FanWing design notes

October 2025

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 EU funded session at the Von Karman institute in Belgium where the CFD results done with Fluent software by a very expert engineer and the wind tunnel results were completely different.

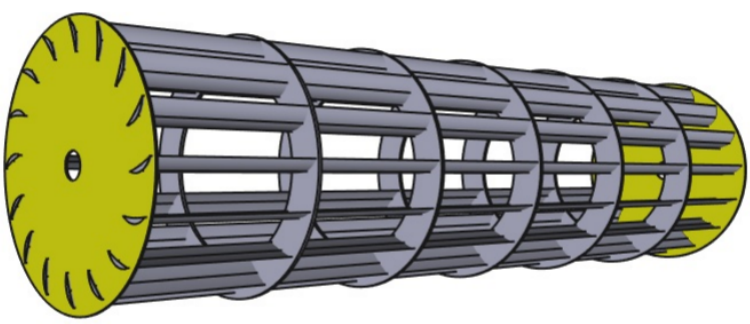
Note) The wing shape described below is one that works and provides a model that flies well. This design is not fixed and there are many aspects that could be changed, number of blades, chord of blades, basic shape. In other words there is still work to be done.

1) 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 closest analog to the airfoil I have used is the A18. 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. In this design a 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. At this point I am having second thoughts about the central shaft. The rotors should also have a free wheeling Sprag clutch so that if the engine stops the aircraft can autorotate.

1b) second thoughts on the rotor construction

As set up until now the rotor blades contribute nothing to the longitudinal rigidity of the rotor. If you take out the central shaft and push on the rotor the blades will buckle because they can twist. If you can keep the blades from twisting the blades can probably offer all the rigidity the rotor needs. So the rotor could be built with a complete disk at each end and then rings spaced along the span of the rotor which hold the blades and keep them from twisting. There could be a very small diameter shaft running from end to end to carry the torque from the inside disk to the outside disk. It may be possible to build without a central shaft and allow the rotor to twist slightly with the applied torque. This could be a solution to increase the efficiency by removing the central shaft which interferes with the vortex.



Most rotors on my models were made with balsa wood. Balsa is extremely strong relative to its weight. A rotor with balsa blades and numerous disks (to stop the blades from moving or twisting) as shown could work well on a small model.

2) The wing shape

The leading edge height (entrance point for the incoming airflow) seems to be best at 16° below the center of the rotor. If the entry point is lower than the recommended 16° the rotor might not autorotate if the engine fails. 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 below) 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. In this design the 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.

3) 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 there is no nose down torque. The aircraft is extremely stable.

4) 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. A T tail is a good solution with the horizontal stabilizer on the top of the vertical tail & rudder. The tail surfaces are standard with rudder and elevator but are bigger than standard because of the low flight speed of the aircraft. The rudder must be very big because it has to be able to rotate the aircraft around the vertical axis with all the inertial weight of the wings while flying slowly. The roll control is accomplished with ailerons on winglets that extend from the upper part of the wing end-plate. 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.

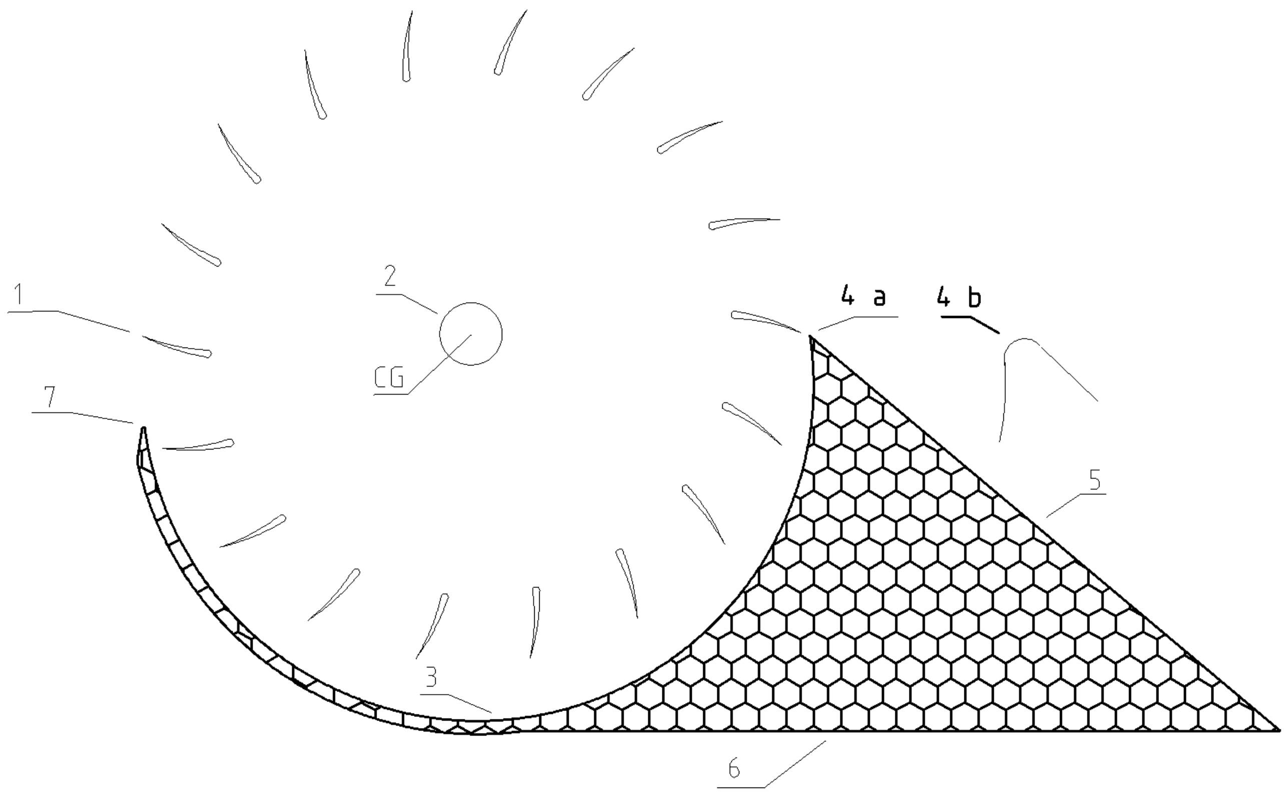
5) Wing ends, wing center and leading edge:

