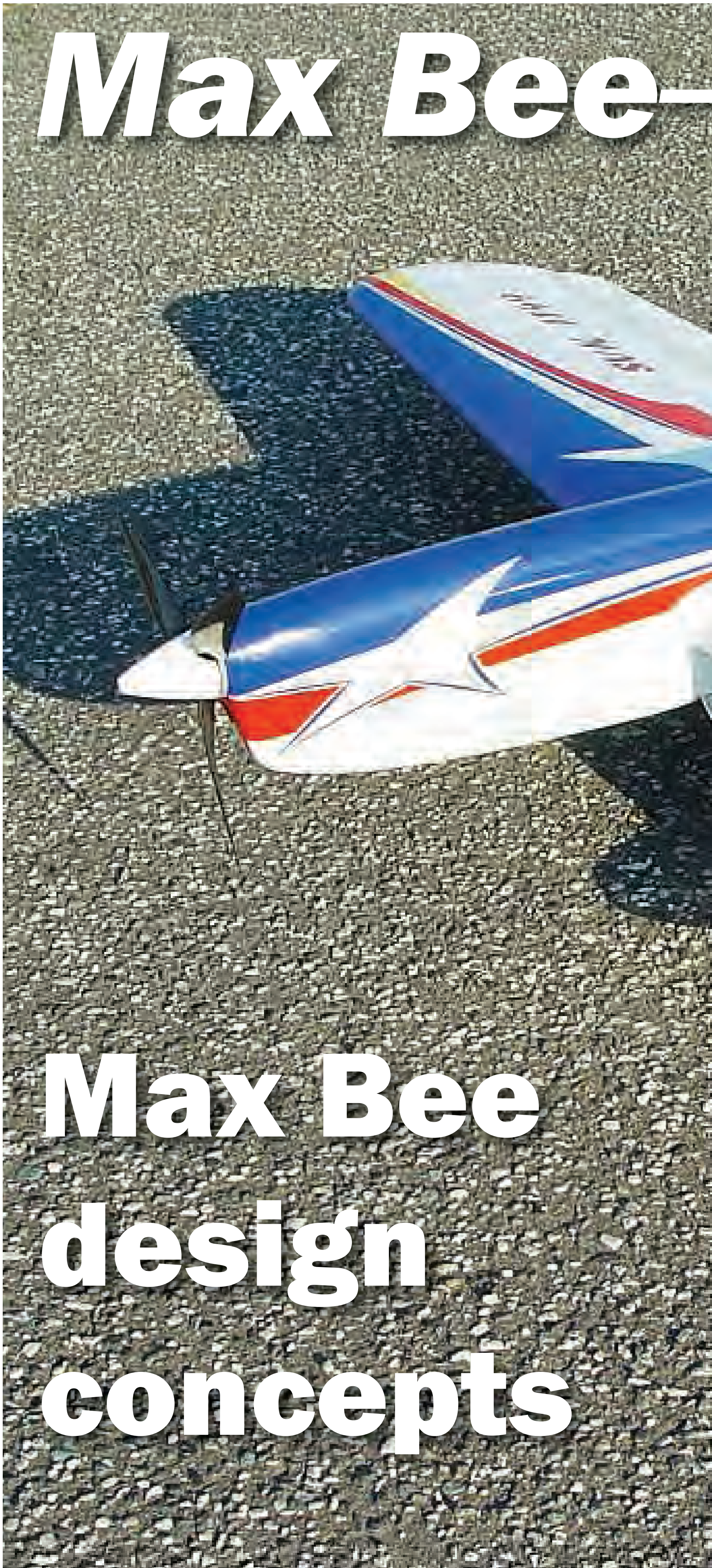
Max Bee design concepts



It was 1998. The good old times of Jozef Gabris were gone and we Slovak F2B fliers, copying what others have done, and were doing, were not able to keep pace in the world stunt arena. Having experience with many models from our side of the Atlantic, like Gabris's Supermaster, Cani's Zralok, and others like the Juno, Stiletto, Dreadnought, and Cardinal, I told myself there must be way to collect all their strong points and concentrate them to some good design.

