FanWing design notes

1) Introduction
What follows is knowledge that was acquired over the years. In total 12 flying models have been built and three sessions were done in wind tunnels. Many design points are critical to produce an efficient lift and propulsion wing. It is not enough to put a cross flow fan in the upper side of a wing. Note also that CFD cannot simulate the operation of the wing section. This became clear in the UE funded session at the Von Karman institute in Belgium where the CFD results and the wind tunnel results were very different.

2) The rotor
The rotor design is important. It is quite different from the rotors in a standard tangential/cross flow fan. The blade angle is important. After a lot of trial and error the best angle appears to be 7°. The chord of the blades is about 12% of the rotor diameter. The airfoil for the blades is hard to pin down but it must be understood that it should be optimized so that it is most efficient for the exit area of the rotor where the velocity of the air is at a maximum. The blades consequently have the trailing edge of their airfoil at the outside of the rotor. The camber of the blades is approximately same as the outer curvature of the rotor. See the diagram below. The rotor should also have a twist to reduce the blade noise. An important mechanical consideration is that the rotor should have a carbon fiber central shaft. Aluminum shafts can bend slightly on landing and are then impossible to straighten out. The rotors should have a free wheeling Sprag clutch so that if the engine stops the aircraft can autorotate.

3) The wing shape
The leading edge height (Lower entrance point for the incoming airflow) seems to be best at 16° below the center of the rotor. The trailing edge is angled at about 40° and the top of the trailing edge is in line with the center of the rotor. See diagram. One of the most important features of the wing shape is the curvature under the rotor. It is known that in tangential fans a vortex is set up off center and that this vortex helps propel the air through the fan. The area underneath the rotor must have a curvature that is centered on this vortex and not on the rotor. As seen from the diagram the surface under the rotor curves away from the rotor. This curve has a maximum distance from the rotor of approximately 1/10 of the rotor diameter. The curve of the this surface has a radius close to that of the rotor. Moving the under surface away from the rotor as described greatly increases the static thrust and flight efficiency.

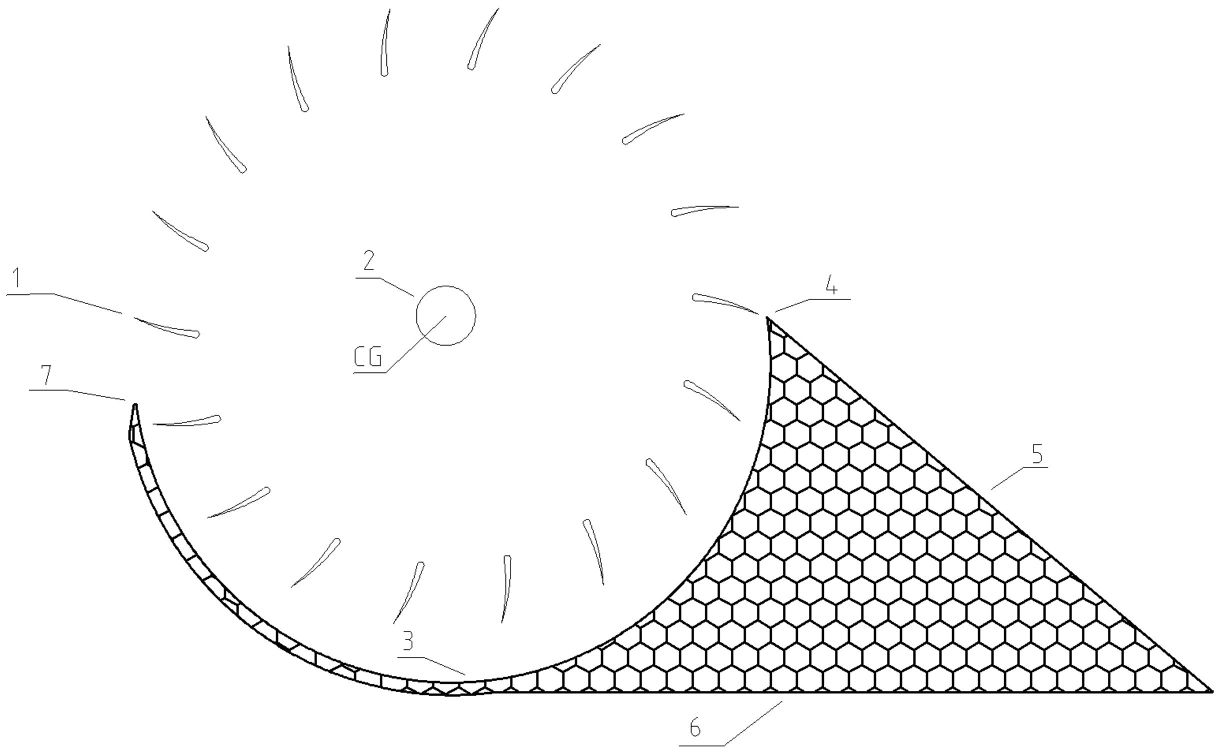
4) CG placement
The CG of the aircraft is essentially at the center of the rotor. On take-off there is a torque which pushes the nose down. When the aircraft is in stable flight the is no nose down torque. The aircraft is extremely stable.

