AIRPLANE ADAPTIVE STRUCTURES

A passed station or a promise yet to be fulfilled?

For more than a century, aircraft have benefitted from changes in wing geometry to account for variable flight conditions or for flight control. Although early incarnations of continuous wing deformation were quickly replaced by discrete high-lift devices and hinged control surfaces, a renewed interest in wing morphing has resulted in new implementations of this relatively old technology. Some highlights are presented in this article.

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MISSION ADAPTIVE WING

In the 1980s the mission adaptive wing (MAW) explored the effectiveness of continuous leading and trailing edge deformation. This wing had an internal mechanism to flex the outer wing skin and produce a symmetrical section for supersonic speeds, a supercritical section for transonic speeds, and a high-camber section for subsonic speeds. Flight tests demonstrated that an improvement in lift-to-drag ratio of 20% could be obtained in large parts of the flight envelope while some parts even showed an increase of 100% (Ref 1, 2). Even though the flight tests demonstrated advantages of wing morphing, there were significant drawbacks to the way the morphing was achieved. Bulky, heavy hydraulic screw jacks were employed to induce the deformation in the wing. In addition, internal mechanisms employing multiple linkages ensured the desired kinematics of the mechanism. This resulted in a relatively heavy and complex actuation system.

ACTIVE AEROELASTIC WING

Another way to achieve wing morphing is to build aircraft structures that allow aeroelastic deflections to be used in a beneficial manner and to enhance aerodynamic performance. This concept has been investigated in various research programs over the past two decades. The Active Flexible Wing (Ref. 3) and Active Aeroelastic Wing (Ref. 4) programs investigated the use of leading and trailing edge control surfaces to control the wing twist. With very little control surface motion, the AAW techniques employed the energy of the airstream to achieve the desirable wing twist. This was eventually successfully flight tested on an F/A-18 (see Figure 2) that demonstrated roll rates up to 400deg/s. This approach reduced the need for powerful (heavy) actuators but increased the complexity of the control system and the more flexible wing decreased the flutter speed.

PLANFORM MORPHING

Other, more contemporary endeavors are under way in military aircraft, where wing morphing is applied to satisfy various mission requirements such as loiter and high-speed dash. One morphing concept relies on the simultaneous change in wing sweep, aspect ratio, and span (see Fig. 3). This is achieved by a scissor-link mechanism inside the wing in combination with an elastic skin (Ref. 5). Another morphing concept folds part of the wing against the side of the fuselage, such as to reduce the total wetted area of the wing during high-speed dash (see Fig. 4). In the latter approach the wing hinges are locally covered with a flexible membrane wing skin (Ref. 6). Both of these morphing concepts have been tested in the wind tunnel and have demonstrated promising results. One of the main drawbacks for both concepts is the level of complexity that is required to achieve wing morphing. For instance, the scissor link structure consists of a complicated mechanism of hinging spars and ribs that are all interconnected. The folding wing requires individual hinges at the root and mid-span of the wing that must be able to carry the wing bending moment. In addition to the added complexity, this also must add considerable weight to an otherwise relatively lightweight wing structure.

ADAPTIVE CHEVRONS

In 2005, Boeing introduced a higher level of adaptivity when it flew its shape memory alloy (SMA) actuated chevrons. These chevrons, designed to reduce noise levels during take-off and landing, were slightly bent into the jet exhaust. At elevated altitude the decreasing local temperature caused the SMA actuators to deform such that the chevrons opened up, increasing the efficiency of the engine (Ref. 7). Even though this demonstrated the effectiveness of SMA actuators in civil aircraft structures, application of adaptive materials in primary and secondary structure of CS23/25 type airplanes is still prohibited due to the lack of a documented material database. Wing morphing based on this technique is therefore still something to be achieved in the future.

In general, one can conclude that research has demonstrated the potential of adaptive materials and structures for military and civil aircraft applications. However, more work needs to be done to ensure a successful introduction on production aircraft. Anybody interested?

Figure 2. F/A-18 Active Aeroelastic Wing vibration test

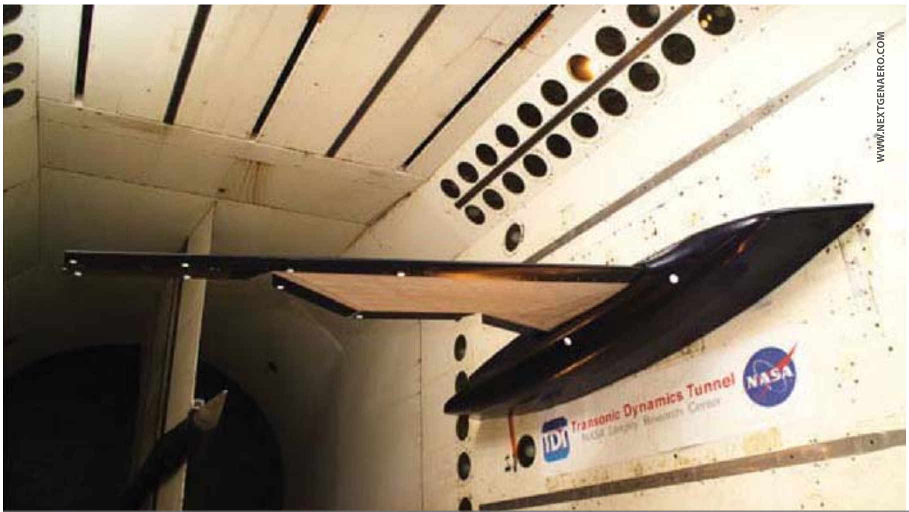

Figure 3. NextGen Adaptive Wing Concept in NASA's Transonic Dynamics Tunnel

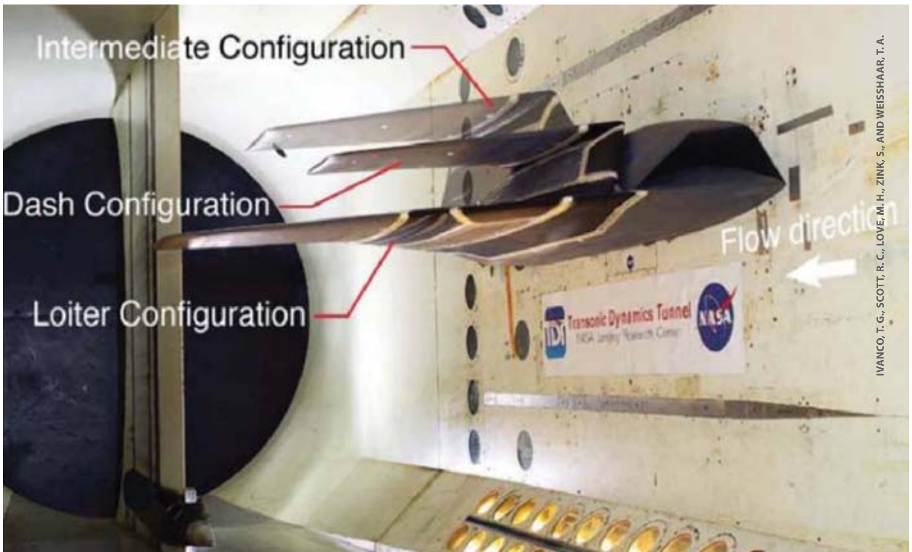

Figure 4. Lockheed Martin Adaptive Wing Concept; Half model at NASA's Transonic Dynamics Tunnel

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