NASA To Test Drag-Reducing Inflight Wing Folding

Aviation week
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Boeing will introduce folding wings to commercial aviation when the 777X airliner enters service at the end of 2019. But the devices could become commonplace on future aircraft as wingspans increase in an effort to reduce drag and fuel burn.

The 777X has almost 24 ft. more wingspan than today's 777 to optimize lift distribution and maximize cruise efficiency. Folding the tips on the ground keeps the larger aircraft compatible with existing taxiway and gate size restrictions. But NASA is investigating whether also folding the wing in flight could save still more fuel.

The Spanwise Adaptive Wing (SAW) concept will be tested on the ground and in flight in a rapid feasibility assessment under NASA's new Convergent Aeronautics Solutions project. The goal is to show that angling the outboard wing sections up or down can increase yaw stability and control, and reduce rudder size and tail drag.

In addition to raising subsonic aircraft efficiency, wingtips that fold in flight could improve lift and drag on supersonic transports by increasing stability and control authority, and compression lift on the wing. This was done in the 1960s on the North American XB-70 Valkyrie bomber, shrinking the vertical tails and boosting supersonic lift.

Key to the SAW concept are advances in shape-memory alloy (SMA) actuators compact enough to enable the active fold mechanism to be accommodated within the outer mold line of the thin outboard wing section, so as not to increase drag, says Matt Moholt, NASA principal investigator.

Folding outer wing panels up or down can increase yaw stability and control and reduce drag through a smaller tail. Credit: NASA

SAW is built around torsion actuators made of an alloy that, when heated electrically, “remembers” and returns to its original twisted shaped and in doing so moves the wingtip. This avoids the weight and complexity of running hydraulic lines through the wing to conventional actuators.

NASA plans to flight-test the concept at small scale in spring 2017 using Area-I’s PTERA unmanned research aircraft. Analysis of the PTERA—with the outer 15 in. on either side of its 176-in.-span wing hinged to fold up or down by up to 75 deg.—suggests SAW can provide almost 40% of total rudder authority. “And PTERA is not designed for SAW, so it is not optimal,” Moholt says.

The basic PTERA has a straight wing, and the SAW concept requires enough sweep to place the folding tips sufficiently far behind the aircraft’s center of gravity to provide an adequate moment arm for yaw stability and control. So the unmanned aircraft will be modified by sweeping the wing outboard of the engines by 20 deg.

A completely new wing would have allowed 30 deg. of sweep, and provided a full 50% of rudder authority from the folding tips, but would have required a redesign of the landing gear. “We can do 20 deg. affordably,” says Moholt, adding “We are building the hardware now.”

Modifying the subscale PTERA is a quick way to get real flight data with which to understand how the folding wings work as an integrated system and help develop robust control laws that will allow an aircraft to fly safely should a fold actuator freeze or fail, he says.

In parallel, the SAW team plans to ground-test a full-scale structure with the SAW mechanism integrated into the wing of an unidentified target aircraft, to pave the way for a flight demonstration. “We are sensitive to scaling. The flight demo will test control laws and flight loads. The ground test will show scaling and make the argument for a full-scale flight demo,” Moholt says.

The PTERA unmanned research aircraft will be fitted with swept-wing sections outboard of the engines, with the outer 15 in. actuated to fold. Credit: NASA

There are tradeoffs to be made. The hinge cannot be too far inboard or the wing bending moment is too great. And folding the wing to provide yaw control on takeoff and climbout—flight phases that today size the rudder and tail to counteract asymmetric thrust after an engine failure—results in a loss of lift.

“The trade is lift,” he says. “But assuming an elliptical load distribution, the folding section is in a low-lift section of the wing, so we do not give up a whole lot of lift. And when we articulate, we are doing so with a control surface as well [the aileron], so we gain from a yaw stability and control standpoint.

“What we give up in lift, we gain in yaw,” Moholt explains. “And we will use deep-seeking algorithms to deploy the wing to an idealized angle depending where we are in flight. We might deploy on takeoff to 45 deg., then climb may be flat or down, and cruise an idealized position. We don’t know yet.”

There is less of a tradeoff to be made with supersonic aircraft, which tend to be unstable in yaw, requiring large tails. The XB-70 could fold the outer 20 ft. of wing on each side down by 25 or 65 deg. to increase yaw stability and the effectiveness of compression lift as the aircraft surfed its own shockwave.

Moholt says advances in SMA actuators at NASA Glenn Research Center allow a form factor for the fold mechanism that can be “squeezed into the very tight outer mold line of the wing.” But SMAs are low bandwidth, and must cool down to return to their resting shape, which is an inherently slow process.

NASA is not able to detail the design of the actuator, which is being developed by SAW project partner Boeing Research & Technology, he says. But one option is an “antagonistic” arrangement, in which one SMA actuator moves the wing up and another moves it down, while the first cools off.

The SAW application does not require rapid actuation, but NASA is ground-testing more efficient ways of heating the SMAs. The agency is also examining whether a locking mechanism will be needed to carry flight loads across the fold.

“Locking depends on the type of wing. On a high-G wing it is tough to drive the loads through the SMA actuator,” Moholt says. “But on PTERA we are not locking anything. We will drive real airloads through the joint.”