Reflex airfoil in paragliders

One of the paraglider pilots from Poland has explained quite well with simple words how the reflex airfoil in our gliders works and what makes it 'safe'.

At the very beginning I have to apologise to all aerodynamic experts for the simplifications which I have had to make to make this article comprehensible to all paraglider pilots.

To explain what a reflex airfoil is we have to go back to the beginning of aviation. These were times when planes looked like flying scaffolding. Some designers decided to get rid of the plane's tail. The problem was that the airplane was then pitching down. Why was it pitching down? Apparently the lift force which was created by the wing was fixed to the point behind center of airplane's gravity causing the rotation.

The point where lift force was 'attached' to the wing is called the center of pressure. Its value and position depends on the total sum of all the forces acting on the airfoil. The airfoil is simply a wing's cross-section.

To solve the pitching problem described above the only solution is to put the center of pressure at the same place as the center of gravity. Only then will the weight of the wing (airplane) will be pulling the wing down and the lift force will be pulling the wing up without rotation in any direction (which means without changing the angle of attack).

Unfortunately the airplane has to pitch the nose down during landing. When the angle of attack decreased, the center of pressure was moving backwards but the center of gravity stayed in the same place. This caused an increasing tendency to pitch the nose down.

The same effect was obtained when the angle of attack was increased (the nose was pitching up). The center of pressure movies forward and causes the wing to pitch up more.

The breakthrough was when aerodynamic experts designed an airfoil (reflex airfoil) where the center of the pressure was working in the opposite way - causing the nose to pitch down when the angle of attack was increased and vice-versa. This happened as early as 1906. (A lot of people who think that the reflex airfoil was invented by/for paraglider pilots).

The author of the original text is Zbigniew Gotkiewicz. It was presented on [www.paramotor.com.pl Leszek's blog]

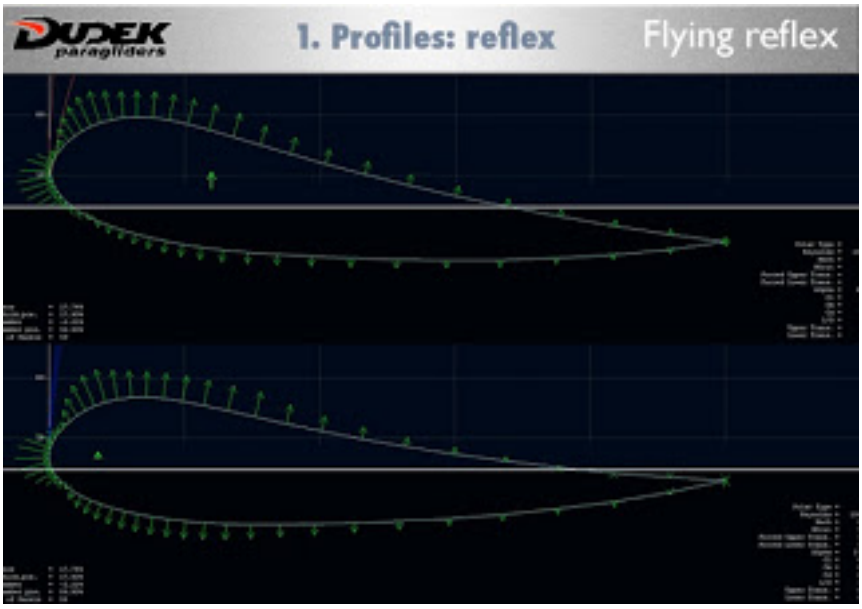
If you have any questions please post a comment or send an email to lukaszpg (at) gmail.com

TD – Riaan Struwig

These two pictures will be helpful to understand what is the difference between classic and reflex airfoils.
Classic airfoil:

The top picture shows the wing flying on a high angle of attack. The lower picture shows the airfoil on a small angle of attack. The arrows show the pressure distribution along the airfoil and the arrow 'inside' the airfoil shows the magnitude of the lift force and its attachment point (the center of pressure). You can see that when lowering the angle of attack the point of pressure is moving backwards.

Reflex airfoil:



This picture shows the reflex airfoil flying on high (upper picture) and low (lower picture) angle of attack. The arrow inside the airfoil shows how the center of pressure moves forward when the angle of attack is decreased.

This is the end of part one. Next part will be published in one week.

Take your time to understand the above because in the next part we will look more into what is happening to the airfoil when it is changing angle of attack in the reflex mode.

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Reflex glider - how does it work - part 2/4

Why reflex gliders are safe?

Welcome to part 2 of the reflex airfoil post series.

