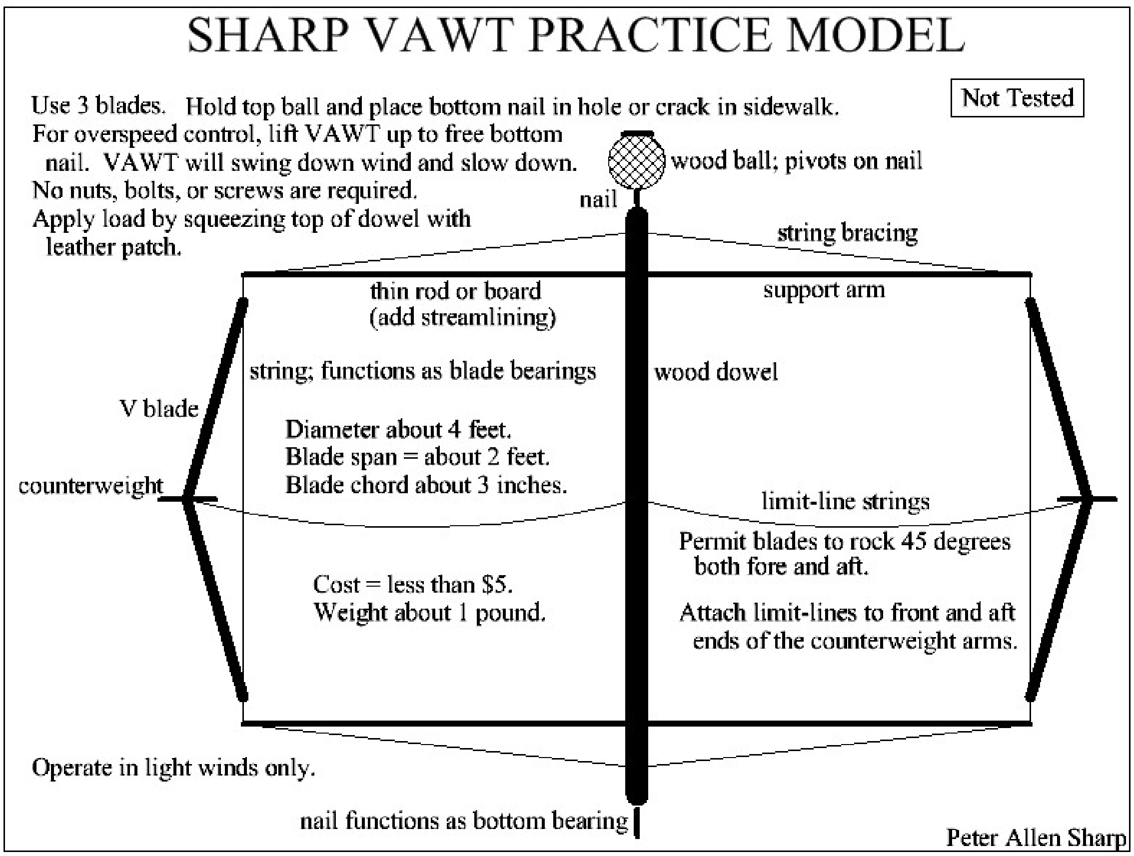
THE SHARP VAWT
Practice Models

Peter Allen Sharp
Sharp Products, 2786 Bellaire Place, Oakland, CA 94601
sharpencil at sbcglobal.net 8/10

The Sharp VAWT cycloturbine is a lift-type vertical axis windmill/turbine (VAWT) that solves most of the problems associated with VAWT. (A list of problems and solutions is not included here.) The blades passively control their own pitch. It is self-starting with good torque, has a broad torque curve, typically operates at a TSR of 3 to 3.5, and should have a Cp of about .45 (based on 3 research theses for closely similar VAWT). So it is almost as efficient as high-speed HAWT. It can be used to generate electricity or to operate a water pump. By stacking it, it can produce a much higher rpm for a given swept area than a conventional HAWT. By making it much wider than tall, it can produce much higher torque than a conventional horizontal axis windmill.



