



## **The aerodynamic method of the Archimedes Windturbine**

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## SUMMARY

### THE ARCHIMEDES WINDTURBINE

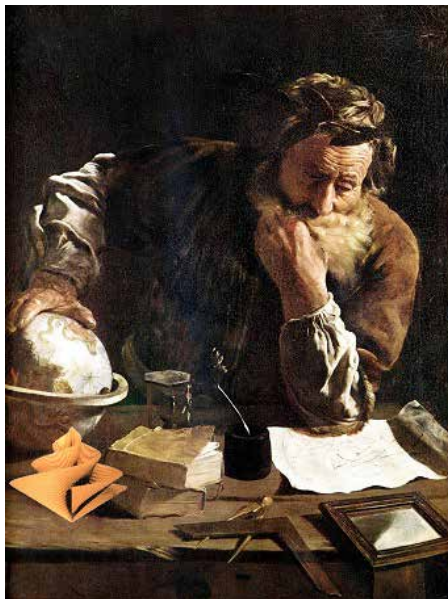
The first thing people ask me is How. How does it work, followed by how did you get it done. So, let us first explain WHAT the Archimedes Rotor in fact is.

A windturbine consists of several parts. A rotor, which converts the straightforward movement of the wind into a rotary movement, a yawing mechanism that aims the rotor in its most favorable position, the generator which converts the kinetic energy into electricity and a number of safety systems. Altogether, a number of disciplines are called upon to come to a working product. In this paper I will address to each of the subjects separately. The greatest innovation concerns the shape of the rotor. Therefore we will elaborate on this most extensively.

### THE DESIGN

#### THE ROTOR

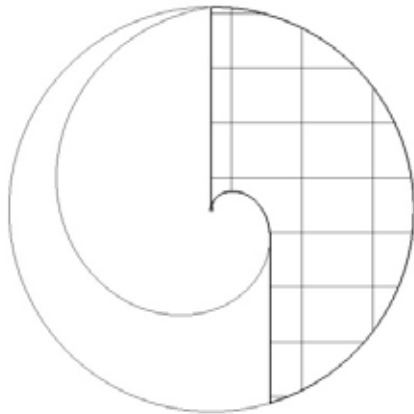
The shape of the Archimedes blades feel resembles a familiar yet unknown object. Its shape makes you feel as if it already exists for centuries but then it also could be something coming from a distant future. We could imagine that it has been on the desk of Archimedes himself, but might also be a futuristic spaceship searching for distant planets.



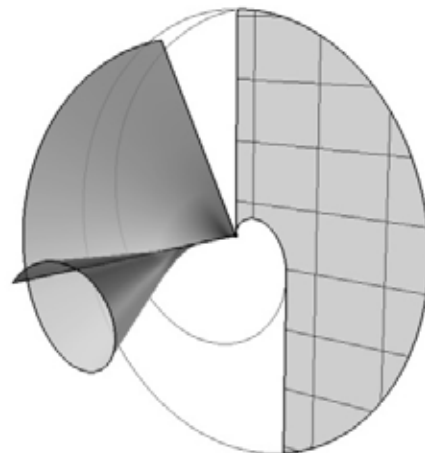
The Archimedes rotor can convert a straightforward movement into a rotating movement, and vice versa And it also functions as a dispel mechanism. This means that the rotor can be utilized as wind- and water mill, as well as a ventilator (*blower*) or a ship's propeller.



The Archimedes rotorblade is a flat surface elongated to give it depth and, therefore its shape perceived to have volume. From a sheet of paper one can obtain the spatial form of an Archimedes rotor blade by turning and simultaneously stretching out a cutout of the plane between a circle with radius R and a flat spiral.



The used flat plane



expended spatial figure

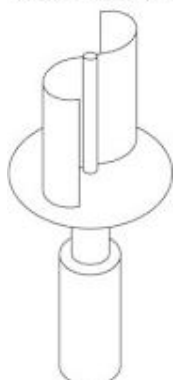
Windturbines are divided into two types . A resistance type and a lift type .