Averaging … Did you ever try averaging? It is pretty simple: take all those good models, take the average of all you see there, and you will certainly get the best model in the world. Unfortunately, it does not work. Do not ask me how I know!

Averaging adopts all the weak points, rather than the strong points, so it is not the way. To get a good result one needs to explore those strong points and extend them. This means that the result certainly cannot be the average; it will be something like letting the good things grow to extremes. However, they need to be found first.

Control Line Stunt has undergone many years of development. It is not so easy to push it further simply by trial and error. Once I saw Lou Crane's stunt analyzer (thanks, Lou), I told myself that this is the way. I built myself a larger analyzer which gave me a lot of numbers which explained what is going on during tethered flight, what the flaps and elevator are for, what the facts and the fictions are of so many "rules" we have, and much other useful information. That was the initial point of my development, which actually ends in my latest model called Max Bee. (I hope not for long.)

In the first half of this two-part article I will describe the aerodynamics which I first used on my 2002 model. I flew it at the World Championships in Sebnitz with a piped OS Max .46LA (I placed 10th). It survived for a long time, and in 2008 I converted it to electric power and I flew it in the World Championships in Landres (I placed 2nd).

In 2011 I made a newer version, built specifically for electric and with almost the same aerodynamic configuration, just with a little larger tail and with a new fuselage shape. Yes, I wanted something "different," so the look of the fuselage is little bit unusual, but it works well.

With it I placed first in the European Championships in Czestochowa, Poland, and just recently placed first in the 2012 World Champs in Pazardzhik, Bulgaria. Let's take a look at the technical details of the design.

Wing

The first thing I tried to play with was the wing airfoil. It is not so easy to do a full aerodynamic analysis of an airfoil with an amateur program if the airfoil changes its properties with changing angle of attack (AoA, or alpha). Additionally, it is also very bad for the pilot if the airfoil changes properties.

So the task was to design an airfoil which can safely fulfill everything necessary for easy calculation and for predictable flying. In other words, it was necessary to find an airfoil which can

—the Slovak Way

by Igor Burger

make lot of lift in the linear segment of the lift vs. alpha curve.

I think this needs a little explanation. Every airfoil has a range of angle of attack (AoA) in which the lift coefficient changes linearly by 0.11 per 1 deg of angle of attack, independently of airfoil shape. If we know the maximum lift coefficient of that linear segment, then we can very easily calculate how the airplane flies at any lift coefficient up to that maximum (knowing the area, wing loading, etc.).

That is one point. Besides that, if we keep the wing in the linear segment, then also its responses to control inputs are very predictable, so flying such a model gives a much better feeling compared to a model with an airfoil that is going to stall, or has some bumps on the lift curve. Lastly, such a model is easier to trim, as we do not need to avoid some unstable regimes.

Here is example airfoil (NACA 0012) (Fig. 1). The lift curve shows clearly that the linear segment at positive AoA is from 0 to 10 degrees. The lift is linear with AoA, and a program can very easily calculate the AoA for that wanted lift. It is a symmetrical airfoil, so we can use that airfoil in the range from -10 to 10 degrees AoA. An AoA greater than 10 degrees will not only make complications for any calculations, but also flying will be difficult.

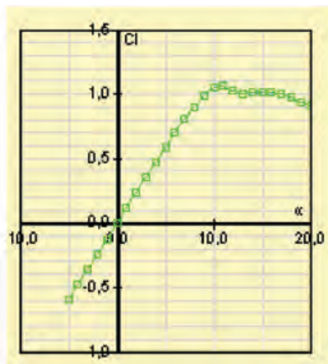


Fig. 1

As you can see in the illustrations from Martin Hepperle's JavaFoil program, we are in the time of computers, and since we have several airfoil analyses available and design tools like this one, the work is not so hard. I found that the best way to proceed for me was modifying the NACA 0018 airfoil, known for its good properties, for our use with flaps. Unfortunately, flaps are very tricky. They extend the lift of an airfoil, but they also do one not-so-good thing.

Let's take this slowly. The top surface of the airfoil should be a smooth curve. The curvature of the upper side should change from a small radius at the leading edge to a large radius at the trailing edge, because air flow stability is good at the front of the airfoil, but weak at the back.

