Flipperons for Improved Aerodynamic Performance

For a given airfoil design, lift is increased and drag reduced.

Langley Research Center, Hampton, Virginia

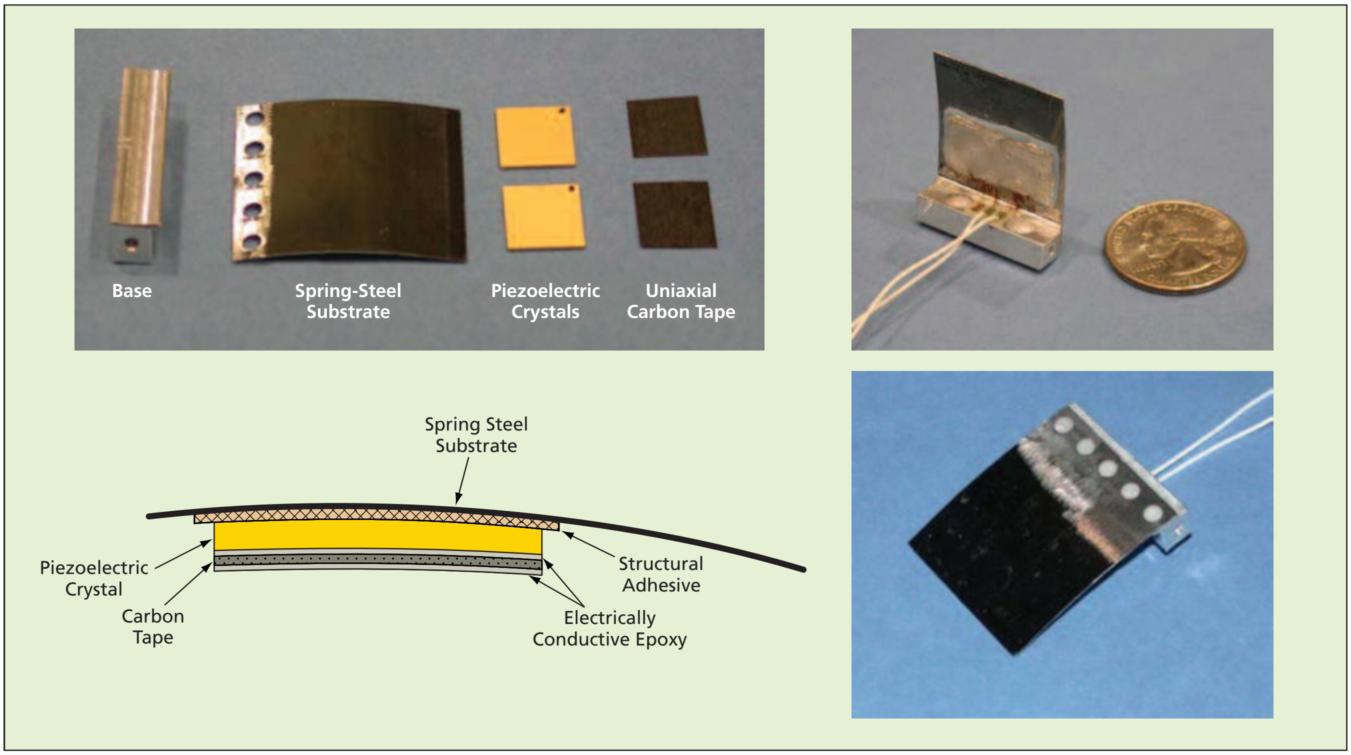

Figure 1. The **Piezoelectric Crystal** in a lightweight bending actuator is maintained in compressive preload by a spring-steel substrate.

Lightweight, piezoelectrically actuated bending flight-control surfaces have shown promise as means of actively controlling airflows to improve the performances of transport airplanes. These bending flight-control surfaces are called "flipperons" because they look somewhat like small ailerons, but, unlike ailerons, are operated in an oscillatory mode reminiscent of the actions of biological flippers.

The underlying concept of using flipperons and other flipperlike actuators to impart desired characteristics to flows is not new. Moreover, elements of flipperon-based active flow-control (AFC) systems for aircraft had been developed previously, but it was not until the development reported here that the elements have been integrated into a complete, controllable prototype AFC system for wind-tunnel testing to enable evaluation of the benefits of AFC for aircraft.