Versatility is its most important attribute. It is also quite simple to build, and cheap. If you can make a paper airplane, you can build a basic Sharp VAWT. However, the minimum diameter for a 3 blade model is about 4 feet, with 24” blade spans and 3” chords. That is because the blades need enough time to pitch, and because the Reynolds number gets too low with a chord of less than 3”.

SHARP VAWT V BLADE

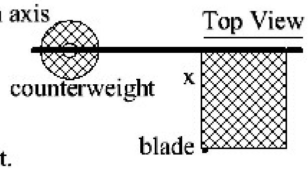
This blade unit controls its own pitch angle and does not stall.

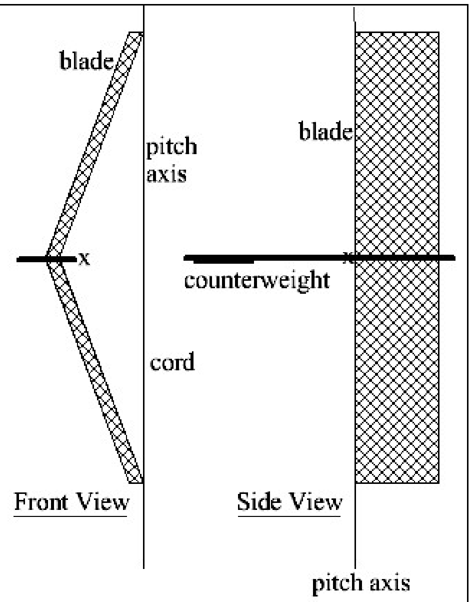
The V blade, counterweight, and counterweight arm together constitute the "blade unit".

The length of the centrifugal pendulum arm is the distance between the pitch axis and the center of mass of the blade unit.

Blade unit = centrifugal pendlum mass.

x = center of mass of blade unit.





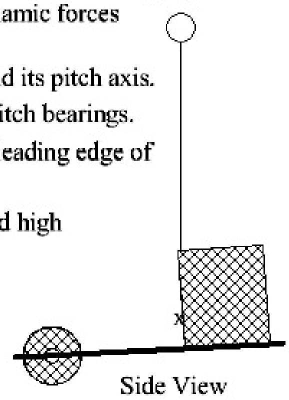
The blade unit functions as a "centrifugal pendulum spring" to balance the aerodynamic forces acting on the blade.

The blade pitches around its pitch axis.

The cord functions as pitch bearings.

The pitch axis is at the leading edge of the blade tips.

A V blade can withstand high centrifugal force.

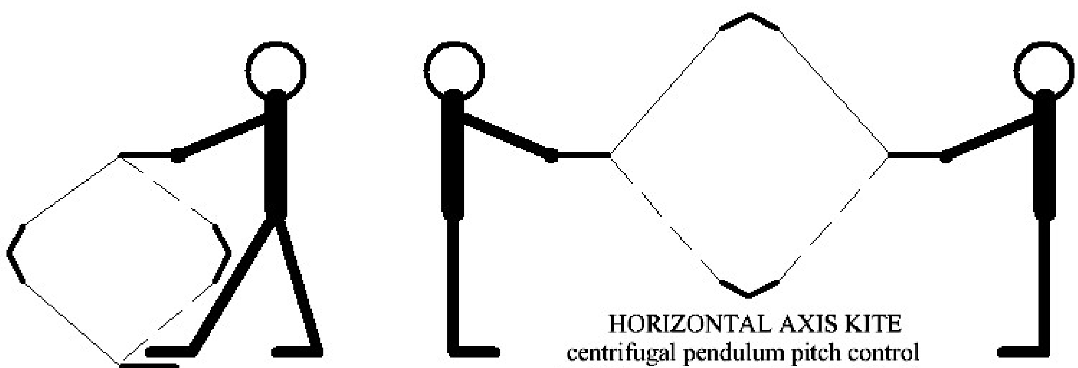


BLADE BALANCING

Suspend the blade with its span horizontal.
Adjust the counterweight on the arm until the blade is tangent to its orbit at the 1/4 chord point.
This is the neutral, zero pitch angle.
The blade may look like it has toe-out, but it does not.

