High Lift, High Drag, and Other Control Devices

The wings on most modern-day airplanes are equipped with control devices not only to steer the airplane, but also to improve its flying capabilities at specific times, particularly during landing and takeoff. Devices such as slotted wings and flaps increase lift when an aircraft requires it the most. They are also excellent examples of how different people working in isolation from each other can arrive at similar solutions for a problem simultaneously.

The design feature generally known as the slotted wing is a long slot that runs lengthwise along the wing, either at the leading edge of the wing or at its trailing edge. It creates greater lift, but also increases drag. It was invented nearly simultaneously in three different places—by two individuals working independently in Germany and also by a research team in the United Kingdom.

In 1917, German pilot G. V. Lachmann crashed his airplane into the ground after stalling it. A stall happens when a wing no longer generates sufficient lift to keep the airplane in the air. This can happen because the plane is traveling too slowly and/or because the angle of the wing to the airflow is too sharp (such as what happens in a climb). This latter situation is commonly called too high an angle of attack. Lachmann was lying in his hospital bed recovering from his injuries when he started thinking about airplane wings. He surmised that if a wing was made up of several smaller wings, separated by open spaces or “slots” that ran straight outward from the fuselage parallel to each other, then air would flow between the slots at high angles of attack at low speeds. The wing would act like a group of separate wings, each operating at a normal angle of attack. In normal, level flight, air would pass over the slots, the slots, not through them, and this slotted wing would act like a normal wing. As a result, a plane equipped with a slotted wing would not stall as easily as one without it. Lachmann made some model tests and applied for a patent for his slotted wing design in February 1918, but his patent was rejected because the patent authorities argued that the slots would destroy the wing lift. Lachmann had to conduct further tests to prove his doubters wrong.

Around the same time, the British firm Handley Page was trying to solve a problem similar to stalling; just before a wing stalls, the airflow “bubbles,” or becomes turbulent over the upper surface of the wing, increasing drag and decreasing lift. Handley Page engineers tried slots that ran chordwise, or front to back, to reduce this burbling. But they soon found that a slot near the leading edge of the wing and running parallel to the span increased lift dramatically, by an astounding 60 percent.

Handley Page engineers made a number of different tests, including a retractable slot (a piece of metal that ran along the length of the wing from the fuselage) in front of the wing that could be extended (pushed forward from its position at the front of the wing) so that a slot would open up between the wing and the slot. Another design involved a multi-slotted wing that increased lift by 300 percent; it looked like a venetian blind, but it also increased drag and had other drawbacks. In the meantime, the German Lachmann was ultimately able to gain a patent for his design and soon joined forces with Handley Page.

At the same time as Lachmann’s theorizing and the Handley Page company’s experiments, O. Mader of the German airplane manufacturer Junkers was also testing a wing design to reduce burbling and increase lift, but in a slightly different way. Mader’s approach involved mounting an auxiliary airfoil behind the main wing. It had a larger slot between it and the main wing, running parallel to the main wing and auxiliary airfoil, but worked in a manner similar to the Lachmann and Handley Page designs. Junkers incorporated slotted wings in some of its aircraft. Meanwhile, leading-edge slots were incorporated into military airplanes in the United States and Britain.

The full impact of the slotted wing design was not realized until it was incorporated with another lift device, the flap. Flaps are extensions on the trailing edge of a wing that the pilot extends during landing and takeoff to increase lift. When they are extended, they move downward, increasing the camber (making the wing shape curvier) and forcing the airflow down, providing lift. Ailerons, developed in 1908 and essentially the first flaps, were large surfaces on the rear of a wing that provided lateral (sideways) control of an airplane: lowering an aileron on one wing increases the lift on that wing and raising the aileron on the other wing decreased it on that wing. These ailerons were essentially evolved versions of the wing warping control system that the Wright brothers developed.

By 1914, flaps were introduced on the British S.E.-4 biplane, but pilots rarely used them because they did not increase performance all that much. By the 1920s, flaps were combined with slots to provide lift and to eliminate the drag caused by the slots in normal flight. They were used in some commercial aircraft but remained rare for several years despite their ability to improve performance. In 1920, Orville Wright...
and J. M. H. Jacobs invented the split flap, which consisted of a hinged section on the trailing edge of the underside of the wing. The split flap was simple and also had the benefit of increasing drag, which helped a pilot descend toward the runway at a steeper rate than current wings would allow and thus made landing approaches easier.

In the mid-1920s, Harland D. Fowler, a U.S. engineer who worked for the Army Air Corps as well as numerous aircraft manufacturers throughout the decade, used his own time and money to develop a new kind of flap. Fowler's flap did not simply hinge down from the wing, but actually slid back from the wing and then rotated down, while creating a slot between it and the wing. The Fowler flap had the benefit of actually increasing the wing area in addition to increasing the wing's lift. Fowler built a wing and tested it on several airplanes in 1927-1929. He had a hard time convincing others that his design was useful and during the Great Depression, he had to work as a salesman to support his research. He persisted in pushing his design and ultimately got it adopted on an unsuccessful Martin bomber and then the Lockheed 14 twin-engine airliner in 1937.

By the 1930s, flaps were incorporated into many passenger planes and became more sophisticated. The Italian Piaggio company introduced the double-slotted flap in 1937. As its name implies, it had two slots, improving performance even more. It dramatically improved lift, like the Fowler flap, but also increased drag, making it more useful during landing than takeoff. Its main advantage was that it was simpler and lighter than the Fowler flap. Another innovation was the leading-edge flap that extended forward of the wing. Boeing also introduced the triple-slotted flap with its 727 airliner, which is still in wide service today, particularly for express package delivery.

Today, large commercial passenger jets have many complicated control systems for improving controllability during the takeoff and landing phases of flight. A passenger looking out a window over the wing just before landing will often notice the forward edge of the wing extending outward and down and the trailing edges extending backward and down, opening up gaps (the slots) in the wing. This complicated system of controls represents the highly evolved descendent of the ideas of Lachmann, Mader, and the engineers of Handley Page during that remarkably productive period from 1917-1921.

--Dwayne A. Day

Sources and further reading:


