Test Results for an SMA-Actuated Vortex Wake Control System

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ABSTRACT:

This paper describes recent test results obtained on a prototype SMA-actuated deformable foil that serves as a key element in a vortex wake control scheme for lifting surfaces. Previous papers have described the theoretical basis and feasibility studies for this scheme - which is based on a novel wake control concept known as vortex leveraging - as well as prior work on device design, test planning, and fabrication. The critical item in the realization of this scheme is a Smart Vortex Leveraging Tab (SVLT), a device designed to provide perturbations in the vortex system downstream of lifting surfaces at frequencies and amplitudes carefully selected to accelerate overall wake breakup. The paper summarizes the background of the effort, but focuses on the detail design and fabrication techniques used in the construction of a prototype SVLT and the results of water tunnel tests of a near full-scale prototype device.

Keywords: Shape memory alloy, vortex wake control, hydrodynamics, aerodynamics

1. BACKGROUND

The ability to control the vortex wake structure downstream of lifting surfaces is a topic of continuing importance for a variety of applications. For example, the encounter of jet transports with the wakes of preceding aircraft in approach to landing produces a significant safety hazard, and the current conservative separation standards between aircraft – standards driven chiefly by the time required for vortex wakes to dissipate - limit capacity at all major U.S. airports. Also, as discussed previously[1-3], analogous challenges in wake mitigation exist in the hydrodynamic arena as well.

Prior papers[1-3] have outlined the conceptual basis for the vortex leveraging strategy for accelerating deintensification of vortex wakes. The overall approach involves using secondary "leveraging" vortices to excite naturally occurring instabilities in multipair vortex wakes. Computational simulations of wake breakup mechanisms of realistic wakes of lifting surfaces have allowed the identification of the dominant phenomena in the breakup process. These studies indicated that wake deintensification may be accelerated by factors of three to ten, depending on the strength and positioning of the vortex wake system and the amplitude and frequency of active forcing generated by Smart Vortex Leveraging Tabs (SVLTs).

Early work on this effort centered on the extension of established vortex wake analysis tools to assess the feasibility of mitigating undesirable vortex wake behavior using Shape Memory Alloy (SMA)-actuated SVLTs. The performance required of a prototype SVLT and its preliminary design was defined by way of computational studies of the effect of the introduction of secondary vortices, vortices whose presence accelerates destructive wake-on-wake interactions. SMA technology provides an actuation mechanism (embodied in the SVLT) with a suitable combination of force/deflection capability, compactness, and bandwidth to enable the generation of the appropriate leveraging vortices with reasonable power consumption. A study of background information on previous work[4-7] on the development of SMA-actuated surfaces for hydrodynamic applications established that cyclic SMA actuation at the required frequency (roughly 0.2 Hz.) was possible, and that there was no obstacle to scaling up the demonstration devices previously fabricated for use in the SVLT.

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