Peter Allen Sharp 2007

SHARP VAWT SINGLE V BLADE PRACTICE MODEL



VERTICAL AXIS WINDMILL
centrifugal pendulum pitch control
Self starts in low wind.
Orbits at 2 to 3 times wind speed.

HORIZONTAL AXIS KITE
centrifugal pendulum pitch control
First kite to fly upwind part of the time.
Requires moderate wind speed.

To start the vertical axis windmill, take up the slack in the elastic cords. The blade will oscillate and then transition to an eliptical orbit, and finally to a circular orbit as it expands its diameter as the wind speed increases. To stop the blade, move your hand rapidly back and forth toward the blade.

To start the kite, it should face the wind when it is hanging down. Pull the handles apart to put the cord under tension. To stop the kite, shake the handles.

Peter Allen Sharp

I invented the Sharp VAWT in 1978 and patented it in 1982 (US Patent # 4,334,823, June 15, 1982). I tried for many years to get grants to develop it, and to get help from the federal government to analyze it, and to interest engineers in helping me. I failed, although I came close a few times. So the two models I still have are hanging in my garage, each with a broken blade, collecting dust. The reason I could not get any grants or engineering help is that engineers simply refuse to believe what I tell them about my models, even when I cite supporting academic research that validates the underlying principle. They don't understand my VAWT so they fault my VAWT (or me) rather than their own level of understanding.

I discovered validating research only a few years ago and I've been studying the underlying principle. Since I'm getting old, and since there is a renewed interest in VAWT among amateurs, I've decided to ask amateurs to help me develop the Sharp VAWT for their own purposes. But a strong word of warning: The Sharp VAWT, even in small sizes, is potentially dangerous because it accelerates very rapidly due to the fact that the blades do not stall. If allowed to spin freely, it can create explosive centrifugal forces in seconds. The runaway TSR is over 5 if it is well streamlined.