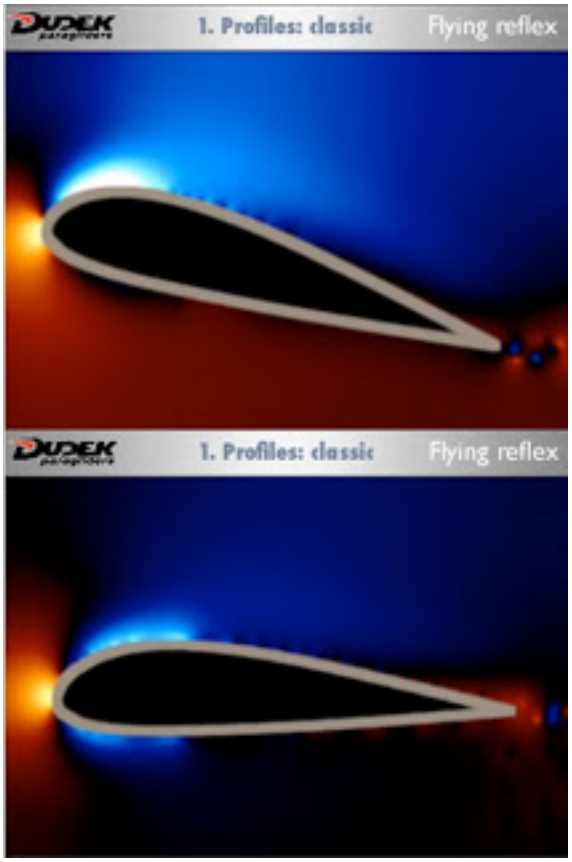
Despite the fact that a paraglider does not have a tail there was no need to use reflex airfoils in our gliders. The center of gravity is located a few meters below the canopy which makes the the whole system stable and the movements of the center of pressure does not affect it that much.

The fact is that the reflex airfoil has a much worse gliding ratio than a classic one. The other disadvantages are the difficulties with controlling such a wing (deformations of the airfoil to make a turn etc.)

Piotr Dudek was one of the pioneers in applying reflex airfoils to paragliding. His idea was successfully popularized worldwide by Paramania. Most paramotor pilots are flying reflex wings because they are more resistant to collapses, and faster.

What makes the reflex airfoil so safe and popular?

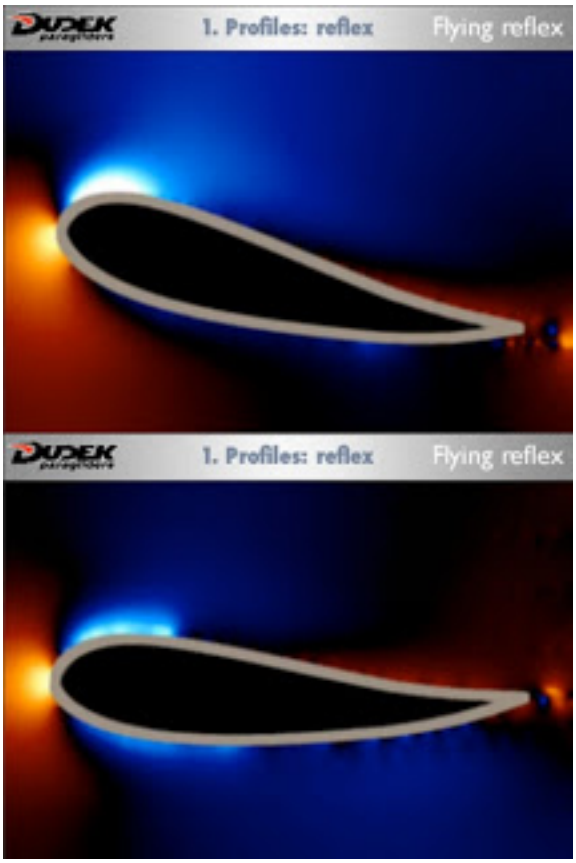
Please have a look at this picture showing classic pressures in an airfoil



The airflow is most important above the upper wing surface because this is the place where the most of the lift force is generated.
The lift force in our case is caused by the lower pressure on the upper part of the airfoil (blue area). The brighter the blue, the lower the value of the pressure. It makes the pressure difference between the upper and lower part of the wing bigger.

From the above pictures we can conclude the following for the classic airfoil:
- the lower the angle of attack, the lower the lift force generated
- the lower the angle of attack, the more the center of pressure is moving backwards

Reflex airfoil:



In the case of the reflex airfoil we can see that even though the angle of attack decreased, the center of the pressure did not move backwards. This makes the wing resistant to deformations and collapses. The pressure to 'keep the wing open' is always there.

Another characteristic of the reflex is that the area where the pressure is acting is smaller then in the classic airfoil. Additionally it is located at the front of the airfoil so the turbulence which is necessary to 'blow' this pressure out has to be stronger.

Another myth is related to the speed bar. When pressing the speedbar we are decreasing the angle of attack. In reflex wings the center of pressure is not moving backwards so the wing's collapse resistance does not change.

What is important to keep in mind is that if the deformation occurs on the full speedbar and opened trimmers, the result will be very violent to the pilot due to higher speed.

This is the end of part two of this article. Part three will be posted soon.

