HANGAR ECHOES

EXPERIMENTAL AIRCRAFT ASSOCIATION
CHAPTER 168 DALLAS TEXAS

Finding Hidden Drag

by K. Truemper

Editors Note: Thanks to Klaus for providing this article. We are sure you will find this topic very interesting since the performance improvements due to drag reduction to Klaus's Zenith 601 HDS have been absolutely phenomenal.

For us low and slow fliers, it is convenient to consider the total drag of an airplane to be composed of parasite drag and induced drag. Parasite drag is the resistance produced by irregular surfaces. The airflow is disrupted by such surfaces and becomes turbulent. Bending of smooth airflows creates induced drag. It is easy to see the causes of parasite drag. For example, unfaired gear legs and external antennas are indicators. Induced drag is harder to identify. A sleek-looking airplane may have lots of induced drag and thus may not fly fast. This is a story about such hidden drag.

After Mel Asberry and I finished the Zenith 601HDS (N314LB) about four years ago, I made a number of modifications, such as moving the radiator into the cowl, to reduce parasite drag. The changes improved climb and cruise performance. Nevertheless, the plane still had some undesirable flight characteristics that I could not explain and hence could not work on.

(1) In cruise, the plane sometimes would fly fast in level flight. But when a slight turbulence or downdraft would force me to raise the nose just a bit, the speed would almost instantly deteriorate and then stay at that lower value.

(2) When trimmed for power-off glide, the speed would fluctuate considerably when very small elevator adjustments were made. The sink rate was high regardless of glide speed.

(3) When loaded close to max weight, the plane would require a nose-up attitude for level flight that seemed much higher than I expected to be necessary.

Since small changes in airplane attitude, particularly at low speeds, cannot cause large parasite drag changes, parasite drag could not be the culprit. That left me with induced drag. But how could induced drag do this? That question had me baffled for a long time. Then, after I solved the problem, I realized that the answer had been there all along, in the shape of the RVs. So, don't expect anything new to be reported here. Any aeronautical engineer is well aware of what I am writing about. But, equally true, the simple facts I will describe have been ignored in some of yesterday's designs and are still being ignored in some of today's designs. There are notable exceptions, in particular the RVs. They are so fast and exhibit such nice behavior because attention has been paid to many things, among them the item I describe here.

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Hidden Drag

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We need a basic understanding of why airplanes fly. D. Anderson and S. Eberhardt have written an excellent article on this in the February 1999 issue of Sport Aviation, "How Airplanes Fly." Another illuminating article is "Foiled by the Coanda Effect" by J. Raskin in the September/October 1994 issue of Quantum. Briefly, a flowing liquid or gas tends to follow a smooth surface. You can convince yourself of this as follows. Hold a spoon rather loosely as shown in Figure 1 so that the water running from a faucet flows around the bowl of the spoon.

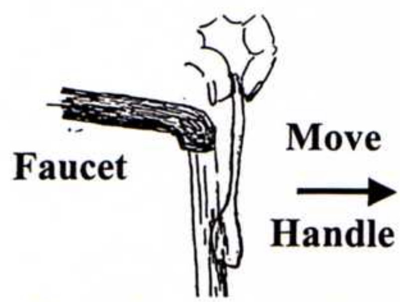

Figure 1. Demonstration of Coanda Effect

Try to move the spoon away from the flowing water as indicated in Figure 1. As you will see, the spoon bowl wants to stay with the flowing water and separates from it only when a surprisingly large force is applied. In the case of the wing of an airplane, the air moving over the top surface of the wing follows the downward slope. See Figure 2.

Figure 2. Airflow over Wing

The air continues the downward movement once it reaches the trailing edge. In effect, the wing pitches the air past the trailing edge at a downward angle. The action of the downward pitching of air creates as reaction a lifting of the wing. This interpretation is beautiful for understanding why airplanes fly. But it does not help much to see what is wrong when a plane does not fly well. For this, one may look at the air pressure above the wing. The air flowing above the wing is effectively bent downward. There is only one thing that could cause such bending: a low pressure above the wing. That low

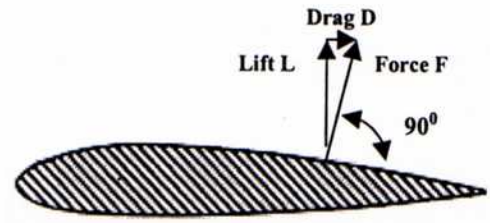

Figure 3. Force F, Lift L, & Induced Drag D

pressure produces a force F that, when depicted as a vector, rises at a 90 deg angle from the top surface of the wing. See Figure 3

Assuming level flight, gravity is the only force to be counteracted by the lift of the wing. Hence, the required lift L, which is opposite to and of the same magnitude as the gravitational force acting on the plane, is vertical. If the force F is to produce the lift L, it must be somewhat larger than L, as shown in Figure 3. In fact, the vertical vector L and the horizontal vector D must together, in vector addition, give the slanted vector F. The force D is the induced drag of the wing. When D is multiplied by the speed of the plane, and when that product is divided by the propeller efficiency, say 65-70%, one gets the horsepower required to overcome that induced drag.

Thick wings produce more induced drag than thin wings if they create the same lift using the same angle of attack. See Figure 4. Of course, thin wings require a faster airflow than thick wings to achieve that same lift.

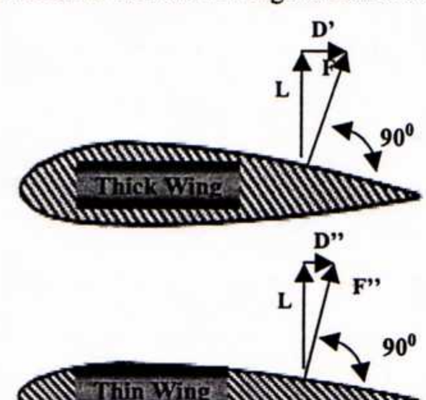

Figure 4. Effect of Wing Shape on Induced Drag

Induced drag is also produced by other parts of the airplane: for example, by the fuselage, by the fairing of the landing gear, and by the tail surfaces. Here we look at just one item, the fuselage.