But a deflected flap causes a small radius at the hinge line, allowing the air flow to separate from the flap upper surface, and the worst thing is that it happens abruptly at some particular AoA. Flow separation does not progress slowly with angle of attack from the trailing edge (TE) to the wing leading edge (LE); the flow just simply separates abruptly at the hinge line.

So while a smoothly curved airfoil makes more and more lift with AoA to the point where it starts to stall (called critical angle of attack), a flapped airfoil does it only to the point when flow on the flap separates. Then, as the angle of attack increases further, the lift falls down a little bit, and then it continues to rise again up to the stall point. This means that a flap makes a kind of bump on the lift curve slope. That makes the flight characteristics hard to calculate and the airplane not so easy to fly and trim.

Such a model must be trimmed to fly without getting to such a place on the lift curve slope. For example, it will fly well only tail heavy, or only nose heavy, or it will need some particular flap-to-elevator ratio or such, while a model with a well-working airfoil is easy to adapt to the pilot's preferences, because it will allow any regime of flight.

Photos and illustrations by the author

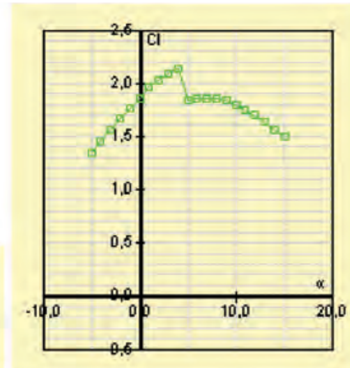


Fig. 2

Here is an airfoil clearly showing that illness. It is flapped and the flap is deflected 30 degrees (Fig. 2).

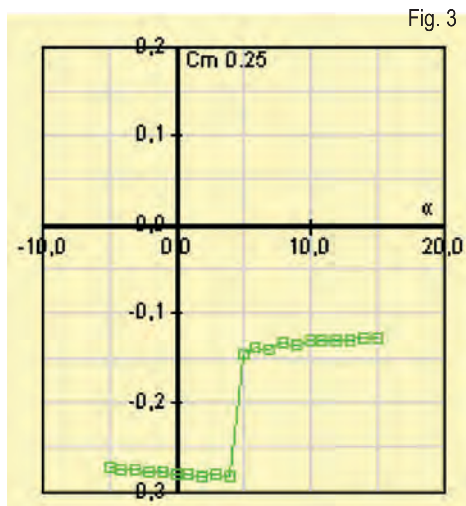
The lift curve shows what is happening. It works well until 4 deg AoA, but as the AoA increases, flow past the hinge line separates, and the airfoil loses a fraction of its lift. As we go further with AoA, the lift curve looks like the classic top of any airfoil lift curve at its critical AoA. Flying at those 4-5 degrees of AoA is impossible, or at least definitely cannot be called precision aerobatics.

This not a very rare problem; I know fliers who are trying to use the Wortmann FX71 flapped airfoil. Soon they encountered exactly this problem. This airfoil is dedicated to tails, and it means that the AoA with deflected flap is typically negative, and that means that is the area where that airfoil works well. Unfortunately, in positive AoA this causes problems.

There is another issue. The airfoil moment polar also has a problem. A deflected flap makes a pitching moment, pushing the nose down. We must counter balance that moment by a deflected elevator.

But look what the moment does at about 5 degrees of AOA. As the air flow separates, the pressure difference between the upper and lower surfaces at the flap falls down so far from the center of wing, and thus the moment also changes. So the pitching rate will also quickly change; the elevator will be too strong and the model will go to an even larger AoA, so it has a kind of unstable feedback as we cross that AoA (Fig. 3).

Fig. 3



So what can we do to solve these problems? There are several things. The first and simplest solution is a really blunt and thick airfoil with the thickest point moved as far forward as possible, far from the flaps. This usually spreads lift to a larger area, <u>unlike a thin and sharp airfoil which</u>

concentrates lift at the leading edge and the deflected flap.

A small-radius corner at the hinge line of such a thick and blunt airfoil does not mean too much. Unfortunately, it has lot of drag. This is not a big problem, but my future model was meant for a .46 cu in engine, and I do not like simple solutions.

