Urban Wind Turbine Design

For Scheveningen

Hengfeng Chi Msc Graduation Project Report

Acknowledgements

I would like to thank all the colleagues in Actiflow, especially Tom Fahner and Roland Broers. I feel lucky to work in this company. I really appreciate the guidance from the supervisory team, Annemiek van Boeijen, Oscar Person, Oskar van Dijk and Rudolf Wormgoor. In the end I would like to thank my parents a lot for their support for my study in TU Delft.

Graduation project Report

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Introduction

This report describes the graduation project of Hengfeng Chi, a master student of Integrated Product Design at the faculty of Industrial Design Engineering TU Delft. The project is to design an urban wind turbine with appreciated appearance in the context of coastal area in Scheveningen, in collaboration with Actiflow BV.

The project consists of four phases: Technology and product semantic analysis, Context research, Product concept development, Concept finalization. In the end, an innovative urban wind turbine was designed, which would be further engineered and probably to be built on the Pier of Scheveningen in a few years.

1. Project description

1.1 Company

This project is in collaboration of the company Actiflow. Actiflow is an aerodynamics focused consultancy & design engineering company based in Breda. It was founded in March 2005 as a spin off from Delft University of Technology. After being a service-based company for more than 5 years, Actiflow wants to develop its own product. Because of the growing market of renewable energy technology, Actiflow wants to explore new concepts of urban wind turbines (UWT) especially for high-end market segment. With this project, the company aims to show their capacity in both aerodynamics and design.

1.2 Assignment

Currently, most urban wind turbines in the market are seen as ugly. Sometimes they are even labelled as visual pollution in the building environment. This leads to a low public acceptance.

In order to increase the acceptance of small wind turbines in the urban environment, extra value should be created by improving the design. Shapes should be developed which are visually appreciated by consumers, while keeping a relatively high power efficiency. The turbine design should add value to the surrounding environment, instead of polluting the neighborhood.

The coastal area is proven to be one of the most suitable places for urban wind turbines. It has high annual mean wind speed and less obstacles. In this project, coastal area Scheveningen (Den Haag) is chosen to be the particular location for research and product development. The goal is to design new wind turbines visually appreciated in the context of coastal area by public people. At the same time it shows the company's ability in the field of both aerodynamics and design.

1.3 Design Process

The design process used in this project is visualized in Figure 1.1.

After exploratory study, technology related to urban wind turbines is studied to understand the possibilities and limitations for product design. It is followed by an analysis of existing products concerning the forms and semantics. This analysis helps to gain an insight into how people appreciate different shapes in this kind of products.

In the second phase, a contextual research is conducted to find out the desires and requirements, mainly concerning public people in the environment of coastal area Scheveningen (Den Haag). During the field research, optimal locations are selected as well. The design vision is based on the context research.

The third and fourth phase of the project are Concept development and Concept finalization. Starting from technology, with guidelines and requirements from semantic analysis and contextual research, a few initial ideas are generated. Ideas are evaluated from engineering perspective first. Selected ideas are further developed to concepts to achieve the design vision. The concepts are evaluated and compared to each other, the best one is selected for finalization.

The final design is evaluated and verified, in aspects of both design and engineering. Some engineering recommendations are made for embodiment product development in the end.

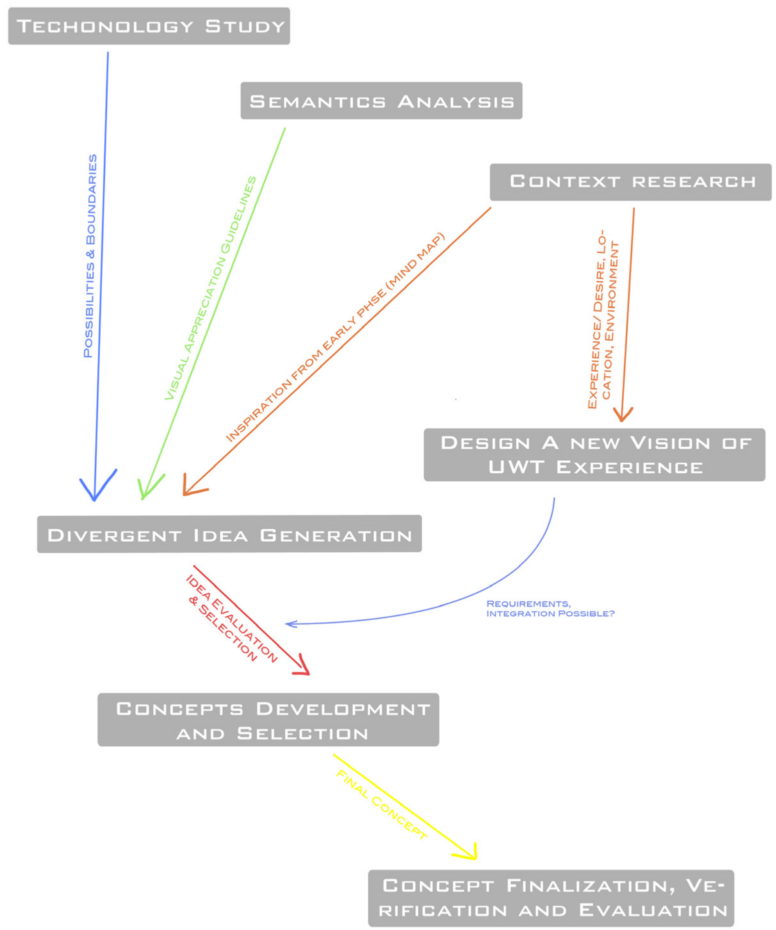


Figure 1.1 Design Process

2. Technology Study of UWT

In order to gain general knowledge of urban wind turbine technology, and understand the possibilities and boundaries of design, technology study is performed initially. Literature research is the main method used in this phase.

2.1 Definition of urban wind turbine

Urban wind turbines are defined as turbines that are specially designed for the building environment, and can be located on buildings or on the ground next to buildings. This implies that the turbine has been adapted for the wind regime in the built environment and can, in theory at least, resist wind gusts and turbulences. The capacity of these turbines is generally between 1 and 20 kW. [1]

The rotor area varies between 0.5 m^2 and 200 m^2 with a rotor diameter of 0.75 to 15 meters. The mast height varies from 3 to 25 meters. [2] In the Netherlands, according to NWEA's (Netherlands Wind Energy Association), the pole of UWT in built surroundings should be shorter than 15 m. In industrial and rural areas, it should be shorter than 25 m.

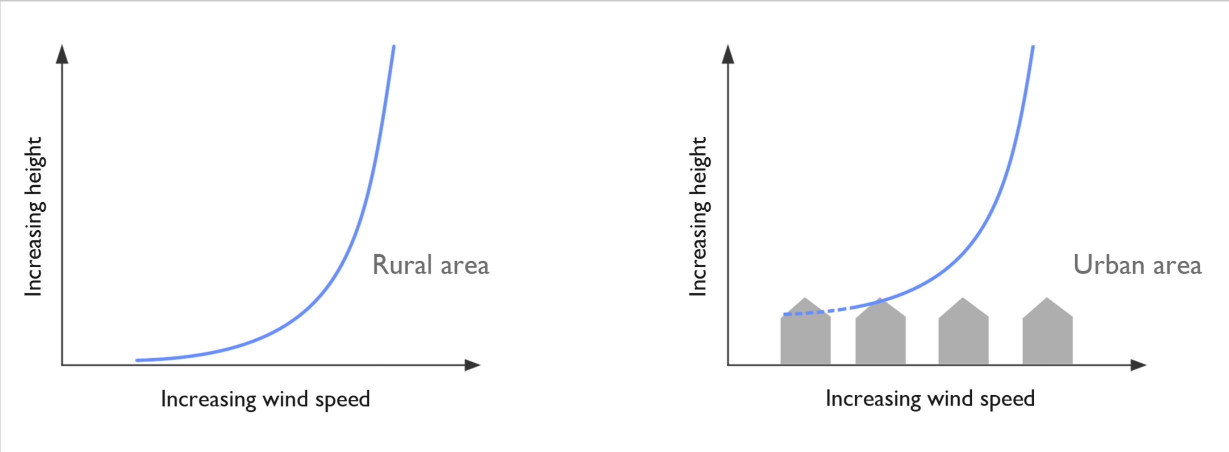


Figure 2.1

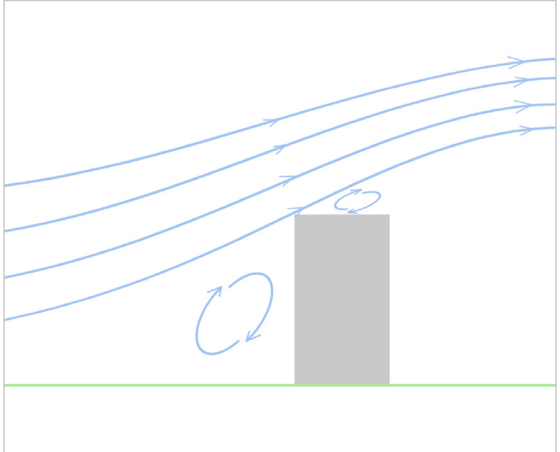


Figure 2.2

2.2 Wind characteristics in Urban environment

The wind resource is crucial for a wind turbine generating electricity. Understanding the wind characteristics in urban environment, especially in coastal area, can help to decide which technology to use for the product design.

2.2.1 Wind regime in urban environment

There are two typical features of urban wind regime compared to rural area:
- Lower mean wind speed;
- More turbulent flow.

Wind speed increases with height. Buildings, street furnitures and other features of urban landscapes create 'rough uneven ground', which lower the wind speed. As a result, at the same height the urban wind speed is generally lower than rural wind speed. (Figure2.1)

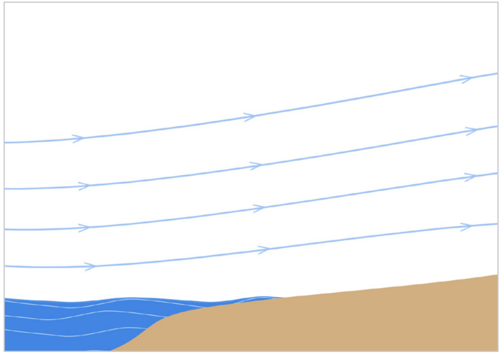


Figure 2.3

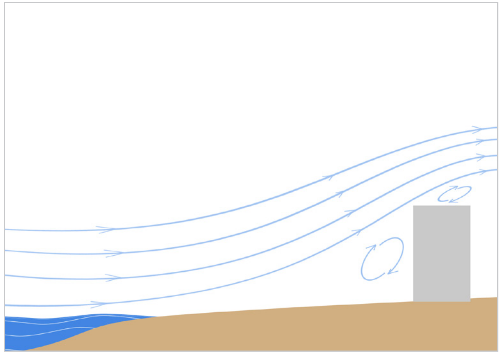


Figure 2.4

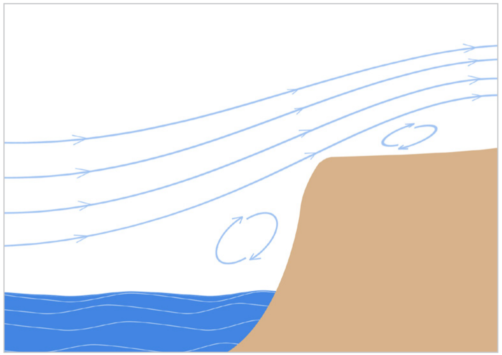


Figure 2.5

There are more turbulence in urban compared to rural area, especially at lower height. Because there are much more obstacles in urban environment. Figure 2.2 typically shows turbulent flow caused by a single building.

2.2.2 Wind regime in coastal area

In the context of this report, the coastal area refers to urban coastal area with artifacts instead of rural coast.

The wind regime in coastal area is slightly different from the building environment. There is no obstacle from the direction of the sea. It results in very strong prevailing wind. Thus coastal area is considered as one of the best urban locations for setting up wind turbines.

Figure 2.3 to figure 2.5 show three different situations when the wind is blowing to the coast.

When the coast connects to the ocean very ‘smoothly’, the wind can be seen as similar as in rural areas.(Figure 2.3) When there are buildings or other obstacles, the wind turbine is better to be placed as close to the coastline as possible, or on the upwind edge of the buildings.(Figure 2.4) There is also a possibility that it is a cliff. Turbulence will occur both in front of cliff and on the flat ground above cliff. In this case, the wind turbine should be placed close to the edge of the cliff.(Figure 2.5)

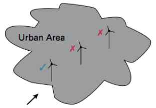
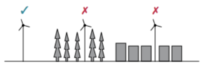
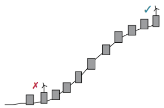
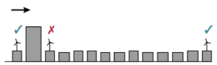
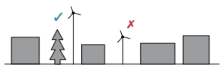
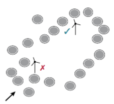
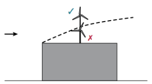
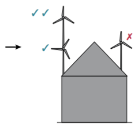
	1.Turbines should be sited near the edge of built up or forested areas in preference to central locations. It is best to choose a location on the side of the prevailing wind.
	2. Locate the turbine over a rural, non-forested area in preference to built up or forested areas.
	3. Site turbines near the top of smooth hills. For steep hills, the turbine should be placed at the highest point or on the side of the prevailing wind if the summit is not an option.
	4. For each obstacle that protrudes above the general level of the roughness elements, try to ensure that the turbine is located. Either further away than 3 to 10 times the obstacle height; Or higher than 1 to 1 1/2 times the obstacle height.
	5. Position the turbine as high as practicably possible or allowed.
	6. Position the turbine above the height of near by trees or buildings.
	7. If practical considerations prevent the turbine being mounted above the height of nearby trees or buildings, ensure there is a clear view on the side of the prevailing wind direction.
	8.Turbines mounted on flat roofs should be placed above the turbulence in the wake of the air stream.
	9. For turbines mounted on pitched roof buildings that extend above the surrounding obstacles, ensure that: Either the turbine height above the roof peak is at least half the vertical depth of the roof (base to peak); Or the turbine is mounted in front of the peak from the perspective of the prevailing wind direction (and ideally both).

Table 2.1

2.2.3 General guidelines for UWT location choosing

The fundamental purpose is to find a location with best wind regime in a certain area. With different landscapes, generally there are some different guidelines. Studies have been performed by different scholars to construct guidelines for UWT location choosing. The guidelines from “Small-scale wind energy - Policy insights and practical guidance” (2008) are used as reference in this project. [3]

In urban areas, turbines should be sited near the edge of built up or forested areas rather than central location. It is best to choose a location on the side of the prevailing wind. Because in the center, turbines will be surrounded by obstacles. When the wind reaches turbines, the power of wind is already reduced by those objects. Turbines are better to be built in an open area. As the turbulence, caused by natural objects or artifacts in the air, can lower the efficiency of wind turbines. (Point1,2 in Table 2.1) If the wind turbines are planed to be built in somewhere with hills, the tops of ‘smooth’ hills are the optimal places. Sharply changing gradients, such as cliff tops, can cause turbulence. In lower area, wind speed is lower due to the obstacles. (Point 3 in Table 2.1) If there are some high objects in the environment, some solutions are recommended as follows. The turbines can be positioned higher than the object or far away from the object. In addition, make sure there is a clear view on the side of the prevailing wind direction. (Point 4, 5, 6, 7 in Table 2.1) When the turbines are mounted on the roof top, the turbulence, shown in Figure 2.2, should be specially taken into account. The turbine should be place above the turbulence. On pitched roof buildings, the front peak of the prevailing wind direction is preferred. (Point 8,9 in Table2.1)

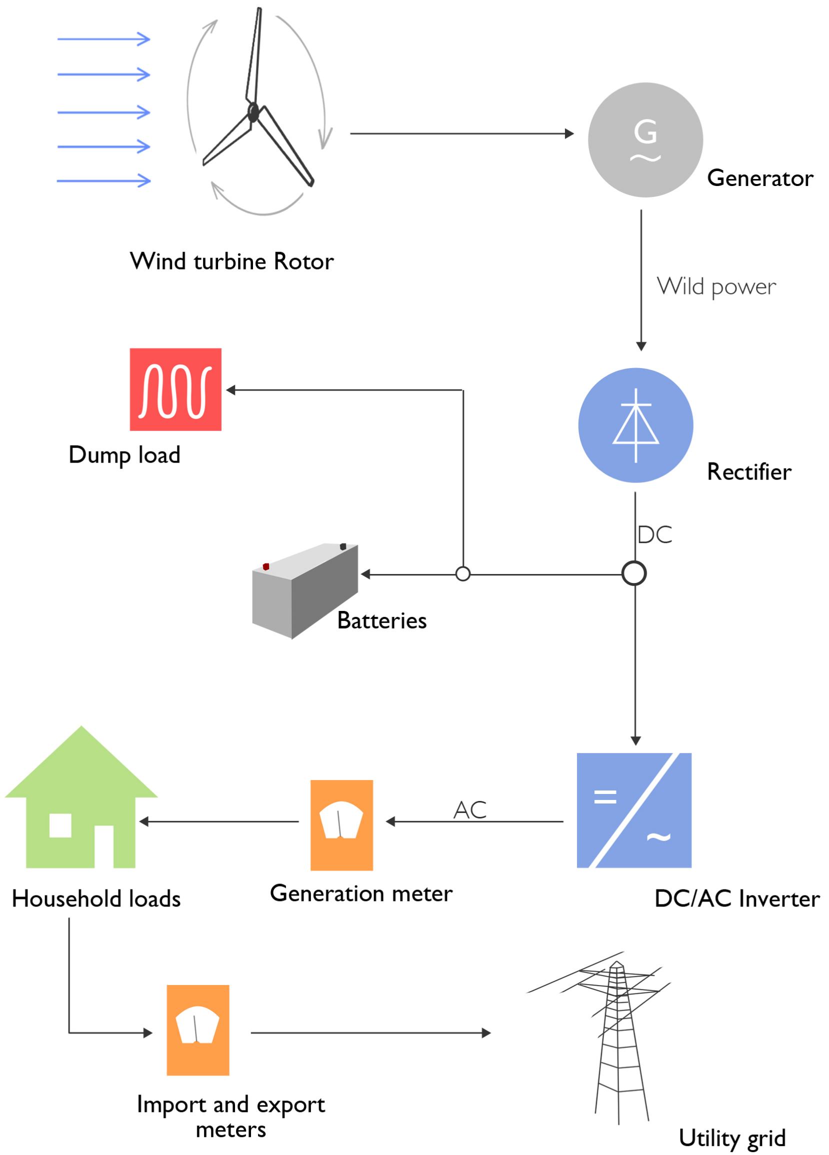

G
Generator
Wind turbine Rotor
Wild power
Dump load
Rectifier
DC
Batteries
AC
=
~
Household loads
Generation meter
DC/AC Inverter
Import and export
meters
Utility grid

Figure 2.6

Aeocon4600

Aurora PVI-3.0

Windy Boy 1200

Figure 2.7

2.3 UWT system

The basic working principle of wind turbines is turning kinetic energy of the wind into electric energy. Figure2.6 illustrates components in a normal urban wind turbine system. In this graph, the 'three blades' rotor is only one example of the rotor design, which does not represent a particular model.

The rotor captures the wind power and converts it into rotation movement. In most small wind turbine designs, the rotors are connected to the shafts of generators directly. In some other products (Jacobs 31-20), gear boxes are used to connect blades to the generators. Permanent magnet alternators (generators) are commonly used.

When the wind is blowing above certain speed, the blades start to rotate and generator produces 'wild' electric power. The output is rectified by a rectifier to direct current (DC). This DC can be used to charge batteries. In grid connected design, the DC is inverted into alternating current (AC) by an inverter for common house use. In some countries, the electricity generated by individuals can be fed into the local distribution network and get payment.

Some companies have developed the 'controllers' for small wind turbines. The controller integrates the whole power management system into one product. Figure2.7 shows several product examples from different suppliers. The power management and feed-in systems are out of the scope of this project. It is recommended to select an appropriate controller for the new design. With a purchased controller, the system architecture is simplified as shown in Figure2.8. In this project the main focus is the design of rotor with generator.

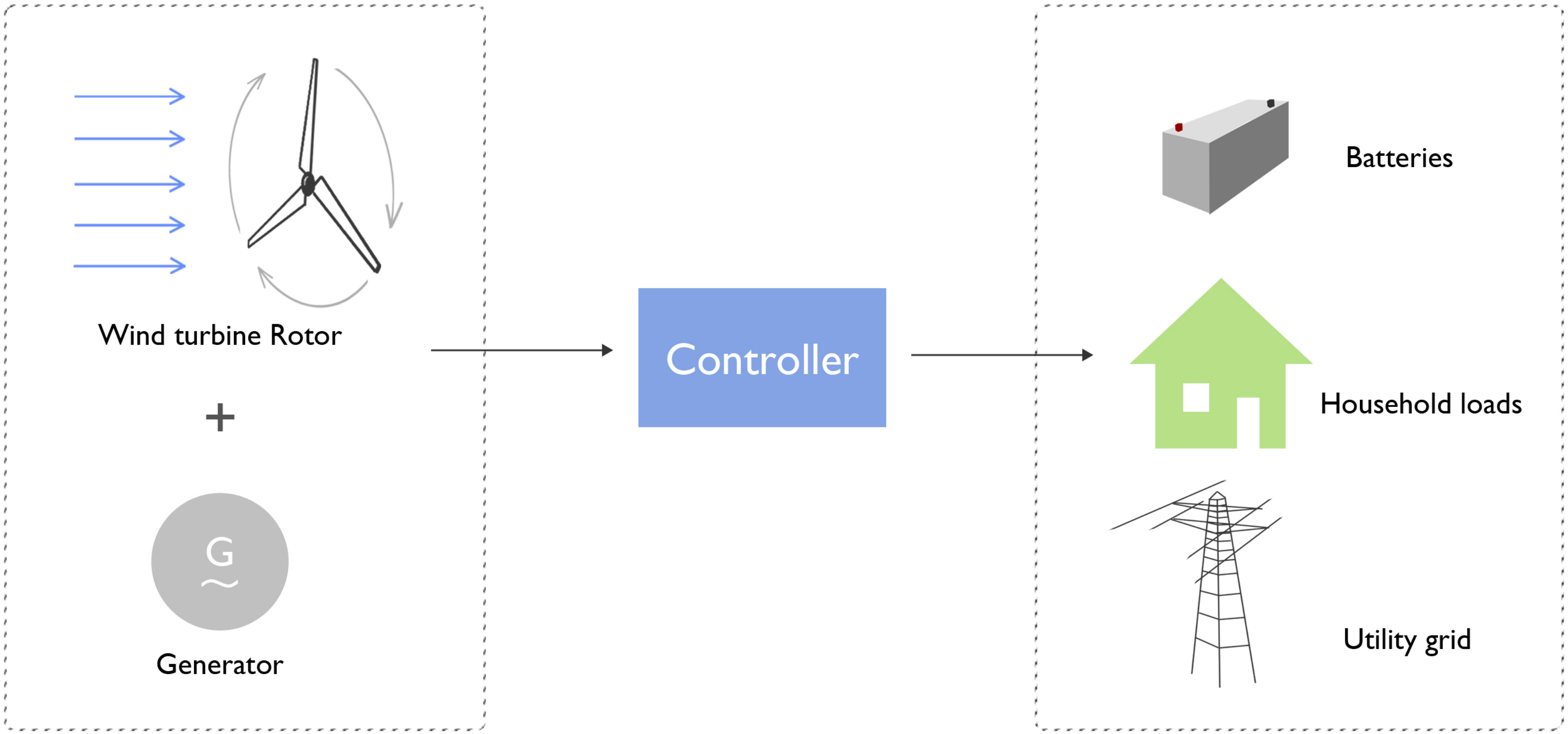

Wind turbine Rotor
+
G
Generator
Controller
Batteries
Household loads
Utility grid

Figure 2.8

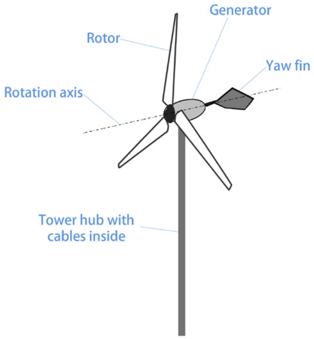


Figure 2.9

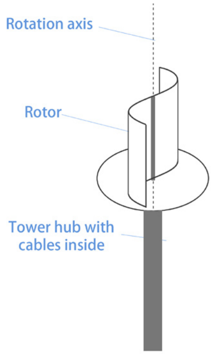


Figure 2.10

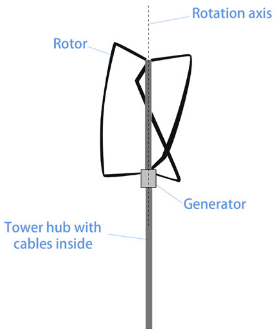


Figure 2.11

2.4 Classifications of UWT and relevant technology review

2.4.1 HAWT and VAWT

Wind turbines are classified into two typical categories: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT).

HAWT
Horizontal axis wind turbines rotate about horizontal axes.(Figure 2.9) They have the rotors and generators at the top of a mast. To make the blades spin, the axes must be pointed into the wind. Large turbines use wind sensors coupled with servo motors to control the direction of the axes. Small turbines use simple yaw fins as shown in figure 2.9. Large HAWT have gearboxes connecting the rotors and the generators. They turn the slow rotation into faster rotation to drive the generators. However, in a small HAWT system, rotor normally connects to the generator directly with a shaft. Because small wind turbines can rotate at a relatively high speed. Using a gearbox might increase the possibilities of failure as well as maintenance cost by adding much more components. [4]

In modern HAWT design, most of them are lift based turbines, employing airfoil rotors. The basis of working principal will be explained in the next section ‘Aerodynamics in wind turbine’.

VAWT
Vertical axis wind turbines rotate about vertical axes. They do not need to be pointed into the wind, which is the key advantage of this type. With a vertical axis, the generator and gearbox can be placed near the rotor or near the ground. [5]

There are two subtypes of VAWT: Savonius VAWT and Darrieus VAWT. Savonius VAWT (Figure 2.10) is a drag driven turbine, which is also used in anemometers. Theoretically, this type of turbine cannot reach a tip speed higher than the wind speed. Darrieus VAWT (Figure 2.11) is a lift driven turbine, which can have a tip speed much higher than the wind speed.

Hence this type is more power efficient than Savonius type.

2.4.2 Aerodynamics in wind turbine

Drag driven wind turbines are the most traditional type. When the airflow blows to the surfaces of the device, it causes different pressures on the concave surfaces and convex surfaces. (Figure 2.12) The pressure difference makes the turbine rotate in the wind. It has a better self starting ability, compared to the lift type vertical wind turbine. The main disadvantage of drag driven turbines is the low power efficiency. The tip speed ratio* cannot be higher than 1. It means these turbines can never rotate faster than the wind speed. Hence the power they capture from the wind is relatively low.

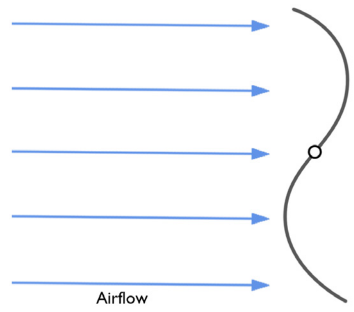


Figure 2.12

The mainstream of wind turbines design nowadays is lift driven turbines. This type of wind turbines takes advantage of lift force by employing airfoil blades. It can achieve a tip speed ratio much higher than 1, hence higher efficiency.

The airfoil can be used in both HAWT and VAWT. The shape of airfoil has been studied for decades. NACA airfoils is a series of standard profiles developed by National Advisory Committee for Aeronautics.[6] In most of the existing lift driven turbines, standard profiles like the NACA 0015 and NACA 0018 are used. [7]

Figure 2.13 illustrates the basic working principals of airfoil. The direction of airflow in figure 2.13 is the relative airflow direction instead of the direction of real wind. Angle of attack is defined to be the angle between relative air direction and chord line. The chord line is a straight line connecting the leading and trailing edges of the airfoil. Lift force is defined to be perpendicular to direction of the oncoming airflow. The lift force is a consequence of the unequal pressure on the upper and lower airfoil surfaces. Drag force is defined to be parallel to direction of the oncoming airflow. The drag force is due both to viscous friction forces at the surface of the airfoil and to unequal pressure of the airfoil surfaces facing toward and away from the oncoming flow. [8]

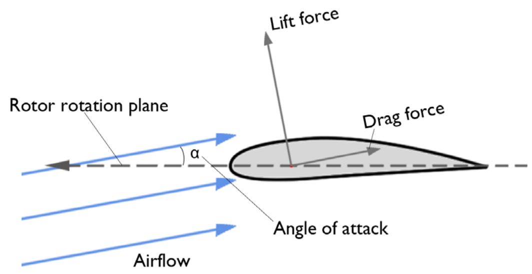


Figure 2.13

*Tip speed ratio = Tip speed of blade / Wind speed

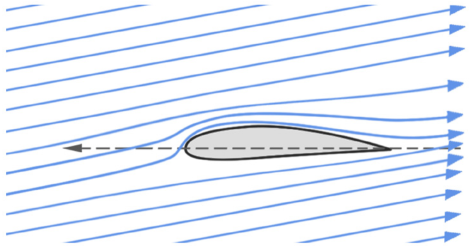


Figure 2.14

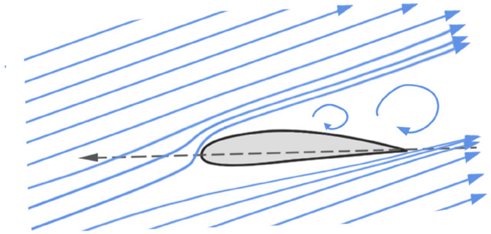


Figure 2.15

At low angle of attack, the flow is attached to the upper surface of the airfoil.(Figure 2.14) Within a range, the lift force increases with the angle of attack and the drag force is relatively low. When the angle of attack continues increasing, at a certain moment the airflow will separate.(Figure 2.15) The separation starts at the trailing edge of the airfoil and shifts forward with increasing angle. If the angle is increased further the separation moves forward to the leading edge. [9]

The angle of attack should be controlled to have a better aerodynamics performance. It can be achieved by controlling the angle of airfoil, and rotation speed of the turbine.

In HAWT, the blades design according to aerodynamics theories is already very mature. There are even programs to generate certain blade's shape according to engineers' requirements. In most of existing Darrieus VAWT, standard profiles like the NACA0015 and NACA0018 are used.

2.4.3 Performance

Wind may be considered to be a combination of the mean wind and turbulent fluctuations about that mean flow. Wind turbine performance (mean power output and mean loads) is determined by the aerodynamic forces generated by the mean wind. [8]

The power calculation equation of wind turbines is as follows:

$$\text{Power} = 1/2\, C\rho A V^3$$

ρ = Air density
C = Coefficient of performance
A = Frontal area
V = Velocity of the wind

As seen from the equation, the power output is directly proportional to the frontal area. A doubled frontal area results in a doubled power. It is also directly proportional to wind speed cubed. Doubling the wind speed gives eight times the power.

2.4.4 Comparison of different UWT types

Efficiency
Horizontal axis wind turbines are proved products. Generally they have higher power efficiency and cost efficiency than vertical axis wind turbines. Because VAWT suffer additional drag force when the blades rotate into the wind. [10]

Coping with turbulence
Turbulent wind flow decreases the performance of HAWT. Lift driven VAWT are less sensitive to turbulence than HAWT. Drag driven VAWT can benefit from turbulent flow. [11]

Coping with changing wind direction
HAWT have to be pointed into the wind. When the direction of wind changes, they have to 'find' the direction with help from yaw devices. VAWT are independent of wind direction for their operation. As wind in urban environment has frequently changed direction, VAWT would perform better than HAWT.

Vibrations
VAWT create fewer vibrations than HAWT.[12] With lowest rotation speed, drag driven turbines create the least vibrations.

Noise
The noise in wind turbines can be created by aerodynamic noise and mechanical noise. The mechanical noise can be reduced by careful attention to the design and manufacture.

Compared to horizontal turbines, vertical ones are more silent with the same power coefficient at normal operating speed. [13] The blades do not create the usual whooshing noise that occurs with horizontal turbines when the blades pass close to the mast at each revolution. The drag driven turbines generate lowest noise level because of the low rotation speed.

While it is rotating, tip vortex noise forms an important part of the noise generation process on the outer part of the wind turbine blades. Blade tip noise is caused by different effects. The exact mechanisms of blade tip noise generation is out of the scope of this project, which will not be further elaborated here.

Self starting ability
Drag driven turbines are naturally self starting device. Horizontal turbines have a big starting torque force when wind blow onto it. Therefore they have good self starting ability. Most lift driven turbines have low starting torque. They have negative power coefficient at low tip speed ratios. However, this problem of lift driven turbines can be solved by carefully designed airfoil, or providing external power source.

An overview of comparison is shown in table 2.2 in the next page.

	HAWT	VAWT	
		Savonius	Darrieus
Power Efficiency	Good	Bad	Neutral
Cost Efficiency	Good	Bad	Neutral
Coping with turbulence	Bad	Good	Neutral
Coping with changing direction of wind	Bad	Good	Good
Vibration	Bad	Good	Good
Noise	Bad	Good	Neutral

Good Neutral Bad

Table 2.2

2.5 Conclusion

The technology study helps to gain technical knowledge and basic working principle of urban wind turbine system, as well as location choosing guidelines.

As a design project, technology study is done mainly considering what are necessary for the product design. It does not go much beyond the design scope. In this conclusion, it also mainly focuses on the findings related to the later product design. Through the technology study, there are some technical restrictions and guidelines useful for urban wind turbine design, concluded as follows:

1. Generally HAWT have better power efficiency, while VAWT cope better with urban wind regime. Both of them have the potential for further design in this project.

2. The power output is directly proportional to the frontal area of the turbine, also to the wind speed cubed. In wind turbine design, a bigger frontal area results in a higher power output.

3. Lift driven system would be preferred in this project to drag driven system, as it can better show Actiflow's ability in the field of aerodynamics. Drag driven structure could be used if necessary.

4. Lift driven wind turbines (both HAWT and VAWT) take advantage of 'airfoil'. To design a lift driven turbine, the cross-section of the blade should be airfoil-shaped and has the right angle of attack. As long as the design fits these two conditions, it will work. NACA airfoils are airfoil shape series developed for aircraft wings, which are also used in wind turbine designs. In this project, the airfoil of wind turbine will be chosen from NACA airfoils with recommendation from aerodynamics experts in Actiflow.

5. Power efficiency of lift driven wind turbine is determined by the value of 'lift force' divided by 'drag force'.

6. The blade tip causes whooshing noise. The noise level increases with the tip speed. The noise can be reduced by careful design. Normally HAWT generates louder noise than VAWT.

7. Rotation speed of rotor can be controlled by different methods. These methods will be considered in the embodiment engineering, which is not in the scope of this project.

8. For lift driven VAWT, self starting ability is related to airfoil types. Airfoils with better self starting ability have lower performance in high wind speed situation and vice versa. Self starting ability can also be solved by external controller.

9. An optimal location for building wind turbines is somewhere with a good wind regime. Normally it should be high in the air, without obstacles surrounding.

3. Semantic analysis of existing products

Since this project deals with aesthetic design to increase the public acceptance of urban wind turbines, it is important to understand how people value the appearance of this kind of products.

Designers are trained to have a relatively high level of sense of aesthetics. But sometimes it is considered to be subjective. Differences exist between designers and other people, which is also proved in the end of this semantics analysis. It is meaningful to conduct a semantics analysis in advance, to understand how people appreciate the shapes of urban wind turbines. The results will be used as guidelines for the form development in the design phase.

3.1 Objectives

The purpose of conducting this analysis is to understand how people evaluate different shapes of urban wind turbines by analyzing the existing products. The research consists of three steps. The objective of each step is: 1. To find out what words are preferred to describe urban wind turbines base on the aesthetics, and prepare appropriate adjectives for user research in the next phase; 2. To determine what components are important for communicating semantic quality of such products; 3. To map the selected existing products with adjective words, where form design guidelines will be drawn out for later product design.

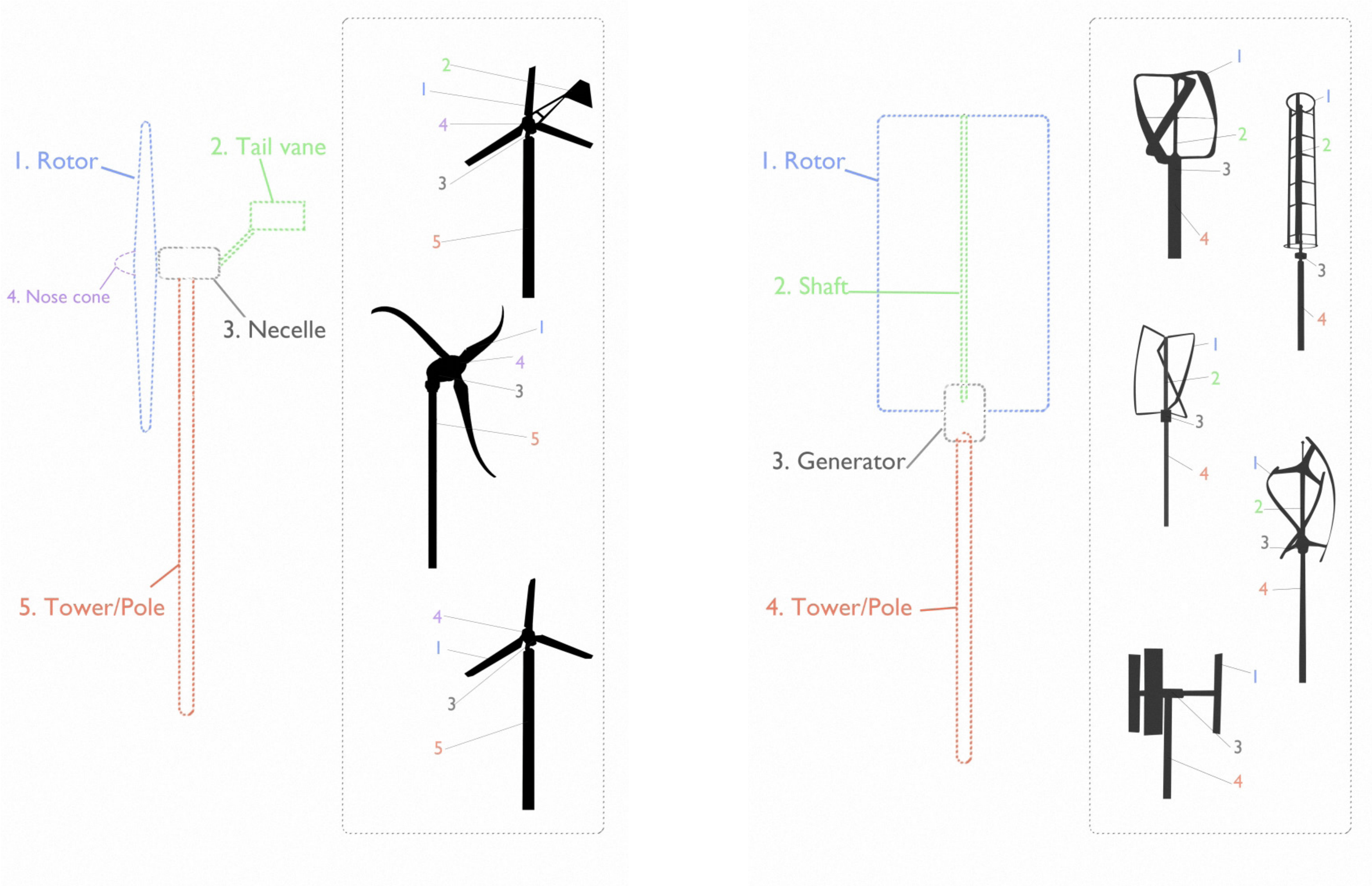

1. Rotor
2. Tail vane
4. Nose cone
3. Necelle
5. Tower/Pole
1. Rotor
2. Shaft
3. Generator
4. Tower/Pole

Figure 3.1

3.2 Methods

According to Johnson (2003) [14], products communicate different levels of properties: sensory, symbolic and stylistic. Sensory attributes are directly received by our senses, such as color, sound, glossiness. Symbolic attributes are perceived as the interpretation of what is sensed, such as elegant, futuristic, simple. Stylistic attributes are the placement in a period of style, such as Modernist, Pop, Post-Modernist. [15]

In this analysis, the symbolic attributes are the main focus. There are two reasons. First, sensory attributes do not differentiate much between different persons as they are quite objectively universal. To some degree, the designers' interpretations can represent other people's interpretations. In the design of wind turbines, the amount of sensory attributes are very limited. It is not very necessary to look into them with a full scale research. Second, it is very difficult to link a name of style to a form of a wind turbine. Because most of the turbines are developed for the function, instead of considering the styles. This might automatically result in a certain style, but it does not make much sense to analyze the stylistic attributes of wind turbines in this case.

Online questionnaire survey is used for the semantic analysis of existing urban wind turbines. It is coupled with some qualitative interviews with the responders to further understand how the shapes influence their opinions.

The semantic analysis is divided into two sections. The first two steps are done in the first section, the third step in the second section.

In the first section, an online survey questionnaire is used. The questionnaire can be found in appendix A. 30 pairs of bipolar adjectives are heuristically selected, derived from informal discussion with other persons, or from other sources such as 'Soft and hard product attributes in design'[16].

A collection of images of existing urban wind turbines are shown to the responders. It helps them get an idea of what the product is. Then they are asked to select out adjectives they would like to use to describe such a product. They can also add other words they want to use which are not in the list. In the second page general product structures of VAWT and HAWT are shown on the left.(Figure 3.1) Profile drawings of existing wind turbines are on the right to indicate which component is which, in case that some responders may not know the terminologies in wind turbines. Responders are asked to answer how important each component is contributing to the whole product's aesthetics.

In the second section, another online questionnaire survey is conducted. The questionnaire can be found in appendix B. Base on the result of the previous one, 10 pairs of adjectives are selected. Twelve representative products are carefully selected to evaluate their semantic differential scales.(Figure 3.2) Trying to present the entire appearance of each product, two different pictures of each product are given. In the following questions, they are asked to assess their opinion about the visual appearances of the products. With 10 pairs of bipolar

Figure 3.2

words, the responders mark his or her opinion on seven-step scale respectively.

Some experts consider ordinal estimation scale with single descriptive word is better than semantic differential scale with contradictive adjectives on each end. The reason is that certain words do not have a natural antonym, and that some words may have several antonyms since they may have several meanings.[17] However, in this case bipolar adjectives are prepared on purpose to limit responders' divergent interpretations of the adjectives. For example, 'functional' - 'ornamental' is used in the survey. If only a single descriptive word 'functional' is given with ordinal estimation scale from 'not at all' to 'extremely', the responders may have different references in their mind. One may think the contradictive side of 'functional' is 'ornamental', while another one may think it is 'unworkable'. As a result, 'not functional at all' could represent 'very ornamental' or 'very unworkable'. This will bring an incomparable result. In order to deal with this problem, bipolar adjectives are selected to provide simpler 'linear' scales.

After the result of the surveys are collected. A few interviews are done trying to find out how the shape influence their opinions.

3.3 Findings

3.3.1 The First section

For the first section, there are 28 valid questionnaires taken back. The result of first part can be seen in appendix C. The chart in the next page shows the result of first part visually.

To describe the urban wind turbine, trendy - classic, fragile - robust, and high-tech - low-tech are the most selected bipolar adjectives. More than 15 responders chose these three pairs of words. They are followed by 7 pairs of words: expensive - cheap, outstanding - common, elegant - graceless, functional - ornamental, energetic - unenergetic, dynamic - static, attractive - unattractive. 12 to 14 responders selected these 7 pairs. Decorated - simple and strong - weak are selected by 10 people respectively. It is however noticeable that the following adjectives are seldom considered appropriate to describe such a product: formal - informal, humorous - serious, mature - youthful, restrained - extravagant, clever - silly, narcissistic - humble.

Some responders suggest other adjectives, such as organic - geometric, figurative - abstract, moderate - sharp, scenery, modern, scientific, and biomimetic. Some of them are describing sensory attributes. Some are very personal, for example 'biomimetic' is suggested by a fan of biomimetics. These adjectives are not used for further research after consideration.

In the second part of first section, responders are asked to mark how important each component is, respecting contribution towards overall aesthetics. The result of this part can be found in appendix D.

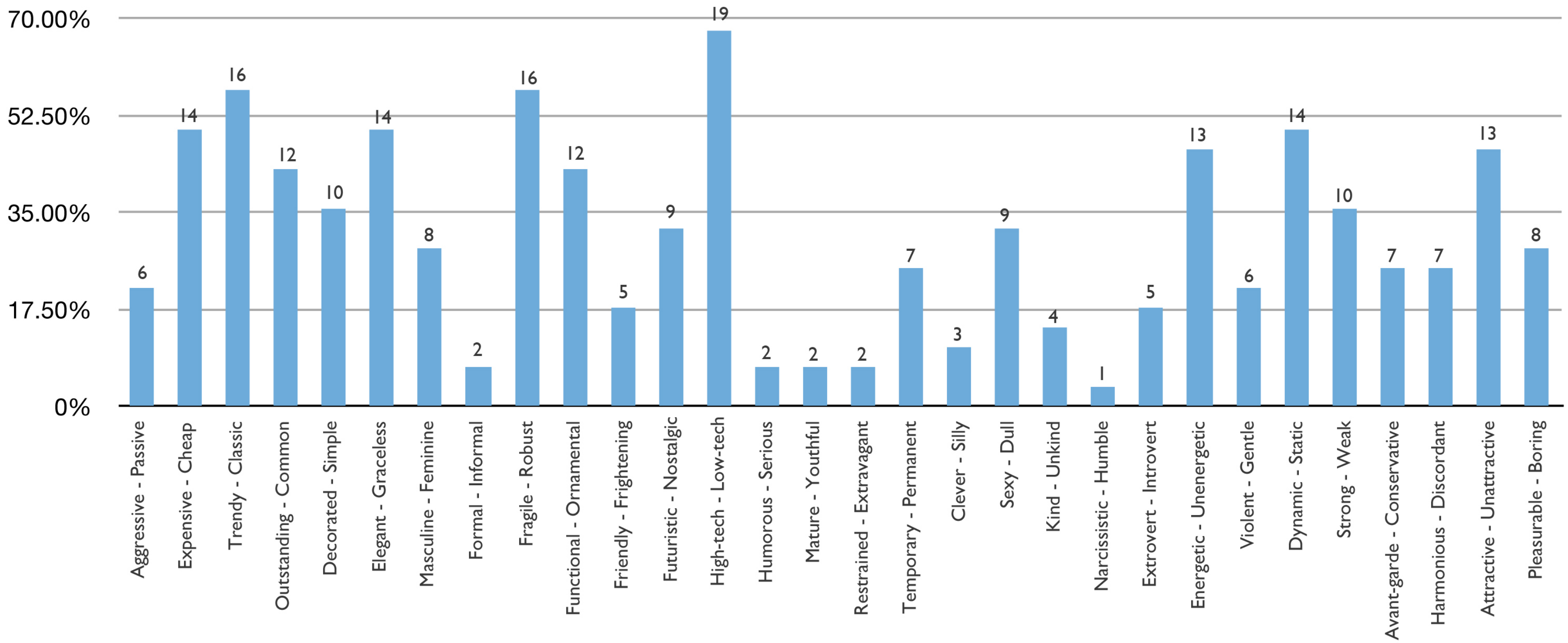


Figure 3.3

For horizontal axis wind turbines, the rotor is rated as the most important component, which has an average score of 6.5. It is followed by tower / pole, nose cone and nacelle, which has 4.89, 4.57 and 4.14 respectively. The tail vane is considered as not so important with an average score of 3.68.

For vertical axis wind turbines, the rotor is also much more important than the rest components. It is rated with the average score of 6.14. It is followed by shaft, tower / pole and generator, which had 4.82, 4.53 and 4.46 respectively. Besides rotor, the rest components are almost equally important.

3.3.2 The Second section

For the second section, there are 35 valid questionnaires taken back. The result of semantic differential analysis can be found in appendix E. It is visualized into line chart in figure 3.4.

In the line chart, it can be directed perceived that which wind turbine is evaluated as the most 'elegant' or 'fragile'. The UWT 2 and UWT 12 look more expensive than the rest. Together with UWT 11, they are also considered to be more trendy, elegant, attractive and outstanding. UWT 11 is the most fragile. UWT 2 and UWT 12 also have the most high-tech looking. UWT 1 and UWT 3 are evaluated as classic and common. UWT 8 is the most graceless and robust turbine.

There are much more informations can be drawn out from the line chart. However, it is very complicated and indirect to link the product appearances to the semantic scales. In order to make the relation between appearances and semantic scales more explicit, 12 UWT products are mapped onto five X-Y axes graphs. (Appendix F) 10 pairs of adjectives are represented on the axes of graphs. They are paired intentionally, on the presumption that some of them have a link with other ones. For instance, it is assumed that 'outstanding - common' has a link with 'attractive - unattractive'. So these two scales are made into one graph as shown in figure 3.5.