The author of the original text is Zbigniew Gotkiewicz. It was presented on [www.paramotor.com.pl Leszek's blog]

Reflex glider - how does it work - part 3/4

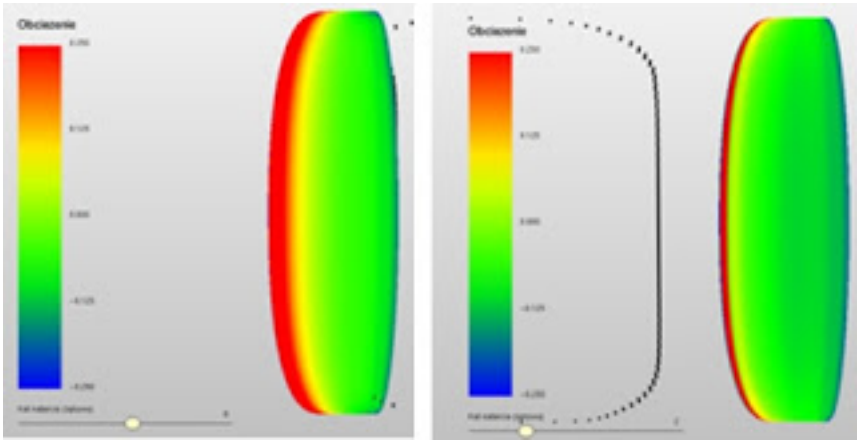
Why reflex airfoil is 'safe'?

The problem with the certification of the reflex wings is that the whole weight of the pilot and gear is equalised by the lift force generated on the leading edge of the airfoil. In this case it is very difficult to pull the collapse deliberately because even when the test pilot is pulling the A risers with his full weight he is not able to add more force upon them then his own weight acting on the risers.

This is the reason why reflex wings cannot pass the certification tests - they cannot be tested. The tests define how quickly and in what configuration the wing is coming out the deformations, not how easy it is to cause the deformation.

For example test pilot of Dudek Synthesis (and the author of the original text in Polish) was not able to cause 50% collapse on the full open trimmers so the wing could not pass the test.

Another thing is that in the wings with reflex airfoil the surface which is generating the lift force is much smaller in comparison to the classic airfoil. From this we can conclude that to equalize the pilots weight the effective wing load will be higher in comparison to the classic airfoils. And this is causing reflex airfoils to fly faster then the classic ones.

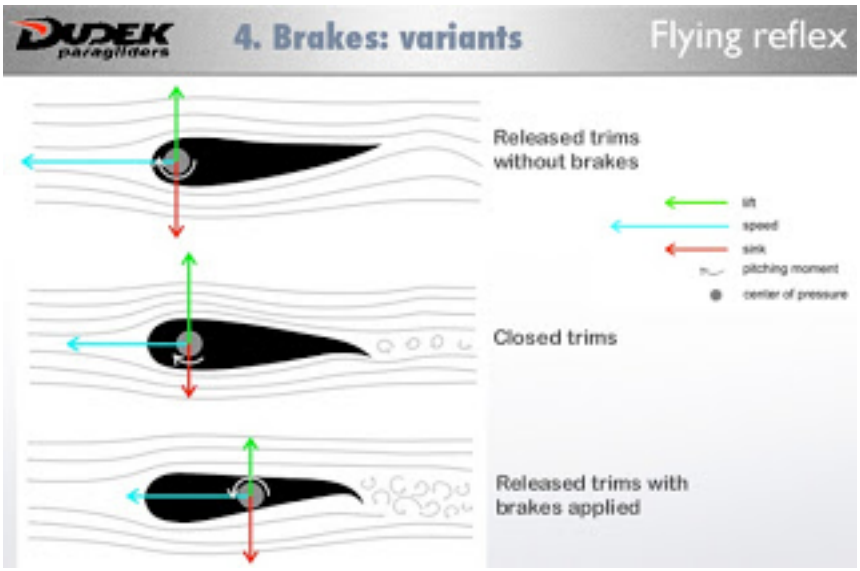


In the above picture we can see the lift force distribution on the reflex wing without speedbar (angle of attack 6 degrees)on the left hand side and with full speedbar on the right hand side (angle of attack 2 degrees).
We can see how the lift force moves forward with speedbar loading only A lines and making the wing more resistant to deformations.

In summary reflex wings are more stable, more resistant to deformations, faster. The downside is worse gliding ratio, certification is impossible in some configurations according to nowadays certification rules. Wing design is more complex as well.

The complexity in wing design are caused by the fact to control the glider we use trailing edge. When the pilot pulls the brakes the wing is lowering the trailing edge and the airfoil is not reflex anymore. In reflex mode the whole lift force is acting on the leading edge. When we pull the brakes (even a little) then lift force is also generated on the trailing edge. While not increasing the drag force enough it can cause a turn in the opposite way that pilot wants. For example we pull right hand brake in the reflex mode, additional lift force is generated on the trailing edge of the right wing (total sum of lift forces on the right half of the wing is higher then on the left), right wing is going up according to the increased lift force and we turn left. Normally this would be overcompensated by drag force generated on the right half of the wing (in classic airfoils) but in reflex mode the drag force can be not enough. In this way we can have left turn caused by pulling the right brake.

The other problem is that pulling the brake we kill the reflex airfoil characteristics which is causing the center of the pressure to move backward. This can result in wing tip collapses when pulling the brake even a little in reflex mode.



This is the end of part 3.

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Reflex glider - how does it work - part 4/4 – To follow soon