The Open University

Soaring by Design

Wing Design: Predictions

Narrator:
The performance of a glider depends almost exclusively on the Lift and Drag on the wings. So it's important to look at models which can be used to describe this relationship. The Akafliegs in Germany, associated with Technical Universities, have produced generations of glider designers from their engineering students. This is Akaflieg Darmstadt. The Lift and Drag forces transmitted between the wings and the glider can be considerable and because a glider needs to be assembled together, these forces have to be catered for where the wings join the fuselage.

Ian Johnston:
Judith, all the force has to be transmitted through these bars?

Judith Feige: (Akaflieg Darmstadt, Germany)
Yes.

Ian Johnston:
And how much force is that roughly?

Judith Feige:
The fuselage has 200 kilograms plus both pilots, it's altogether 400 kilograms.

Ian Johnston:
What's the maximum acceleration it's designed to take?

Judith Feige:
It's about 7 Gs.

Ian Johnston:
So that's a total force of about?

Judith Feige:
It's about 28 kilonewtons.

Ian Johnston:
So it's very important to make these the right size?

Judith Feige:
Yes it is. It's very important.

Ian Johnston:
Although you put the two wings on one at a time, they aren't really two separate wings, are they?

Judith Feige:
It's one big wing divided into two parts, and they are fixed together, fixed with a great big pin in the fuselage in this action.

Narrator:
This glider is a two-seater where the pilots sit side by side. It was, in fact, developed to have a performance specifically suited to competition flying. However, the students are using the

experience they've gained from building this glider as the basis for designing and building a new version, one which will be more suited to the role of pilot training. The shape of the wings has been modified to change the performance. The new wing design has been the work of Jörg Bergner.

Ian Johnston:
Hello Jörg.

Jörg Bergner:
Hello.

Ian Johnston:
What are you working on here?

Jörg Bergner:
I am working on the mould of the lower surface of the new wing for the new glider.

Ian Johnston:
And how's that made?

Jörg Bergner:
We made ribs with a special surface and now covered with plastic sheet.

Ian Johnston:
When you chose the shape what were the important considerations?

Jörg Bergner:
Well, you see we want to have as much Lift as possible but there's always Drag in this direction, and we want to keep this Drag as low as possible.

Ian Johnston:
And how do you know how much Lift and Drag this shape will produce?

Jörg Bergner:
Well, we don't know it exactly but we have mathematical models that help us to predict the behaviour of the wing. We tried different shapes of the wing and we decided that these sections fit our demand best. And this mould is already nearly finished – the only thing that we have to do is to glue these ribs up with plastic sheet.

Ian Johnston:
The wing is straight, is it?

Jörg Bergner:
No, it's not plane, it slopes up and the leading edge bends backwards in a series of straight lines. Would be better if it was an ellipse but it is very hard to manufacture.

Ian Johnston:
So when the wing's finished this will be the cross-section. But there's more to designing than just choosing the shape?

Jörg Bergner:
Yes, there's a lot more. We have to find a structure that fits in this space that takes all the forces that are generated by the wing. That involves a large spa in the middle and additionally we need room for the controls, and for water ballast and such things.

Narrator:
The mathematical models for air passing over a wing predict how Lift and Drag change. You can compute the airflow as Dirk Münzner has done at the Akaflieg Karlsruhe.

Dirk Münzner:

The computer now has computed for every little particle the amount of velocity, and now shows us in those little arrows the amount and direction of the velocity. The yellow colour means very fast moving particles. The blue ones mean very slow moving particles. The direction we see is changed from direct flow in ex-direction round the profile, moving up the profile, in front of, moving down the profile afterwards. This means the wing will lift up. In the last third of the wing there's a little turbulence which causes the lift to go down.

Narrator:
And theory can be compared with physical experiments in the Wind Tunnel. To visualise the pattern made by the air stream better, this set-up uses a heated wire to burn a steady stream of oil droplets from an overhead oil reservoir. The resulting image confirms predicted flow and if you look behind the wing, there's an area of disturbed turbulent air which is caused by the Drag. Incidentally, there's some structure evident in the turbulence, it's 'chaotic', although the details are beyond the scope of this unit. The fact that the Drag is highly dependent on the speed of the airflow can be investigated experimentally. The relationship between Drag and airspeed can be graphed – part of the Drag force increases with the square of the velocity – this is the Profile Drag – essentially the force resisting the motion. However, you also get a Drag caused by the production of Lift which can be experimentally determined. This is called the Induced Drag, and for a constant Lift force it decreases as the airspeed rises. Combined together these two sources of Drag account for a large total Drag force at both high and low airspeeds with a minimum in Drag somewhere in between. This change in Drag is reflected in the shape of the polar curve, showing how the speed of descent relates to the airspeed of gliders, with best performance in the middle of the speed range. As well as airspeed, another factor which influences the Lift and Drag over the wing is the 'angle of attack' made by the wing to the airflow. This wing is lined up along the direction of the airflow and, as such, is angled near to the horizontal. Let's ignore the Drag and consider just the Lift. At this angle a high airspeed is required to produce Lift. Increase the angle of attack to five degrees to the horizontal and the wing can produce more Lift. So the airspeed required to balance the glider can be lower. As the angle of attack increases further, the required airspeed decreases even more, but not indefinitely, and by 15 degrees the amount of Lift produced starts to fall very rapidly. In fact, each point on a glider's polar curve corresponds to a specific angle of attack of the wing. The right-hand end of the curve has a low angle of attack, close to zero degrees. The left-hand end is where there's a high angle of attack, around 15 degrees. The optimum angle of attack lies somewhere between zero and 15 degrees, which is somewhere in the middle of the speed range. We can demonstrate the effect of changing to a very high angle of attack during a real flight.