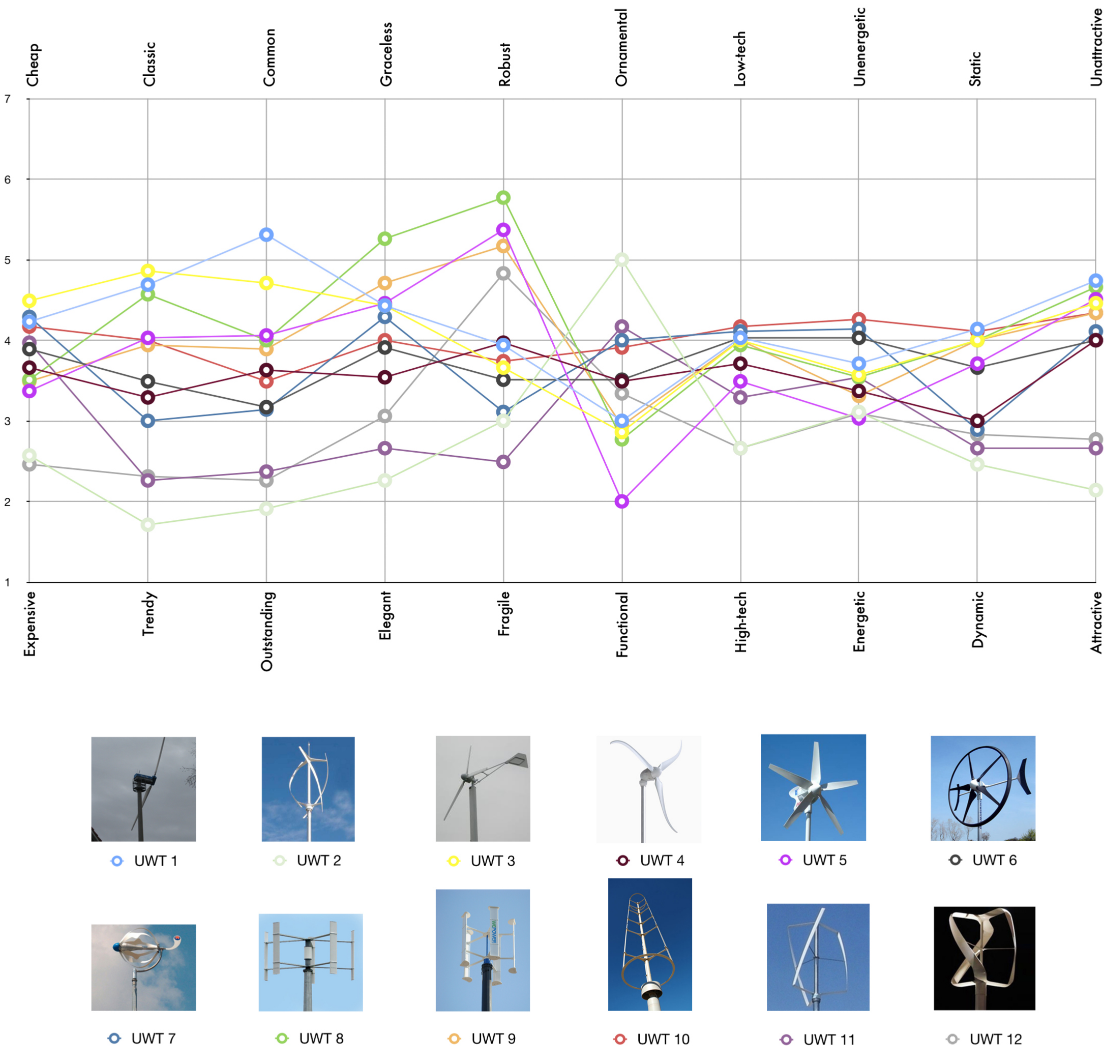


Figure 3.4

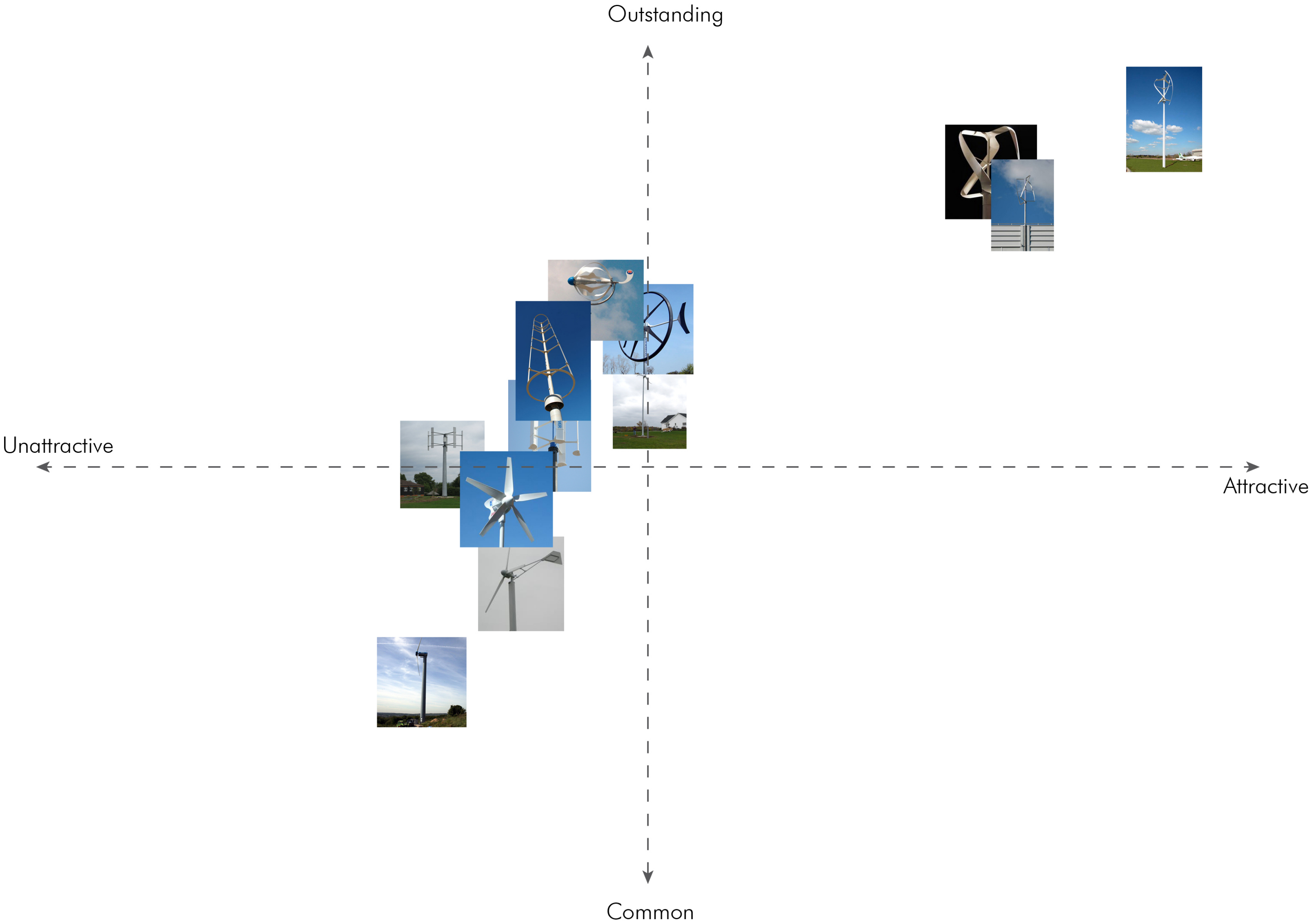


Figure 3.5

The X-Y axes graphs is a more direct visual way to gain a better understanding of relative differences between products. It also provides an overview of each product's position in semantic scales. With careful analysis, how the product appearances influence the semantic quality could be drawn out of the graphs. The result of this analysis will be concluded in the conclusion of this chapter.

A few short interviews are made after the survey. There are some interesting quotes from the responders as follows.

Ma Kezheng: "I rated the strange shapes higher than normal ones."

Wang Xiaowei: "The blades of Turby are too thin, it looks dangerous. It makes me feel nervous. It also looks doesn't generate much electricity."..."the more it does not look like a wind turbine, the cooler it is!"

Xu Ruoyun: "I like the five blades with round frame, the tail vane looks like a fish tail."

Qiu Ye: "I like the vertical one with long straight blades, it reminds me my favorite food shashlik."

3.4 Discussions

The findings provide valuable information for understanding people's view of wind turbines' appearance. Some of them are different from mine, which makes this analysis very valuable. The 'Energy Ball' is not rated as high as I expected. I rate it higher because it is an innovative product, while responders only rate it base on the appearance. It is important to keep in mind that innovation doesn't automatically lead to a better acceptance.

In the part of rating the visual importance of different components, the result is almost same as expected. It gives a convincing reference. However, the results are limited to the existing product structures. The result can be seen as a reference to some degree, but it should not be a critical principal for the design in this project. Because during the design, it is possible to create a new structure. In some case, a very well designed component can contribute a lot towards the whole product impression. One responder in the second survey rates attractiveness of UWT 6 very high, because she likes the tail vane. The tail vane here has a very important contribution towards the overall appearance.

In second section of the research, different UWT with very different shapes are selected. These chosen UWT can represent almost all the products' forms in the market. They are evaluated with selected adjectives by responders. As semantics interpretation is quite subjective, the result could only reveal relative relations instead of absolute values. The five X-Y axes graphs are made to show the result of semantic differential analysis more directly. With these graphs, how the shapes cause different semantic feelings can be seen. Some guidelines of form design are drawn out from these graphs, with help from interviews.

A limitation of this research should be mentioned. In both questionnaire surveys, most of the responders are young people. Although the responders group is limited, it is believed that the survey results can represent common sense in general.

3.5 Conclusion

The semantic analysis of existing urban wind turbines helps the designer to understand how people appreciate different shapes of turbines. It provides not only the guidelines for form design, also inspirations for idea generation.

The results of semantic analysis indicates that with the same airfoil (same technology), turbines can be designed into different forms, hence different visual impressions. The rotor design has the biggest influence on the wind turbine's appearance. It could be the main design focus in the later phase, but other components should not be overlooked. When a single component is very well designed, it can have a very big positive influence on the overall feeling. ('Fish tail' metaphor)

Together with the interviews with some responders, the five X-Y axis semantic graphs are analyzed to understand how forms influence visual appreciation. Some guidelines are drawn for the later UWT design in this project:

- Stand geometric frames or structures of blades design gives a 'static' feeling.

- Properly designed curved blades make the product look more elegant / dynamic / attractive, compared to straight ones in VAWT.

- Width and thickness of VAWT blades influence the elegance and robustness of the product. Too thin blades design leads to a fragile feeling, while too thick blades results in a robust impression. Thin blades make the turbine look more fragile and breakable. It also makes people feel tense when see it. Very thick blades create an impression of inelegance.

- 'Strange' forms are somehow more appreciated, as some responders in the survey preferred to rate 'strange' turbines higher.

- 'Metaphor' plays an important role in product visual evaluation. It creates meanings for perceivers.

4. Contextual Research

The terminology ‘context’ describes the environment of the human-product interaction. Human-product interaction is defined as the way people use, understand, and experience the product. [18] The human-product interaction is highly influenced by the specific context in which the product is used or perceived.

In this project the goal is to increase people’s acceptance of urban wind turbines. The quality of human-product interaction directly influences people’s attitude towards certain products. In order to design a product with better interaction, it is necessary to investigate the context of the new wind turbines. Coastal area of Scheveningen was chosen to be the environment to design for. In this phase, the context of Scheveningen and people’s experiences in the context will be looked into. Furthermore, the optimal locations, from engineering perspective, will be selected out by a field study. The result will help me gain deeper insight into the needs and dreams of prospective users / perceivers of new products. It will also be informative and inspiring for idea generation.

4.1 Objectives

The purpose of conducting a context research in this project is threefold:

I) To get an overall image of Scheveningen coastal area.

Physical circumstances create certain ambience with their appearances and inherent characteristics. The feelings and understandings of the designed products will be highly influenced by the ambience. For instance, a ‘ZEN’ design will be very outstanding with a peaceful and empty background, but it will be overwhelmed in a complex surrounding.

Scheveningen is a famous seaside resort, which has its own history and future plan. Probably there is already some visions and plans for development of this place from local government or city planners. Product design is always designing for the 'future' as the development takes time. When the product is launched, the environment might already change. Making a study of Scheveningen aims to get an overall image of the environment, and get to know the 'real' future environment for the design. At the same time, it can also provides inspirations for idea generation.

II) To gain insight into people's experience and desire in the context.

Working in an office has a relatively serious feeling, while watching a sports game in a stadium gives an exciting and energetic mood. To some degree, the basic experiences are already set when people are doing activities in different environment. With these different experiences, they will perceive and interpret a product differently. For instance, a water bottle normally stands on a desk quietly just as a container in office, but it could be waved and hit for cheering players in the stadium.

Looking into the experience of people in the existing context helps designer gain empathy with the users / perceivers and understand their real needs and dreams for a new product.

In this project, people's experience in current context of Scheveningen will be looked into. What do they do and what kind of experience do they want will be discussed. Requirements concerning people's experience for the new product will be concluded. Base on the findings, new visions of interaction between the wind turbines and people in the context of Scheveningen will be developed for further design phase.

III) To find the optimal locations for setting up urban wind turbines.

Picking the right place with good wind regime is crucial for wind turbines. The wind is influenced by natural landscape as well as artificial objects. In the coastal area of Scheveningen, there are a lot of buildings and human-made objects, which results in different wind regimes in different places. Choosing the right places is the basic need for showing the aerodynamics knowledge.

The selected locations will also provide very valuable informations and inspirations. It helps to determine who are the most important stakeholders for product development, and where would be the specific location the wind turbine could be seen and interacted with.

4.2 Method

I) The internet is the main source for studying the development of Scheveningen coastal area. Informations about the history, current image and future plan are collected.

'Collecting' artefacts and local objects by photography is used as a complement to online research. A photo collection of the buildings, public furnitures, and other objects in the environment is made. These photos are sorted according to the objects' styles and functions. They are briefly analyzed to get an impression of current view of Scheveningen coastal area.

II) To investigate people's experience in the coastal area, passive observation is the main method used.

People in different parts of Scheveningen are observed. Photos are taken to capture what they do, how they do it. During the observation, notes are taken for later interpretation and analysis. Though 'Notes taking' is a very individual activity, it is one of the important links between the field experience and how one later interprets that experience [19].

With the notes, collected photos are sorted to understand people's experience in that context. An attempt is made to dig deeper to find out why people are doing those things and what do they really desire in the context of coastal area. In this discussion, online information is also used. Many people are discussing 'why do people like to go to the beach'. Some of their online conversations are quoted to help understand people's real desire.

III) In order to find the optimal locations with good wind regime, 'Google Map (Street View)' is used, together with field research.

With 'Google Map', the boundary of coastal area for this project is set. Some potential places are initially selected for further field research. However, 'Street View' could only reach where a car could reach. Because the 'View' is recorded by cameras in a car. Therefore, a field research is carried out as complement. The possible locations are recorded by a digital camera. The guidelines for optimal locations are:

- There is a good wind regime;
- It has a nice surrounding environment to show the urban wind turbine design;
- It doesn't downgrade people's experience in that area.

4.3 Results and Discussions

4.3.1 Overall image of Scheveningen coastal area

Overview
Scheveningen is one of the eight districts of The Hague, as well as a subdistrict of that city. Scheveningen is a modern seaside resort with a long beach, a boulevard, a pier, etc. It has one of the most popular beach in Netherlands for tourism and water sports. A nudist section is 1 km to the north. The harbor in the south part is used for both fishing and tourism. [20]

History
In the 16th century Scheveningen was a small fishing village with less then 900 inhabitants. Fishing was the main source of food and income for them. In 1470, a heavy storm destroyed the church and half the houses. The village was again hit by storms in 1570, 1775, 1825, 1860, 1881 and 1894. After this last storm, the villagers decided to build a harbor.

In 1665, the Scheveningen Road was build. Since then, the beach became accessible to the inhabitants of The Hague. Scheveningen slowly became more busy with tourists. In 1818, Jacob Pronk, born and raised in Scheveningen, constructed a wooden building on a dune

Figure 4.1Het Strand van Scheveningen, Adriaen van de Velde (1658) [22]

Figure 4.2 Scheveningen between 1890 and 1905 [23]

near the sea, from where people could bathe from four separate rooms. This was the very first beach house, which was also the beginning of the famous Kurhaus Hotel.

The Pier and the Kurhaus hotel are the remarkable landmarks for Scheveningen. In 1886, a destructive fire destroyed the old Kurhaus Hotel. They decided to rebuild the hotel and include an impressive Pier along with it. After some years, the Pier and Hotel was destroyed again by a big fire. A new design of the Pier and Kurhaus Hotel was made and rebuild several years later.

In the 19th century tourism became the number one source of income rather than fishing. By the end of the 19th century the fishery of Scheveningen almost came to an end since not many young people followed in their fathers footsteps in becoming a fisherman. Instead, hotel after hotel popped up in this region. Scheveningen became a popular holiday destination. [20] [21]

Current

Nowadays, the beaches in Scheveningen are one of the most popular once amongst the Dutch coast. The beach can be divided into four main parts: boulevard, harbor, Northern beach and nude beach. All four beach parts have there own unique characteristics and visitors.

The “Boulevard beach” in Scheveningen is best known by tourists and Dutch people. Famous tourist attractions are the Kurhaus hotel, the Pier

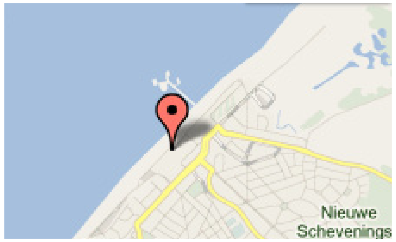


Figure 4.3 Location of Boulevard beach

Figure 4.4 Location of Harbor beach

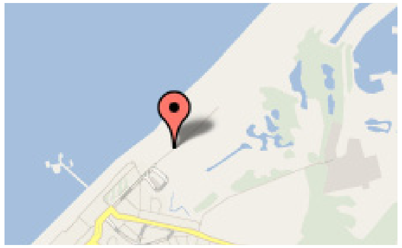


Figure 4.5 Location of Northern beach

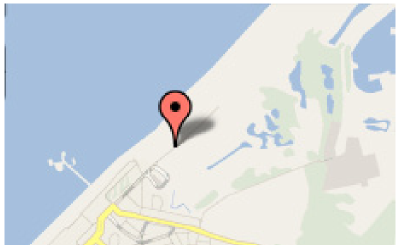


Figure 4.6 Location of Nude beach

and the boulevard can be found here. The many restaurants and beach clubs make this beach very alive and well visited. This part of beach is very easily accessible by public transportation. Almost all the trams and busses stop within 5 minutes walking distance. With many tourism attractions and easy accessibility, this area has the most visitors. It can get very crowded during weekends or in the summer. There are many temporary clubs on the beach in summer, which will be gone in winter days. In winter it is more peaceful. [25]

The “Harbor beach”, close by the Scheveningen harbor, is on the southern side of the beach. No hurdles of tourists here. People seem to be a bit more relaxed and easy going. Because of the good waves, it is very popular amongst surfers and water sport fans. During the summer months there is the Hommerson beach volleyball stadium for competitions every day. Tourists can stroll on the water breakers, where they can enjoy the view of the entire beach. [26]

The “Northern beach” is the hippest and trendiest part of the Scheveningen beach in summer. The atmosphere is very relaxed, casual and friendly. The biggest crowds of tourist are usually not found here. This is the place for beach parties. During the day people can relax on one of the lounge sofas and enjoy a nice cool drink. During the night there will be many parties organized by the beach clubs. During the winter months this is a popular part for a good beach walk, along the water or through the dunes. There is also a war bunker, preserved from the Second World War, for visiting. [27]

The “Nude beach” of Scheveningen is one of the oldest nude beaches of Holland. It is located in the very northern part of Scheveningen beach. The area is marked with clear signs indicating that nudist recreation is allowed. There are also two beach clubs located on the nude beach. This part of the beach has an atmosphere of serenity and peace. [28]

The beach is one big playground for children. It is especially mentioned on Tourist Information website of Scheveningen. [29] It was also proved by the field study I made. There are plenty of fun activities for children in Scheveningen.

Figure 4.7 Trampoline jumping

Figure 4.8 Signs on beach

Figure 4.9 'Fairy tale pictures to sea' [34]

The Hommerson play hall in the shopping mall Palace Promenade is open though the whole year. In the large playroom all different kinds of games and slot machines for children can be found. [30] There is a Sea Life aquarium where children can discover the under water world. More than 5 different aquariums with all types of sea life can be visited. There are exhibitions from time to time with different themes. [31] The Trampoline jumping next to the Pier is one of the favourite activities for the kids, which is only there during summer. (Figure 4.7) There is two options: a normal or bungee trampoline. [32] During the field study, it was easy to find that many children are having fun with it.

With collected photos, it is easy to notice that some public objects in Scheveningen were designed with children's taste. For instance, the row of signs standing on the beach have cartoon graphics on them. (Figure 4.8) The Tom Otterness sculpture design - 'Fairy tale pictures to sea' (Figure 4.9), currently moved due to the renovation, was designed in particular for children to enjoy. [33]


Figure 4.10 Different street lamps in Scheveningen

The photo collection of the buildings, public furniture, and other objects was sorted and briefly analysed to get an impression of current view of Scheveningen coastal area. It is found that Scheveningen had eclectic styles of artefacts in current environment. For example, there are more than eight types of street lamps. (Figure 4.10) Some of their forms are little more decorative, while others are quite simple and functional. It is also similar to other public objects like the benches and trash bins.

The temporary restaurants and bars along the beach compose a big part of the environment in summer. Some of them are 'themed restaurants', like Indian restaurants, Indonesian restaurants. To communicate their themes, the buildings are made into some specific styles individually. They all contribute to the variety of styles in Scheveningen. The eclectic styles might be a reflection of local government's vision of the city and the beach. 'By the end of 2020, the Hague will be known for its multi- cultural inhabitants.... Scheveningen is unique for its variety in coast line....' [35]

Future Plan

A large part of the Netherlands is located below sea level and is therefore at constant risk of flooding. Dunes, dykes and other water works along its coastline ensure that the Netherlands remains a safe place to live. However, due to the changing climate, certain places on the coast will no longer be capable to deal with extreme weather conditions. Therefore the Dutch government is reinforcing these 'weak links'. The coast of Scheveningen is one of them. A new dyke is being constructed and the beach has been widened. Combined with the coastal reinforcement, the Municipality of the Hague planed a complete makeover of the resort. [36]

With Scheveningen and Kijkduin (another beach in the Hague), the government wants to make the Hague 'The world city by sea'. A huge renovation project was planed to develop Scheveningen further. The aim is to make Scheveningen a bustling seaside resort, but safer and even more attractive than before in 2013.

Figure 4.11 Renewed harbor [35]

Figure 4.12 The future plan of Pier [35]

The harbor of Scheveningen will be divided into two parts. The existing harbor will be transformed into a portal for the fishery, the sailing ships and recreational ships. (Figure 4.11) The new part will become a multifunctional cruise terminal, with the name ‘Port of Holland’. A proposal of new design of the Pier was made. (Figure 4.12) But it is now under discussion whether to renovate it. The boulevard will be completely renovated.

The new boulevard in Scheveningen was designed by Spanish architect Manuel De Solà-Morales. It will be both safe and attractive. [37] The scheme of the new boulevard can found in Appendix G. Currently, Scheveningen beach is undergoing the major renovation. It started in 2009. The construction is scheduled to finish early 2012 giving Scheveningen a complete new image. [35]

The beach is being widened to diminish the power of the waves. Consequently, there is no need for the dyke to be so high. The new dyke is 1 kilometre long and 12 metres above Amsterdam Ordnance Datum. However, not much of it will be visible: most of it is designed to be integrated under the new boulevard. Following the original undulating course of the dunes, the boulevard merges naturally into its surroundings. Its different height levels separate cars, bicycles and pedestrians. It creates a relaxing and safe environment in which to take a stroll or bicycle ride with a wonderful view over the sea. Wide steps all along the boulevard provide easy access to the different levels. The Keizerstraat will have an imposing gateway to the beach. Natural stone, paving bricks, bands of green space and shell asphalt provide high quality appeal. Lovely

Figure 4.13 New boulevard [38]

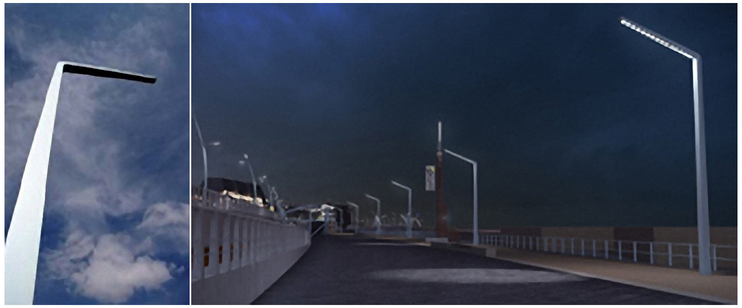


Figure 4.14 New Street lamp design AZO [22]

Figure 4.15 Public bench on new boulevard

benches and atmospheric lighting give the boulevard its wonderful ambiance in the evening. [37] Figure 4.13 shows several rendered images of the new design of boulevard.

Sustainability is also a concern in the beach area development. The street lamps on the new boulevard is a good example. They take advantage of technology of LED, which is environmentally friendly. Uniquely, the degree and angle of illumination can be controlled remotely. There are two different types of light poles used on the boulevard. At the lower part of the boulevard is a completely new model of lamppost, pole type AZO. On the upper part of the boulevard, along the road, are the more familiar light masts of Philips. Figure 4.14 shows rendered images of street lamp on boulevard. [39]

A series of public benches were designed for the new boulevard Scheveningen by architect Solá-Morales. The benches comes in 3 different sizes: 3 meters wide, 1.5 meters wide, 0.75 meters wide. One of them (1.5 meters) is shown in Figure 4.15. The legs of the bench are made of aluminium and the seat of solid wood. The fresh, light blue colour with the warm glow of the wood soon fit perfectly with the light coloured, new boulevard. The bench has a fun shape by combining a rugged, functional form and the free, round circles in the back. [40]

4.3.2 People's experience in Scheveningen

Focus of experience study

There are different groups of people in Scheveningen. They can be mainly divided into local habitants, tourists and workers. All of them are stakeholders of the urban wind turbines in this project. All of them will be taken into account during product development. Due to the time limit, it is impossible to take in them all for experience study. Choices are necessary to be made according to the priorities.

In the technology study, it was already known that there are some requirements for choosing a location for an urban wind turbine. Because of the inherent feature of this product, it needs good wind regime. An open area without obstacles or somewhere high in the air will be preferred. It was assumed that there would be two kinds of places suitable for wind turbines in Scheveningen: some open areas and some builds' roofs. This assumption is also proved, in the next section, by the field study for selecting the optimal locations. There are a few roof tops of residential buildings very suitable for setting up wind turbines. However, it will be very difficult to get all the residents' agreement in the buildings. For the sake of this practical reason in the future, these residential buildings will not be considered in this project. Roof tops of some individual buildings with fewer or even single party involved will be possible options, e.g. hotels. Another possible kind of locations are open areas, which have no obstacles near by. It means there should not be buildings, including residential buildings, near the wind turbines in this case. So the wind turbine will be a little far away from where people live.

Most of the 'workers' in Scheveningen normally have their fixed areas to work as bar tenders, waiters or others. The final designed wind turbines will stand in somewhere as a landmark. There will be only a small group of workers having close relation to the product.

The context of this project Scheveningen is a popular holiday destination throughout its history. With government's vision and renovation plan, "In 2013 Scheveningen will still be a bustling seaside resort, but safer and even more attractive than before. A resort worth visiting in all seasons! "[38] As a beach resort, tourists are the major group of people in the context. Their experiences are supposed to be primarily considered. Compared to others, tourists are more mobile. When there is an attraction in a resort, tourists are likely to have more interaction with it.

With considerations above, the experience of tourists will be specially studied in this section. The reasons are simply concluded as follows. With the potential locations, the wind turbine will not have a very big 'forcing' influence on local habitants' daily life. It will not have much interaction with habitants either, if they do not want to. When they are 'experiencing' this product on the beach, they could also be considered as tourists. For workers, only a small group of them have connection with the product. By comparison, tourists will be the major group, who could have much interaction with such a landmark product.

The tourists will also be the main group involved in developing the interaction and experience of the new design. Nevertheless, to be mentioned, local habitants and workers will be taken into account during design to some degree.

Tourists' experiences in Scheveningen

The following part is the research result of the experiences of tourists in Scheveningen. It includes 'what they see', 'what they do' and 'what they feel'. It is followed by a discuss to gain an insight into their real desire in this context.

What can people see in Scheveningen

Besides the beach and beautiful view over the North Sea, Scheveningen has a lot of interesting attractions for young and old. Along the boulevard, tourists can see many different restaurants, bars and shops, or sit on one of the benches and enjoy the beautiful view over the North Sea. The harbor is also one of the most visited attractions. There is a Museumship Mercuur. The former marine ship lies in the harbour of Scheveningen and welcomes everybody to come and take a look. Every morning the fresh caught fish gets auctioned in the visafslag. The light house on the jetty can be seen from everywhere in Scheveningen. In the Sealife aquarium, tourists can enjoy amazing under water world. The Kurhaus hotel and Pier are also 'must see' attractions. Luxury and history come together in this world famous hotel. On the Pier you can enjoy a very nice view of the sea. [41]

What can people do in Scheveningen

There are many fun activities to do in Scheveningen throughout the year. Along the beach people can enjoy shopping in the excellent shopping areas. In Scheveningen there are plenty of nice trails for hiking. People can also bike around relaxedly. Scheveningen has many different water sports to offer. Surfing, fishing, sailing, to name a few. Bungee jumping is located on the building at end of Pier, for adventurous experience. Making a cruise along the shore line will give a beautiful view as well as special experience. [42] Riding school the Fjorden paard offers horse riding trips for beginners and more advanced riders. The different routes lead you to the most beautiful spots Scheveningen has to offer. During the summer months it is possible to make a ride twice a week, in the winter only once a week. [43] There are a lot of activities for kids to do, which are already mentioned in previous part of this report. In summer you can also enjoy a ride over the boulevard with the train. From March until September there are many beach clubs for you to enjoy a bite to eat and/or a drink. [44]

What can people feel in Scheveningen

This part is the result of passive field observation and interpretation. With photos and notes recording the observation, I tried to understand their feelings in that context both simultaneously with observation and afterwards. Briefly, in Scheveningen tourists have the feeling of Relaxing & Releasing, Vivid & Energetic, Sporty, Being with companions. Why and how they have these feeling is explained as follows.

A. Relaxing & Releasing

The beach has a quite relaxing ambience. When it is a nice weather, lots of people come to the beach for relaxation. They walk, play games, take a sun bath on the beach, play in water, or do beach sports. They bare their feet, take off clothes. It is out of daily routine work. Even those people who works there are in a relaxing mood.

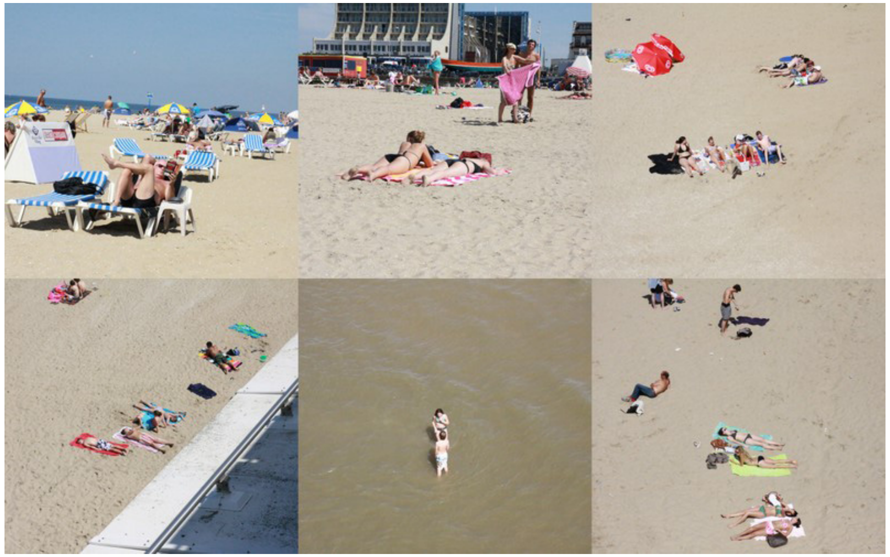


Figure 4.16 Relaxing & Releasing

Figure 4.17 Vivid & Energetic

Figure 4.18 Being with companions

The major group are there to enjoy the sunshine. They lie or sit on blankets or chairs on the sand. Some of them lie under covers, which create pieces of shadows for their heads and up bodies. There is a row of cartoon signs (Figure 4.16 Signs on beach) and trash bins on the beach. There are almost no people lying in the thin shadows of the poles, and few of them lying close to those trash bins. It seems that they prefer a more open area without anything disturbing.

B. Vivid & Energetic
Unlike some tranquil beaches, Scheveningen gives an impression of vivid and energetic.

There are many children brought by parents on the beach. They do not stay quietly enjoying the sunshine like some adults. Instead they run into the water, build sand sculpture, play with peers. Some facilities are there specially for children play, e.g. merry-go-round and wire-trampoline (Figure 4.17 Vivid & Energetic). In additional, some young people are playing active games and sports. Sometimes they also act like children.

There are a lot of sea gulls. They also contribute to make it a very vivid and lively environment.

C. Sporty
Different sports can be found in Scheveningen. It is interesting to find that people do different sports in different parts of the beach.

In the northern part in front of the dunes, there are many sailing boats. In the centre of the beach, where is more busy with lots of people, beach soccer can be found very often. When it comes to south area close to the harbor, there are more people doing surfing in the sea. On the sand near jetty of the harbor, in front of the dike, it is an area for beach volleyball. On the jetty of the harbor, there are a lot of people fishing. All these sports items and relevant facilities make the beach feel sporty.

D. Being with companions
It is seldom that people are on the beach alone, without companions. Obviously they prefer to enjoy good time with friends or families.(Figure 4.18)

Discussion
The findings of experience study will be very valuable for later design phase. However, so far, these findings are still staying on the level of direct and explicit experience. To understand people in that context better, and gain deep empathy with products perceivers as a designer, it is necessary to dig deeper with the findings. Having an idea of people's real desire is very helpful for designing a desirable interaction and experience with this product.

In this discussion, the main question is: 'why do people want and enjoy these experiences'; 'what are the implicit desires behind the experiences observed'?

First, the stepping back question 'why do people want to go to beach' is looked into. As Scheveningen is famous for its beach, and the beach is also the context for the urban wind turbine design. Beach has its own quality and inherent characteristics, e.g sand, sea, sun shine, which do not differ much between different beaches. So opinions for other beaches could also apply to Scheveningen. To find the major reasons of going to beach, online materials, such as forum, discussion board, are used to get many other people's ideas.

To give a brief impression of the informations collected online, the most striking and inspiring quotes are picked out as follows.

"It's like taking a day off from everything, no TV, internet, school, work."

"It's awesome. Get out of the house, swim in the waves."

"Just a nice escape for me...."

"Extremely scenic, something you don't get in the city... Fun place just to hang out & it makes people happy!"

"Even if I knew I was going to be the only human there, I would still go to the beach."

"It's a nice view at night. You cut light pollution roughly in half just by having the ocean in front of you, the air smells & feels nice."

"Walking on sand is relaxing, sitting in the water & feeling the waves is downright therapeutic."

"You are connecting with nature, beats a chlorinated pool any day, as long as the beach is nice."

"The feel/smell of the beach, the board walk, it's like a totally different atmosphere from everyday life."[45]

There are also a few people saying they go to the beach to hang out with friends. Some people go to get a tan, while some other people go for bikinis.

Reviewing their reasons of going to beach, it is interesting to find there are some dominant inmost desires. They want to 'escape' from everyday life. They want to experience some atmosphere different from the city. These two can be really implicit and original desires for people to go to relax on the beach. With looking back to the results of experience study, they can also be proved.

In Scheveningen, all the activities people can do are far away from their daily routine.(Here we mainly discuss about the tourists.) All the things they can see, e.g. Vast ocean, long beach, cannot be found in the city. People come to relax or do sports all by their interests, without any pressure. The feelings people experience in Scheveningen are also really different from a city life.

Spending too much time in the daily routine, most of the time stressed, people have the desire to escape from it. Scheveningen is a beach resort. A lot of people like to visit and spend time here. Because the experiences they have on the beach somehow can fulfill their desire of getting aways from everyday's life.

To conclude, 'escaping from daily routine' is one of the main inmost desire for going to beach. It also answers the questions 'why do people want and enjoy these experiences', 'what are the implicit desires behind the experiences observed'.

4.3.3 Optimal locations for UWT in Scheveningen

Netherlands has a rich wind source due to its geographical location. Figure 4.19 shows the wind map of Netherlands. The coastal line has the highest wind speed, whose anal mean speed is higher than 7 m/s. Figure 4.19 shows where Scheveningen is. It falls into the region with best wind power in the Netherlands.
With 'Google Map' and one day's field research, several possible places are selected. They are mainly in two categories: roof tops and public open areas. The 'busy' sand area of beach, where lots of people are enjoying the sunshine, is not considered to be suitable places. Because the rotating wind turbines might be a little disturbing for them.

The selected locations are indicated in the map of Figure 4.20, marked out by color pieces.

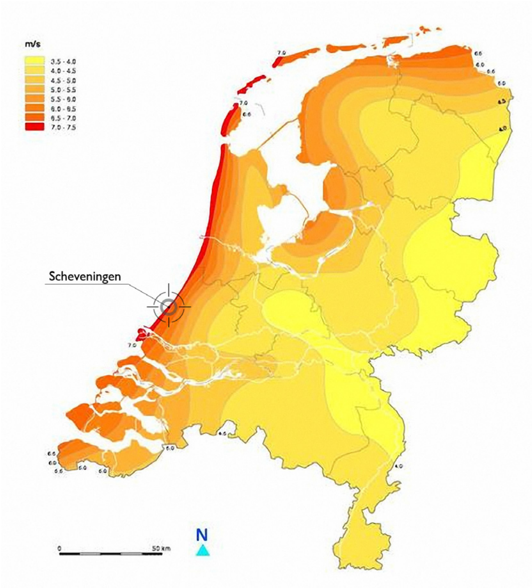


Figure 4.19 Wind map of Netherlands[29]

The green areas are open public places. From 1 to 4, they are the Jetty(1), the Dike(2), the Dunes(3) and the Viewing deck(4) respectively. The common feature for these places is very open and without any obstacles surrounding. Hence there will be a better wind regime for turbines.

The roof tops of two hotels are selected as potential locations. They are Carlton Hotel (5) and Strand Hotel (6). Both of them have a very 'clear' roof top, which is very suitable for wind turbines. To be mentioned, there are some residential buildings' roof tops very suitable for setting up wind turbines. But they are not considered. Because it would be very difficult

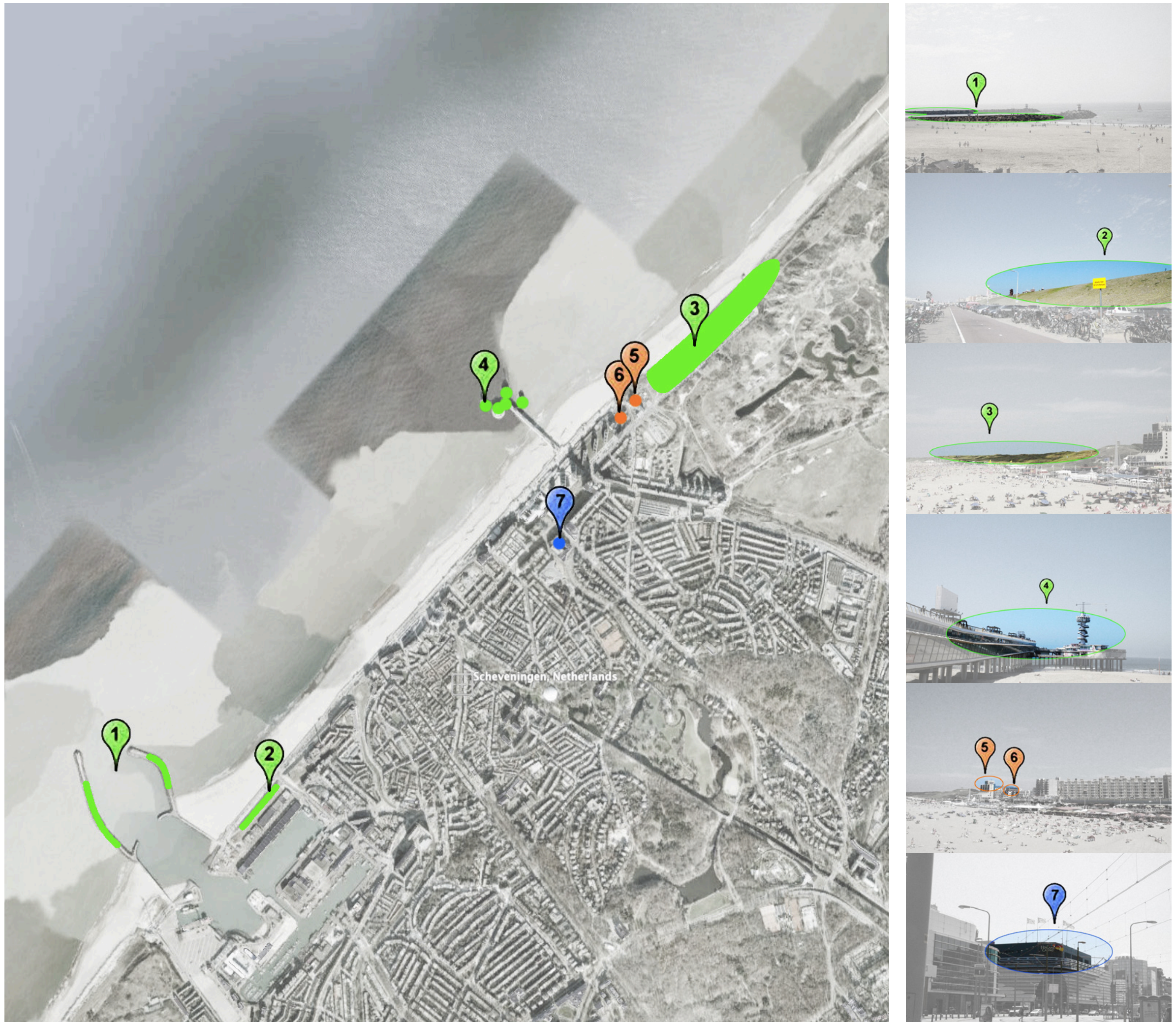


Figure 4.20 Possible locations

to persuade everyone in the building to have a wind turbine on the roof.

The roof of 'Holland Casino' (7) could be another place for building wind turbines. It is high and receives strong wind. The building is owned by a single party, which avoids complicated negotiation.

4.3.4 Final chosen location

During the context research, attempts are made to get into contact with some potential buyers.

Henry Terlouw, Coordinator Climate Change of The Hague, is contacted. He replies that in scheveningen, most of the areas are already planned. The only possibility might be the Pier, which is owned by Van der Valk Hotels & Restaurants. Dennis van Gulik, De Scheveningse Pier Vastgoed BV (The Pier of Scheveningen Real Estate), who mainly works with the Pier, is contacted. A meeting is arranged on the Pier on 18th of August.

In the meeting, some new informations

Figure 4.21 Pier

are gained for the project. The owner of the Pier, Van der Valk Hotels & Restaurants, is very interested in this project. They would like to provide the location for the designed wind turbines. However, the permit is the biggest problem in such a project.

Setting up wind turbines on the Pier needs to ask permit from Welstands commissie of Den Haag. It is difficult to get the permit. Donqi, an urban wind turbine company already failed. Donqi proposed a project to build four small wind turbine at the entrance of the Pier. It was rejected by the Welstands commissie. The reason was there were a lot of complaints from local people after the big LED screen was built besides the Pier, and they did not want to get more complaints.

There is no concrete regulative limitations for building new artefacts on the Pier from the government. As long as the Welstands commissie can be convinced, the new wind turbines can be built on the Pier.

There was proposal to renew the Pier with the new design, shown in Figuren 4.12 in previous chapter. But due to the financial problem, the complete renewal will not be realized in the near future. Only some minor renovations will be made.

After discussion with Oskar and Eric, the company mentor and manager, we agree to choose the Pier to be the location for the design. As a very practical project for Actiflow, the goal is to build the final design, and the Pier is an ideal place to show the design. The difficulty in setting up wind turbines on the Pier is the public acceptance, which is exactly the problem to be solved in this project. The strategy of the company now is to impress and convince the Welstands commissie with vision and results of this project. This commercial part is out of the scope of the project, which would be done by the company. This design project will still focus on the original goals-increasing public acceptance and showing Actiflow's ability, with a specific location the Pier.

4.4 Conclusion

The contextual research helps to get an overall image of Scheveningen coastal area, understand people's experiences and desire in that context, find the Pier to be the location for design.

From a historical point of view, Scheveningen has been a popular holiday destination for centuries. It will be developed into a more attractive beach resort in the future. A renovation project was planed and now is in execution. The boulevard will be renewed with Spanish architect Manuel De Solà-Morales' design. As product development takes at least a few years, the surroundings for the new design will actually be the renovated beach. The found designed scheme and rendered images show the change of the lanscape in the near future. On one hand, these informations help in location finding. Because it is clear to see whether the optimal locations would be changed. On the other hand, it provides the 'real' image of the environment for the designed wind turbines to fit into. When the turbine design come into a real product, the environment would not be as same as today. In addition, it gives inspirations for idea generation.

In people's experience research, the tourists are the main group to be studied. In Scheveningen they can see many attractions and do many activities. They have feelings of relaxing and releasing, vivid and energetic, sporty. They usually are there with companions. These experiences are desired by people in the context of Scheveningen. They should not be downgraded with the new turbine design. Some requirements for wind turbine design are be concluded base:

- People should not be disturbed by the product, as turbines might create flicker and noise.

- People should not get stressed because of the design. From semantic analysis, it was known very thin blades and high rotation speed could make perceivers nervous and stressed.

- The bird risk should be seriously considered during design. Because people do never want to see dead bodies of sea gulls when they are relaxing on the beach.

A discussion was made to find out their deeper desire in that context. It is found that the most common reason is 'escaping from daily routine'. This desire will be a key consideration in designing the interaction and experience of the new product in the next phase.

From technical view, 7 locations are selected as potential places for the product. Most of them have clean surroundings, which reduces problems to make the wind turbine stand out. Only the roof tops of 'Holland casino' and 'Strand Hotel' have a more complex surroundings. The physical landscape conditions of them will not change much in the renovation of Scheveningen. In the end, the Pier is chosen to be the specific location for the urban wind turbine design.

5. Design Goal

Before starting idea generation, a design goal brief is made, including the target group of the design assignment, requirements and guidelines from different aspects, and design vision to be achieved in design.

5.1 Target Group

The most important target group for this design is the tourists in Scheveningen.

The reason why they are chosen was explained in chapter 4 - People's experience in Scheveningen.

The experiences of tourists in Scheveningen were studied. They feel 'Relaxing & Releasing', 'Vivid & Energetic', 'Sporty' and 'Being with companions' in that context. A distinctive inmost desire of this group is 'escaping from daily routine'. They are not force to do anything.

The interaction vision of design will be developed mainly base on the experiences and desire of the tourists in Scheveningen.

5.2 Design requirements and guidelines

With reviewing the research done previously, requirements and guidelines for product design are concluded as follows.

5.2.1. Technical guidelines

- Lift driven system will be chosen in the turbine design instead of drag driven system, as it can better show Actiflow's ability in the field of aerodynamics.

- Lift driven wind turbine (both HAWT and VAWT) takes advantage of 'air foil'. In the lift driven turbine design, the profile of the blade has to be air foil shaped. During design, blade form can only be created with extruding the air foil section view in different ways.

- Both of HAWT and VAWT have the potential for further design in this project. Generally HAWT has better power efficiency, while VAWT cope better with urban wind regime.

- The bigger frontal area of turbine makes higher power output. This principle can be used in concepts evaluation and selection. Higher power output design is preferred in selection, to show Actiflow's engineering ability.

- The blade tip causes whooshing noise. The noise level increases with the tip speed. Principally thiner blades result in higher rotation speed, thus tip speed. 'Reducing' the tip by connecting them with continuous shape in design is a way to lower the aerodynamics noise.

- The rotation speed of rotor self starting ability can be controlled by external electrical system. So during design, it would not be extremely important to dig too deep into the relation between the 'rotation speed, self starting ability' and the 'shape of the blades'. The focus could still be the aesthetics rather than too much engineering aspects.

5.2.2 Aesthetic guidelines

- Stand geometric frames or structures of blades design give a 'static' feeling, which is not preferred by people. During design, when geometric shapes are used, there need to be more variety.

- The thickness of the blade should be in proportion to the size of the turbine. Too thin blades design leads to a fragile feeling, while too thick blades results in a robust impression. Thin blades make the turbine look more fragile and breakable. It also makes people feel tense when see it. Very thick blades create an impression of inelegance.

- 'Strange' forms are more attractive than the normal ones, which are same or similar as those ones already existing in people's mind.

- 'Metaphor' plays an important role in product visual evaluation. It creates meanings for perceivers. Getting inspiration from other natural or man made objects could be a good method for idea generation.

5.2.3 Requirements and Guidelines from Context research

Requirements

- The wind turbine should not disturb

people with flicker. Materials with low reflection glossiness will be used to reduce the flicker in this case.

- The product should not stress people with shapes or high rotation speed. The blades shape should not be too thin, the chord line of blade not shorter than 10 cm. The rotation speed needs to be controlled by external electrical system, up to 160 rpm, in usual wind speed (lower than 7 m/s).

- The bird risk should be seriously considered in design. It is better to make the product more visible. Some transparent materials should be avoided in this environment, as it will be not visible while rotating.

Guidelines
- People have different experience in Scheveningen. It is assumed that most of them have the common desire of getting away from daily life. This inmost desire should be captured for designing the interaction vision and experience of the wind turbine.

5.3 Design Vision

People live and dream through design. Designed artefacts help to create our subjective experience by acts of what Louis Althusser (1972) called ‘hailing’. These are acts of attracting attention(hailing), compelling individuals to generate meaning (interpretation) and behave in specific relation to designed artefacts......People consume and integrate designed artefacts into their lives through interaction (use and embodiment) and through their experience creates understanding. [30]

In this project, the goal is to increase the acceptance of urban wind turbines. The tourists in Scheveningen are chosen to be the main group to design for. Their interaction and experience with the new designed product would be very important to achieve this goal. As a result, the design vision mainly focuses on creating desirable interaction between these people and the product. Through the positive experience with this designed product, people will better accept wind turbines.