A resistance type rotor is generally made out of flat surfaces with a tip speed ratio smaller than or equal to 1. The tip speed ratio is the ratio between the rotor blade's tip speed at its tip and the wind speed.

$$\text{TSR} = (\text{speed at blade tip}) / (\text{wind speed})$$

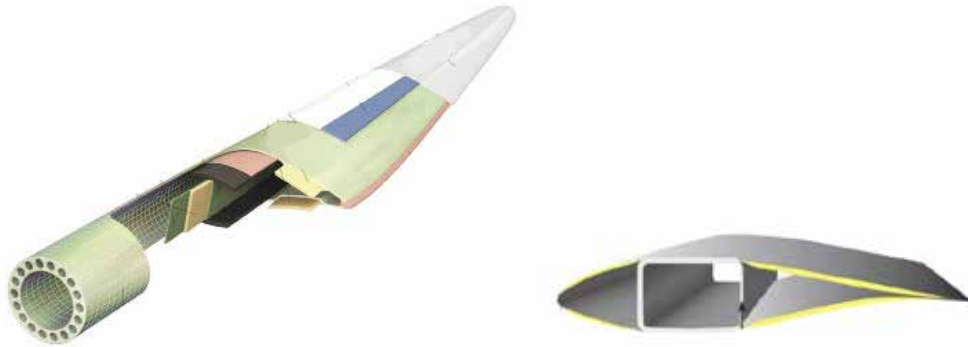
The wind tries to push the rotor away as it were. You could compare this with a boat propelled by paddles . The boat will never move faster than the speed of the paddle through the water. Examples of the resistance type windturbine are the savonius rotor, the turby and the so-called American windturbine.

Savonius-Rotor





The second type of wind turbine operates in accordance with the lift principle. The blade operates like an aircraft's wing, generating a lifting force in relation to the blade. Such blades require a higher degree of accuracy and finishing. The tip speed ratio in these cases is larger than 1. The speed of the blade tip is therefore greater than the wind speed. A higher relative tip speed means higher efficiency, but is also related to more noise and a more robust and heavier design.



Especially birds fly by the lift principle. Bird wings are shaped like airplane wings (or rather vice versa, as birds are of course much older than aircrafts) and provide for lift. (video goose). The wings are in most cases parallel to the direction of the wind.



The mix of resistance and lift principle, however, is a natural phenomenon. Insects, such as bees, can generate both resistance and lift with their flat membrane wings. Bats too adapt a similar technique. By changing the direction of the flow in relation to the angle of the wing, it becomes possible to create lift as well as resistance. ( video, and bat) .

