## STRETCH KITES

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Stretch Kites is a simple concept that was probably invented long ago, but I haven't found any references to the concept, so maybe it is actually a new idea. I invented the concept in 2008. In my opinion, it has the potential to be superior to other kinds of energy kites.

Stretch Kites are long-pull energy kites for producing electricity. They pull a cable or cord to spin a drum or reel located on the ground, and the drum spins a generator. Stretch Kites operate in teams of two or three kites. At least two of the kites on a team move apart from each other in order to pull ("stretch") a pull-cord. By doing so, they amplify the speed of the pull-cord before it extends to the ground. The drum spins at a high rpm so the drum can be directly coupled to the generator. The pull-cord can move out and in as a single line, or it can move back and forth as a reversing half-loop, or an alternating double pull-cord connected to two drums.

The pull-cord passes around pulley wheels mounted on one or more of the kites. By so doing, the speed of the pull-cord can be multiplied 2, 4 , or more times the ground speed of one of the kites. That is a simple, light, inexpensive, and efficient way to transfer energy from the kites to the ground, and it does not need to transmit electricity.

Pulleys are typically used to amplify the pulling force of a rope that is pulled. But they can be used in reverse to amplify the speed of a rope -- so as to spin a reel or drum at a high speed. In other words, they can be used as a step-up transmission. In the case of Stretch Kites, the pulley wheels convert a high pulling force of the kites into a lower pulling force moving at a higher speed.

Most long-pull energy kites use a single tether to spin a drum. The kite rises and pulls the tether to spin the drum. But this arrangement has a serious disadvantage. As the kite rises, it also moves downwind. By moving downwind, the pulling force of the kite is greatly reduced. That is because the energy in the wind is proportional to the cube of the wind speed.

If the kite moves downwind at about $1 / 3$ of the wind speed, which is typical of such kites, the wind speed available to the kite has been reduced by about $70 \%$. For example, if the wind speed is 6 meters per second, the kite will experience a wind speed of 4 meters per second. So we can compare the cube of each wind speed. 6 cubed is 216.4 cubed is $64.64 / 216$ is about 0.30 . In other words, the kite has available to it only about $30 \%$ of the energy in the wind because it is moving in the same direction as the wind.


## STRETCH KITES: MOTHER AND DAUGHTERS

The mother kite remains in position while the daughter kites fly together to the left and then to the right. The pull-cord loop around the generator pulley moves at twice the speed of the daughter kites.
Additional pulleys could be used to increase that ratio.
This schematic does not illustrate the actual design of the kites.


In contrast, Stretch Kites do not move downwind. They move across the wind in an arc. So they move somewhat upwind during their power stroke. Instead of losing energy, they actually gain some energy. They can be seen to function like the blade of a vertical axis wind turbine (VAWT) that starts from the downwind position and follows the arc of its orbit. The longer that arc is, in degrees, the more the kite's path moves to windward. If the arc could be a full 90 degrees, the kite would be traveling directly into the wind. For Stretch Kites, the arc in degrees will probably be closer to 45 degrees on either side of the downwind point.

Because the pull-cord would typically move at two or four times the speed of each kite, the pull-cord can be much lighter and thinner. Similarly, because the surface speed of the drum spun by the pull-cord is much higher, the drum could usually be directly coupled to a smaller, higher rpm generator, which would be cheaper. So Stretch Kites offer higher power for a lower cost, as compared to downwind-moving long-pull energy kites.

The schematic drawings illustrate two different ways to convert the motion of the kites into rotation of the generator. The twin kites in the top drawing spin the generator in one direction for a limited number of turns. Then the pull-cord must be retracted by a small motor as the kites fly back toward each other. Since they can fly back together much faster than they fly apart, the recovery time will be a relatively small percentage of the total operating time -- perhaps $25 \%$.

The three kites in the second drawing cause the generator to spin for a limited number of turns in one direction, and then spin for a limited number of turns in the opposite direction, with less recovery time required because the daughter kites merely need to reverse direction. As an alternative, over-running clutches, and two separate drums could be used to convert that reversing motion into a unidirectional motion of the generator. The twin kite variation is probably more cost efficient than the three kite variation, but that assumption needs to be analyzed in more detail.

Stretch Kites are subject to two main forces from their attached cords: the pulling forces from their normal tethers/control cords, and their pull-cords. So the kites must be designed to handle those two forces in a way that does not cause the pulling force of the pull-cord to interfere with the control of the kites. It is not yet clear how easily existing kites can be adapted to that requirement. Many different designs may be possible. For example, Stretch Kites could be configured to function like kiteboard kites with the pulley wheels and controls located where the pilot and board would normally be, relative to the kite, but high aloft instead of on the surface of the water. The tether from the ground would attach near to the pulley wheel and the controls, and in a manner that did not interfere with the control of the kite.

Stretch Kites should require relatively simple controls. They do not require the kites to carry complex electrical machinery, as is the case for flying wings equipped with ram-air-turbines, such as the Makani power kite. They can transmit energy to ground level using a simple and efficient means. The kites could probably be soft kites because they do not need to travel at an especially high speed. (However, the higher the kite speed, the better, since lift and thrust are proportional to the square of the kite's air speed.) The reason that they do not need to travel at an especially high speed (like a rigid-wing kite) is that two kites moving apart from each other (as in the first drawing) sweep a very large total area of wind very quickly. For these reasons, Stretch Kites should prove to be competitive.

Even rotary kites based on the Sharp Rotor might prove to be efficient Stretch Kites because they could be made buoyant, thus eliminating the need for frequent relaunching, and the equipment that requires. For their size, Sharp Rotors could provide a very strong pulling force on the pull-cord.

The first proof-of-concept Stretch Kites might make use of modified, 4-line Revolution kites, since they are highly maneuverable and reasonably fast fliers.

In my opinion, if Stretch Kites prove to be competitive, the first person to demonstrate Stretch Kites producing power will win a prominent place in the history of airborne wind energy.