5) Control and control surfaces
Behind the main wing there is a strong down-draft. Because of this it is important to keep the horizontal tailplane above this down-draft. If the tailplane is in line (at the same height) with the rotor the aircraft can become unstable. If the aircraft is put into a nose up attitude the tailplane will get caught in the down-draft. The control surfaces are standard with rudder and elevator and ailerons but are bigger than standard because of the low flight speed of the aircraft. The roll control is accomplished with ailerons on winglets that extend from the upper part of the wing endplate. Note that the ailerons should not be placed on the trailing edge of the blown wing because this would cause severe adverse yaw with the roll control.

6) Wing ends, wing center and leading edge:
The FanWing uses a modified form of a tangential fan. Tangential fans are notoriously sensitive to the direction of the incoming air. The powered rotor creates a much lower pressure above the wing than over a standard passive wing. This tends to suck the air into the rotor from the side. Air coming in from the side disturbs the internal vortex and lowers the overall efficiency. This affects two regions of the aircraft. If there is a space between the two wing rotors this can allow air to flow into the rotor at an angle and disturb the airflow. To remedy this the two wing halves are kept as close as possible. The wing ends are also critical see the photo at the bottom.

6) Power consumption:
Some of the prototype flying models achieved a lifting efficiency of over 30G of lift per watt of input power to the rotor. This is at fairly low speed.

Diagram of the rotor and wing body shape



Notes on the diagram

1) Fan blades:
The chord of these blades is approximately 12% of the rotor diameter and they are
angled at 7° from the center of the rotor. The camber of the underside of the blade is approximately equals the outside curvature of the rotor. The airfoil is not specified – the trailing edge of the airfoil of the blades is on the outside of the rotor.

2) Central support shaft:
It would be better to do without this shaft as it interferes with the internal vortex and the airflow through the rotor. Unfortunately this is difficult to do. The shafts on my prototypes are about 10% of the rotor diameter. They are made of carbon fiber preferably spiral wrapped. Aluminum shafts tend to bend slightly with a rough landing and are then impossible to straighten out.

3) Wing surface under the rotor:
This is not concentric with the rotor. It has a curvature almost equivalent to the rotor radius but is moved to about 10% of the rotor diameter below. This is important because it enhances the internal vortex and greatly increases the static thrust reducing the take off distance and improving the flight efficiency.

4) Upper exit point:
This is almost exactly in line with the center of the rotor. If this is kept sharp it increases the efficiency. If it is slightly rounded the efficiency falls but it reduces the fan noise.

5) Trailing edge angle:
This was found best (by trial and error) at 40°. Do not put a positive (bulging out) camber on the surface as this will create a lift vector aiming aiming to the rear and will slow the flight speed.

6) Lower wing surface:
This is kept in most of the prototypes completely horizontal.

7) Input point to the rotor:
This was found best at 16° below the center line of the rotor. This should be kept fairly sharp to allow air to enter the rotor cage almost vertically enhancing the internal vortex and thus the efficiency of the wing.

Note in this photo:

1) Undercarriage:
This is a tricycle with two wheels in front. This is necessary because as the aircraft accelerates for take-off it tends to lift the tail wheel.

2) Twist in the rotors:
This is to reduce the noise. As the blades come past the top of the trailing edge they make a noise. This twist reduces the noise.

3) High horizontal tail plane:
This is high to keep it out of the powerful downdraft coming off the wing. The rudder could also be below the horizontal tail.

4) Wing ends: Note both the flat vertical plate and the winglet (wing extension) . These are built like this to exploit the strong up-draft at the wing end. This arrangement also keeps the air from rolling over the end of the wing and disturbing the flow inside the rotor. The ailerons are on the winglets.

5) Long fuselage:
This is this to keep the CG centered on the rotor. The batteries (in the model shown) are in the nose.

Specifications of the prototype above:

Rotors: 800 mm each Diameter 160 mm, blades 20 mm chord, central shaft 16 mm carbon fiber.
Wing section: 1730 x 340 mm
Vertical dams at wing ends: 190 x 340 mm
Winglets (with ailerons): 300 x 440 mm
Horizontal stabilizer (with elevator): 780 x 320
Vertical tail (with rudder): 400 x 470
Tail strut: 1000 mm with 300 mm rise
Engine: electric outrunner 700 grams 190 KV direct drive
Flight weight 8 Kg
Take off: 3000 rpm @ 1 Kw
stable flight: 2000 rpm @ 200 W
Flight speed: 10-14 M/sec

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