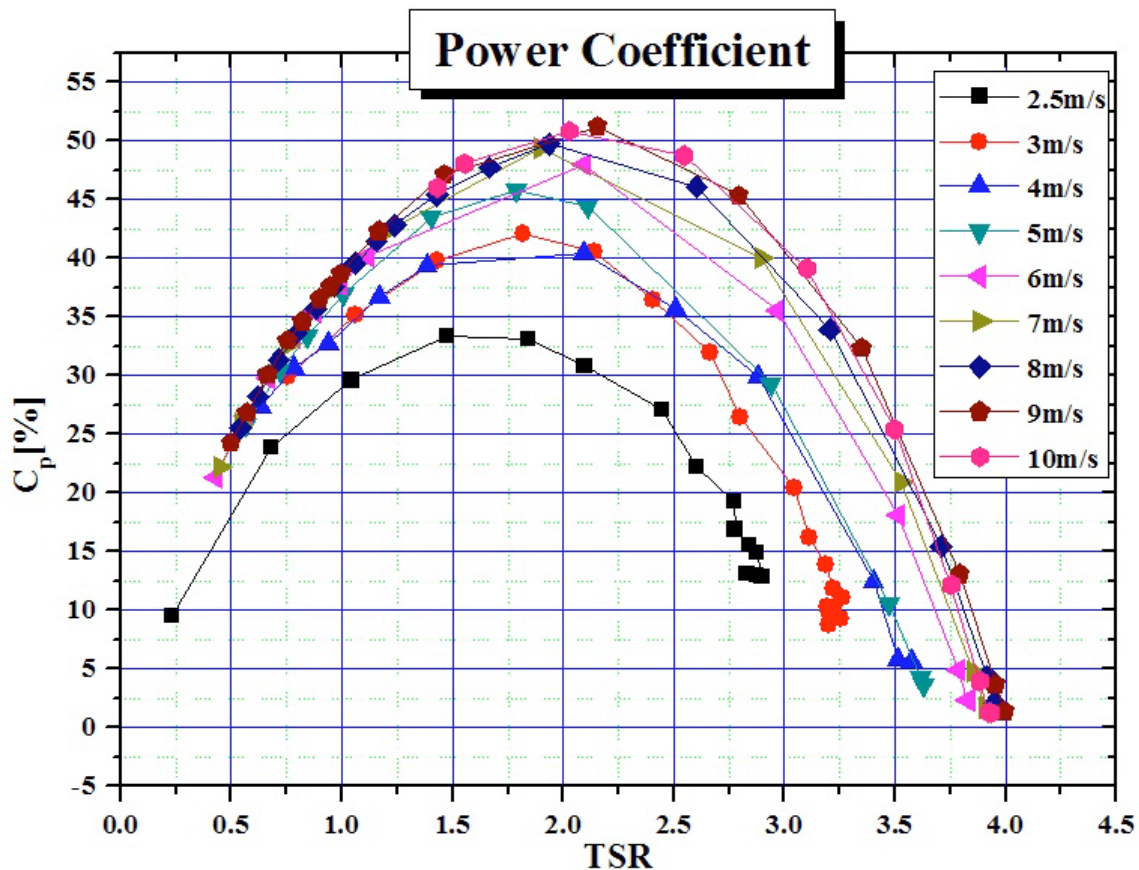




## DE ARCHIMEDES ROTOR

The Archimedes Rotor has the characteristics of both. The blade is constructed from flat sheets, can work under a large margin of error, produces very low noise (<42 Db) and is lightweight. All are characteristics of a resistance type rotor. In contrast, the Archimedes Rotor tip speed ratio is greater than 1, and its efficiency is extremely high, characteristic of the lift type.

The efficiency of the rotorblades has been measured by way of computer simulations, windtunnel tests and field tests at around 52%. This means that 52% of the available kinetic energy in the wind is converted into rotational movement. The theoretically maximum achievable efficiency is 59 % , the so-called Betz Limit . Despite friction of bearings and obstruction on account of its frame, the Archimedes Rotor is able to extract 88 % of the theoretically viable energy from the wind.



### Power coefficient of the AWM set off against the TSR

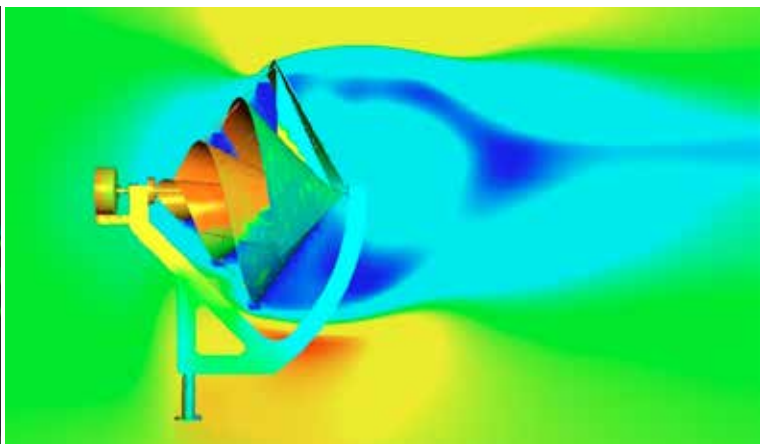
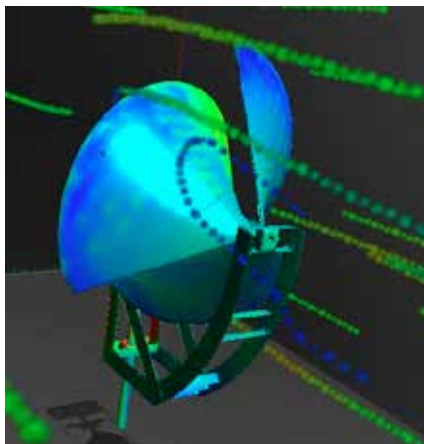
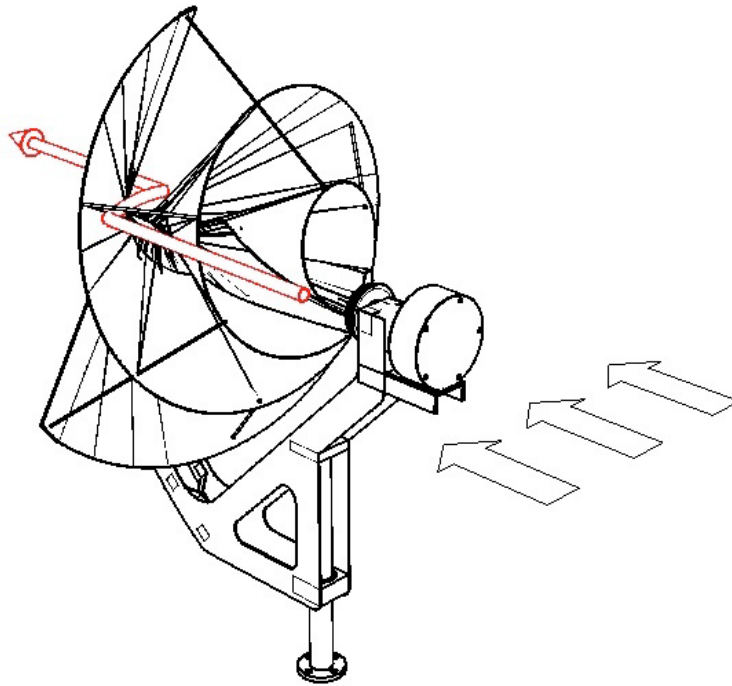
One can harvest energy from the wind by bringing the wind current to an overall hold, but one can also harvest energy from the wind by redirecting its flow 90 degrees relative to the original direction. Relatively speaking, the wind current in its original direction has stalled. Newton's third law says that redirecting an object with a rectilinear motion requires force. In all, the wind currents inside the windturbine are complicated. So complicated, in fact, that computer simulations only give a general impression of the movements in and around the Archimedes Rotor.