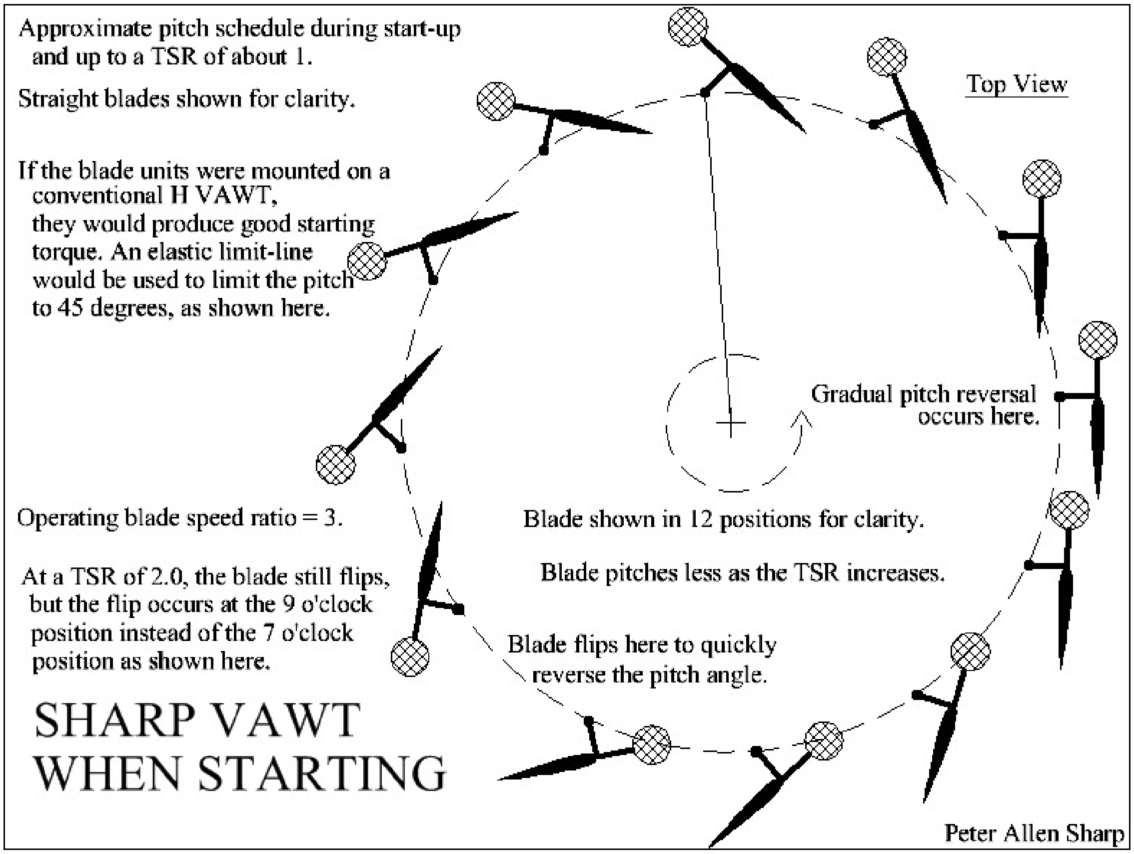
Ed Lenz invented his Lenz2 VAWT because he was rightfully scared by a runaway H rotor. So if you are not the very careful type, don't build a Sharp VAWT. Another word of warning: Never build a Sharp VAWT with only 2 blades. Its produces much higher torque than fixed-blades and that translates into strong rotor drag pulses that can cause destructive vibrations if only 2 blades are used. Two blades will seem to work just fine until you hit the resonant frequency of the VAWT, and then it will vibrate intensely. Three blades smooth out those pulses. Use 3, 5, or more blades unless you are building a single blade model with elastic cords (see below).

The blades are laughably simple to make. Because the blades do not stall, due to the pitch control system, they do not need to be carefully designed (except for commercial VAWT where every percentage point counts). For models, just folding a piece of sheet material and then fastening the trailing edges is all that is required. I've made lots of blades out of thick, business-card paper, and they were powerful. They can be waterproofed by unfolding them and covering both sides with overlapping clear packaging tape. Trim the tape so it leaves a tiny margin around the paper. The simplest blades to make are V blades, so that is what I will discuss here.

The simplest Sharp VAWT uses only one V blades suspended between vertical elastic cords attached to handles. You hold one handle and step on the other, and then lean back. It self-starts and the orbit expands as the wind speed increases. Its unbalanced motion could be used to operate an oscillating pump. I recommend that you make this Sharp VAWT first so that can observe how the pitch control system works.

If two people each hold one of the handles, the blade will self-start and orbit in vertical circles. Start with the blade hanging down and facing into the wind. It does not work well when revolving in the opposite direction. The reason has to do with how the advancing side of a VAWT produces more thrust than the retreating side, plus the effects of gravity and the storage of rebound energy in the elastic cords. To stop the blade, quickly move one of the handles back and forth toward the blade.

To make the above V blade, start with thin sheet plastic or business-card paper that is 11" by 4 inches. Fold the paper the long way first, and then fold it at mid span to form the V shape. Tape or staple the trailing edges together. A bamboo skewer (thicker type, 5/32", 4 mm) works well for the counterweight arm. I cover it lengthwise with white strapping tape in case it breaks, and to waterproof it. The counterweight is a 1" fender washer. Unfold the paper and tape a string along the inside of the leading edge crease. That string ties to the elastic cords. Tie the counterweight to the counterweight arm and tie the counterweight arm to the inner side of the blade. Put a drop of glue on your knots.