I prefer another solution. It is an airfoil with a smooth upper surface curve at the hinge line with deflected flap. It also minimizes drag for high lift instead of minimizing drag for low lift (cruise speed at low angle of attack), as it is done with usual airfoils. We make stunters, which need constant speed, not best mileage.

So minimizing drag at high lift (corners) is good. This can be done either by flat flaps matched to the fixed part of the wing at maximum flap deflection, or by an airfoiled flap surface matched to the wing surface.

My choice was a flat flap made out of one sheet of balsa. The result was an airfoil derived from NACA 0018-63. Originally, I wanted 0018, but I also wanted to have a little bit of reserve because I was not sure how much I could believe the airfoil analyzer and how well I could later make it work on the real model. I used it from the leading edge to approximately its thickest point. It has an LE radius which is still on the safe side, even if the wing is made with a mildly imprecise LE (sharper than should be).

The back side is reshaped so the airfoil surface slope at the hinge line is 30 degrees, and that angle is also the maximum flap deflection (to be explained later). So the flap is tangent to the wing at maximum flap deflection, while the radius of the airfoil surface at the hinge line is negative at all smaller flap deflections. This means that the air flow is safely attached at that place even if drag is not necessarily the best—for example, in level flight.

Fig. 4

So here is the airfoil. Fig.4 shows the flap at 30 degrees.

The lift curve slope is linear up to 7 deg AoA and transfers without a bump to the classic smooth top. Additionally, the moment does not change until 10 degrees AoA (Fig. 5).

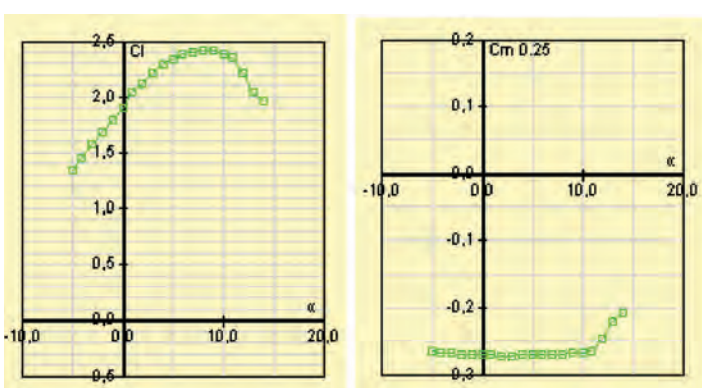


Fig. 5

So far it looks like an airfoil having lots of lift, good properties, and predictability for precision aerobatics, but it is still not the whole story. We fly corners, and airflow in corners does not hit the airfoil as a straight line. The flow looks like a segment of a circle. The radius of that circle is the radius of the corner. It means that the LE of the wing airfoil has a lower AoA than its flap (Fig. 6).