The angle at which the wind is being caught by the Archimedes rotor changes continuously during rotation. The induced air currents and resistance between the blades also change as a consequence. During rotation the blades seem to be moving backward. While stationary the forces are distributed over the entire blade. When the blades start rotating this changes. A complex force pattern reveals itself during rotation,



## THE YAWING SYSTEM

The blade's shape also ensures that the blade automatically turns itself into the most optimum wind direction. Methods for finding the optimal wind direction are unnecessary even when the airflow to the rotor is blocked unexpectedly



## GENERATOR

The generator is a high voltage generator and can achieve up to 400 volts. The advantage of such a high voltage generator is the relatively higher efficiency and lower copper losses that occur during transport of the energy through the copper power cables (compared to low voltage generators). In addition, the risk of overheating is reduced to a minimum.



## THE SAFETY FEATURES

The Archimedes windturbine has several safety features to ensure safe operation. Both the generator and the brakes have an automatic mode and a manual mode .

The controller sets an upper limit to the number of rotations per minute (RPM) . This prevents the rotor from spinning too fast. The mill can also be stopped manually by means of the generator, the so-called emergency stop .

An electrical brake is installed at the back of the machine, which is governed by a controller that measures the actual wind speed. When the wind speed exceeds a certain value (e.g. 15 m / s ) this electrical brake kicks in. Only when the wind speed reaches a lower limit (say, 10 m / s ) will this break kick out again. This governor thus prevents wind gusts to spin the mill too fast. This brake too can be activated manually in order to stop the machine.

## HOW DID THIS ALL COME INTO BEING

One question remains unanswered: How did this design come about?

Einstein once said: “The more we look at nature, the better we understand the world. We as humans are part of nature and I am therefore convinced that we all have the same knowledge”. Plato confirmed this when he stated that each person already has the knowledge, but that this knowledge can be used if one asks himself the right questions. answered Or, can one state that knowledge is merely the re-discovery of forgotten information?

In any case, the works of Archimedes gave me the inspiration and the tools to do the job. In my estimation one who sticks to the rules of geometry and symmetry will never end up riddled .

In my opinion "The works of Archimedes " by L. T. Heath forms the basis but also expands our knowledge about planes and their relations to volume types.

In my view, the method of Archimedes consists in particular of the relation between planes and volumes and the relation amongst volumes .

Archimedes uses a fixed method in all his works. It includes the creation of a volume shape from a flat plane by turning or pulling at or along its central axis.

The flat plane is always represented by an edge or projection of a cone edge. This leads to a triangle, circle, ellipse, parabola, line and a point. A triangle rotated around a central axis produces a cone. A half-circle rotated around its axis produces a dome , but a circle drawn along its central axis turns into a cylinder. Turning or pulling a flat surface shape thus provides a spatial figure. Except for the coil, Archimedes experimented with any flat shape according to this design. The flat, one-dimensional, shape of a spiral does not in all his surviving works find a follow-up as a spatial form. The single act of twisting or pulling a spiral does not turn it into a valid volume shape either. Overlaps or inclusions are the result of a single action.

Employing both operations at the same time, however, does provide a valid volume figure --but is not described as such by Archimedes. However, extension of his method leads us to a new mathematical spatial figure also subject to common theories.

Additionally, there is also an unhealthy amount of labor, luck and good partnership required (privately and in business). I will not recommend such a challenge to anyone .

The rotor blade in our first patent, granted in 2006, had an opening angle of 30 degrees and Pi number of revolutions. Two manners of suspension were examined, and separate resistance measurements were performed on the frame. The rotor in its first type of suspension was supported at the front and at the back. In the second



type it was only supported at the back. Resistance values of the suspension were measured separately, so that the resistance values of the rotor could also be calculated separately. March 2007 tests carried out by Tu Delft showed a very different resistance profile. Where resistance increases exponentially in normal cases, Tu Delft's figures showed a very different profile that is best described as a proportional relation to the resistance. Explanations were not found. It also showed a wide range of tip speed ratios and angles of attack that would allow this model to perform optimally. Efficiency of this model was approximately 10%. It was noted that further research was needed to explain the theoretical deviating results.