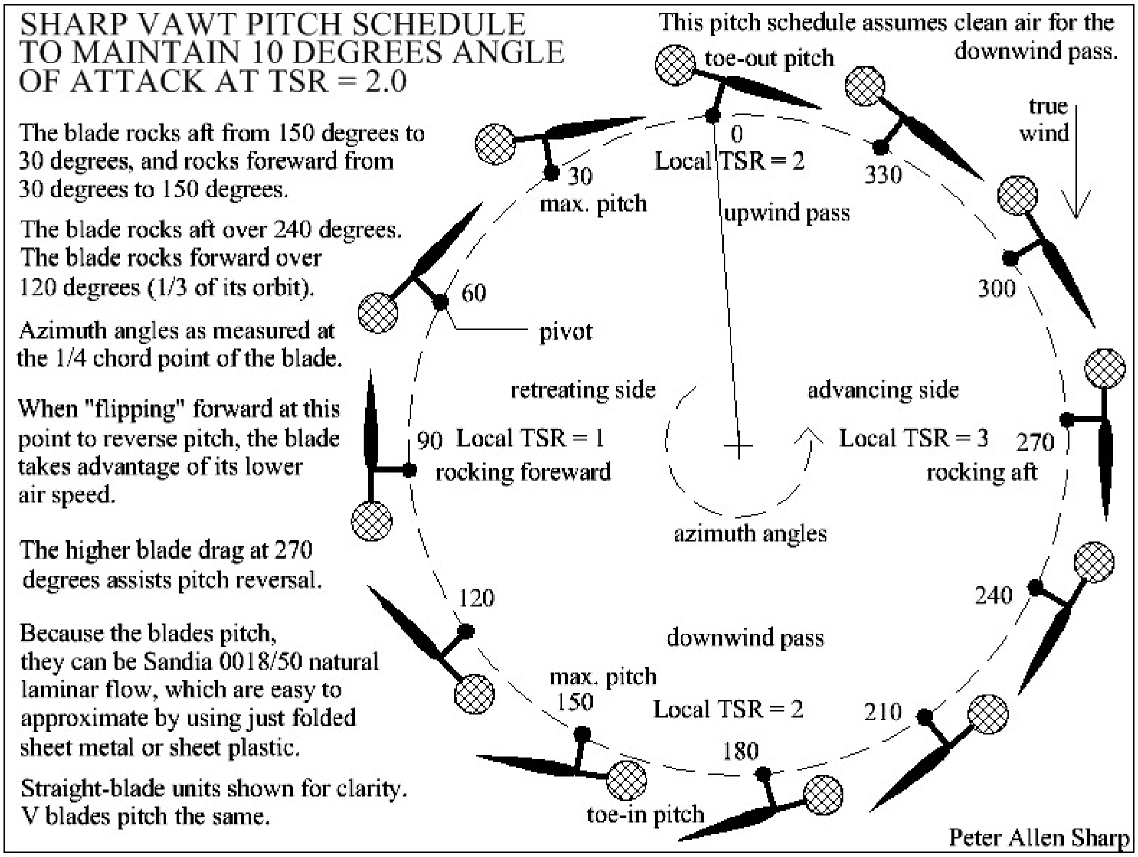


The elastic cords can be found in any sewing/fabric shop. I use 18" long pieces of Stretchrite (1/32"). Fishing swivels should be located between the handles (bamboo skewers or sticks) and the elastic cords to keep the cords from twisting. The smallest ball bearing swivels work best, but the next to smallest size of the standard fishing swivels work well too. For self-starting, just take up the slack in the elastic cord. The blade will start to oscillate and then begin to orbit. The cost of the materials, with ordinary swivels, is under $1 for a complete and accurate pitch control system. With ball bearing swivels, the cost will be roughly $5.

For the single V blade VAWT, the string between the blade tips (as shown above) is not needed. When finished, this little VAWT looks quite unimpressive. But in a strong wind, watch out! It moves at between 2 and 3 times the speed of the wind. If you want larger vertical circles, use longer elastic cords. When flying in vertical circles, this VAWT is actually the first kite in history to fly upwind of its anchor points under it own power.

I started experimenting with V blades a few years ago, but I have almost no wind where I live (near a creek beside 100' redwoods and eucalyptus trees in the middle of Oakland, CA). So I haven't yet used them on a 3 bladed VAWT. I hope to make one soon. If you want to be the first, here is how to construct it. I suggest a hand–held model because it can be quickly tipped away from the wind for overspeed control. Just be sure to always keep it above your head when it's running, or near the ground like this one, and wear safety glasses, or better, a motorcycle helmet with a face shield. It's always better to look stupid than die.

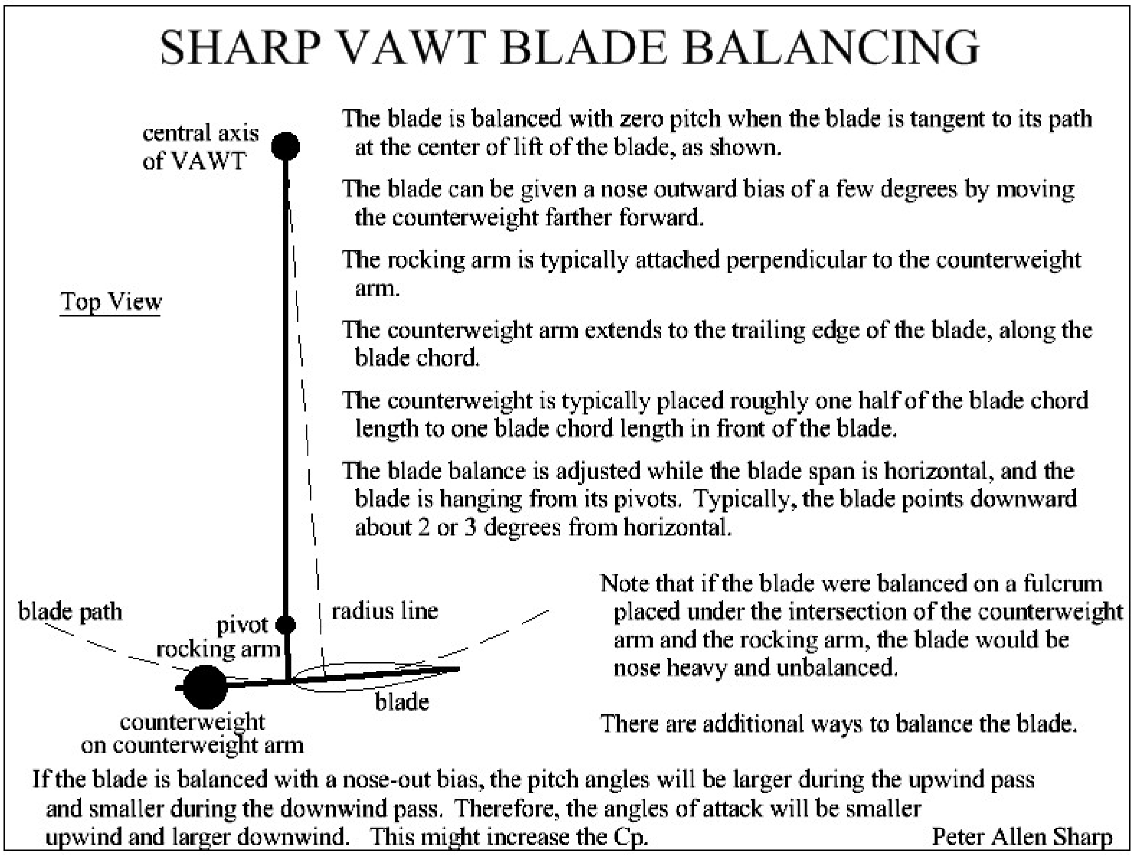
It is made to hold upright while standing next to it. Don't wear loose pants cuffs that could be caught by the blades. I lost a pair of Levi's that way – torn from cuff to knee and the VAWT didn't bother to slow down. Stiff-paper blades will work fine, but I suggest waterproofing them with tape. My first model like this melted before my eyes when the San Francisco fog rolled in because I didn't waterproof the blades. Use a larger fender washer for the counterweight, or 4 of the 1" fender washers. Fender washers are easy to tie to a counterweight arm.



