On the 'Wing... #111

We have referenced the following article many times since its publication in the *TWITT Newsletter* in May of 1995. We present it here in response to "popular demand."

BIRDS OF A FEATHER...

(*TWITT Newsletter* Editor - The following article was contributed by our Secretary, Phillip Burgers, at the request of Bob Fronius, our Treasurer, after a rousing session of feeding the sea gulls on New Year's Day at a local (San Diego) shoreline. The antics of the gulls while trying to catch bread tossed into the air fired a debate on how they used their tail feathers as flight controls. This is Phillip's answer to Bob's challenge. Read and enjoy.)

DOES A BIRD HAVE A TAIL TO TELL...?

by Phillip Burgers

Has a bird a tail or not?

Many of the readers may ask themselves if this question has any relevance to the goals of TWITT. Even though this following discussion seems academic or superfluous, I personally think that birds, together with bats, are the most sophisticated flying wings in existence today. What follows is a justification of this statement. This article is dedicated to those interested in flying wings, to Karl Sanders and to Bob Fronius, who were dear friends of mine... until they read the lines that follow. They started it all!

Let's define what we understand as a tail in an airplane.

The tail of an airplane is defined as a surface, be it vertical or horizontal, at the end of the aircraft's fuselage which supplies the following conditions for flight:
1) directional stability by means of a vertical surface;
2) pitch control, longitudinal trimming and stability by means of a horizontal surface.

Lets analyze each of the aforementioned functions of a tail and compare them with birds.

1) Regarding directional stability by means of the vertical surface: This is an easy one... A bird does not have a vertical tail. In birds, directional stability can be obtained by variable washout/washin of the outer part of the wing (as observed and entered by Wilbur Wright in his diaries in 1900) and at low speeds is being accomplished by the feathers attached at the end of its body. These feathers turn up to be actually low speed ailerons.

2) Pitch control, longitudinal trimming and stability during bird flight is not done by the tail, as in airplanes were there is a download on the tail. This primitive way of obtaining stability that we still use in our airplanes penalizes the aerodynamic efficiency during flight. The bird's pitch control and trimming is more sophisticated — it is done by adjusting the relative position of the aerodynamic center of the wing with respect to the center of gravity of the bird. At low speeds, the bird places the center of gravity backwards with respect to the aerodynamic center of the wing so the back feathers (don't call it a tail yet!) act as a secondary lifting surface that lifts a small percentage of the bird's weight and in so doing it unloads the main wing.

So the obvious question arises: What does the bird's tail do? The main function of the tail is to unload the main wing at high angles of attack, and in so doing it delays its stall. It does so by sweeping the wing forward, moving the center of gravity backwards relative to the main wing and "fanning out" its aft feathers to increase its secondary lifting area. This aft lifting surface area is exactly opposite to a canard surface: it is located behind of the main wing and has a low loading, while the canard is placed forward of the main wing and is highly loaded.

When the bird is at very high angles of attack, the tail is right behind the main wing and immersed in the downwash of the main wing. This is not a problem for the end feathers due to the fact that they form a low aspect ratio surface that makes it immune to the sudden changes in downwash of the wing. A high aspect ratio secondary lifting surface behind the main wing would stall with a small change in downwash induced by the main wing.

It is apparent at this point that the so called "tail" does act not only as a low speed aileron but also as a flap. The other large function of this flap is to increase the lift of the main wing by creating an upwash in front of the wing.

A DIFFERENT APPROACH TO THE "BIRD DON'T HAVE NO TAIL" APPROACH

Even biologically speaking, the bird lacks a tail. Bats don't have one either. The last vertebrae of a bird are fused and called a pigystile. From the oseo-morphological standpoint, there is no tail to be found in birds, as we may find in dogs, rodents or lizards. Now let me get quickly back to my preferred field of work — aerodynamics...

IS THE FLYING WING THE BEST CONFIGURATION? ANOTHER APPROACH

People have discussed the merits of flying wings. Karl Sanders has been an excellent devil's advocate for flying wings and it is a challenge to challenge him, but there it goes, Karl... We are going to visualize (praise) flying wings from a different perspective.