In 2009 an improved model was tested at the Peutz wind research center. The rotor suspension consisted of a simple attachment at the rear of the rotor. Lead weights were arranged on the outer ring in order to balance the model. This model broke at 21 m / s because it could no longer resist the rotational forces caused by the lead balance weights. It was then decided to shorten the model. The number of revolutions along the rotor axis was approximately one, and its opening angle was unchanged at 30 degrees. That positively affected the model's efficiency which increased to approximately 15 %.

Research at Peutz pointed toward a lower number of revolutions which, however, also meant a change in the opening angle and the length of the shaft. The model, with one single revolution leading to an opening angle of approximately 60 degrees, was virtually completed in 2010. Also in 2010, a patent application for the new model was submitted. CFD studies were performed showing an efficiency of around 25 percent.

Not until 2012 a very detailed study at the university to Pusan Korea was begun. CFD analysis confirmed the computer calculations made earlier and the theoretical efficiency was determined at 25 %.

However, in the wind tunnel our first prototype registered an efficiency of 28 %. This model, though, broke apart at 7 m / s. Improvements and reinforcements were applied to the model. Over the two subsequent years rotor efficiency rose to an astonishing 52 %. Measurements were performed several times in order to confirm the results, as well as to determine the consequences of a possible blocking effect. The results were the same in each and every situation. All tests were performed with the same suspension, with support on both sides and with calibrated measuring equipment. Resistance measurements were not performed, but were determined by means of CFD computations. Which showed that the resistance coefficient is approximately 0.9. CFD and wind tunnel research also confirmed the wide range of tip speed ratio and large angles of attack.

We owe much to our Korean partner Esco RTS. Despite the fact that according to experts in the Netherlands our rotor model could not work, would not be built and certainly would never come to production, we have done the impossible in collaboration with the people at Esco RTS and the University of Pusan. My thanks goes out to these people –naturally, without doing short to those who also deserve my gratitude.

## NOTES TO THE THEORY

In my opinion the work of Archimedes himself are not separate books nor a summary of his live. We have tried to place his work in its historical context. Research into the Greek ancient history has placed his work in a different light (or air). The strenght is combining many theories, these so called COMBINATORIA. The evolution and history of all the work of Archimedes is needed for understanding this.

Here are two examples of his way of thinking based on only two propositions from the book on "Floating Bodies"

Proposition 2:

the surface (skin) of any rest, a sphere with the centre

The centre of the Earth spinning force. Proposition 6:



fluid, including air, form while at of the Earth at it's centre.

actually spins which causes the





When a solid object, lighter than fluid, is forced upon a fluid, it will experience an upward force equal to the difference between the weight of every object lighter or heavier explained by this thesis. The hot while keeping the same weight. difference in the hot air and its experiences a positive upward



the object and the fluid. This goes for than fluid or gas. The rise of hot air can be air expands and therefor increases in space Hence the difference between the weight surroundings is positive, the hot air force and rises.

The air seems to be moving the space it inhabits. Air can also expand and extract through speed differences. And so this air also experiences an upward force and will rise. The upward and downward movement of the air seems to take place without the loss of kinetic energy. The combination of sideway, upward and spinning force creates a spiral. One has to ask himself if Graham's law can be applied to these accelerations (upward force) and if the compilation of the gas changes through speed. Graham's Law:

effortlessly up and down by influencing

$$\frac{\text{Rate of effusion of gas}_1}{\text{Rate of effusion of gas}_2} = \sqrt{\frac{M_2}{M_1}}$$

This all brings us back to Archimedes. This spiral movement, which is caused by a horizontal and vertical movement is found al throughout nature. From a Nautilus shell to plants and even in our own body. The Archimedes windturbine (AWM) turns and accelerates internally by which an optimal lift and tranfer of kinetic energie is realized. The AWM doesn't stop the wind, but turns her to a mere 90 degrees. The forward force is relatively seen reduced towards zero and is bend to a sideway force. Within the windturbine the wind accelerates in almost all directions. One of the underlying theories is the so called coanda effect. This effect can also be observed when you put the round side of a spoon in a jet of water. The water partly follows the shape of the spoon before falling down.

## Learning objectives

More higher Power Coefficient for small scale wind turbine fields to householder or small business.  
Power generation characteristics and initial rotational characteristics with the theory method.

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