Each half of a V blade can be made from a sheet of business-card paper, and then use strapping tape on the inside to join them before sealing the trailing edges together, and seal the outside of the joint with clear tape. If you wish, additional internal bracing for the blades can be provided by lacing short sections of plastic straws along the thickest part of the blade every few inches. Make sure any external lacings run chordwise so as to not create drag. The lacing goes around the leading edge of the blade and through the thickest part of the blade, and through the short length of each short section of plastic straw to hold it in place. The knots can be slid inside of the blade.

A Sharp VAWT blade can be constructed to limit its own thrust by using a flexible counterweight arm, perhaps music wire. If the counterweight flexes outward due to excessive centrifugal force, that will cause the blade to toe-in too much. The blade will not pitch enough when upwind, causing some stalling, and it will pitch too much when downwind, causing some feathering. More testing is needed to explore this option.

Now for a simplified explanation about how the Sharp VAWT works using either straight blades or V blades (they both work the same way). If you took physics in high school, this is simple. If not, then you may need to do a bit of research on the Internet to understand a little about pendulums and centrifugal force. Not much, just a little.



The blade functions as a horizontal pendulum in a centrifugal force field. The center of mass of the blade and its counterweight are equivalent to the center of mass of a pendulum bob. The centrifugal force acting on the “bob” can reach many times the force of gravity (many G’s).

If a gravity pendulum is hanging still, it will seek its lowest position. Similarly, a centrifugal pendulum will seek its most outward position. Force is required to push a gravity pendulum bob sideways because the mass must be lifted against gravity. Similarly, force is required to push a centrifugal pendulum bob sideways (fore or aft) because the mass must be “lifted” inward against centrifugal force.

A gravity pendulum acts like a spring in that it tries to return to its neutral position. However, it stores gravitational potential energy when it is lifted, so when released, it will swing back past its neutral point and swing almost all of the way to the same angle on the opposite side. A centrifugal pendulum behaves similarly. It stores centrifugal potential energy when it is swung inward against centrifugal force. When released (by a shift in the apparent wind acting on the blade), it will swing almost to the equal angle on the opposite side.

In the case of the Sharp VAWT, the centrifugal pendulum swings to the opposite side when the blade reverses its pitch angle. It is easy for the blade to reverse pitch because it has lots of centrifugal potential energy to work with. And like a gravity pendulum, a centrifugal pendulum requires very little energy to keep it swinging back and forth. The energy required to pitch the blades is inconsequential. Light blades work best because they have less inertia, and that makes them more responsive.

There is a difference in the way that a centrifugal pendulum spring behaves as compared to a gravity pendulum because it must contend with aerodynamic lift acting on the blade. On the advancing side of the VAWT, the blade swings gradually aft during pitch reversal. The blade uses its own aerodynamic drag to help it swing aft when the blade is not producing thrust.

On the retreating side of the VAWT, the blade swings rapidly forward during pitch reversal because the aerodynamic lift on the blade reverses more quickly on that side of the VAWT. At low TSR, the blade will “flip”. So the blade stays in phase with demand, meaning that it pitches correctly on both sides of the VAWT.