It is probably safe to say that Man has learned how to fly from nature. What is also safe to say is that every time Man has strided apart from what nature had to show him, his designs have failed miserably. For the brief period of a year, roughly from mid 1917 to mid 1918 the triplane format suddenly came to dominate the world of fighter plane design, particularly in Germany. If we are in any way aware of this design, we must give credit to Rittmeister Manfred von Richtofen and to Anthony Fokker. Never more did this configuration came back. Nature never did favor two, three or any other larger number of birds flying one above the other. Flying in the downwash of another bird is not the idea that a bird has of flying efficiently. No airplane is flying at its optimum condition when flying in the downwash of another airplane flying in front of it.

In the seventies, the canard configurations (remember, it is the opposite of Nature's chosen configuration for a bird!) became fashionable. In the canard we find a very heavily loaded canard (so it stalls first) placed in front of the main wing. Even though from the safety standpoint this is an excellent arrangement, the main wing is immersed in the powerful downwash of the canard. We never heard of this configuration again in the civilian market. Why not? If we go to nature looking for help, we will find that no bird favors flying right behind another bird! In the military arena, canard configurations can be of benefit as long as the canard is not heavily loaded.

Throughout this article we have mentioned the word "configuration." If we define this word as the best way of locating one lifting surface in the most efficient manner with respect to another lifting surface and go to nature for the answer, we will see the best solution — a bird, which is a flying wing with a large secondary surface attached to it or so called flap for low speed.

So the first round was won by the flying wing. If we are still not convinced, let's go one step further and see what birds do to reduce their intrinsic induced drag — they form a lambda formation (erroneously called 'V' formation, which would point to the wrong flight direction!). Here we see a large flying wing as the configuration (again) favored by nature, where every bird is part of the wing and every bird gains in lift and minimizes energy exertion by reducing induced drag.

It is most interesting to note that the flowfield around a bird formation as a whole is similar to the flowfield around a swept back flying wing!

A VERY SOPHISTICATED FLAP INDEED...

As to finish and prove once more that nature has always been ahead of us by millions of years and that it pays to look back at nature for the best of results, we will discuss now another remarkable example. The tail of the fork tailed sparrow or fairy tern.

At very low speeds, the tail of the sparrow or a tern goes down and the forked tail opens, slightly reducing the very large sweep of its leading edge feathers. At this point, vortex enhanced lift is present over the tail, giving it a very powerful source of lift and creating a sophisticated tool for unloading the main wing.

Did we humans ever use vortex enhanced lift in the horizontal tail of an airplane? Yes, we did, but without knowing it! Fokker, around 1918, designed his triplane airplane (the same we dared criticize earlier) and a unique feature was the sweep of its vertical and horizontal tail. It could achieve very large angles of sideslip and yaw, as well as pitching angles, without vertical or horizontal stall, by a combination of light loaded surfaces and vortex enhanced lift (at high angles of attack). Without realizing it, Anthony Fokker took advantage of the vortex enhanced lift long ago and we would start to use it in our supersonic designs. Vortex enhanced lift was used “knowingly” the first time by Dr. Reimar Horten in Argentina in 1953, on the high speed fighter I.Ae. 47 delta wing with highly swept wings with sharp leading edges.

CONCLUSIONS

As can be seen, the so called tail is actually a sophisticated second lifting surface or flap that can take the form of a low aspect ratio lifting surface or a delta wing in the case of the sparrow, creating vortex enhanced flow over it, or a single slotted flap on the case of most birds like the pigeon. At high speeds, when not needed, it decreases its wetted area and at low speeds it opens up by increasing its span not only to share the weight of the bird with the main wing but to create an upwash in front of the bird’s main wing (any flap does this). Once more it seems that nature is telling us something about the efficiency of flying wings. But for us to imitate a bird will be an unreachable goal as long as we do not have reliable active stability mechanisms to keep the unstable flying wing flying! We seem to be flying in the stone age with airplanes with a download in their horizontal tails!

Last but not least, I would like to invite our worldwide TWITTers to contact me if you have any information on ground effect, formation flying, and documentation (videos or still photographs) of birds flying at very high angle of attack and videos on birds flying in ground effect and in formation simultaneously. This information would be highly appreciated.

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