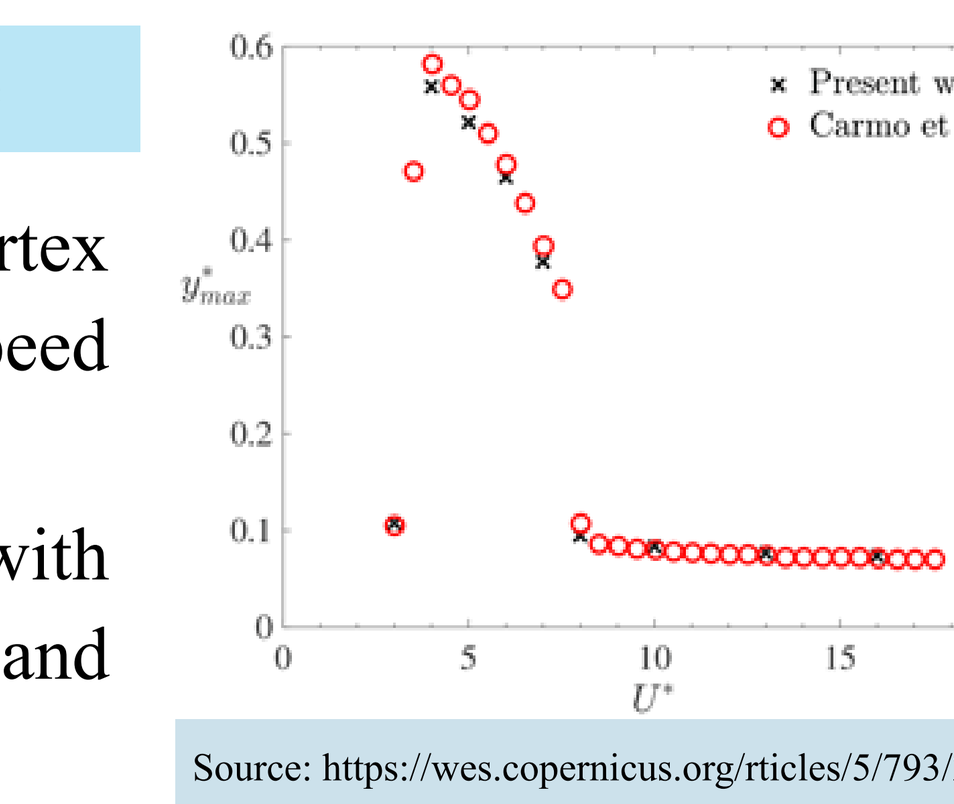
Verification experiments based on the optimal parameter combinations show that the S/N ratios for both HUBA and VUBA verification experiments fall within the 95% confidence interval of the expected S/N ratios.

Discussion

Vibration Amplitude and Nominal induced Electromotive

In comparison with previous studies of wind speed versus vortex vibration amplitudes, the trend is similar to that of wind speed versus electrical pressure.

It is hypothesized that the amplitude is positively correlated with the change of flux (nominal induced electromotive) and experiments will be conducted to test this hypothesis.



Source: https://wes.copernicus.org/rticles/5/793/2020

Theoretical Analysis

Due to the size of the wind tunnel, the current experimental setup is approximately 3-5 times smaller than the estimated actual machine, therefore it is still to be determined whether the best combination of parameters derived from the experiments can be directly scaled up in a commercial machine.

At present, we have started to design an experiment to investigate the interactions between the parameters and analyze the theory, in order to derive a theoretical basis for the future scaling of the machine.

Conclusion

In this study, A new design of VUBA is proposed which allows the UBA to suit the urban environment with unstable wind direction, and the optimum parameter setting is derived by the Taguchi method and dramatically increases the output power of the UBA by 50.5%.

In addition, through the independent variable experiments and ANOVA analysis, multiple parameter effects on generation efficiency and system percentage contribution were derived, which provided a conceptual model and empirical formulas for future research and study.

Future plan

1. Exploring the effect of additional parameters on output power and vortex-induced vibrations.
2. Add dimensional analysis for theoretical analysis and discuss the interaction between parameters.
3. To seek the relationship between each parameter and electrical power.

Reference

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