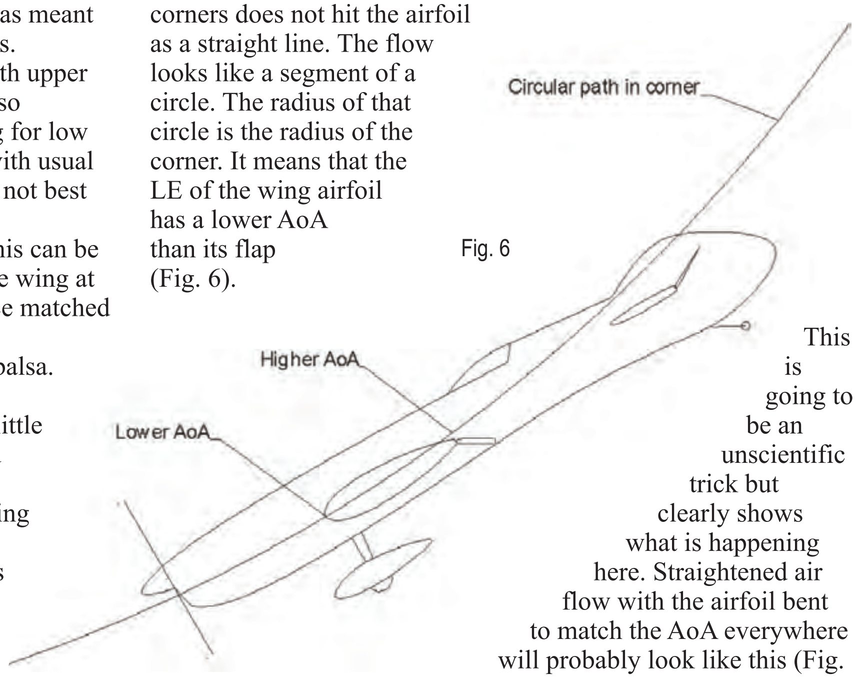


Fig. 6

This is going to be an unscientific trick but clearly shows what is happening here. Straightened air flow with the airfoil bent to match the AoA everywhere will probably look like this (Fig. 7).

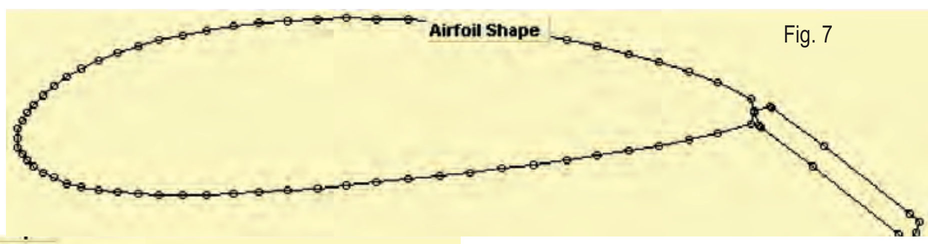


Fig. 7

The flap is now deflected more than those projected 30 degrees, because of air hitting it at some angle, but all still works well. The lift coefficient is even higher than in straight air, and the moment curve is nice and flat, even better than in straight air. This means that the airfoil will work well in straight flow before it enters a circular path, in circular flow, and also during the transition (Fig. 8).

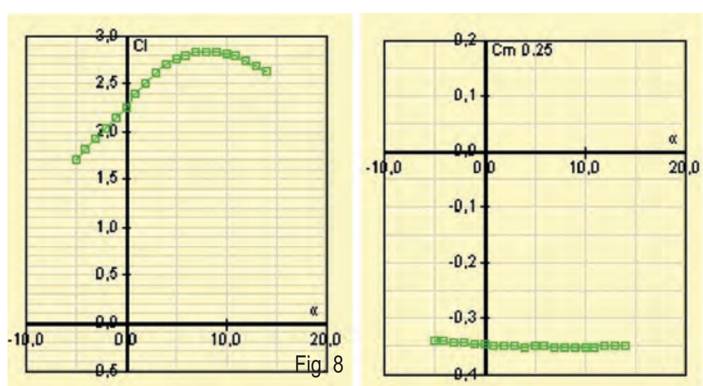


Fig. 8

Elevator

Circular airflow also affects the elevator. The same trick of having a smooth curve at the hinge line does not work here, or at least not so much. Unlike a wing airfoil, which must perform well at positive AoA, a tail airfoil is at relatively high negative AoA (relative to its camber).

It is approximately 15 degrees, which could cause separation at the leading edge, but on the opposite side from the usual – on the positive-pressure side. It is not complete flow separation as we know from stalled airfoils; it is simply a rotating bubble just behind the stab leading edge (Fig. 9).