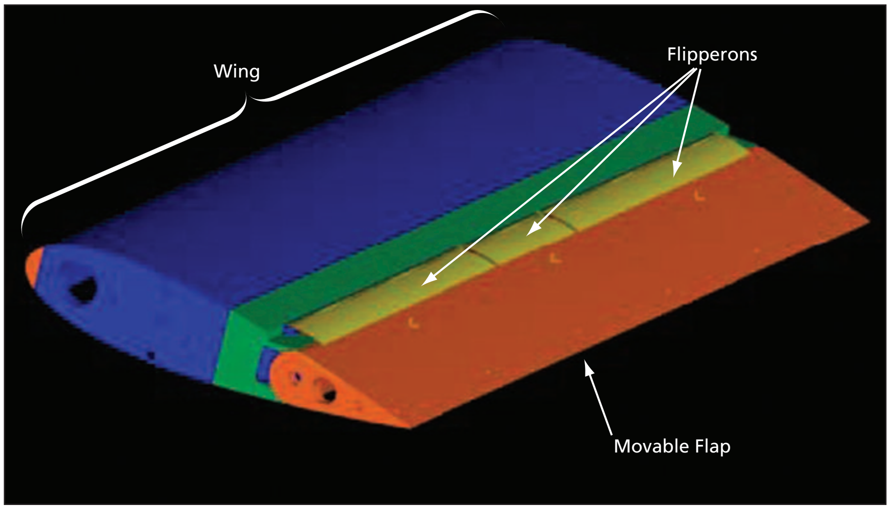

Figure 2. **Flipperons on the Upper Surface** of a wing are made to oscillate at amplitude, frequency, and phase chosen to obtain increased lift and reduced drag.

The piezoelectric actuator materials chosen for use in the flipperons are single-crystal solid solutions of lead zinc niobate and lead titanate, denoted generically by the empirical formula $(1-x)[\mathrm{Pb}(\mathrm{Zn}_{1/3}\mathrm{Nb}_{2/3})\mathrm{O}_3]:x[\mathrm{PbTiO}_3]$ (where $x<1$) and popularly denoted by the abbreviation "PZN-PT." These are relatively newly recognized piezoelectric materials that are capable of strain levels exceeding 1 percent and strain-energy densities 5 times greater than those of previously commercially available piezoelectric materials. Despite their high performance levels, (1 – x)[Pb($Zn_{1/3}Nb_{2/3}$)O_3]:x[$PbTiO_3$] materials have found limited use until now because, relative to previously commercially available piezoelectric materials, they tend to be much more fragile.

What has made it feasible to incorporate (1 –x)[Pb($Zn_{1/3}Nb_{2/3}$)O_3]:x[$PbTiO_3$] crystals into flipperons is a design and fabrication approach in which the crystals are preloaded and reinforced so as to minimize exposure to tensile stresses, which could break them. The essence of this approach is to place the piezoelectric crystals in each actuator under a compressive preload along the fore-and-aft axis and to bond tapes of uniaxial carbon fibers to the outer surfaces of the crystals to minimize lateral tensile strain in each crystal (see Figure 1). By minimizing tensile strains in the crystals, one minimizes crystal damage, thereby minimizing the probability of actuator failure.

The prototype AFC system includes not only flipperons but also flipperon-displacement position sensors, a power subsystem, and a control subsystem. For initial tests, the flipperons were installed on the upper surface of a standard airfoil (wing) model at the flap hinge (see Figure 2). The model was mounted in a low-speed wind tunnel at the University of Arizona, where the tests were performed. The tests included measurements of customary aerodynamic-performance parameters (e.g., coefficients of lift and drag) at various angles of attack and airspeeds. During these tests, the flipperons were actuated at various amplitudes, frequencies, and phases.

The tests showed that with appropriate actuation of flipperons, lift was increased and drag reduced, by amounts of the order of a percent. Data from these tests were then used to estimate the benefits that could be obtained by adding flipperon-based AFC systems to transport airplanes in two tests cases. In one case, it was found that the addition of the flipperons to the vertical stabilizer of a Boeing 777 (or equivalent) airplane would make it possible to reduce the size of the vertical stabilizer, thereby reducing the drag, by an amount sufficient to enable a reduction of fuel consumption by as much as 1.7 percent. In another case, it was found that by exploiting the ability of a flipperon-based AFC system to delay the onset of stall, one could safely increase the angle of attack (thereby increasing lift) while reducing the size of the wings (thereby reducing the weight) of a blended-wing/body airplane by an amount sufficient to enable a reduction of fuel consumption by as much as 0.6 percent.

This work was done by James H. Mabe of The Boeing Co. for Langley Research Center. Further information is contained in a TSP (see page 1).
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System Estimates Radius of Curvature of a Segmented Mirror

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A system that estimates the global radius of curvature (GRoC) of a segmented telescope mirror has been developed for use as one of the subsystems of a larger system that exerts precise control over the displacements of the mirror segments. This GRoC-estimating system, when integrated into the overall control system along with a mirror-segment-actuation subsystem and edge sensors (sensors that measure displacements at selected points on the edges of the segments), makes it possible to control the GROC mirror-deformation mode, to which mode contemporary edge sensors are insufficiently sensitive. This system thus makes it possible to control the GRoC of the mirror with sufficient precision to obtain the best possible image quality and/or to impose a required wavefront correction on incoming or outgoing light.

In its mathematical aspect, the system utilizes all the information available from the edge-sensor subsystem in a unique manner that yields estimates of all the states of the segmented mirror. The system does this by exploiting a special set of mirror boundary conditions and mirror influence functions in such a way as to sense displacements in degrees of freedom that would otherwise be unobservable by means of an edge-sensor subsystem, all without need to augment the edge-sensor system with additional metrological hardware. Moreover, the accuracy of the estimates increases with the number of mirror segments.

This work was done by John Rakoczy of Marshall Space Flight Center.

This invention has been patented by NASA (U.S. Patent No. 7,050,161). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31807-1.