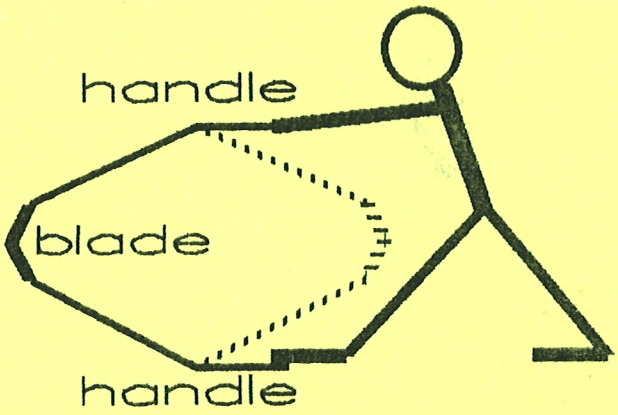
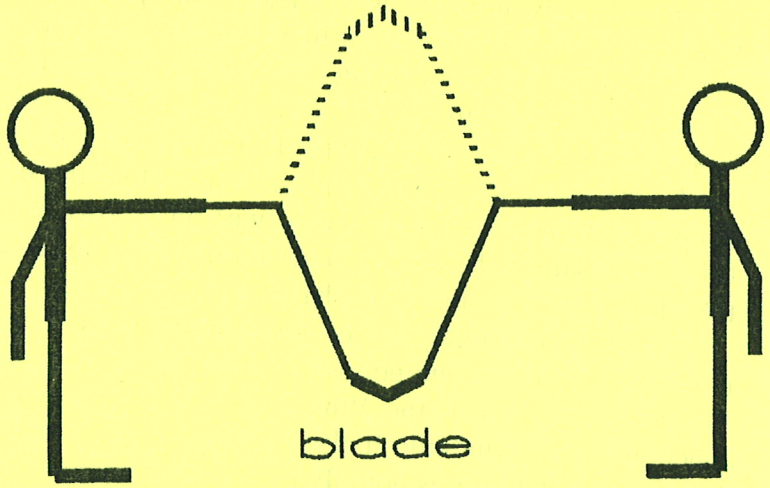
The WHIRLWING

FUNCTIONS AS EITHER A SINGLE-BLADE, VERTICAL AXIS WINDMILL OR, WHEN ON ITS SIDE, AS A HORIZONTAL AXIS, 2-LINE KITE THAT FLIES UPWIND! DURING 1/2 OF ITS REVOLUTION (the first kite to do so!)



ORBITING AS A WINDMILL



ORBITING AS A KITE

For ages 12 through professor. Although very small and light (so as to be reasonably safe), this is a real vertical axis windmill. It spins at about 2 to 3 times the wind speed (tip speed ratio, or TSR, = 2 to 3). The single, V blade is suspended on elastic cord. Its diameter expands as the wind speed increases. The diameter can reach 6 feet. Excellent for science fair projects or Ph.D. dissertation topics.

WINDMILL DIRECTIONS: Use only in winds under 10 mph. Keep away from small children. Hold one stick handle and step on the other. Hang the V blade vertically. Leave a little slack. Arch your body away from blade as far as possible. It will self start in light breezes. Or, swing the blade in a circle to start it if the wind speed is very low. If the blade bumps into you, tape the stick handles to longer sticks such as wooden dowels.

To stop the blade, move your hand toward the blade quickly, or shake the handle side to side rapidly. That disrupts the centrifugal force acting on the blade. Practice stopping the blade indoors by twirling the blade around manually and then stopping it quickly. You can also grab the elastic cord to stop the blade. The blade is very light (22 grams; 3/4 ounce), so it will not hurt much, if at all, if it hits your leg while spinning very fast.