Normal consuming products have their interaction integrated in usage (function). For example, a shaver’s main function is shaving, where the interaction happens using this function. Design a new interaction for such products starts with some certain function, which is something ought to be in interaction design methods. However, unlike these products, the main function of urban wind turbines do not directly link to the ‘interaction’. An urban wind turbine’s function is generating electricity. This function is only used by the owner, who is not the main party for interaction design in this project. For the target group of this design, the interaction and experience do not lie in the main function. So the interaction should be designed with some other perspectives instead of starting from function or usage.

Considering ‘what interaction and experience could be achieved well’ by wind turbines in the context and the goal of this project, the vision of design is made. Scenario is used as a tool to visualize the interaction, experience. The vision is explained with scenarios in the following pages.

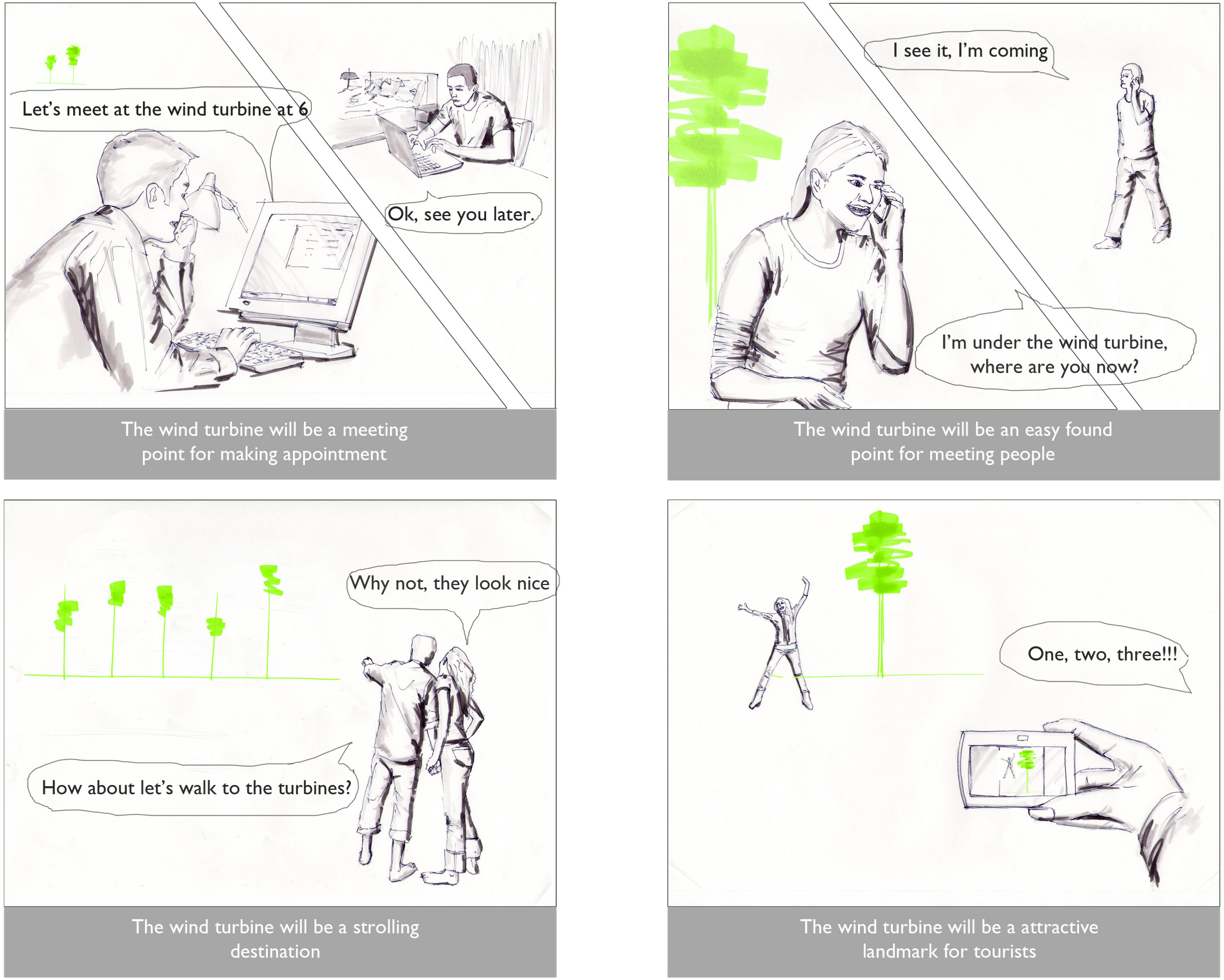
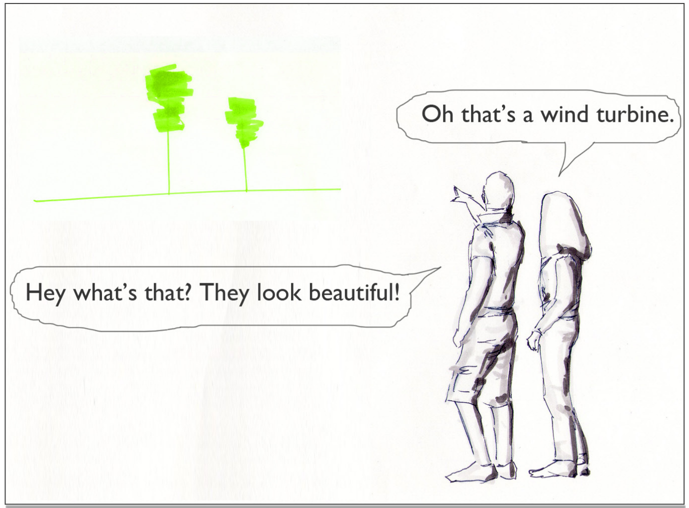


Figure 5.1 Scenario 1

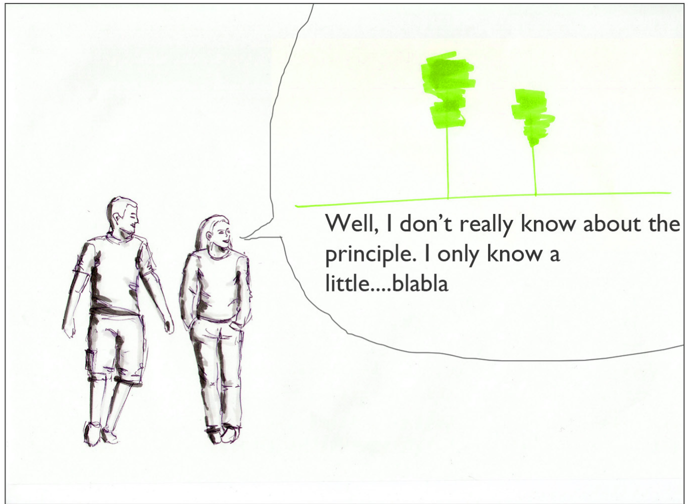
AS A LANDMARK

One of the goals of this project is to show ability of Actiflow. The wind turbines should be out standing and easily recognizable. When they are built on the Pier, it can be interacted as a landmark. It improves the quality of the surroundings. It can be a meeting place, a walking destination, even objects to take photo with, as the turbines are easy to notice, to find and attractive.

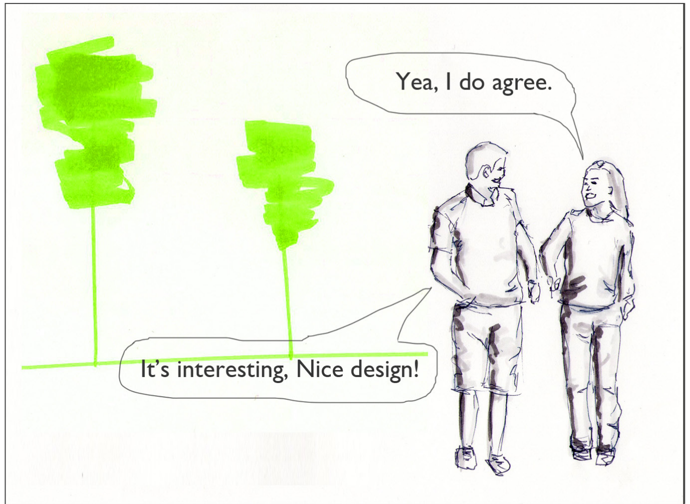


From far away, 'new' people in Scheveningen will be attracted by the wind turbine design

It will be an original design, people will be courious about what it is and how it works



Curiosity makes it interesting to understand this product, and get to know wind turbine

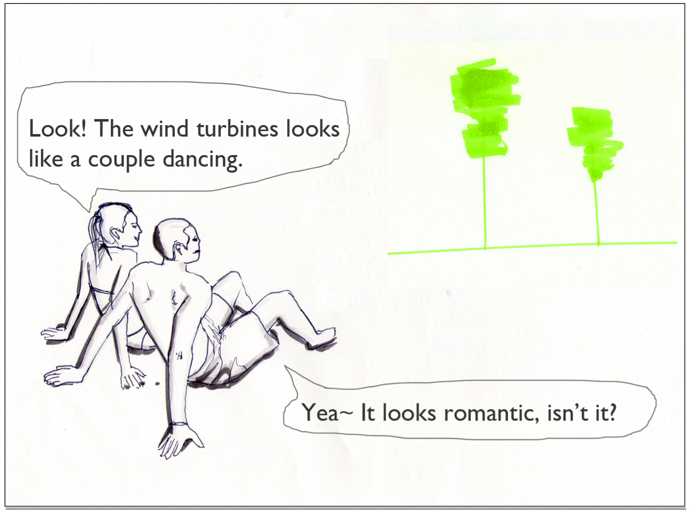


They will be impressed by the design

Figure 5.2 Scenario 2

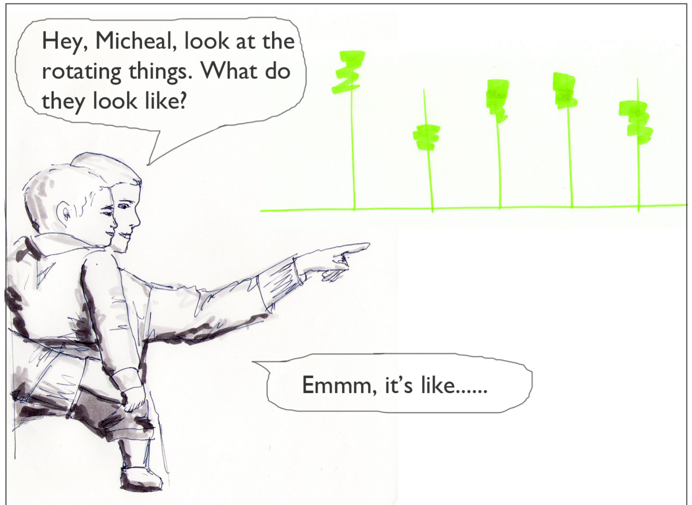
AROUSE CURIOSITY

As a way of showing ability of Actiflow, the new turbines will be a very original design in both engineering and design aspects. From semantic analysis, it is shown 'strange' (different) shapes from conventional turbines are preferred. In this project, the design aims to create an innovative wind turbine, which will be quite different from the existing urban wind turbines. People might not know what the object is when they first see it. It attracts them to come closer and to explore.

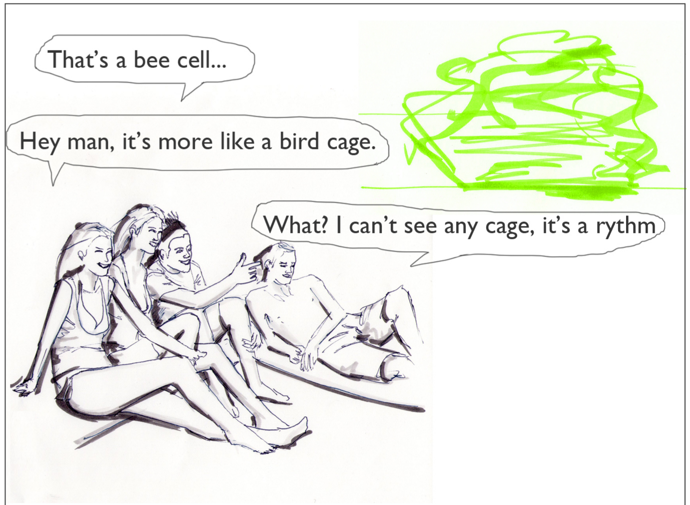


For different people, the design could make different meanings or them. For lovers, it might evoke their feel of romance

The design will be a triger of imagination



Adults can fansy and talk with children, which could be a way to enhance the relation



Inspiring for daydreaming, provide them a topic for conversation. Daydreaming makes them relax and out of daily life

Figure 5.3 Scenario 3

INSPIRING FOR DAYDEAMING

People come to beach with desire of getting away from the daily routine in the city. Relaxing is the general mood people have in Scheveningen. Relaxing does not mean doing nothing at all. There are many ways of relaxing, as long as you are not forced to do something. This vision is inspired by some people daydeaming with shapes of cloud in the sky. It is an interesting way of escape from city life, which could happen in the context of beach. The design of this project will be inspiring for imagination. When it is / they are rotating in the wind, it triggers people's daydeaming by itself. In the end people will accept and like this design.

6. Product Development

6.1 Divergent Idea generation

Urban wind turbines are products starting from technology. The form design is strictly limited by technical requirements. Before considering the interaction and design vision, there are already many limitations. In this divergent idea generation phase, it is preferred to get as many ideas or directions as possible. In this sense, it is better not to consider too much about the vision first.

The divergent idea generation starts only with the technology boundaries, some semantic guidelines, and inspiration from the context. During the idea generation, the mind map is used as an inspiring tool. The generated ideas are evaluated by different criteria from engineering perspective. Initial idea selection is made with help from experts in Actiflow in the end of this phase.

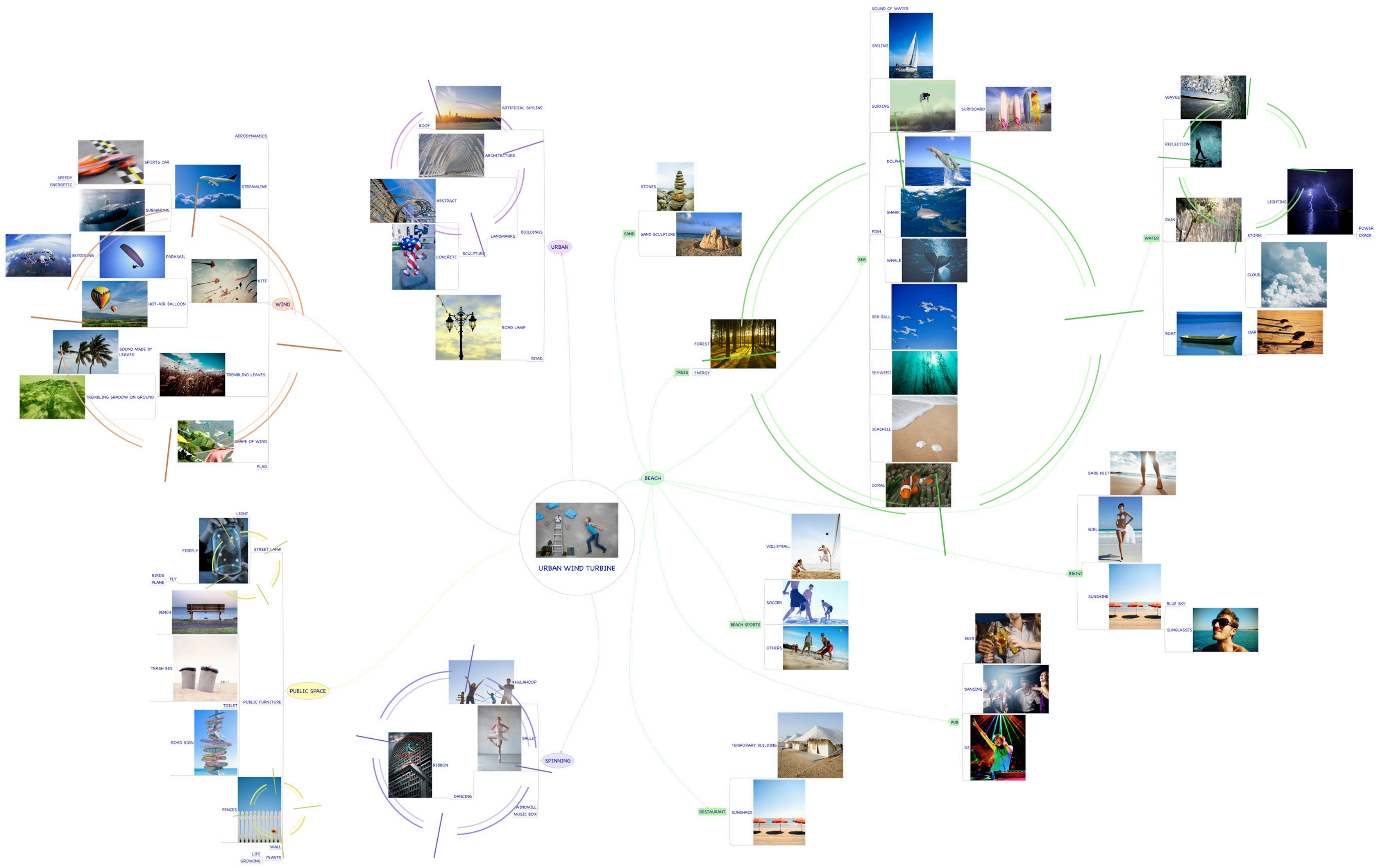


Figure 6.1 Mind Map

6.1.1 Mind Map

Mind map is a way of making notes, which combines visual and verbal thinking. A great advantage of Mind map is that it provide an overview, that it merge a variety of different types of information, and that it bring things in the open by giving them a place and form: you can point at parts of the map, and scribble notes on them. [31]

Before idea generation, a mind map is used to help get some inspirations. Figure 6.1 shows the mind map. Several areas are marked out with circles, as there are some inspiring elements which might be useful for idea generation.

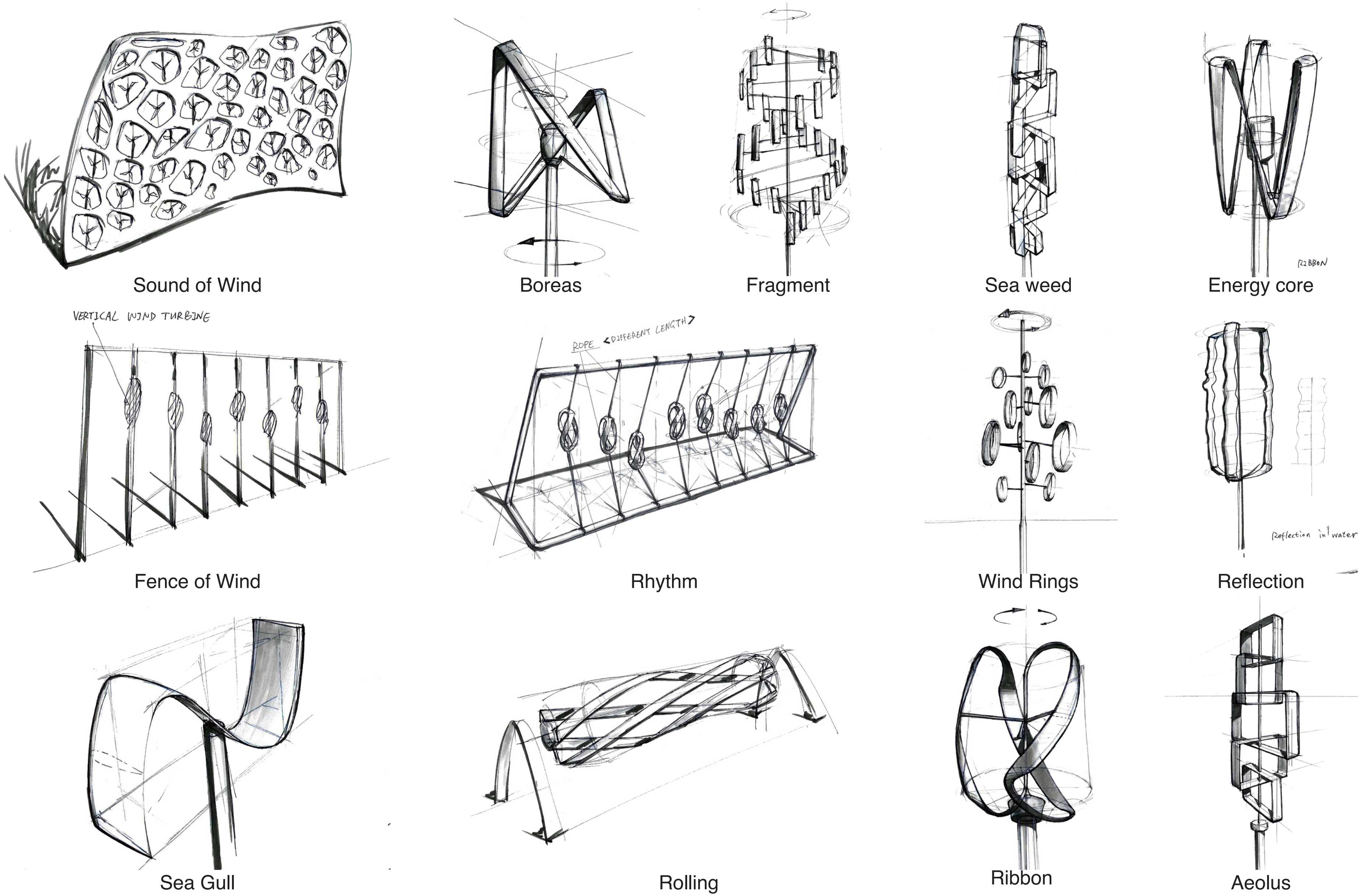


Figure 6.2 Idea sketches

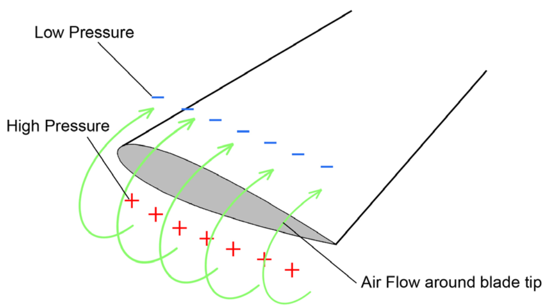


Figure 6.3

6.1.2 Ideas

More than ten ideas are generated with different starting points or inspirations. Figure 6.2 shows an overview of the ideas.

All of them are described with sketches with more details in Appendix H.

6.1.3 Comments from engineering perspective

Some informal interviews are conducted with several people in the company Actiflow. They provides some valuable comments from different perspectives on the ideas.

Roland is an aerodynamics engineer, specializing in wind turbine engineering. From engineering perspective, Roland would like to choose some forms having better performance. He chooses ideas with bigger front areas, like ‘Sound of Wind’, ‘Ribbon’, ‘Fragment’ and ‘Boreas’.

Eric, the manager of Actiflow, likes ‘Aeolus’ most. He mentions that ‘Sound of wind’ can be a very ‘designed’ artistic work, but it does not really show aerodynamics ability of the company.

Oskar, the aerodynamics engineering designer in Actiflow, mentions similar concepts as ‘Ribbon’ have been done too much by other companies. The many blades tips of ‘Fragment’ causes aerodynamics problems, which lowers the efficiency of the wind turbine. The principle is illustrated in Figure 6.3. When the air foil blade is moving in the air, it has unequal pressure on the upper and lower surfaces. In the middle part of the blade, it creates lift force appropriately. However, in the tip area of each blade, air from higher pressure side is going to the lower pressure side, which lowers the efficiency.

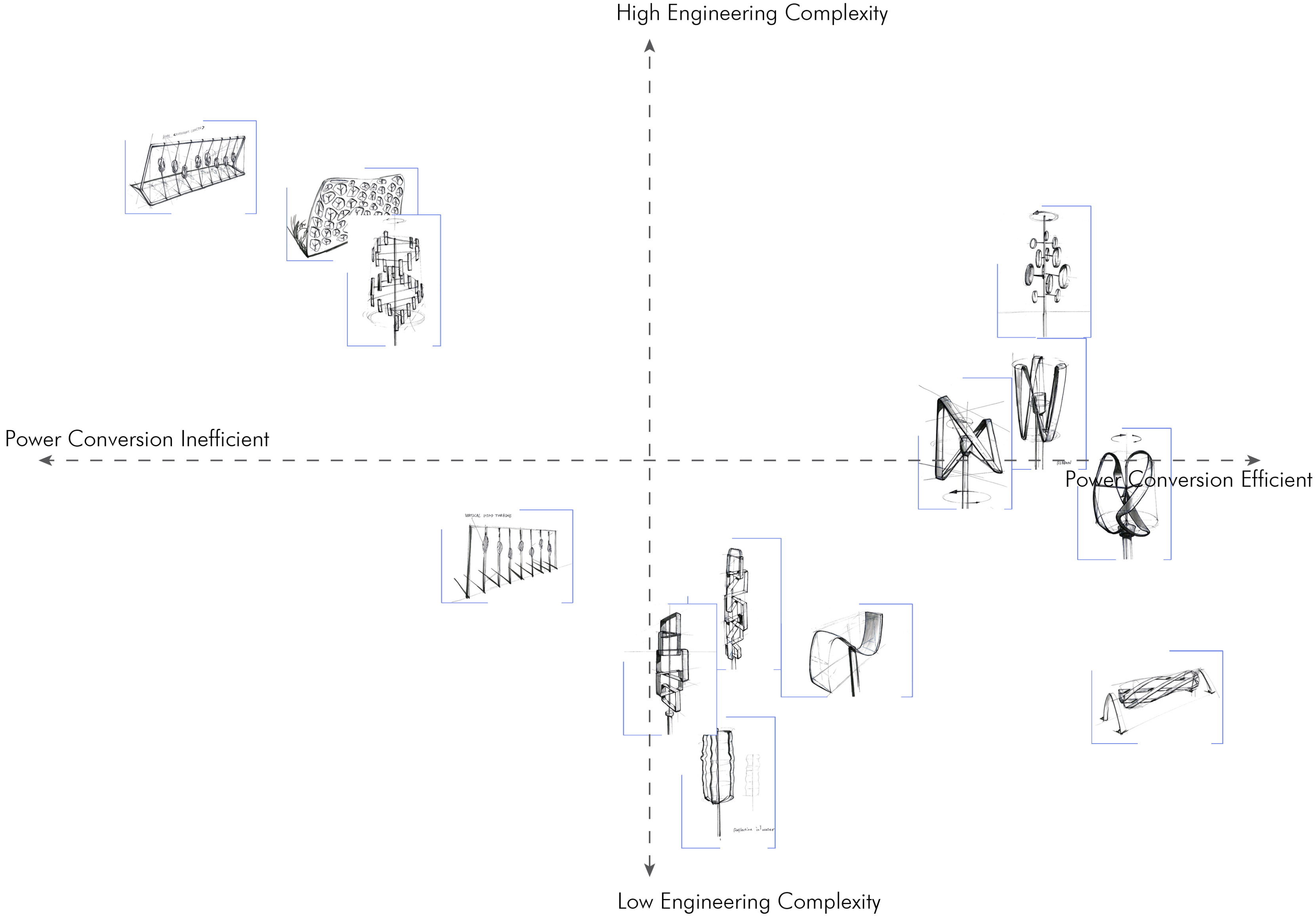


Figure 6.4 Idea evaluation

The other designer of the company Jeroen likes the ‘Wind rings’ best, as it is a very original design.

The other designer of the company Jeroen likes the ‘Wind rings’ best, as it is a very original design.

6.1.4 Initial Idea Evaluation and Selection

In this step the ideas are evaluated mainly with engineering criteria. Several ideas are selected in the end for further concept development.

First, ideas are mapped with two criteria: Power conversion efficiency and Engineering complexity. (Figure 6.4) To show the aerodynamics engineering capacity of Actiflow, high power conversion efficiency is a necessity. Engineering complexity indicates how complex it is to engineer the design into a high performance product, including aerodynamic and mechanical aspects.

Figure 6.5 ‘Windspire’

The turbine units of ‘Rhythm’ swing with the wind. It wastes energy with mechanical movements. The actual energy transfered into electricity would be very low. The design ‘Sound of Wind’ consists of many horizontal wind turbines in a wall. The solid wall acts as obstacle to the turbines when the wind is not blowing perpendicularly towards the wall. Therefore, it has low power conversion inefficiency in average. The low efficiency of ‘Fragment’ is caused by the blade tips problem, which is explained previously. The small turbine units of ‘Fence of Wind’, as well as the obstruction between each other, results in low efficiency.

‘Aeolus’, ‘Sea Weed’ and ‘Reflection’ have relatively low efficiency. Because their frontal areas are small. Yet they are acceptable, referring to the existing product ‘Windspire’ (Figure 6.5) on the market, which has a similar long slim frontal area.

When there is existing similar product on the market as a reference, the engineering complexity would be lower. There is no similar wind turbine as ‘Wind Rings’. So it is complicated to engineer this design. The mechanical components and multi-generators increase the engineering difficulty of ‘Rhythm’ and ‘Sound of Wind’. ‘Fragment’ has many short blades. The air flow for each blade is complex to analyze. Because they are close and overlapping in vertical direction, the previous blade influences the air flow for the next one. It is difficult to arrange the blades to achieve optimized performance.

Ideas with high power conversion efficiency and relatively low engineering complexity are preferred (Lower right area of the map). As a result of this evaluation, ‘Rhythm’, ‘Sound of Wind’, ‘Fragment’ and ‘Fence of Wind’ are excluded.

Originality from engineers’ point of view is another criterion used in this section. Some of the ideas might be considered by other engineers as only superficial shape design rather than solving engineering problem, which is not desired to show Actiflow’s ability. In this sense, ‘Reflection’, ‘Sea Gull’ and ‘Rolling’ are excluded. ‘Reflection’ and ‘Sea Gull’ only have blades deformation. ‘Rolling’ is too similar to the existing product ‘Wind Wall’ (Figure 6.6). The rest six ideas not only have different form design, but also solve the tip problem.

‘Aeolus’ and ‘Sea Weed’ have nearly the same form language and visual appearance. As ‘Sea Weed’ has higher engineering complexity due to the construction, ‘Aeolus’ is chosen for further development. The ‘Ribbon’ is chosen over ‘Energy Core’ for the same reason.

Four ideas are chosen to be developed into concepts after evaluation. They are ‘Wind Rings’, ‘Boreas’, ‘Ribbon’, and ‘Aeolus’.

6.1.5 Conclusion

13 initial ideas are generated with help of mind map. They are evaluated by engineering criteria - Power conversion efficiency, Engineering complexity and Originality from engineers’ point of view. In the end, four ideas are selected for concepts development in the next section. They are ‘Wind Rings’, ‘Boreas’, ‘Ribbon’, and ‘Aeolus’.

Figure 6.6 Wind Wall

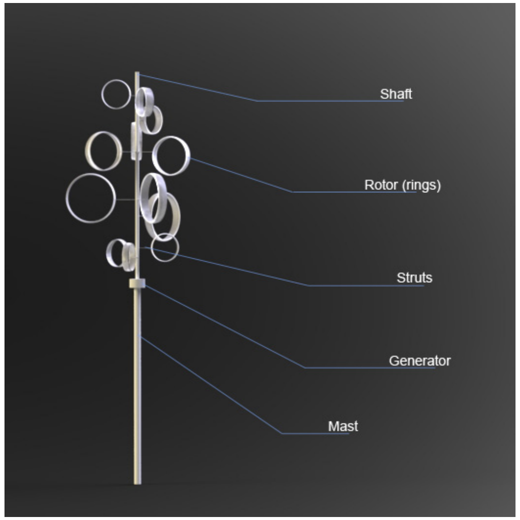


Figure 6.7

6.2 Concepts development

3D-modeling and rendering are the tools to help develop and visualize the concepts in this phase. Concepts development starts with rotor design, followed by supporting structures design to enhance the overall appearance. In the end of this section, a refined 'Wighted Objectives Method' is used to rank the concepts and make the final selection.

6.2.1 Rotor Design

In the rotor design, complex curved surfaces and twisting shapes are involved in the selection ideas. It is difficult to visualize and develop design with 2D sketchs. 3D models are built in Rhino to develop the forms. The following section briefly describes how the forms are developed for the concept 'Wind Rings'. The other three are shown with the final visualized results. Because the basic aesthetic principles are the same. It is not necessary to show the development process of the rest three repetitively.

The first 3D model of 'Wind Rings' is created base on the sketch. The section view of rings is air foil shaped. The rings have four sizes. The top rings have the smallest diameter. The positions of rings are played a little bit to make the form balanced and dynamic. (Figure 6.7) However, rings are quite chaotic when the rotor is rotating in Rhino.

In the field of visual perception, Gestalt theory indicates that people tend to perceive visual components as organized patterns or wholes, instead of many different parts.[49] If the attempt of 'grouping parts into patterns' fails, the visual components could be seen as chaotic. In this design the different sized rings already create many variations. Creating some relationships or consequences between these rings will improve the visual appearance.

The following images show some attempts to improve the shape. For easier modeling in 3D program, flat bands are used to represent air foil rings (1~5 in Figure 6.8).

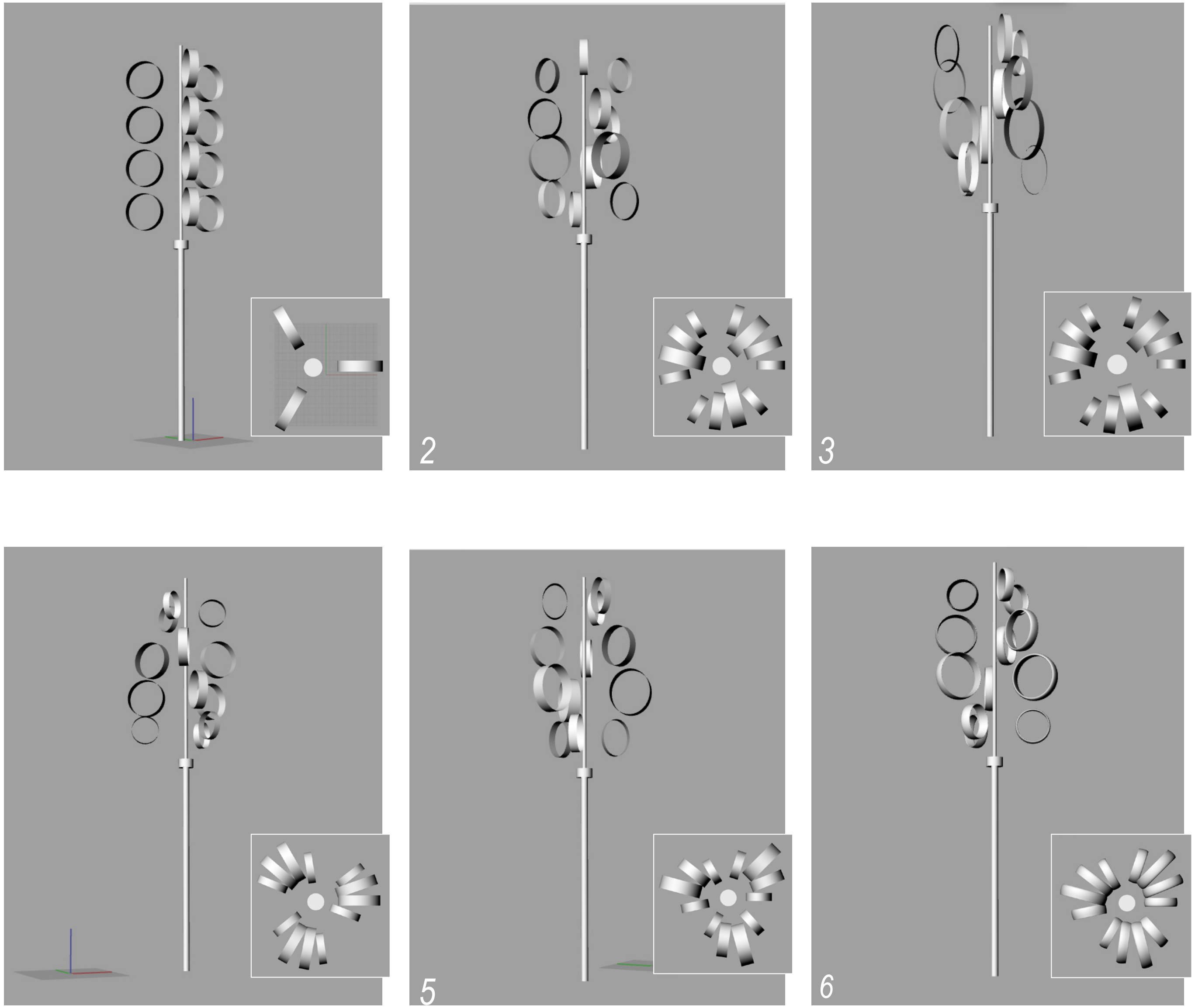


Figure 6.8

The first trial is to make rings into the same size and array them into straight lines. (Figure 6.8-1) Apparently the stand geometry makes it too ‘static’, which is mentioned in aesthetic guidelines. Then it comes back to the idea of using different sizes of rings. They are arrayed into three helical curves, the outer edges are on a circle from top view.(Figure 6.8-2) Ellipses are also tried out.(Figure 6.8-3) Another trial is to make the inner edges of rings compact, on three helical curves. (Figure 6.8-4,5) This version appears more compact as well as dynamic, compared to the previous ones.

The ellipses and round rings have almost the same visual result. Compared to the ellipses, round rings have a bigger frontal area, which can capture more wind. So it is chosen, and modeled with air foils in Figure 6.8-6 for preliminary visualization. During the modeling, the positions of rings are further refined. The inner edges of the rings are placed on a circle from top view. As a result, the distance between the axis pole and rings are all the same. In production, there will be only one mold needed for all the struts, hence lower cost.

The other three chosen rotor design ideas are also developed into concepts with 3D modeling. The visualized images of four rotor concepts are shown in Figure 6.9.

6.2.2 Rotor Rotation Animation

When an object is moving, the visual appearance is very different from static one. The rotors of wind turbines are rotating most of the time. It is necessary to look into the appearance when they are rotating.

Making physical or digital models are both considerable options. However, it is very difficult and time consuming to make physical models. Because there are too many complicated curved surfaces. The possible way would be rapid prototyping, which needs 3D models. Considering the time limitation, digital rendered animations are used in this case to get an idea of how they look like while rotating.

For each concept, two animations are made. One of them has a lower rotating speed, 20 rpm (revolutions per minute). The other one has a rotating speed of 120 rpm. The sequential frames like Figure 6.10 can be found in Appendix I - Rotation Animations.

With helical shapes, the ‘Bibbon’ and ‘Wind Rings’ appear more energetic than the other two while rotating. The movements give a feeling of extending in vertical direction. The ‘Boreas’ seems a little ‘forced’ to do the rotation movement, which is not supposed to spin regarding to the form visually.

So far the concept selection could not be made yet, as the design of supporting structures in the following section will have a big influence on the aesthetics.

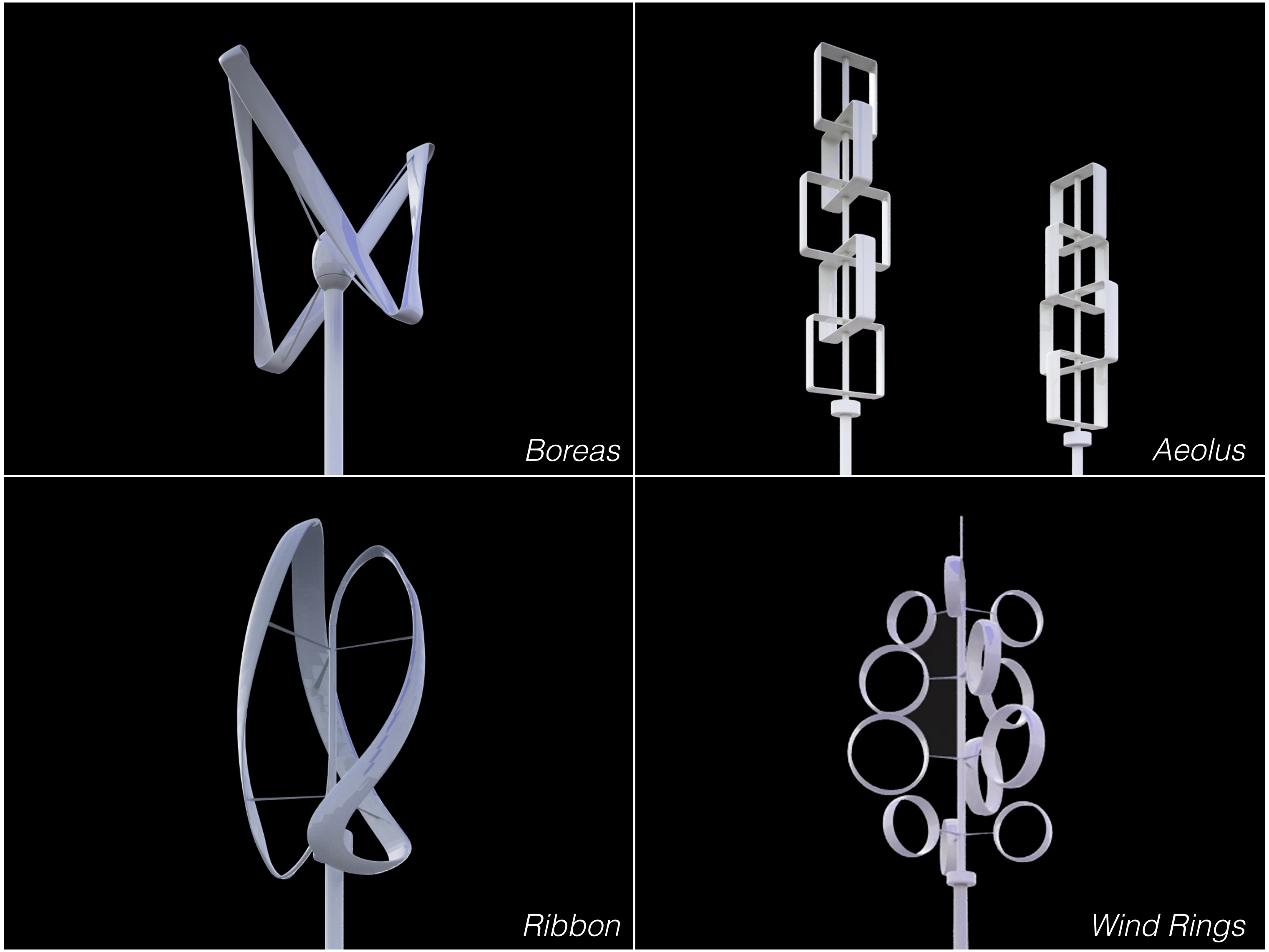


Figure 6.9

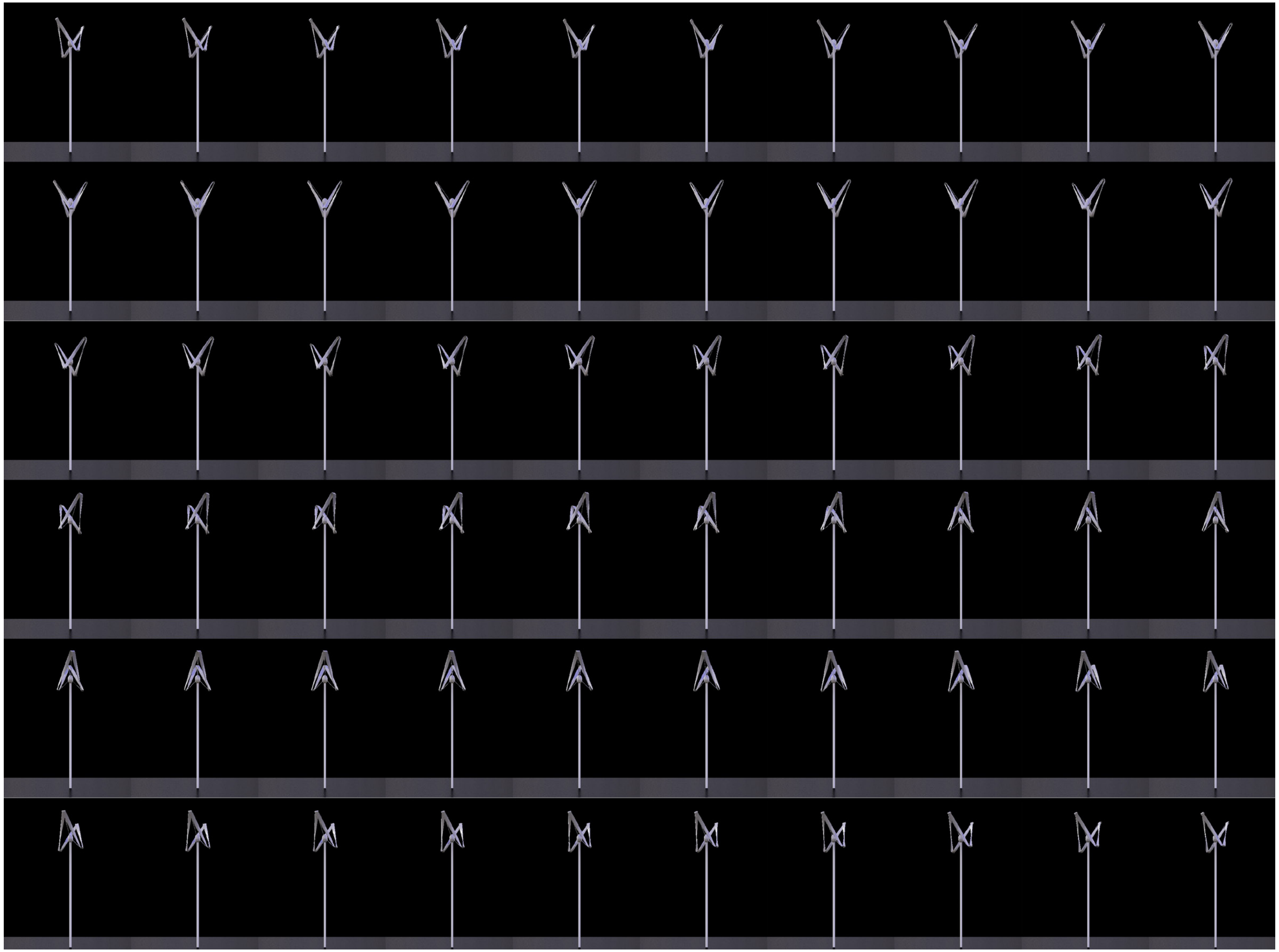


Figure 6.10

6.2.3 Supporting Structure Design

From the result of part 1b of semantics analysis, the masts (supporting structures) have big influences on the appearance of wind turbines. In previous section the focus is mainly on the rotor design. In this section, the supporting structures of the four concepts are elaborated. The masts design is based on the form language of each rotor concept.

The rotor of Boreas are connected straight lines. Polylined supporting structures are created. (Figure 6.12) The lowest parts of the masts are twisted, recalling twisted rotor blades. The three - branches design is inspired by the street light design (Figure 6.11 - 3 'takken' scréder light) for the new boulevard of Scheveningen, by Manuel De Solà-Morales. It helps to make the design fit into the environment because of the links with other objects in the environment.

The shape of 'Ribbon' rotor is organic and extending vertically while rotating. In the masts design, two intertwined poles are made with growing tendency. Each of them has a 'Ribbon' rotor on it. The higher one is a little bigger than the lower one, to create more dynamics. (Figure 6.13)

The designs of 'Aeolus' and 'Wind Rings' are not so out speaking as previous two. According to aesthetics principle of 'maximum effect for minimal means', people tend to be attracted by objects with relatively simple design features revealing a wealth of information. [50] The attempt here is to create rich meanings with simple abstract mast designs. The masts of 'Aeolus' are simply deformed cylinder poles.(Figure 6.14) It creates directions. Six wind turbines are placed in a row. They are 'grouped' by adjusting the distances and directions. Different interpretations and daydreaming stories could be made by perceivers. The masts of 'Wind Rings' are a little bent.(Figure 6.15) The sections are gradually deformed along the pole, which creates a shape like a skirt being blowed by the wind. Two modules are made with different sizes, different amounts of rings. They provide more inspirations and triggers for imagination. Both 'Aeolus' and 'Wind Rings' can enhance the interaction with exploring experience in the context. From a distance, the detailed designs of masts cannot be seen directly. While approaching, people discover more details.