The reason for using a centrifugal pendulum spring to control the pitch angle of the blade instead of a coil spring is that both centrifugal force and aerodynamic lift increase at the same general rate – by the square of the ground speed and the air speed respectively, whereas the resistive force of a coil spring increases only linearly. So in general, when the blade produces more lift and the VAWT spins faster, the resistive force of the centrifugal pendulum spring increases at the same rate as the aerodynamic lift of the blade that tries to pitch the blade.

That means that the two forces can work together over a broad range of tip speed ratios (TSR) to pitch the blade correctly. All that is required is to balance the blade correctly in the first place. And that is easy to do. The blade is balanced correctly when the blade chord is tangent to its orbit at the center of lift of the blade (the ¼ chord point).

The distance from the rocking axis to the center of mass must be pre-selected to match the mass of the blade unit. In practice, that is easy to do by simple trial and error to see what works best. The proportions I show should be used as a starting point. They work fine for a range of blade weights. To adjust the zero pitch angle of the blade, slide the counterweight forward or backward along the counterweight arm, and then lock it in place. With the blade span hanging horizontal, it is easy to adjust the zero pitch angle of the blade.

The centrifugal restoring force (CRF) tries to keep the blade from pitching, like a fixed blade. The aerodynamic pitch force (APF) tries to make the blade face directly into its apparent wind, like a wind vane. The two forces reach an ever changing balance. That balance point determines the pitch angle of the blade at every point along its 360 degree orbit. As the blade pitch increases, the CRF increases, the APF decreases, and the angle of attack decreases.

If the wind gusts, that lowers the TSR and makes the APF stronger than the CRF, so the blade pitches a lot and that in turn reduces the angle of attack. The blade does not stall. If the wind dies, that raises the TSR and makes the CRF stronger than the APF, so the blade acts almost like a fixed blade and pitches very little. Consequently, a centrifugal pendulum spring is an excellent way to control the pitch of a VAWT blade. It is able to take into account changes in the average TSR, and also take into account changes in the local TSR (the TSR at any given point around the blade's orbit).

Remarkably, a simple Sharp VAWT blade unit is able to control the pitch of the blade almost as accurately as a computer. In fact, each blade unit actually functions as an analog computer. The blades don't pitch quite as precisely as the blades of the original Giromill (1978) , but because the Sharp VAWT requires none of its wind sensors, pitching motors, gear belts, or computer, the Sharp VAWT ends up being as efficient as the Giromill overall, and for only a tiny fraction of the cost.

A more complete explanation of the Sharp VAWT, including straight blades, potential overspeed control techniques, and various configurations, would require a book. I have a 34 page summary article that I can send via Email (almost 5 MB). It is more technical, with vector diagrams and discussions of the technical literature, but still no math. It explores some of the potential applications of the Sharp VAWT. It also presents a new type of transmission and a new design strategy for Sharp VAWT. It is free, but if you can afford it, donations are welcome to help support my research on wind energy conversion systems. (One of them is capable of supplying all of the world's energy.)

Once you have successfully built and observed the practice models, you will be qualified to build your own design.

By the way, the Sharp VAWT is not a variation of the Darrieus rotor. The opposite is true, even though the Darrieus rotor was invented first. The Sharp VAWT is technically more fundamental. The Darrieus rotor can be derived from the Sharp VAWT, but not the reverse.

If you are an engineering professor and think that blade thrust will cause the blade to rock forward when upwind, please draw a vector diagram. If you think that unbalanced forces will cause vibration, please do a careful analysis of the constantly shifting center of mass of the VAWT that includes all three blades pitching simultaneously.

Good luck with your experiments, guys and gals, and please keep me posted. One last time, let me repeat: This is a dangerous experimental device. Keep it away from children, pets, and careless friends. Use at your own risk. Don't drink and VAWT at the same time. Be safe!