WINDMILL THEORY: The Whirlwing is a variation of the **SHARP ROTOR**. (It is not a Darrieus rotor.) Sharp rotors (and Sicard/Bayly-Kentfield rotors) with 3 or more blades operate at a tip speed ratio of 3, produce strong starting torque, a broad torque curve, and high efficiency. (In contrast, Darrieus H-rotors with straight, fixed blades have low starting torque, low torque at low tip speed ratios, a steep and narrow torque curve, and their power is limited by static and dynamic stall.) The Whirlwing continuously adjusts its own angle to the wind by dynamically balancing wind forces and centrifugal force. The operating principle, which is almost as accurate as a computer, is called "passive dynamic, centrifugal pendulum, variable pitch control" -- also known, in the research, as "mass balancing" and "freely hinged blades".

Centrifugal force acting on the counterweighted blade (the pendulum bob) functions as a variable-rate spring to control the blade pitch. Pitching prevents the blade from stalling. This is possible because aerodynamic and centrifugal forces both increase by the square of the blade speed (air speed and ground speed, respectively). Consequently, the blade pitches fore and aft many degrees at low TSR and only a few degrees at high TSR. The blade pitches to reduce the blade's angle of attack to below the blade's stall angle. Consequently,

the blade does not stall. At low TSR, watch how the blade "flips" to quickly reverse pitch on the retreating side of its orbit (heading down wind). The predicted efficiency (Cp) = .45 (based on Bayly and Kentfield, 1981). This is about the same as modern, propeller-type wind turbines (Cp = .47).

PRACTICAL APPLICATIONS: The increasing unbalanced motion, combined with a counter balancing pump weight, can be used to operate variable-stroke pumps. The expanding diameter reduces the rpm (piston pumps must cycle slowly). The unbalanced motion also provides, in effect, a starting clutch. Watch the handles bend back and forth like a pump handle. More advanced models include automatic overspeed control. The cost of such windmills could be extremely low and could benefit poor farmers in developing countries.

KITE DIRECTIONS: You need another person to help you. Have them hold one stick handle while you hold the other stick handle. Stand facing each other about 5 feet apart. Let the Whirlwing hang down so that it is pointing directly into the wind. The wind speed must be fairly high -- about 10 mph or more. Give the Whirlwing a start by twirling it like a jump rope. When the wind is strong enough, the Whirlwing will produce enough thrust to keep revolving on its own like a wind propelled jump rope!

As an alternative, you can fly the Whirlwing on your own by taping each stick handle to the end of a 4 foot long dowel or stick, 1/2 inch diameter or larger. Hold both dowels as handles, one in each hand. Face the wind, with the Whirlwing facing the wind. Hold the dowels vertical (straight up). Twirl the Whirlwing like a jump rope to get it started. It will twirl on its own if the wind is strong enough. You should wear a bicycle helmet and safety glasses to protect yourself in case something breaks. So it is safer to use a partner -- as long as they do not let go of their stick handle.

KITE THEORY: When the Whirlwing is flying like a jump rope, it is actually a kite that is flying upwind of its attachment points during 1/2 of each revolution. This is the first time in history that a kite has ever flown upwind. When the Whirlwing is flying upwind, it is producing thrust just as it did when it was functioning as a windmill. It also flies 1/2 of the time above the anchor points (the two stick handles). So during 1/4 of its revolution it is both flying above its anchor points and also flying upwind. In other words, during 25% of its jump rope orbit, the Whirlwing entirely satisfies the definition of a kite flying upwind: It is supported by aerodynamic forces, restrained by strings, and above its anchor points. That might not seem like much, but no other kite has ever managed to fly upwind at all (except perhaps when falling to the ground).

Looking to the future, my experiments indicate that someday it may be possible to fly kites continuously and entirely upwind, held there by centrifugal force. They may fly back and forth across the wind in figure 8 patterns -- gaining altitude when crossing the wind, and diving when reversing direction at the cross wind positions.

DISCLAIMER: The Whirlwing is an experimental device. Use at your own risk. While the maker believes the Whirlwing to be safe if used with reasonable caution, he assumes no responsibility or liability whatsoever for any damage, injuries or other losses involving the Whirlwing.

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