Figure 6.11 3 'takken' scréder light

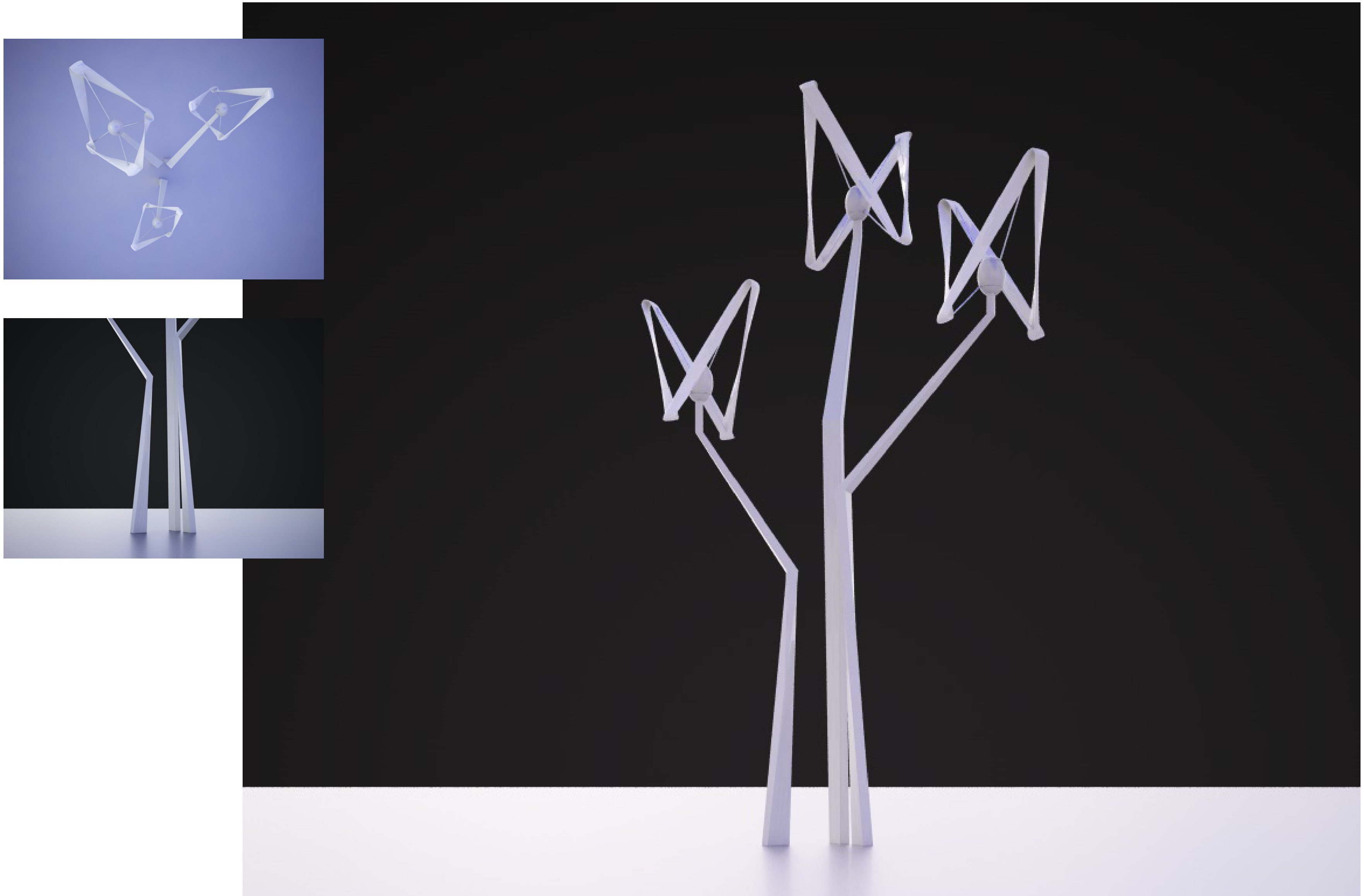


Figure 6.12

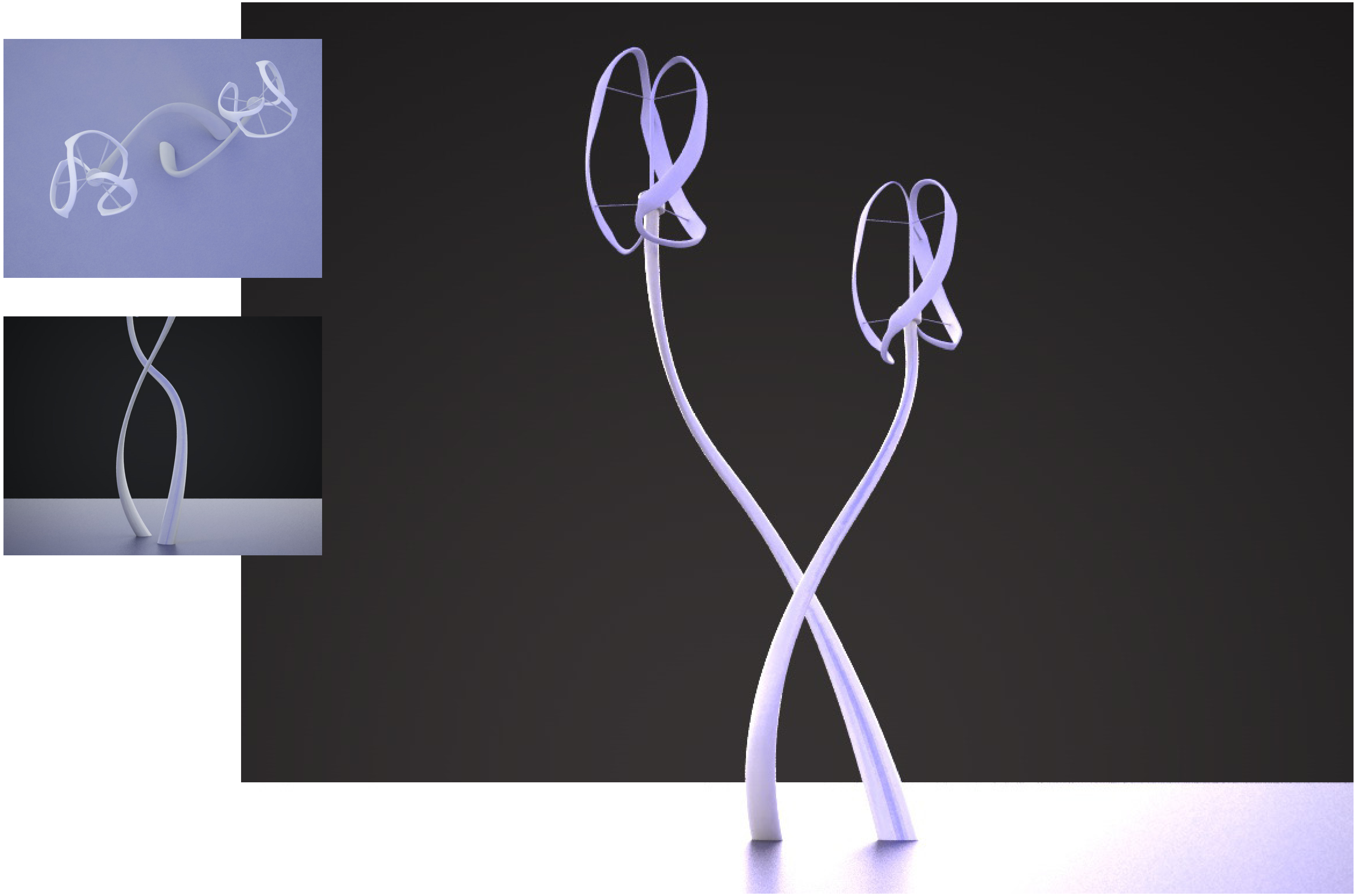


Figure 6.13

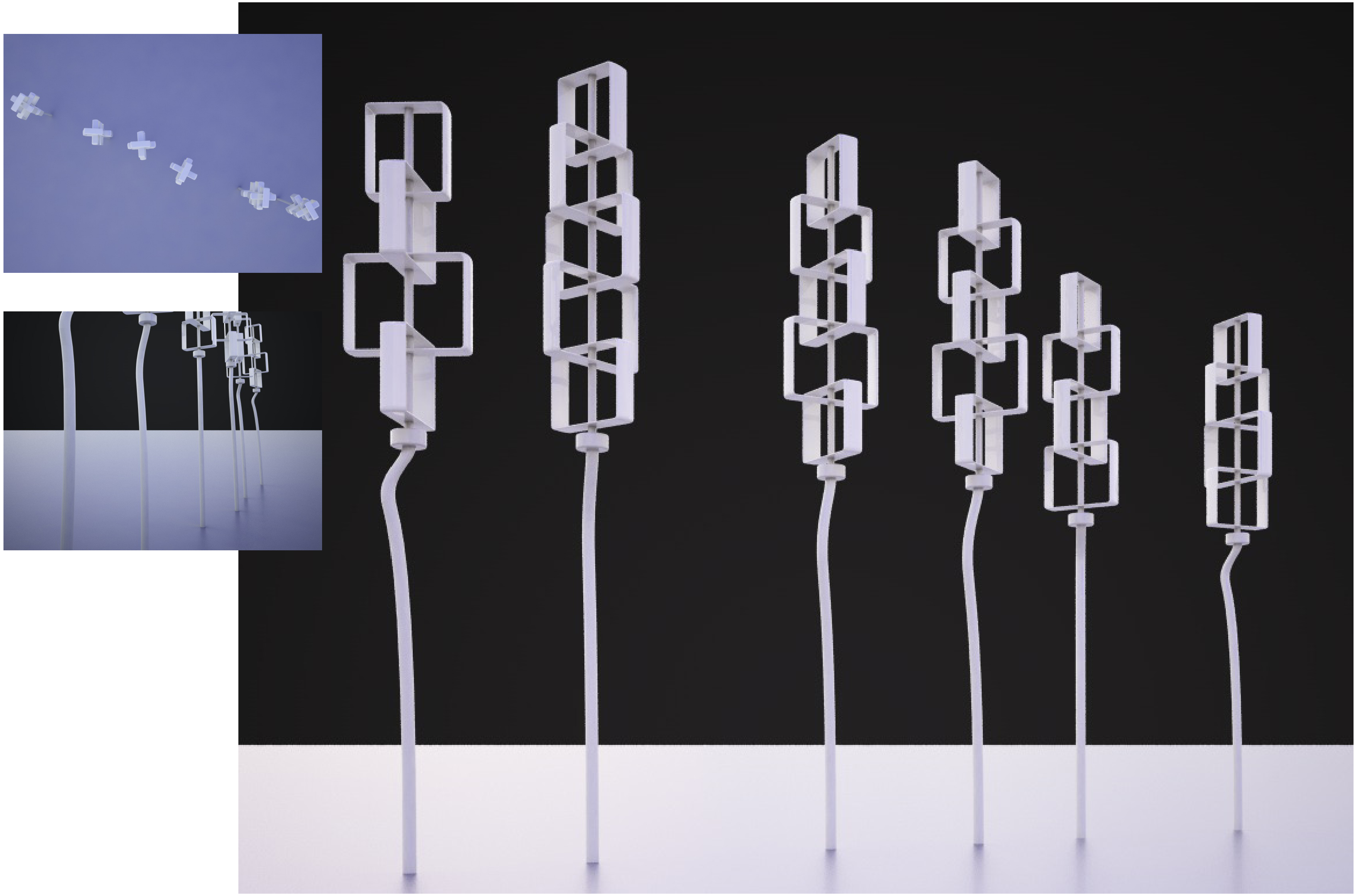
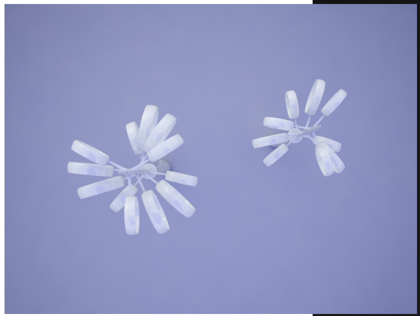
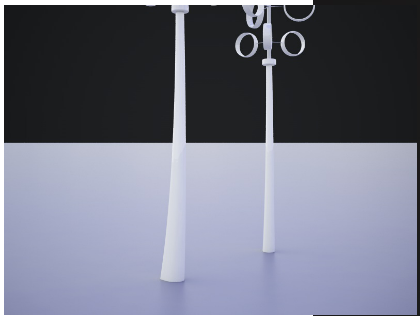


Figure 6.14





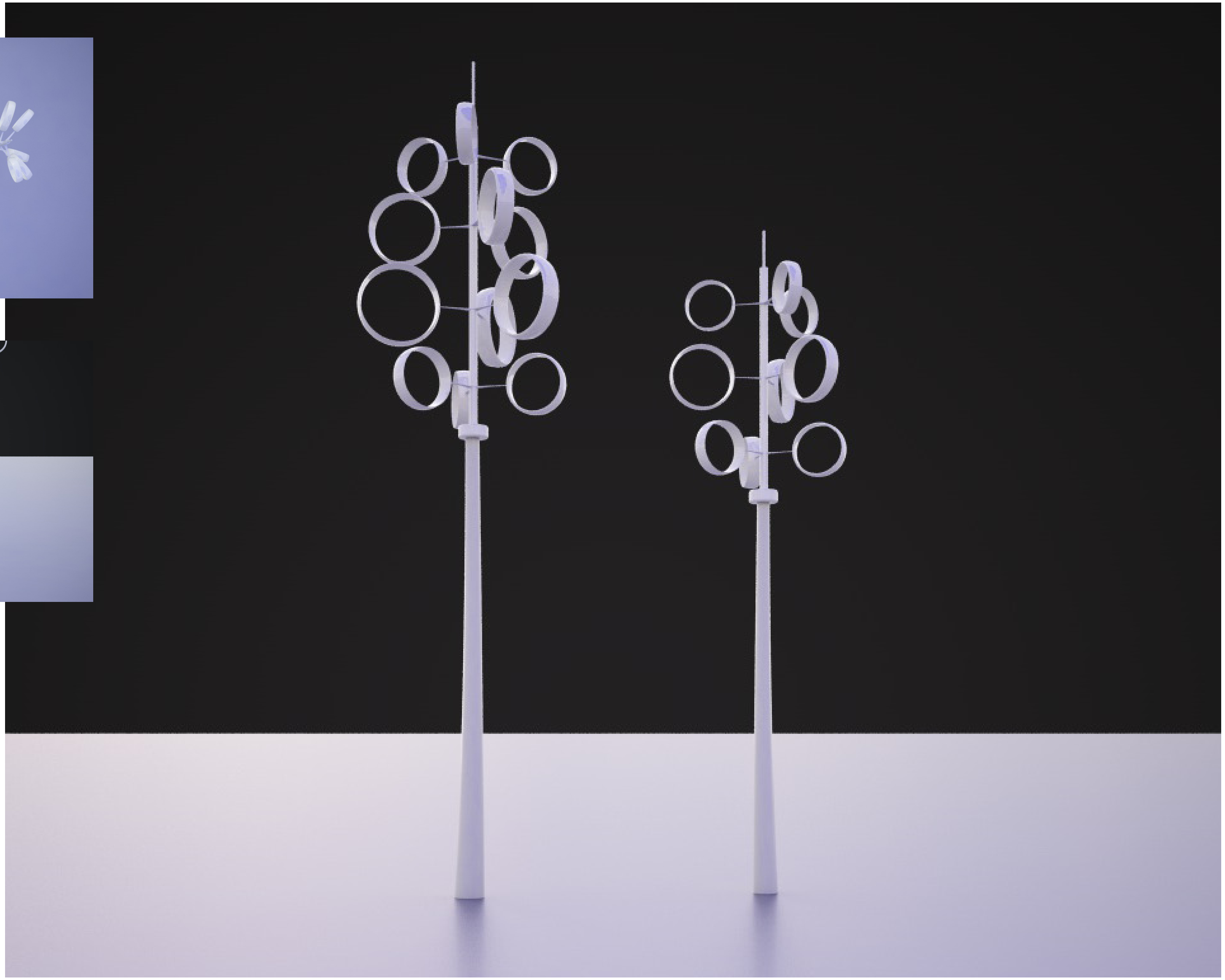


Figure 6.17

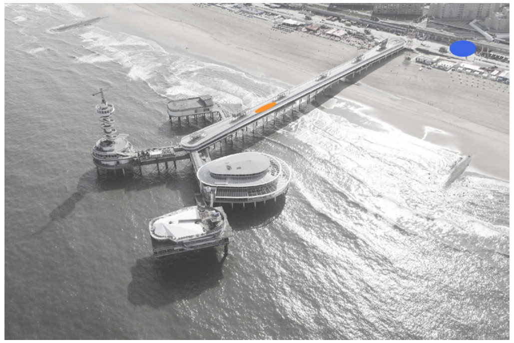


Figure 6.16

6.2.4 Concepts In Context

The four concepts are placed in the southern side, between the second and third cubes on the Pier from the end. The location is marked with orange in Figure 6.16. At the beginning of the Pier, connected to the boulevard, there are three very big LED (about 5 m high) screens on the first three cubes. They would be very distracting if the wind turbines are close to them. In the end of the Pier, the bungee tower is also distracting visually. It also obstructs the wind from some direction. So the appropriate location should be somewhere not close to the end of the Pier, neither the first three cubes at the beginning of the Pier.

The blue dot in Figure 6.16 is the main entrance for most of the tourists. Standing from that area looking at the Pier, the chosen orange area on the Pier is the optimal location. It avoids the bungee tower being in the back of the turbines. The beach in southern side of the Pier is the most busy area. Putting the wind turbines in south side on the Pier will make it more visible for more tourists. It also helps to create more meanings of the designs compared to making them in the middle of the Pier.

Products on the Pier are shown in Figure 6.17, to get an idea of appearances in the context. These visualized concepts images will be used as references in the following concepts evaluation section.

6.2.5 Concepts Evaluation and Selection

A refined weighted objectives method is used to evaluate, compare the concepts and make the final selection.

The weighted objective method assigns scores (1~10) to the degree to which a design al-

Figure 6.13

ternative satisfies a criterion. It also assigns weights (1~5) to the different criteria according to their importances. [51]

A list of criteria is first made base on the design goal. (Table 6.1) The weight factor of criteria are determined by comparing in pairs. In this case, the goal of this project is twofold: to increase acceptance and to show Actiflow's ability. They are equally important. But there are more criteria for 'increasing acceptance' than 'showing Actiflow's ability', the full scores are different. The normal way of using weighted objectives method is not suitable for this situation. The method is refined. The full score of 'increasing acceptance' is 280, and 'showing Actiflow's ability' 150. The final score of 'increasing acceptance' for each concept is divided by 280 and multiplied by 150, to make them equal. The scores are briefly explained as follows.

The bird risk is related to the visibility, moving blades speed and amount of rotating components. As the 'Aeolus' has the much more rotating components than the rest, it is more dangerous for birds. Flickering refers to the reflections of the sun light. With the same material, it is mainly related to the surfaces. More curved surfaces could reflect light with a bigger range of angles. 'Wind Rings' has many round surfaces, which creates more flickering. The 'Aeolus' has a smaller diameter, it will rotate faster than others with the same wind speed. The speed as well as the more modules makes more noise and higher stressing feeling. All of them are outstanding in that environment, which are designed to be. To arouse curiosity and inspire daydreaming, the 'Wind Rings' is the best. Because it has a 'surprising' shape, and the abstract form allows for many different interpretations.

It is mentioned by Oskar that similar shapes like 'Ribbon' are developed too much by other companies in the field of urban wind turbines. 'Wind Rings' is a very original design from engineers' perspective. There is no similar shape in the market at all. The power efficiency differs with the sizes of frontal areas. 'Aeolus' has the smallest frontal area, hence the lowest efficiency. Stability of structures here are mainly considering the shapes of supporting masts. The straight masts have better stability, while the more exaggeratedly curved ones are more difficult to be stable. The mast of 'Wind Rings' is the most stable one. The masts of 'Ribbon' would be very difficult and expensive to build. So it is scored low in both production cost and embodiment engineering difficulty.

In the end, the concept 'Wind Rings' has the highest total score of 230.11. 'Boreas', 'Aeolus' and 'Ribbon' are scored 212.43, 194.86 and 190.61 respectively. As a result 'Wind Rings' is the selected final concept, to be finalized in the next phase.

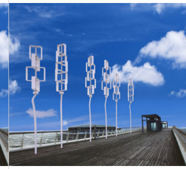
Criteria			Weight (1~5)	 Boreas (1~10)	 Aeolus	 Ribbon	 Wind Rings	Weight*
Increase Acceptance	Requirements	Bird Risk	4	7	6	8	8	50%
		Flickering	3	8	8	6	5	
		Noise	2	7	5	8	7	
		Not Stressing	4	8	6	7	8	
	Interaction Vision	Outstanding in the context (as a Landmark)	5	8	8	8	8	
		Arouse Curiosity	5	7	6	7	8	
		Inspiring Daydreaming	5	7	8	6	8	
Score A			280	208	192	199	213	
Score A / 280 *150				111.43	102.86	106.61	114.11	
Show Aerodynamics & Design Ability		Original Engineering Design	5	7	6	4	9	50%
		Power Efficiency	4	6	4	7	6	
		Stable Structure	2	7	7	6	9	
		Production Cost	1	7	8	6	8	
		Embodiment Engineering Difficulty	3	7	8	6	7	
Score B			150	101	92	84	116	
Total Score * = Score A / 280 *150 + Score B				212.43	194.86	190.61	230.11	

Table 6.1

7. Concept Finalization

In this section, the concept finalization will be explained in two aspects. One is further development of the concept design, to better achieve the design vision. The other one is embodiment design for the products themselves. The animation of the final design can be found in Appendix M- The flip book.

Figure 7.1

7.1 Final Concept explanation

7.1.1 A pair

A pair of ‘Wind Rings’ turbines are designed for the Pier of Scheveningen. People tend to assign meaning to some objects base on their own experience. Two ‘Wind Rings’ with different sizes standing on the Pier could provide many potentials and triggers for imagination (day dreaming). They can be seen as a couple, parent with child or two friends, etc.

The bigger one has 12 rings, with 4 different sizes. The smaller one has 9 rings, with 3 different sizes, which is also lower than the bigger turbine. The rings are aligned on helical curves, which gives a dynamically growing tendency. The details of the rings positions will be explained in product design detailing section.

Figure 7.2

7.1.2 Facing to the sea

With subtle design of the masts, the turbines have their directions. The masts are designed to be a little curved. (Figure 7.2) It gives an image that the masts are bending in the wind.

The pair of 'Wind Rings' will be located between the second and third 'cube' from the end of the Pier, shown in Figure**. Because in the area close to the boulevard there are three large LED screens on top of those 'cubes', which will be distracting. In the end of the Pier, the bungee tower is also a big distraction. The rotors of turbines are designed to be higher than the 'cubes', which is around 4 meters high. With the chosen location, there is no big obstacles surrounding. As a result, there is not much distraction from other objects near the turbines. From engineering perspective, it is also beneficial for capturing more wind power.

Two 'Wind Rings' will be placed near the handrails in the southern side of the Pier. Because the beach in the southern side of the Pier is the busiest area of Scheveningen. So more tourists will see the 'Wind Rings'. The curved masts are mainly facing to the sea. Yet two turbines' directions are not parallel. They turn a little bit to face to each other. This subtle detail design creates metaphor, as they are two persons or two living creatures. This detail can only be noticed when people are close to the 'Wind Rings'.

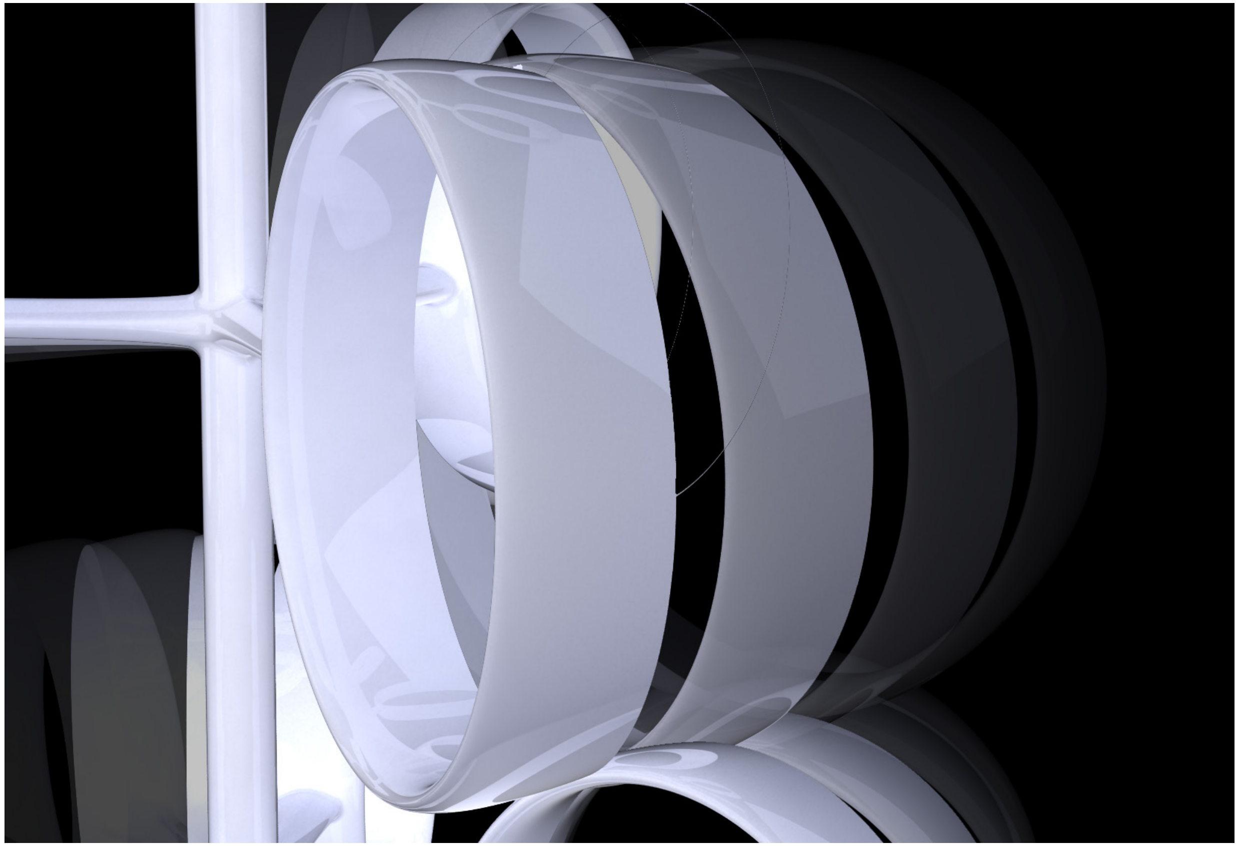


Figure 7.3

7.1.3 Capturing the wind

The rotors are composed of rings with struts and axis poles. Rings have different sizes, increasing visual dynamics of the turbines. They are connected to the axis poles by struts. The section views of the rings are air-foiled shapes. The air-foiled rings create lift force in the wind to improve the efficiency. The tip-less rotor design solves the tip inefficiency problem, compared to conventional vertical wind turbine blades design.

The original inspiration of this rotor comes from the butterfly net. When the rotor is rotating, rings have movements like ‘capturing’ something in the air. It contains a metaphor of ‘capturing the wind’.

7.1.4 'Swaying' in the wind

The masts of 'Wind rings' are not only simply curved. At the bottom of each mast, the section view is the biggest. It gradually becomes smaller when it is getting higher. The shape of the section view also changes along the mast. On the ground, it has a smaller curvature in front part than the back part. On the top of the mast, it is a circle. It looks like a girl's skirt swaying in the wind.

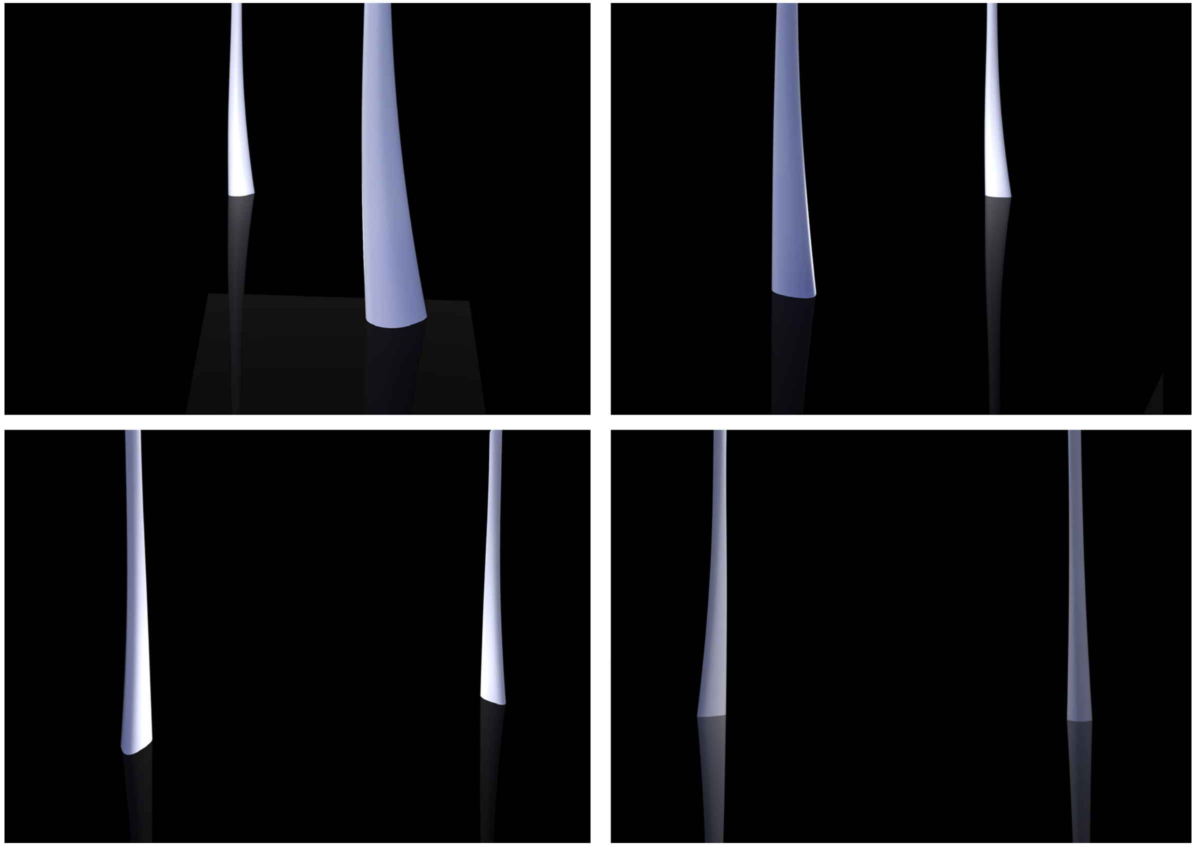


Figure 7.4

Figure 7.5

7.1.5 Allowing exploring experience

'Wind Rings' allows people to have an exploring experience when approaching it.

When it is far away, people only see a pair of turbines with different sizes. The rings are rotating around the axes. When it is closer, people will find the masts are bent and the turbines are facing to certain directions. When people come to the 'Wind Rings' and walk around them, they will see the masts' deformation. As they get closer, more features and details will be explored.

7.1.6 Glowing with wind (night effect)

The night effect of ‘Wind Rings’ is designed to make it stand out in the dark. It provides multi-sensory experience to the perceivers.

Two spotlights are placed in the ground, directed to two turbines separately. The spotlights are driven by the electricity generated by the wind turbines. The lightness of the spotlights is related to the rotor rotation speed, as well as the wind speed. For the perceivers, they can feel the wind with tactile sensory. They can hear the wind blowing with hearing sensory. At the same time, they can see the wind ‘glowing’ and ‘dimming’ with visual sensory.

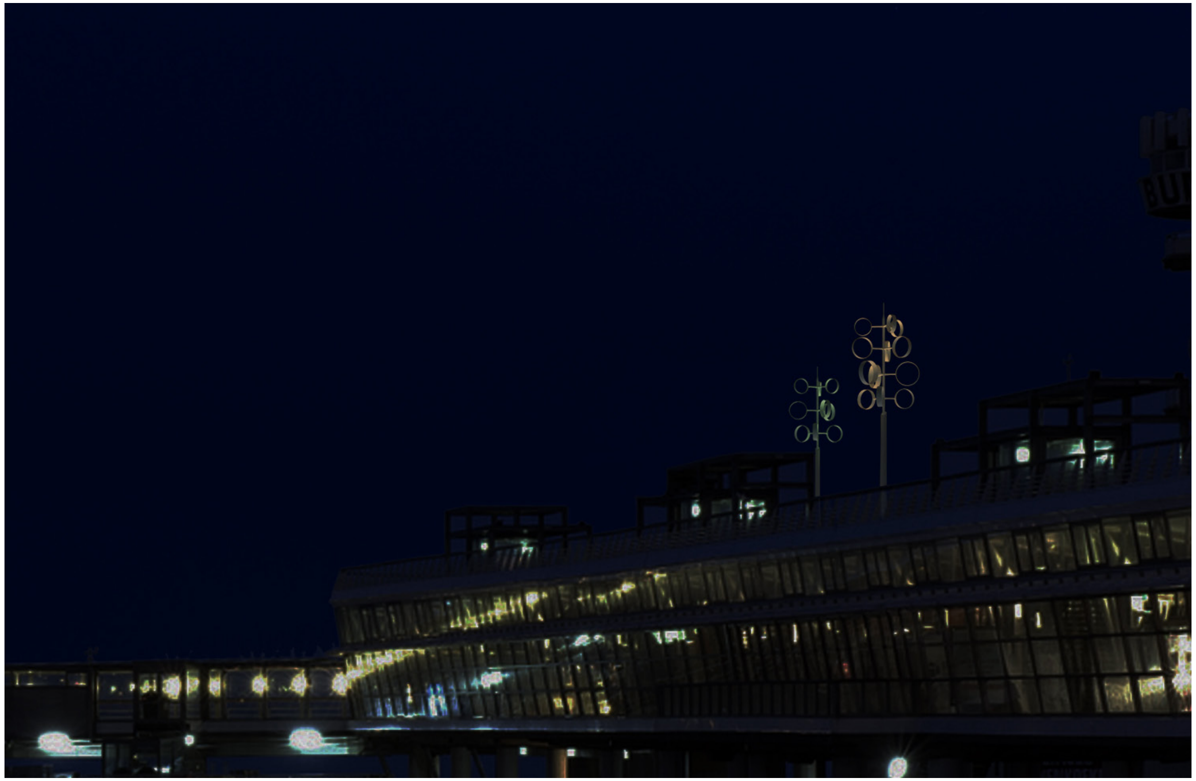


Figure 7.6

7.2 Product Design Detailing

7.2.1 ‘Blades’ Design

The ‘blades’ of the rotor in this design are the rings. All the rings have the same air foil shaped section view, with different sizes. It is very complex for aerodynamics engineers to find out what kind of air foil shape, or combination, works the best for this turbine design. It needs a lot of time and efforts to optimize the performance, which is not in the scope of this project.

In the design of this project, air foil type - NACA 0018 is used for the rings. (Figure7.9) Because referring to the existing product ‘Turby’, NACA 0018 works very well. From engineering perspective, it can be a good starting point for further aerodynamics optimization of the rotor design.

The angle between each ring on the same level is 120 degrees. The angle difference between each level is 60 degrees. The material of the rings is carbon fiber. This material has a high strength-to-weight ratio, which is desired in this product.

7.2.2 Struts Design

The struts are the connections between the rings and the axis pole.

They are holding the weight of the rings and bearing the centrifugal force when rotating. It is assumed that they are the most problematic parts in term of mechanical engineering. The SolidWorks simulation is used in the design of the struts.

An initial SolidWorks analysis simulation proves the assumption. The simulation report can be found in the Appendix J. The memory of my computer is not big enough to run a simulation for the whole rotor. In this case, only the biggest rings are taken for the mechanical simulation. The rings, together with structs and axis pole, have shell structures as shown in

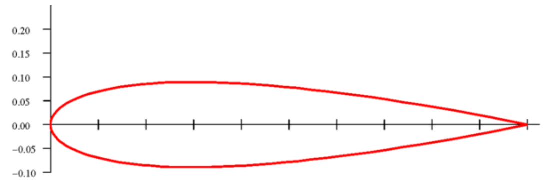


Figure 7.8

Figure 7.9 Carbon fiber

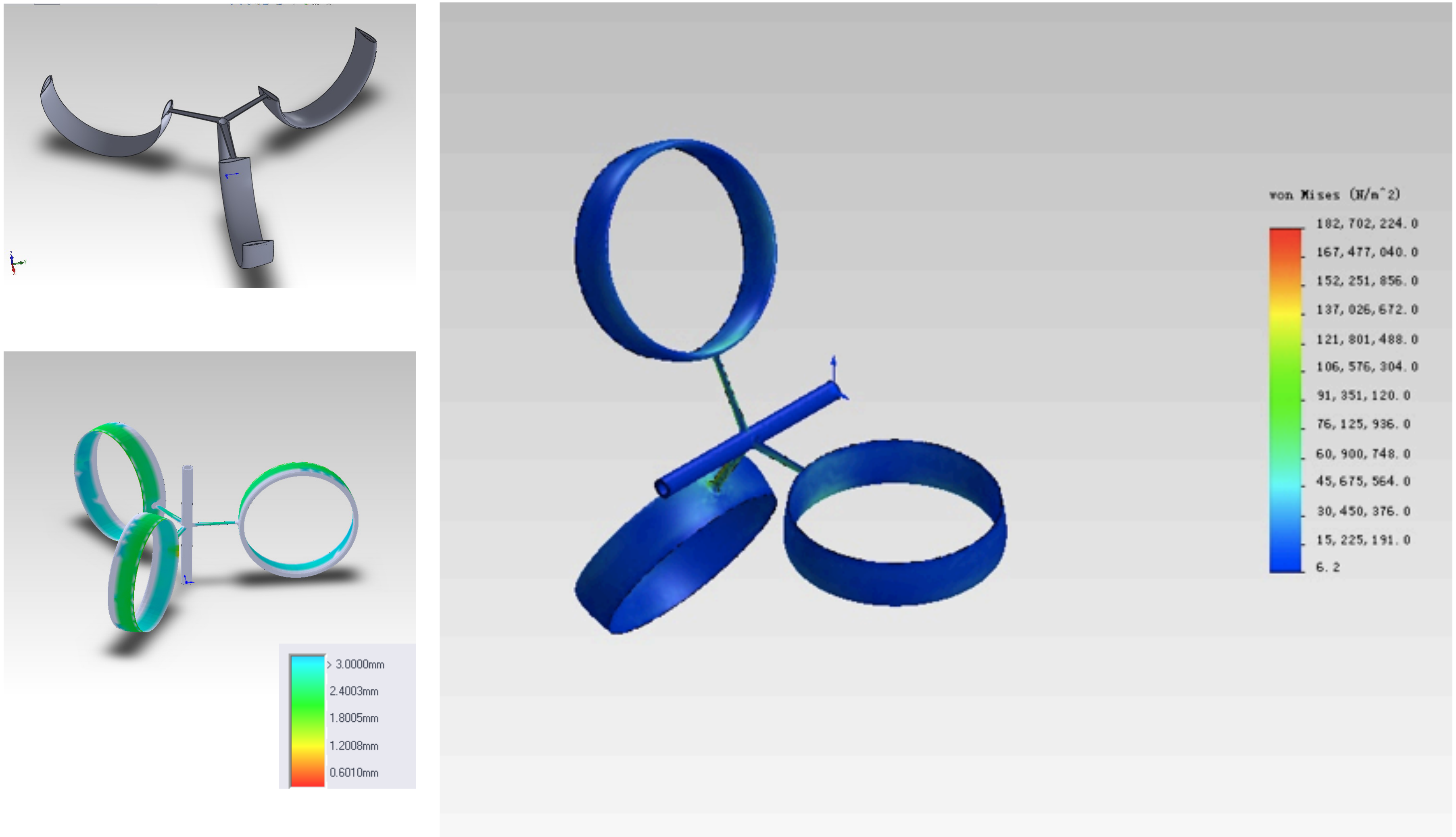

> 3.0000mm
2.4003mm
1.8005mm
1.2008mm
0.6010mm
von Mises (N/m^2)
182,702,224.0
167,477,040.0
152,251,856.0
137,026,672.0
121,801,488.0
106,576,304.0
91,351,120.0
76,125,936.0
60,900,748.0
45,675,564.0
30,450,376.0
15,225,191.0
6.2

Figure 7.10

Figure 7.10. The minimum thickness is abound 1.8mm. Carbon fiber Hexcel AS4C (3000 Filaments) is the material for the rotor. Base on the over engineering principle, an extreme situation is created for the simulation. Three rings are rotating with a speed of 300 rpm, which will not be reached in reality. Because the rotation speed is controlled to be lower than 300 rpm. An angular acceleration of -6000 rpm^2 is applied. Within 3 seconds, the rotation speed decreases to 0 from 300 rpm. The result of the stress study is shown in Figure **. The maximum value is 1.82702e+008 N/m^2. The red area on the struts is bearing the maximum stress. The ultimate tensile strength of Hexcel AS4C (3000 Filaments) is 4.15e+9 N/m^2, which is 23 times bigger than the maximum stress in this design. The initial struts design is already strong enough in terms of mechanical performance.

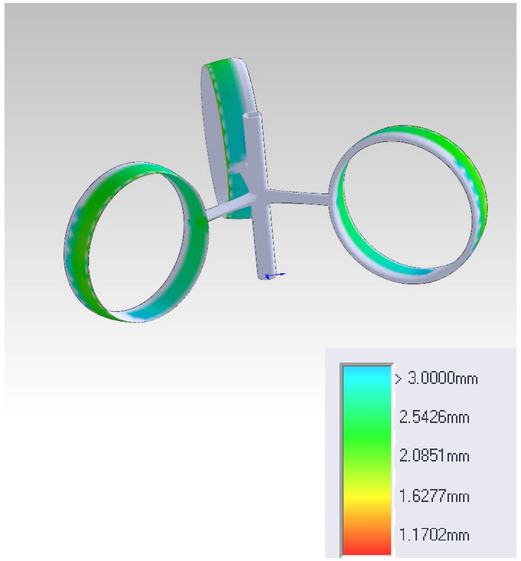
However, decision is made to make the struts thicker for the visual acceptance. In the initial design, the thickness of the struts is less than 20 mm. They are designed to be glued on the pole and rings with carbon fiber glue separately. This gluing process creates many problems for production.

In the new design, the struts are thickened. The minimum thickness is around 50 mm. Three struts on the same level are made into one module, to make the production process easier and the structures even stronger. A simulation is done for the improved structs design. (Figure 7.11) The simulation report can be found in the Appendix K. The mechanical performance is improved as assumed. The maximum value of stress is 7.85434e+007 N/m^2, which is more than twice smaller than the previous one. The maximum stress is not on the struts anymore.

The length of the struts, from center to the edge of rings, is 403 mm. The detailed dimension drawing will be shown in '7.2.6 Modular Design'.

7.2.3 Mast and Generator

There are two designs for the masts with two different types of generators. One of them needs a special generator, which is not available in the currently market. It needs some efforts and


> 3.0000mm
2.5426mm
2.0851mm
1.6277mm
1.1702mm

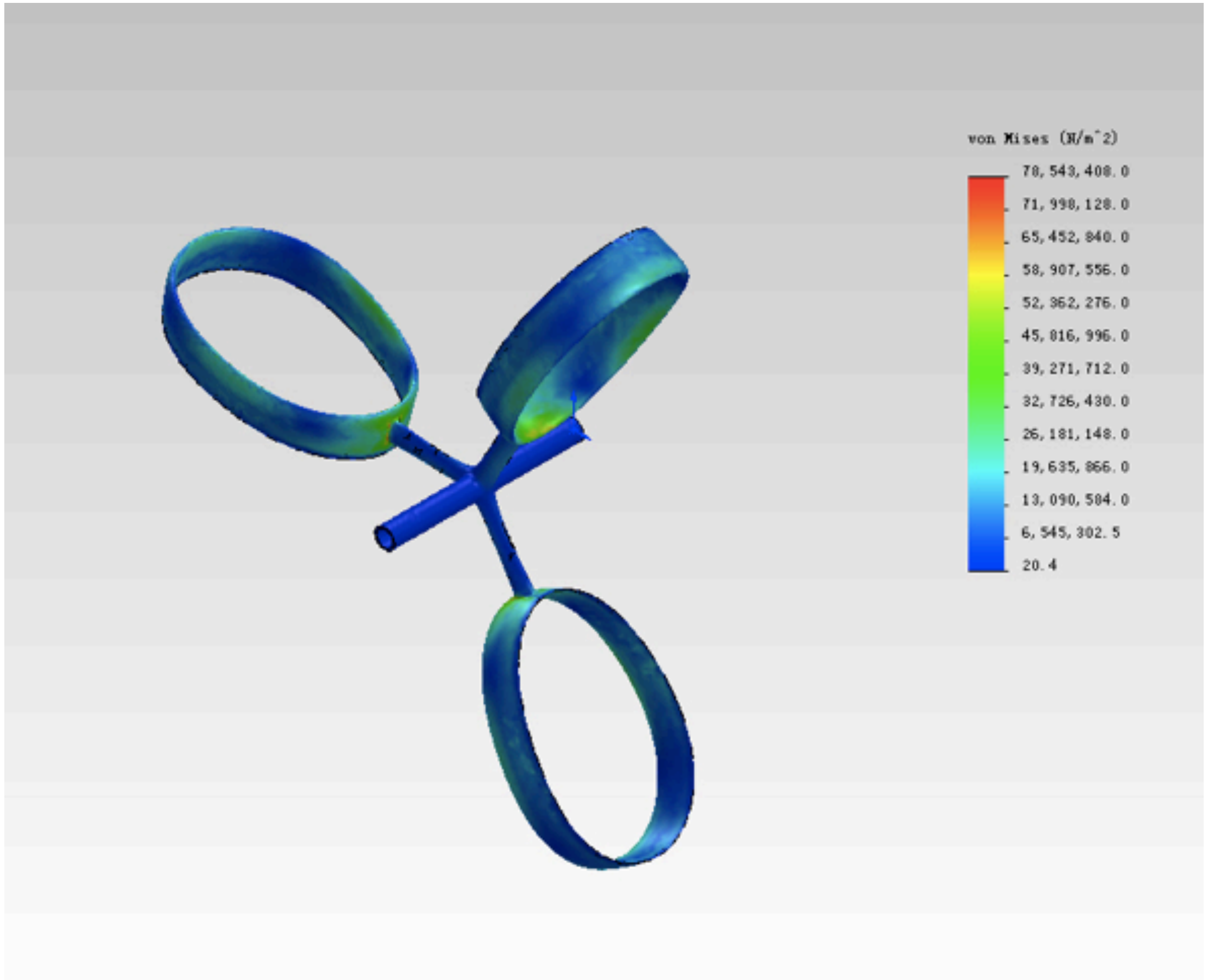

von Mises (N/m^2)
78, 543, 408. 0
71, 998, 128. 0
65, 452, 840. 0
58, 907, 556. 0
52, 362, 276. 0
45, 816, 996. 0
39, 271, 712. 0
32, 726, 430. 0
26, 181, 148. 0
19, 635, 866. 0
13, 090, 584. 0
6, 545, 302. 5
20. 4

Figure 7.11

Figure 7.12

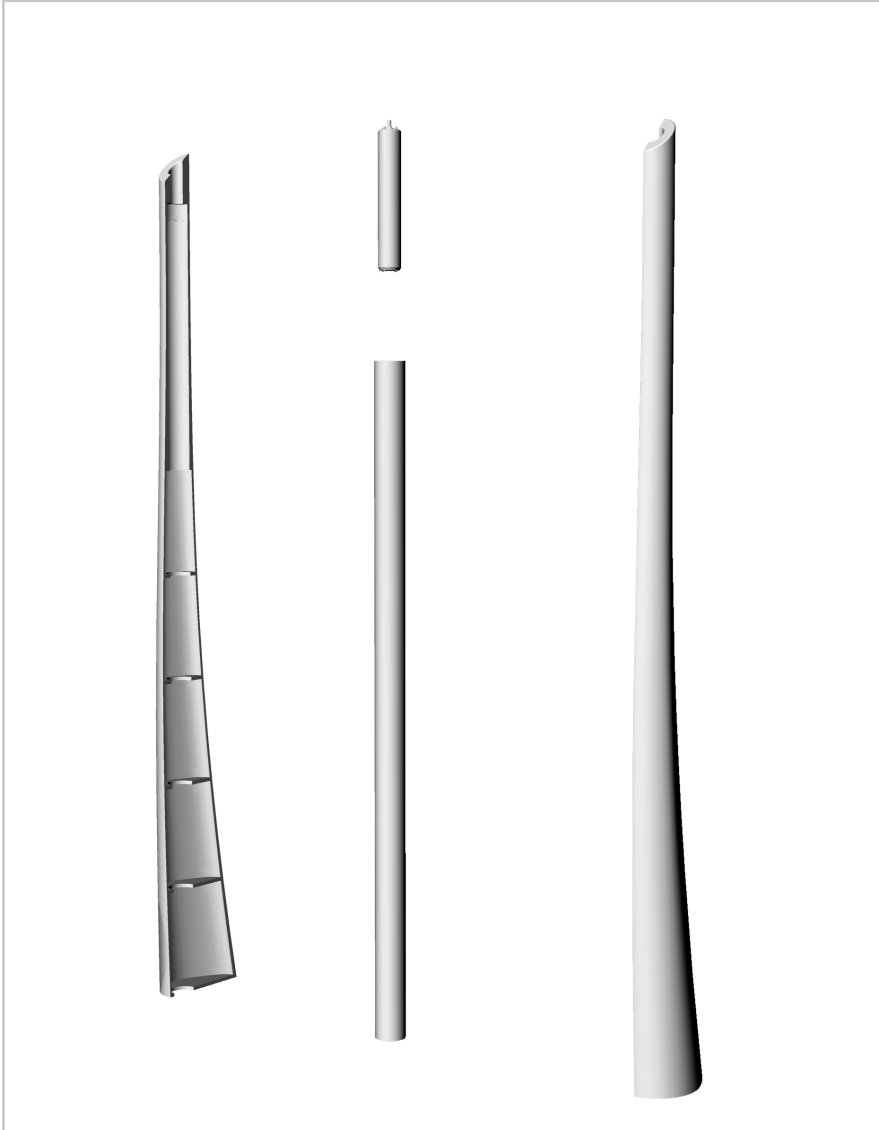


Figure 7.13

money to develop a special generator for the design. As a back up option, the other design uses an existing generator. This design is cheaper and easier, but not as aesthetic as the other one. It depends on the company which one they want to develop in the later engineering phase after this project.

In the more aesthetic design (Figure 7.13), the generator is hidden inside the mast. The generator is long with a small diameter. The mast consists of a shell and a pole inside. The pole is the structural component supporting the generator and the rotor. The shell is attached to the pole, for aesthetic appearance. The top of the mast is a inclined plane. This detail enhances the 'direction' design of the wind turbine.

In the other design (Figure 7.12), the generator is on the top of the mast. The mast consists of a shell and a pole inside with a platform on the top. The generator is fixed on the platform. The dimension of the generator in this design is from the existing product '', developed by DVE (a Denmark company) specially for small wind turbines.

7.2.4 Dimensions

The dimensions of the two 'Wind Rings' are shown in the next three pages. (Figure 7.14 and Figure 7.15)

7.2.5 Modular Design and Customized Design

In order to simplify the manufacture process, the design is trying to reduce the modules, hence reduce the molds. The rings have four sizes in total. (Figure 7.16) The legends for the two rotors are shown in Figure 7.17 and Figure 7.18, with dimensions. All the struts have the same size. (Figure 7.19)

In addition, the modular design creates possibility of customization. With the modules, the consumers can make their own designs. They can choose the rings and stack up them on the pole as they like.