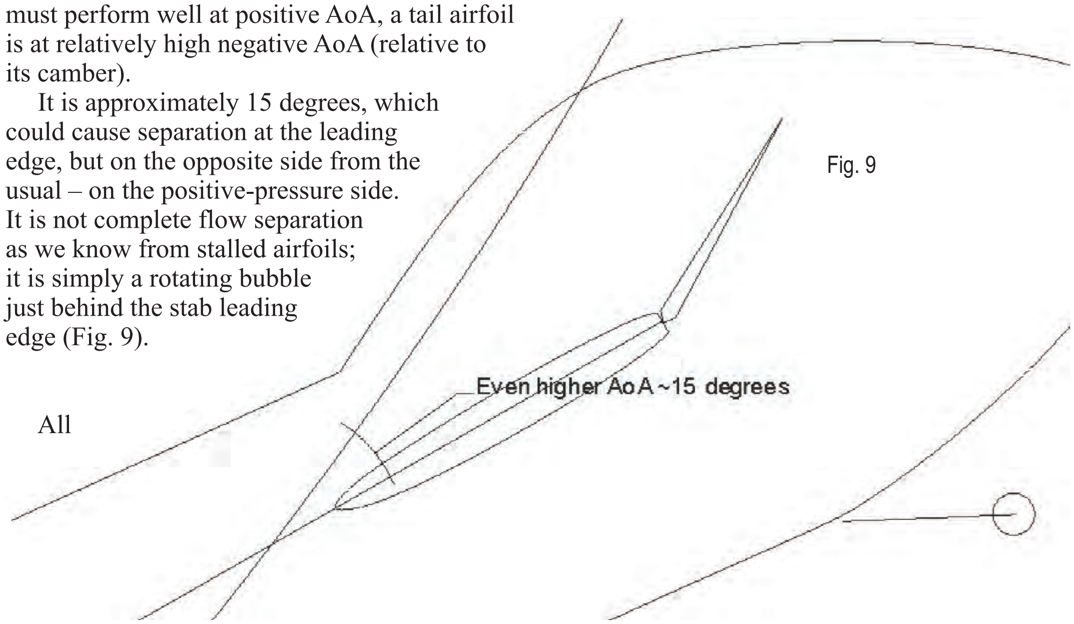


Fig. 9

All depends on the leading edge radius. Sharp airfoils will have such a separation while blunt airfoils will not. Experience shows that both really sharp and also really blunt LE's work well, while those with moderate radius make problems, probably because those moderate radii sometimes separate, and sometimes do not.

I decided to use a sharp LE. It also has good properties in level flight, because the stab flies at a relatively low Reynolds number, and a sharp LE helps to avoid the problem of unstable or wandering laminar-turbulent boundary layer transition point typical of a blunt-LE flat stab.

That "unstable" or "wandering" means that transition point can move far from its position with only little change of AoA, or elevator deflection. It can make some pressure changes, which prevent the pilot from keeping the model exactly at that one particular AoA, and it can cause impossible level flight.

We found on several models converted from IC engines to electric that they tend to hunt after conversion. This typically happened on models having a blunt or moderate LE radius. It is probably caused by the vibrating IC engine which acts like a turbulator. Note: This conclusion it is only my hypothesis, but it seems to be so. A sharp LE typically works well.

Logarithmic unit on flaps

Flaps give strong feedback to the handle. This tendency of flaps to center is a kind of stabilization, but it is just the opposite of what we really need. The feedback depends on the amount of lift produced by the wing. Lift on the wing is low in level flight and large in corners, but in reality we need good stabilization in level flight or straight segments of figures and rather low in corners.

Additionally, effective camber of the airfoil depends on flap deflection and on the radius of a corner flown. So it is very good to have quicker flaps and stronger feedback in level flight and on straight segments of square figures, and slower flaps in corners and limited feedback from hinge moment. With this in mind, I decided to use a device which makes a logarithmic function and which is inserted in the control linkage between the bellcrank and flaps.

It is not a new idea, but it brings so many new variables to the model that trimming in a finite time was almost impossible and thus not used for more that just tests. But here again, in this age a computer program can help. I modeled the whole situation so it was much easier to adjust the basic function "theoretically." I was able to determine the whole linkage between bellcrank, flaps, and elevator, and I was sure that the wing, flaps, and elevator are in proper positions during flight.

This figure (Fig. 10) shows the main function. Flaps have a slot controlled by a pivot which is a small ball bearing.

