Variable-Pitch Propellers

Some innovative aspects of aircraft were first proposed long before airplanes were actually flying. One of these was the variable-pitch propeller, which, as its name suggests, changes the pitch of the propeller blades (the angle at which they cut through the air) in order to produce more thrust.

The first proposal for a variable-pitch propeller was made in 1871 by a Frenchman named J. Croce-Spinelli. Croce-Spinelli proposed a design for a propeller whose pitch was changed by hydraulic pressure (forcing oil through a tube). Croce-Spinelli claimed that this would be most useful during takeoff, when an airplane needed the most power (Croce-Spinelli was one of two men who died in 1875 when they went too high in a balloon). Another Frenchman, Alphonse Pénaud, also proposed using a variable-pitch propeller in his patent on airplane design in 1876.

Many of the people who worked on airplane design for the next several decades, both before and after the Wright brothers took flight in 1903, recognized the obvious advantages of the variable-pitch propeller, which could change the engine thrust without having to change the engine power and the speed of the propeller. But nobody could make it work until 1910, when the first variable-pitch propellers were used on some airships. Airships used the propellers to reverse thrust, so that they could slow down rapidly and even back up. But these early designs were not safe enough to use on airplanes.

One reason why variable-pitch propellers were not developed quickly was that although they could improve performance, they could not improve performance significantly during this early period, so there was little demand for them. Airplanes still flew relatively slowly and at low altitudes, and a variable-pitch propeller was most useful at higher speeds (more than 200 miles per hour [322 kilometers per hour]) and higher altitudes. Before World War I, a fixed-pitch propeller could work well enough both during takeoff and at top speed and maximum altitude so that a more complicated device proved unnecessary. But airplane designers knew that as engines became more powerful and planes flew higher, a variable-pitch propeller would be useful to improve performance.

World War I led to much aircraft innovation and experimentation and propellers benefited from this boom. In 1917 the British Royal Aircraft Factory built and tested a variable-pitch propeller on a single-engine plane. In 1918, the German R-30 bomber took flight with variable-pitch propellers, becoming the first multi-engine plane to do so.

Most of these early attempts by companies in the United States, Britain and elsewhere, involved mechanically controlled propellers. The German Garuda company developed a much more advanced approach involving centrifugal weights and a hydraulic servo-motor (a small motor used to control the position of the propeller), but the company disappeared after the war and nobody benefited from its work.

The biggest problem with all of the early mechanically actuated designs was wear and tear. Although they could work in flight, they did not work for long, and the bigger and more powerful the engine, the faster they wore out. Designers thus had to limit these to relatively small engines. But by the 1920s, designers in the United States, Great Britain, and Canada had abandoned the mechanical approach for a variable-pitch propeller that used either hydraulics or electric motors to change pitch.

An American engineer, F.W. Caldwell, conducted research on hydraulically controlled propellers in the late 1920s. He did some of his work on his own, but ultimately went to work for the Hamilton-Standard division of United Aircraft. He built a test propeller in 1929-1930 and tested it on an airplane. His plan was to build a propeller that automatically adjusted its pitch according to the needs of the airplane, a so-called "constant speed" design. This was an ambitious goal, but by this time, there was a great demand for variable-pitch propellers. Planes were operating at speeds and altitudes where fixed propellers were very inefficient. Because of this demand, while at Hamilton-Standard, Caldwell compromised with his design. He made a simpler two-position propeller that could be set at one position for takeoff and another for cruising. He then continued working on the constant-speed variable-pitch propeller.

Hamilton-Standard soon began selling its first two-position variable-pitch propellers to engine manufacturers in 1932. American aircraft designers quickly incorporated them into several aircraft, such as the B-10 bomber. They also incorporated them into the Boeing 247 commercial transport plane. The new propellers reduced the airplane's takeoff run by an amazing 20 percent and increased its climbing rate by 22 percent and its cruising speed by 5.5 percent. These figures were so impressive that very quickly all high-performance aircraft were redesigned to have variable-pitch propellers and Hamilton-Standard licensed the propellers to several foreign manufacturers.
While Caldwell was doing his research in the United States, other engineers in other countries were also working on variable-pitch propellers. W.R. Turnbull, a Canadian, first proposed using an electric motor to vary the pitch of the propeller. The advantage to this design was that it did not require any modifications to the engine itself to provide the oil to power a hydraulic mechanism. He designed his first system in 1925 and tested it in 1927. The tests were successful and the American company Curtiss-Wright licensed the design and began to modify it, but it took several years before the company began to incorporate the new propeller into its Navy and Army Air Force aircraft. The Curtiss-Wright propeller soon became a rival for the Hamilton-Standard propellers.

German and French firms also developed electrically driven variable-pitch propellers during the 1930s and most German airplanes during World War II flew with automatically adjusting propellers produced by the firm VDM. The British had been the first to start work on hydraulically driven variable-pitch propellers, but took the longest to develop them. Ultimately, this forced the British aircraft manufacturer de Havilland to license the American Hamilton-Standard propeller instead of using a British propeller.

Today, variable-pitch propellers are common to virtually all propeller aircraft. It is not unusual to see commuter prop planes at an airport parked with their propellers rotated forward, "feathered" so that the pilot can start spinning the propellers on the ground without generating thrust. This barely noticeable, but challenging technological innovation plays a major role in improving the aircraft's performance.

--Dwayne A. Day

Sources and further reading:


<table>
<thead>
<tr>
<th>Educational Organization</th>
<th>Standard Designation (where applicable)</th>
<th>Content of Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Technology Education Association</td>
<td>Standard 6</td>
<td>Students will develop an understanding of the role of society in the development and use of technology.</td>
</tr>
<tr>
<td>International Technology Education Association</td>
<td>Standard 8</td>
<td>Students will develop an understanding of the attributes of design.</td>
</tr>
<tr>
<td>International Technology Education Association</td>
<td>Standard 9</td>
<td>Students will develop an understanding of engineering design.</td>
</tr>
<tr>
<td>International Technology Education Association</td>
<td>Standard 10</td>
<td>Students will develop an understanding of the role of experimentation and research and development in problem solving.</td>
</tr>
</tbody>
</table>