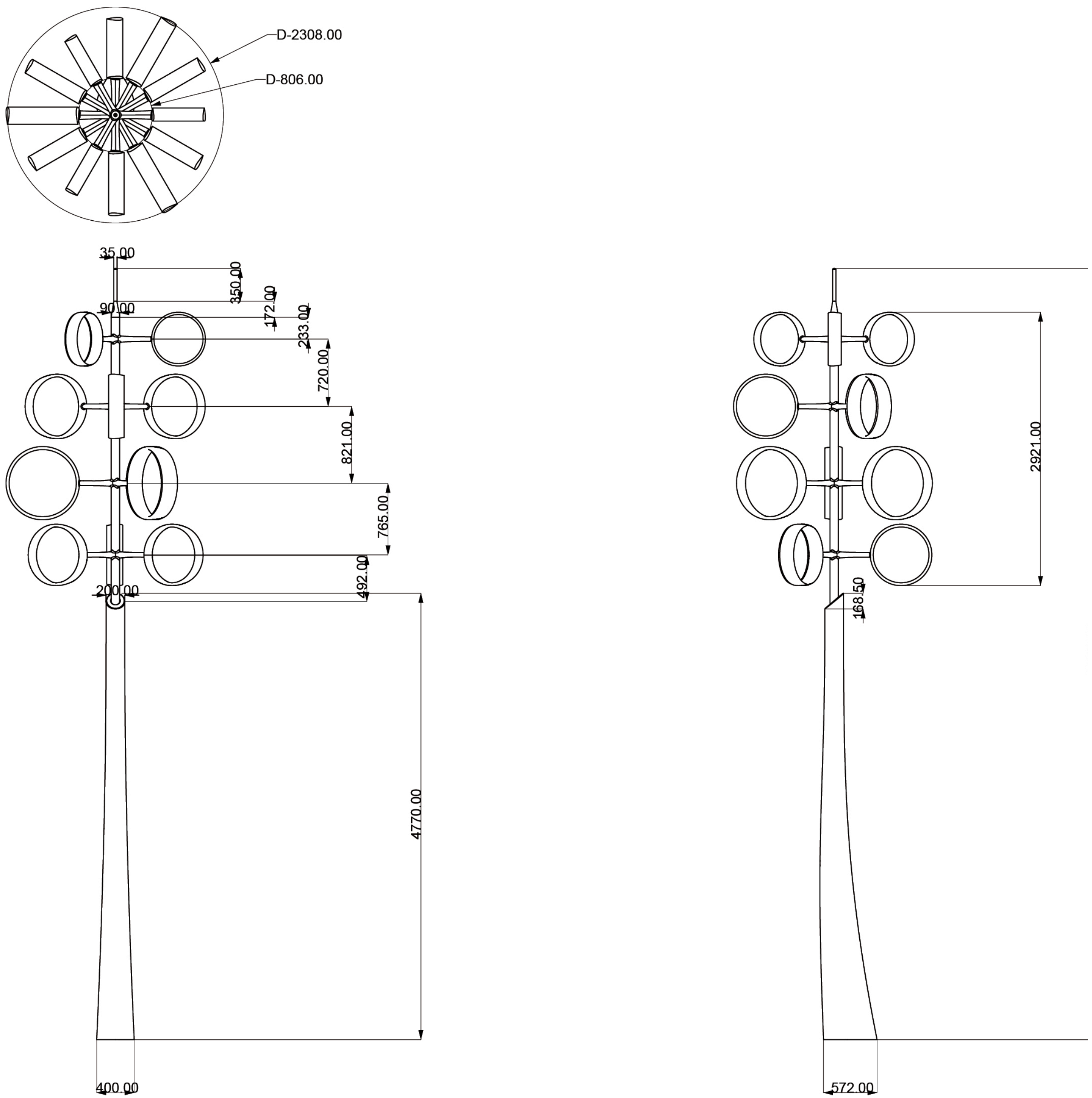
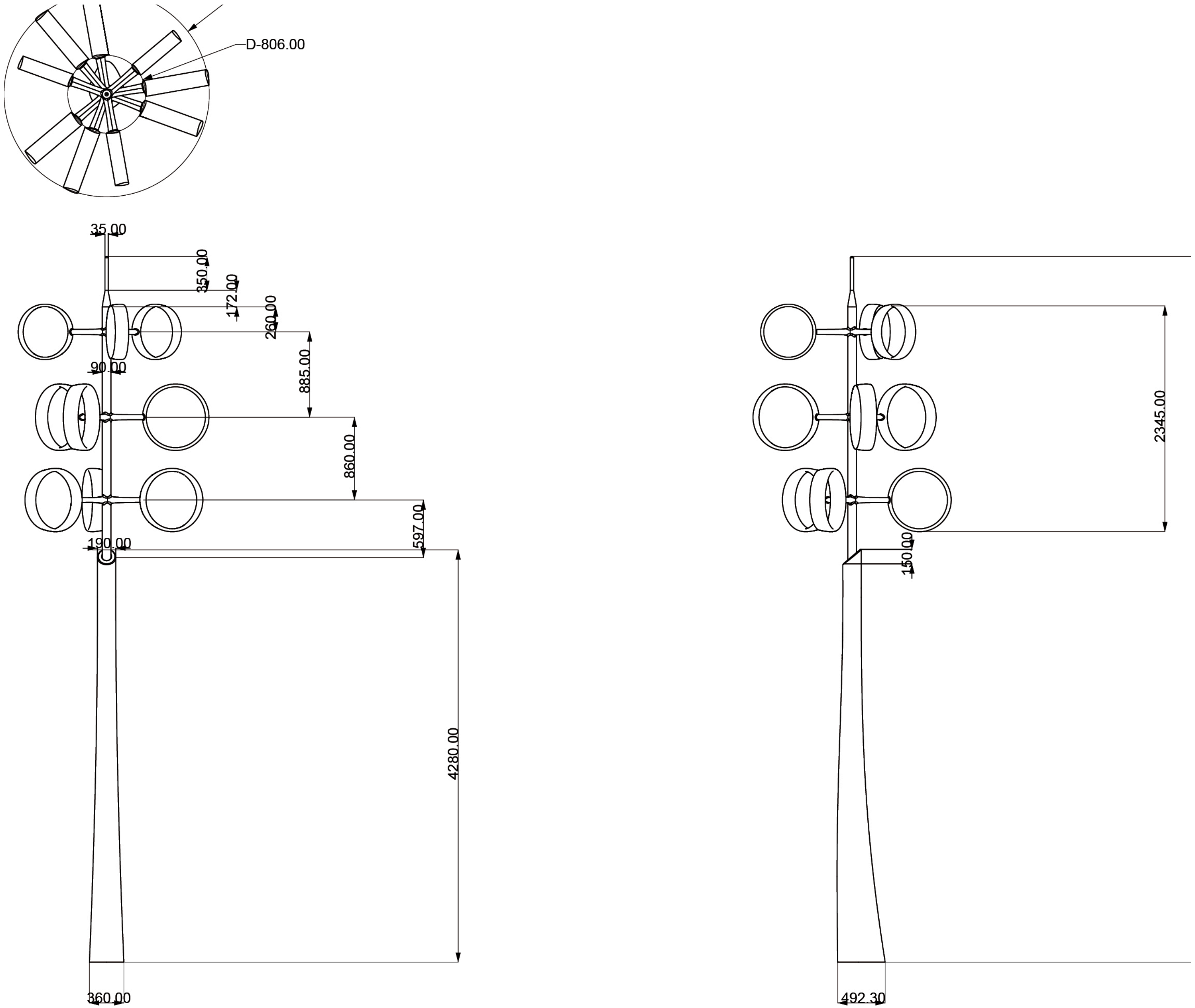

D-2308.00
D-806.00
35.00
350.00
172.00
90.00
233.00
720.00
821.00
765.00
492.00
200.00
4770.00
400.00
2921.00
168.50
572.00

Figure 7.14


D-806.00
35.00
350.00
172.00
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885.00
860.00
597.00
190.00
4280.00
360.00
2345.00
150.00
492.30

Figure 7.15

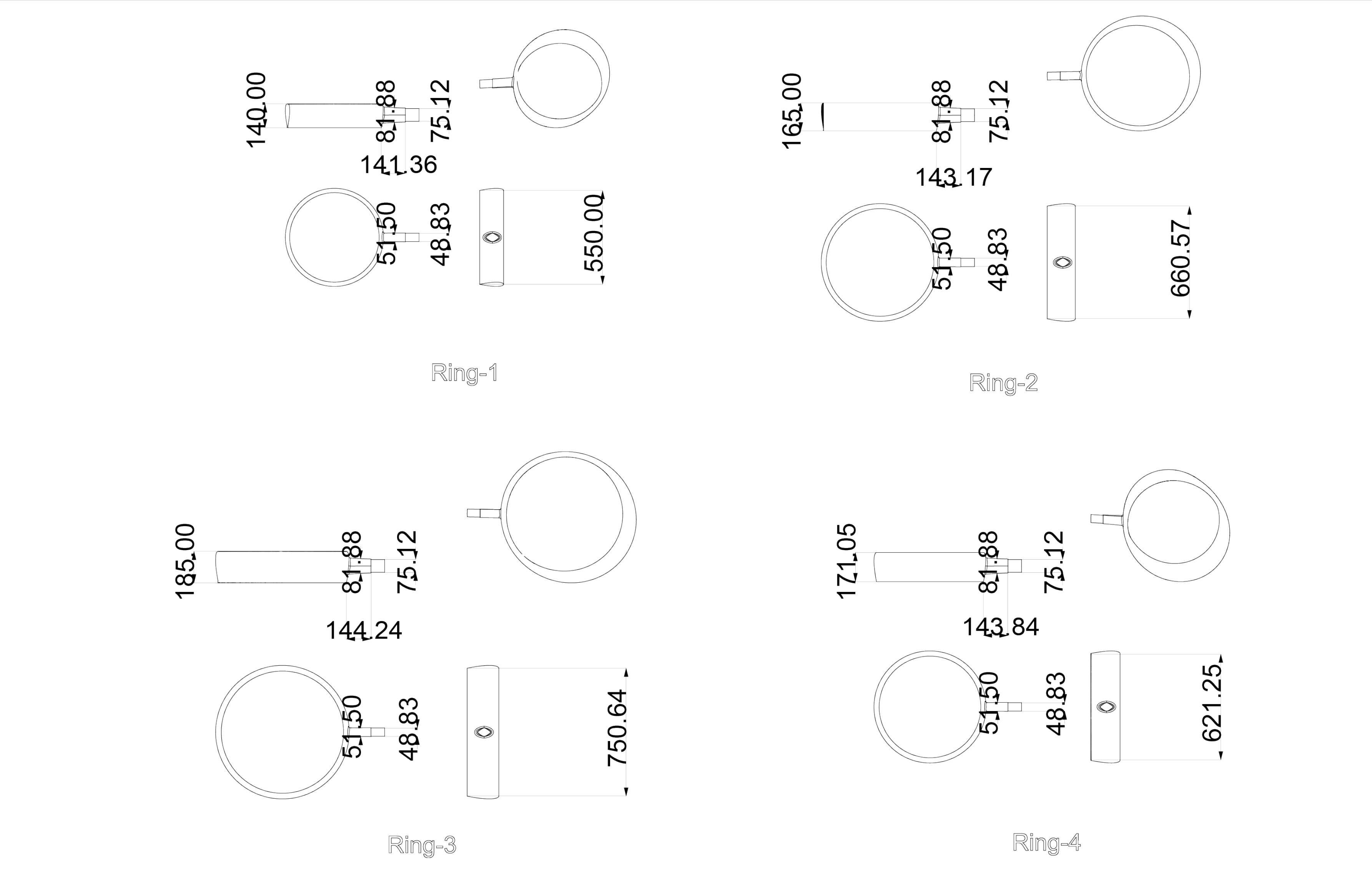
140.00
81.88
75.12
141.36
51.50
48.83
550.00
Ring-1
165.00
81.88
75.12
143.17
51.50
48.83
660.57
Ring-2
185.00
81.88
75.12
144.24
51.50
48.83
750.64
Ring-3
171.05
81.88
75.12
143.84
51.50
48.83
621.25
Ring-4

Figure 7.16

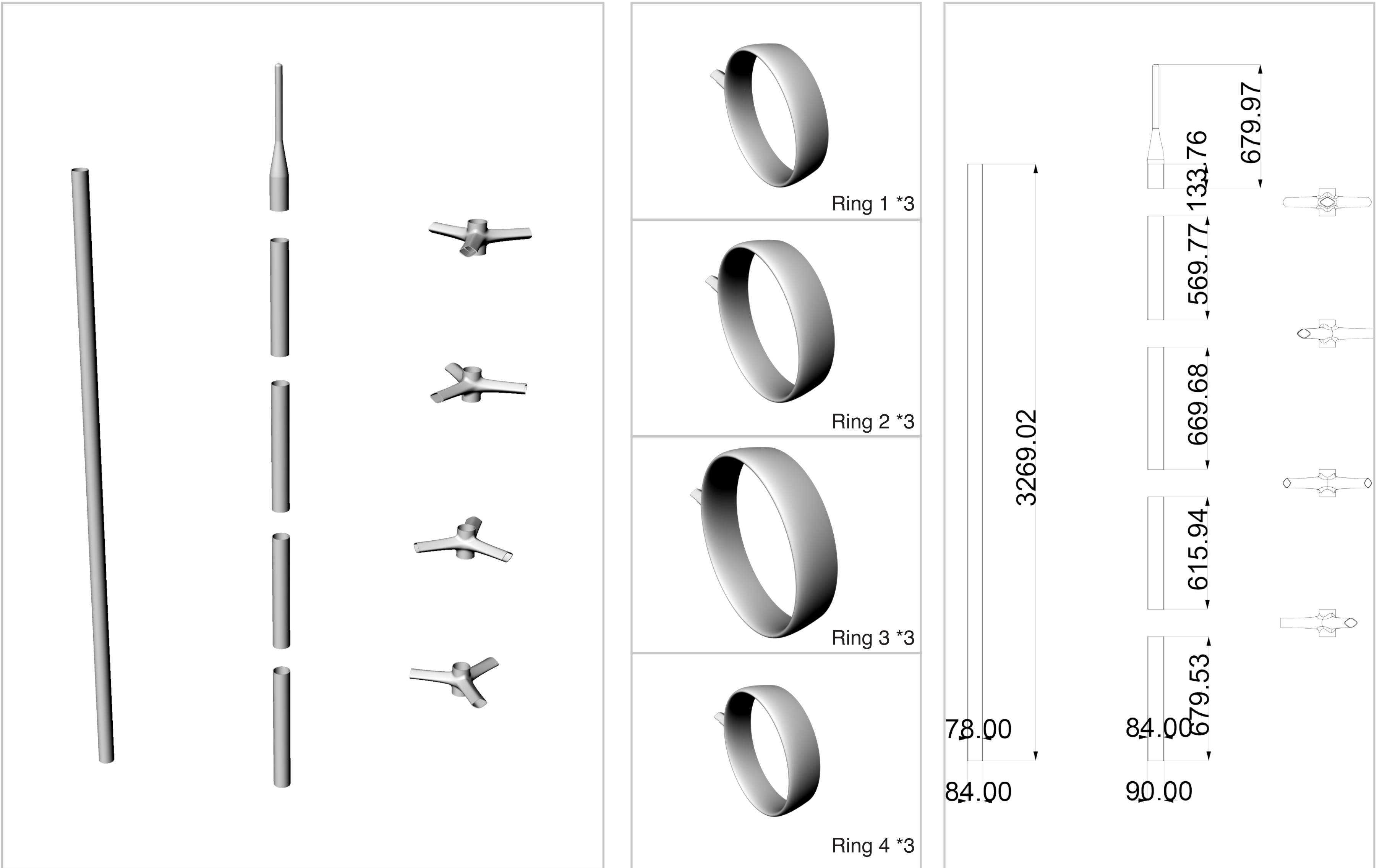
Ring 1 *3
Ring 2 *3
Ring 3 *3
Ring 4 *3
3269.02
78.00
84.00
679.97
133.76
569.77
669.68
615.94
679.53
84.00
90.00

Figure 7.17

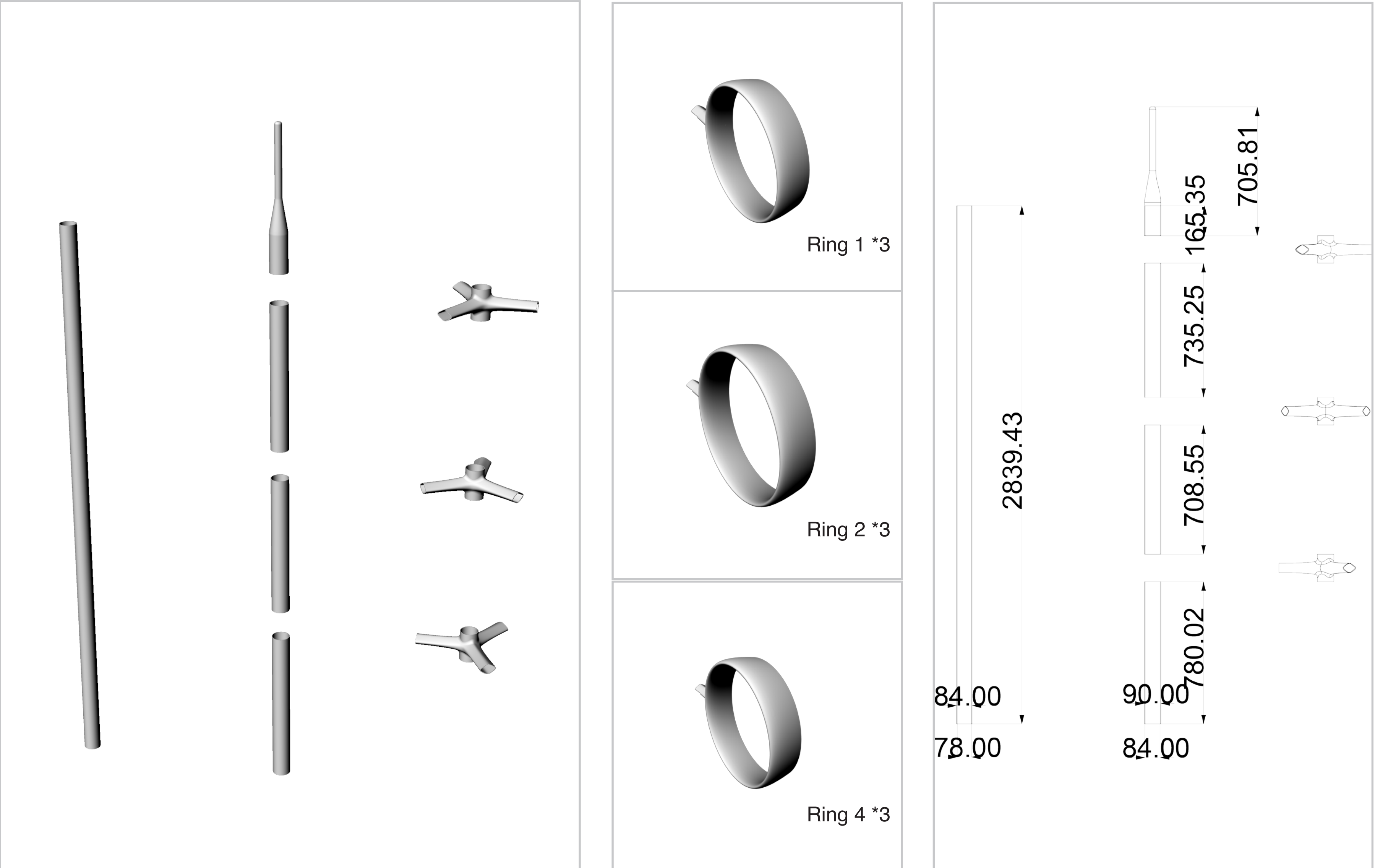
Ring 1 *3
Ring 2 *3
Ring 4 *3
705.81
165.35
735.25
708.55
780.02
2839.43
84.00
78.00
90.00
84.00

Figure 7.18

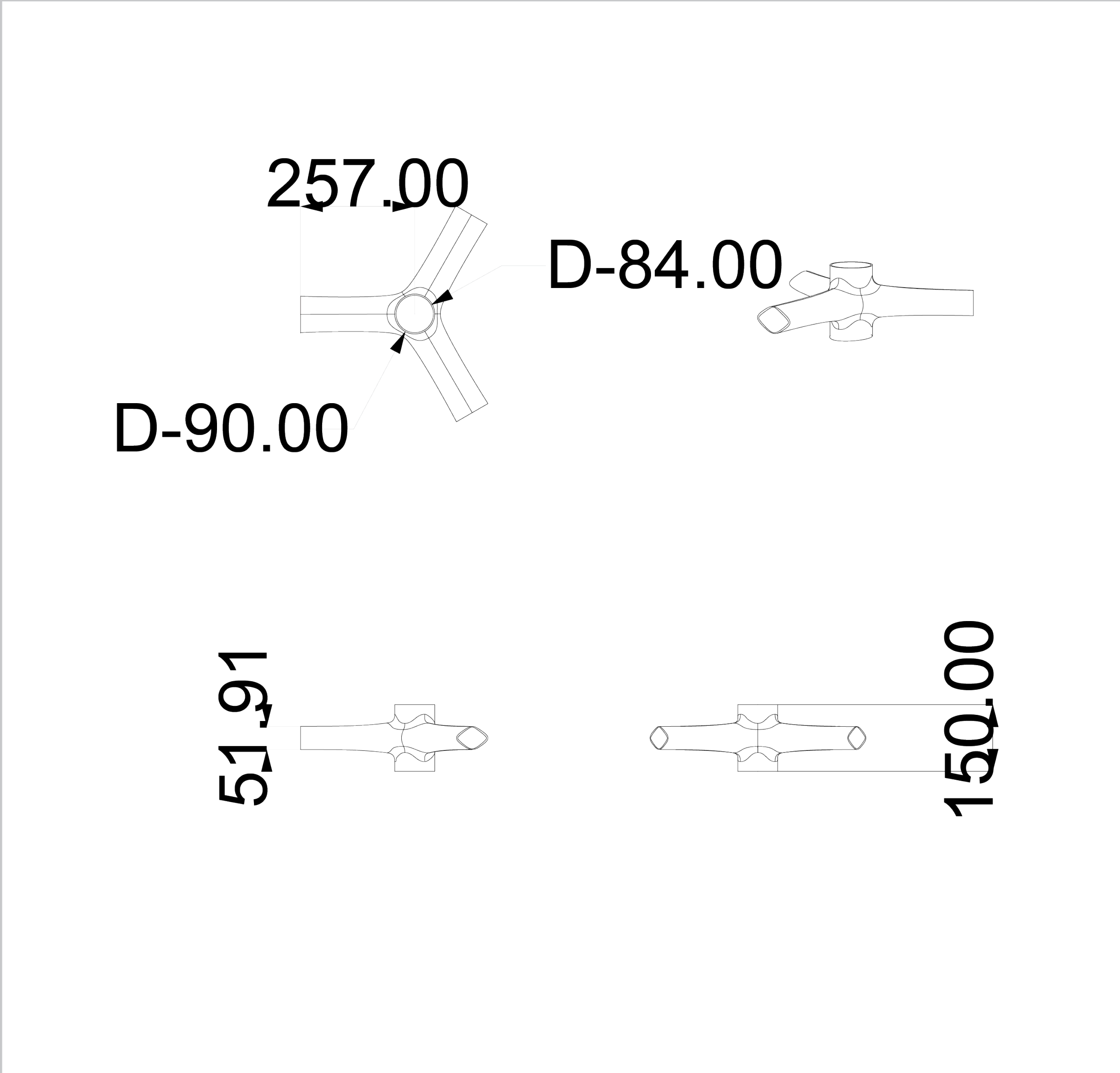

Figure 7.19

8. Final Concept Evaluation and Verification

The final concept evaluation and verification consist of two aspects: aerodynamics engineering aspects and design aspects. In this section, CFD simulation is used to prove the concept, and calculate the rated power output of the design. A target group feedback study is conducted to find out whether the design achieves the design visions.

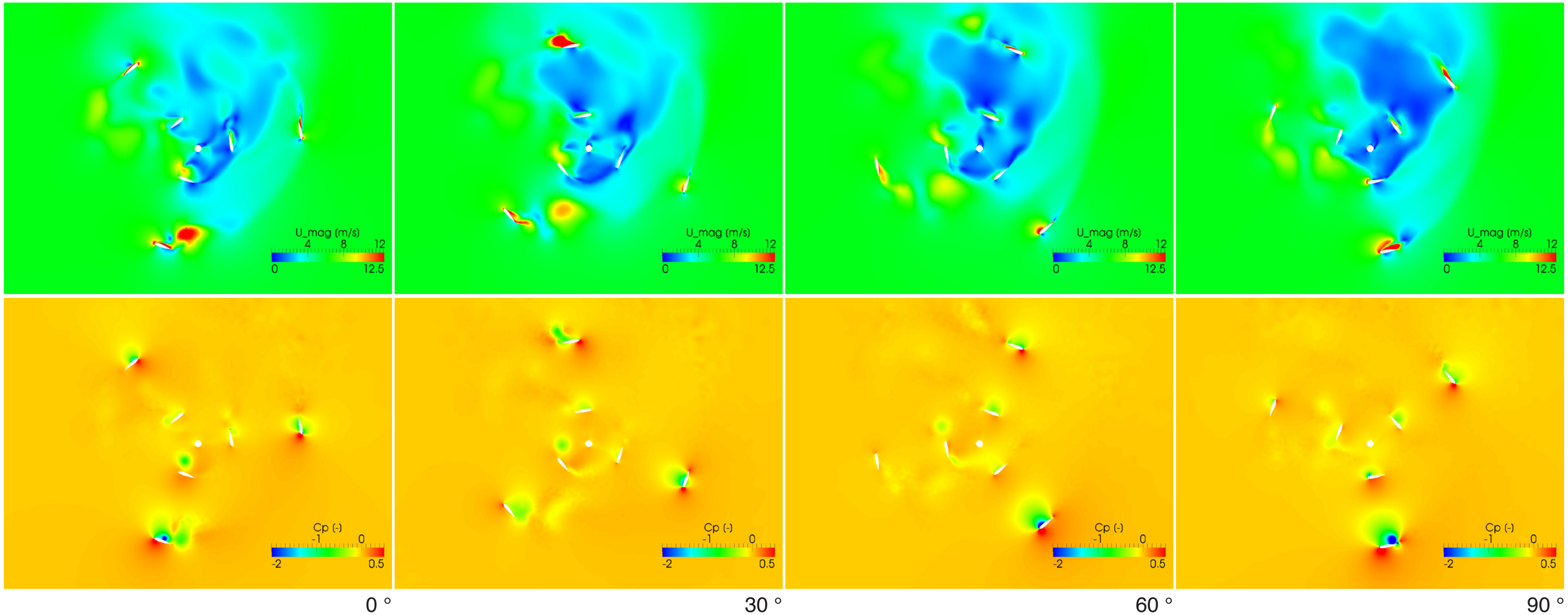

Figure 8.1

8.1 Aerodynamic engineering aspects:

8.1.1 CFD Simulation

Thanks to Tom Fahner and Roland Broers, aerodynamics engineers in Actiflow, CFD (Computational fluid dynamics) simulation is made to prove the design.

To simply the simulation, the three biggest rings are used for the simulation. If these three rings are proved to have some lift effects, the whole rotor will work. The rotation speed is designed to be low. In the simulation the tip speed ratio is 2, which is relatively small for NACA 0018. The wind speed in the simulation is 6 m/s, which is close to the anual mean wind speed in Scheveningen. So the tip speed is 12 m/s (V'). As the distance between outer edge of the rings and the axis is 1.050 m (R). So the rotation speed (V) is cal-

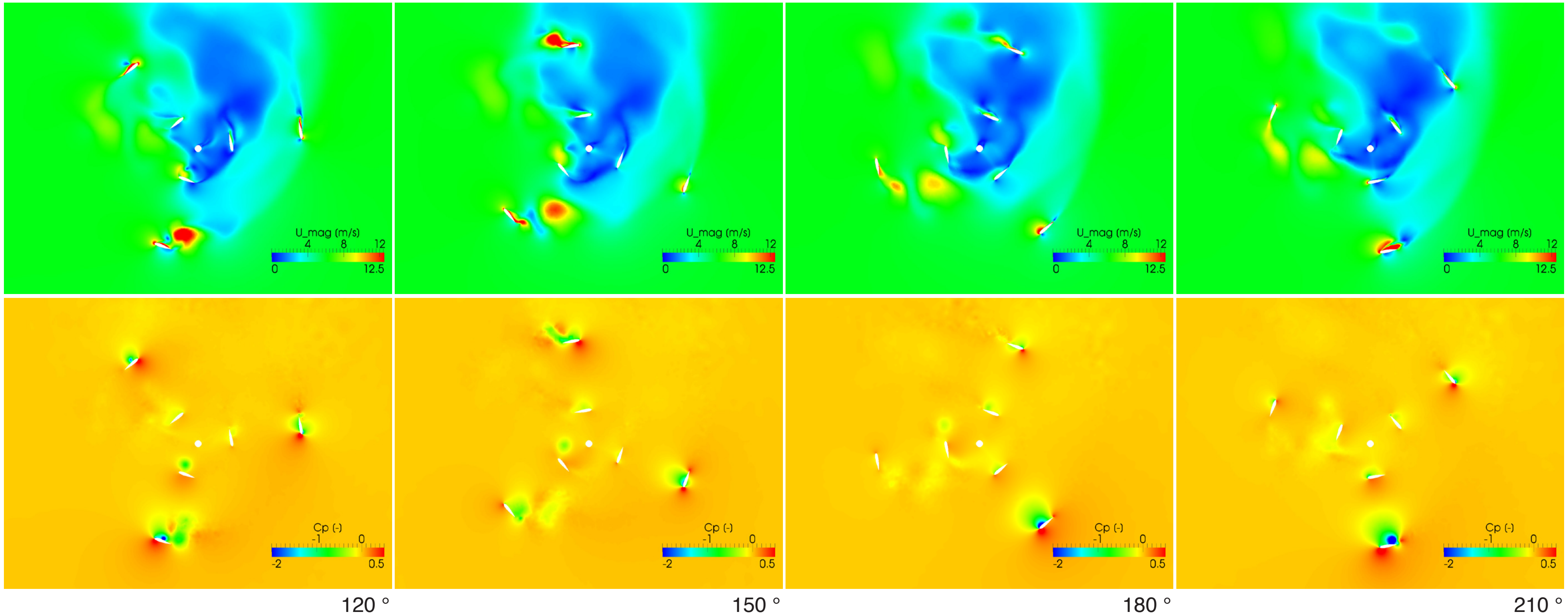

Figure 8.2

culated as follows:

V/60s* 1.050m*2*π = 12 m/s
V ≈ 109.66 rpm

In total, it simulates 0.943782 second of the rotation, from starting. In this period, the rotor rotates around 1.72 revolutions. Figure 8.1 and Figure 8.2 show some visualized data with different angles from the simulation. They are the section views of the rotor. The green background images indicate the air velocity. The red areas have high air velocities, while the blue areas have low air velocities. Air with higher velocity results in a lower pressure on the surface. The pressure coefficient is shown in the row of images with yellow background. The pressure coefficient is a dimensionless number which describes the relative pressures throughout a flow field in fluid dynamics. Every point in a fluid flow field has its own unique pressure coefficient, Cp. The relationship between the Cp (dimensionless coefficient) and the air velocity (dimensional numbers) is :

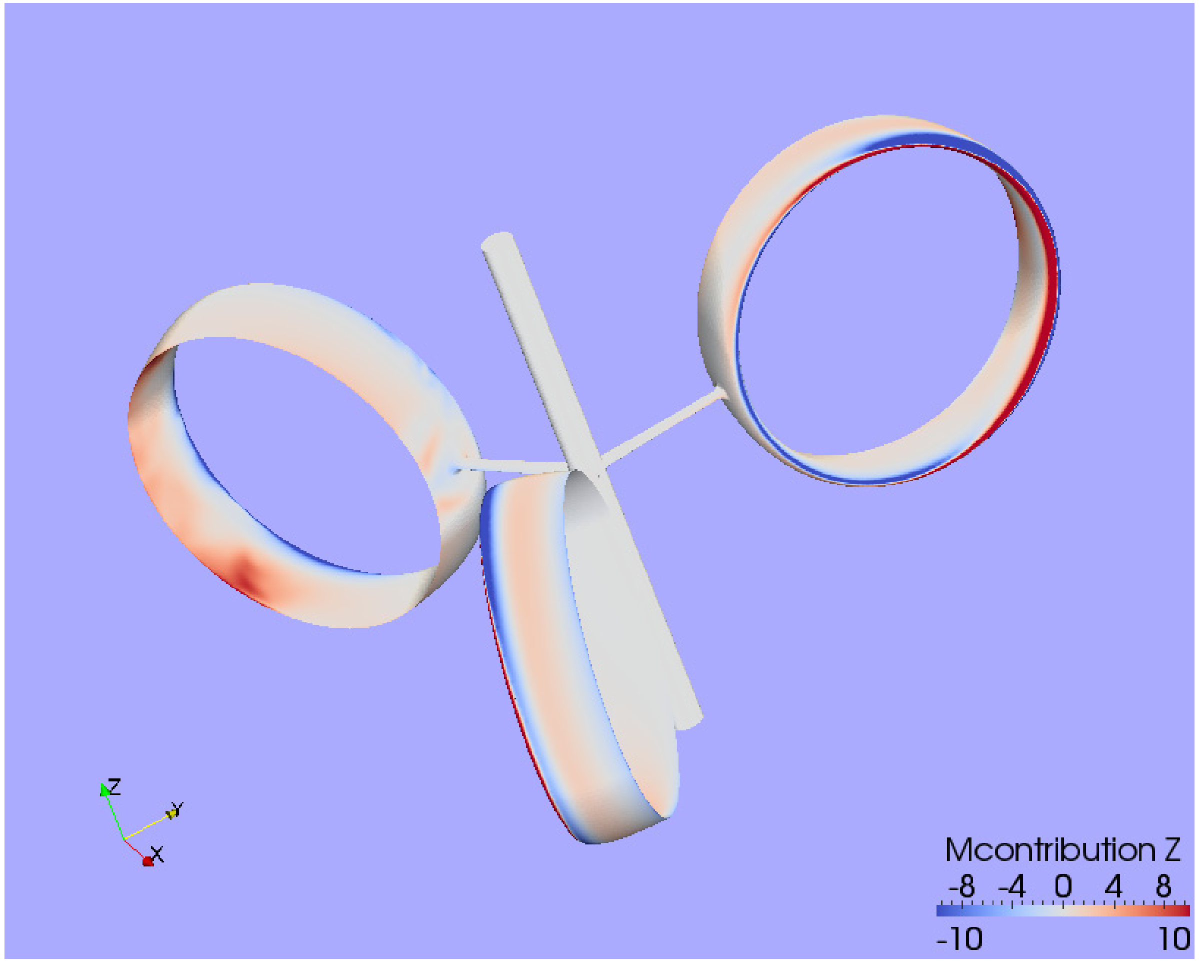

Figure 8.3

$$C_p = \frac{p - p_\infty}{\frac{1}{2}\rho_\infty V_\infty^2}$$

p is the pressure at the point at which pressure coefficient is being evaluated

p_∞ is the pressure in the freestream (i.e. remote from any disturbance)

ρ_∞ is the freestream fluid density (Air at sea level and 15 °C is 1.225 kg / m3)

V_∞ is the freestream velocity of the fluid, or the velocity of the body through the fluid [52]

When Cp is lower than 0, the local pressure is lower than the pressure of freestream. These areas are shown with yellow to blue color around the air foil in the images. The red areas have a higher pressure. These pressure differences creates moment to accelerate the rotation. The moment data is collected, which will be used in the following section to calculate the power output. The moment contribution of the rotor surface is visualized in Figure 8.3. This image is only one frame of the simulation.

It shows at a certain moment, which areas are giving positive or negative moment. The positive moment accelerates the rotation speed, which the negative moment decelerates the speed. In the image, the red areas have negative moment and the blue areas positive.

8.1.3 Rated Power Output Estimation

The moment data is collected in the CFD simulation. It is made into a chart shown in Figure 8.4 The relationship between the Power Output and the moment (dimensional numbers) is :

Power (W) = Moment (NM) * Rotation Speed (Rad/s)

The rotation speed in this case is '109.66 rpm / 60 * 2 π', 11.48 Rad/s. By integraling the power, the power output is 28.99 W.

The power out put is directly proportional to the frontal area, and directly proportional to wind speed cubed. The rated wind speed is decided to be 14 m/s, referring to the existing products.

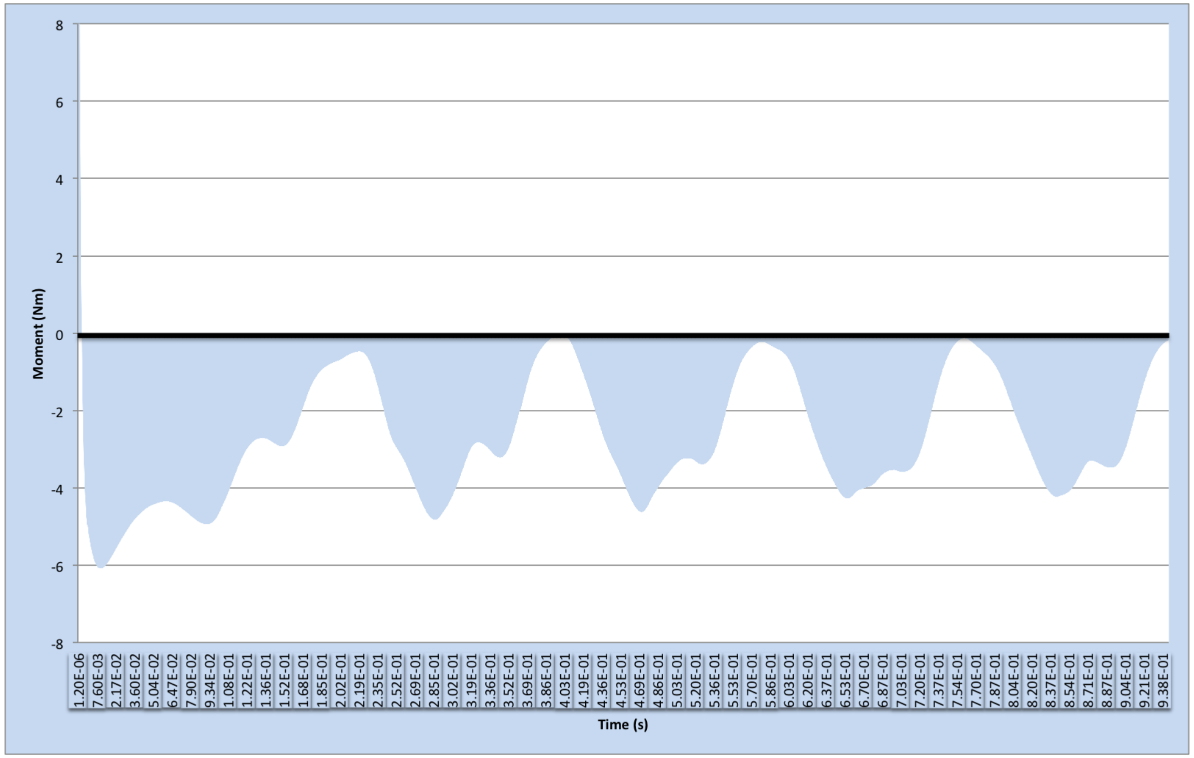

Figure 8.4

So the rated power output of these three rings is '28.99 * (14/6)^3' W, equals 368.28 W. The frontal area calculation of the whole rotor will not explained in detail here. The rated power output of the big rotor is around 1 kW for the current design, and small rotor 0.7 kW.

8.2 Design aspects

A target group feedback study is conducted to find out whether the design achieves the design visions. The interviewees in this study also gives some interesting suggestions to the design. Some of them are used in the recommendations in the last chapter.

8.2.1 Method

The feedback study takes place in Scheveningen. A semi-open interview method is used. The interviewees are chosen with different ages, both male and female.

The animation of the 'Wind Ring' and some renderings with the environment background are shown to the interviewees, not telling them what they are. Interviewees are asked to answer the following questions:

a. If there are objects like these standing on the Pier, will they draw your attention, and make you curious?
b. Do the shapes remind you some other things? It looks like what?

Then interviewees are told that they are wind turbines. Some existing urban wind turbines are shown. They are asked to make a rating:

c. Referring to the existing products, how much do you value the following characteristics for 'Wind Rings' in this context.

Outstanding:

Not at all				Very much
0	0	0	0	0

Attractive:

Not at all				Very much
0	0	0	0	0

Trigger Curiosity:

Not at all				Very much
0	0	0	0	0

Inspiring imagination:

Not at all				Very much
0	0	0	0	0

In the end interviewees is an open conversation about comments and recommendations.

8.2.2 Results and Conclusion

In the feedback study, there are 8 participants, one of them did not finish it because she need to catch up friends. Some of the interviewees do not come to the beach very often, some of them do. There is one person living next to the beach.

All of them are really curious about what the objects are. They like the moving animation much more than the static images on paper. All of them like the night effect very much. 7 out of the 8 people want to get closer to have a look.

For the imagination aspect (day dreaming), it depends on the person. Only three of the interviewees directly respond to the question about imagination. They mention that the shapes remind them the sea, the waves of the sea, some trees, some flowers, some fishes, the butterflies, the baking molds, and toilet paper. The rest interviewees think they are just nice design, but do not remind them any thing else.

Seven people finish the rating question, which is the last one. 3 of them think this design is 'very outstanding', 3 of them rate it 'outstanding' and 1 rate it 'neutral'. 5 interviewees think it is very attractive, 1 attractive and 1 neutral. 5 interviewees think it can trigger curiosity very much. For 'inspiring imagination' only 1 person rates it 'very much', 2 'inspiring', 2 'neutral' and 2 'not much'.

There are some quotes from the interviewees as follows:

'It's a new design! Looks like a butter fly, the organic shape, also like waves, the sea.'

'It is an art piece, like a sculpture.'

'I like the animation. The images are only ok, but the animation is cool.'

'Wow! So beautiful in dark.'

'I like the effect in dark.'

To conclude, the interviewees give positive feedbacks to the design, in terms of outstanding, attractive, and arousing curiosity. However, the vision of inspiring day dreaming is not very well achieved as expected. During the feedback study, most people are more willing to know what it is and what is the function of it, rather than to imagine something else. Someone of them says, 'it is just what it is.' It depends on the person whether he or she is imaginative and willing to imagine something.

9. Recommendations

9.1 The Masts and Generators

The masts should be further engineered to for both structural and productional reasons. In this project, only initial ideas are created for the masts design.

The generator for the 'backup' concept can be bought from the market directly. There is one generator found very suitable and high quality for this design. It is PMGO-1K-200, from the Denmark company DVE. The datasheet can be found in Appendix L.

For the more aesthetics concerned concept, the generator needs to be designed specially. The shape should fit in the size of the mast. It needs to be long with a small diameter. As generators can be made from some motor. The submersible motor (Figure 9.1) can be an option for developing the generator for this design. However normally the rated speed of a submersible motor is very high, up to 3800 rpm. So a gear box is necessary. Another option is design a completely new generator specially for this concept.

9.2 Rotor improvement

The rotor needs to be optimized, in terms of aerodynamic performance. Currently, the air foil type and angles of the air foil can be used as a starting point of optimization. As seen from the simulation result, some areas (close to the axis) are not contributing much. The optimized air foil shapes and angles of the air foil need to be investigated. With a optimized design, the performance of the rotor can be improved up to 50%.

In this design, the rings can also create some special effect. There might be some bending and squeezing effects on the air flow, passing through the rings. This effects are unconventional in the field of wind turbines engineering. It is unknown now whether they are beneficial

Figure 9.1

for the performance. It will be interesting to looking into these effects in the optimization phase.

9.3 Customization

The rotors of ‘Wind Rings’ are modular designs. It provides possibility of customization, which is very unique in wind turbine designs. It can be used as a selling point for the business. The buyers can design their own unique ‘Wind Rings’ for their own purposes, e.g. branding.

9.4 Need to rotate

From the feedback study, it is known that people like the turbines rotating much more than standing still. To be more acceptable and appreciated, the ‘Wind Rings’ need to keep rotating. Even when there is no wind, they need to be driven to rotate slowly, probably 5 rpm.

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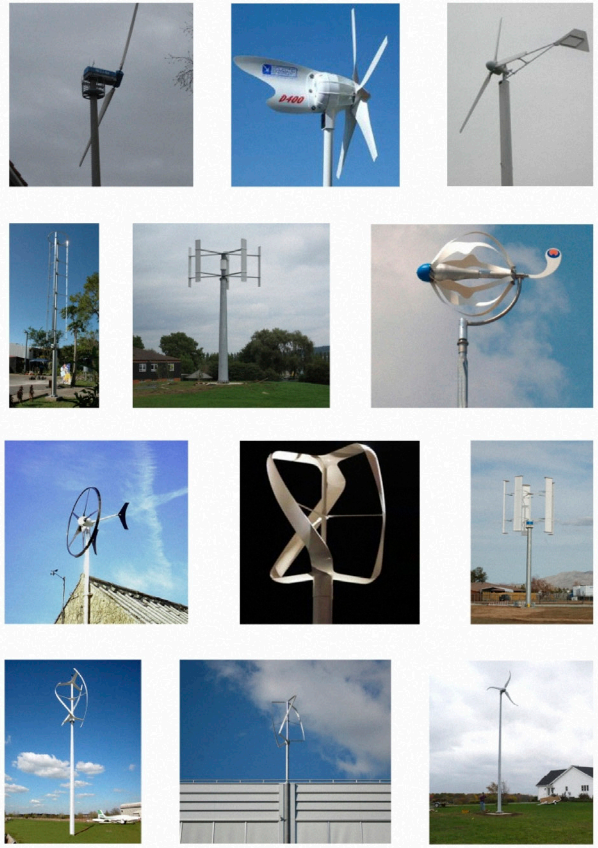
Semantic words to describe urban wind turbines & Visual importance of different components

Page One



Images above show some examples of existing urban wind turbine (UWT). Please have a look, to get a general idea of what UWT is and how it looks.

1. In the following pairs of adjectives, which of them would you like to use to describe such a product base on the appearance? (e.g. this UWT is very elegant or ungraceful.) You can select up to 15 pairs. *

- ☐ Aggressive - Passive
- ☐ Expensive - Cheap
- ☐ Trendy - Classic
- ☐ Outstanding - Common
- ☐ Decorated - Simple
- ☐ Elegant - Graceless
- ☐ Masculine - Feminine
- ☐ Formal - Informal
- ☐ Fragile - Robust
- ☐ Functional - Ornamental
- ☐ Friendly - Frightening
- ☐ Futuristic - Nostalgic
- ☐ High-tech - Low-tech
- ☐ Humorous - Serious
- ☐ Mature - Youthful
- ☐ Restrained - Extravagant
- ☐ Temporary - Permanent
- ☐ Clever - Silly
- ☐ Sexy - Dull
- ☐ Kind - Unkind
- ☐ Narcissistic - Humble
- ☐ Extrovert - Introvert
- ☐ Energetic - Unenergetic
- ☐ Violent - Gentle
- ☐ Dynamic - Static
- ☐ Strong - Weak
- ☐ Avant-garde - Conservative
- ☐ Harmonious - Discordant
- ☐ Attractive - Unattractive
- ☐ Pleasurable - Boring

2. If you think some other words can be used to better describe this product, please write them down in the following text box. (unnecessary to be a pair of

antonym)

Next

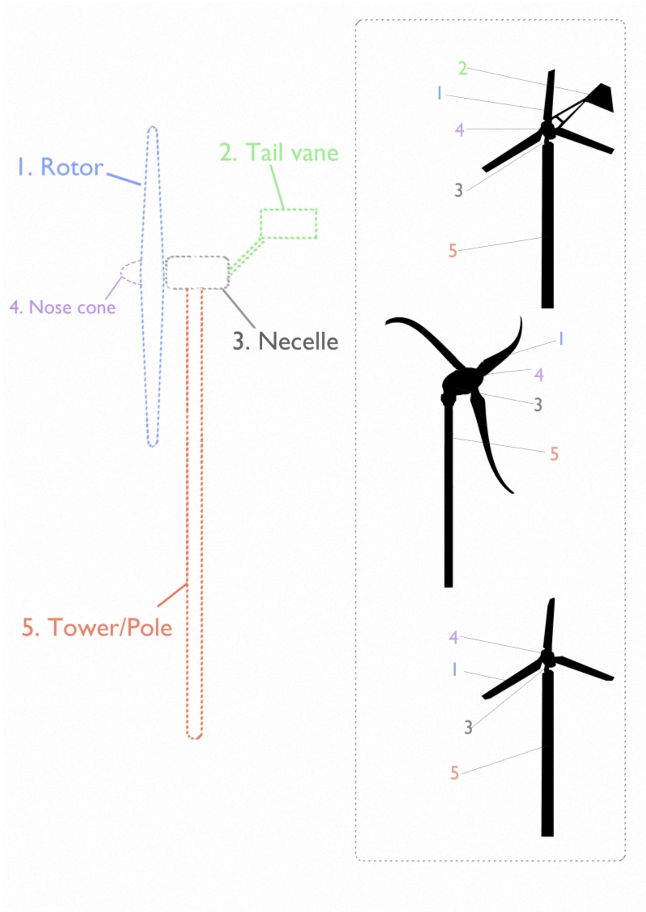
0%

Online Surveys powered by SurveyGizmo

Take a look under the hood

Semantic words to describe urban wind turbines & Visual importance of different components

New Page



This image shows normal architecture of Horizontal Axis UWTs. Different elements have different levels of contribution towards the overall appearance. In the following questions, different elements are listed to value their importance respectively. Please choose how important do you think the element is, for a Horizontal Axis UWT's visual appearance.

3. Rotor *

Not important at all						Very important
○	○	○	○	○	○	○

4. Tail vane *

Not important at all						Very important
○	○	○	○	○	○	○

5. Necelle *

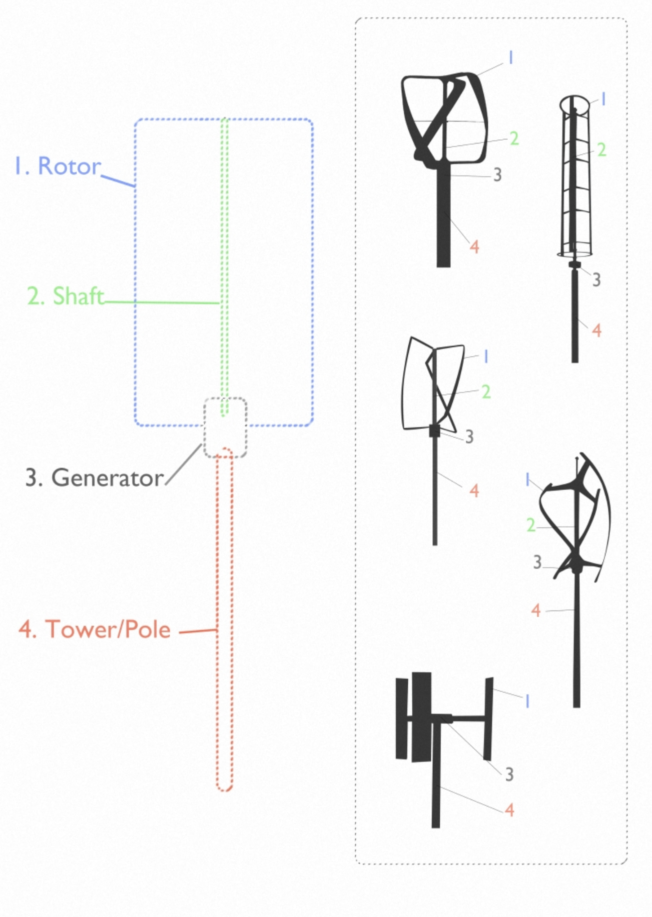
Not important at all						Very important
○	○	○	○	○	○	○

6. Nose cone *

Not important at all						Very important
○	○	○	○	○	○	○

7. Tower/ Pole *

Not important at all						Very important
○	○	○	○	○	○	○



This image shows normal architecture of Vertical Axis UWTs. Different elements have different levels of contribution towards the overall appearance. In the following questions, different elements are listed to value their importance respectively. Please choose how important do you think the element is, for a Vertical Axis UWT's visual appearance.

8. Rotor *

Not important at all						Very important
○	○	○	○	○	○	○

9. Shaft *

Not important at all						Very important
○	○	○	○	○	○	○

10. Generator *

Not important at all						Very important
○	○	○	○	○	○	○

11. Tower/ Pole *

Not important at all						Very important
○	○	○	○	○	○	○

Back Submit

50%

Semantic differential scales

Page One

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *

Expensive ○ ○ ○ ○ ○ ○ ○ Cheap

It looks... *

Trendy ○ ○ ○ ○ ○ ○ ○ Classic

It looks... *

Outstanding ○ ○ ○ ○ ○ ○ ○ Common

It looks... *

Elegant ○ ○ ○ ○ ○ ○ ○ Graceless

It looks... *

Fragile ○ ○ ○ ○ ○ ○ ○ Robust

It looks... *

Functional ○ ○ ○ ○ ○ ○ ○ Ornamental

It looks... *

High-tech ○ ○ ○ ○ ○ ○ ○ Low-tech

It looks... *

Energetic ○ ○ ○ ○ ○ ○ ○ Unenergetic

It looks... *

Dynamic ○ ○ ○ ○ ○ ○ ○ Static

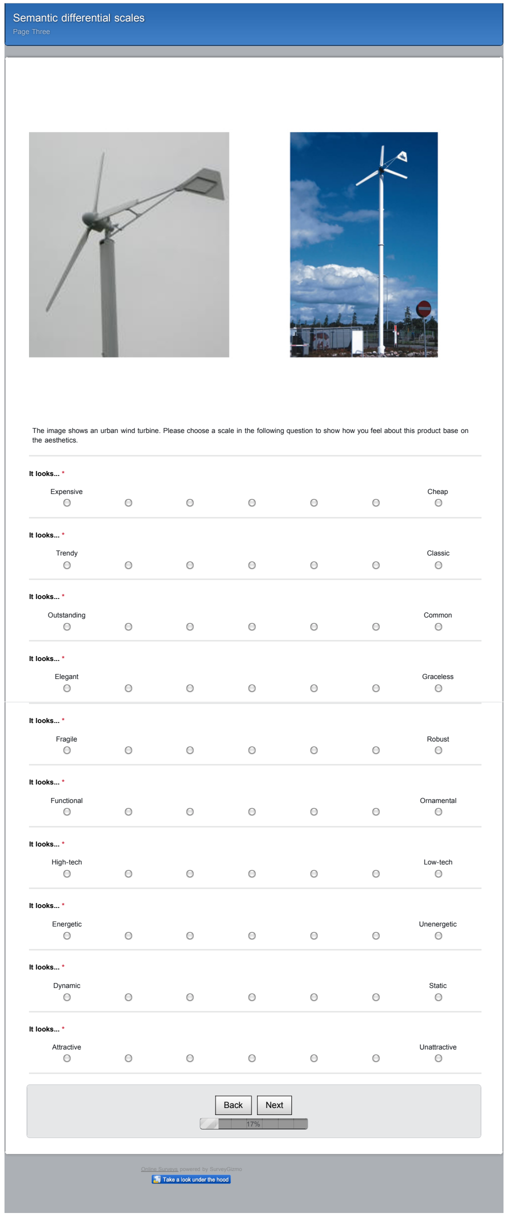
It looks... *

Attractive ○ ○ ○ ○ ○ ○ ○ Unattractive

Next

0%

Semantic differential scales
Page Two
The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.
It looks... *
Expensive
Cheap
Trendy
Classic
Outstanding
Common
Elegant
Graceless
Fragile
Robust
Functional
Ornamental
High-tech
Low-tech
Energetic
Unenergetic
Dynamic
Static
Attractive
Unattractive
Back
Next



Semantic differential scales
Page Three
The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.
It looks... *
Expensive
Cheap
Trendy
Classic
Outstanding
Common
Elegant
Graceless
Fragile
Robust
Functional
Ornamental
High-tech
Low-tech
Energetic
Unenergetic
Dynamic
Static
Attractive
Unattractive
Back
Next

Semantic differential scales
Page Four
The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.
It looks... *
Expensive
Cheap
Trendy
Classic
Outstanding
Common
Elegant
Graceless
Fragile
Robust
Functional
Ornamental
High-tech
Low-tech
Energetic
Unenergetic
Dynamic
Static
Attractive
Unattractive
Back
Next

Semantic differential scales
Page Five

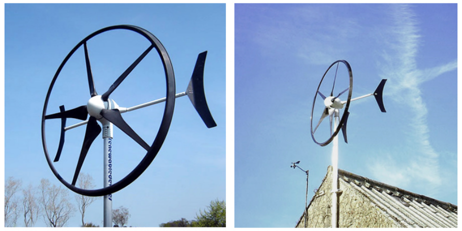
The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *		
It looks... *	Expensive	Cheap
It looks... *	Trendy	Classic
It looks... *	Outstanding	Common
It looks... *	Elegant	Graceless
It looks... *	Fragile	Robust
It looks... *	Functional	Ornamental
It looks... *	High-tech	Low-tech
It looks... *	Energetic	Unenergetic
It looks... *	Dynamic	Static
It looks... *	Attractive	Unattractive

Back Next

33%

Semantic differential scales
Page Six



The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *		
It looks... *	Expensive	Cheap
It looks... *	Trendy	Classic
It looks... *	Outstanding	Common
It looks... *	Elegant	Graceless
It looks... *	Fragile	Robust
It looks... *	Functional	Ornamental
It looks... *	High-tech	Low-tech
It looks... *	Energetic	Unenergetic
It looks... *	Dynamic	Static
It looks... *	Attractive	Unattractive

Back Next

42%

Semantic differential scales
Page Seven

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *		
It looks... *	Expensive	Cheap
It looks... *	Trendy	Classic
It looks... *	Outstanding	Common
It looks... *	Elegant	Graceless
It looks... *	Fragile	Robust
It looks... *	Functional	Ornamental
It looks... *	High-tech	Low-tech
It looks... *	Energetic	Unenergetic
It looks... *	Dynamic	Static
It looks... *	Attractive	Unattractive

Back Next

50%

Semantic differential scales
Page Eight

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *						
Expensive	○	○	○	○	○	Cheap
Trendy	○	○	○	○	○	Classic
Outstanding	○	○	○	○	○	Common
Elegant	○	○	○	○	○	Graceless
Fragile	○	○	○	○	○	Robust
Functional	○	○	○	○	○	Ornamental
High-tech	○	○	○	○	○	Low-tech
Energetic	○	○	○	○	○	Unenergetic
Dynamic	○	○	○	○	○	Static
Attractive	○	○	○	○	○	Unattractive

Back Next

58%

Semantic differential scales
Page Nine

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *						
Expensive	○	○	○	○	○	Cheap
Trendy	○	○	○	○	○	Classic
Outstanding	○	○	○	○	○	Common
Elegant	○	○	○	○	○	Graceless
Fragile	○	○	○	○	○	Robust
Functional	○	○	○	○	○	Ornamental
High-tech	○	○	○	○	○	Low-tech
Energetic	○	○	○	○	○	Unenergetic
Dynamic	○	○	○	○	○	Static
Attractive	○	○	○	○	○	Unattractive

Back Next

67%

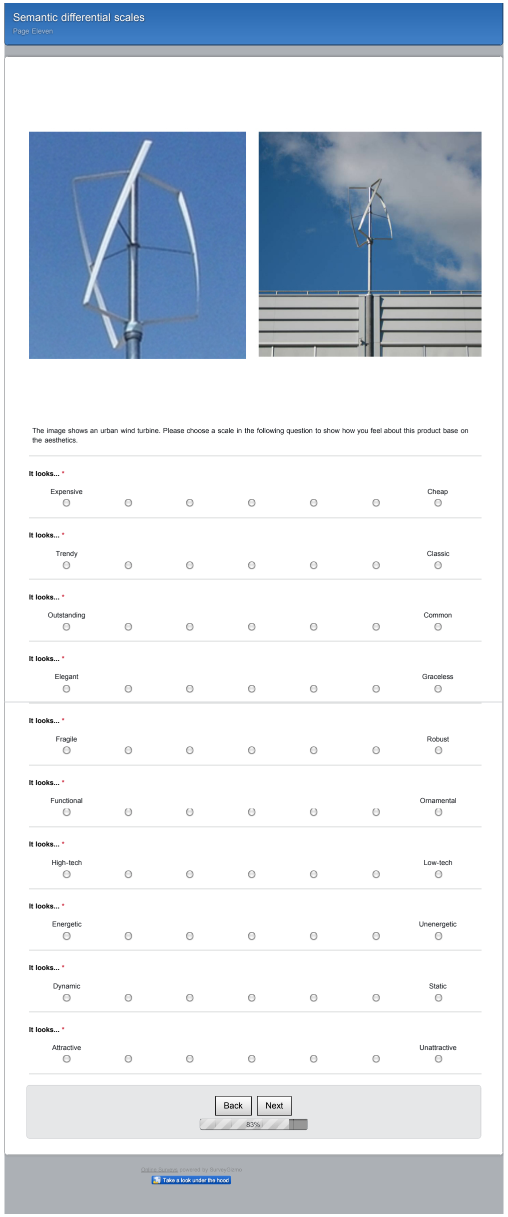
Semantic differential scales
Page Ten

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *						
Expensive	○	○	○	○	○	Cheap
Trendy	○	○	○	○	○	Classic
Outstanding	○	○	○	○	○	Common
Elegant	○	○	○	○	○	Graceless
Fragile	○	○	○	○	○	Robust
Functional	○	○	○	○	○	Ornamental
High-tech	○	○	○	○	○	Low-tech
Energetic	○	○	○	○	○	Unenergetic
Dynamic	○	○	○	○	○	Static
Attractive	○	○	○	○	○	Unattractive

Back Next

75%



Semantic differential scales
Page Eleven

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *						
Expensive						Cheap
Trendy						Classic
Outstanding						Common
Elegant						Graceless
Fragile						Robust
Functional						Ornamental
High-tech						Low-tech
Energetic						Unenergetic
Dynamic						Static
Attractive						Unattractive

Back Next
83%

Online Surveys powered by SurveyGizmo
Take a look under the hood

Semantic differential scales
Page Twelve

The image shows an urban wind turbine. Please choose a scale in the following question to show how you feel about this product base on the aesthetics.

It looks... *						
Expensive						Cheap
Trendy						Classic
Outstanding						Common
Elegant						Graceless
Fragile						Robust
Functional						Ornamental
High-tech						Low-tech
Energetic						Unenergetic
Dynamic						Static
Attractive						Unattractive

Back Submit
92%

Online Surveys powered by SurveyGizmo
Take a look under the hood

Appendix C - - Result of Semantics Analysis Part 1a

Adjectives pairs	Times of being selected	Percentage	Adjectives pairs	Times of being selected	Percentage
Aggressive - Passive	6	21.43%	*Restrained - Extravagant*	2	7.14%
Expensive - Cheap	14	50.00%	*Temporary - Permanent*	7	25.00%
Trendy - Classic	16	57.14%	*Clever - Silly*	3	10.71%
Outstanding - Common	12	42.86%	*Sexy - Dull*	9	32.14%
Decorated - Simple	10	35.71%	*Kind - Unkind*	4	14.29%
Elegant - Graceless	14	50.00%	*Narcissistic - Humble*	1	3.57%
Masculine - Feminine	8	28.57%	*Extrovert - Introvert*	5	17.86%
Formal - Informal	2	7.14%	*Energetic - Unenergetic*	13	46.43%
Fragile - Robust	16	57.14%	*Violent - Gentle*	6	21.43%
Functional - Ornamental	12	42.86%	*Dynamic - Static*	14	50.00%
Friendly - Frightening	5	17.86%	*Strong - Weak*	10	35.71%
Futuristic - Nostalgic	9	32.14%	*Avant-garde - Conservative*	7	25.00%
High-tech - Low-tech	19	67.86%	*Harmonious - Discordant*	7	25.00%
Humorous - Serious	2	7.14%	*Attractive - Unattractive*	13	46.43%
Mature - Youthful	2	7.14%	*Pleasurable - Boring*	8	28.57%
Other words suggested by responders	Organic - geometric, figurative - abstract, moderate - sharp, weak, scenery, modern, scientific, biomimetic, delightful-depressed				

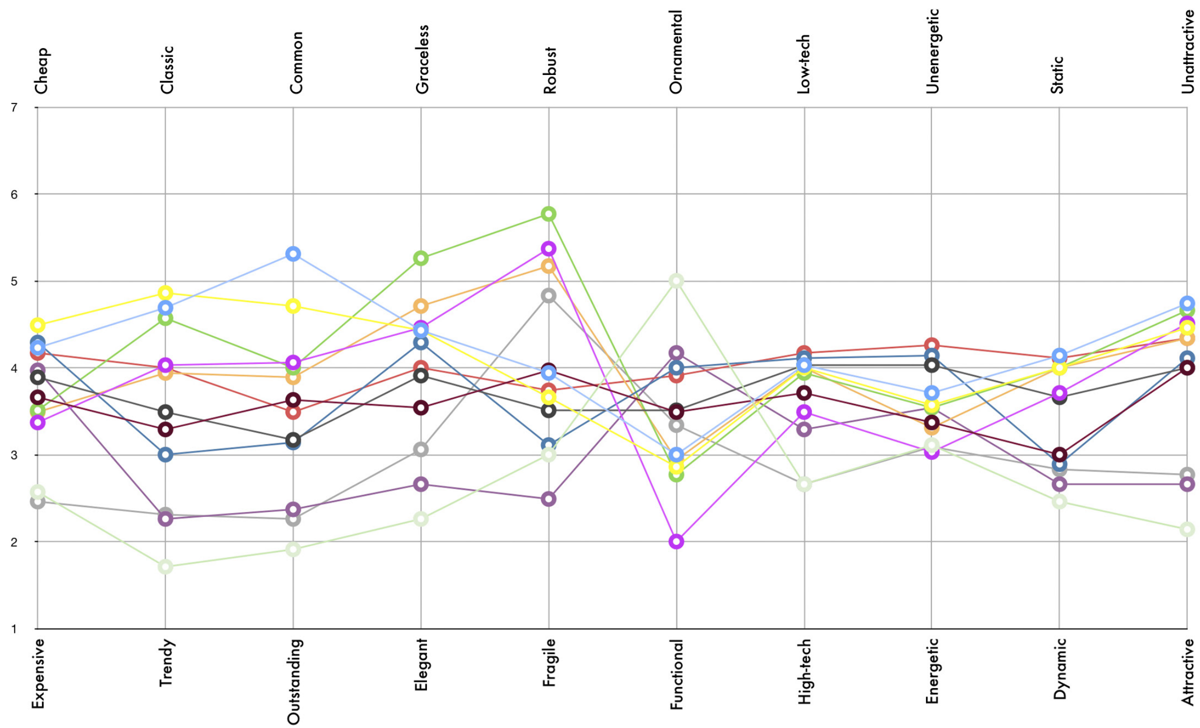
Appendix D - Result of Semantics Analysis Part 1b

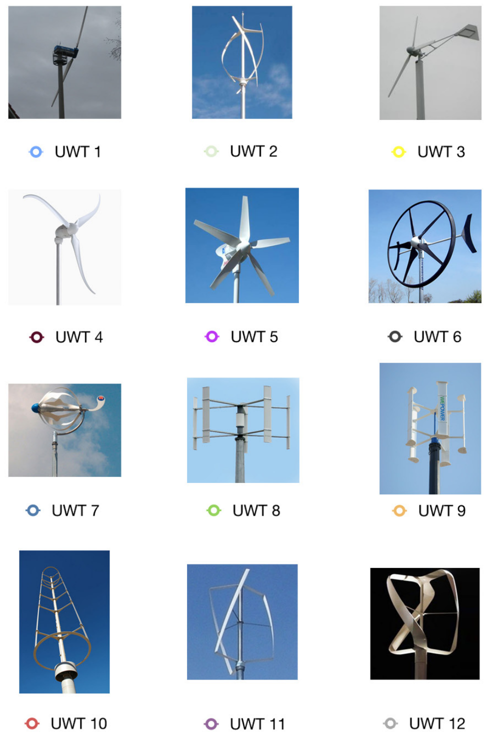
Visual importance of different components (HAWT)					
Response ID	Rotor	Tail vane	Necelle	Nose cone	Tower/ Pole
1	6	4	2	2	2
2	5	4	4	4	5
3	7	2	7	4	4
4	7	6	7	7	7
5	7	2	1	5	5
6	7	3	4	5	5
7	5	1	1	4	6
8	7	7	6	6	6
9	6	2	7	6	4
10	6	6	6	3	4
11	7	4	2	5	6
12	7	2	5	6	7
13	7	6	3	4	4
14	7	2	6	5	6
15	6	7	3	3	4
16	7	2	5	5	5
17	7	4	6	6	3
18	7	5	7	7	6
19	7	4	7	3	4
20	5	3	4	5	5
21	6	4	3	2	6
22	7	5	3	6	6
23	7	4	4	6	4
24	6	2	2	2	7
25	6	7	3	2	1
26	7	2	2	6	2
27	6	2	2	4	6
28	7	1	4	5	7
Average score	6.5	3.678571428571	4.142857142857	4.571428571429	4.89285714286

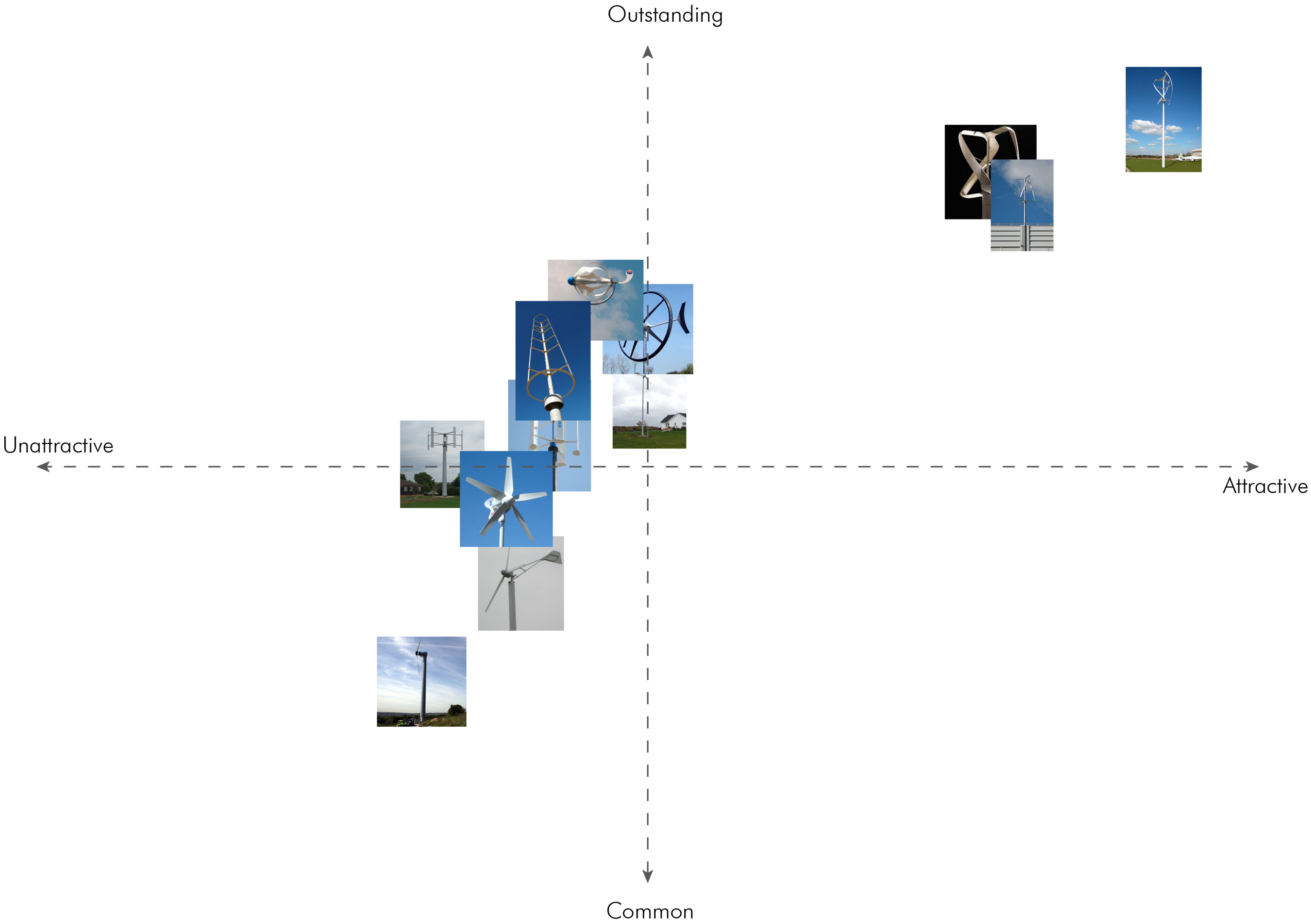
Visual importance of different components (VAWT)				
Response ID	Rotor	Shaft	Generator	Tower/ Pole
1	6	4	3	2
2	7	5	4	4
3	7	2	3	2
4	7	7	7	7
5	7	2	2	3
6	7	5	4	4
7	5	4	4	3
8	4	5	6	6
9	7	7	3	4
10	5	5	5	4
11	7	7	5	6
12	7	5	7	7
13	7	3	3	3
14	6	7	6	5
15	7	4	5	5
16	6	6	5	6
17	7	4	5	5
18	7	7	7	6
19	2	3	7	4
20	5	5	3	5
21	6	4	4	5
22	6	6	5	5
23	6	5	4	4
24	6	5	2	6
25	7	2	2	1
26	6	4	4	2
27	5	6	6	6
28	7	6	4	7
Average score	6.142857142857	4.821428571429	4.46428571429	4.535714285714

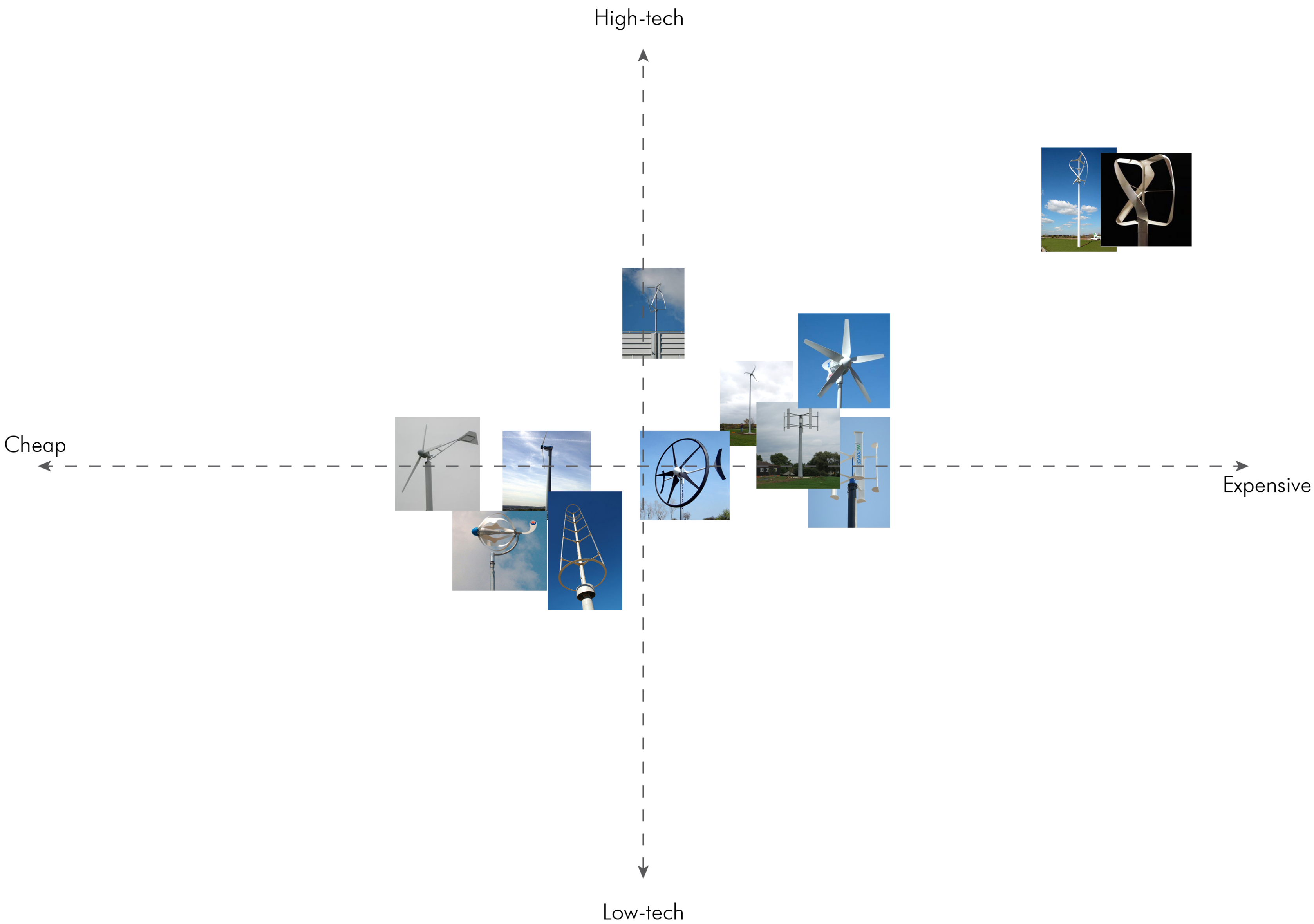
Appendix E - Result of Semantics Analysis Part 2

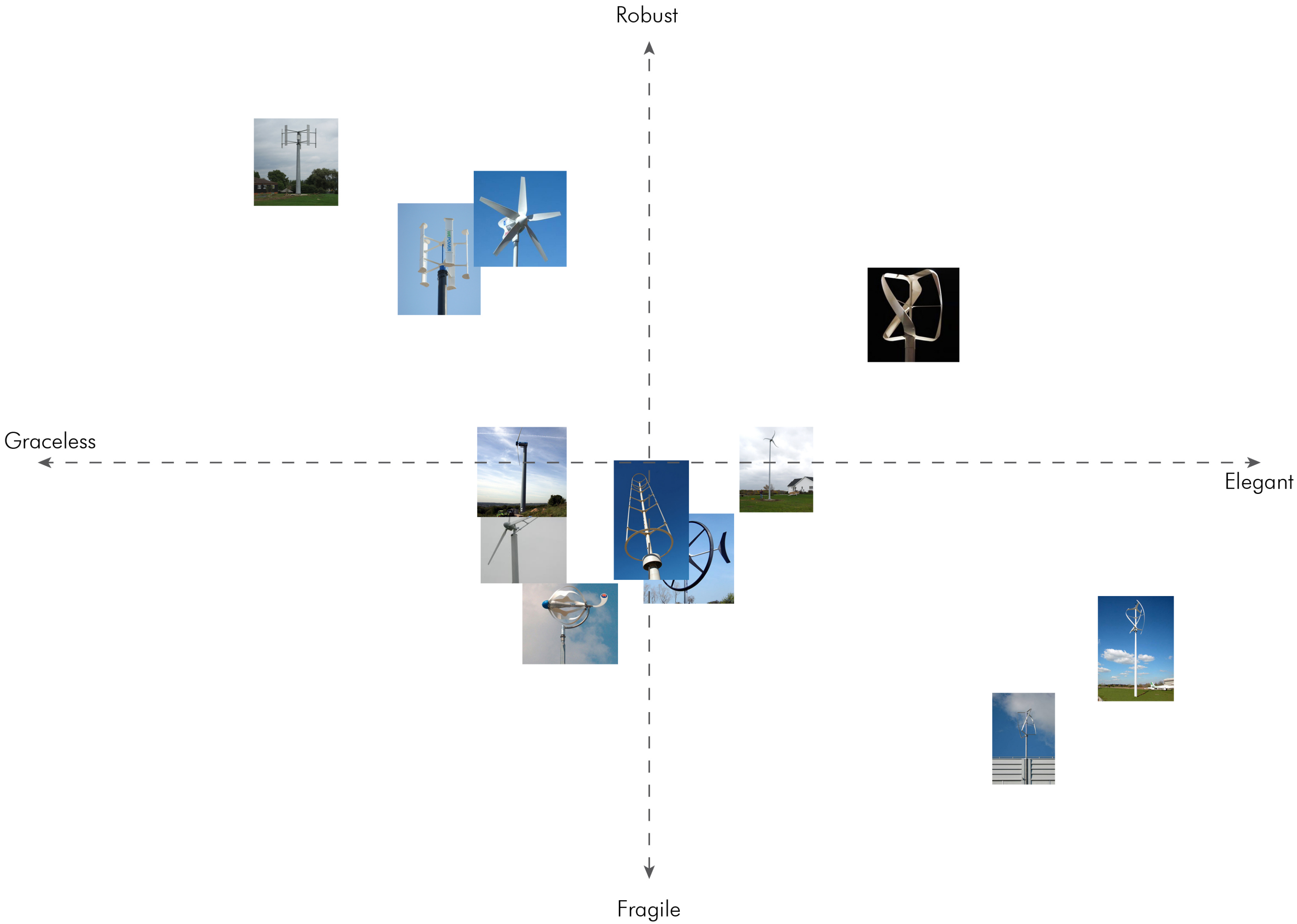
	UWT 1	UWT 2	UWT 3	UWT 4	UWT 5	UWT 6	UWT 7	UWT 8	UWT 9	UWT 10	UWT 11	UWT 12
1 Expensive ~ 7 Cheap	4.23	2.57	4.49	3.66	3.37	3.89	4.29	3.51	3.49	4.17	3.97	2.46
1 Trendy ~ 7 Classic	4.69	1.71	4.86	3.29	4.03	3.49	3	4.57	3.94	4	2.26	2.31
1 Outstanding ~7 Common	5.31	1.91	4.71	3.63	4.06	3.17	3.14	4	3.89	3.49	2.37	2.26
1 Elegant ~ 7 Graceless	4.43	2.26	4.43	3.54	4.46	3.91	4.29	5.26	4.71	4	2.66	3.06
1 Fragile ~ 7 Robust	3.94	3	3.66	3.97	5.37	3.51	3.11	5.77	5.17	3.74	2.49	4.83
1 Functional ~ 7 Ornamental	3	5	2.86	3.49	2	3.51	4	2.77	2.94	3.91	4.17	3.34
1 High-tech ~ 7 Low-tech	4.03	2.66	4	3.71	3.49	4.03	4.11	3.94	4	4.17	3.29	2.66
1 Energetic ~ 7 Unenergetic	3.71	3.11	3.57	3.37	3.03	4.03	4.14	3.54	3.31	4.26	3.54	3.09
1 Dynamic ~ 7 Static	4.14	2.46	4	3	3.71	3.66	2.89	4	4	4.11	2.66	2.83
1 Attractive ~ 7 Unattractive	4.74	2.14	4.46	4	4.51	4	4.11	4.66	4.34	4.34	2.66	2.77

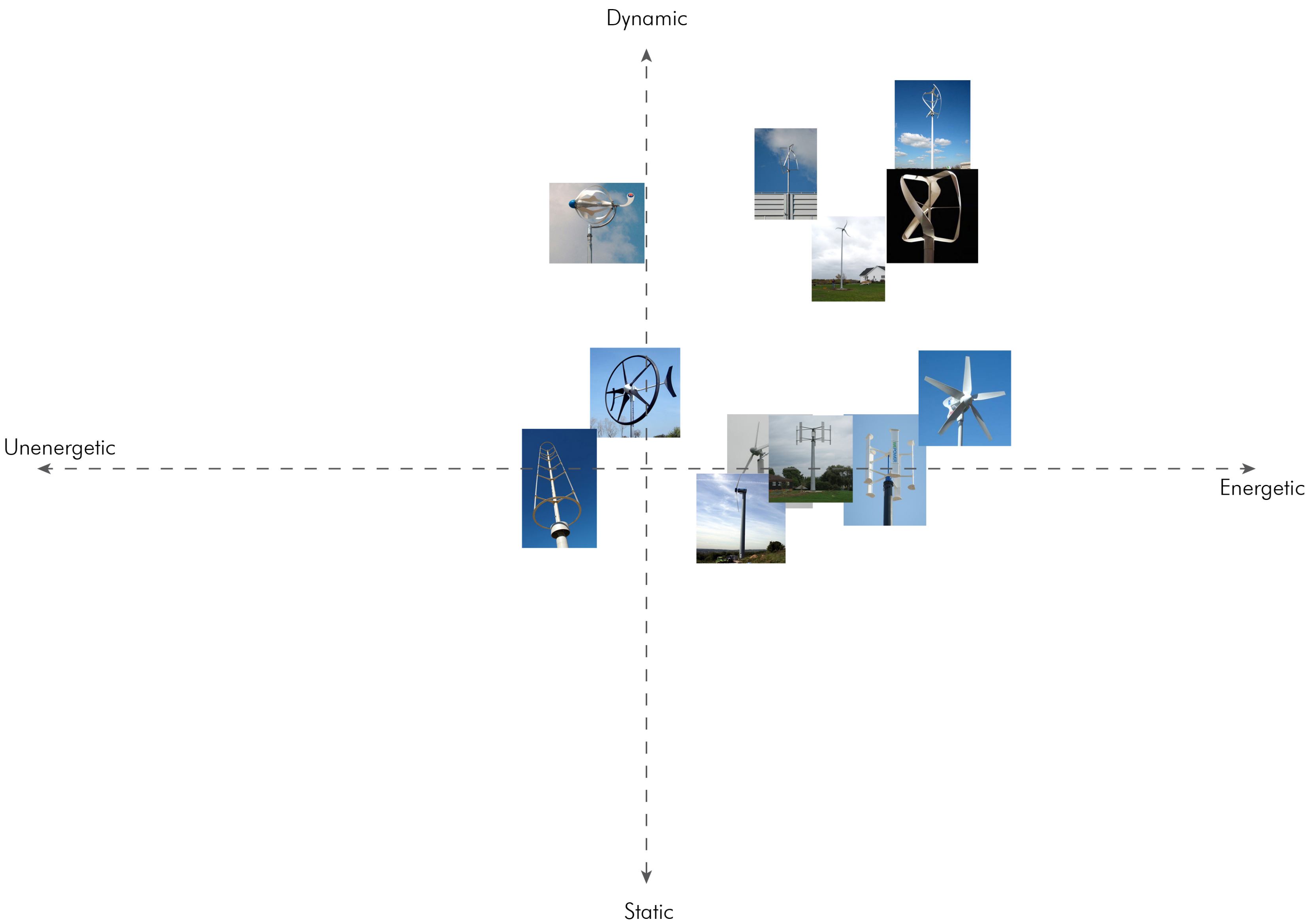


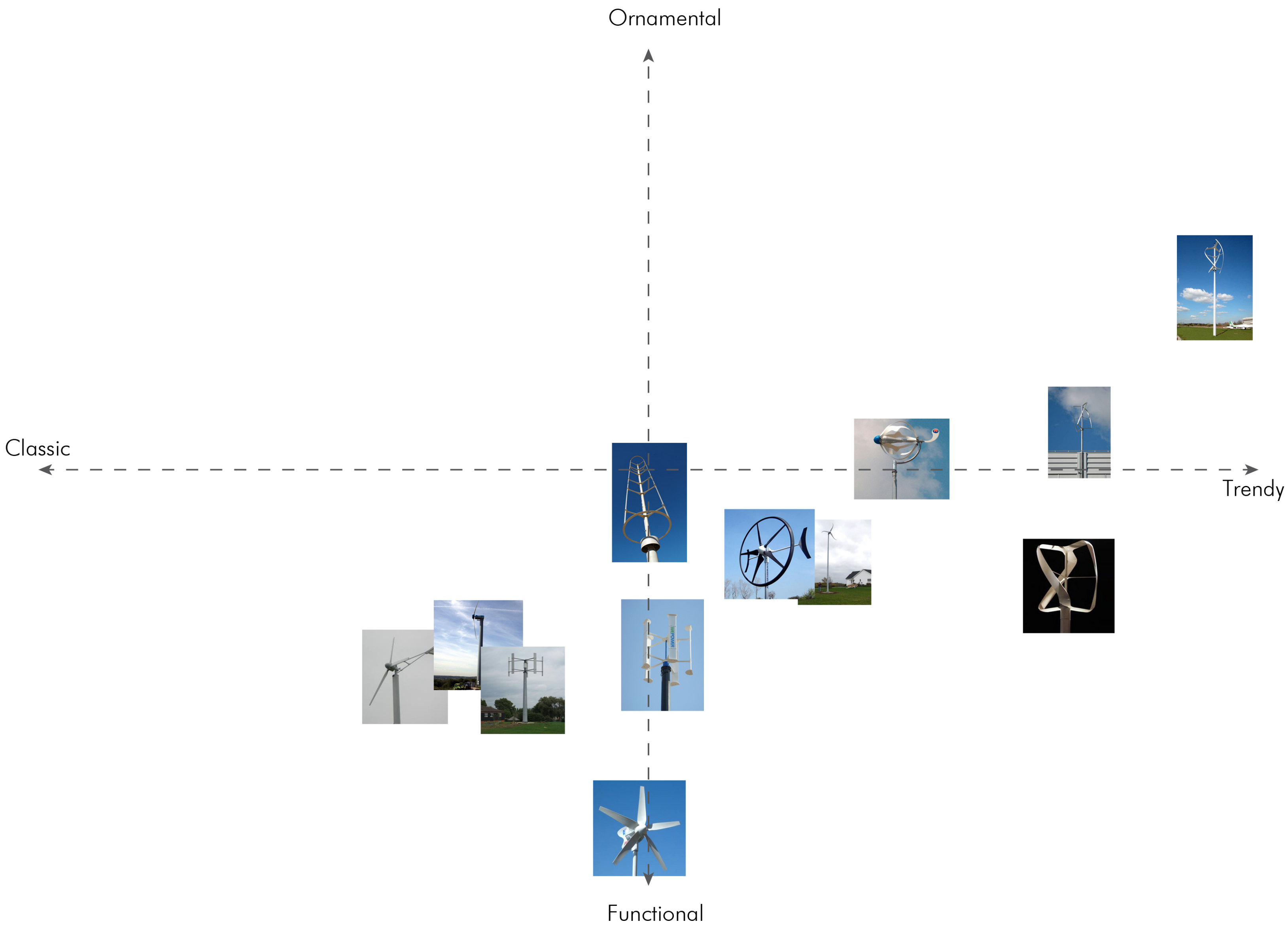



Outstanding
Unattractive
Attractive
Common

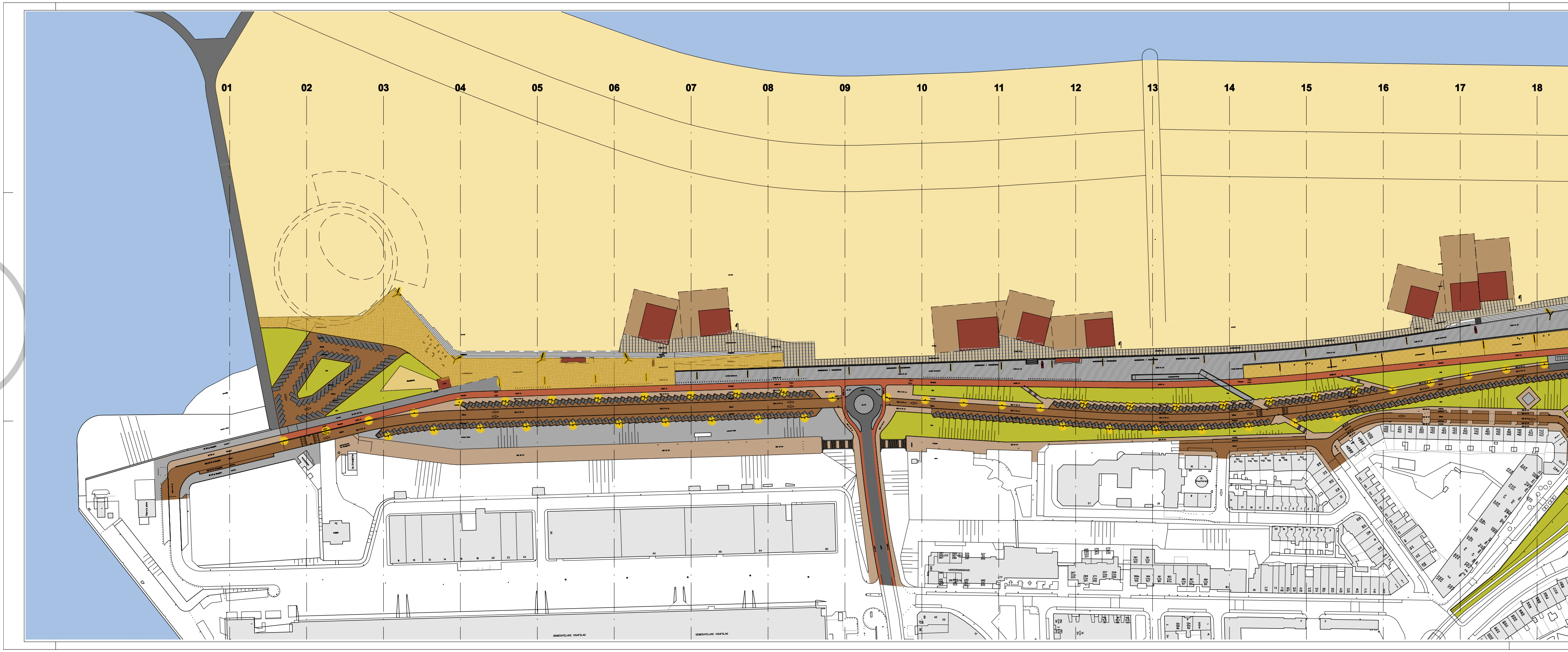

High-tech
Cheap
Expensive
Low-tech

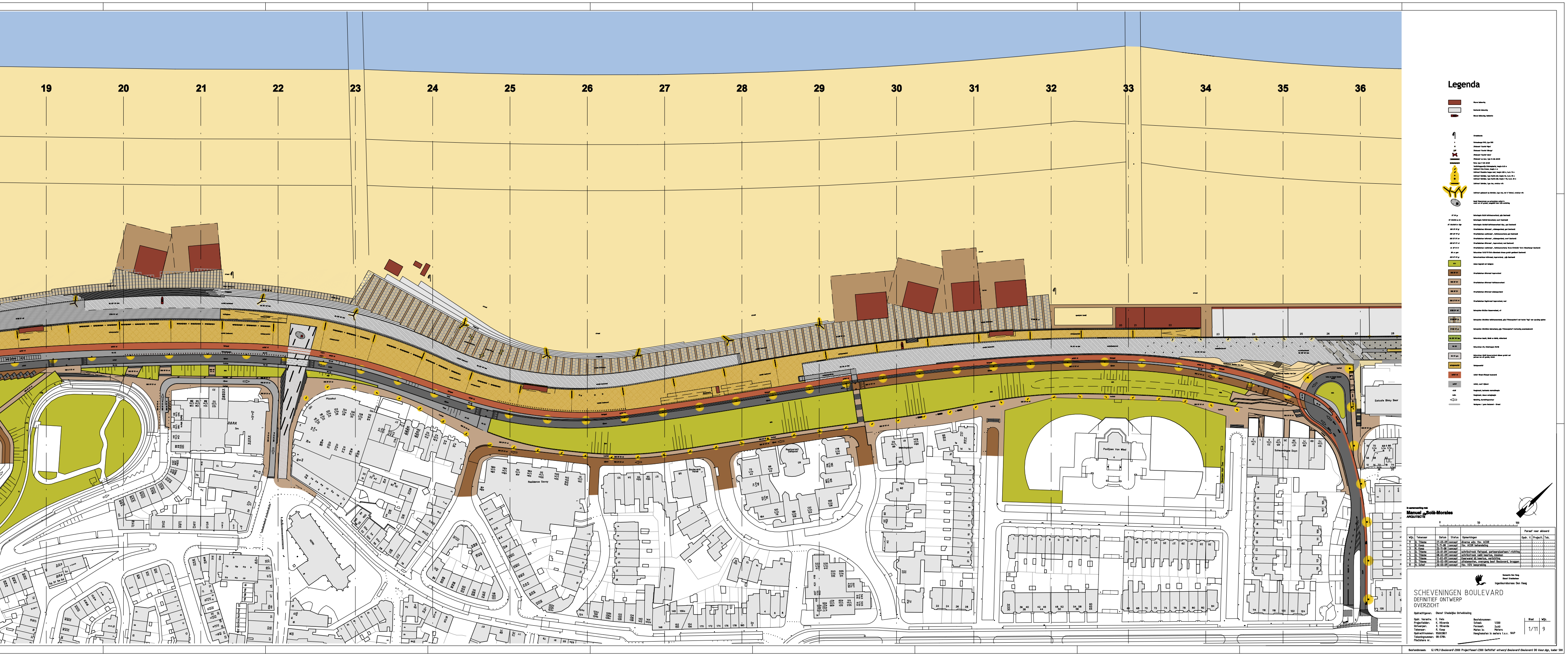

Robust
Graceless
Elegant
Fragile


Dynamic
Unenergetic
Energetic
Static

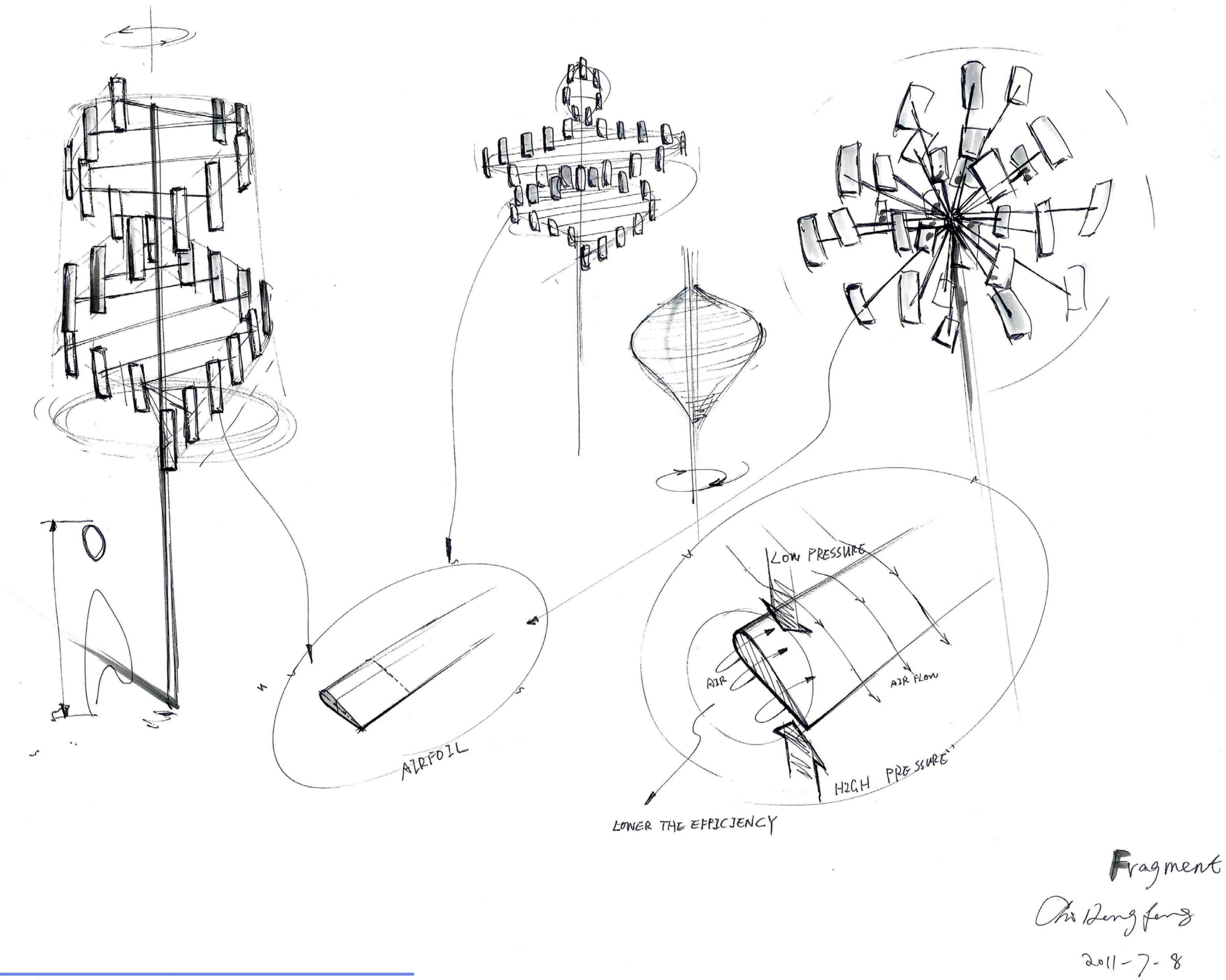

Ornamental
Classic
Trendy
Functional

Appendix G - Scheme of new boulevard

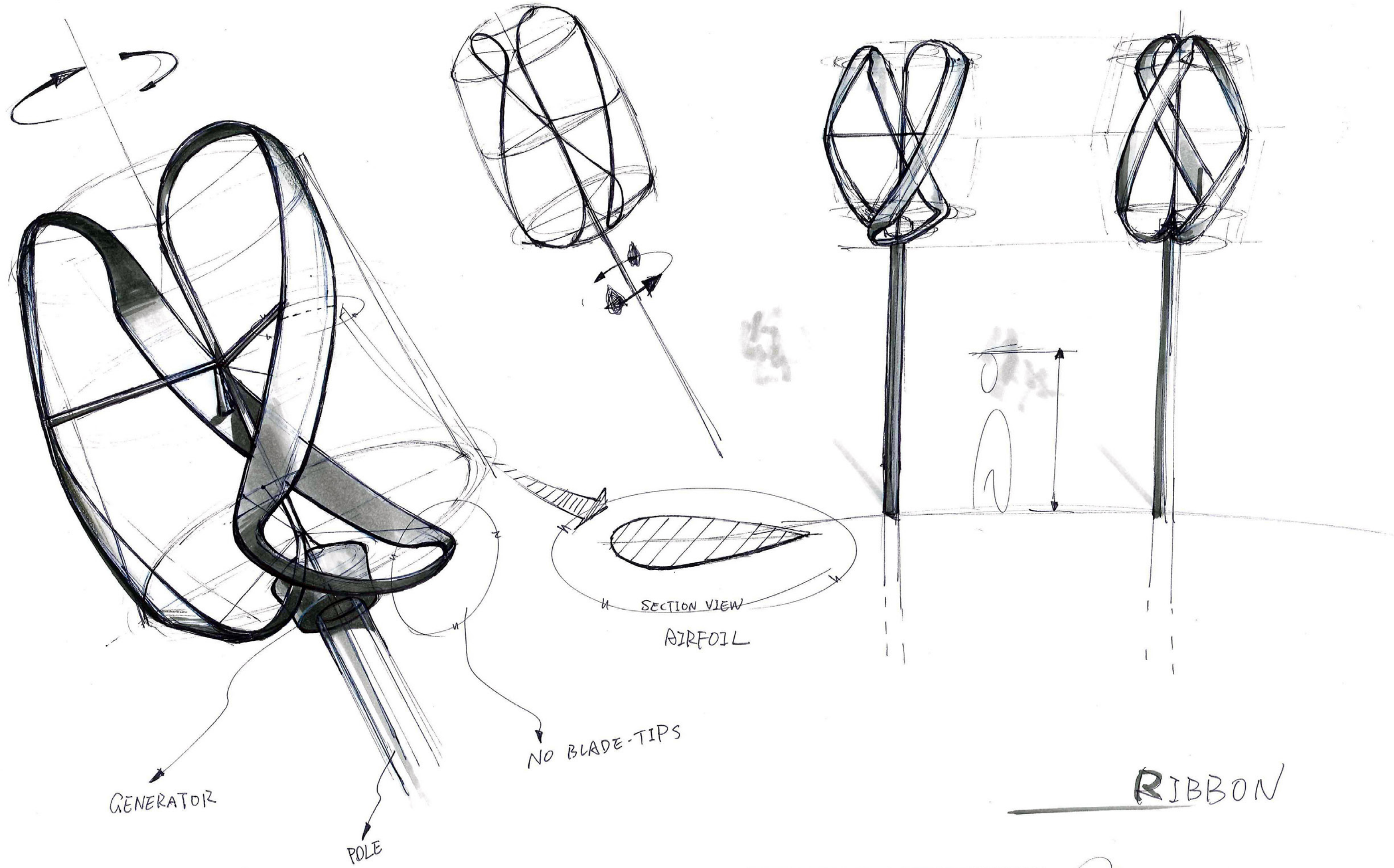


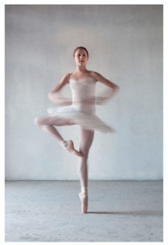


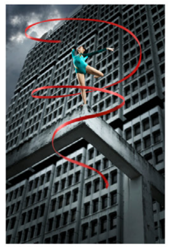
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Legenda
In samenwerking met:
Manuel de Solà-Morales
ARQUITECTE
0
50
100
Paraaf voor akkoord
Wijz. | Tekenaar | Datum | Status | Opmerkingen | Opdr. V. | Projectl. | Tek.
9 | D. Thieme | 27-03-09 | concept | diverse wijz. tbv. ACOR
1 | R. Koop | 11-11-08 | concept | tbv. ACOR behandeling
3 | R. Koop | 25-11-08 | concept
4 | D. Thieme | 23-01-09 | concept | schrikstrook fietspad, parkeerplaatsen/-richting
5 | D. Thieme | 08-02-09 | concept | schrikstrook nabij keerlus, kiosken
6 | D. Thieme | 12-02-09 | concept | Keerwand bij keerlus, verlichting
7 | D. Thieme | 20-02-09 | concept | zitelementen, overgang best Boulevard, bruggen
8 | H. Schot | 20-03-09 | concept | tbv. VOV bespreking
Ingenieursbureau Den Haag
SCHEVENINGEN BOULEVARD
DEFINITIEF ONTWERP
OVERZICHT
Opdrachtgever: Dienst Stedelijke Ontwikkeling
Opdr. Verantw. E. Vols
Projectleider: K. Hilverda
Ontwerper: K. Hilverda
Tekenaar: R. Koop
Opdrachtnummer: 95002807
Tekeningnummer: 08-5784
File2share nr.
Besteknummer:
Schaal: 1:500
Formaat: 2xA0
Maten in: Meters
Hoogtematen in meters t.o.v. NAP
Blad 1/11
Wijz. 9
Bestandsnaam: G:\PRJ\Boulevard\2000 Projectfasen\2300 Definitief ontwerp\Boulevard\Boulevard DO kleur.dgn, kader 500