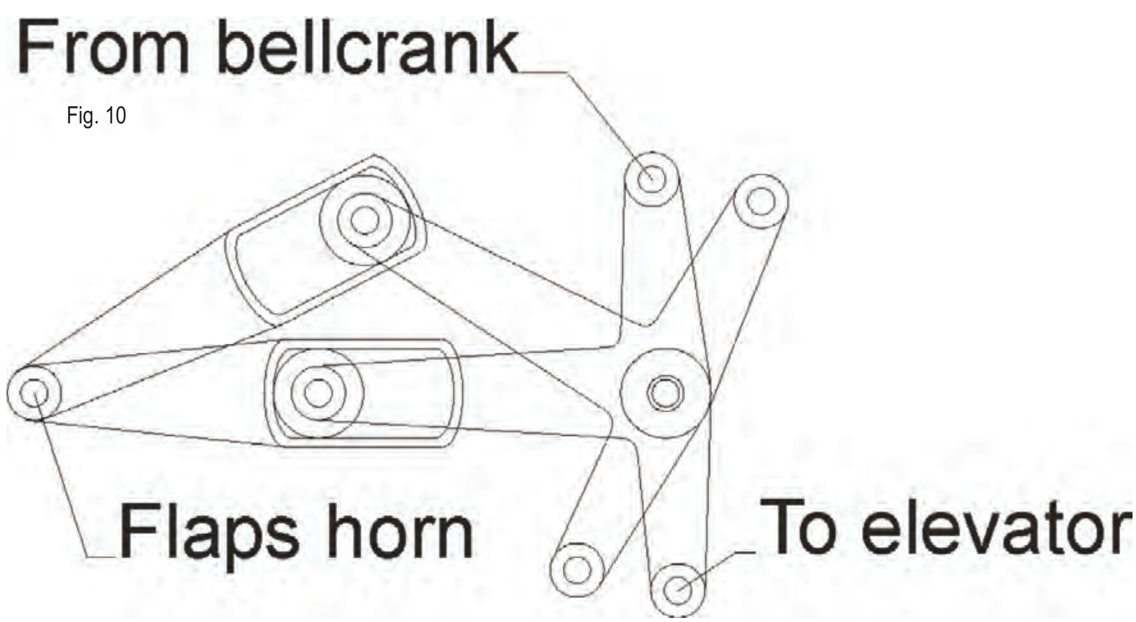


Fig. 10

And here is its function. The straight line is response of the elevator to the bellcrank; the logarithmic line represents the flaps. This means that flaps are a little quicker in neutral and a little slower in corners (compared to 1:1 ratio) (Fig. 11).