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 on the center line of the aircraft. The wing ends are also critical to avoid air entering the rotor from the side. 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 because it interferes with the internal vortex and the airflow through the rotor (see point 1b in the first section). 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 will bend slightly with a rough landing and are then impossible to straighten out. (See possible alternative design at point 1b above)

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 enhances the internal vortex and greatly increases the static thrust reducing the take off distance and improves the flight efficiency.

4) Upper exit point:

This is almost exactly in line with the center of the rotor. This can be either a sharp point [4a] or a rounded surface as shown at 4 b. The 4 b rounded upper part of the trailing edge will create less noise as the blade comes near the trailing edge. It is not clear which gives a better efficiency.

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 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. If this entry point is lowered beyond the suggested 16° the rotor might not enter autorotation.

Test model Flown at the Farnborough air show

Notes in the model 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 down-draft coming off the wing. The rudder could also be below the horizontal tail. A T tail is recommended with the horizontal stabilizer attached to the top of the vertical tail.

4) Wing ends: Note both the flat vertical plate and the winglet (wing extension). These are built like this to recover energy from 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.

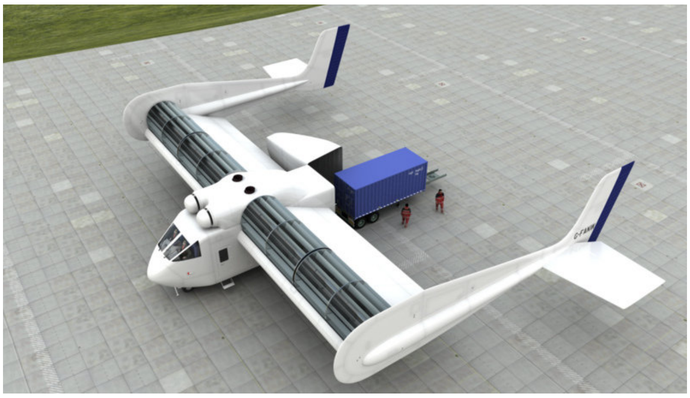
5) Long fuselage:
This is this to keep the CG centered on the rotor. The batteries (in the model shown) are in the nose.

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

Discussion:

Basic configuration.
Some models were built with an OHS (outboard horizontal stabilizer) configuration. This was done with two tail booms attached to the wing ends. Each boom has a vertical tail with rudder and a horizontal stabilizer and elevator on the outside. As illustrated by this artists impression:



The theory behind this OHS system is that there is a strong vortex which starts at the wing end and extends back and will cause the air to be rising at the outboard horizontal stabilizer. This recovers lift and energy for the aircraft. In actual fact this system is more complicated than the model shown above (single tail boom) and probably not more efficient than the aircraft with a single tail boom in the middle.

In the simple version (single tail boom) the horizontal tail is placed high so that it is out of the downdraft so no energy is lost. At the wing ends there is a very high pressure differential between the area over the rotor and the area under the wing. This causes the air to rise at a steep angle at the wing ends. The winglets with ailerons at the wing ends capture this rising air and greatly increase the total lift. A second benefit is that the winglets stop air from entering the rotor from the side which can disturb the internal airflow and vortex inside the rotor.

In comparing the two configurations the single tail boom design probably recovers more energy with the winglets than the OHS system does with the horizontal tails. Mechanically the first option is simpler.

Sizing of parts: (all approximate)

Assume that the chord of the wing & rotor is 1
Suggested shapes and % of wing plan-form area are given. These are just suggestions. Nothing needs to be exact.

The span of the rotor & fixed wing	= 5 - 1:5 aspect ratio	(50 plan-form area)
Vertical end plate at wing ends	= 1.2x .8	(19% of plan-form of wing area)
Winglets	= 1x 1.2 - 15% aileron	(24%)
Vertical tail & rudder	= 1.5 h x 1.2 - 45% rudder	(36%) Note this needs to be large to be able to rotate the aircraft on the vertical axis at low speed.
Horizontal stabilizer	= 2 x .8 - 15% elevator	(32%)

Note this needs to be at least three chord lengths behind the rotor/wing and one chord above the center of the rotor. This is extremely important to keep the horizontal tail out of the very strong downdraft.

Autorotation:
If the rotor is left free to rotate on power loss the aircraft will come down in a steep glide path. This is probably around 1:2 and the aircraft is still controllable in direction and pitch. The airplane will be controllable to the ground but it is not possible to flare for landing because the rotors are very light and do not store energy the way a helicopter does. Landing after autorotation will be hard and can cause damage to the undercarriage.

Good News! This model built by Klaus Jakob recently won first prize at the 2025 Inter-Ex. Inter-Ex is yearly event where experimental modellers fly their original and funny creations.
See: Inter-ex.com Klaus calls it the FENDT-ilator to capture the similarity to the German combine harvesters.

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