AIRFOIL
LOW PRESSURE
AIR
AIR FLOW
HIGH PRESSURE
LOWER THE EFFICIENCY
Fragment
2011-7-8

Appendix H - IDEA2

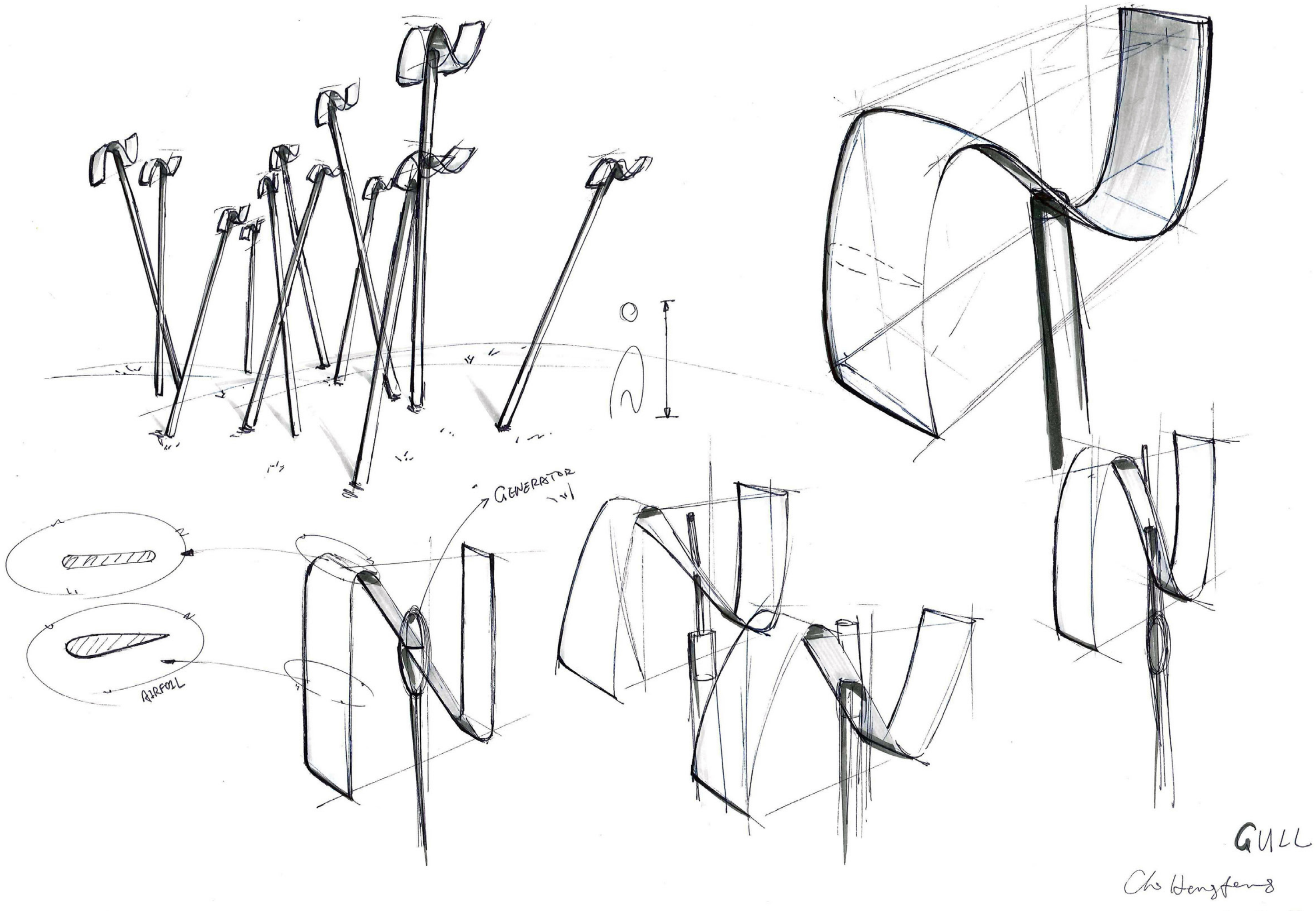


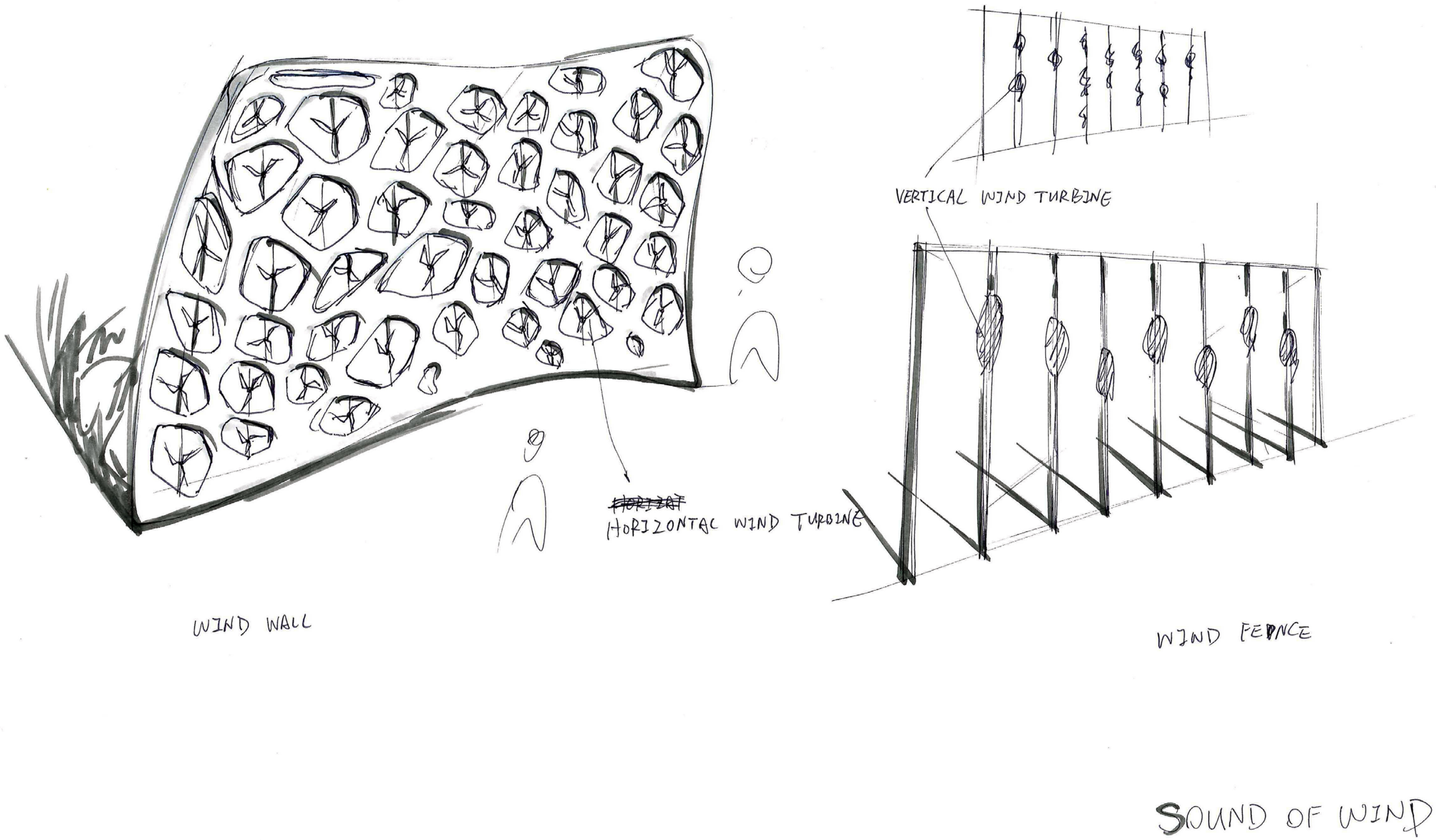


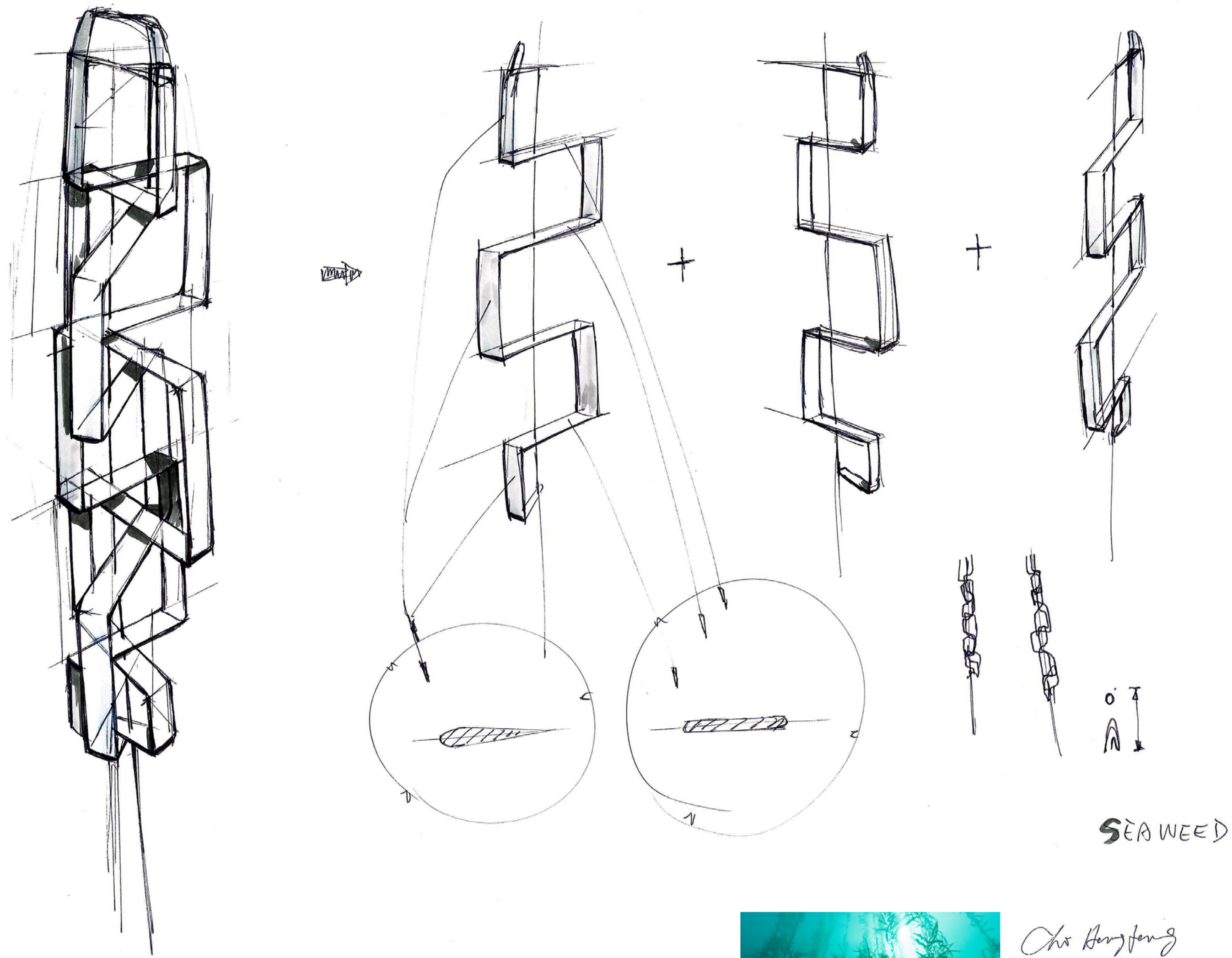


Chi Hengfeng

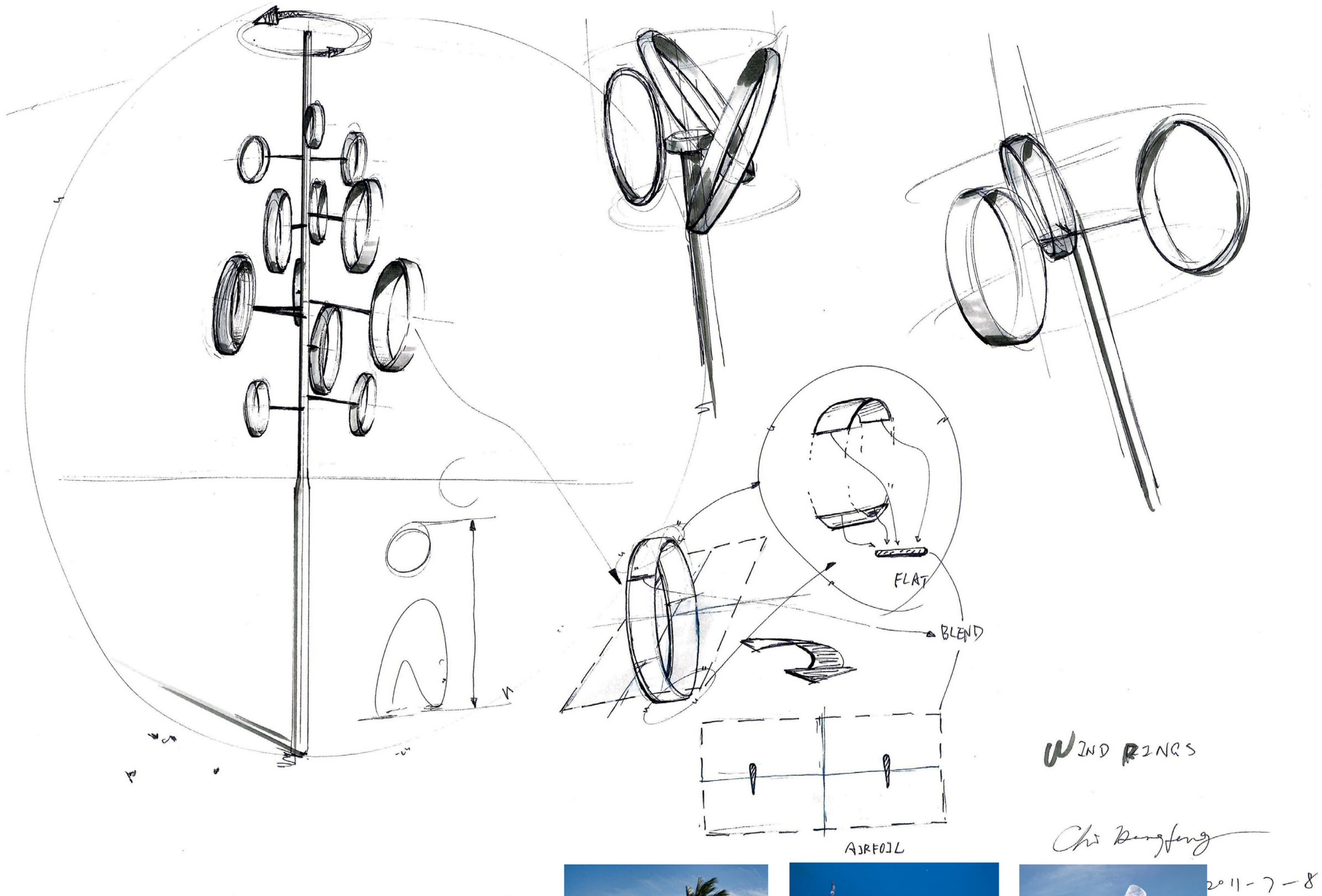
2011-07-06

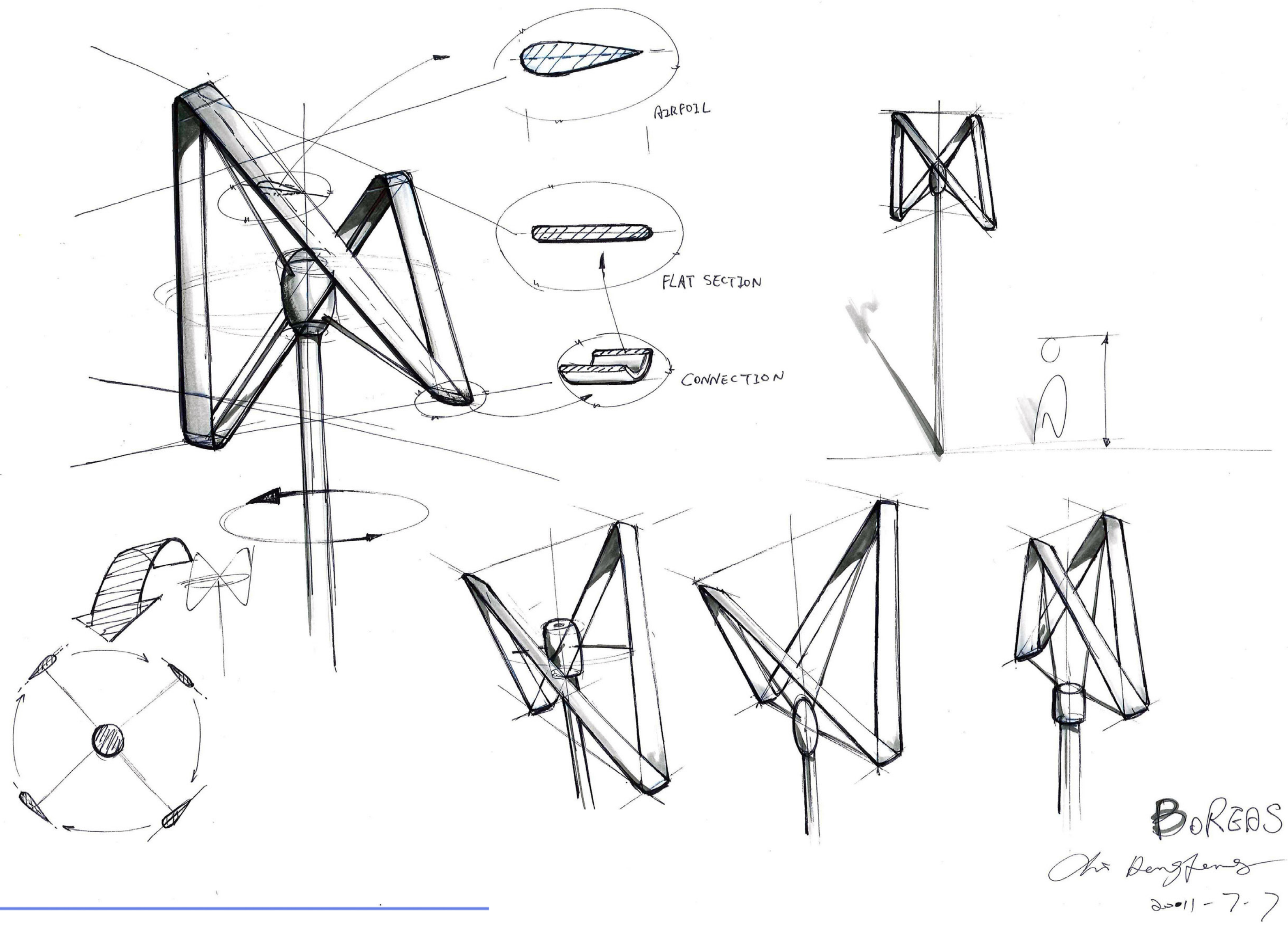

GENERATOR
AIRFOIL
GULL
2017-7-7


VERTICAL WIND TURBINE
~~HORIZAT~~
HORIZONTAL WIND TURBINE
WIND WALL
WIND FENCE
SOUND OF WIND

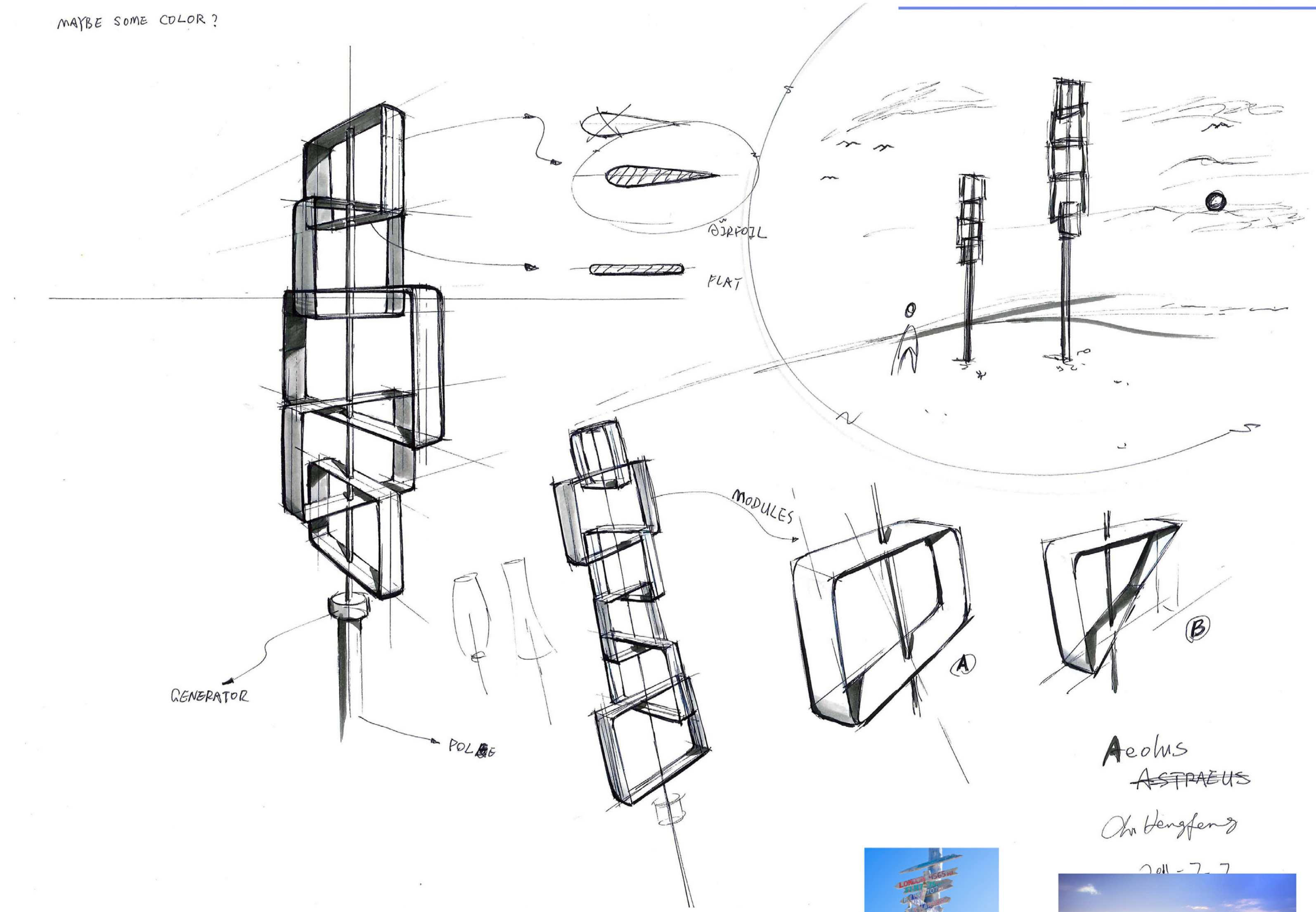


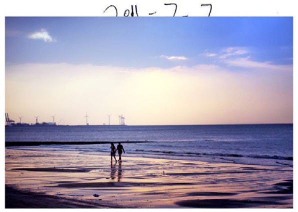
Chi Hengfeng
2011-7-7

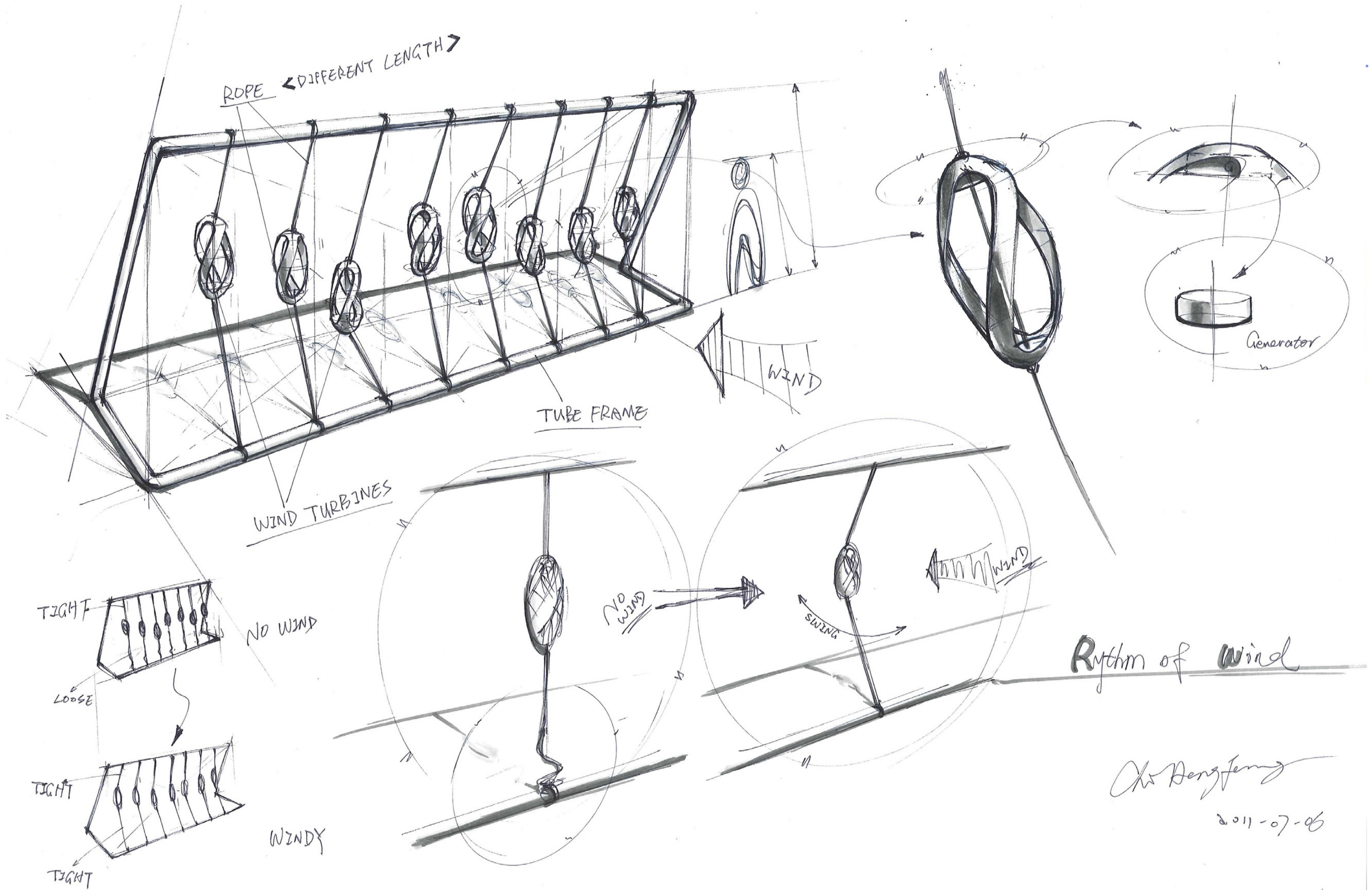

FLAT
BLEND
AIRFOIL
WIND RINGS
Chi Hengfeng
2011-7-8


AIRFOIL
FLAT SECTION
CONNECTION
BOREAS
2011-7-7

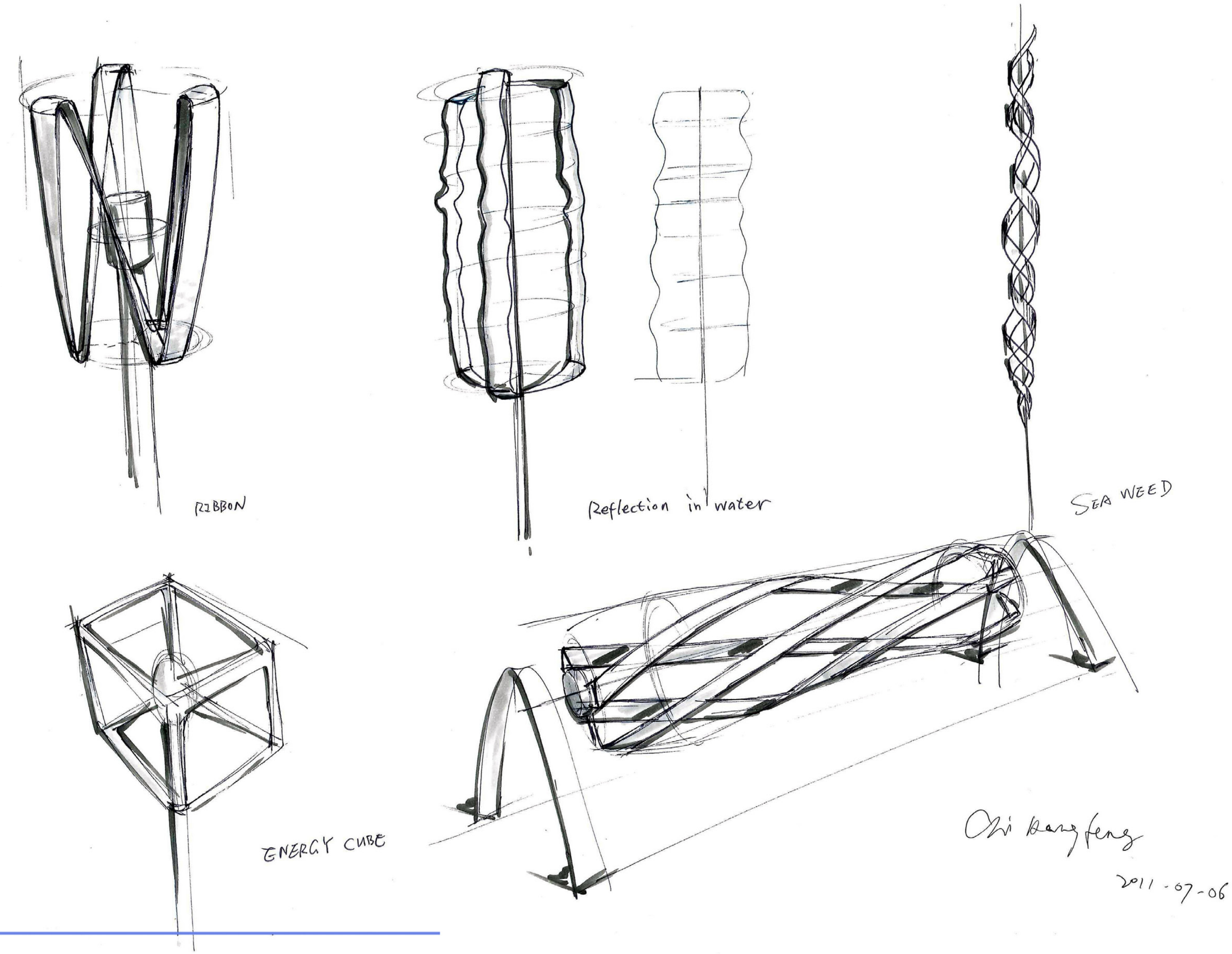
Appendix H - IDEA8

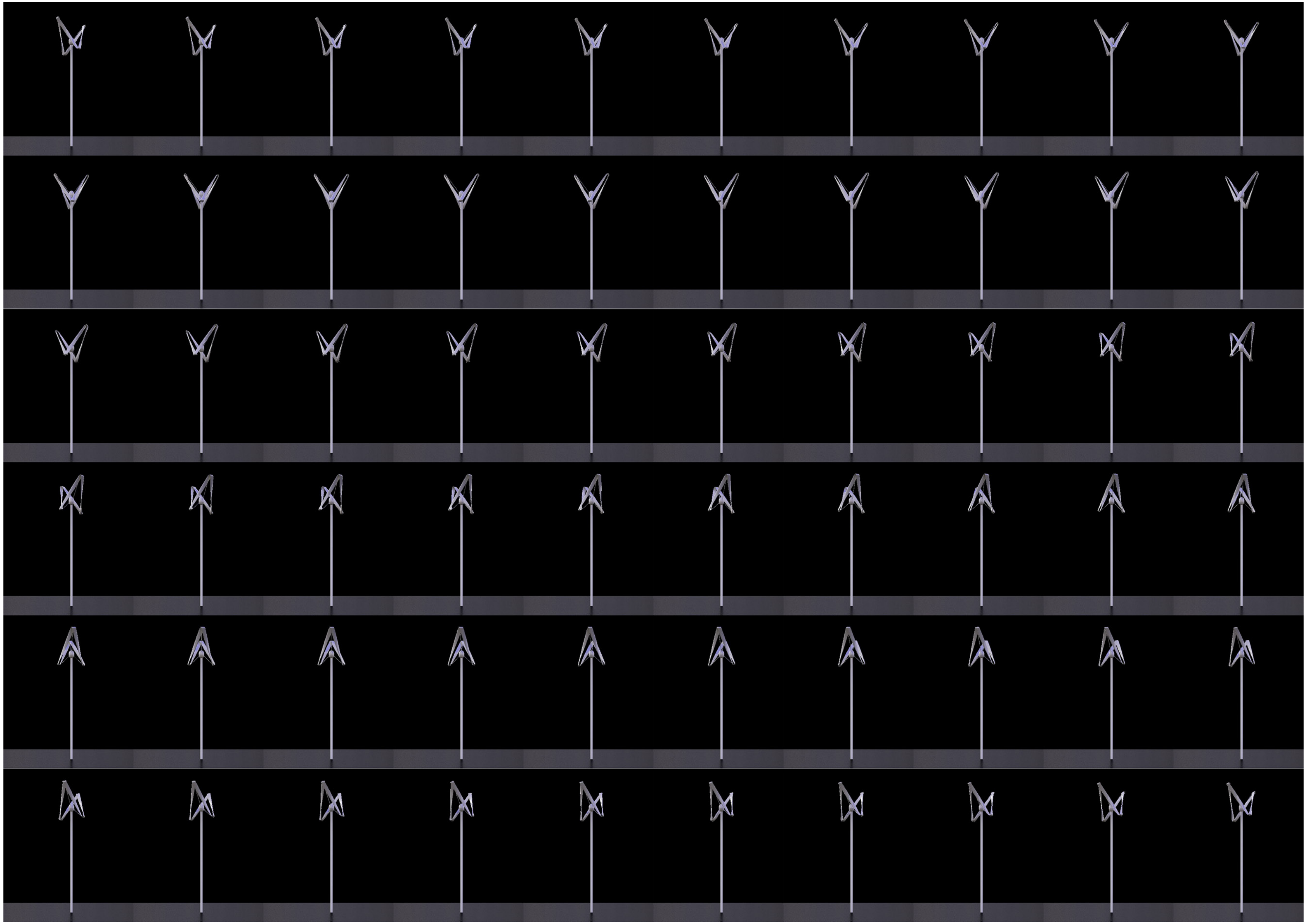


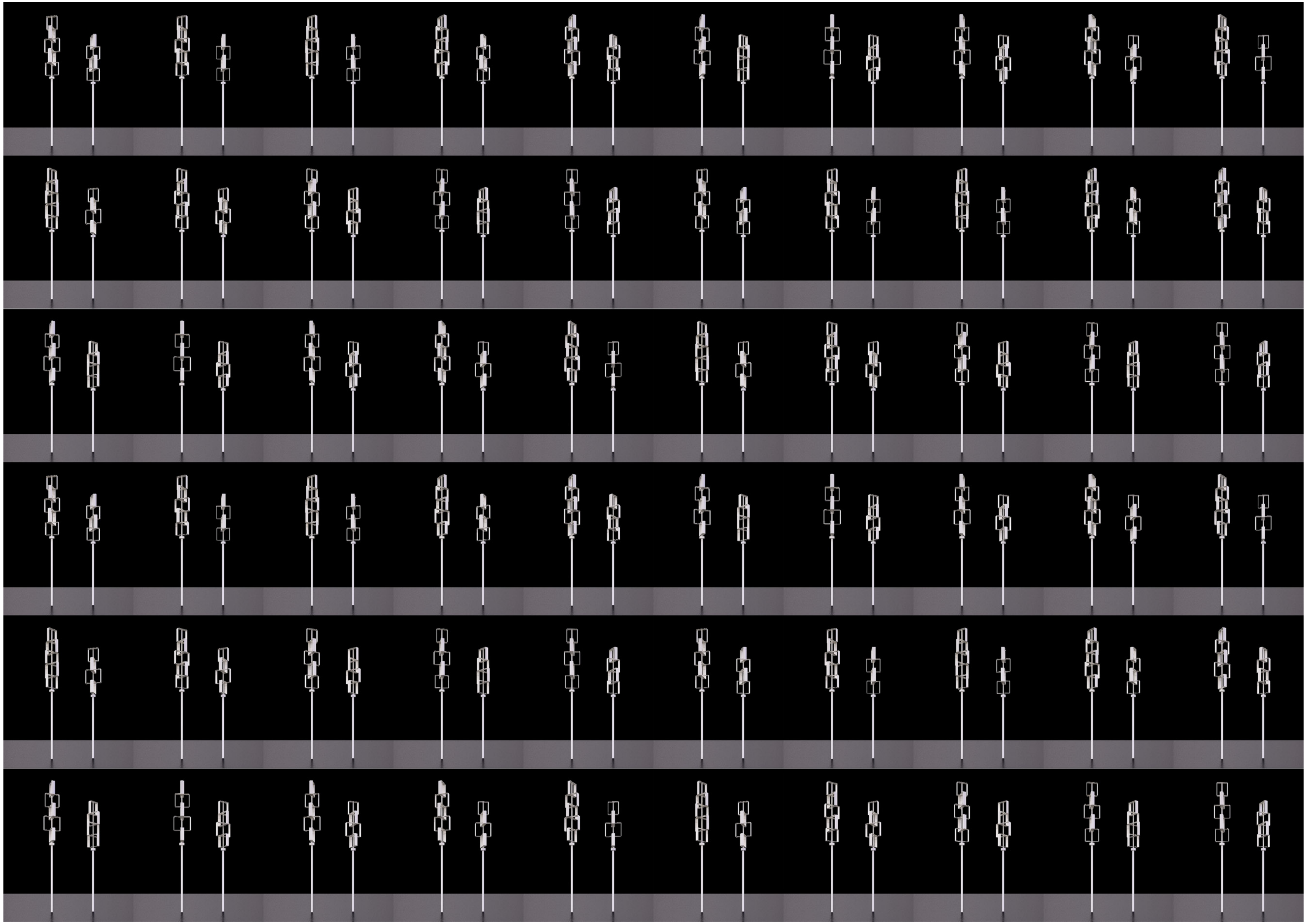


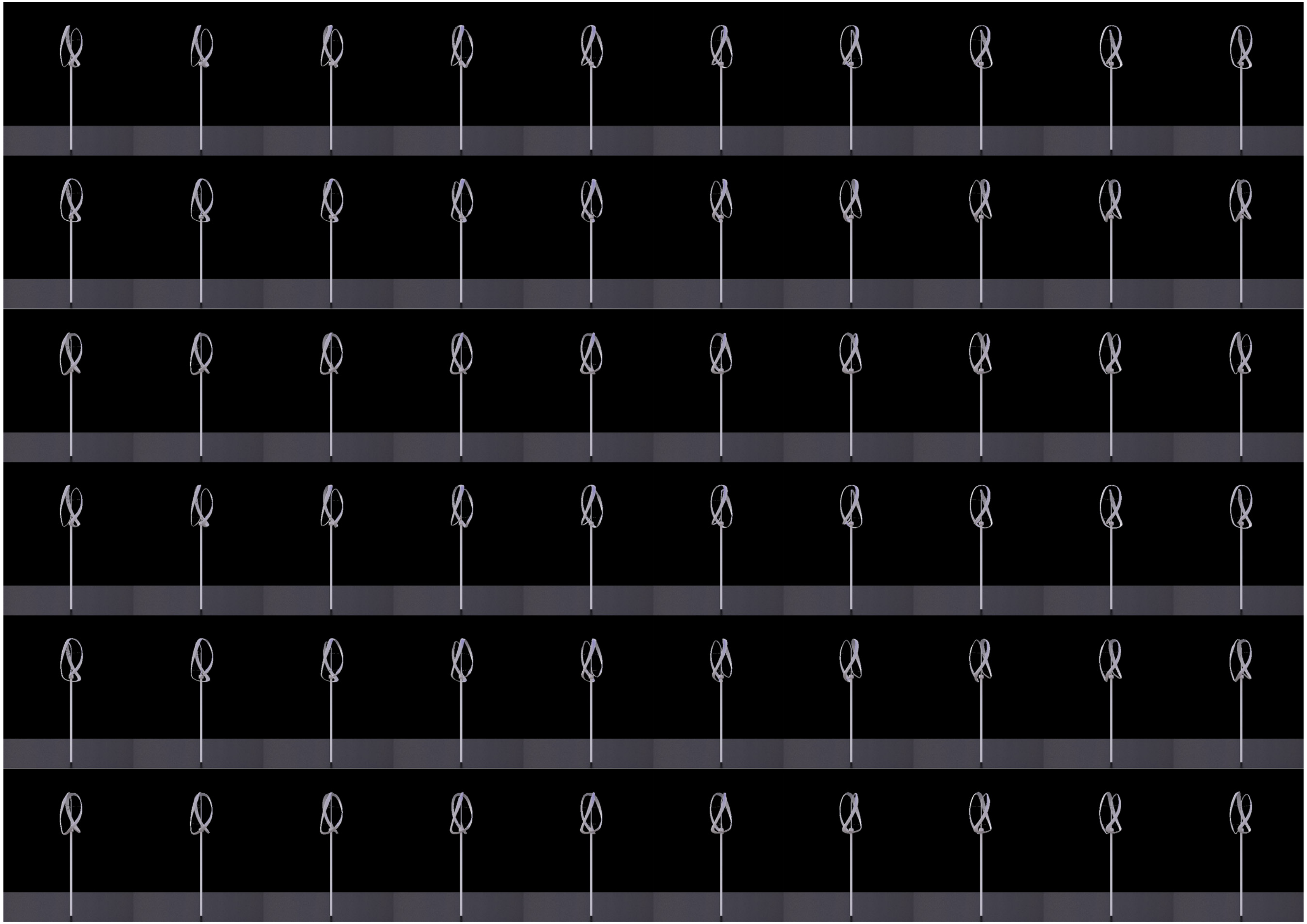

ROPE <DIFFERENT LENGTH>
TUBE FRAME
WIND TURBINES
WIND
Generator
TIGHT
NO WIND
LOOSE
TIGHT
TIGHT
WINDY
NO WIND
SWING
WIND
Rythm of Wind
2011-07-06