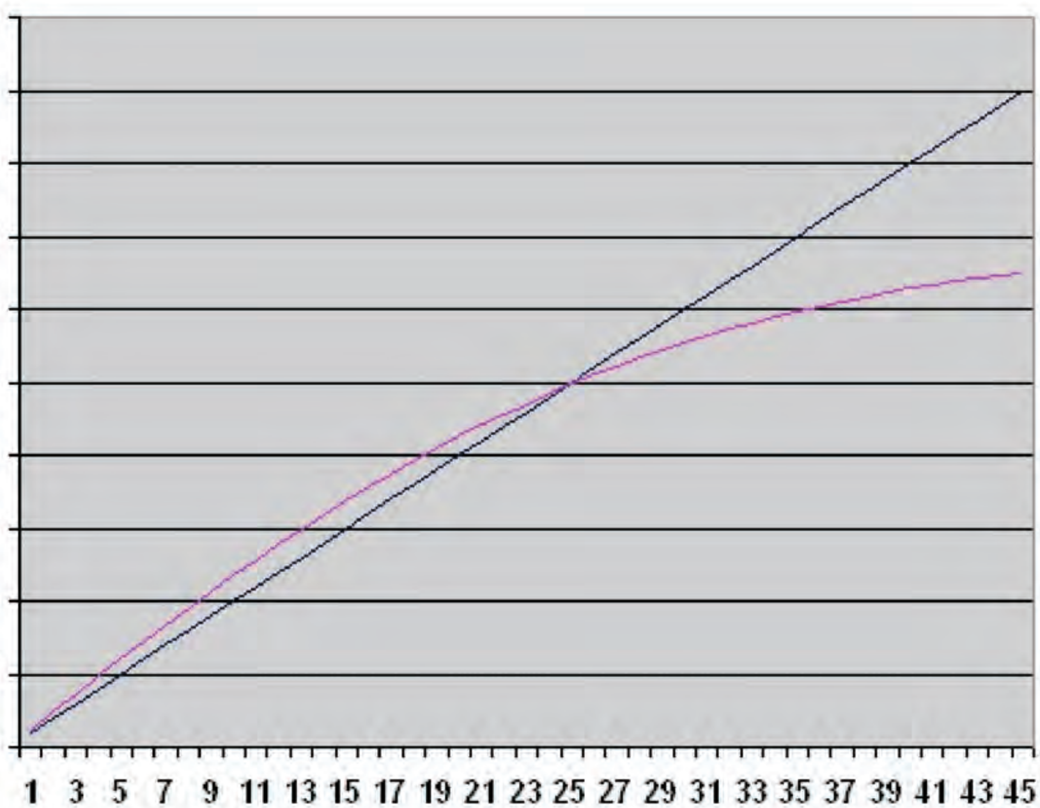


Fig. 11

so it also flies to some extent on its side area. I tried to solve two points:

1: The nose is little longer than usual. Electric power trains allow separating the battery from the motor, so it was possible to make a longer nose without too much CG position penalty. The reason for extending it was the fact that a large tail in strong side wind yaws the model inward.

While an electric model does not have fuel and its CG does not move during flight, I like perfectly positioned lead out guides in relation to the CG, but side wind will yaw the model and the effort is lost. So I decided to extend the nose area to counterbalance the effect of the rudder. For the same reason I use a Rabe rudder which also keeps the fuselage in the wanted position.

The result is that the model does not feel nose heavy in strong wind (which makes LO guide too aft of the CG and thus nose heavy feeling), and does not have that well-known "no line tension" feeling when the wind shifts around the circle and blows in your face.

2: The thrust line is over the wing drag line. I fly tractor props, and the gyroscopic moment pitches the nose up. Also, side wind from the prop in most of maneuvers (those flown on downwind side) makes a pitching moment up. We can counterbalance those moments by drag from the landing gear, but it is not enough.

Thrust line distance will help little bit, but it is still not enough, and the elevator will also have lot of work to keep it in place, so stab incidence is also a little up. For the same reason I use tractor and not pusher props. Pusher props help in some figures, but I believe that a tractor prop allows better overall trim, especially because of the asymmetric landing gear drag.

Control surface dimensions

The rest of the design is now simple. The wing must be able to make enough lift to support the weight of the model plus centrifugal force in a corner at 7 degrees AoA, which is the end of the linear part of the lift curve. It gives backward derived optimal wing area. It also gives size of flaps from airfoil dimensions. Too large a wing (too small wing load) will make model sensitive to wind and turbulence. Excessive area simply makes stronger "kick" in every air whirlpool. Too small a wing area will not carry the mass of the model. So the target is to use linear segment of flapper airfoil as wide as possible by optimizing wing area.

Increasing the tail size up to 25% of the wing size seems to help. Enlarging up to that size allows the CG to go further and further back, while extending the tail size over 25% does not give any further advantage. So I decided to make it a little over 25%, just to be sure it is not too small.

Elevator deflection is 30 degrees from the design of airfoil and linkage, so the last thing we can adjust is elevator-to-stab ratio. The elevator must be able at its maximum deflection (at maximum flap deflection) to keep the wing at that 7 degrees of AoA, which is the end of its linear segment, where we expect its maximum lift.

So the tail must counterbalance the CG moment (the CG is in front of the wing's aerodynamic center, and it makes pitching moment) plus the pitching moment of the flapped airfoil. Both create a moment which must be equal to the lift of the tail acting through the tail moment arm. The result is visible on the Max plan. It is surprisingly small, but it is definitely enough.

Fuselage

Well … yes, the shape of the fuselage is fashionable (maybe unusual?). It is loosely based on the Gee Bee R3 racing airplane, hence the name Max "Bee."

We fly with side wind and our models are a little bit yawed out,

So much for designing

It is hard for me to judge how successful this design is, because it requires several flights for me to adapt to other models which I try to compare. But I know about several models that were influenced by my design, from almost a copy to redesigned models, using only wing and elevator aerodynamics.

The results are usually good. Evidence of this is visible, especially from the contest results of my friends, which keep going up and up, so the mission was fulfilled. If I could simply describe the feeling of flying this model, I would just say, "It is just easy to fly!"

You do not need to battle with the handle, and you do not need any body-building before the season. But, on the other hand, the controls can feel a little sensitive before the pilot adapts to the way this model flies. Overall, I am very pleased with the design and the results achieved so far. SN