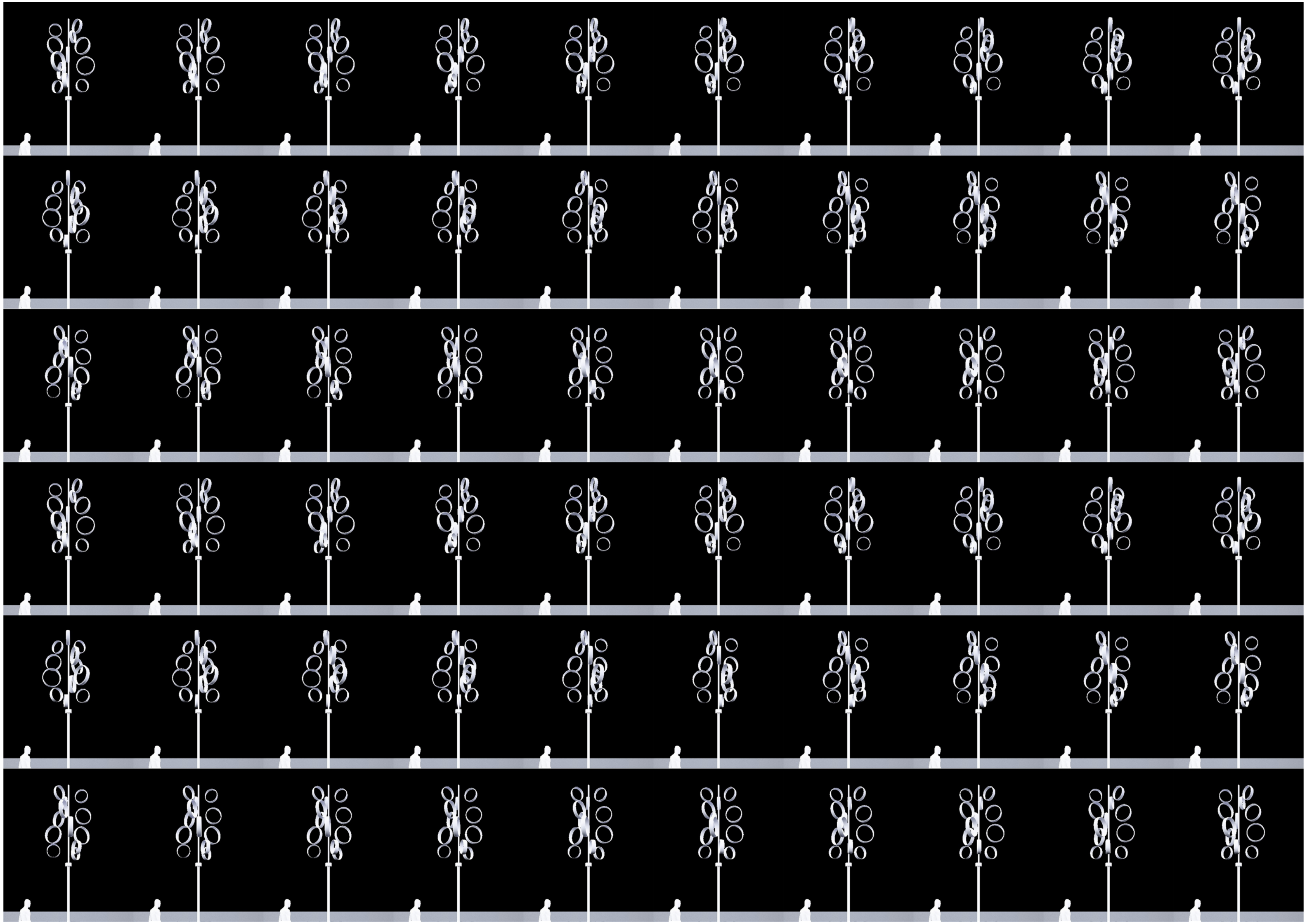
Appendix H - OTHER IDEAS











Appendix J - SolidWorks Simulation Report 1

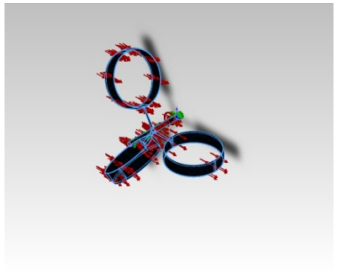
Simulation of simulation_RealV1

Date: Thursday, October 27, 2011
Designer: Solidworks
Study name: Study 1
Analysis type: Static

Table of Contents

Model Information

Model name: simulation_RealV1
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Cut-Extrude1 	Solid Body	**Mass:39.6631 lb** **Volume:616.781 in^3** **Density:0.0643066 lb/in^3** **Weight:39.6362 lbf**	**C:\Users\Hengfeng Chi\Desktop\3D models WIN\final2\Simulation analysis\real size_ Carbon Fiber\simulation_RealV1.SLDPRT** Oct 26 20:16:04 2011

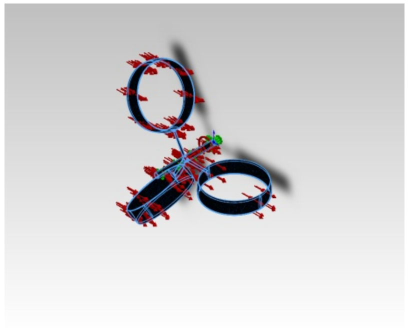
Study Properties

Study name	Study 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	On
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (C:\Users\Hengfeng Chi\Desktop\3D models WIN\final2\Simulation analysis\real size_ Carbon Fiber)

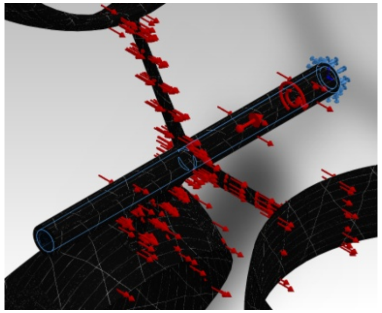
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

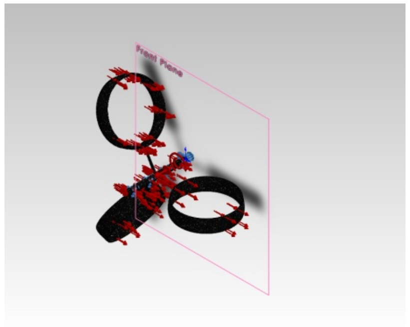
Model Reference	Properties	Components
	**Name:** Hexcel AS4C (3000 Filaments) **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Elastic modulus:** 2.31e+011 N/m^2 **Poisson's ratio:** 0.1 **Mass density:** 1780 kg/m^3	SolidBody 1(Cut-Extrude1)(simulation_RealV1)
Curve Data:N/A		

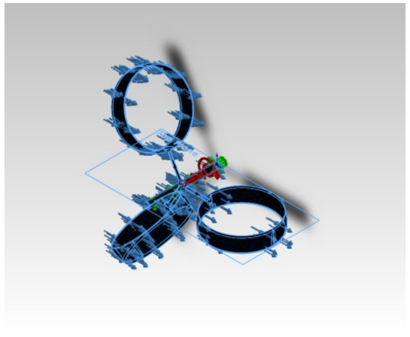
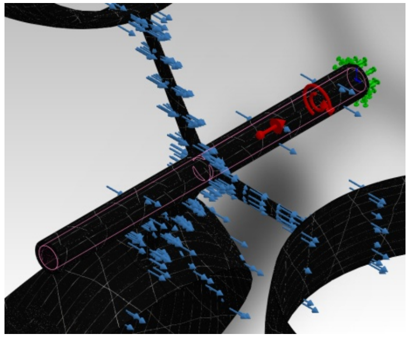
Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-1029.26	-1.37111	178.308	1044.59
Reaction Moment(N-m)	0	0	0	0

Load name	Load Image	Load Details
Gravity-1		**Reference:** Front Plane **Values:** 0 0 -9.81 **Units:** SI

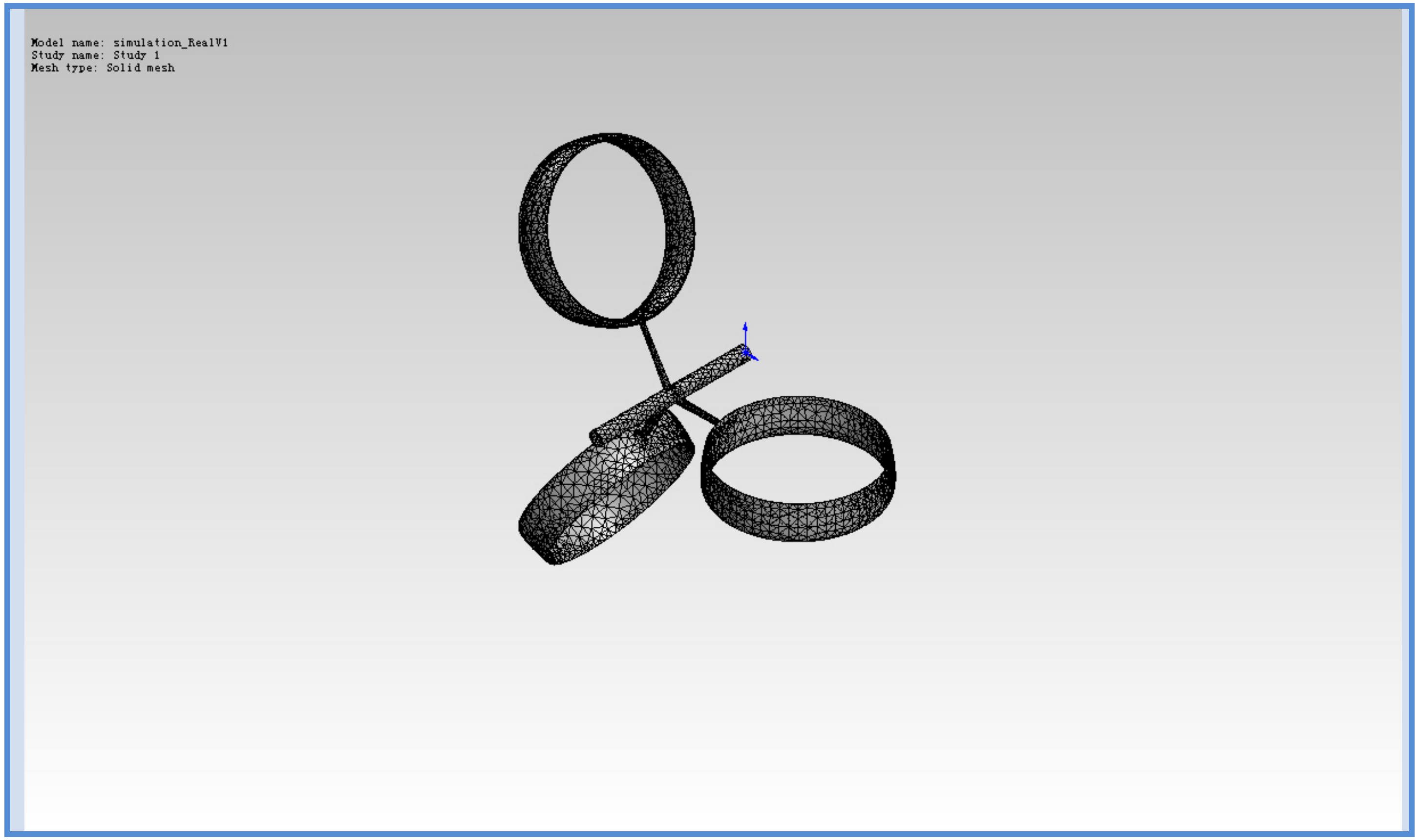
Pressure-1		**Entities:** 52 face(s), 1 plane(s) **Reference:** Top Plane **Type:** Along Plane Dir 1 **Value:** 200 **Units:** N/m^2
Centrifugal-1		**Centrifugal, Ref:** Face< 1 > **Angular Velocity:** 300 rpm **Angular Acceleration:** -6000 rpm^2

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	90.8211 mm
Minimum element size	18.1642 mm
Mesh Quality	High

Mesh Information - Details

Total Nodes	65199
Total Elements	32754
Maximum Aspect Ratio	201.67
% of elements with Aspect Ratio < 3	15.4
% of elements with Aspect Ratio > 10	28
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:13
Computer name:	HENGFENGCHI-PC


Model name: simulation_RealV1
Study name: Study 1
Mesh type: Solid mesh

Resultant Forces

Reaction Forces

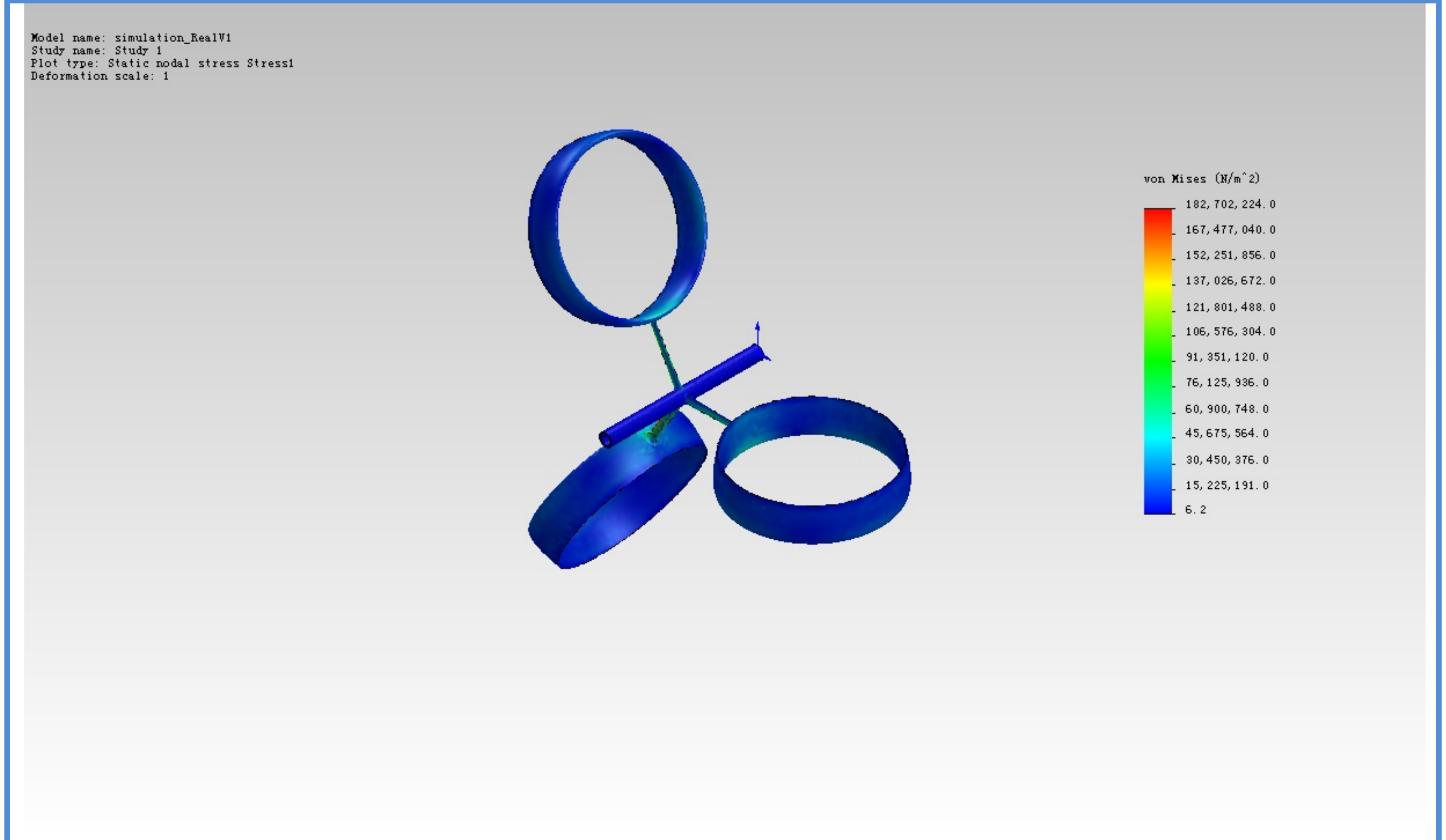
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1029.26	-1.37111	178.308	1044.59

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

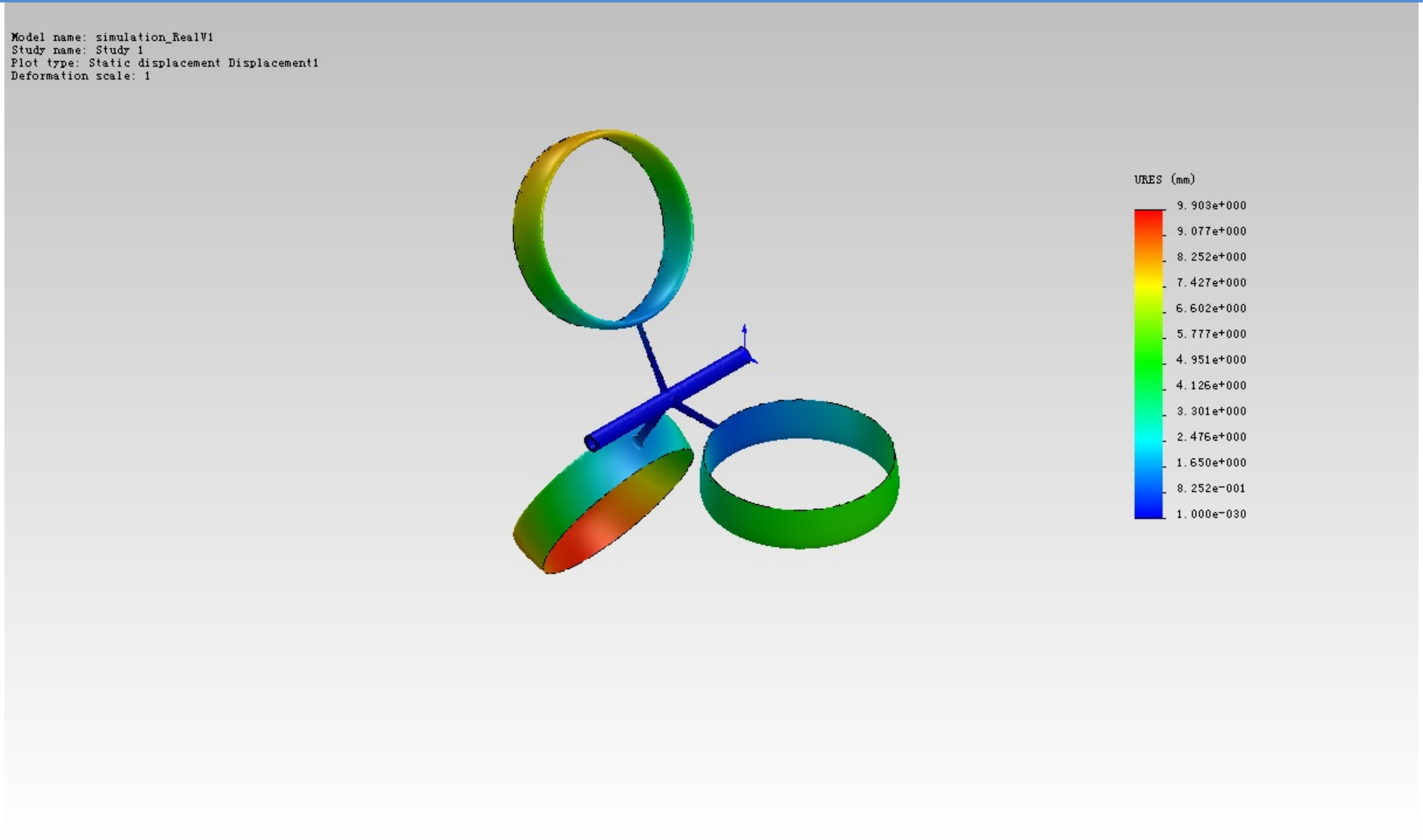
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	6.15302 N/m^2 Node: 461	1.82702e+008 N/m^2 Node: 11304



simulation_RealV1-Study 1-Stress-Stress1

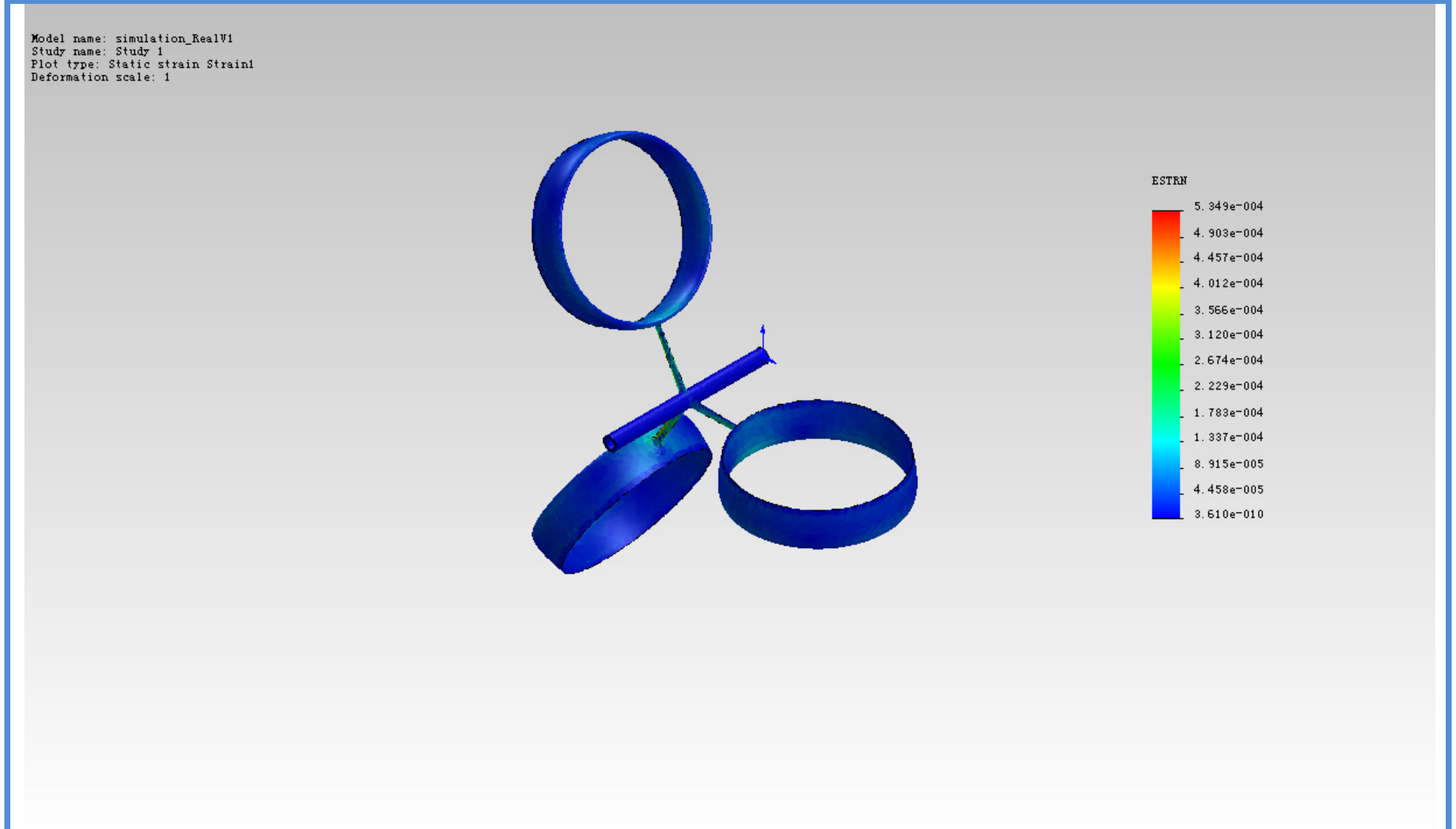
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 26	9.90261 mm Node: 34487



simulation_RealV1-Study 1-Displacement-Displacement1

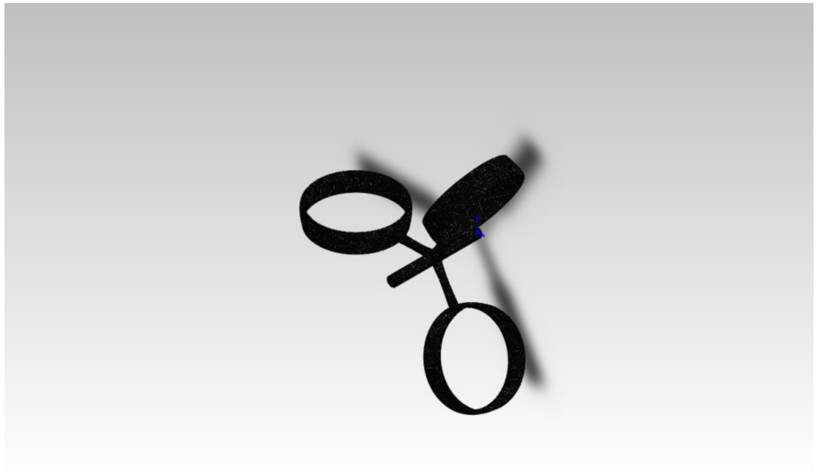
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.61008e-010	0.000534898

		Element: 24007	Element: 21327



simulation_RealV1-Study 1-Strain-Strain1

Appendix K - SolidWorks Simulation Report 2

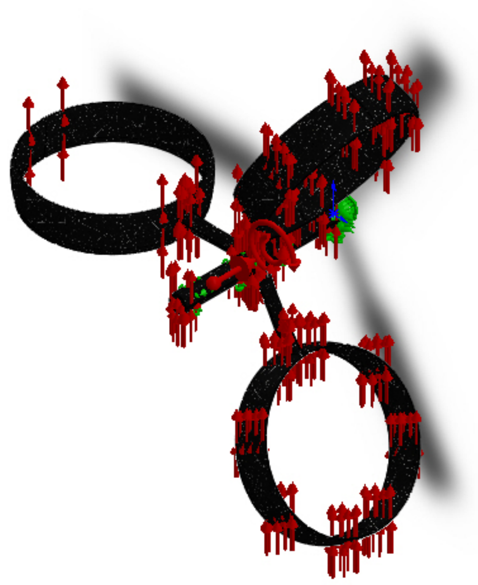


Simulation of simulation_Real V3

Date: Thursday, October 27, 2011
Designer: Solidworks
Study name: Study 1
Analysis type: Static

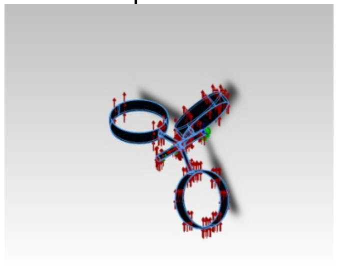
Table of Contents

Model Information



Model name: simulation_Real V3
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Imported1 	Solid Body	**Mass:49.639 lb Volume:771.912 in^3 Density:0.0643066 lb/in^3 Weight:49.6053 lbf**	**C:\Users\Hengfeng Chi\Desktop\3D models WIN\final2\Simulation analysis\real size_ Carbon Fiber\simulation_Real V3.SLDPRT** Oct 26 19:59:49 2011

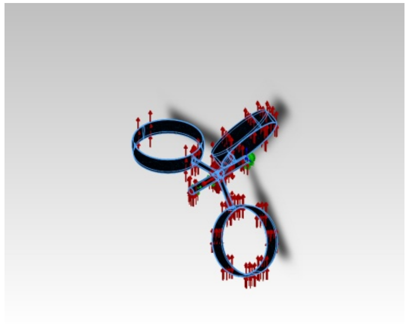
Study Properties

Study name	Study 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (C:\Users\Hengfeng Chi\Desktop\3D models WIN\final2\Simulation analysis\real size_ Carbon Fiber)

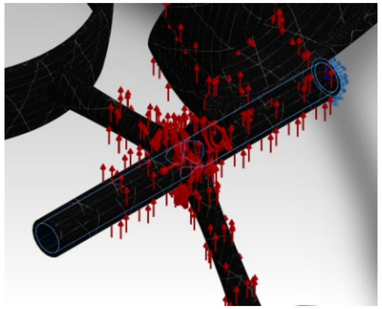
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

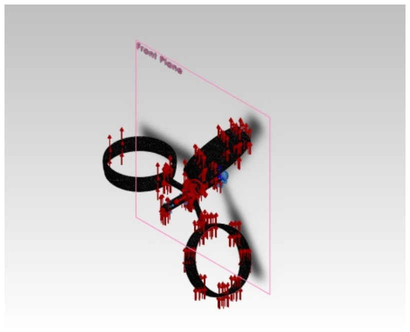
Model Reference	Properties	Components
	**Name:** Hexcel AS4C (3000 Filaments) **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Elastic modulus:** 2.31e+011 N/m^2 **Poisson's ratio:** 0.1 **Mass density:** 1780 kg/m^3	SolidBody 1(Imported1)(simulation_Real V3)
Curve Data:N/A		

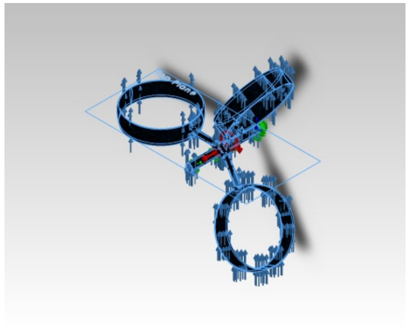
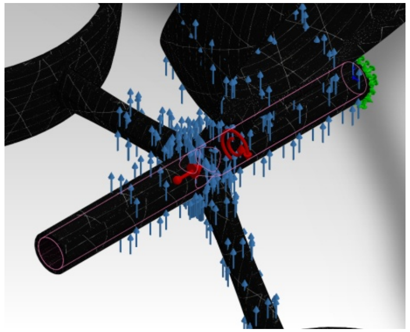
Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-1.43844	-1151.16	220.86	1172.16
Reaction Moment(N-m)	0	0	0	0

Load name	Load Image	Load Details
Gravity-1		**Reference:** Front Plane **Values:** 0 0 -9.81 **Units:** SI

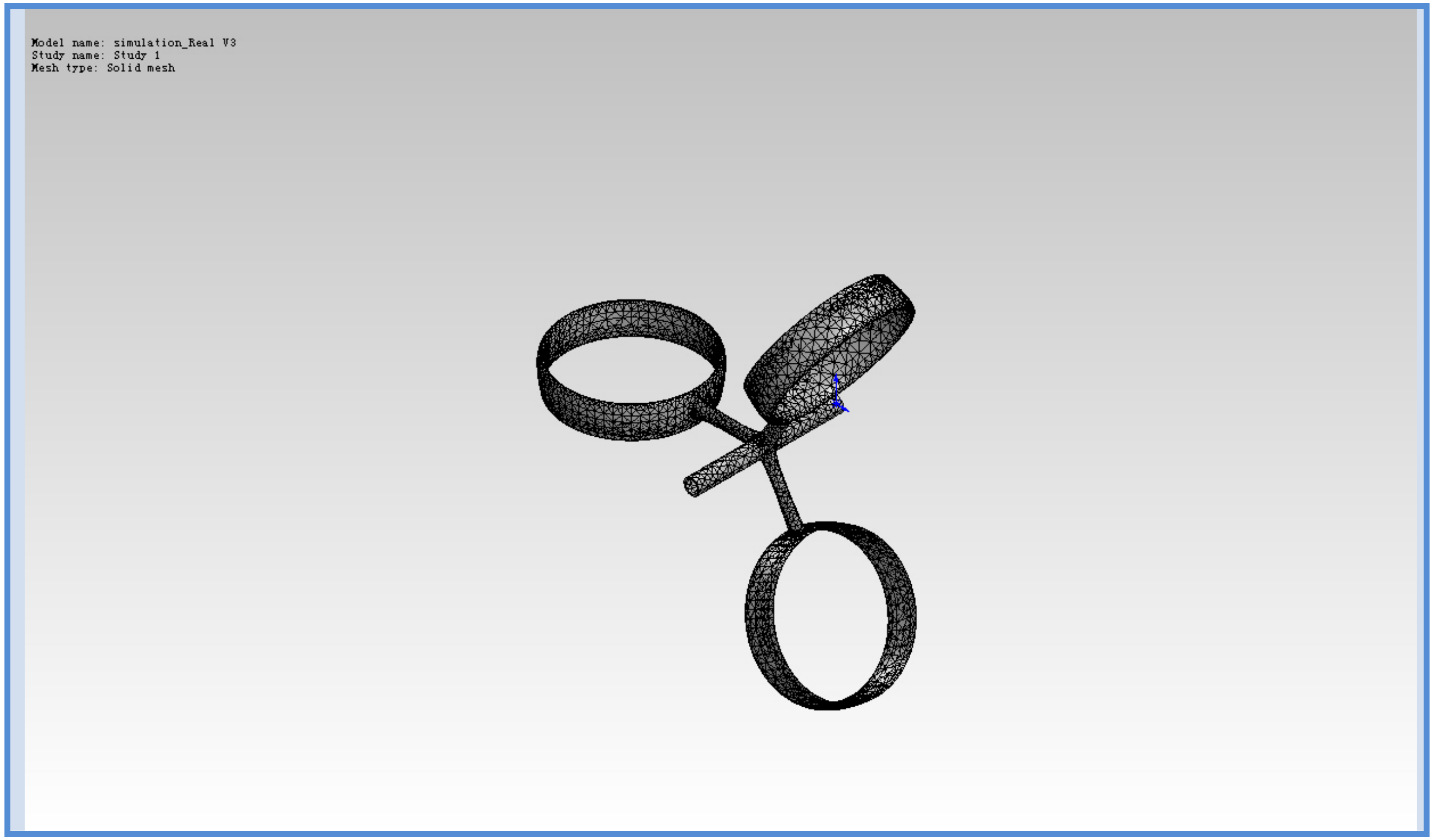
Pressure-1		**Entities:** 139 face(s), 1 plane(s) **Reference:** Top Plane **Type:** Normal To Plane **Value:** 200 **Units:** N/m^2
Centrifugal-1		**Centrifugal, Ref:** Face< 1 > **Angular Velocity:** 300 rpm **Angular Acceleration:** -6000 rpm^2

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	95.9238 mm
Minimum element size	19.1848 mm
Mesh Quality	High

Mesh Information - Details

Total Nodes	64603
Total Elements	32471
Maximum Aspect Ratio	231.34
% of elements with Aspect Ratio < 3	18.3
% of elements with Aspect Ratio > 10	25.1
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:16
Computer name:	HENGFENGCHI-PC


Model name: simulation_Real V3
Study name: Study 1
Mesh type: Solid mesh

Resultant Forces

Reaction Forces

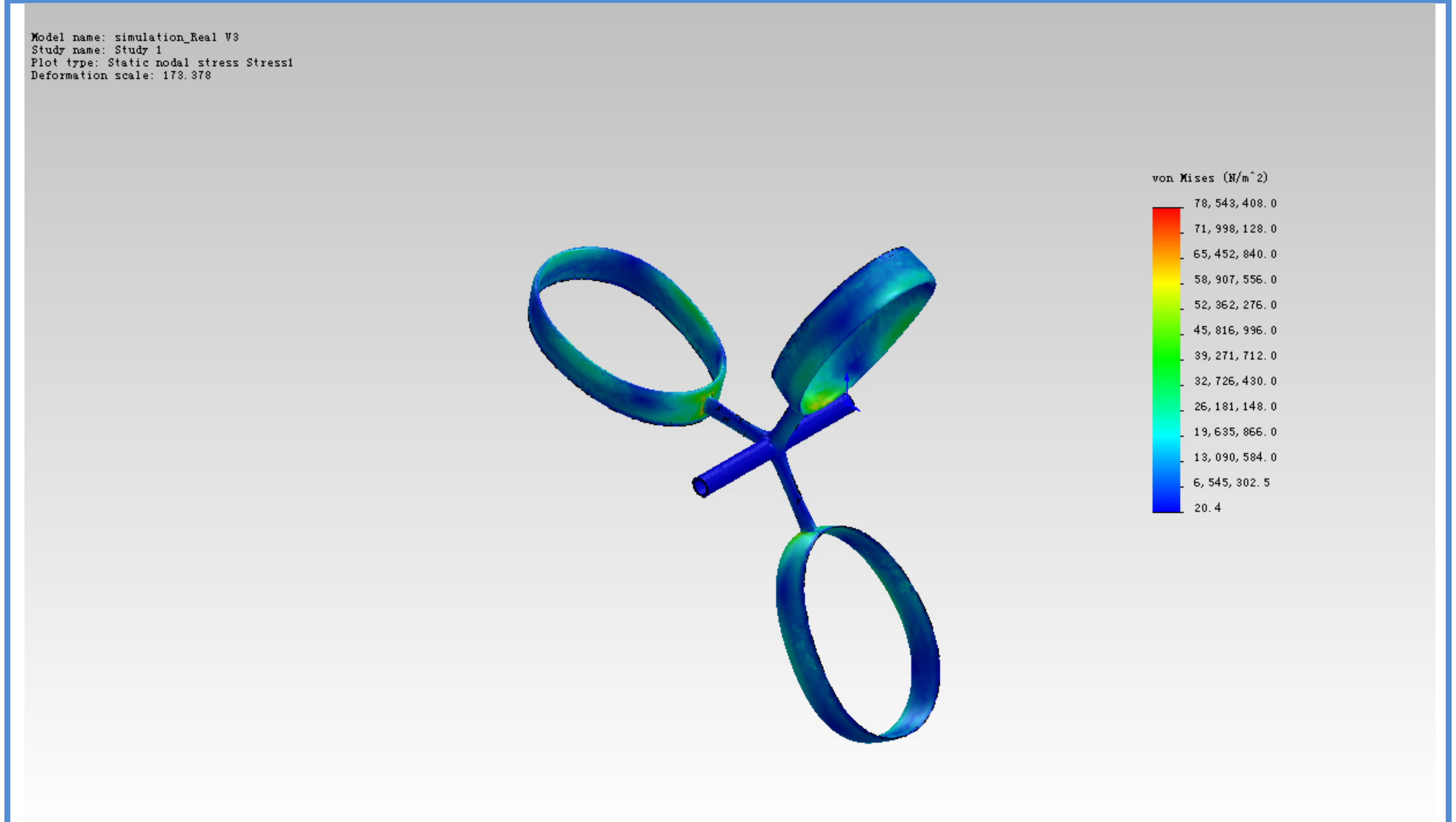
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1.43844	-1151.16	220.86	1172.16

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

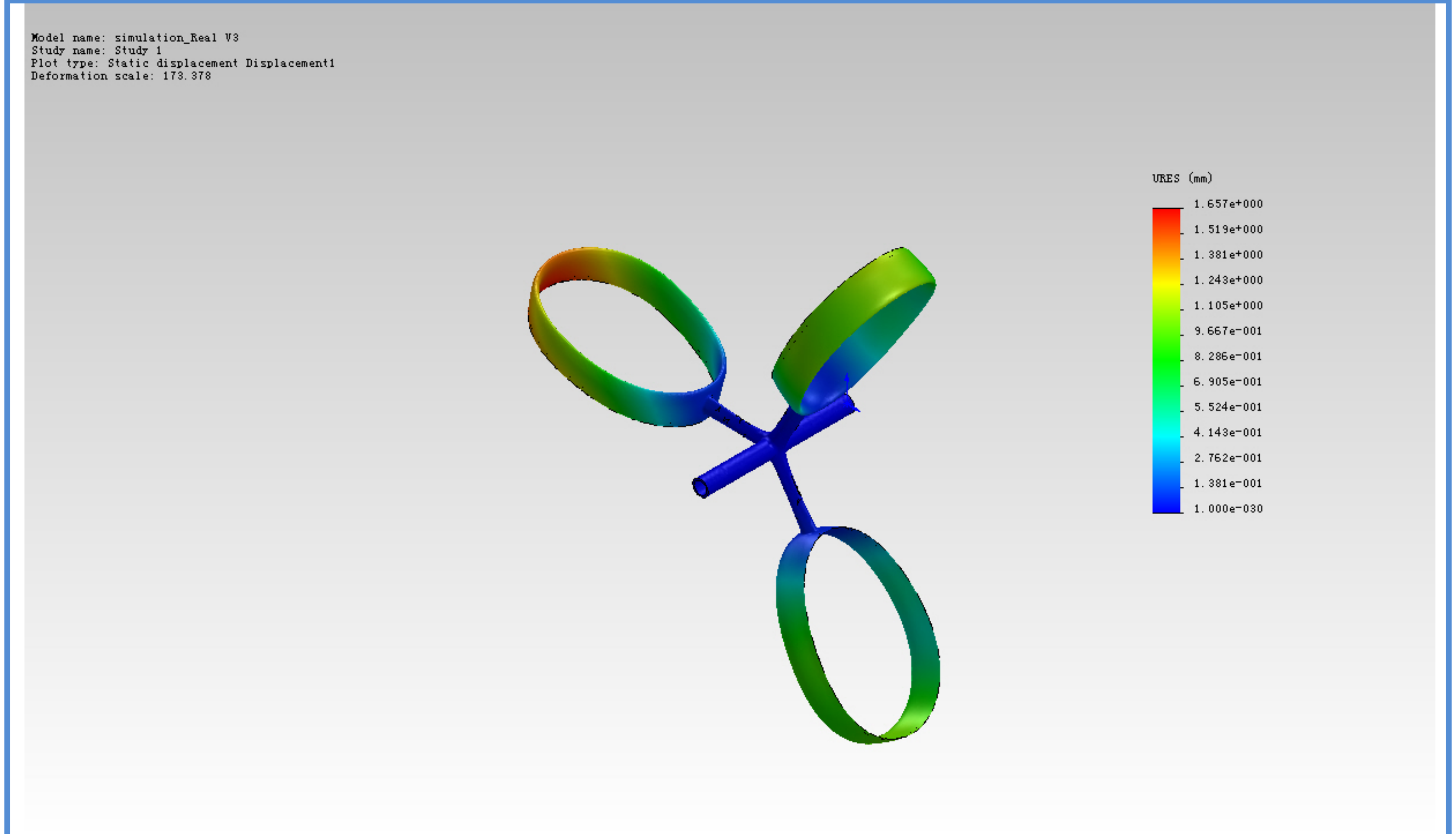
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	20.4486 N/m^2 Node: 11919	7.85434e+007 N/m^2 Node: 12313



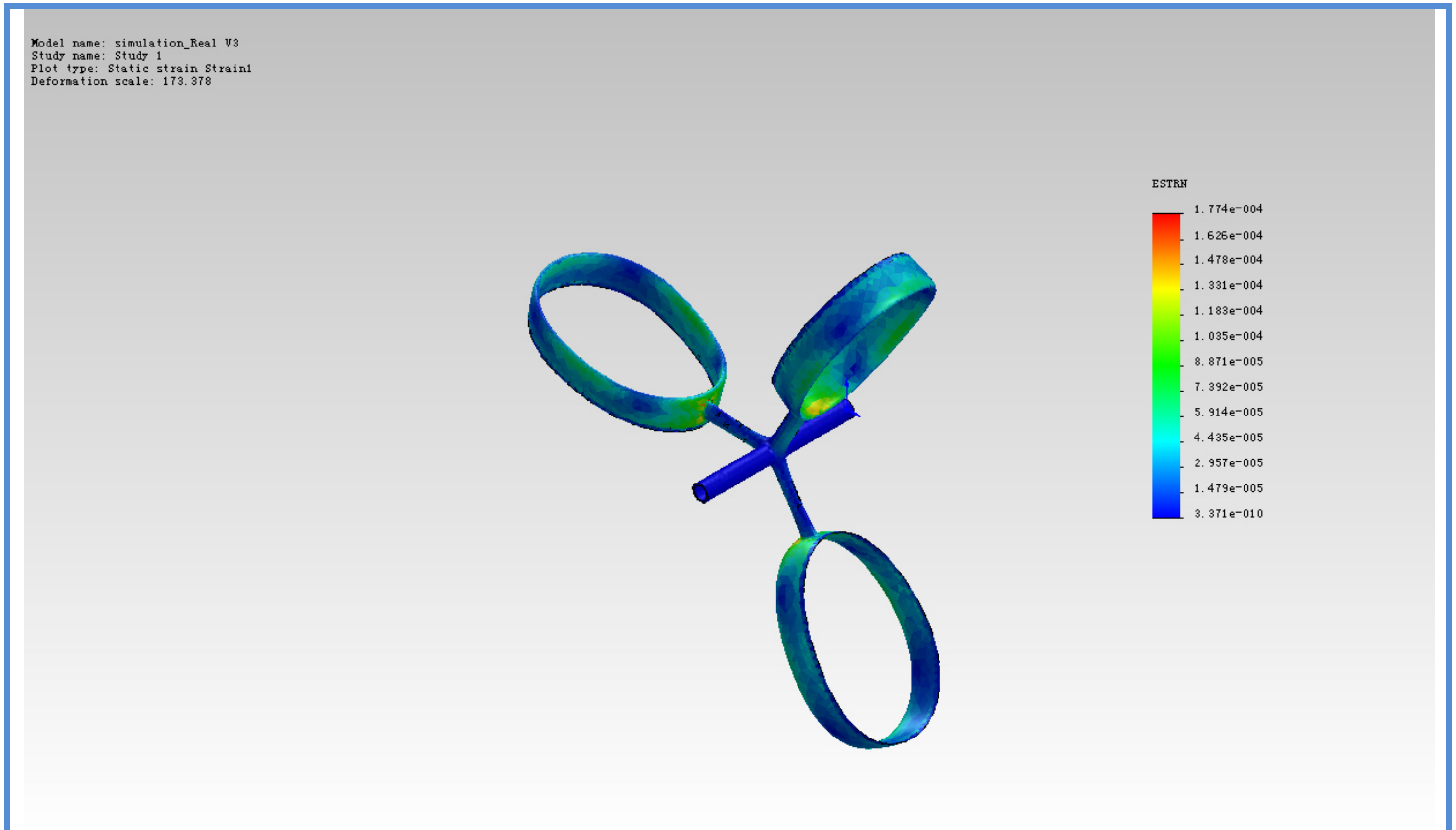
simulation_Real V3-Study 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 193	1.65722 mm Node: 42115



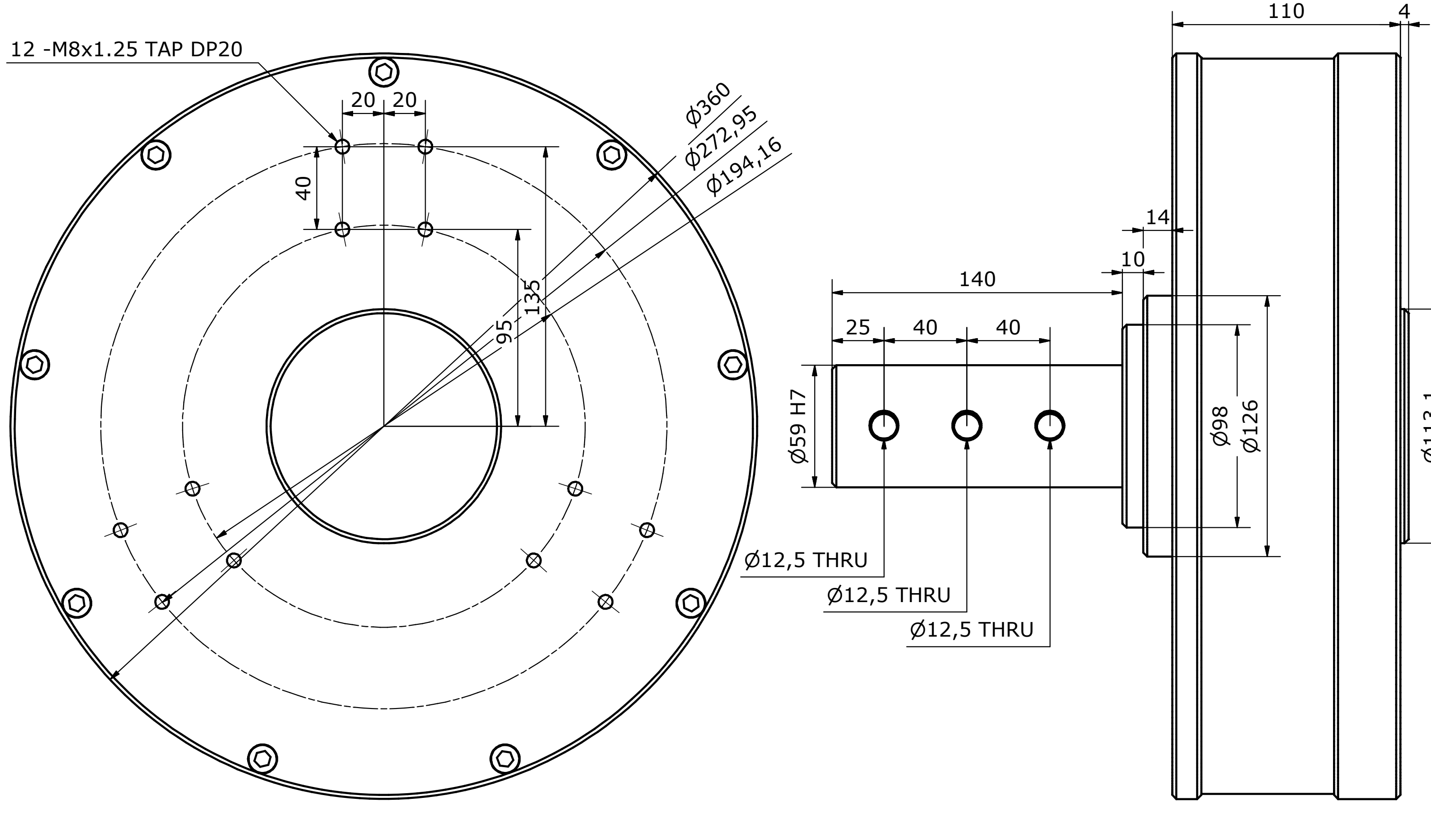
simulation_Real V3-Study 1-Displacement-Displacement1

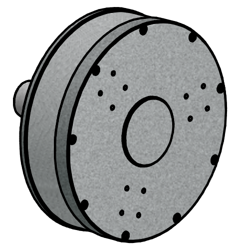
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.37107e-010 Element: 12827	0.000177419 Element: 31943



simulation_Real V3-Study 1-Strain-Strain1

Appendix L - Data sheet of DVE - PMGO - 1K - 200





Technical Data	
Description	Data
Output power (kW)	1.0
Rated speed (rpm)	200
Output voltage (3 phase AC or DC)	220VAC
Max. efficiency (%)	87
Number of poles	24
Speed constant (VDC/krpm)	1970
Resistance at 20C (Line-Line) (ohm)	13.6
Inductance (Line-Line) (mH)	37.2
Rotor Inertia (kg-m2)	0.454
Starting Torque (Nm)	<0.03
Generator Weight (kg)	38

Projection	Scale	Size A3	Material	DVE Standard 1010200
Mrk	Approval/Rev	Date	DVE	PMGO-1K-200 Permanent Magnet Generator 1kW
Replace				
Design				
Approval				
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